SECOND CHAPTER: Structure and physicochemical properties of carbohydrates

Carbohydrates are sugar molecules that belong to a larger category of dietary macromolecules. The word carbohydrate is derived from the French words charbonne and hydrate, which means "carbon" and "water," respectively. the general structure of carbohydrates includes a long chain or ring of carbon atoms with multiple hydrogen atoms or hydroxyl groups (-OH) attached.

40 to 50% of calories provided by the human diet are carbohydrates. They have an energy reserve role in the liver and muscles.

Carbohydrates act as:

- Support, protection and recognition elements in the cell.
- Constituents of fundamental molecules: nucleic acids, coenzymes, vitamins, etc.

I. Classification:

Carbohydrates are classified based on the number of saccharides it contains. A saccharide is the basic unit structure or building block of a carbohydrate.

- A **monosaccharide** is a carbohydrate with one saccharide.
- A **disaccharide** is a carbohydrate with two saccharides.
- An **oligosaccharide** is a carbohydrate with a few (3-10) saccharides.
- A **polysaccharide** is a carbohydrate with more than 10 saccharides.

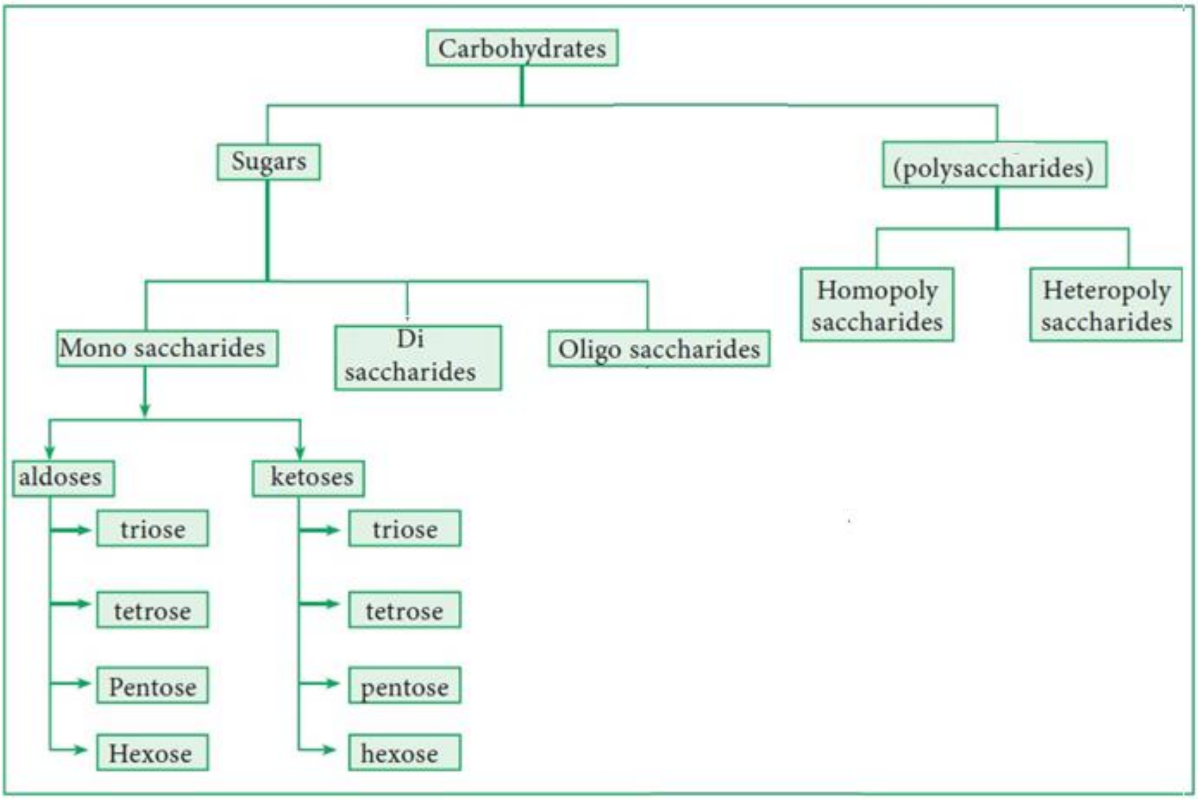


Fig 1. Types of carbohydrates.

