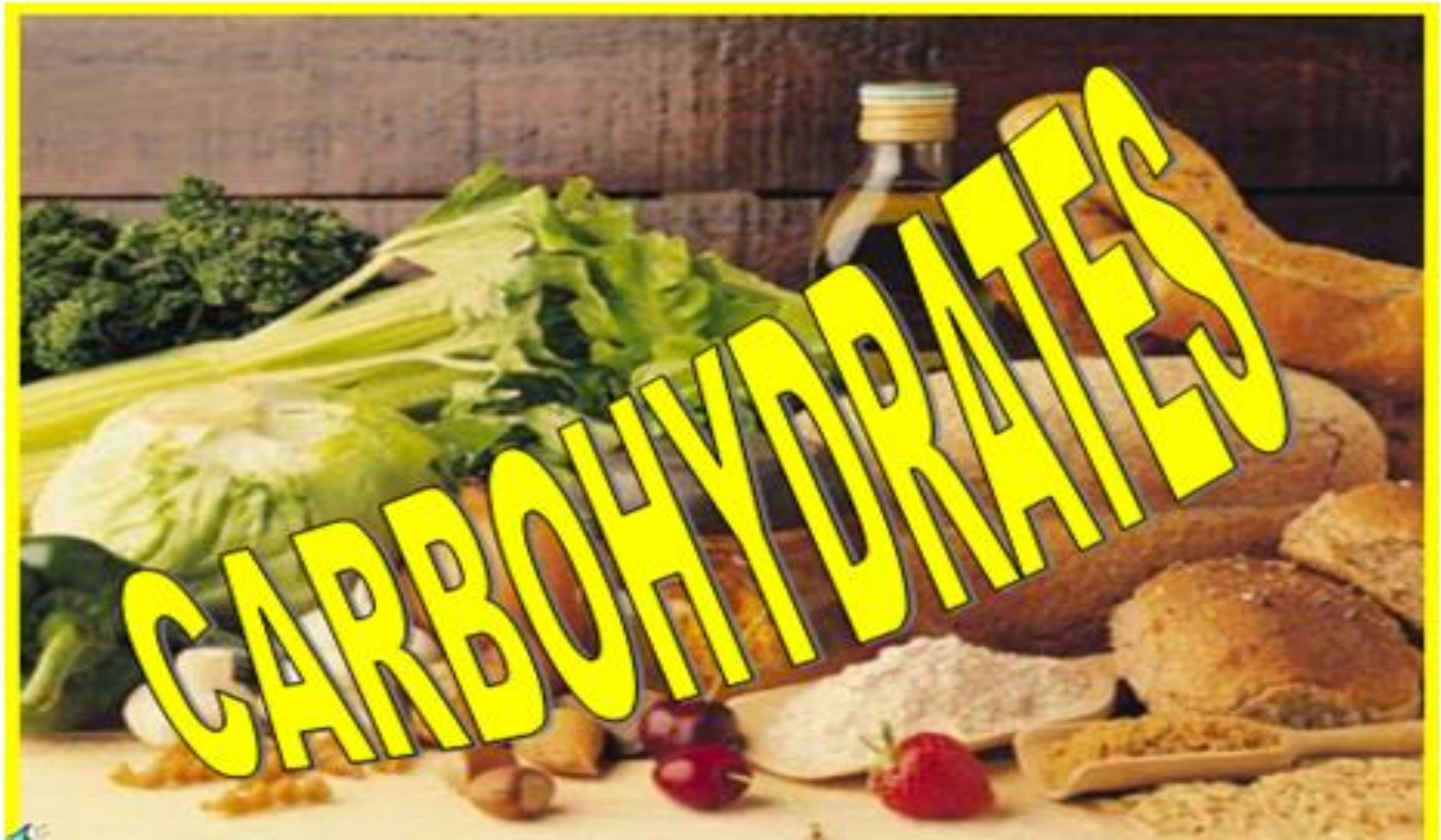
Dr. Saba Al-Abachi



- **Animals (including humans) get their carbohydrates by eating plants, but they do not store much, what they consume.**

Less than 1% of the body weight of animals is made up of carbohydrates. For a photosynthesis, an endothermic reductive condensation of carbon dioxide requiring light energy and the pigment chlorophyll.

$$nCO_2 + nH_2O + \text{energy} \xrightarrow[\text{chlorophyll}]{\text{sunlight}} C_nH_{2n}O_n + nO_2$$

Impotence of carbohydrate

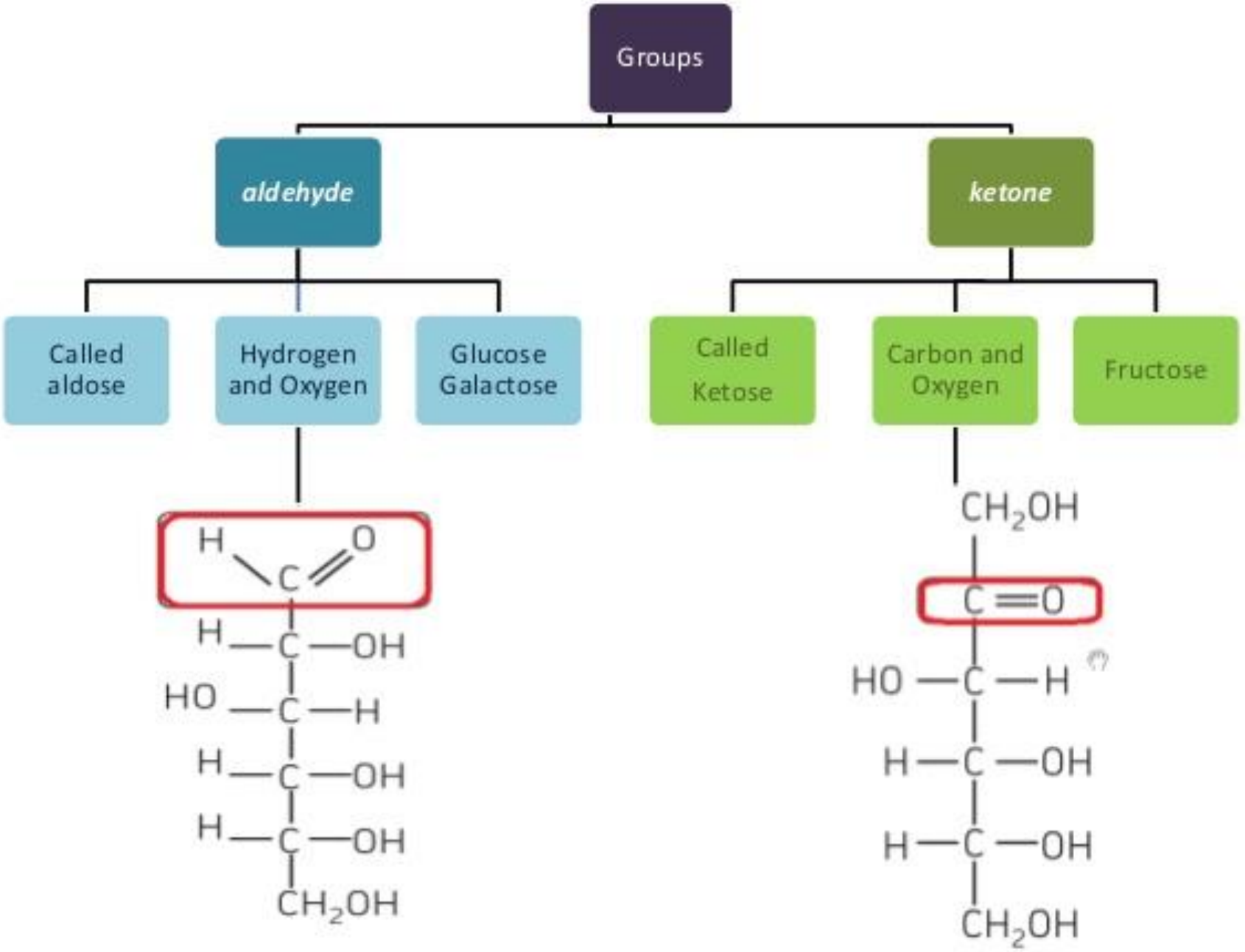
CARBOHYDRATE: IMPORTANCE

- Most Abundant Class of Biomolecules.
- An Important Macronutrient.
- Performs important physiological functions in the body.
- Associated with Pathological Conditions (Diabetes Mellitus, Lactose Intolerance).

Definition

- Carbohydrates may be defined as polyhydroxy aldehydes or ketones or compounds which produce them on hydrolysis.
- Formula = (C.H2O)n

- Or the Formula = ($C_nH_{2n}O_n$)
- Which n= 3 or more
- n=3 the carbohydrate (triose) are glyceraldehyde or dihyroxyacetone.

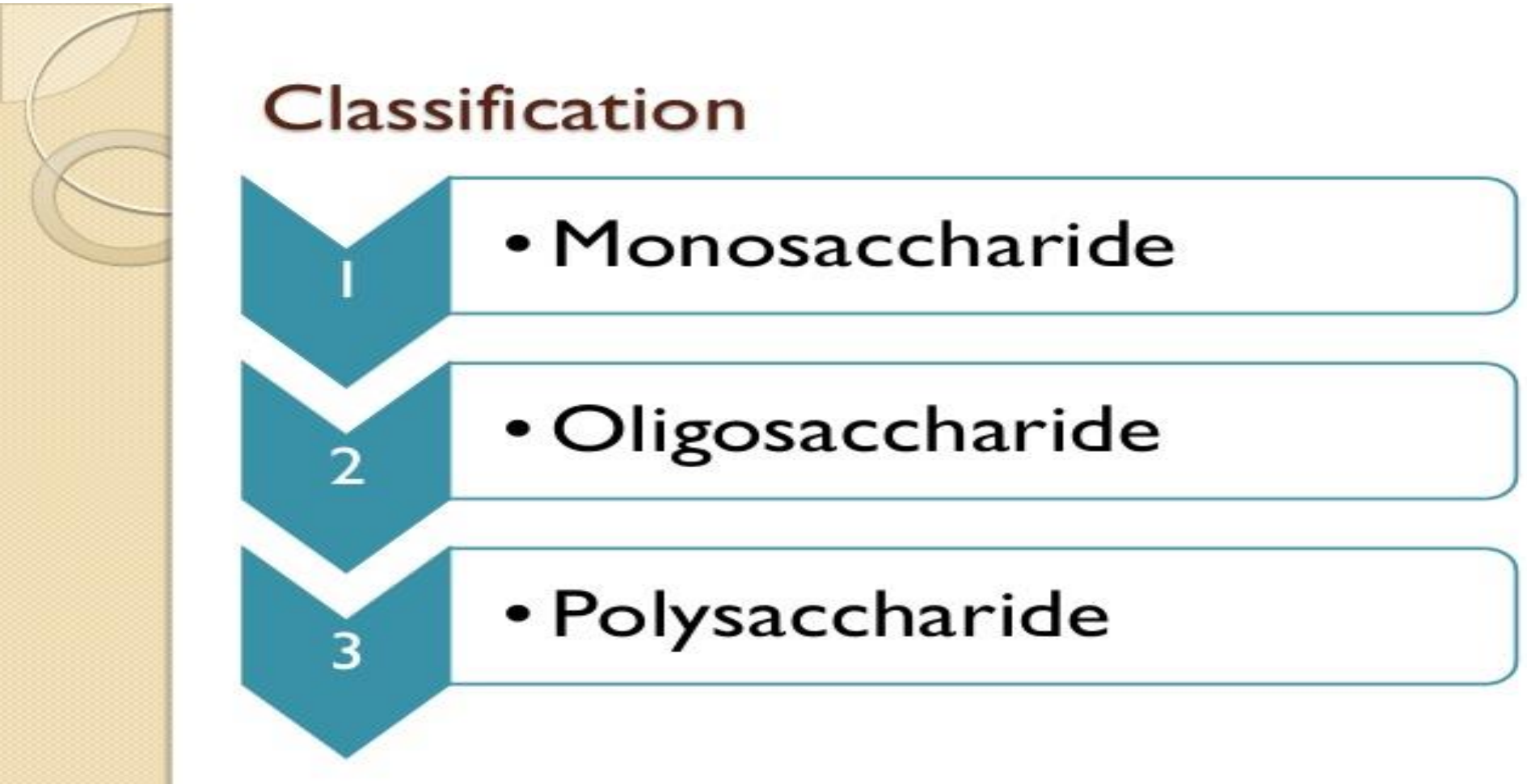

Groups
aldehyde
ketone
Called aldose
Hydrogen and Oxygen
Glucose Galactose
Called Ketose
Carbon and Oxygen
Fructose
H
O
C
H — C — OH
HO — C — H
H — C — OH
H — C — OH
CH2OH
CH2OH
C = O
HO — C — H
H — C — OH
H — C — OH
CH2OH

