

Carbohydrates

- The carbohydrates are a group of naturally occurring carbonyl compounds (aldehydes or ketones) that also contain several hydroxyl groups.
- It may also include their derivatives which produce such compounds on hydrolysis.
- They are the most abundant organic molecules in nature and also referred to as “saccharides”.
- The carbohydrates which are soluble in water and sweet in taste are called as “sugars”.

Structure of Carbohydrates

- Carbohydrates consist of carbon, hydrogen, and oxygen.
- The general empirical structure for carbohydrates is $(\text{CH}_2\text{O})_n$.
- They are organic compounds organized in the form of aldehydes or ketones with multiple hydroxyl groups coming off the carbon chain.
- The building blocks of all carbohydrates are simple sugars called monosaccharides.
- A monosaccharide can be a polyhydroxy aldehyde (aldose) or a polyhydroxy ketone (ketose).

Properties of Carbohydrates

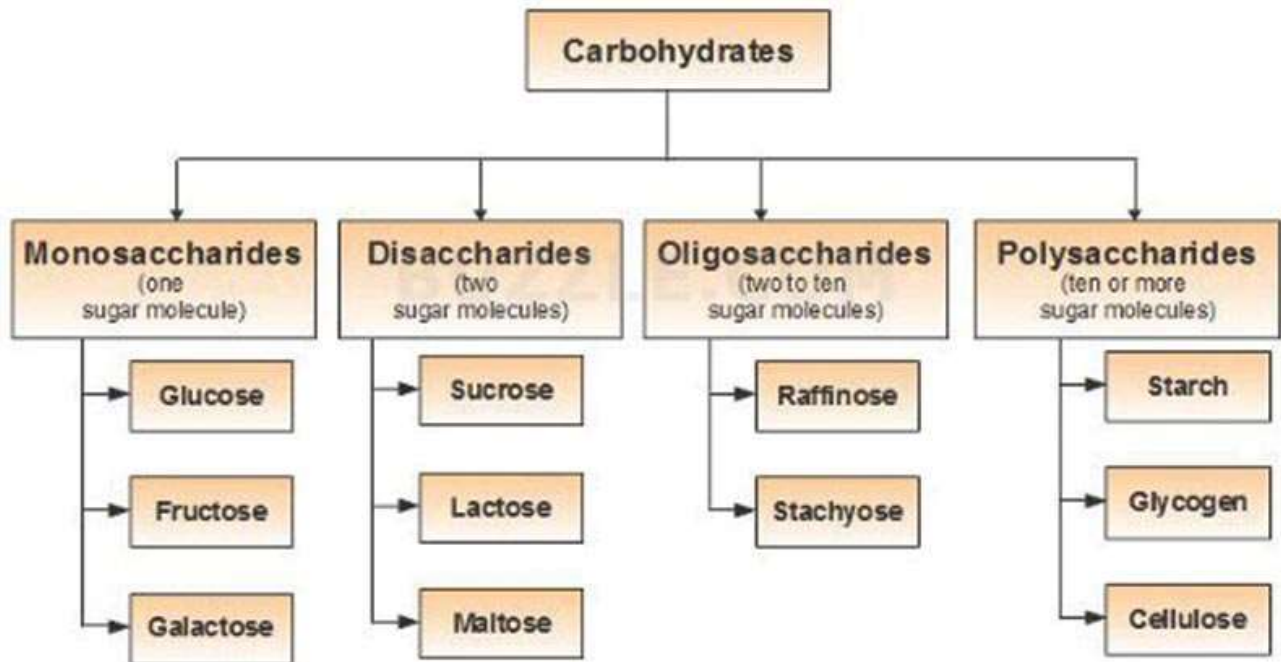
Physical Properties of Carbohydrates

- **Stereoisomerism** – Compound having the same structural formula but they differ in spatial configuration. Example: Glucose has two isomers with respect to the penultimate carbon atom. They are D-glucose and L-glucose.
- **Optical Activity** – It is the rotation of plane-polarized light forming (+) glucose and (-) glucose.
- **Diastereo isomers** – It the configurational changes with regard to C2, C3, or C4 in glucose. Example: Mannose, galactose.
- **Anomerism** – It is the spatial configuration with respect to the first carbon atom in aldoses and second carbon atom in ketoses.

