CARBOHYDRATES

Definition

Carbohydrates are naturally occurring organic compounds and are composed of carbon, hydrogen and oxygen. Carbohydrates received their name because the general formula for most of them could be written as $C_n(H_2O)_n$ and thus might be regarded as hydrates of carbon.

However, this definition was not found to be correct when many carbohydrates such as rhamnose ($C_6H_{12}O_5$) and fucose ($C_6H_{12}O_5$) subsequently became known. These sugars do not have the hydrogen and oxygen atoms in 2 to 1 ratio hence can not be called hydrates of carbon. Furthermore, many compounds of C, H and O (e.g., HCHO, CH_3COOH) have hydrogen and oxygen in 2 to 1 ratio, but they are not carbohydrates.

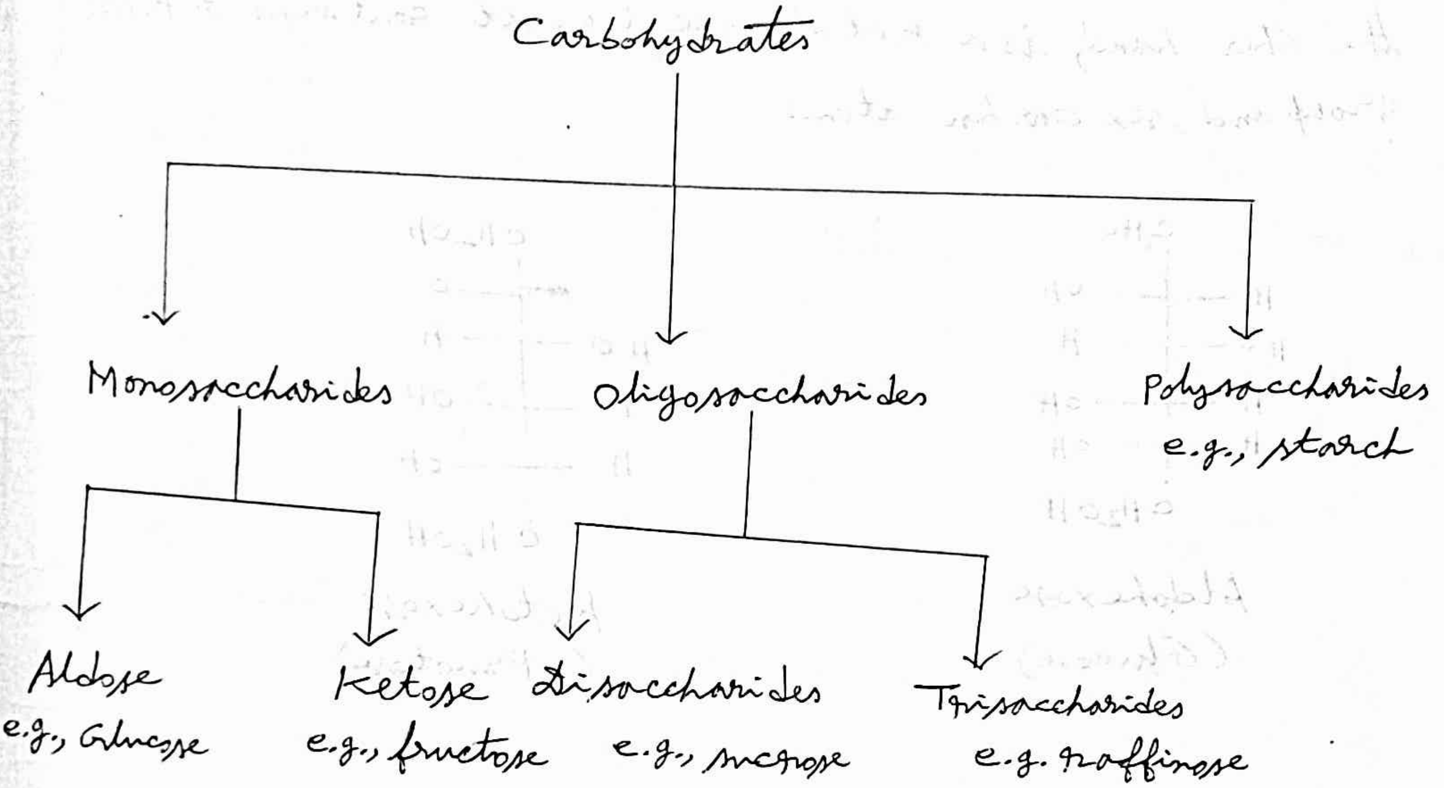
A more accurate definition is as follows:

Carbohydrates are usually defined as polyhydroxy aldehydes and ketones or substances that can be hydrolyzed to yield polyhydroxy aldehydes and ketones.

Simple carbohydrates are known as sugars or saccharides (Latin saccharum, Greek sakcharon means sugar). The ending of the names of most sugars is -ose such as glucose, fructose, sucrose.

Classification of Carbohydrates

Carbohydrates have been classified into three major categories.



1) Monosaccharides

Monosaccharides are the simplest carbohydrates and they can not be hydrolyzed further into smaller units.

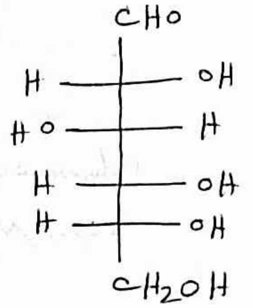
Monosaccharides are further classified according to —

a) The number of carbon atoms present in the molecule.
For example — A monosaccharide containing three, four, five and six carbon atoms is called a triose, tetrose, pentose and hexose.

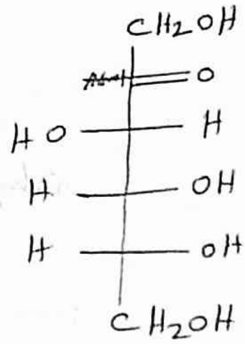
b) Whether carbohydrate contain an aldehyde or keto group.
For example — A monosaccharide containing an aldehyde group is called an aldose and a monosaccharide containing a keto group is called a ketose.

These two classifications are frequently combined.

For example - glucose is an aldohexose as it has an aldehyde group and six carbon atoms. Fructose, on the other hand, is a ketohexose i.e. it contains a keto group and six carbon atoms.



Aldohexose
(Glucose)



Ketohexose
(Fructose)

2) <u>Oligosaccharides</u>

Carbohydrates that hydrolyze to yield 2–10 molecules of monosaccharide are called oligosaccharides.

They have been subdivided into the following groups:

a) <u>Disaccharides</u>

Carbohydrates that undergo hydrolysis to produce only two molecules of monosaccharide are called disaccharides.

For example: ~~Sucor~~ sucrose, maltose, lactose

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + H_2O \longrightarrow \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Fructose}}{C_6H_{12}O_6}$$

$$\underset{\text{Maltose}}{C_{12}H_{22}O_{11}} + H_2O \longrightarrow \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Glucose}}{C_6H_{12}O_6}$$

2) Trisaccharides

Carbohydrates that undergo hydrolysis to produce three molecules of monosaccharide are called trisaccharides.

For example - Raffinose

$$C_{18}H_{32}O_{16} + 2H_2O \longrightarrow C_6H_{12}O_6 + C_6H_{12}O_6 + C_6H_{12}O_6$$

Raffinose   Glucose   Galactose   Fructose

3) Polysaccharides

Carbohydrates that on hydrolysis yield a large number of molecules of monosaccharides (>10) are known as polysaccharides. They are high molecular weight carbohydrates.