Biomedical Importance

- Most abundant dietary source of energy. Brain cells and RBCs are almost wholly dependent on carbohydrates as the energy source.
- Also serve as storage form of energy – Glycogen.
- Carbohydrates are precursors for many organic compounds (fats, amino acids).
- Participate in the structure of cell membrane & cellular functions (cell growth, adhesion and fertilization).
- DM (diabetes mellitus)

CLASSIFICATION OF CARBOHYDRATE

Depending on the number of molecule carbohydrates are classified into three major types :



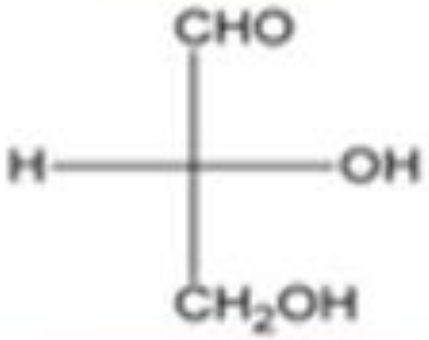
Monosaccharide also called simple sugar

Monosaccharide

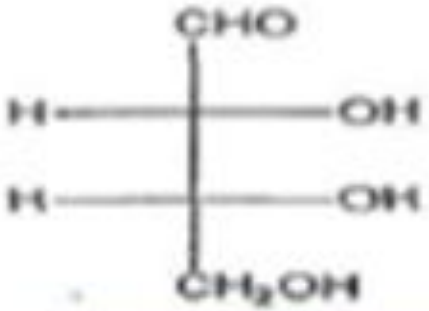
Cannot further Hydrolyzed

No. of Carbon	Type of sugar	Aldoses	Ketoses
3	TRIOSES	Glyceraldehydes	Dihydroxyacetone
4	TETROSES	Erythrose	Erythrulose
5	PENTOSES	Ribose, Xylose	Ribulose, xylulose
6	HEXOSES	Glucose, Galactose	Fructose
7	HEPTOSES	Glucoheptose	Sedoheptulose

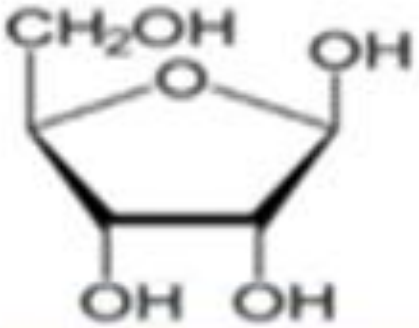
Monosaccharide's: **can't be further hydrolyzed to simple sugars**



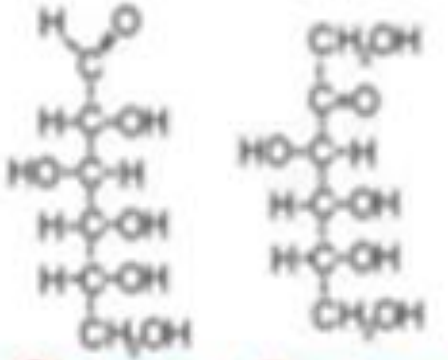
Triose: Glyceraldehydes



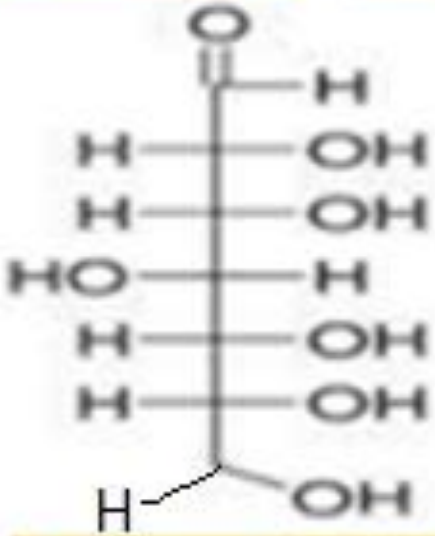
Tetrose : Erythrose



Pentose's : Ribose's



Hexose : Glucose , Fructose



Heptoses : Glucoheptose

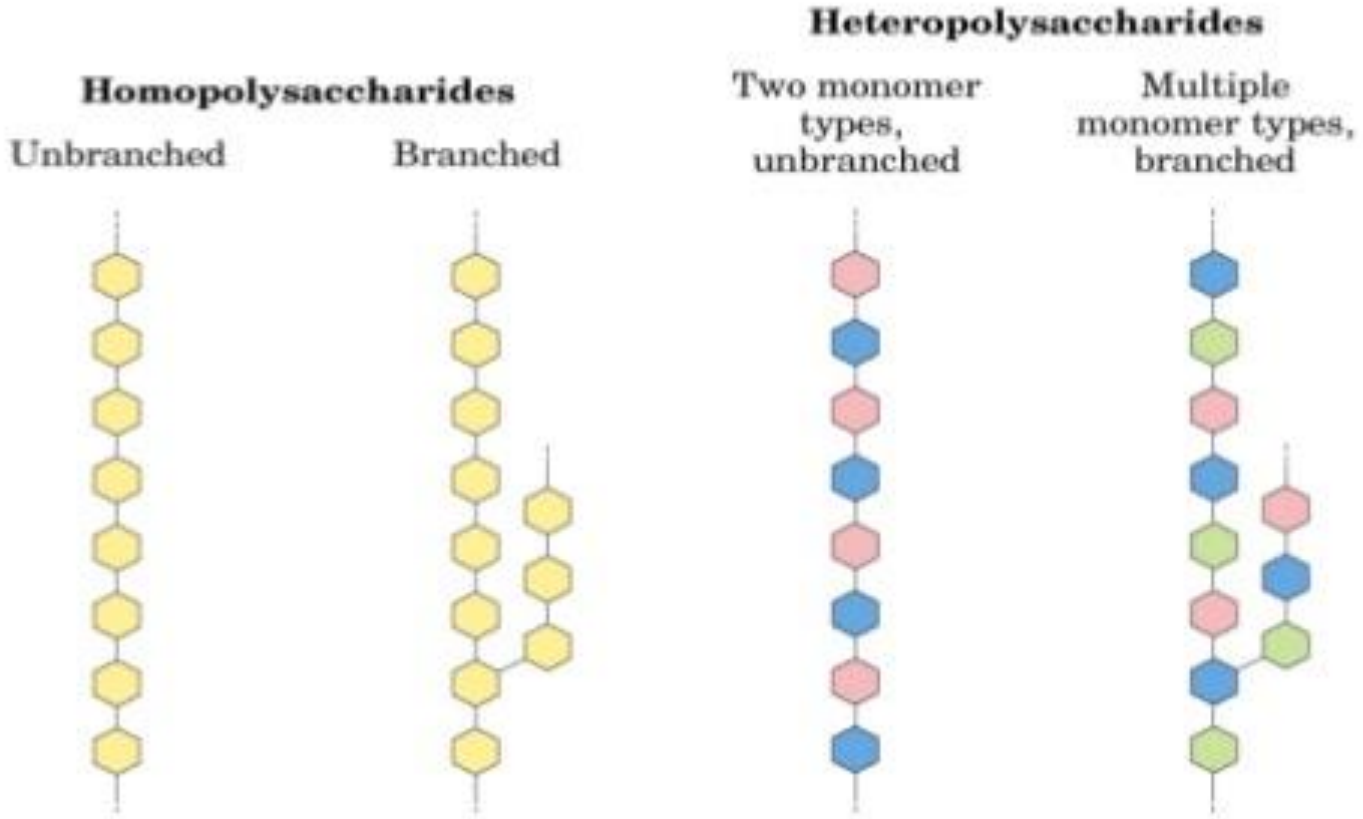
Oligosaccharide

- Oligosaccharides(Greek: oligo-few) contain 2-1O monosaccharide molecules
- Joined by glycosidic bond

	No "C"	Examples	Type of monosaccharide
Disaccharides	2	Maltose	Glucose + Glucose
		Lactose	Glucose + Galactose
		Sucrose	Glucose + Fructose
Trisaccharides	3	Raffinose	Glu + Fruc + Galactose
Tetra saccharides	4	Stachyose	2 Galactose + Glucose + Fructose
Penta saccharides	5	Verbascose	3 Galactose + Glucose + Fructose

Polysaccharides

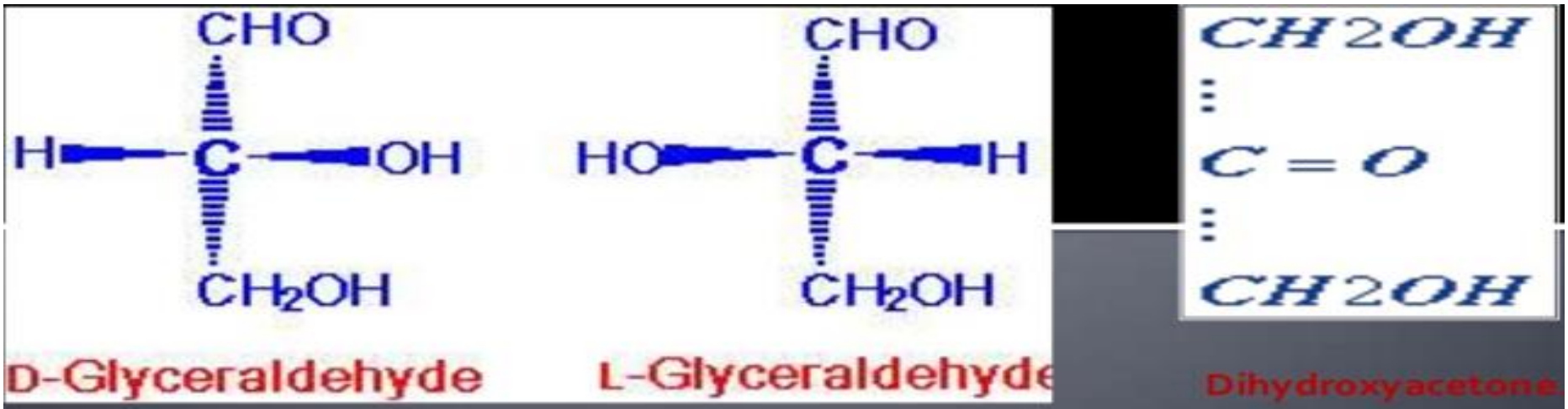
- Contain more than 10 monosaccharide units.



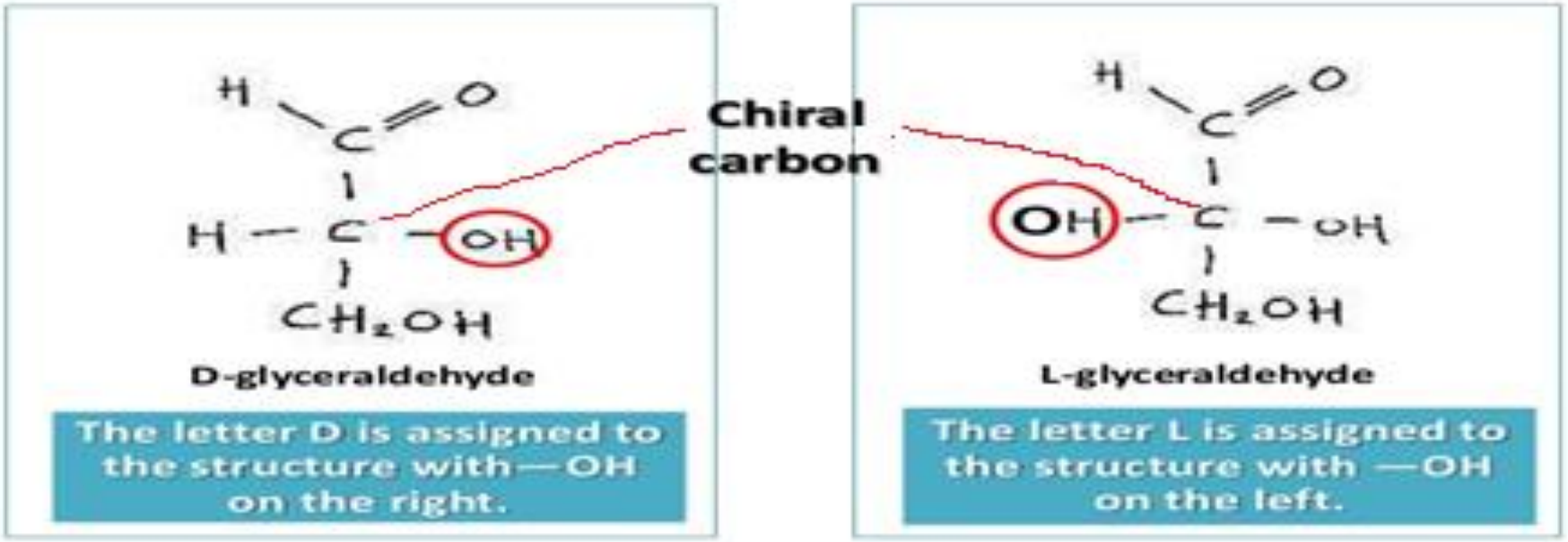
Stereoisomerism of monosaccharaides

Asymmetric carbon atom:

- It is the carbon atom that is attached to 4 different groups.
- All monosaccharaides have it except dihydroxyacetone.
- Different isomers are possible based on the presence of number of asymmetric carbon atoms.



