General Biochemistry
BIOC 201

Chapter III

Chemistry of Carbohydrates

Objectives

- This chapter is aiming to discuss the carbohydrate constituents of human food.
- It is designed to familiarize the student with the biochemical classification of carbohydrates.
- The student will be informed with the nutritional availability and importance of various carbohydrate classes.

General characteristics

- They are polyhydroxy aldehydes or ketones
- Some time, they called (glycans)
- They have the following basic composition:

$$(CH_2O)_n \quad \text{or} \quad H - \overset{|}{\underset{|}{C}} - OH$$

- Compounds composed of C, H, and O
- (CH2O)n when n = 5 then C5H10O5

General characteristics

- Most abundant organic compounds in the plant world
- They are storehouses of energy
- They serve as components of supportive structures in plants (cellulose)
- They are essential components of nucleic acids (D-ribose (RNA) and 2-deoxy-D-ribose (DNA))

Classification of Carbohydrates

- **<u>Monosacharides</u> - simple sugars with multiple OH groups. Based on number of carbons (3, 4, 5, 6), a monosaccharide is a *triose, tetrose, pentose or hexose.***
- **<u>Disaccharides</u> - 2 monosaccharides covalently linked.**
- **<u>Oligosaccharides</u> - a few monosaccharides covalently linked.**
- **<u>Polysaccharides</u> - polymers consisting of chains of monosaccharide or disaccharide units.**

Classification of Carbohydrates

- **Monosaccharides:**
  - Glucose, Fructose & Galactose
- **Disaccharides:**
  - Maltose, Lactose & Sucrose
- **Polysaccharides:**
  - Starch & Glycogen

Monosaccharides: CnH2nOn

- Also known as simple sugars
- Classified by

  1. the number of carbons

  2. whether aldoses (aldehyde)

     or ketoses (ketone)

- Most (99%) are straight chain compounds

Monosaccharides:

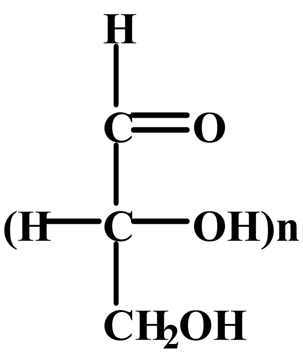
- All other sugars have the ending ose (gluc*ose*, galact*ose*, ribose, lact*ose*, etc…)
- The suffix -ose is added to a molecule that is a carbohydrate, and prefixes tri-, tet-, and pent- are used to indicate the number of carbons
- D-glyceraldehyde is the simplest of the aldoses (*aldotriose*)
- Pentoses and hexoses dominating

Monosaccharides:

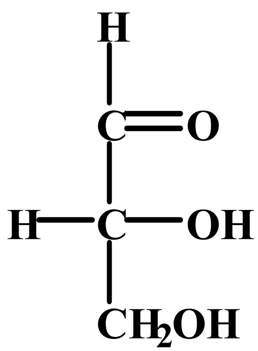
Sugar Nomenclature

- 3 carbon sugar – triose
- 4 carbon sugar – tetrose
- 5 carbon sugar – pentose
- 6 carbon sugar – hexose
- 7 carbon sugar – heptose
- 8 carbon sugar – octoses

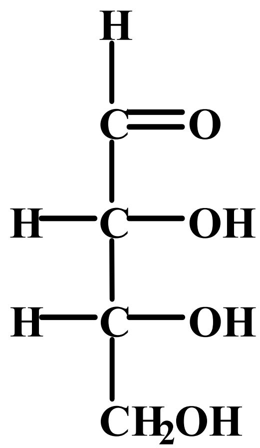
Aldose sugars



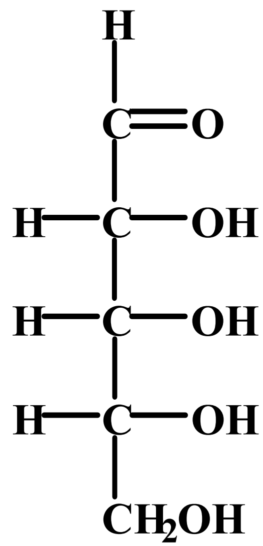
Aldose



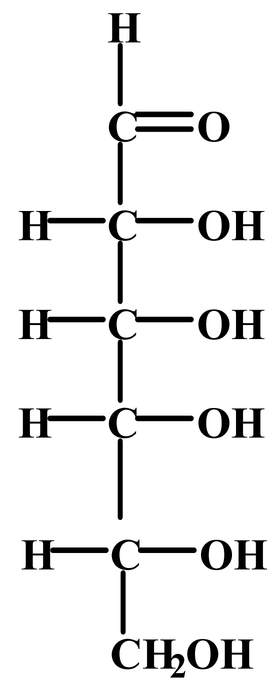
Aldotriose
n = 1



Aldotetrose
n = 2



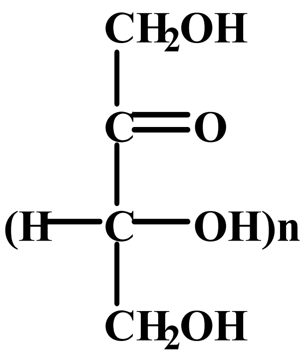
Aldopentose
n = 3



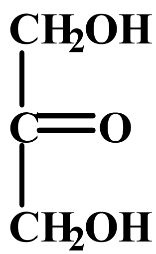
Aldohexose
n = 4

Where n is the number of asymmetric centers.

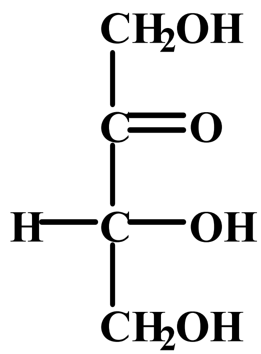
Ketose sugars



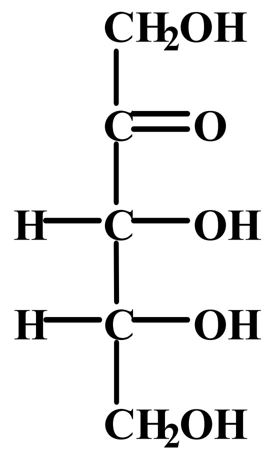
Ketose



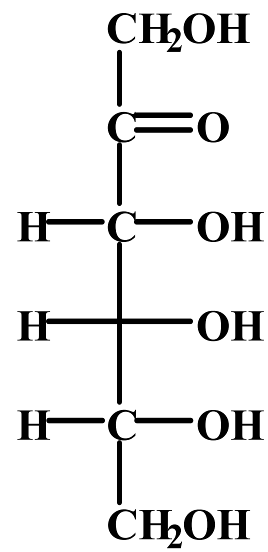
Ketotriose
n = 0



Ketotetrose
n = 1



Ketopentose
n = 2

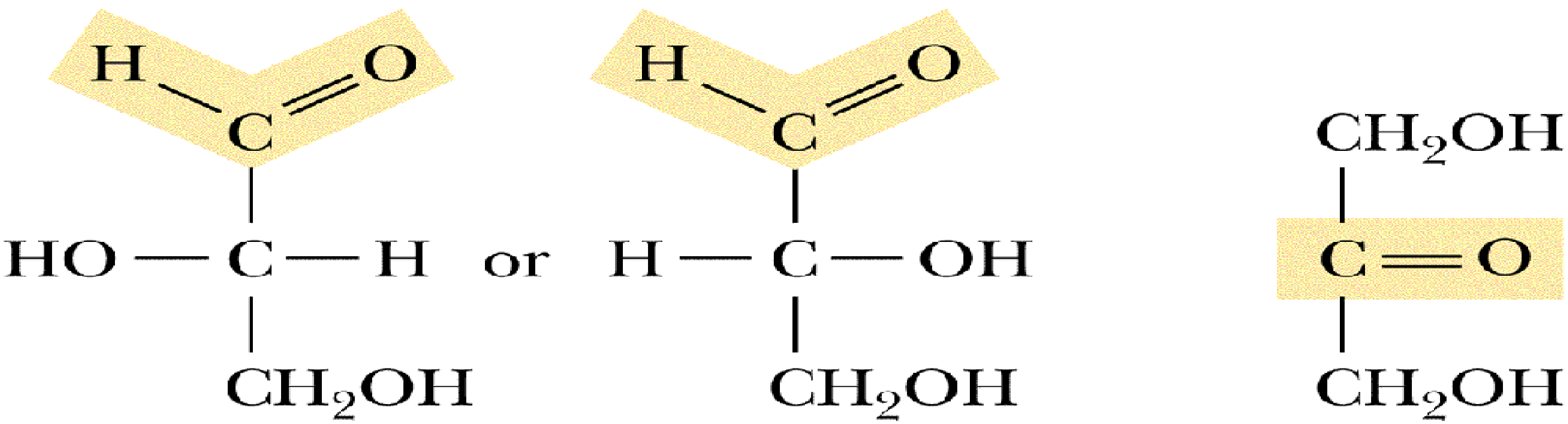


Ketohexose
n = 3

Where n is the number of asymmetric centers.