II. Monosaccharides

Simple sugars, also known as monosaccharides, can generally be written in the form $C_x(H_2O)_x$. It is for this reason they are referred to as carbo-hydrates. Monosaccharide carbohydrates are those carbohydrates that cannot be hydrolyzed further to give simpler sugar. Based on the number of carbon atoms they are further classified into trioses, tetroses, pentoses, hexoses etc. They can also be classified as aldoses and ketoses based on the functional group present in them :

- **Aldoses:** Aldoses contain aldehyde group (-CHO) as a functional group along with two or more hydroxyl groups.

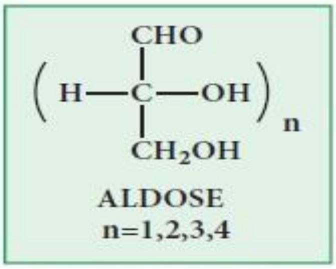


Fig 2. General structure of aldose.

- **Ketoses:** Ketoses contain keto group (>C=O) as a functional group along with two or more hydroxyl groups.

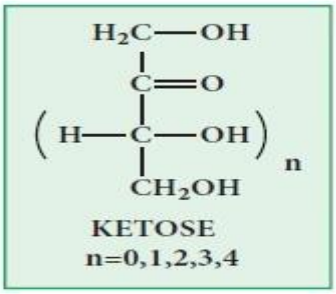


Fig 3. General structure of ketose.

