CARBOHYDRATES (Carbo – Carbon, Hydrates – Water)

Definition

i. Hydrates of Carbon.

ii. Carbohydrates are organic compounds, containing carbon, hydrogen and oxygen, hydrogen a oxygen occur in the ratio of 2:1 as in water (H_2O).

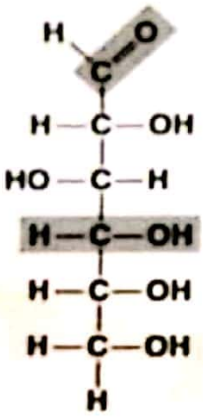
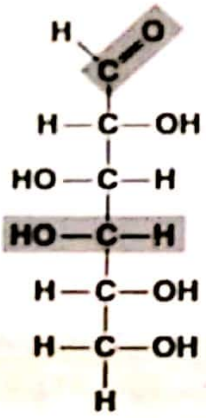
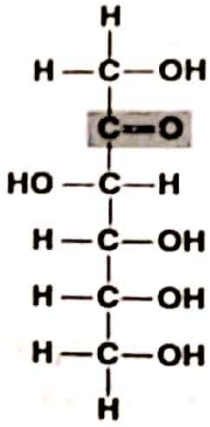
iii. There are certain compounds, which contain carbon, hydrogen and oxygen, hydrogen and oxyg occur in the ratio of 2:1 But these are not carbohydrates. e.g. Acetic acid ($C_2H_4O_2$), Lactic a ($C_3H_6O_3$) etc.

iv. There are certain compounds, which contain carbon, hydrogen and oxygen, in which hydrogen a oxygen do not occur in the ratio of 2:1 but these are carbohydrates. e.g. Deoxyribose ($C_5H_{10}O_4$)

Modern and conclusive definition of carbohydrates is given below:

Carbohydrates are polyhydroxyaldehydes and polyhydroxyketones compounds.

For example:

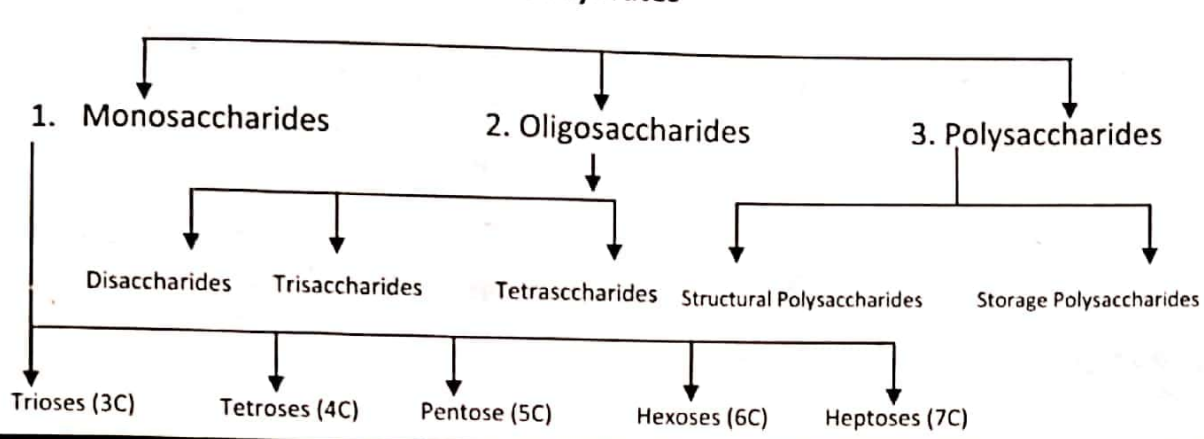
Aldose (Aldehyde Sugar)		Ketose (Ketone Sugar)
Hexoses: 6-carbon sugars ($C_6H_{12}O_6$)		
		
Glucose	Galactose	Fructose

So those compounds, which have many hydroxyl (HO) groups and containing either Aldehyde ( ) or Ketone ( ) group are known as carbohydrates.

- Aldehyde functional group always lies at carbon number 1 e.g. Glucose.
- Ketone functional group always lies at carbon number 2 e.g. Fructose.