Monosaccharides

Structure of a simple aldose and a simple ketose, only two trioses:



L-isomer D-isomer

Glyceraldehyde

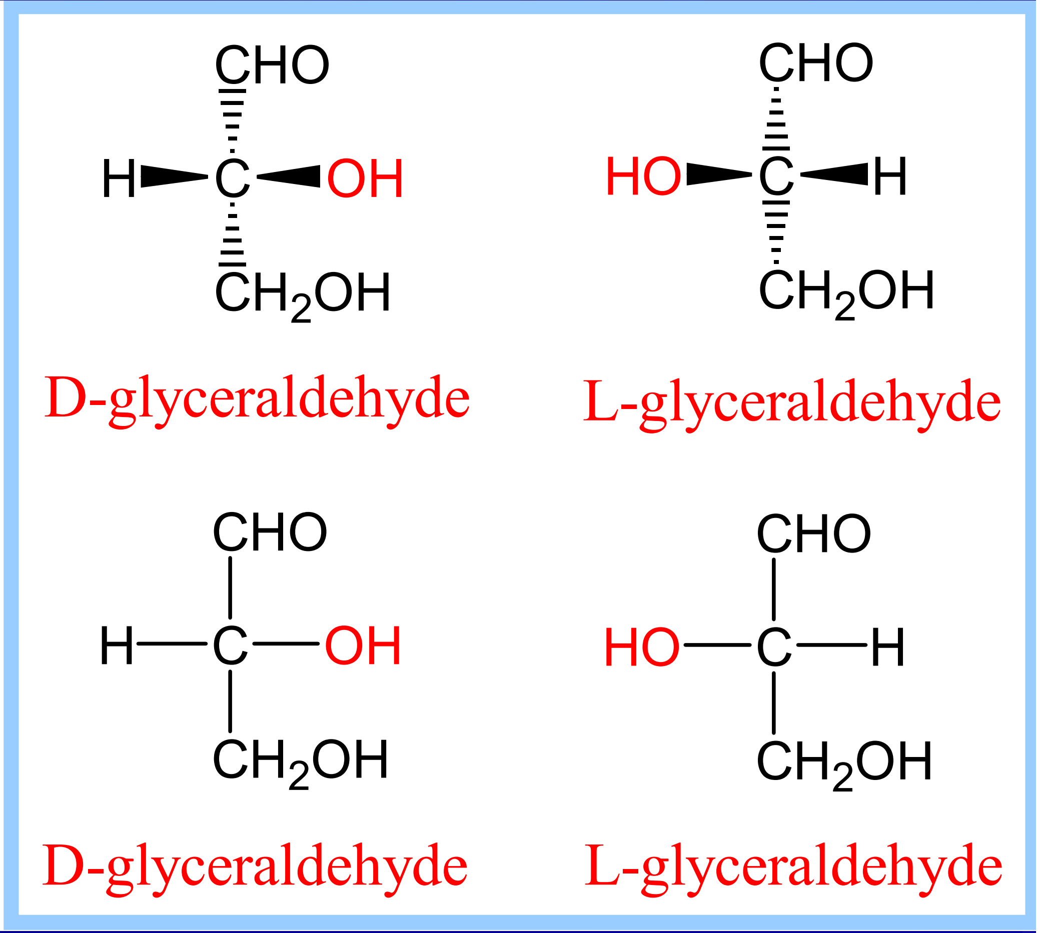
Dihydroxy-acetone

Monosaccharides

Dextrarotary vs. Levarotary Designation

D & L designations are based on the configuration about the single asymmetric C in glyceraldehyde.

The lower representations are *Fischer Projections.* →

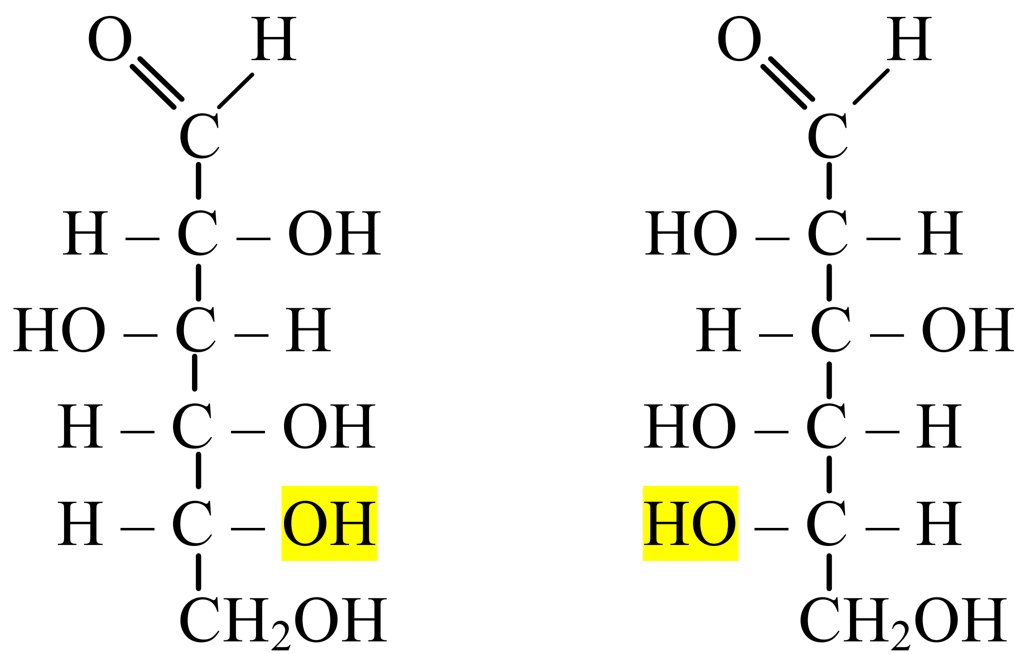


Monosaccharides

For sugars with more than one chiral center, D or L refers to the asymmetric C farthest from the aldehyde or keto group.

