Carbohydrates are the most abundant organic molecules in nature. They are primarily composed of the elements

carbon, hydrogen and oxygen. The name carbohydrate literally means ‘***hydrates of carbon***’. Some of the carbohydrates possess the empirical formula $(C.H_2O)_n$ where n≤3, satisfying that these carbohydrates are in fact carbon hydrates. However, there are several non-carbohydrate compounds (e.g. acetic acid, $C_2H_4O_2$; lactic acid, $C_3H_6O_3$) which also appear as hydrates of carbon. Further, some of the genuine carbohydrates (e.g. rhamnohexose, $C_6H_{12}O_5$;

deoxyribose, $C_5H_{10}O_4$) do not satisfy the general formula. Hence carbohydrates cannot be always considered as hydrates of carbon.

Carbohydrates may be defined as polyhydroxyaldehydes or ketones or compounds which produce them on hydrolysis. The term 'sugar' is applied to carbohydrates soluble in water and sweet to taste.

Functions of carbohydrates

Carbohydrates participate in a wide range of functions

1. They are the most abundant dietary ***source of energy*** (4Cal/g) for all organisms.
2. Carbohydrates are precursors for many organic compounds (fats, amino acids).
3. Carbohydrates (as glycoproteins and glycolipids) participate in the structure of cell membrane and cellular

functions such as cell growth, adhesion and fertilization.

4. They are structural components of many organisms. These include the fiber (cellulose) of plants, exoskeleton of some insects and the cell wall of microorganisms.

5. Carbohydrates also serve as the storage form of energy (glycogen) to meet the immediate energy demands of the body.

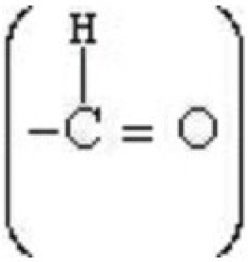
Classification of carbohydrates

Carbohydrates are often referred to as saccharides (*Greek*: sakcharon–sugar). They are broadly classified into three major groups— ***monosaccharides, oligosaccharides and polysaccharides***. This categorization is based on the number of sugar units. ***Mono- and oligosaccharides*** are sweet to taste, crystalline in character and soluble in water, hence they are commonly known as ***sugars***.

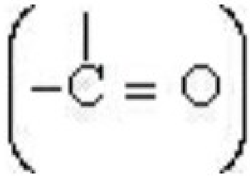
Monosaccharides

Monosaccharides (*Greek* : mono-one) are the simplest group of carbohydrates and are often referred to as simple sugars. They have the general formula $C_n(H_2O)_n$, and they cannot be further hydrolysed. The monosaccharides are divided into different categories, based on the functional group and the number of carbon atoms

Aldoses

When the functional group in monosaccharides is an aldehyde , they are known as aldoses e.g. glyceraldehyde, glucose.

Ketoses

When the functional group is a keto  group, they are referred to as ketoses e.g. dihydroxyacetone, fructose.

Based on the number of carbon atoms, the monosaccharides are regarded *as trioses (3C), tetroses (4C), pentoses (5C),* ***hexoses (6C)*** *and heptoses (7C)*. These terms along with functional groups are used while naming monosaccharides. For instance, ***glucose is an aldohexose while fructose is a ketohexose*** (***Table 2.1***).

Classification of monosaccharides with selected examples

Monosaccharides (empirical formula)	Aldose	Ketose
Trioses ($C_3H_6O_3$)	Glyceraldehyde	Dihydroxyacetone
Tetroses ($C_4H_8O_4$)	Erythrose	Erythrulose
Pentoses ($C_5H_{10}O_5$)	Ribose	Ribulose
Hexoses ($C_6H_{12}O_6$)	Glucose	Fructose
Heptoses ($C_7H_{14}O_7$)	Glucoheptose	Sedoheptulose

Monosaccharides—structural aspects

Stereoisomerism is an important character of monosaccharides. Stereoisomers are the compounds that have the same structural formulae but differ in their spatial configuration.

A carbon is said to be ***asymmetric when*** it is ***attached to four different atoms or groups***. The number of asymmetric carbon atoms (n) determines the possible ***iso-***

mers of a given compound which is equal to $\mathbf{2^n}$. Glucose contains 4 asymmetric carbons, and thus has 16 isomers.

Glyceraldehyde—the reference carbohydrate

Glyceraldehyde (triose) is the simplest monosaccharide with one asymmetric carbon atom. It exists as two stereoisomers and has been chosen as the reference carbohydrate to represent the structure of all other carbohydrates.

aldehyde (glycerose) are depicted in ***Fig. 2.1***.