D and L Notations



n

Numbers of stereoisomer = 2

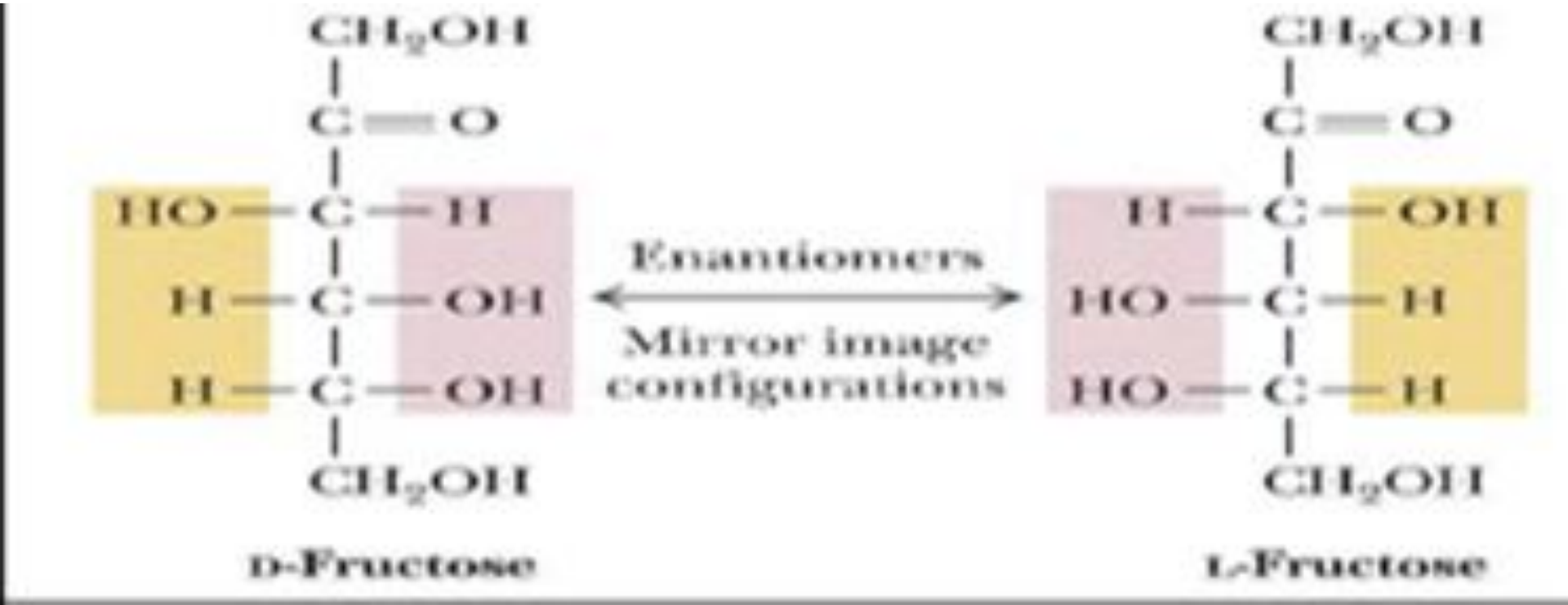
Which n = number of asymmetric carbon atom.

If the aldohexose (formula= $C_6H_{12}O_6$) contain 4 asymmetric carbon atoms, this sugar have 16 stereoisomerisms, 8 of its as L forms and other 8 as D forms.

Enantiomers of fructose

Enantiomers are pairs of molecules:

They exist in two forms that are mirror images of each other. They cannot be superimposed لاتوضع فوق بعض on one another. They are chemically identical.



Isomerism in Monosaccharaides

Optical Isomerism:

The presence of asymmetric carbon atoms also confers optical activity on the compound. When a beam of plane-polarized light is passed through a solution of an optical isomer, it rotates either to the right, **dextrorotatory(+)**, or to the left, **levorotatory(-)**. The direction of rotation of polarized light is independent of the stereochemistry of the sugar, so it may be designated D(-), D(+), L(-), or L(+). For example, the naturally occurring form of **fructose** is the D(-) isomer. In solution, **glucose** is dextrorotatory, and glucose solution are sometimes known as dextrose.

Isomers of Monosaccharaides

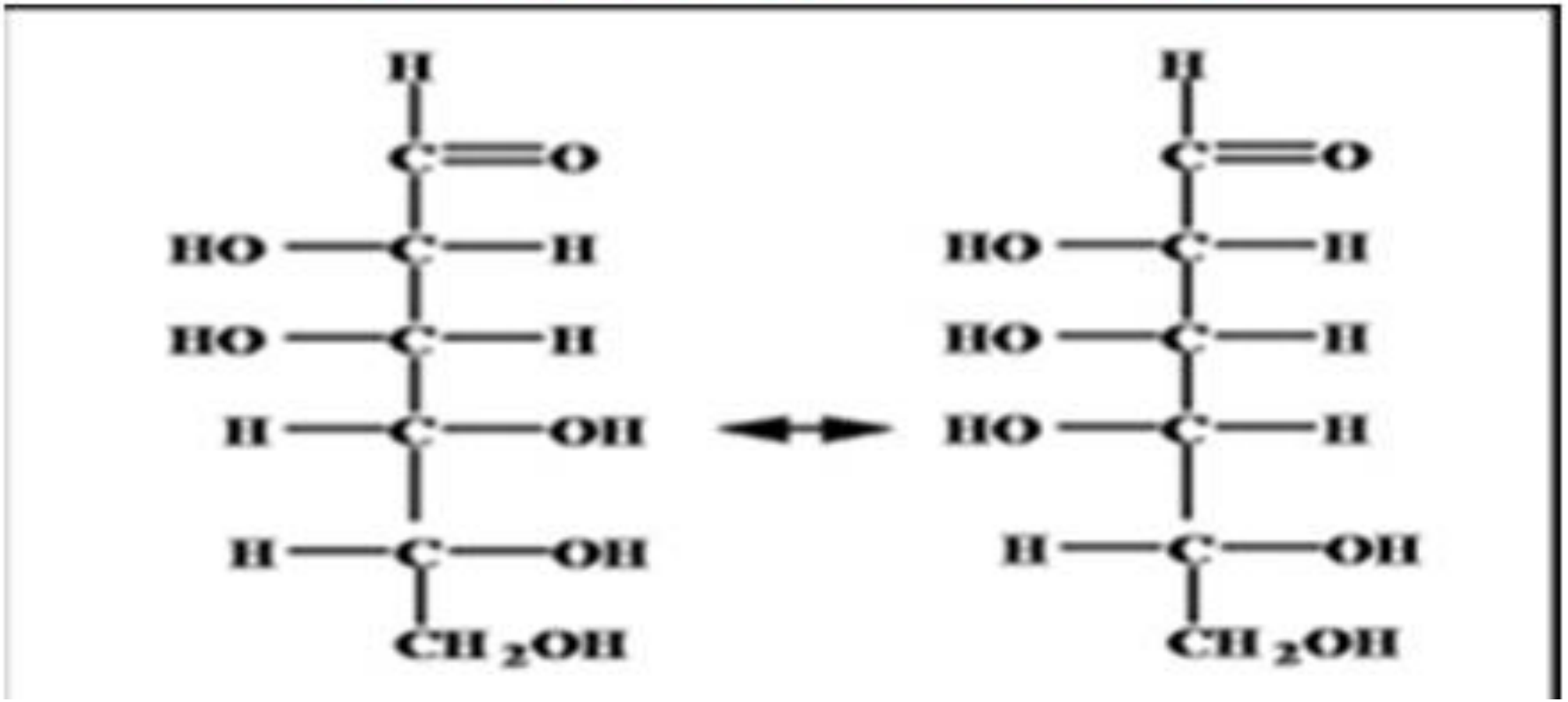
Epimers:

Epimers carbons are the middle asymmetric carbons other than the sub terminal one (related to D&L forms). The differences in orientation of —OH group around only one of these epimer carbons will produce epimers.

Isomers differing as a result of variations in configuration of the —OH and —H on carbon atoms 2,3, and 4 of glucose are known as epimers. Biologically, the most important epimers of glucose are **mannose** and **galactose**, formed by epimerization at carbons 2 and 4, respectively.

Mannose and Galactose are not epimers of each other as they differ in configuration around 2 carbon atoms.

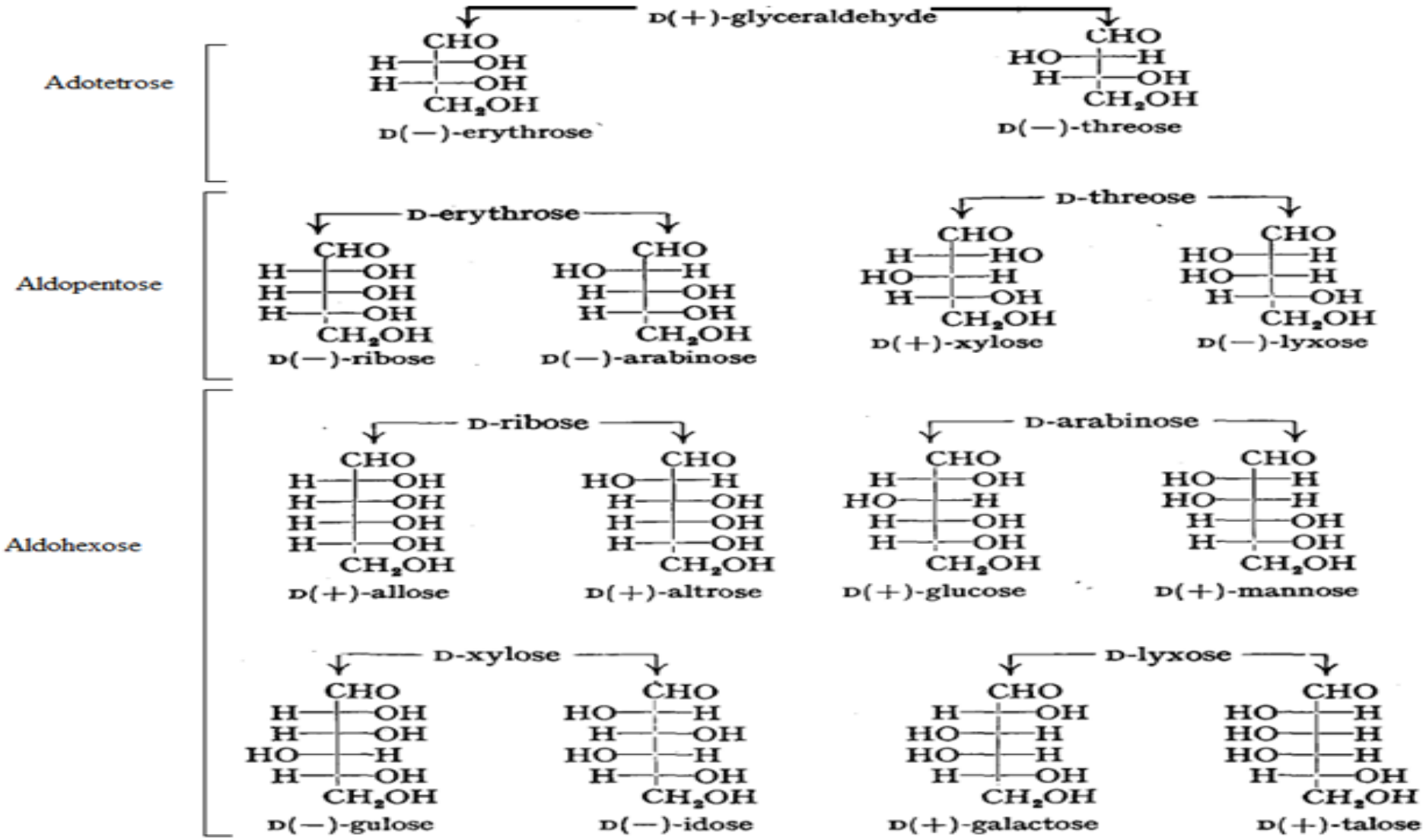
Epimers of Glucose



These two aldohexoses are C — 4 epimers.