Most naturally occurring sugars are D isomers

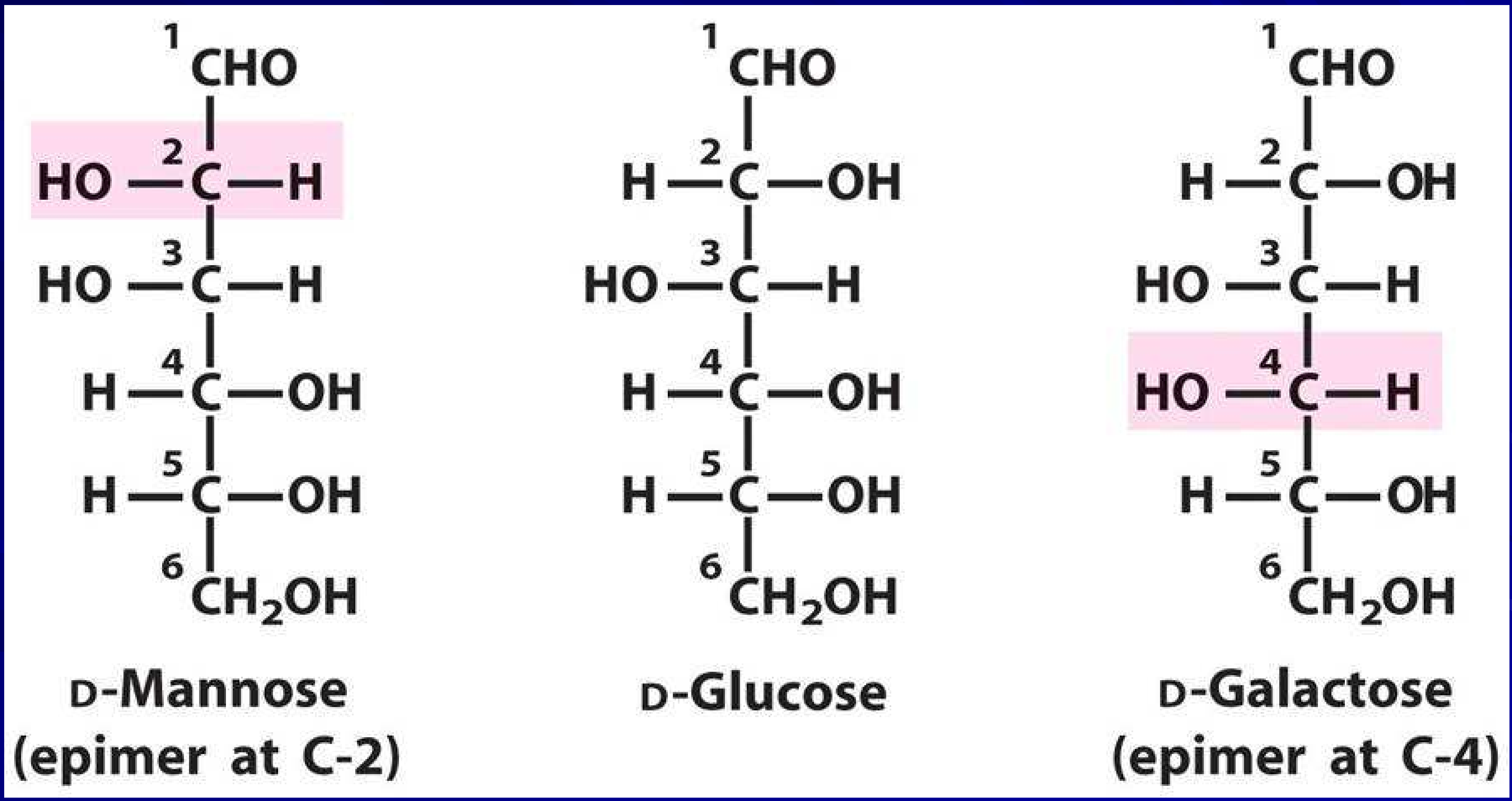
D & L sugars are mirror images of one another



D-glucose L-glucose

Epimers

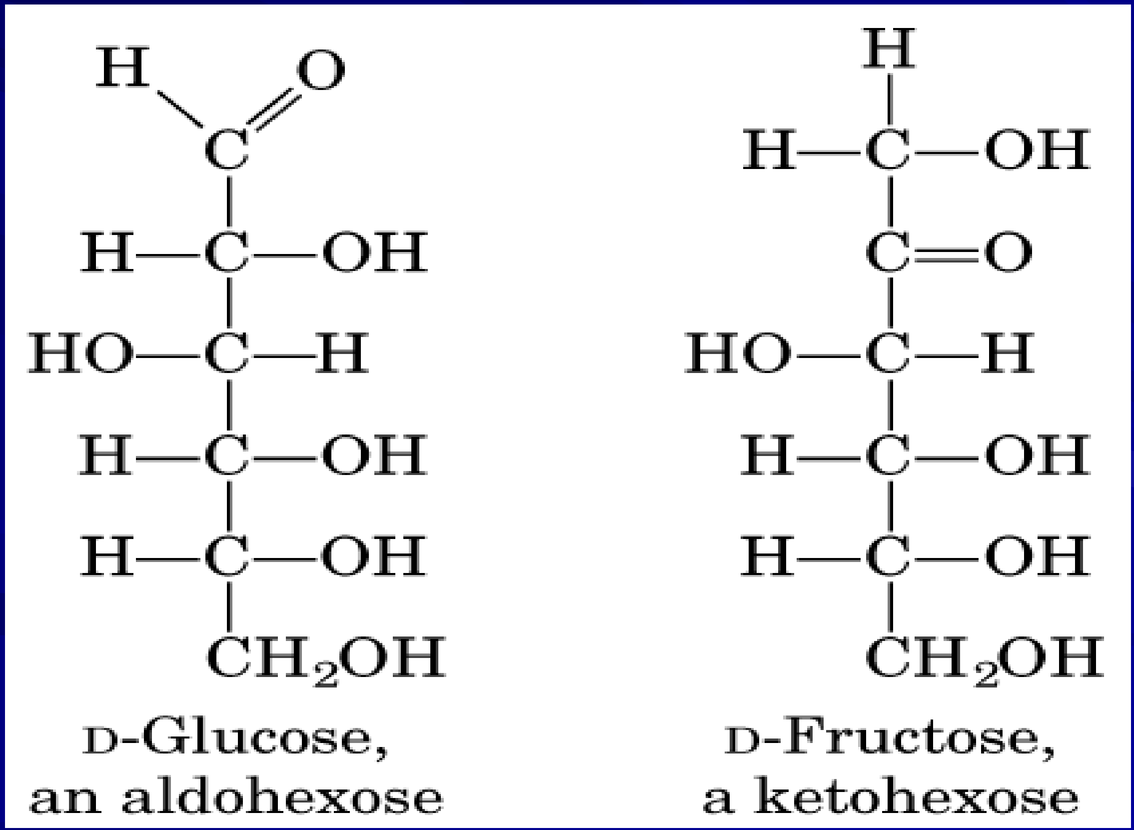
Sugars that differ in conformation around one carbon atom