For example - Starch, Cellulose - both of them glucose polymers. Hydrolysis of either yields a large number of glucose units.

$$(C_6H_{10}O_5)_n + nH_2O \longrightarrow nC_6H_{12}O_6$$

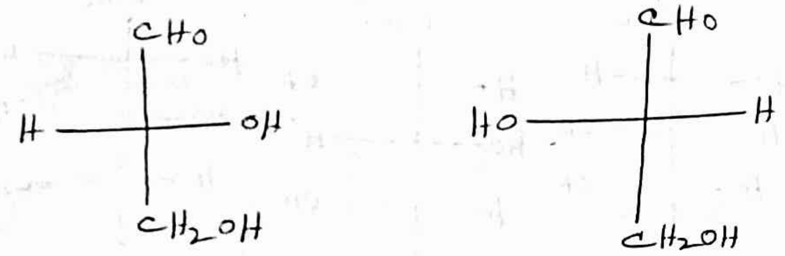
Starch   Glucose

NOTE

In contrast to monosaccharides (and disaccharides), which are water soluble and sweet in taste, the polysaccharides are tasteless and water insoluble substances.

Monosaccharides

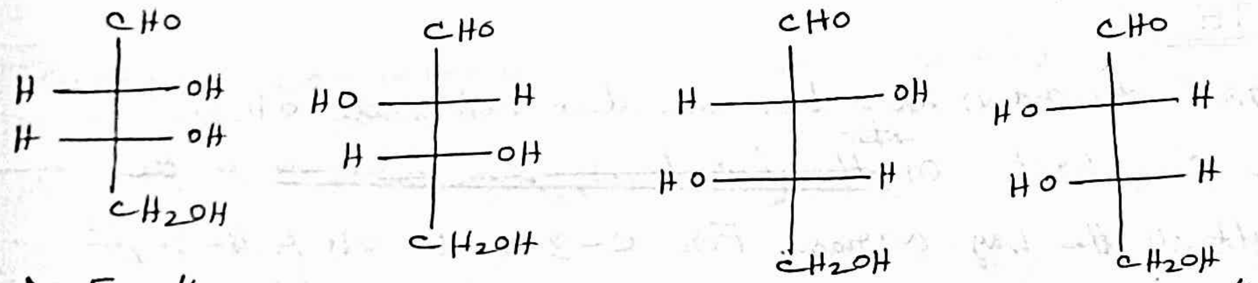
Glyceraldehyde ($HOCH_2\overset{*}{C}HOHCHO$) may be considered as the simplest monosaccharide. Since, the molecule has a chiral carbon atom, it exists in two enantiomeric forms referred to as D- and L- forms.



D(+)Glyceraldehyde L(-)-Glyceraldehyde

Aldotetrose

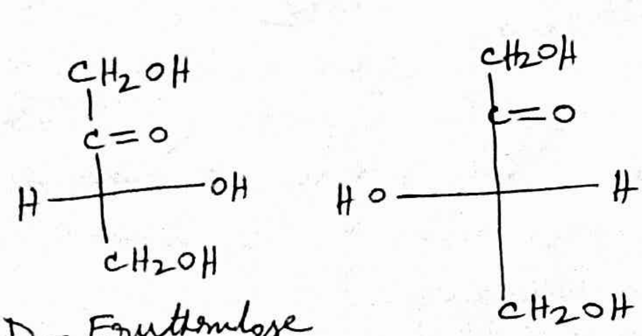
Aldotetroses ($HOCH_2\overset{*}{C}HOH\overset{*}{C}HOHCHO$) have two dissimilar chiral carbon atoms and hence four stereoisomers ($2^2=4$) are possible.



D(-)Erythrose D-(-)-Threose L-(+)Threose L-(+)-Erythrose

Ketotetrose

Ketotetroses ($HOCH_2CO\overset{*}{C}HOHCH_2OH$) has only one chiral carbon atom and hence only two stereoisomers are possible.