Chemical Properties of Carbohydrates

- **Benedict's test:** When Benedict's reagent solution and reducing sugars are heated together, the solution changes its color to orange-red/ brick red. Reducing sugars when heated in the presence of an alkali gets converted to powerful reducing species known as enediols.
- **Oxidation:** Monosaccharides are reducing sugars if their carbonyl groups oxidize to give carboxylic acids. In Benedict's test, D-glucose is oxidized to D-gluconic acid thus, glucose is considered a reducing sugar.
- **Reduction to alcohols:** The C=O groups in open-chain forms of carbohydrates can be reduced to alcohols by sodium borohydride, NaBH_4 , or catalytic hydrogenation (H_2 , Ni, EtOH/ H_2O). The products are known as “alditols”.

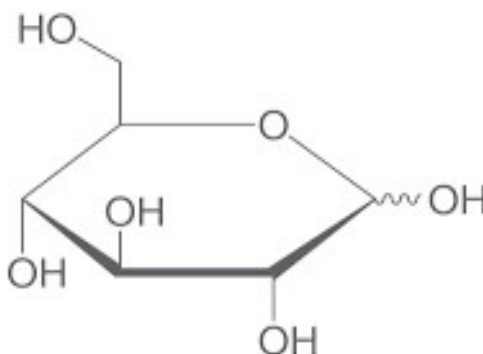
Classification of Carbohydrates (Types of Carbohydrates)

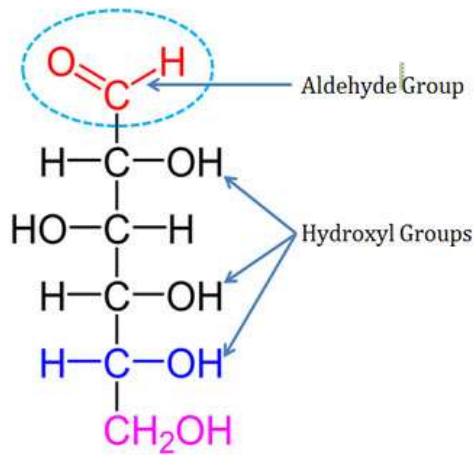


The simple carbohydrates include single sugars (monosaccharides) and polymers, oligosaccharides, and polysaccharides.

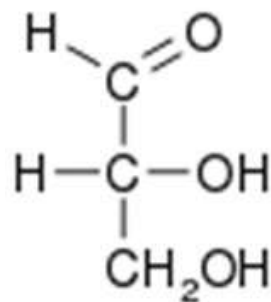
Monosaccharides

- Monosaccharides are the simplest carbohydrates. They are polyhydroxy aldehydes or ketones with a carbon backbone. The carbon backbone in monosaccharides usually consists of 3 – 6 carbon atoms. The simplest monosaccharides are glyceraldehyde and dihydroxyacetone (with 3 carbons).
- Colorless, crystalline solid which are soluble in water and insoluble in a non-polar solvent.
- These are compound which possesses a free aldehyde or ketone group.
- The general formula is $C_n(H_2O)_n$ or $C_nH_{2n}O_n$.
- They are classified according to the number of carbon atoms they contain and also on the basis of the functional group present.
- The monosaccharides thus with 3,4,5,6,7... carbons are called trioses, tetroses, pentoses, hexoses, heptoses, etc., and also as aldoses or ketoses depending upon whether they contain aldehyde or ketone group.