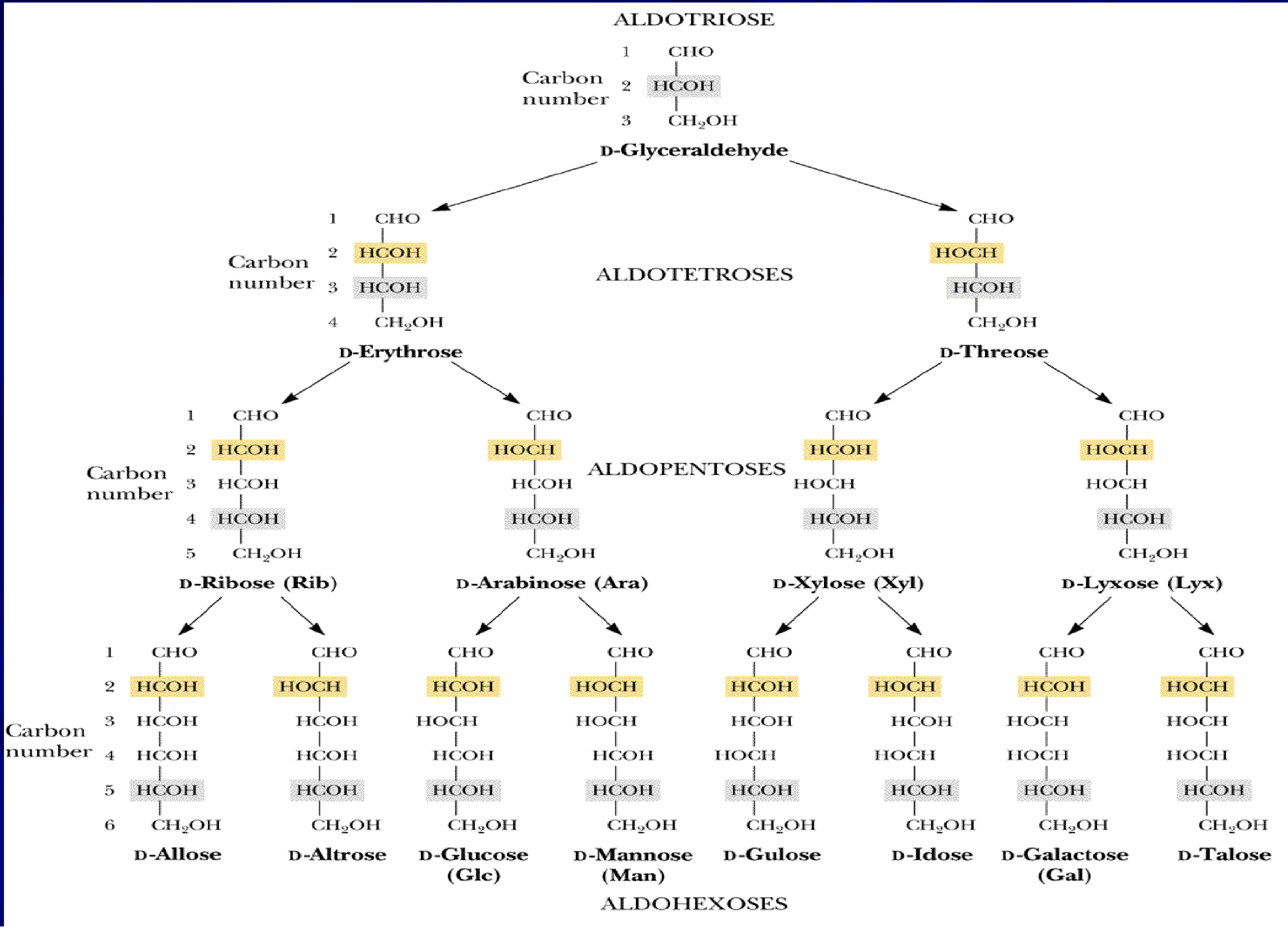
Isomers

Sugars that *differ in configuration* but have the *same molecular weight*

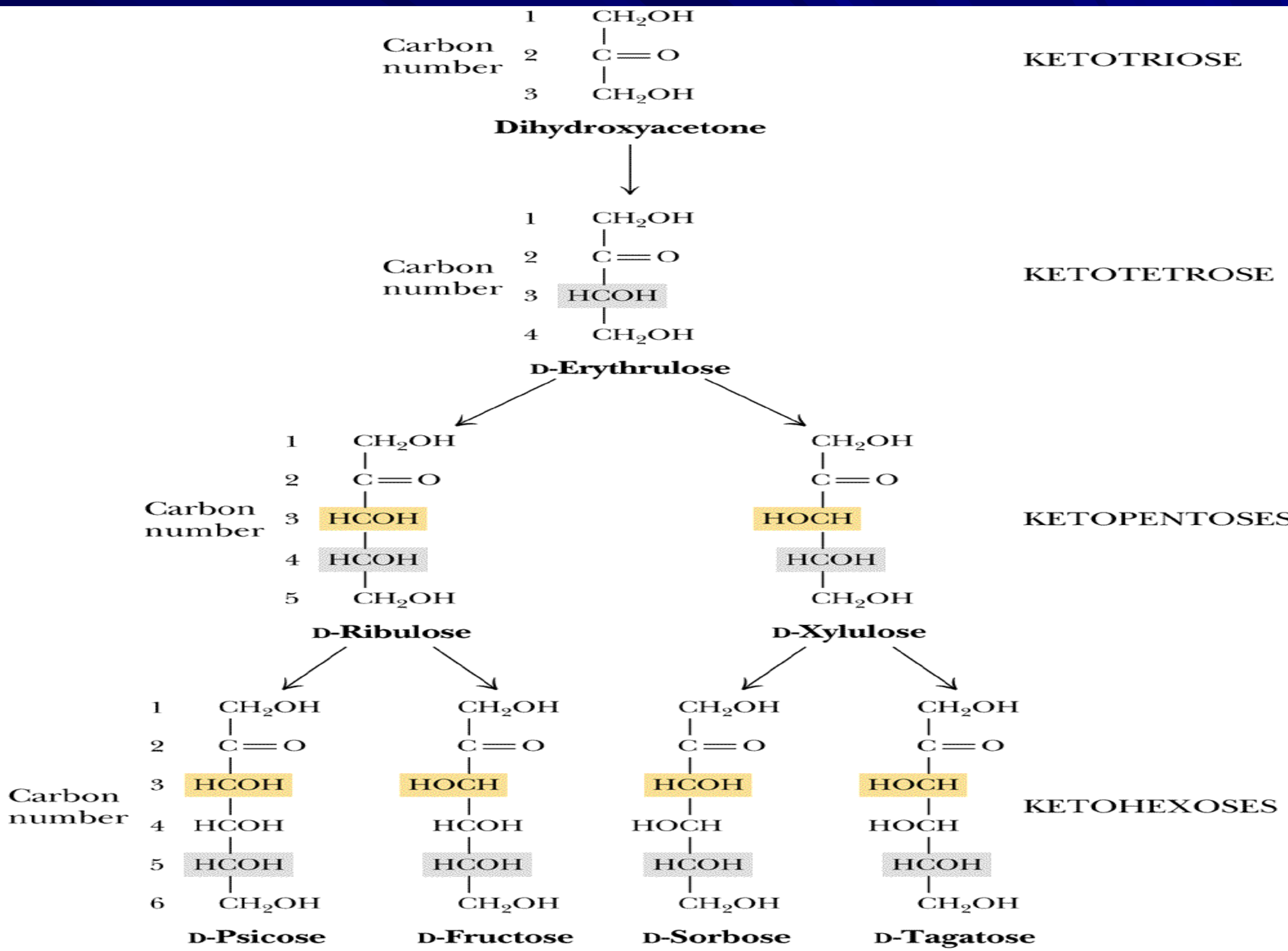
Glucose and Fructose are Isomers



Monosaccharides



Monosaccharides



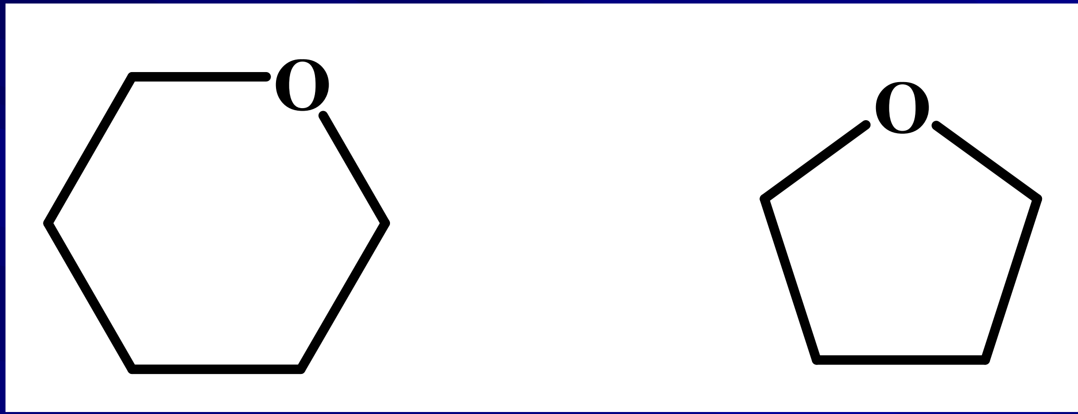
Monosaccharides

Structural representation of sugars

- **Fisher projection:**
  - straight chain representation
- **Haworth projection:**
  - simple ring in perspective
- **Conformational representation:**
  - chair and boat configurations