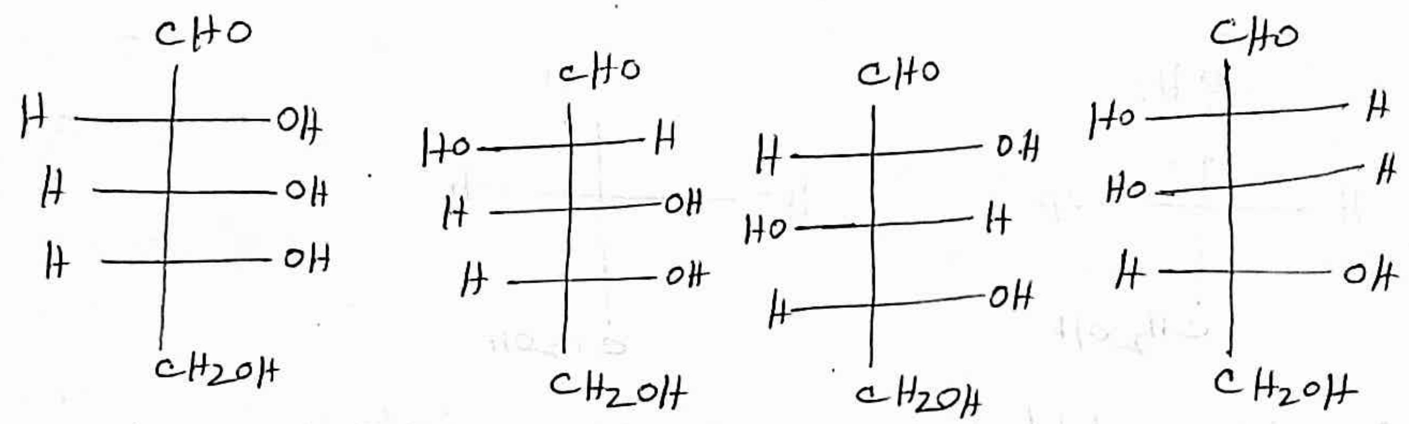


D- Erythrulose

L- Erythrulose

Aldopentose

Since aldopentoses ($HOCH_2\overset{*}{C}HOH\overset{*}{C}HOH\overset{*}{C}HOHCHO$) contain three different chiral carbon atoms, they can exist in eight ($2^3 = 8$) optically active form.



D(-)Ribose ~~D(-)Arabinose~~ D-(-)-Arabinose D(+)xylose D(-)lyxose

The remaining four aldopentoses, which are the mirror images of the abovementioned sugars, belong to L- series.

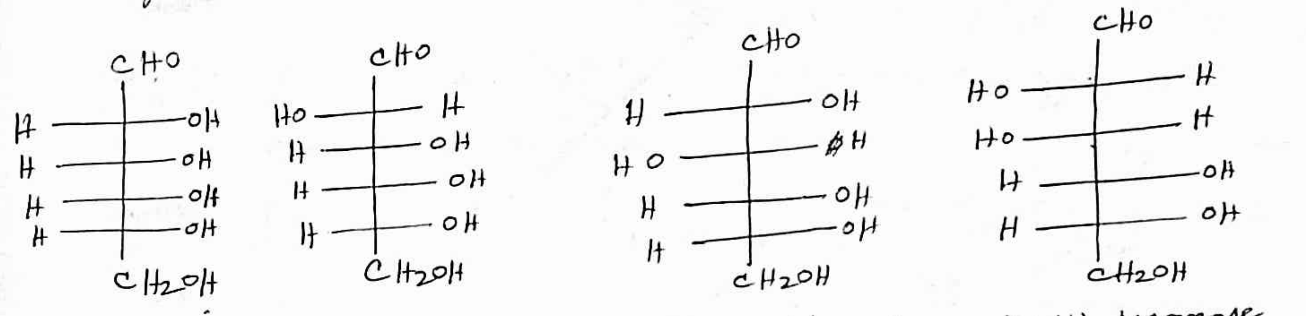
NOTE

Write the names in a line and above each write CH_2OH. Then for C-4 write OH, ~~the four times, then for C-3~~ to the right all the way across. For C-3 write OH to the right two times, then two to the left. For C-2, alternate OH and H to the right.