Glucose

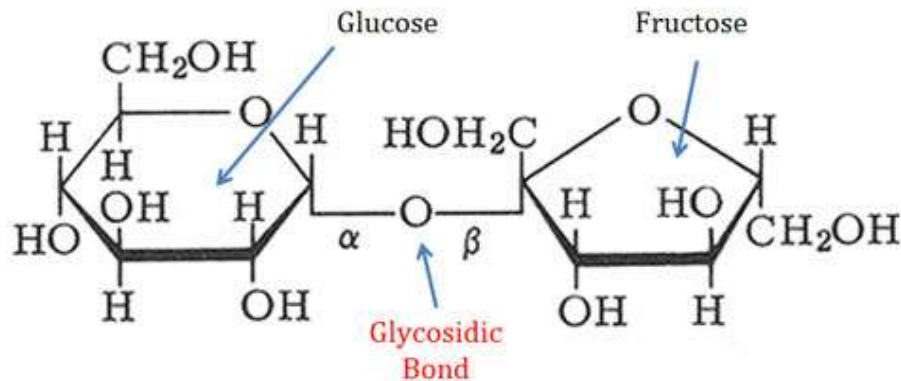
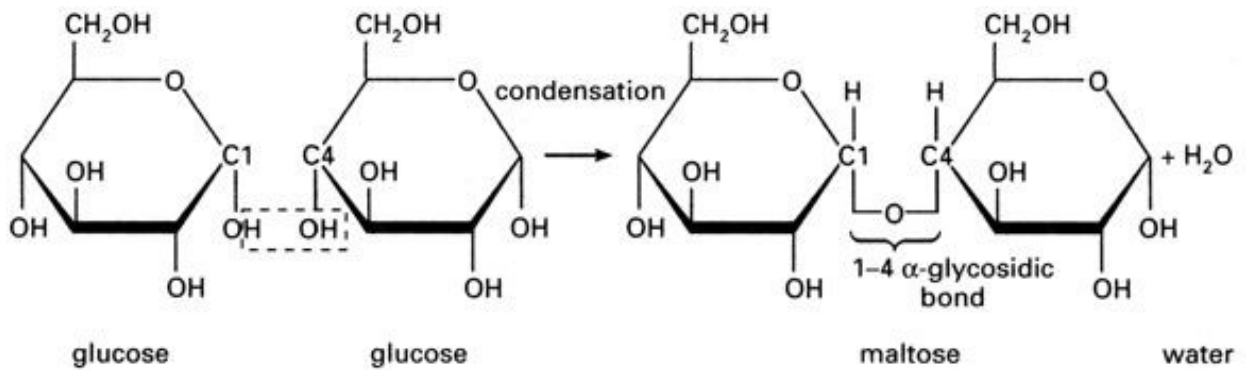


Glyceraldehyde

- Examples of monosaccharides
 - 3 Carbon – Dihydroxy acetone
 - 4 Carbon – Erythrose
 - 5 Carbon – Ribose
 - 6 Carbon – Glucose, Fructose

Oligosaccharides

- Oligosaccharides are compound sugars that yield 2 to 20 molecules of the same or different monosaccharides on hydrolysis.
- The monosaccharide units are joined by glycosidic linkage.
- Based on the number of monosaccharide units, it is further classified as disaccharide, trisaccharide, tetrasaccharide etc.
- Oligosaccharides yielding 2 molecules of monosaccharides on hydrolysis is known as a disaccharide, and the ones yielding 3 or 4 monosaccharides are known as trisaccharides and tetrasaccharides respectively and so on.
- The general formula of disaccharides is $C_n(H_2O)_{n-1}$ and that of trisaccharides is $C_n(H_2O)_{n-2}$ and so on.



Sucrose - Disaccharide

- Examples of oligosaccharides:
 - (a). Sucrose: a disaccharide of glucose and fructose
 - (b). Lactose: a disaccharide of galactose and glucose
 - (c). Maltose: a disaccharide of two glucose residues
 - (d). Trehalose: a disaccharide of two alpha linked glucose residues
 - (e). Raffinose: a trisaccharide of galactose, glucose, and fructose

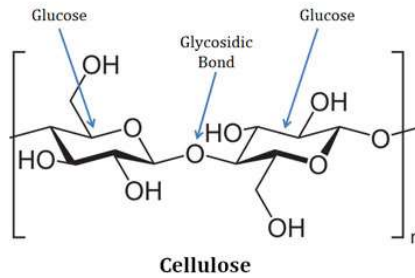
Polysaccharides

- They are also called as “glycans”.
- **Carbohydrates** with more than 20 **monosaccharide** units are called polysaccharides.
- They yield more than 20 molecules of monosaccharides on hydrolysis.
- Polysaccharides differ from each other in the identity of their recurring monosaccharide units, in the length of their chains, in the types of bond linking units and in the degree of branching.
- They are primarily concerned with two important functions i.e. Structural functions and the storage of energy.
- They are further classified depending on the type of molecules produced as a result of hydrolysis.
- They may be **homopolysaccharides**, containing monosaccharides of the same type or **heteropolysaccharides** i.e., monosaccharides of different types.