They differ only in the position of the hydroxyle group on one asymmetric carbon (carbon 4).

Isomers of Monosaccharaides (Aldohexoses)

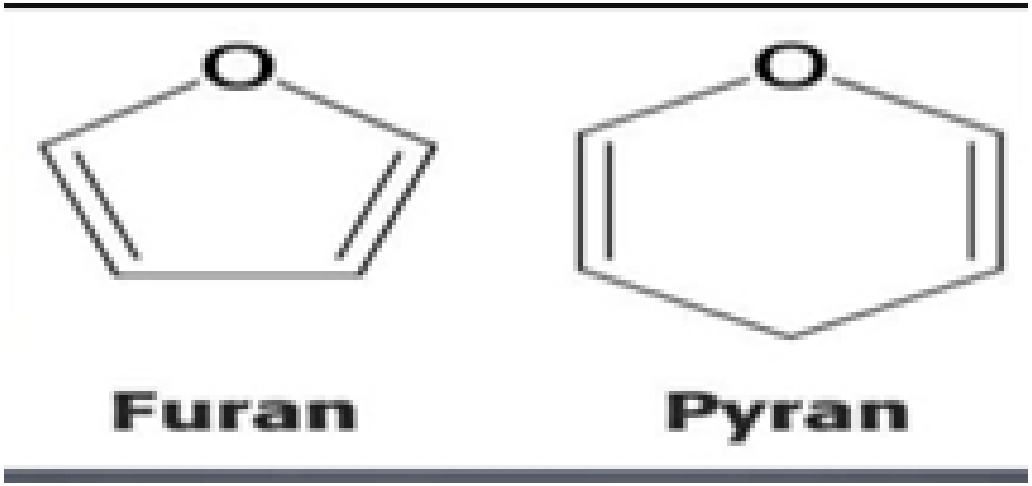


Isomers of monosaccharaides

Pyranose and furanose ring structures:

The ring structures of monosaccharaides are similar to the ring structures of either pyran (a six-membered ring) or furan (a five-membered ring).

For glucose in solution, more than 99% is in the pyranose form.



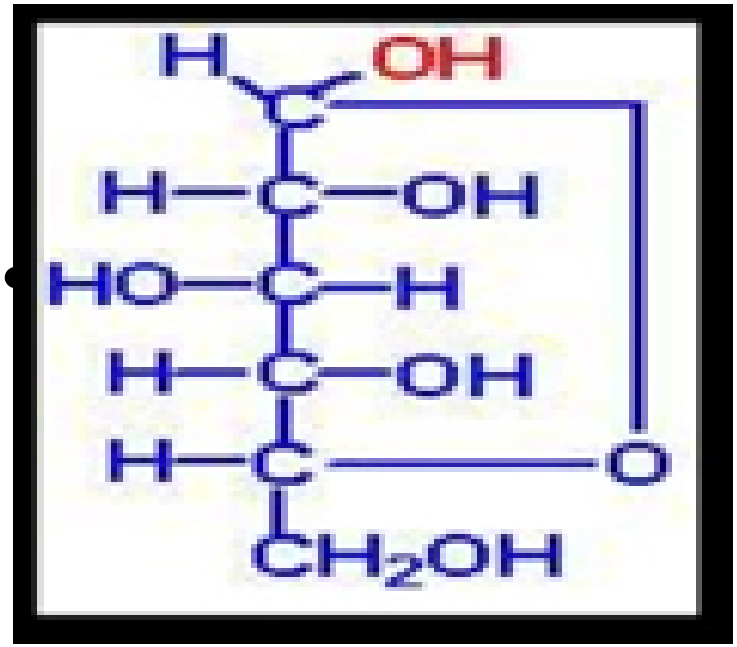
Isomers of monosaccharaides

Anomers:

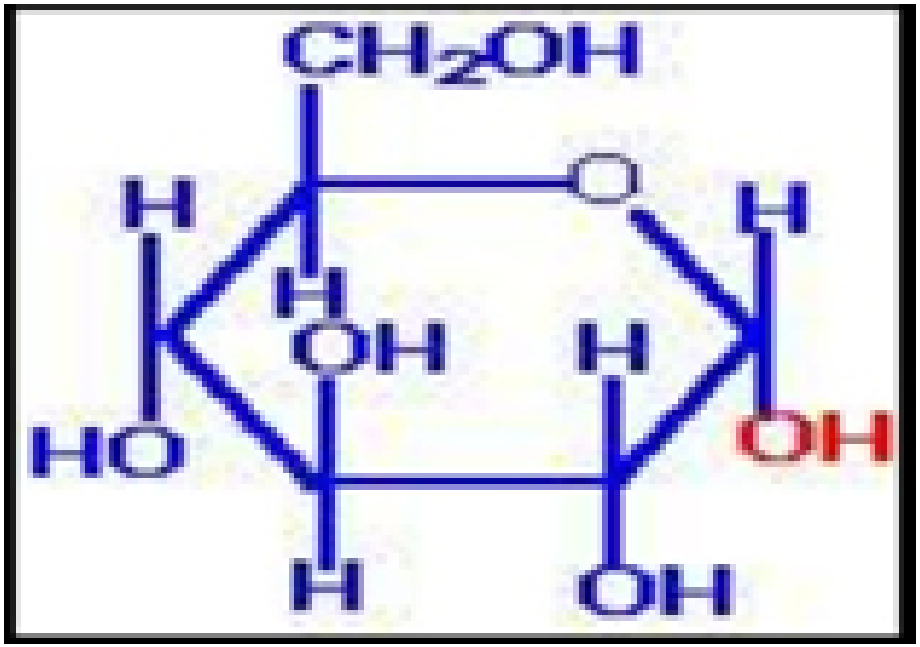
The ring structure of an aldose is a hemiacetal, since it is formed by combination of an aldehyde and an alcohol group.

Similarly, the ring structure of a ketose is a hemiketal. The ring can open and reclose allowing the rotation to occur around the carbon bearing the reactive carbonyl group yielding two possible configuration α and β of the hemiacetal and hemiketal. The carbon about which this rotation occurs is called Anomeric carbon and the two stereoisomers are called Anomers.

Anomers



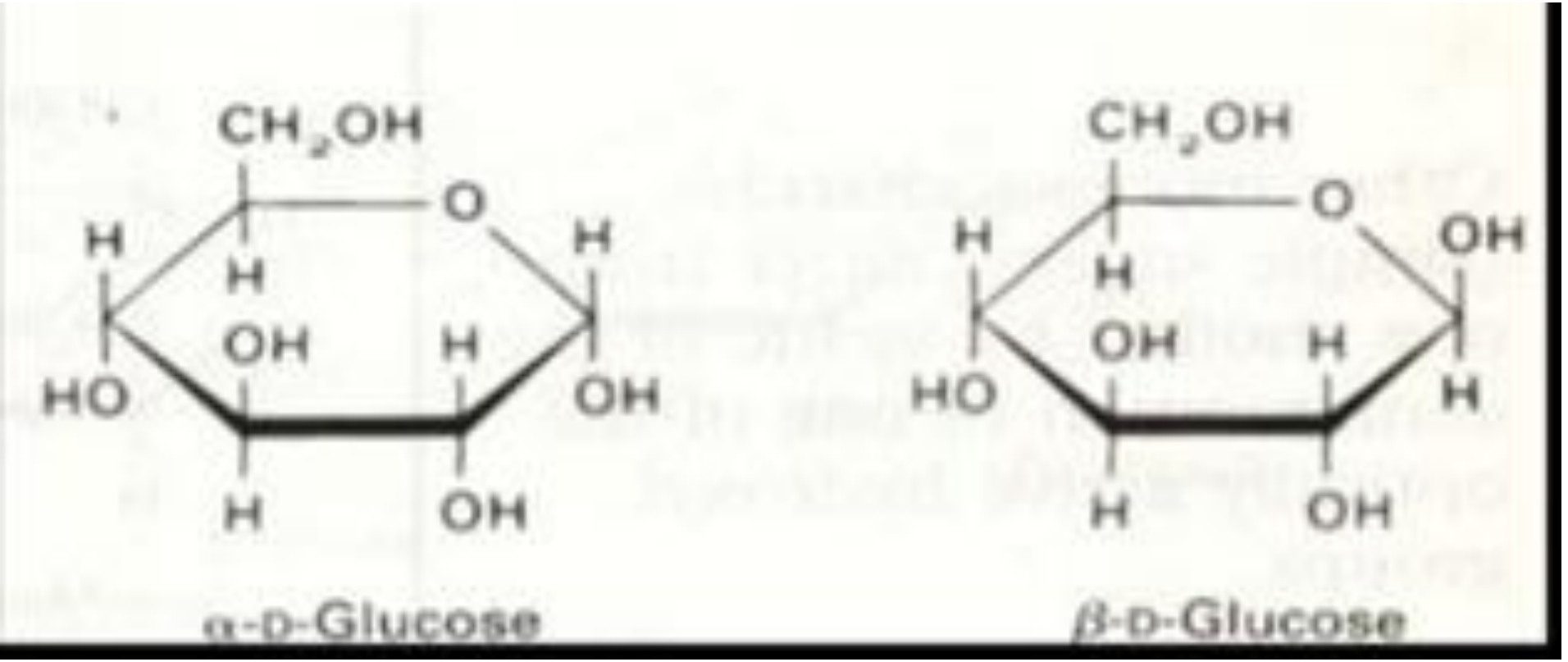
Cyclic Fisher projection of α- D glucose



Haworth projection of of α- D glucose

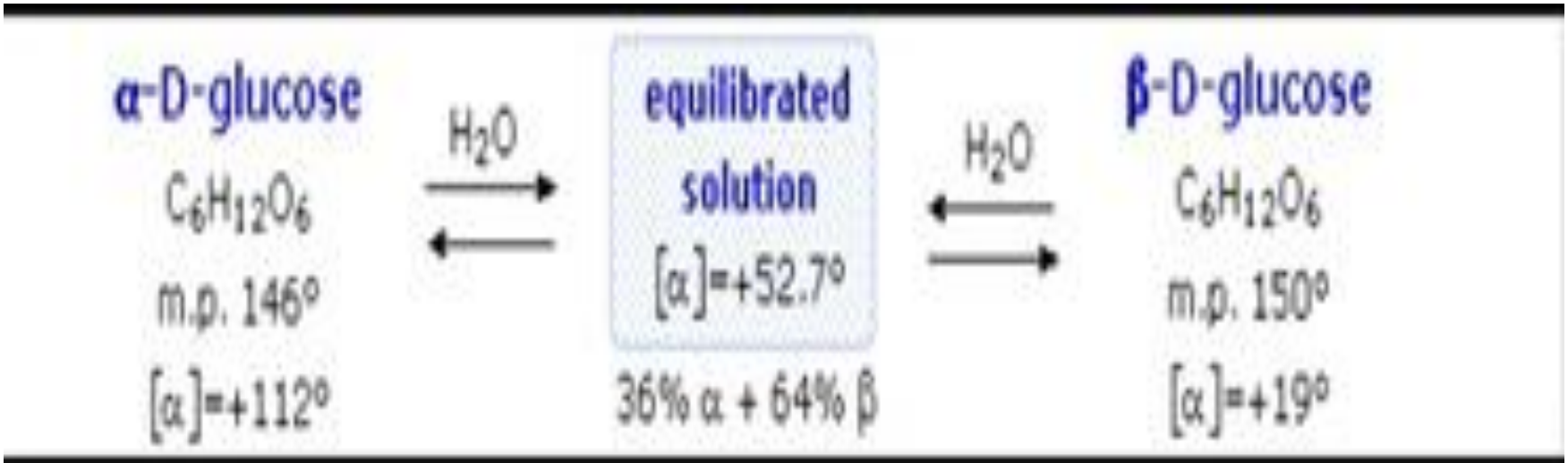
Anomers

When drawn in the Haworth projection, the α configuration places the hydroxyl downward. While the β is the reverse.