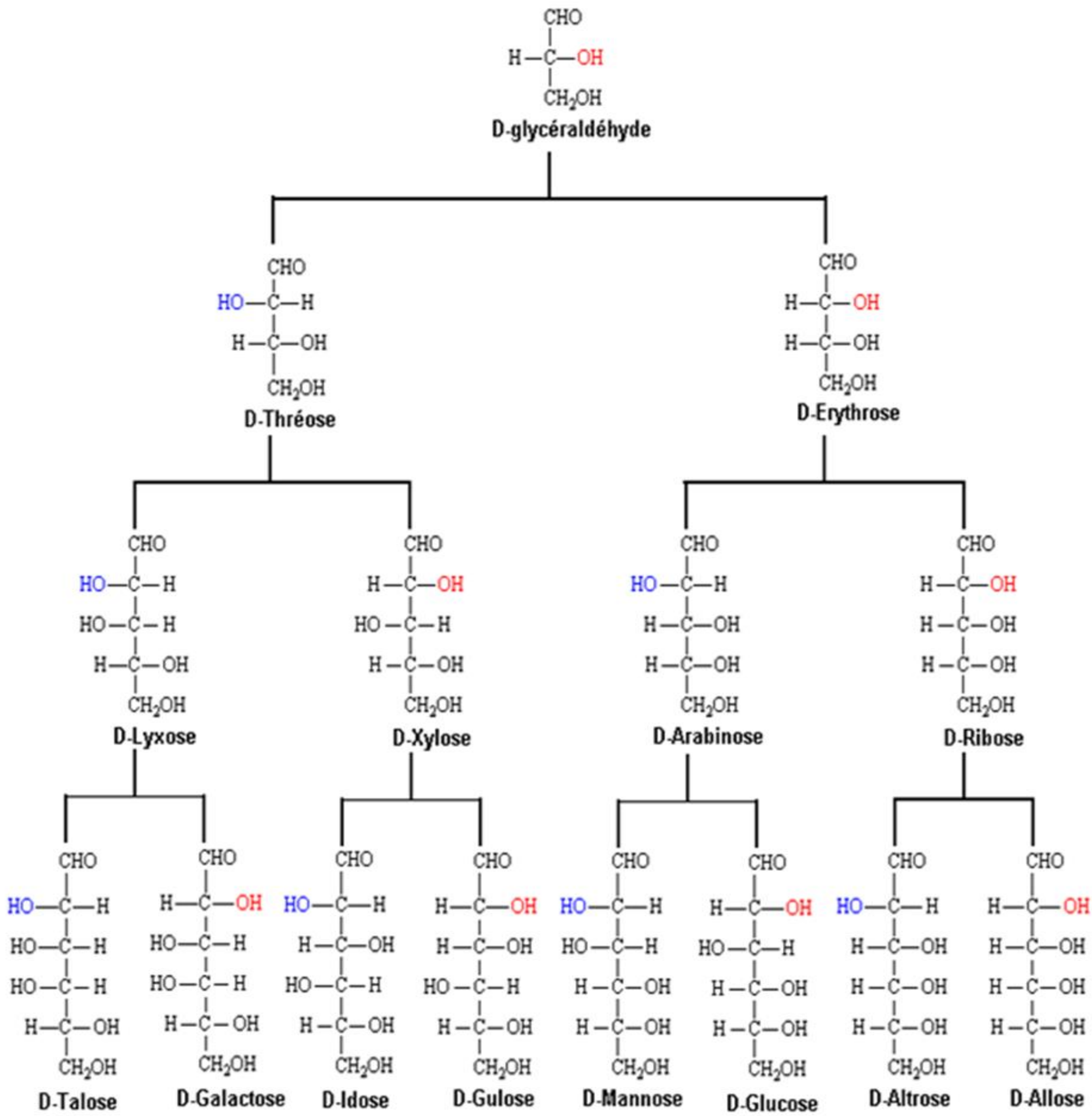


Fig 4. D series aldoses.