- Examples of polysaccharides

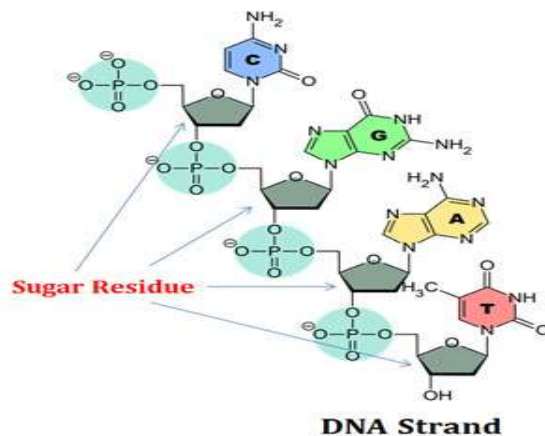
Homopolysaccharides: Starch, Glycogen and Cellulose (monosaccharide units in all three are glucose)

Heteropolysaccharide: Peptidoglycan, Hyaluronic acid, Chondroitin, Heparin



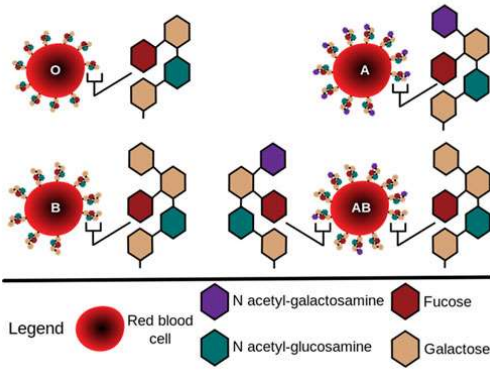
Functions

- Ø **Source of energy:** Carbohydrates are the primary source of energy. They are the food reserve (energy store molecules) in microbes, animals and plants.
- Ø **Source of C, H, and O:** Carbohydrates also act as the source of C, H and O in the cells for the synthesis of other macro molecules.
- Ø **Sweetener:** Some sugars are sweet in taste. They provide sweetness and flavor to a variety of food stuffs.
- Ø **Glycolipids:** Carbohydrate containing lipids (called glycolipids) are one of the important categories of plasma membrane lipids.
- Ø **Dietary fibres:** Carbohydrates are also the source of dietary fibres.
- Ø **Ribose sugar:** A monosaccharide (ribose) is an essential component in the genetic material (DNA and RNA).



- Ø **Cell wall and exoskeleton:** Some carbohydrates form the structural framework of the cells. For example, cellulose from the cell wall of plants, Peptidoglycan forms the cell wall of bacterial cells and chitin forms the cell wall of fungi and the exoskeleton of arthropods.
- Ø **Recognition:** Some carbohydrates on the surface of cell membrane have a recognition role.
- Ø **Protein trafficking:** The glycosylation (attachment of sugar moieties to other macromolecules such as proteins) of proteins are used in protein-trafficking by the cell. Example: a protein tagged with mannose 6-phosphate is destined to lysosome.
- Ø **Anticoagulant:** Heparin, the anticoagulant of the blood, is a carbohydrate which prevents the blood clotting.
- Ø **Blood group:** The ABO blood groups are determined by the carbohydrates and thus carbohydrates also function as antigens.

ABO Blood Group is determined by the composition of Sugar Residues in the membrane lipids of RBC



Ø **Industrial uses:** Some carbohydrates are the raw material for many industries. Example: cellulose in the paper industry, starch, glucose, fructose etc. in fermentation and brewing industry.