Mutarotation

Carbohydrates can change spontaneously between the α and β configurations through the formation of intermediate open chain. This will lead to a process known as **mutarotation**. It is the gradual change of specific optical rotation of sugar.



Pentose sugar

- The pentose sugars **ribose** and **deoxyribose** are part of the nucleotides that make up the crucial nucleic acids like DNA and RNA .
- Also there are:
- **D- Ribulose.**
- **D- Arabinose.**
- **D- Xylose.**
- **D- Lyxoose.**

Hexose sugar

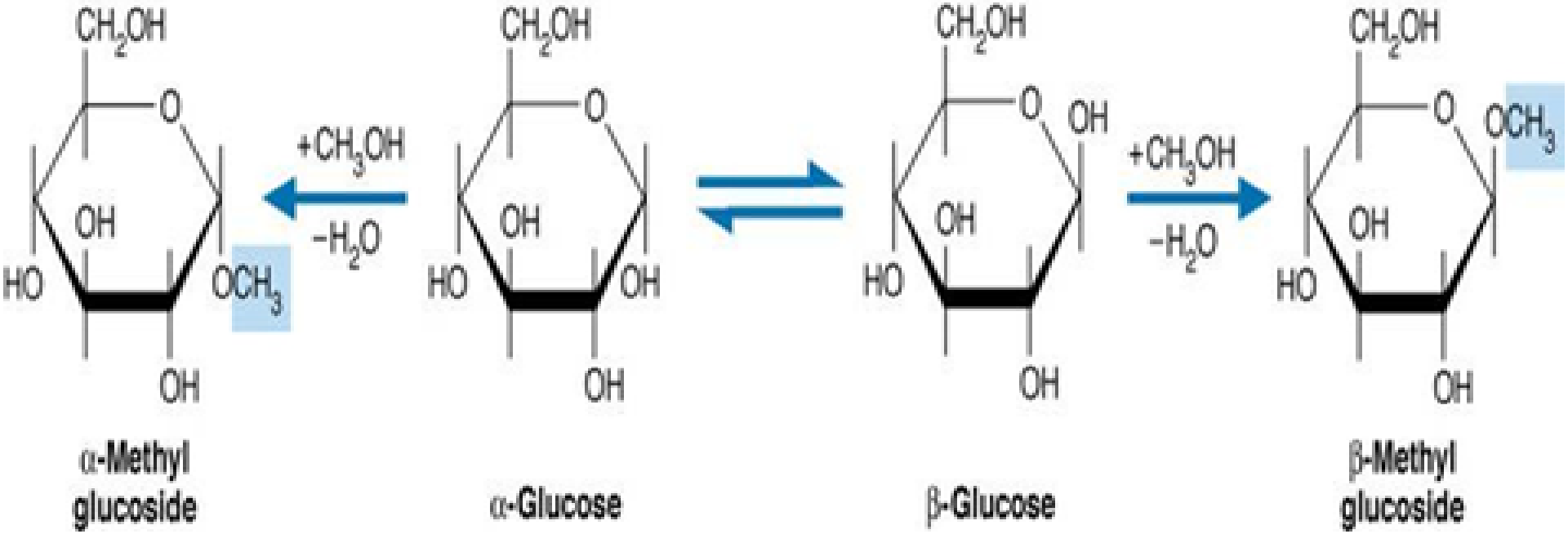
- In bio-organic chemistry, a hexose is a monosaccharide with six carbon atoms, having the chemical formula $C_6H_{12}O_6$. Hexoses are classified by functional group, with aldohexoses having an aldehyde at position 1, and ketohexoses having a ketone at position 2. They are play important role in metabolism as:
- D-Glucose.
- D-Fructose.
- D-Galactose.
- D-Mannose.

H.W./ Source and importance

Glycosides formation

- Glycosides formed when a monosaccharide reacts with an alcohol in the presence of an acid catalyst. This reaction is illustrated for glucose and methanol.
- As is generally all of the most acetals, glycoside formation involves the loss of water. Since acid-catalyzed aldolization is reversible, glycosides may be hydrolyzed back to their alcohol and sugar components by aqueous acid.
- The anomeric methyl glucosides are formed in an equilibrium ratio of 66% alpha to 34% beta.

The equation of glycosides



It involves the synthesis of a large number of medicinal drugs and is also present in spices.

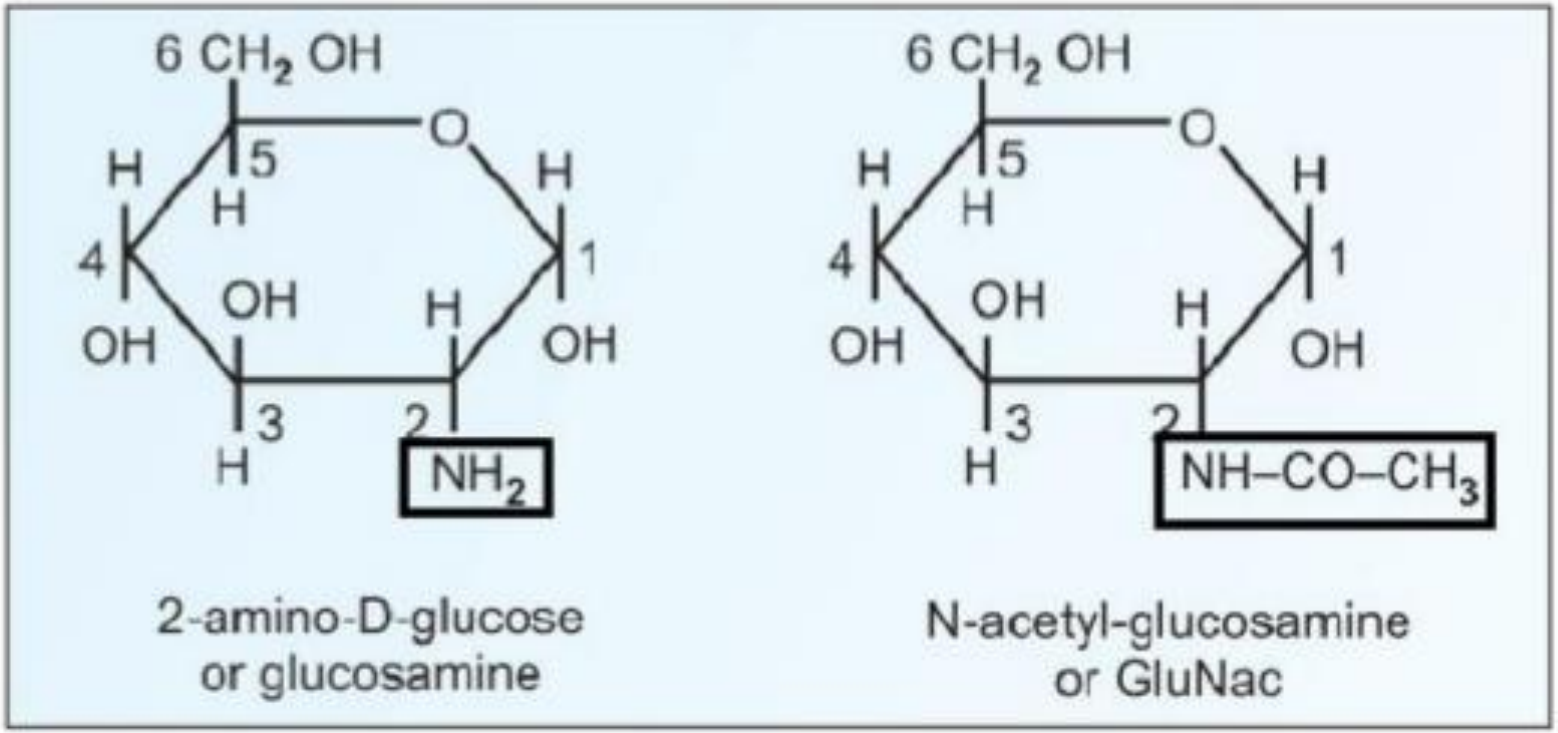
Amino sugars

- They are formed by replacing the hydroxyl group at (C_2 usually)of monosaccharide by amino group. The most common amino sugars are glucoseamine and galactoseamine.

- Glucoseamine is present in heparin.

- Galactoseamine is present in chondroitin of cartilages and tendons.

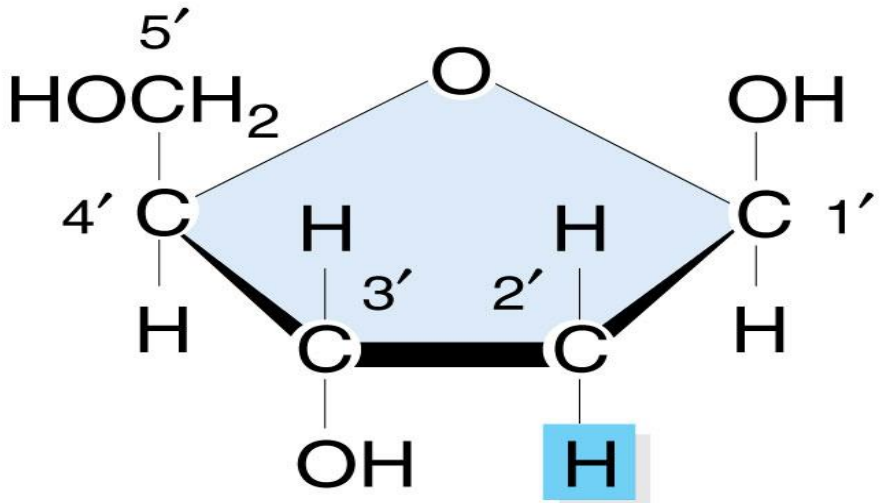
Amino sugars



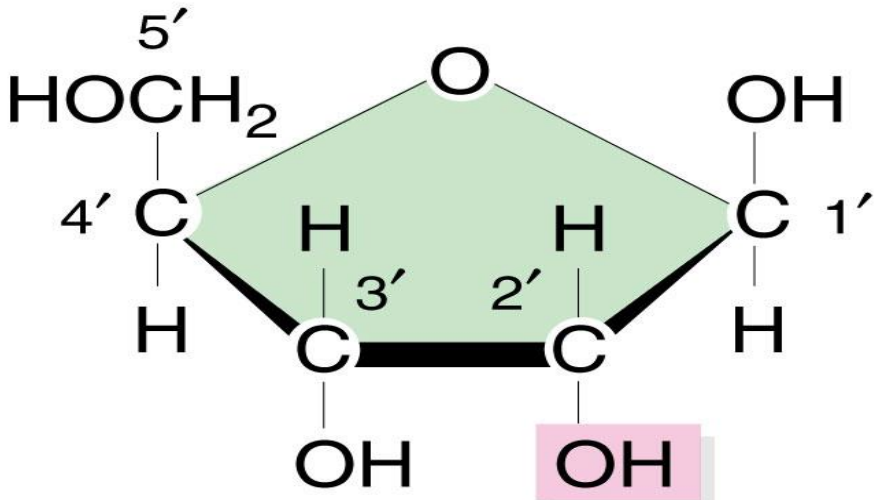
Amino groups may be substituted for hydroxyl groups of sugars to give rise to amino sugars

Deoxy sugars

- Are formed by removal of an oxygen atom usually from 2 nd carbon atom.
- One quite ubiquitous deoxy sugar is 2′-deoxy ribose which is the sugar found in DNA.