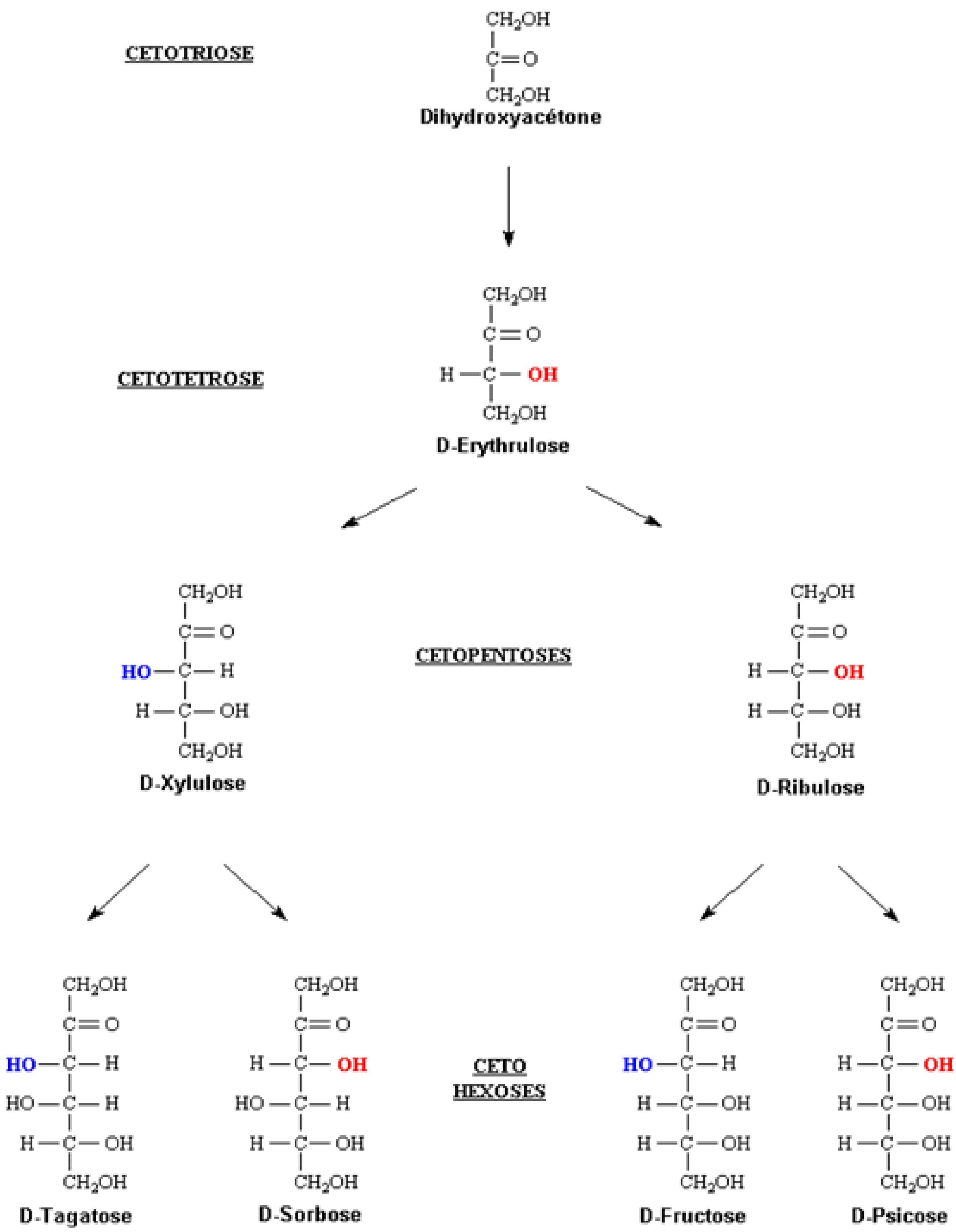


Fig 5. D series ketoses.

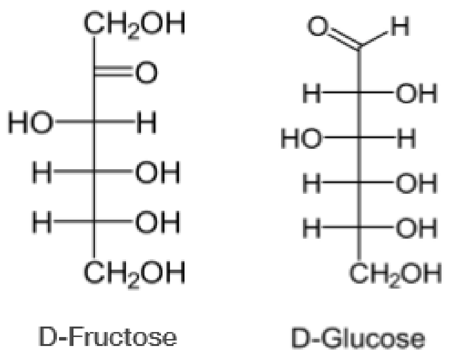
By convention, the letters 'ose' at the end of a biochemical name flags a molecule as a sugar. Thus, there are glucose, galactose, sucrose, and many other '-oses'.

Other descriptive nomenclature involves use of a prefix that tells how many carbons the sugar contains. For example, glucose, which contains six carbons, is described as a hexose. The following list shows the prefixes for numbers of carbons in a sugar:

- Tri- = 3
- Tetr- = 4
- Pent- = 5
- Hex- =6
- Hept- = 7
- Oct- = 8

Other prefixes identify whether the sugar contains an aldehyde group (aldo-) or a ketone (keto) group. Prefixes may be combined. Glucose, which contains an aldehyde group, can be described as an aldo-hexose. The list that follows gives some common sugars and some descriptors.

- Ribose = aldo-pentose
- Glucose = aldo-hexose
- Galactose = aldo-hexose
- Mannose = aldo-hexose
- Glyceraldehyde = aldo-triose
- Fructose = keto-hexose



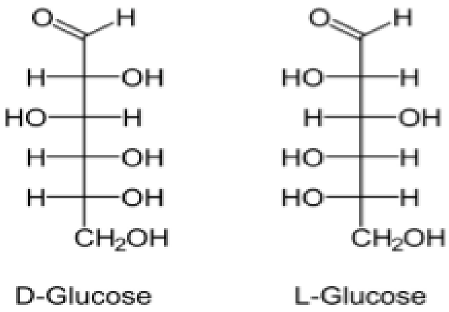
Ketose and Aldose

III. Stereoisomer Nomenclature

Sugars of a given category (hexoses, for example) differ from each other in the stereoisomeric configuration of their carbons. Two sugars having the same number of carbons (hexoses, for example) and the same chemical form (aldoses, for example), but differing in the stereoisomeric configuration of their carbons are called diastereomers. Biochemists use D and L nomenclature to describe sugars.

