Ministry of Higher Education and Scientific Research
AL-Mustaqbal University College of Science
Department of medical biotechnology

Biochemistry

Lecture 2

Carbohydrates

By

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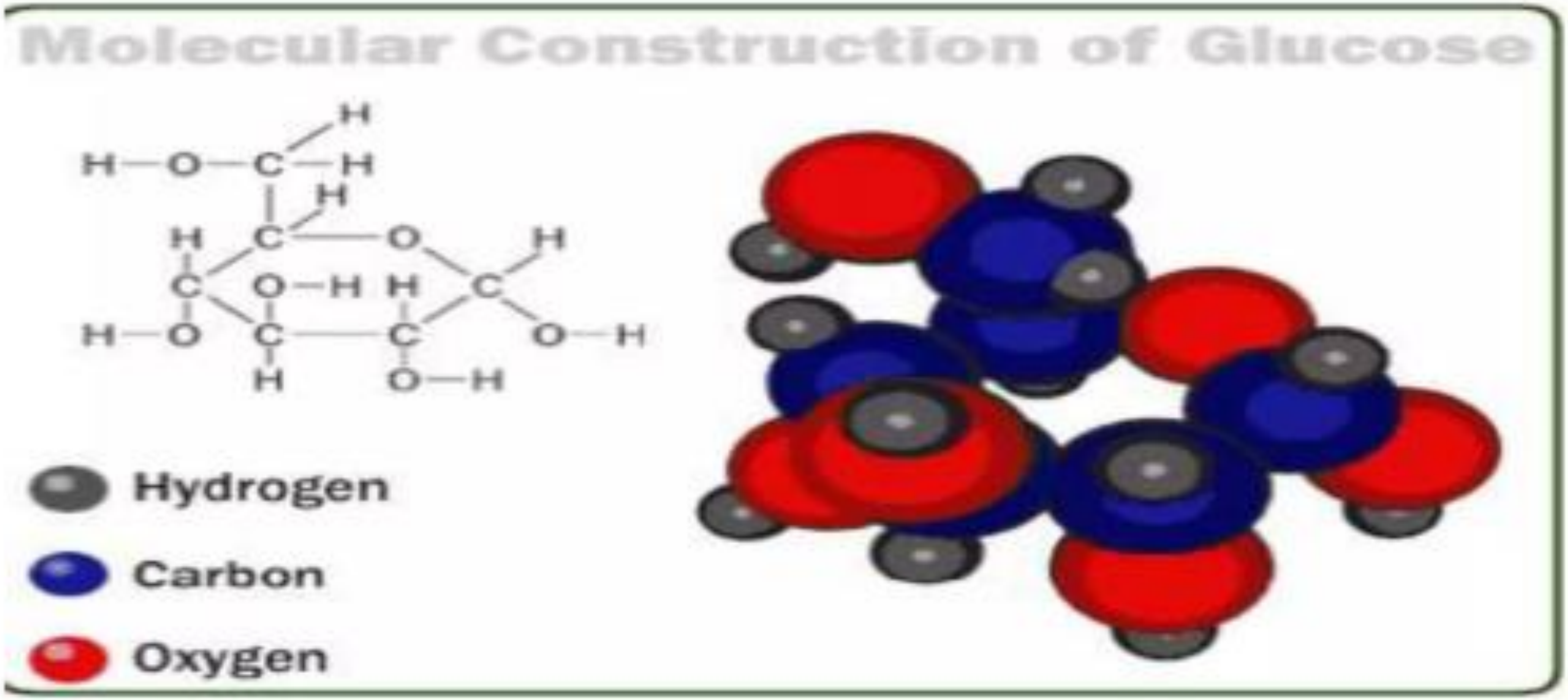
Carbohydrates