Deoxyribose

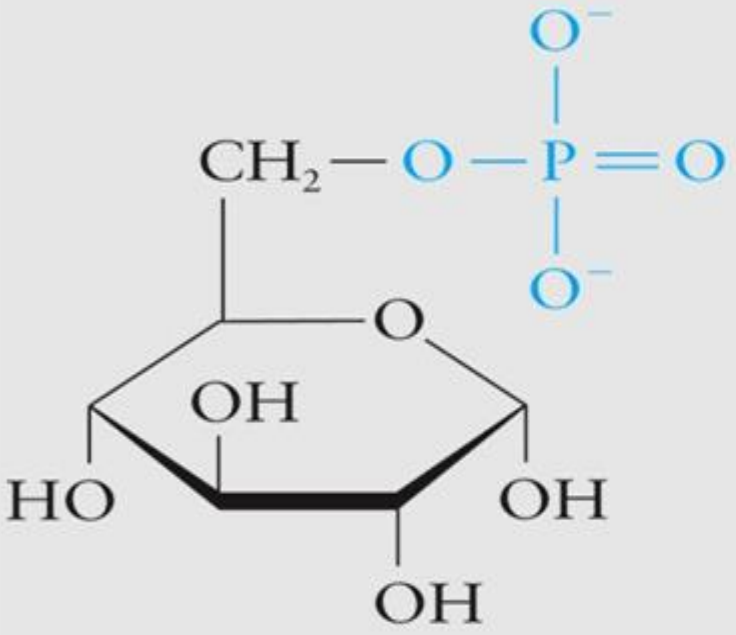


Ribose

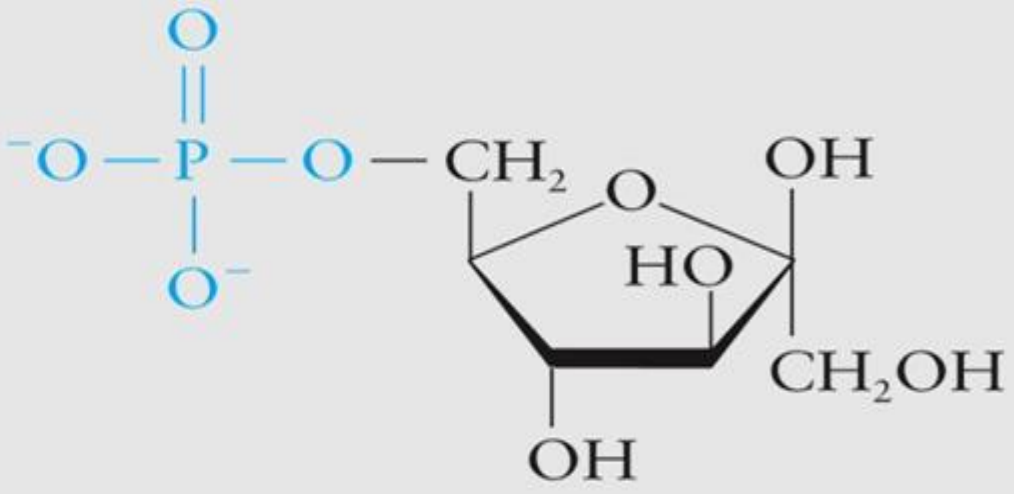
Phosphoric acid esters

- There are many of phosphoric acid esters of monosaccharaides as:

- The –OH groups of **monosaccharides** can behave as alcohols and react with acids (especially phosphoric acid) to form esters.



glucose 6-phosphate



fructose 6-phosphate

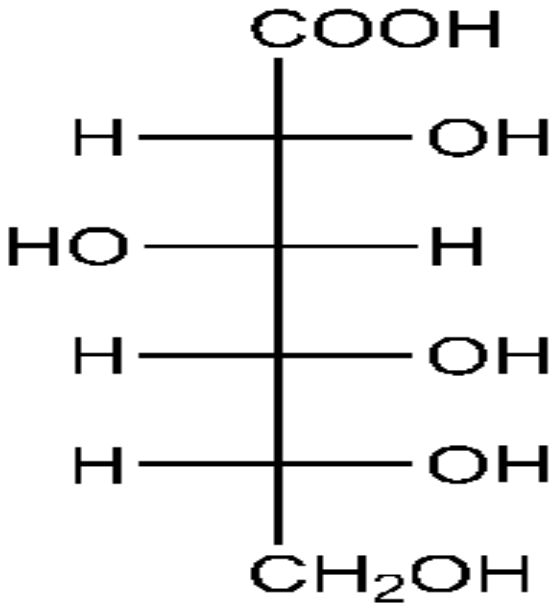
Sugar acids

- Main classes of sugar acids include:

➢ D- Gluconic acid :

- Are formed by the oxidation of aldehyde carbon (C1) to carboxylic group.

- D- Gluconic acid

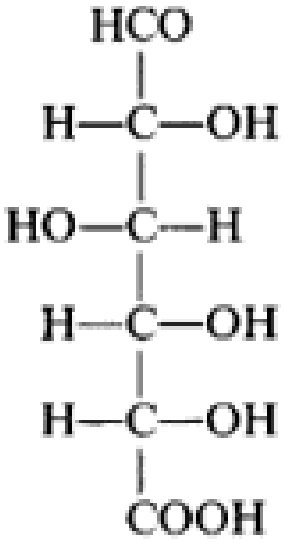


➢ D- Glucuronic acid :

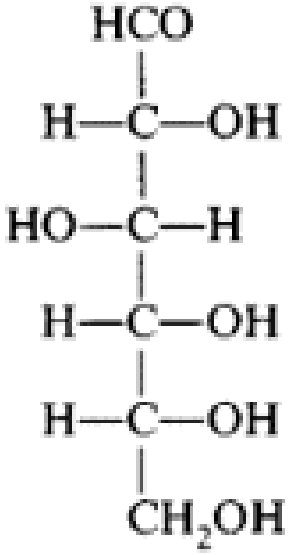
- Are formed by the oxidation the hydroxyl group in carbon number 6 (C6) in D- glucose.

- Is important for the metabolism of microorganisms, plants and animals.

- D- Glucuronic acid



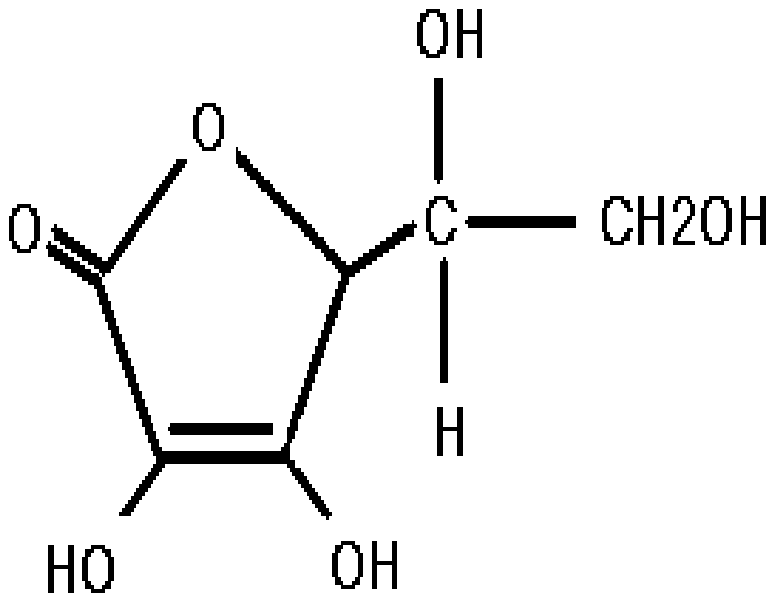
D-Glucuronic acid



D-Glucose, acyclic form

Ascorbic acid:

- Also called vitamin C. It is unstable compound and oxidized to form dehydroascorbic acid .
- It is a vitamin found in food and used as a dietary supplement. The disease scurvy is prevented and treated with **vitamin C**-containing foods or dietary supplements.



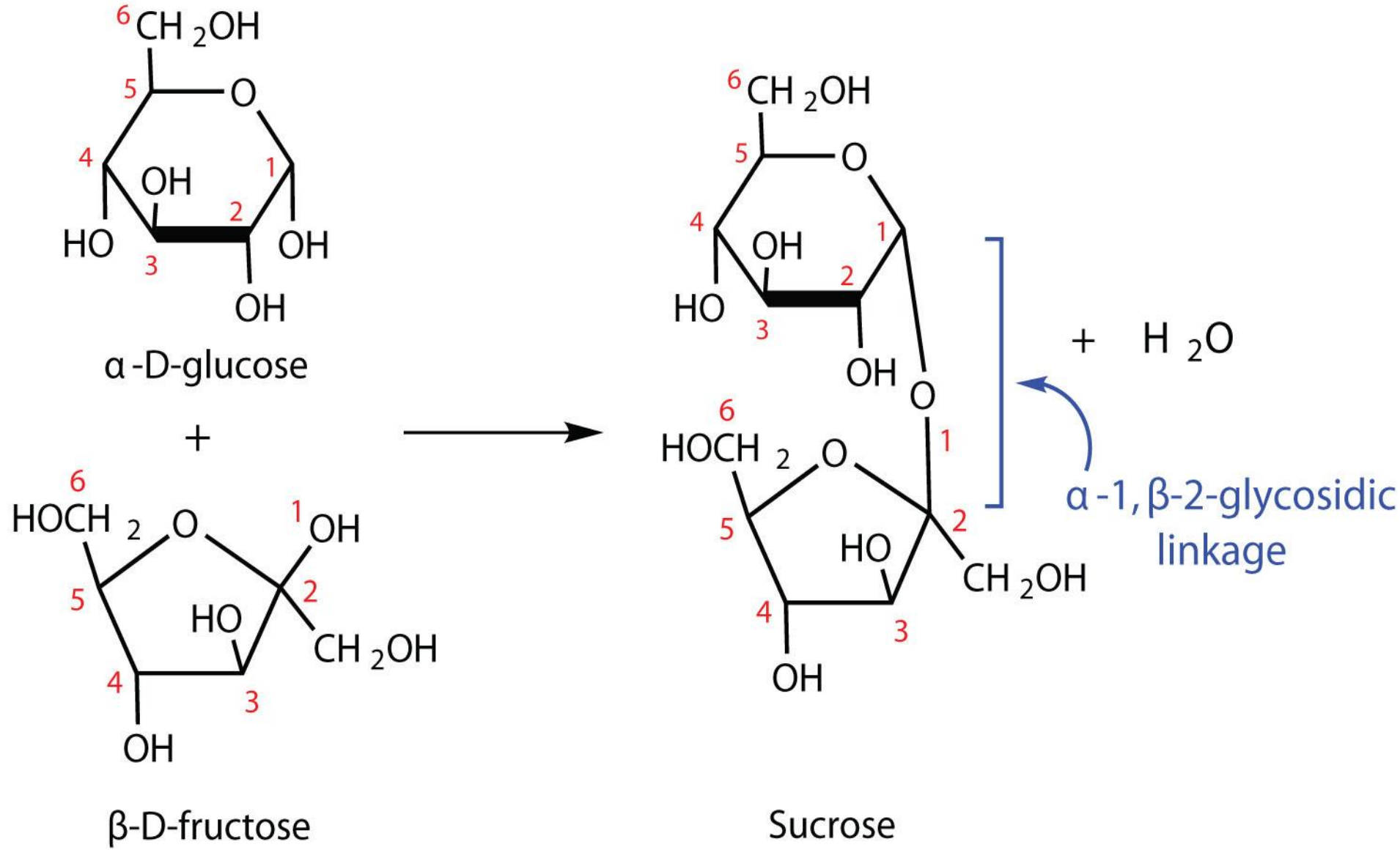
L- Ascorbic acid

Disaccharide

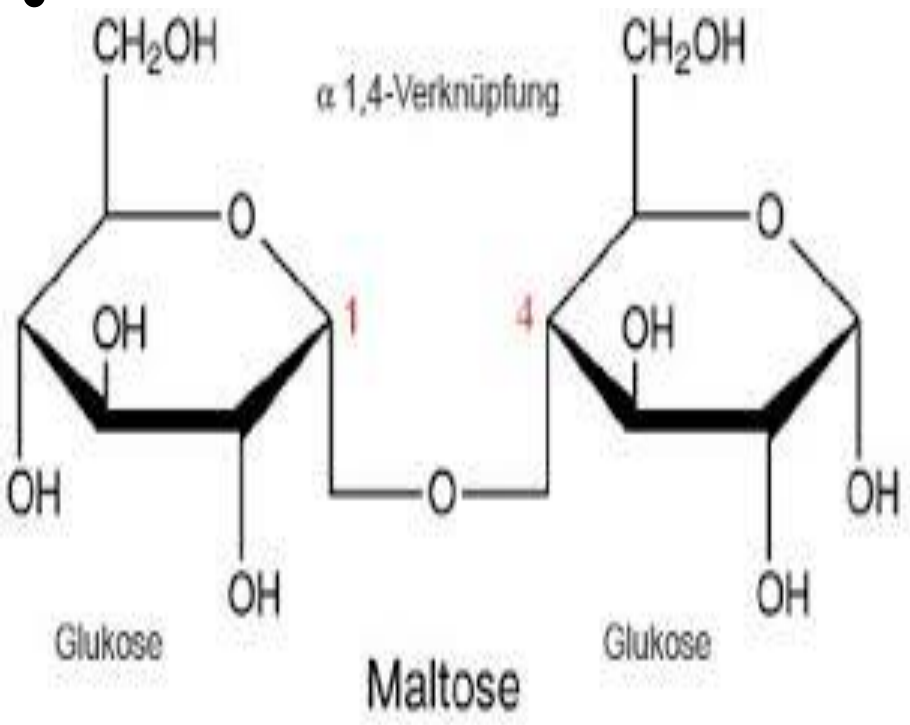
- It is belong to oligosaccharides (also called a double sugar) is the sugar formed when two monosaccharaides (simple sugars) are joined by glycosidic linkage, and elimination of a water molecule.