Rules for drawing Haworth projections

- Draw either a 6 or 5-membered ring including oxygen as one atom

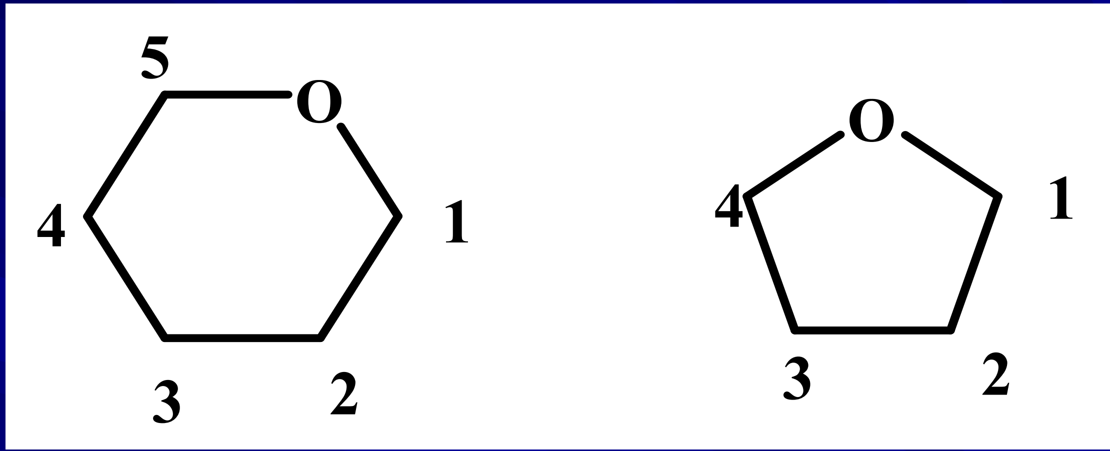


•most aldohexoses are six-membered aldotetroses, aldopentoses,

•ketohexoses are 5-membered

Rules for drawing Haworth projections

Next number the ring **clockwise starting next to the oxygen**



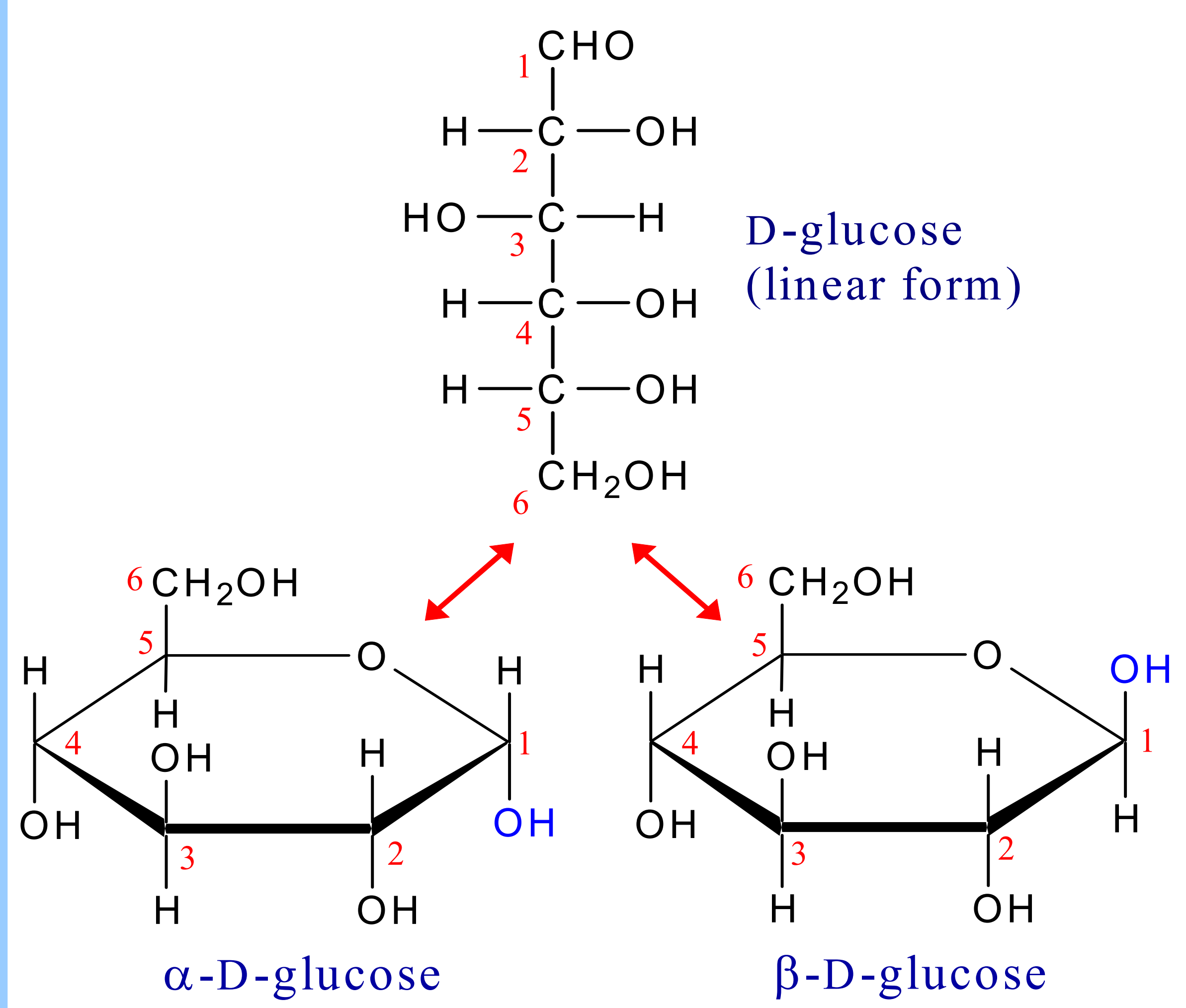
If the substituent is to the **right in the Fisher** projection, it will be drawn **down in the Haworth** projection (Down-Right Rule)

Monosaccharides

<u>Pentoses and hexoses</u> can **cyclize** as the ketone or aldehyde reacts with a distal OH.

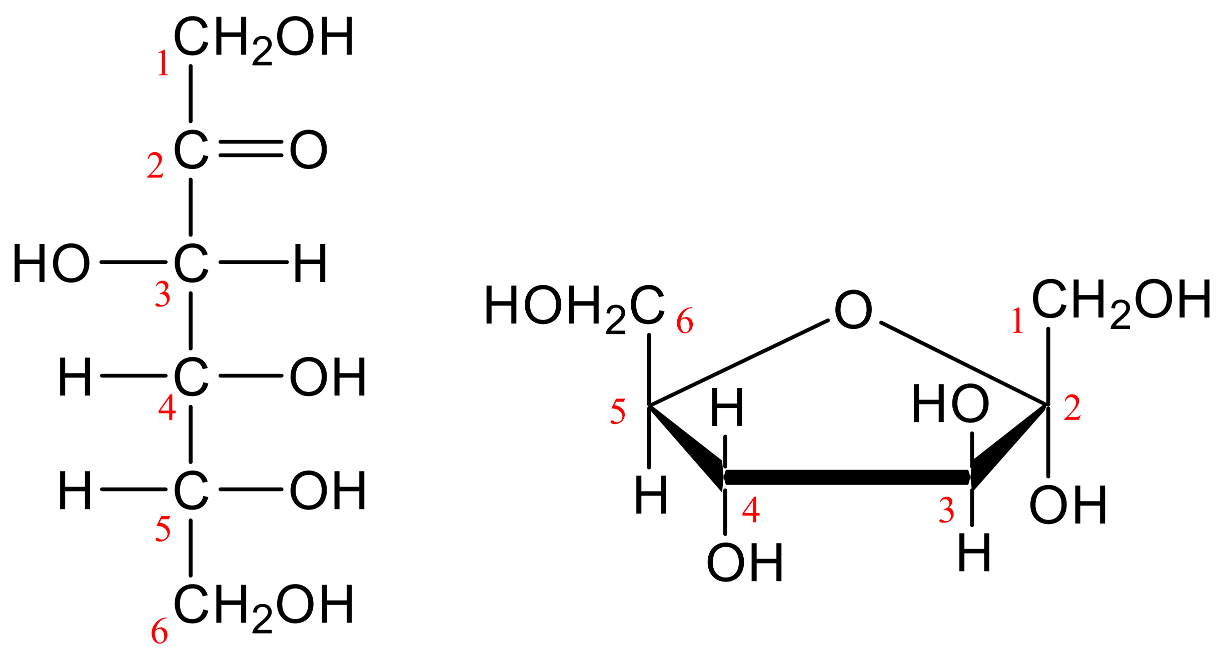
These representations of the <u>cyclic sugars</u> are called <u>Haworth projections</u>.

Glucose forms an intra-molecular hemiacetal, as the C1 aldehyde & C5 OH react, to form a 6-member pyranose ring, named after pyran.