Classification of Carbohydrates

Carbohydrates are classified into three groups:



1. Monosaccharides (Mono-One, Saccharum-Sugar)

Characteristics

i. Monosaccharides are the simplest sugars.
ii. Monosaccharides cannot be further hydrolysed into simple sugars.
iii. Monosaccharides are easily soluble in water
iv. Monosaccharides are sweet in taste.
v. The empirical formula of monosaccharide is $C_n(H_2O)_n$, n = number of carbons

➢ Classification of Monosacharides

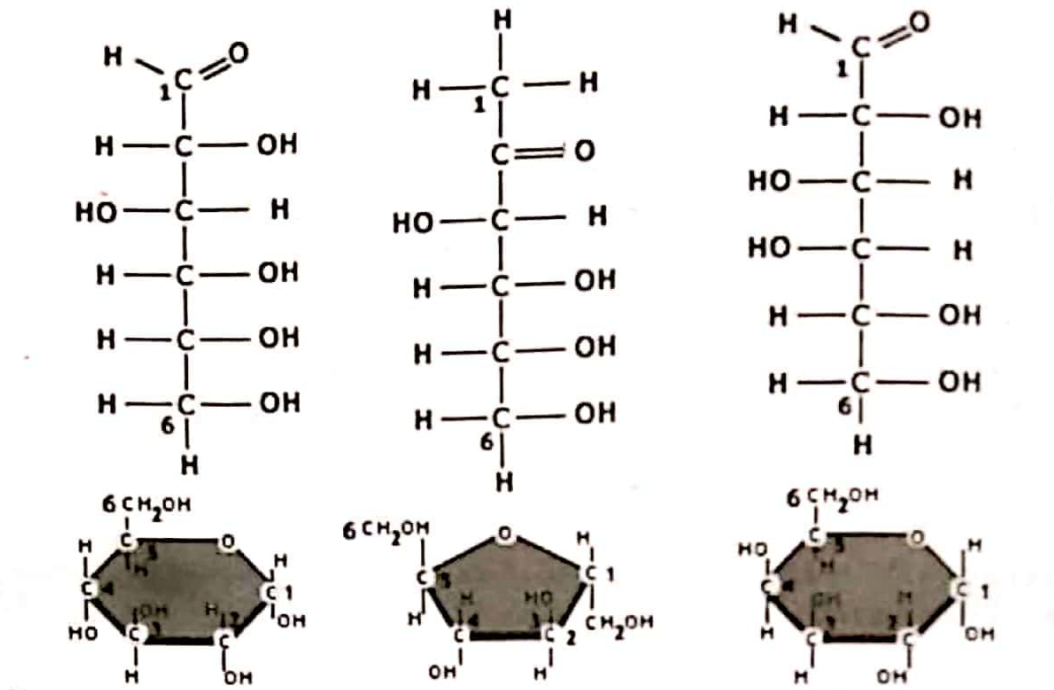
Monosacharides are classified on the basis of number of carbons, in to the following groups:

i. Trioses: Contain Three carbon e.g. Glyceraldehyde, Dihydroxyacetone
ii. Tetroses: Contain four Carbons e.g. Erythrose, Erythrulose
iii. Pentoses: Contain Five Carbon e.g. Ribose, Ribulose, Deoxyribose
iv. Hexoses: Contain Six Carbon e.g. Glucose, Fructose, Galactose
v. Heptoses: Contain Seven Carbon e.g. Sedoheptulose, Glucoheptose.
vi. Monosaccharides names end with suffix "ose".

Examples of Aldose and Ketose monosaccharide sugars

Monosaccharides	Aldose form (containing aldehyde functional group)	Ketose form (containing Ketone functional group)
Trioses (3-C)	Glyceraldehydes	Dihydroxyacetone phosphate
Tetroses (4-C)	Erythrose	Erythrulose
Pentoses (5-C)	Ribose	Ribulose
Hexoses (6-C)	Glucose	Fructose
Heptoses (7-C)	Glucoheptose	Sedoheptulose

Open chain and Ring structures of Glucose, Fructose and Galactose is given below:



Glucose(Pyranose form) Fructose(Furanose form) Galactose(Pyaranose form)

All monosaccharide occur in open chain structure when in solid state and when put in water form ring structure.

➢ Stereoisomerism

Isomer: Isomers are those molecules which have the same molecular formula but different structural formula e.g. Glucose, Fructose, Glucose etc.

Stereoisomerism: It is a type of isomerism in which the molecules have the same molecular formula but differ in arrangement of atoms in space i.e. differ in spatial configuration e.g. D-glucose and L-Glucose

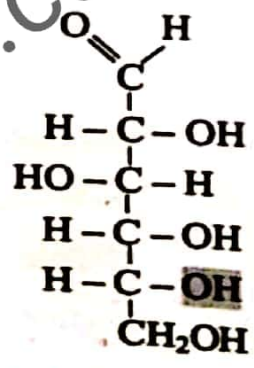
D-Galactose and D-Galactose

D-Fructose and L-Fructose

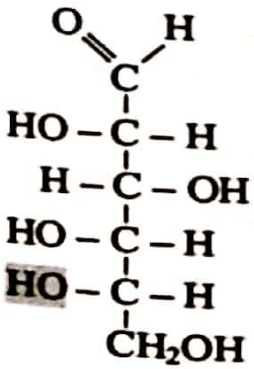
Optical isomer is type of stereoisomer.