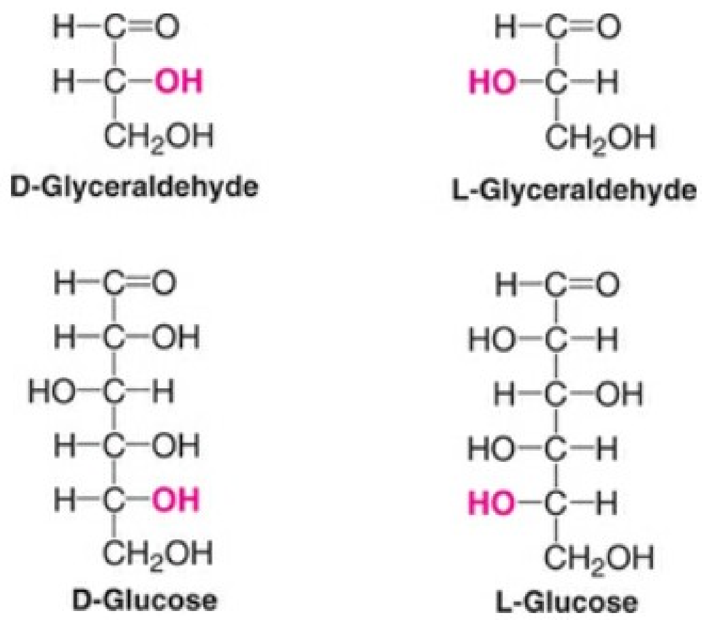


Fig. 2.1 D-and-L- forms of glucose compared with D- and L-glyceraldehydes (the reference carbohydrate).

It may be noted that the naturally occurring monosaccharides in the mammalian tissues are mostly of D-configuration. The enzyme machinery of cells is specific to metabolise D-series of monosaccharides.

Optical activity of sugars

Optical activity is a characteristic feature of compounds with ***asymmetric carbon*** atom. When a beam of polarized light is passed through a solution of an optical isomer, it will be rotated either to the right or left.

Epimers

If two monosaccharides ***differ from each other in their configuration around a single specific carbon*** (other than anomeric) atom, they are referred to as epimers to each other (***Fig.2.4***). For instance, ***glucose and galactose are epimers*** with regard to carbon 4 (C_4-epimers). That is, they differ in the arrangement of –OH group at C_4. Glucose and mannose are epimers with regard to carbon 2 (C_2-epimers).

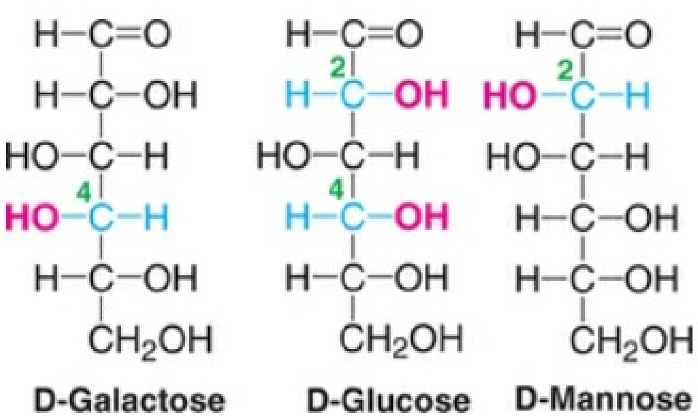


Fig. 2.4 Structures of epimers

Enantiomers

Enantiomers are a special type of stereoisomers that are ***mirror images of each other***. The two members are designated as

D- and L-sugars. Enantiomers of glucose are depicted in [***Fig. 2.5***](#).