- The link between the two units varies from one sugar to another, for example, if the bond are binds between two groups of aldehydes or two groups of ketones. The resulting sugar has **non-reducing** properties such as **sucrose**

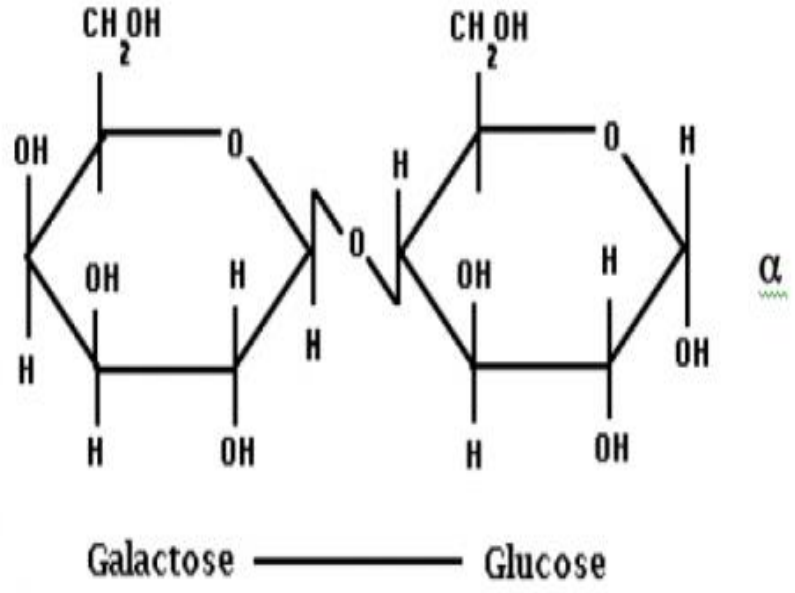
Sucrose

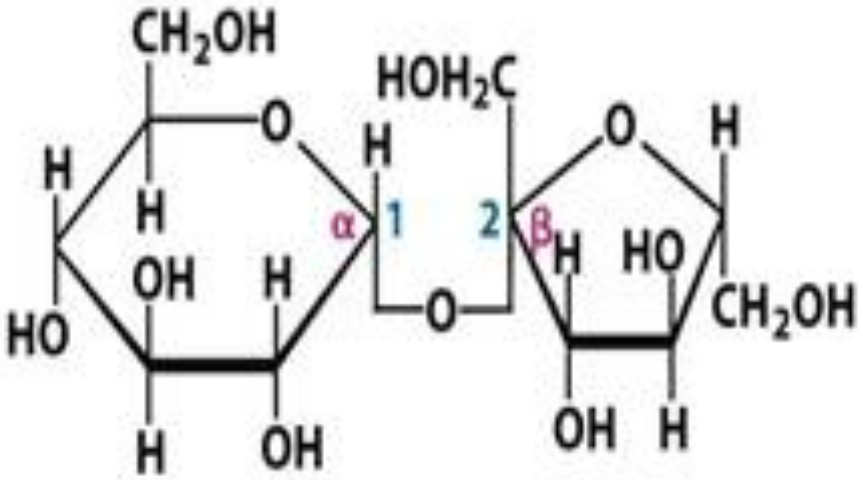

α -D-glucose
+
β-D-fructose
+ H 2O
α -1, β-2-glycosidic linkage
Sucrose

- If the binding involves one group of aldehyde or one group of ketone, so that the other group is free and unconnected, then the sugar is then **reduced** as in **maltose**, **lactose** and **cellubiose**.
-

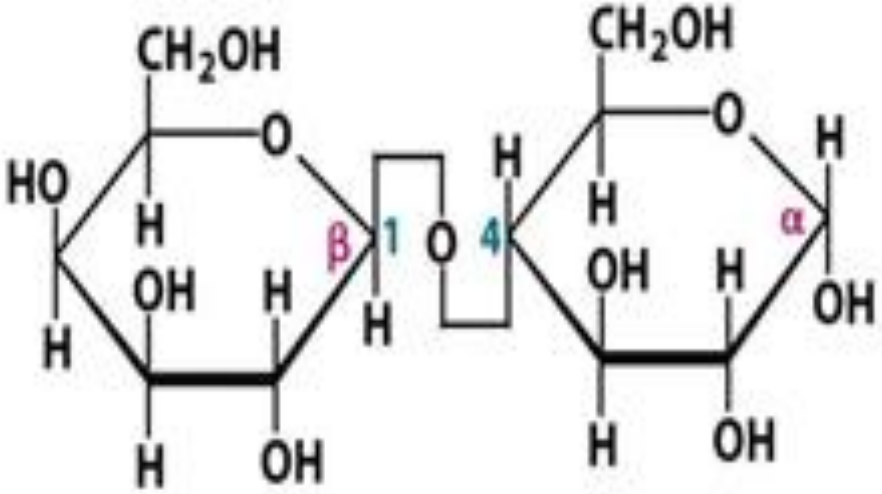


Lactose

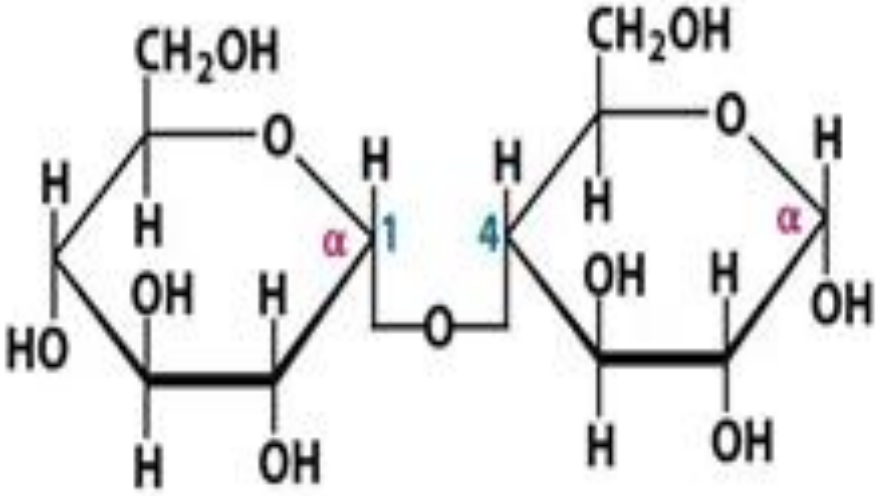




Sucrose
(α-D-Glucopyranosyl-(1→ 2)-β-D-fructofuranose



Lactose
(β-D-Galactopyranosyl-(1→ 4)-α-D-glucopyranose



Maltose
(α-D-Glucopyranosyl-(1→ 4)-α-D-glucopyranose

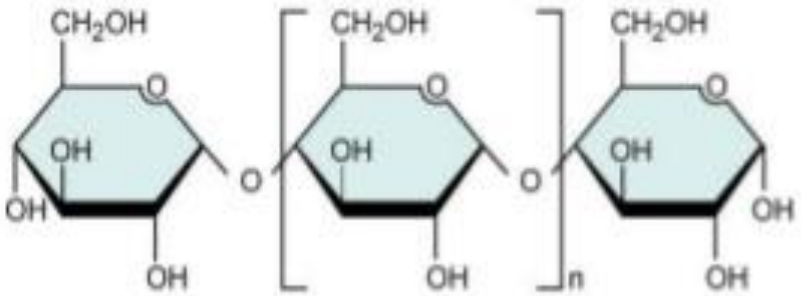
Polysaccharides

- Are polymeric carbohydrate molecules composed of long chains of monosaccharide units bound together by glycosidic bonds, and on hydrolysis by acids or enzymes give the monosaccharaides or oligosaccharides.
- If the polysaccharides contains one type of repeated units called **homopoly saccharide** like starch, glycogen, cellulose, inulin and chitin.
- If the polysaccharides contains two types or more of polysaccharide units called **hetropoly saccharide** like hyaluronic and heparin.

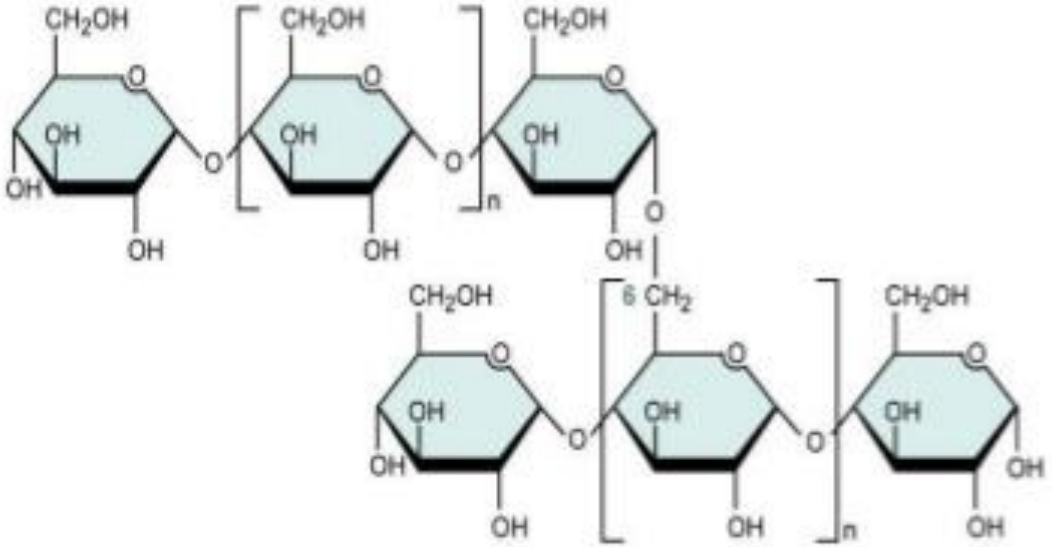
Starch

- Is a polymeric carbohydrate consisting of a large number of glucose units joined by (α- 1-4 glycosidic bonds).
- It consists of two types of molecules: the linear **amylose** and the branched **amylopectin**.
- starch generally contains 20 to 25% amylose and 75 to 80% amylopectin.
- Amylose hydrolysis by α-amylase which present in saliva and pancreas juice, where it works on breaking the α- 1-4 bond to form mixture of glucose and maltose.