D-sugar: The carbon which is asymmetric and farthest from the functional group and OH group is attached towards its right side.

L-sugar: The carbon which is asymmetric and farthest from the functional group and OH group is attached towards its left side.



D-glucose



L-glucose

2. Oligosaccharides (Oligo-few, Saccharide - sugar)

Characteristics:

i. Oligosaccharides can be hydrolysed from 2-10 monosaccharide units.
ii. Oligosaccharides are less sweet in taste.
iii. Oligosaccharides are less soluble in water.

➢ Classification of oligosaccharides

Oligosaccharides are classified on the basis of hydrolysis into monosaccharide units, into the following groups.

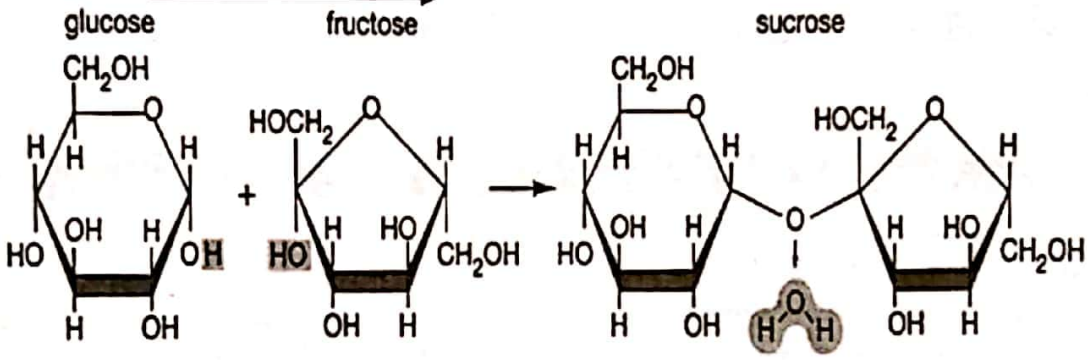
i. Disaccharides: (Di-Two, Saccharide - Sugar)

- Disriccharides are hydrolysed into two unonosaccharides units.
- Disaccharides are the most common oligosaccharides.

For example: Sucrose, Lactose and Maltose.

➢ Sucrose

- Sucrose is present in sugarcane.
- Sucrose hydrolyses into Glucose and fructose.
- Sucrose + H_2O $\xrightarrow{\text{sucrase (hydrolase)}}$ Glucose + Fructose



Condensation or Dehydration

➢ Lactose

- Lactose is also disaccharides.
- It is found in milk, also known as milk sugar.

Lactose on hydrolysis, Lactose yield two monosaccharide units i.e. Glucose and Galactose.

Lactose + H_2O $\xrightarrow{\text{lactase (hydrolase)}}$ Glucose + Galactose

➢ Maltose

- Maltose is also disaccharide and known as malt sugar.
- Maltose is found in our digestive tract as a result of starch digestion.

On hydrolysis: Maltose yield two monosaccharide units i.e. two Glucose units.

Starch + H_2O $\xrightarrow{\text{amylase}}$ maltose + H_2O $\xrightarrow{\text{maltase}}$ Glucose + Glucose

Glycoside bond: It is covalent bond which is formed in between monosaccharide units.

ii. **Trisaccharides:** Trisaccharides are composed of THREE monosaccharide's units e.g. Gentianose.
iii. **Tetrisaccharids:** They are composed of FOUR monosaccharide units e.g. Stachyose
iv. **Pentasaccharides:** Pentasaccharides are composed of FIVE monosaccharide units e.g. verbescose.

3. Polysaccharides (Poly-many, Saccharide-Sugar)

Characteristics

i. Polysaccharides are non-sugars, also known as glycans.
ii. They are composed of many monosaccharide units.
iii. They hydrolyze into many monosaccharide units.
iv. They are tasteless and are insoluble in water.

Classification of Polysaccharides

Polysaccharides are classified into the following two groups on the basis of function.

Polysaccharides

Structural Polysaccharides
Such Polysaccharides form various structures of living organisms
e.g.
Cellulose
Pectin
Chitin

Storage Polysaccharides
Such polysaccharides form storage materials of living organisms
e.g.
Starch
Glycogen

➢ Starch

i. Starch is storage polysaccharide.
ii. Starch consist of two sub-units i.e. amylose and amylopectin.
Amylose has unbranched Glucose structure while amylopectin has branched Glucose structure.
iii. Starch is stored material of plant cells e.g. fruits, seeds, roots, underground stems (i.e. Rhizome, Corm, Bulb, Tuber).
iv. Green plants Prepare Glucose during photosynthesis, which is immediately converted into starch. When plant needs Glucose, starch is again converted into Glucose.