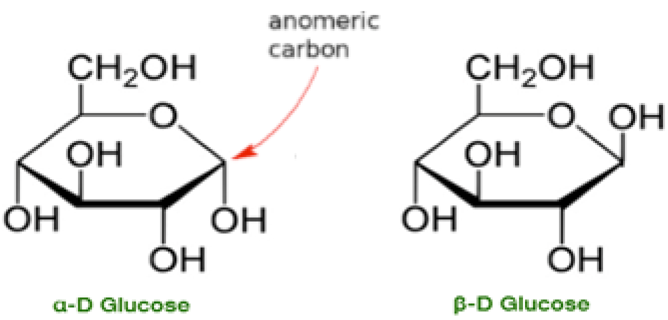
D-sugars predominate in nature, though L-forms of some sugars. To determine if a sugar is a D-sugar or an L-sugar, one simply examines the configuration of the carbon #n-1. If the hydroxyl is written to the right, it is a D-sugar. If the hydroxyl is on the left, it is an L-sugar.

L sugars of a given name (glucose, for example) are mirror images of D sugars of the same name. The sugars that are mirror images of each other are called **enantiomers**.



Enantiomers

Sugars of 5-7 carbons can fairly easily form ring structures (called Haworth structures). The bottom line for both aldoses and ketoses is that the oxygen that was part of the aldehyde or the ketone group is the one that becomes a part of the ring. More important than the oxygen, though, is the fact that the carbon attached to it (carbon #1 in aldoses or #2 in ketoses) becomes asymmetric as a byproduct of the cyclization. This new asymmetric carbon is called the anomeric carbon and it has two possible configurations, called alpha and beta.



Two ring structures are possible:

- The pyranic form corresponds to a hererocycle with 6 vertices (5 C and 1 O).

- The furan form corresponds to a heterocycle with 5 vertices (4 C and 1 O).

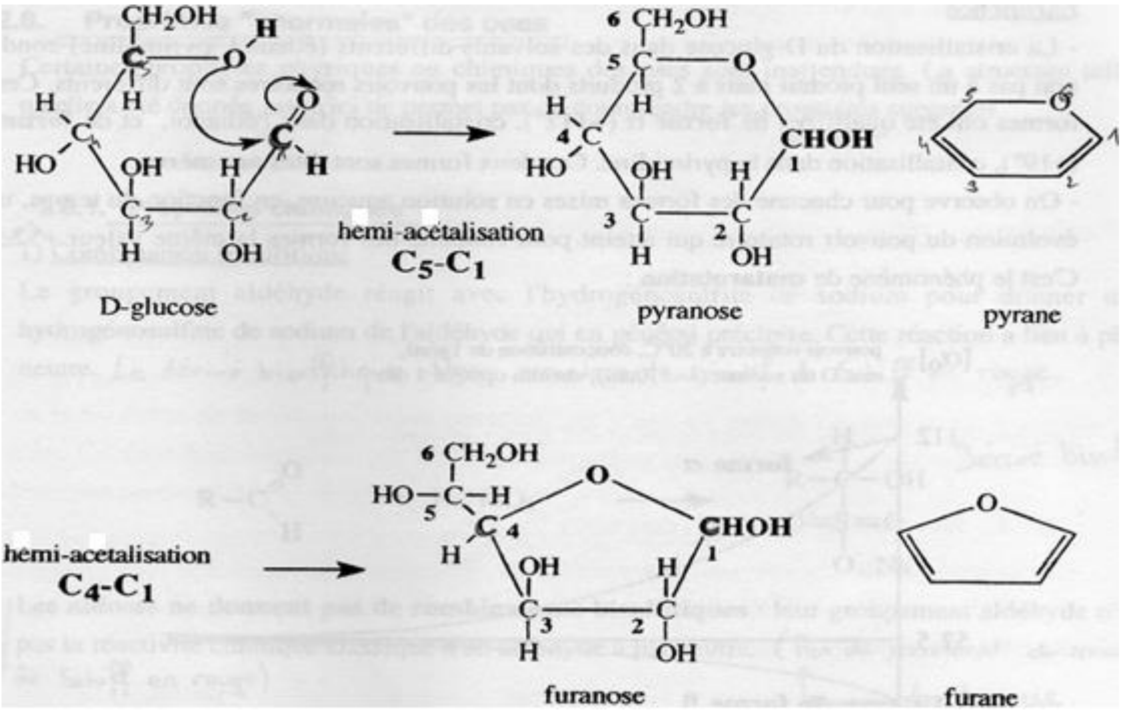


Fig 6. Glucose cyclization (Haworth model) **[3]**.