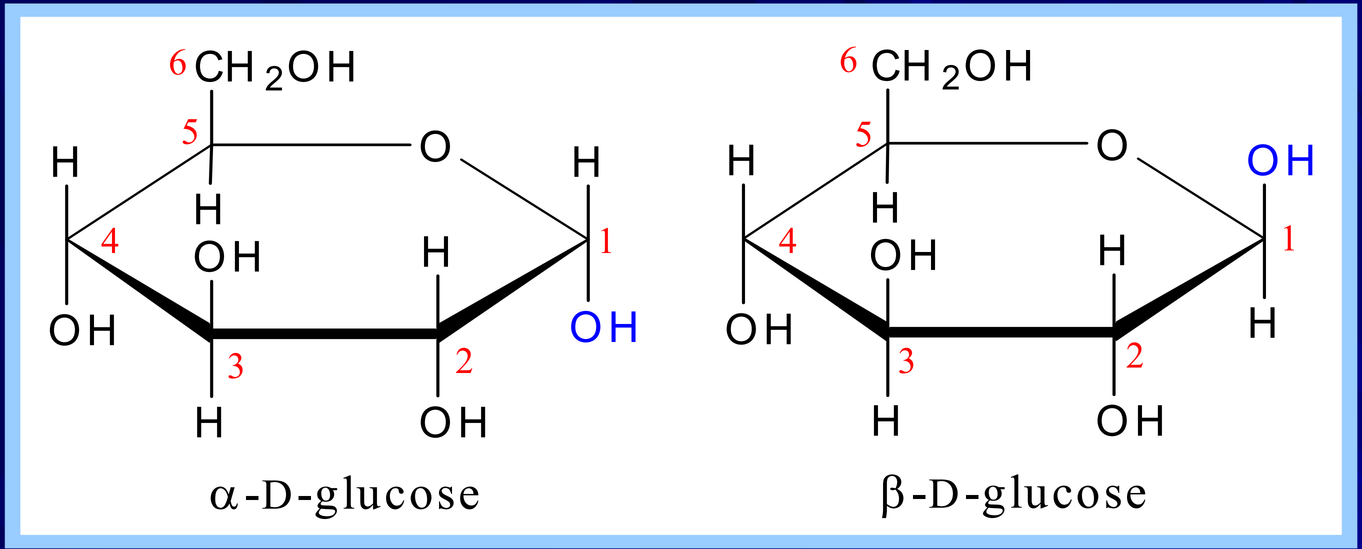


Fructose forms either

- a <u>6-member pyranose ring</u>, by reaction of the <u>**C2**</u> keto group with the OH on <u>**C6**</u>, or
- a <u>5-member furanose ring</u>, by reaction of the <u>**C2**</u> keto group with the OH on <u>**C5**</u>



D-fructose (linear)   α-D-fructofuranose

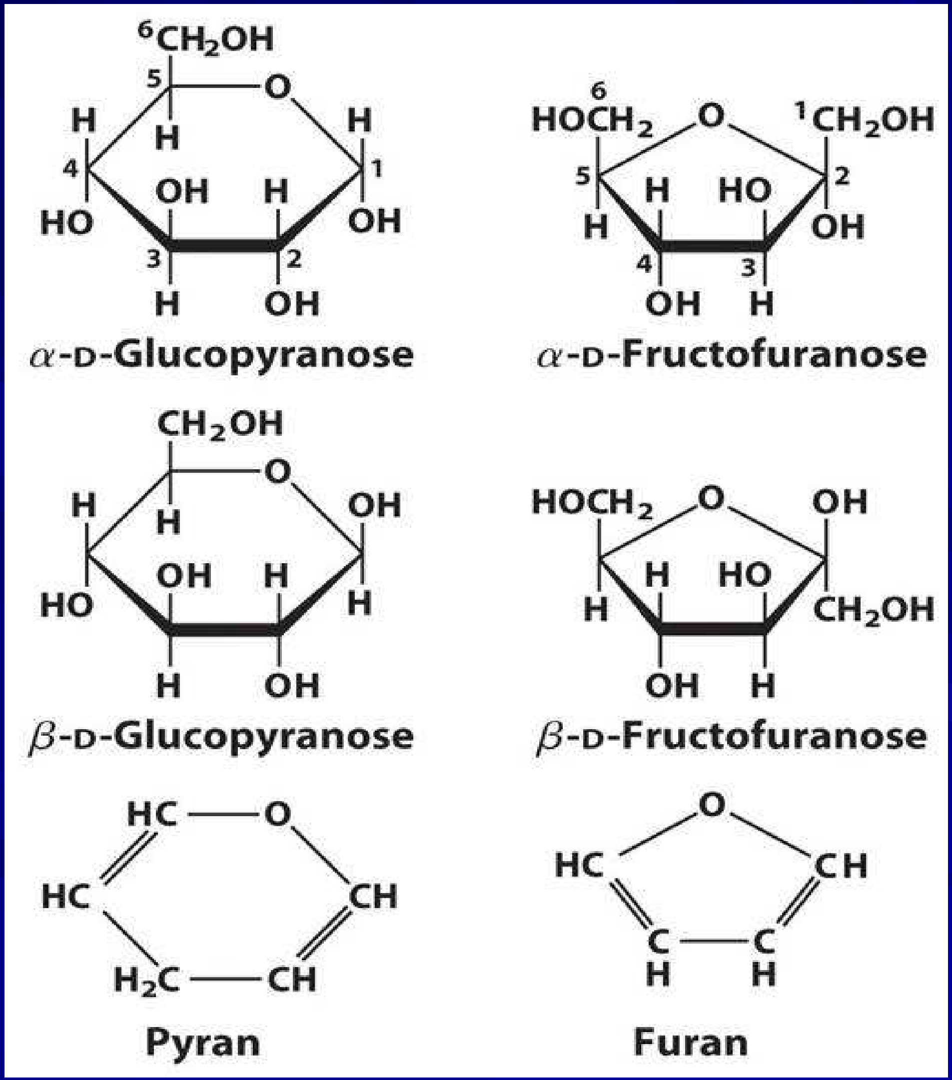


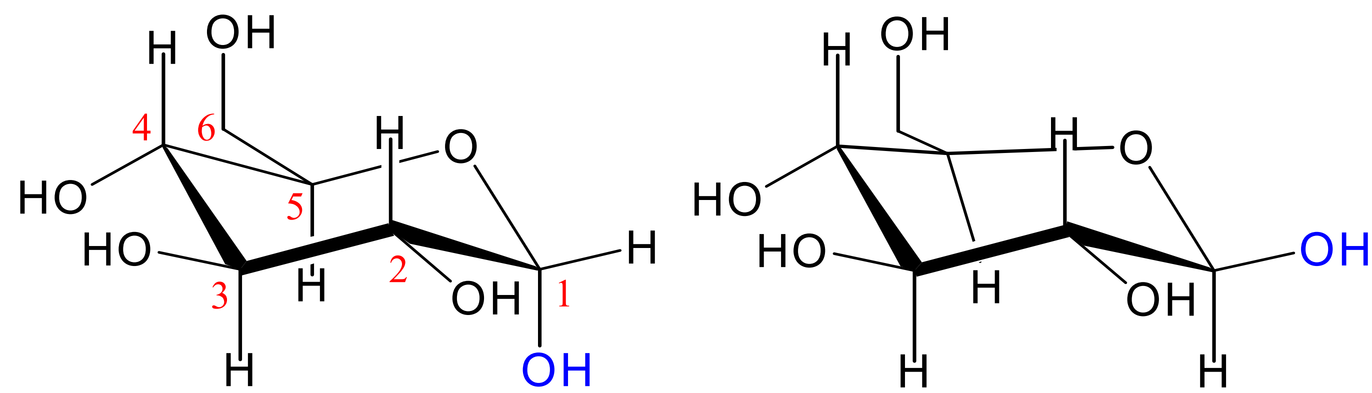
Cyclization of glucose produces a new asymmetric center at C1. The 2 stereoisomers are called anomers, **α & β.**

Haworth projections represent the cyclic sugars as having essentially planar rings, with the **OH at the anomeric C1**:

- **α (OH below the ring)**
- **β (OH above the ring).**

Six membered rings are called pyranoses.
Five membered rings are called furanoses.