Amylose



Amylopectin



Amylopectin

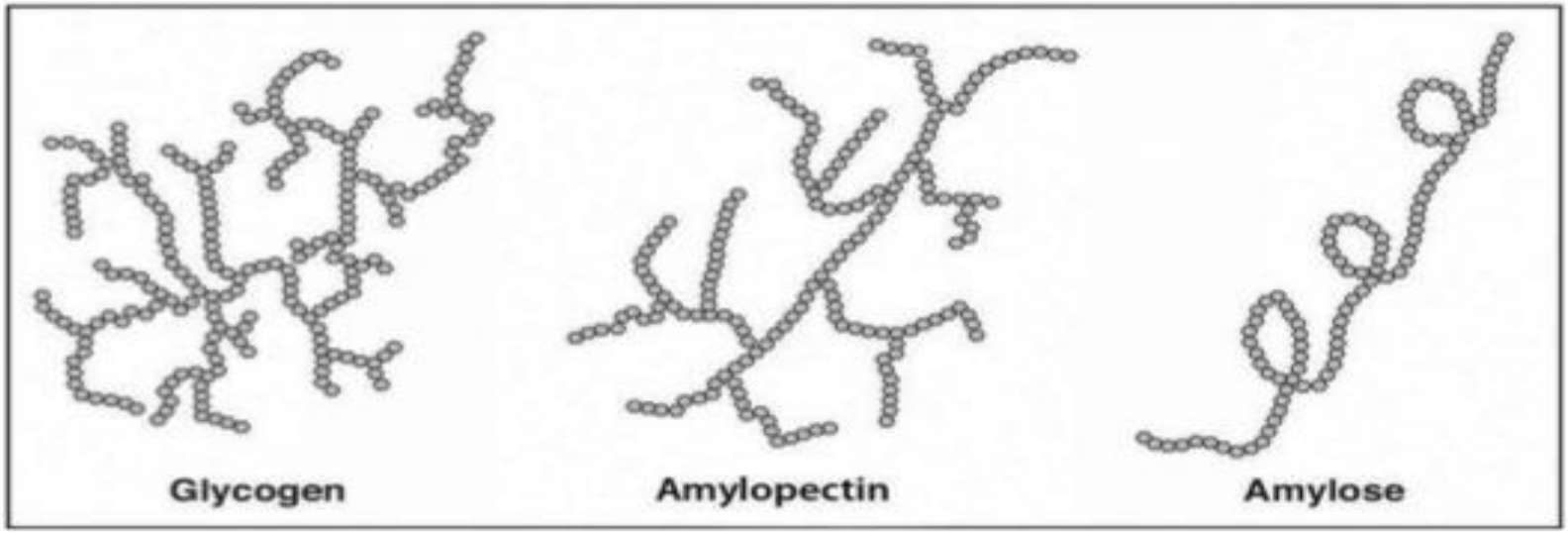
- Is a polysaccharide and highly branched polymer of α-glucose units.
- Glucose units are linked in a linear way with α(1→4) glycosidic bonds. Branching takes place with α(1→6) bonds occurring every 24 to 30 glucose units.
- The hydrolysis of amylopectin by two enzymes α-amylase which broke the α(1-4) bond while the second enzyme α(1-6) glucosidase was broke the α(1-6)bond in branch point to form mixture of glucose and maltose.

Glycogen

- Is a multibranched polysaccharide of glucose that serves as a form of energy storage in humans and animals.
- Glycogen is the analogue of starch. It has a structure similar to amylopectin (a component of starch), but is more branched and compact than starch. The branched happen in 8-12 glucose units.
- Glucose units are linked together linearly by α(1→4) glycosidic bonds from one glucose to the next. Branches are linked to the chains from which they are branching off by α(1→6) glycosidic bonds between the first glucose of the new branch and a glucose on the stem chain.
- Liver glycogen is the direct source of blood glucose, while muscle glycogen is a storage energy uses in muscle strain and exercises.

Glycogen was hydrolysis by the **α-amylase** enzyme and **α(1→6) glycosidase** to form glucose.

Glycogen



It is the reserve carbohydrate in animals. It is stored in liver and muscle. About 5% of weight of liver is made up by glycogen. Excess carbohydrates are deposited as glycogen.

Cellulose

- Cellulose is polysaccharide consisting of a linear chain of several hundred to many thousands of β(1→4) linked D-glucose units. Cellulose is an important structural component of the primary cell wall of green plants. Cellulose is the most abundant organic polymer on earth. The cellulose content of cotton fiber is 90%, that of wood is 40–50%.

- Complete hydrolysis of cellulose by strong acids form glucose units only while partial hydrolysis form the reducing disaccharide cellobiose.

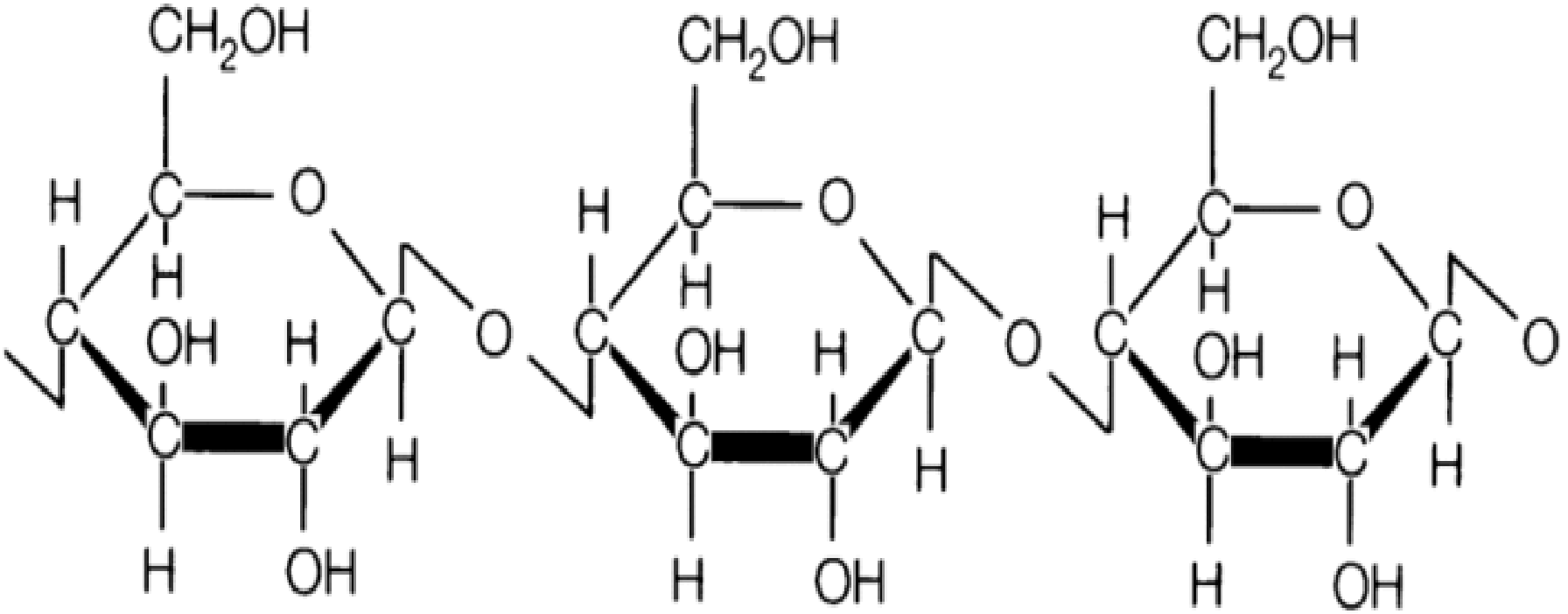
- Beta-1,4 bridges are hydrolyzed by the enzyme **cellobiase (cellulase)**.This enzyme converted the cellulose to maltose and glucose. But this enzyme is absent in animal and hence cellulose cannot be digested.

- Most mammals have only very limited ability to digest dietary fibers such as cellulose by themselves. In many herbivorous animals اكلة الاعشابsuch as ruminants المجترات like cattle الماشيةand sheep, cellulase are produced by bacteria.

The functions of dietary fibers:

- Increasing the bulk of feces so reduces constipation.
الامساك

- Decreasing the absorption of cholesterol from the intestine.



Inulin

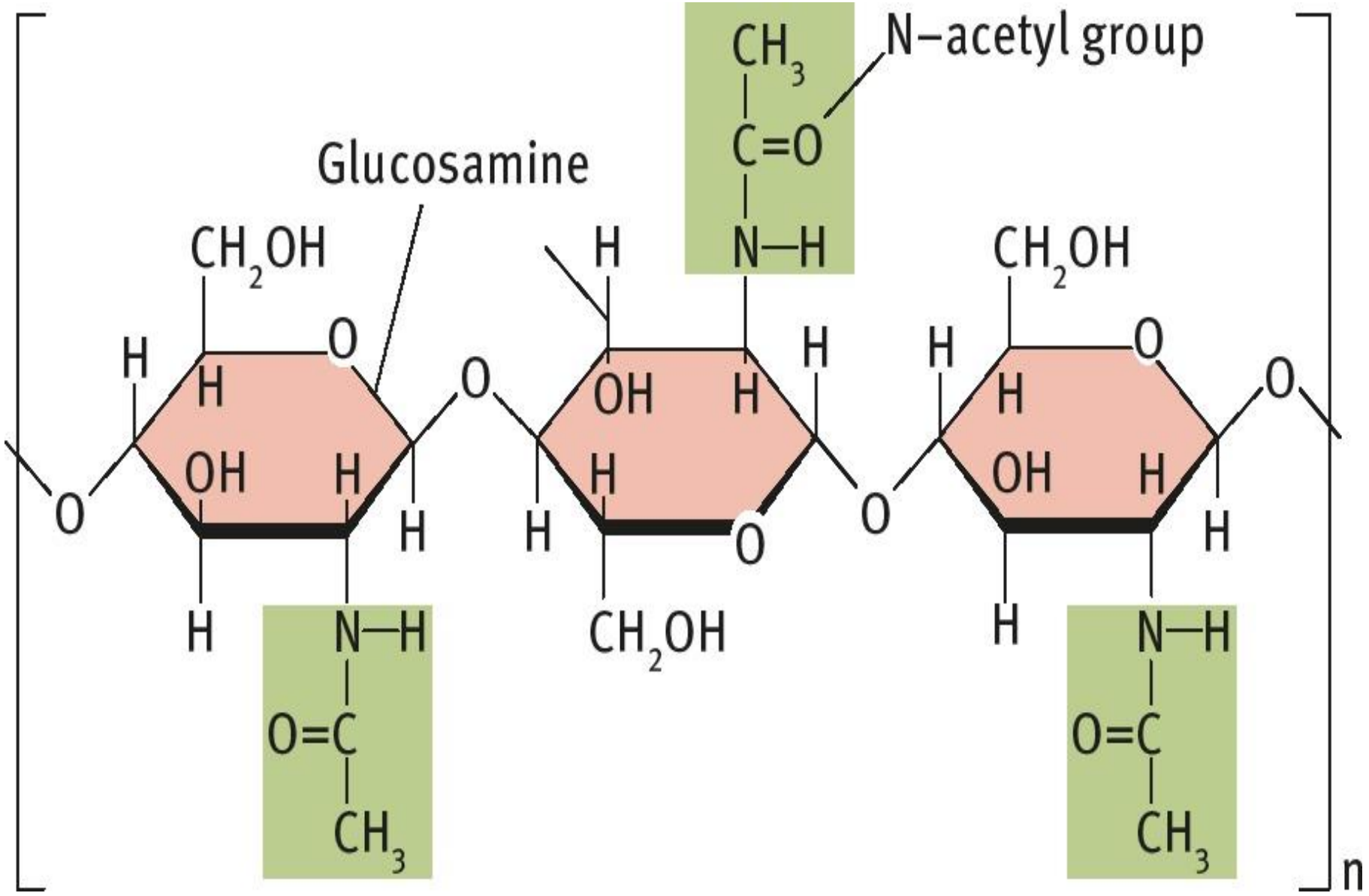
- Inulin are a polysaccharides produced by many types of plants.

- Inulin is used by some plants as a means of storing energy and is typically found in roots. Most plants that synthesize and store inulin do not store other forms of carbohydrate such as starch.

- Inulin is a heterogeneous collection of D-fructose polymers linked with others by β(1→2)glycoside.

Chitin

- Chitin is a long-chain polymer of N-acetyl- D-glucosamine, is a derivative of glucose with β(1→4) glycosidic linkages.
- It is a primary component of cell walls in fungi, the exoskeletons الهيكل الخارجيof arthropods المفصليات, such as crustaceans القشريات(e.g., crabs سرطان البحر, and shrimps الروبيان).
- In terms of function, it may be compared to the protein keratin. Chitin has proved useful for several medicinal, industrial and biotechnological purposes.


N–acetyl group
Glucosamine
CH3
C=O
N–H
CH2OH
H
O
OH
H
O
n