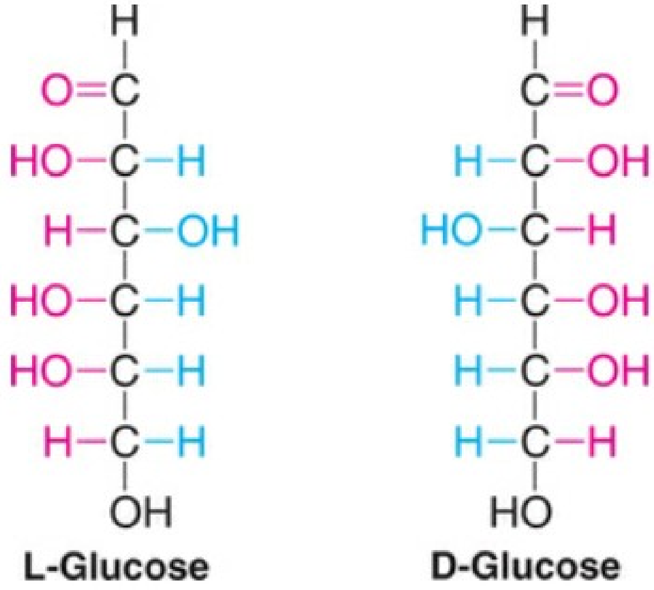


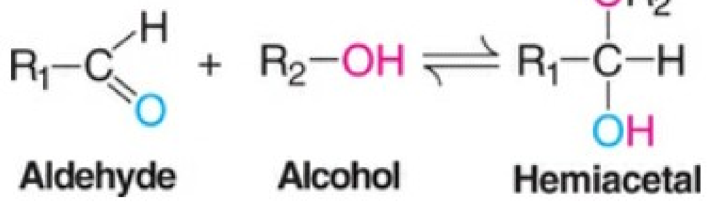
Fig. 2.5 Enantiomers (mirror images) of glucose.

Majority of the sugars in the higher animals (including man) are of D-type (***Fig. 2.5***).

The term ***diastereomers*** is used to represent the ***stereoisomers*** that are ***not mirror images of one another***.

Structure of glucose

For a better understanding of glucose structure, let us consider the formation of hemiacetals and hemiketals, respectively produced when an aldehyde or a ketone reacts with alcohol.



Pyranose and furanose structures

Haworth projection formulae are depicted by a six-membered ring pyranose (based on pyran) or a five-membered ring furanose (based on furan). The cyclic forms of glucose are known as α-D-glucopyranose and α-D-glucofuranose (*Fig.2.7*).

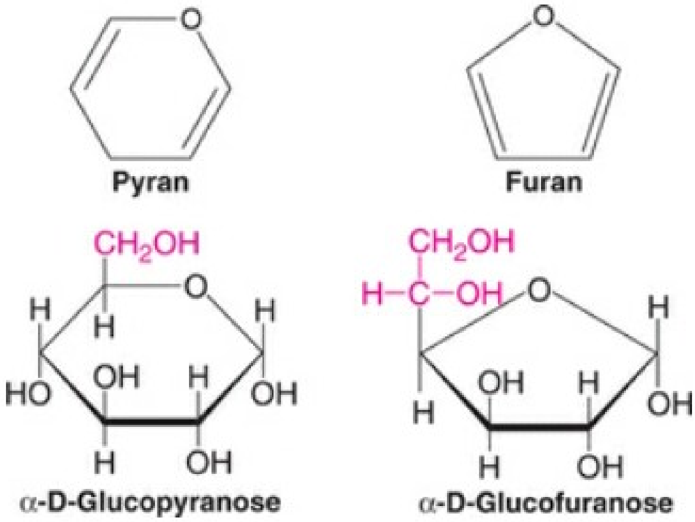


Fig. 2.7 Structure of glucose-pyranose and furanose forms.

Disaccharides

Among the oligosaccharides, disaccharides are the most common (***Fig.2.12***). As is evident from the name, a disaccharide consists of two monosaccharide units (similar or dissimilar) held together by a ***glycosidic bond***. They are crystalline, water-soluble and sweet to taste. The disaccharides are of two types

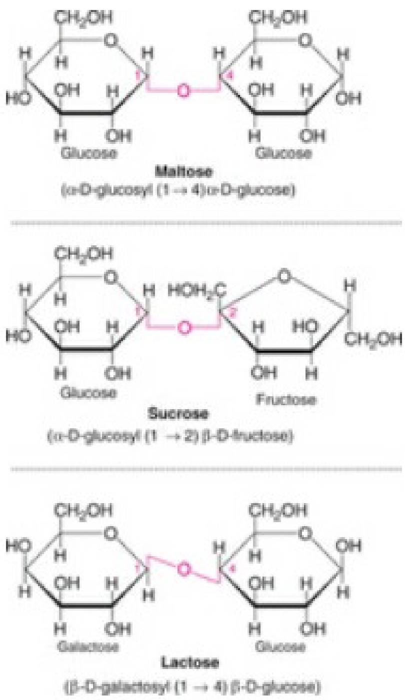


Fig. 2.12 Structures of disaccharides —maltose, sucrose and lactose.