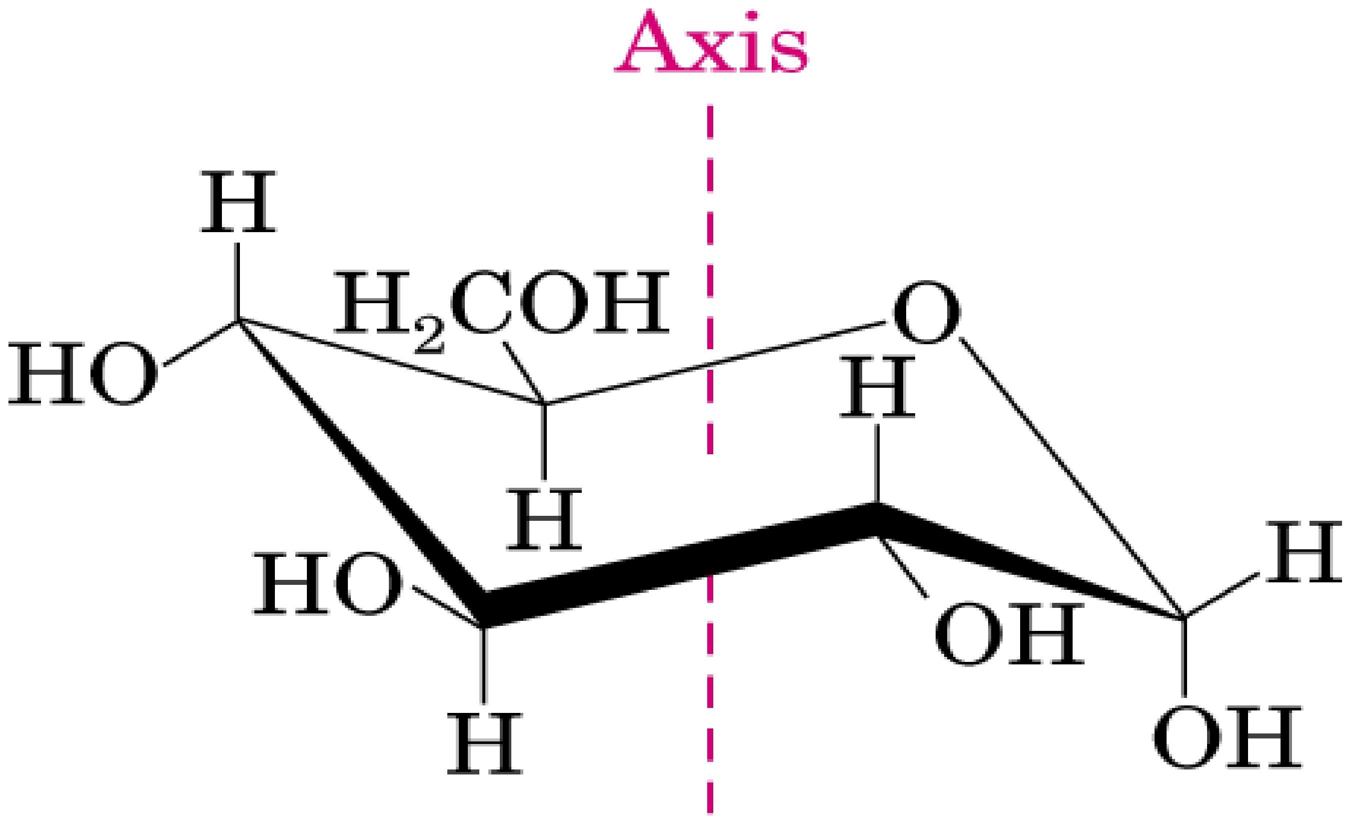


α-D-glucopyranose β-D-glucopyranose

Because of the tetrahedral nature of carbon bonds, pyranose sugars actually assume a "chair" or "boat" configuration, depending on the sugar.

The representation above reflects the chair configuration of the glucopyranose ring more accurately than the Haworth projection.

Sugars are most often in the chair conformation



α-D-Glucopyranose

Anomeric carbon

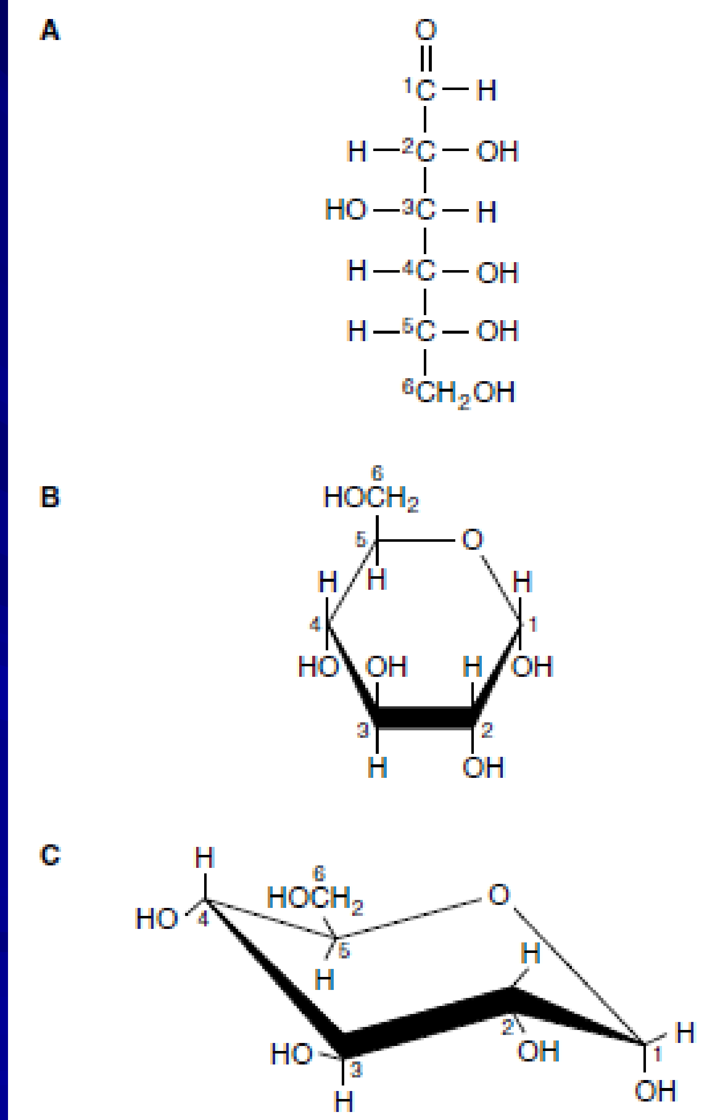
Monosaccharides:

D-Glucose

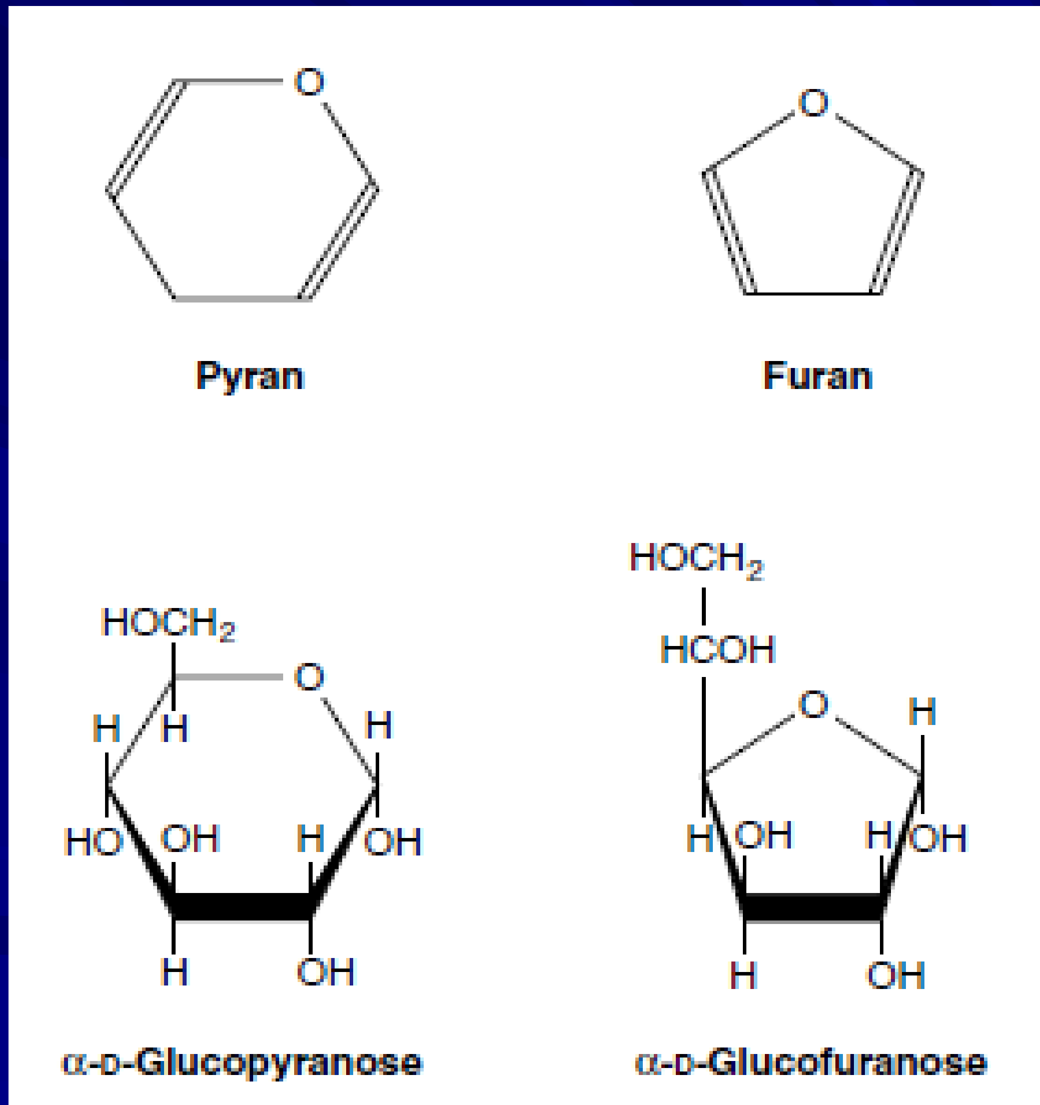
A: straight chain form

B: α-D-glucose; Haworth projection

C: α-D-glucose; chair form

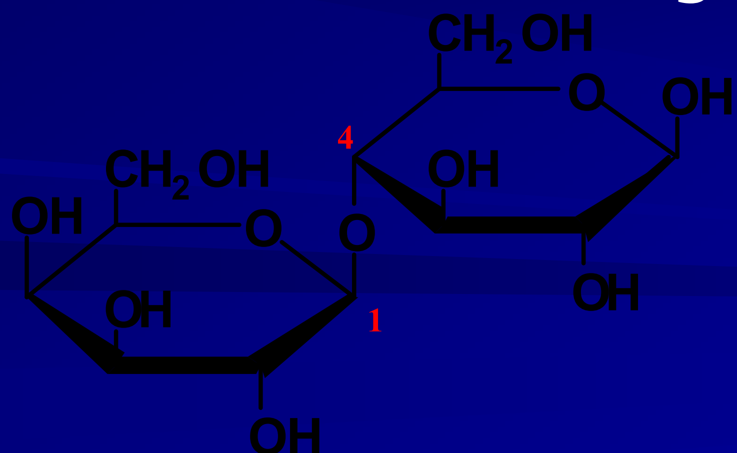


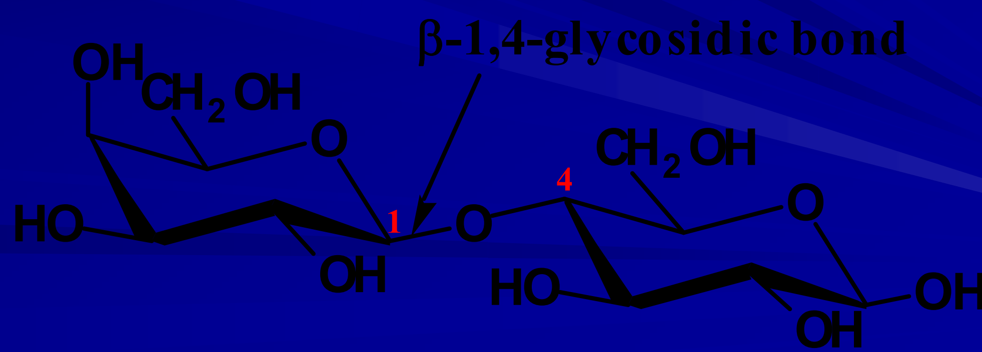
Pyranose and furanose forms of glucose



Disaccharides

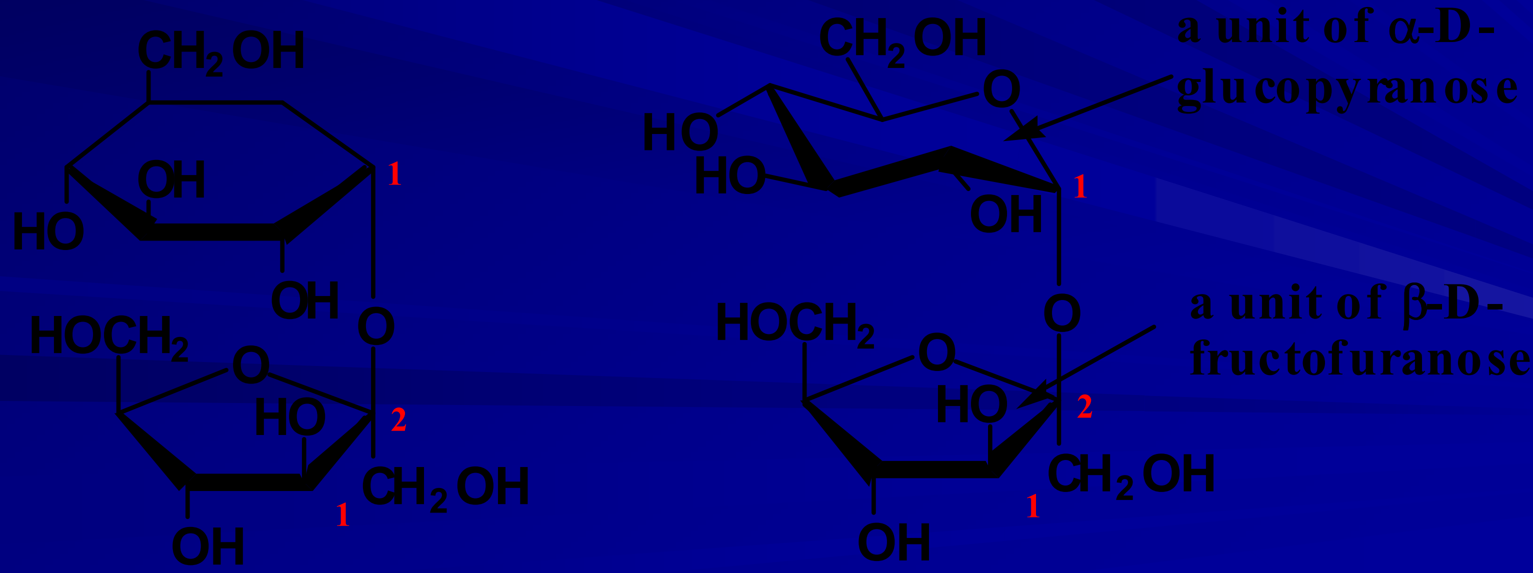
- Lactose (Milk sugar)
  - lactose is the principal sugar present in milk; it makes up about 5 to 8 percent of human milk and 4 to 6 percent of cow's milk
  - it consists of D-galactopyranose bonded by a β-1,4-glycosidic bond to carbon 4 of D-glucopyranose
  - lactose is a reducing sugar





Disaccharides

- Sucrose (table sugar or cane sugar)
  - sucrose is the most abundant disaccharide in the biological world; it is obtained principally from the juice of sugar cane and sugar beets
  - sucrose is a nonreducing sugar



Disaccharides

- Maltose (Malt sugar)
  - present in malt, the juice from sprouted barley and other cereal grains
  - maltose consists of two units of D-glucopyranose joined by an α-1,4-glycosidic bond
  - maltose is a reducing sugar