➢ Glycogen

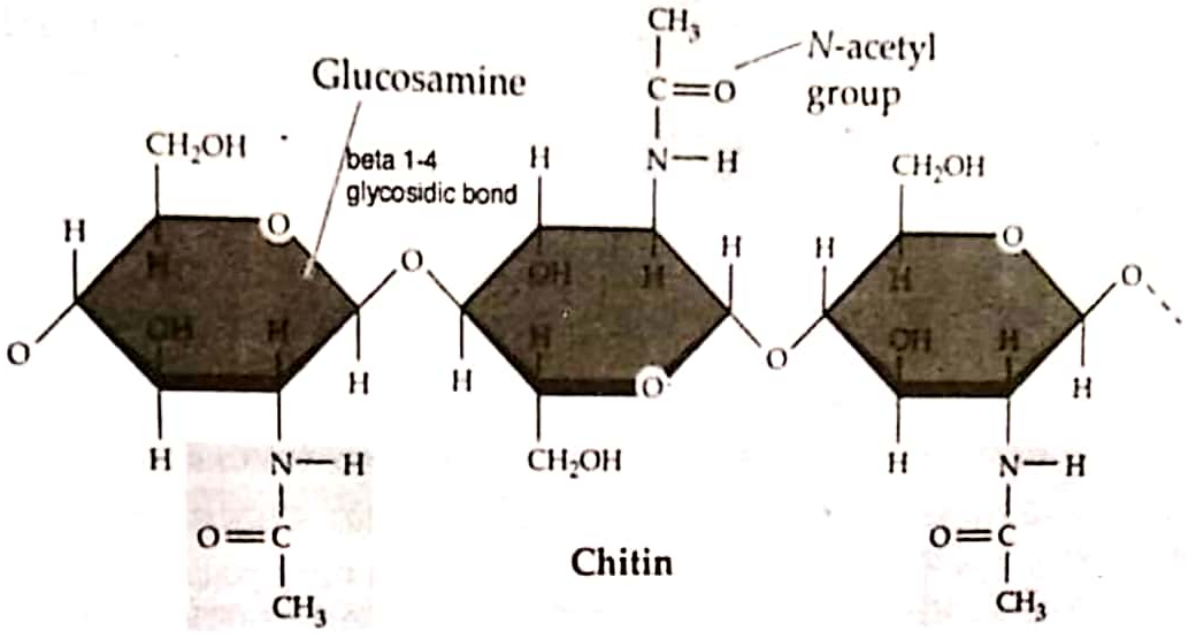
i. Glycogen is storage polysaccharide in animal cells.
ii. Glycogen is polymer of many α-Glucose units.
iii. Glycogen has extensively branched structure.

➢ Cellulose

i. Cellulose is structural polysaccharide present in plant cell walls.
ii. Cellulose is the most abundant carbohydrate in nature.
iii. Cellulose consists of unbranched chin of β-Glucose Units.
iv. Cellulose cannot be digested by human digestive system due to lack of cellulose enzyme.
v. Cotton fibers are the example of pure cellulose.

➢ Chitin

i. Chitin is structural polysaccharide.
ii. Chitin is composed of many β-glucose units but an amino group is attached at C.No. 2. of β-glucose
iii. Chitin is found in exoskeleton of arthropods e.g. crabs and insects.
iv. Chitin, like cellulose is also non-digestible.



Functions of Carbohydrates

The following are the various important functions of carbohydrates:

1. **Source of energy**
   - i. Carbohydrates are used as source of energy.
   - ii. The energy in carbohydrates are present in C-H bonds, during respiration C-H bonds are broken down and energy is released, which is utilized by living organisms for various metabolic reactions.
   - iii. Human blood contains 100mg of glucose per 100ml of blood.
2. **Storage molecules**
   - i. Carbohydrates are the reserve food materials of living organisms e.g. starch and glycogen.
   - ii. Grapes contain 27% Glucose molecules.
   - iii. Honey contain large amount of Glucose and fructose.
3. **Structural building materials**

i. Carbohydrates form various structures of living organisms e.g.

Cellulose..... Primary wall (cell wall)

Pectin..... Middle lamella (cell wall)

Chitin Exoskeleton of arthropods (e.g crabs, insects and cell wall of fungi.