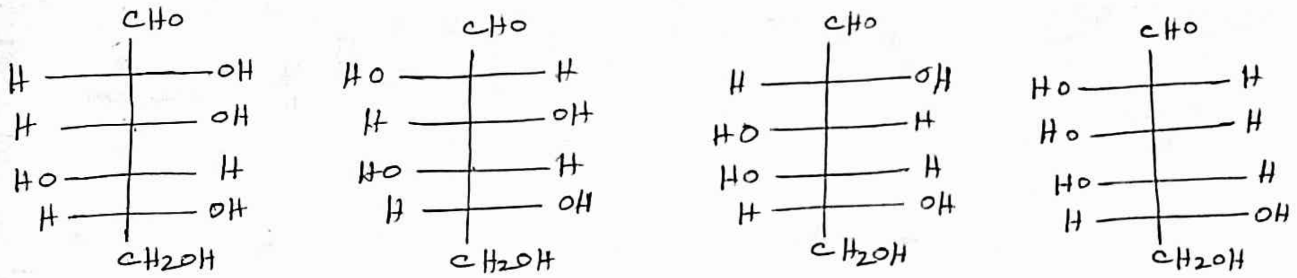
Aldohexose

Since, there are four different chiral carbon atoms in aldohexoses ($HOCH_2\overset{*}{C}HOH\overset{*}{C}HOH\overset{*}{C}HOH\overset{*}{C}HOHCHO$), sixteen stereoisomers ($2^4 = 16$) are possible.

The structures of eight aldohexoses belonging to the D-series are given below.



D-(+)- Allose   D-(+)- Altrose   D-(+)- Glucose   D-(+)- Mannose

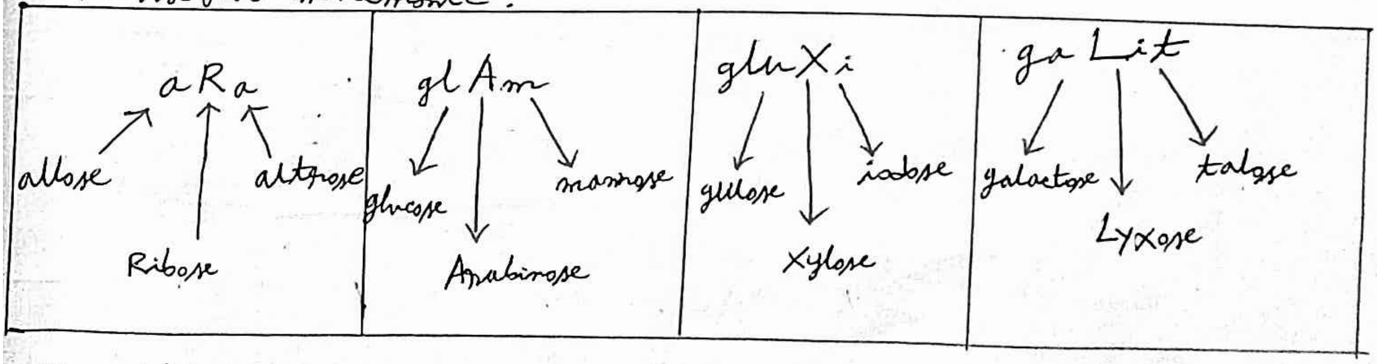


D-(-)- Gulose   D-(+)- Idose   D-(+)- Galactose   D-(+)- Talose

The remaining eight ~~aldop~~ aldohexoses are the mirror images of the abovementioned sugars and are blong to L-series.

NOTE

A useful mnemonic:



For aldohexoses

1. Write the names in a line and above each write CH_2OH.
2. For C-5, Write OH to the right to the all the way across.
3. For C-4, Write OH to the right four times, then four to the left.
4. For C-3, Write OH twice to the right, twice to the left and repeat.
5. For C-2, alternate OH and H to the right.