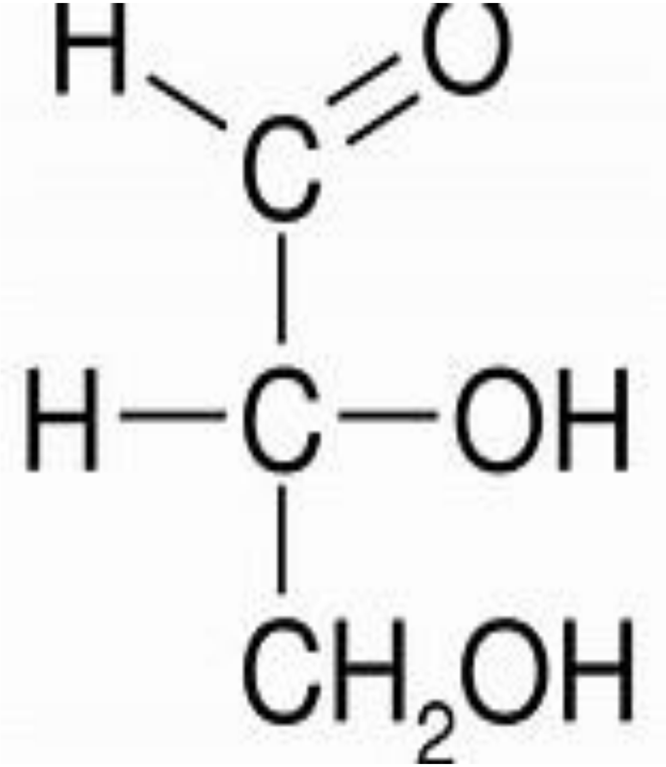


DEFINITION

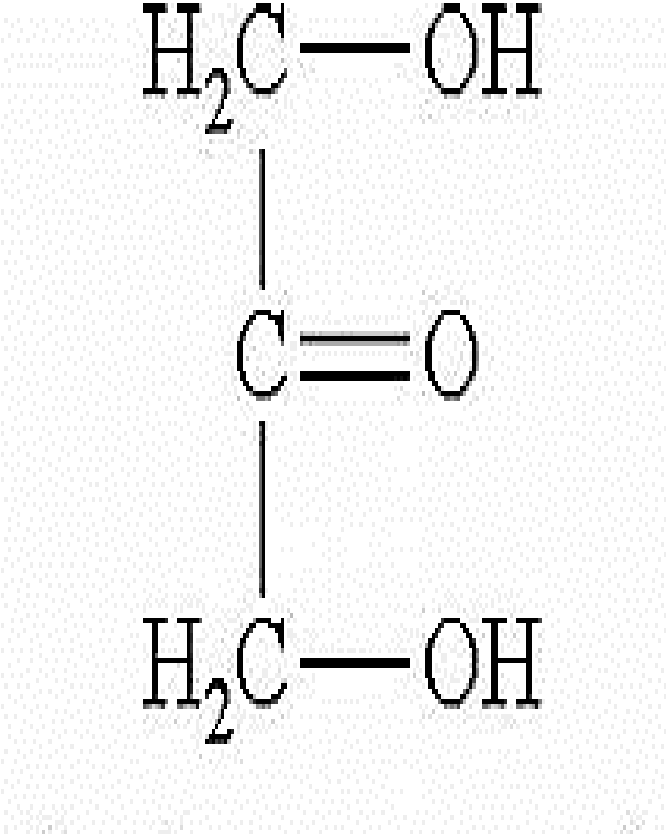
Carbohydrates are polyhydroxy aldehydes or ketones or compounds which yield these on hydrolysis.

Have the empirical formula $(CH_2O)_n$

like glyceraldehyde , dihydroxyacetone



glyceraldehyde



dihydroxyacetone

Carbohydrates - Functions

1) Major energy source

2) Intermediates in biosynthesis of other basic biochemical structures (fats and proteins)

3) Associated with other structures (vitamins & antibiotics)

4) On cells surfaces: cell–cell interactions & immune recognition, activation of growth factors

5) Structural tissues: polysaccharides (cellulose & bacterial cell walls)

Glucose (a monosaccharide)

Plants:

photosynthesis

$$6\,CO_2 + 6\,H_2O \xrightarrow[\text{sunlight}]{\text{chlorophyll}} \underset{\text{(+)-glucose}}{C_6H_{12}O_6} + 6\,O_2$$

$$\text{(+)-glucose} \rightleftharpoons \text{starch or cellulose}$$

respiration

$$C_6H_{12}O_6 + 6\,O_2 \longrightarrow 6\,CO_2 + 6\,H_2O + \text{energy}$$

Classification of Carbohydrates

Carbohydrates – polyhydroxyaldehydes or polyhydroxy-ketones of formula $(CH_2O)_n$, or compounds that can be hydrolyzed to them. (aka sugars or saccharides)

Monosaccharides – carbohydrates that cannot be hydrolyzed to simpler carbohydrates; eg. Glucose or fructose.

Disaccharides – carbohydrates that can be hydrolyzed into two monosaccharide units; eg. Sucrose, which is hydrolyzed into glucose and fructose.

Oligosaccharides – carbohydrates that can be hydrolyzed into a few monosaccharide units.

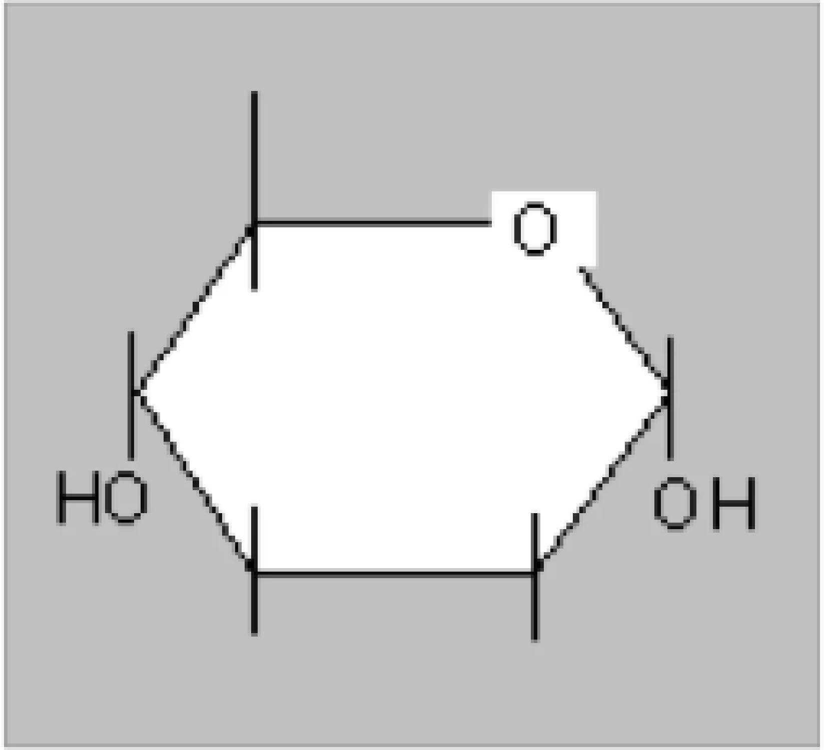
Polysaccharides – carbohydrates that are are polymeric sugars; eg Starch or cellulose.

Monosaccharides

- also known as simple sugars
- classified by 1. the number of carbons and 2. whether aldoses or ketoses
- most (99%) are straight chain compounds
- D-glyceraldehyde is the simplest of the aldoses (aldotriose)
- all other sugars have the ending <u>ose</u> (glucose, galactose, ribose, lactose, etc…)

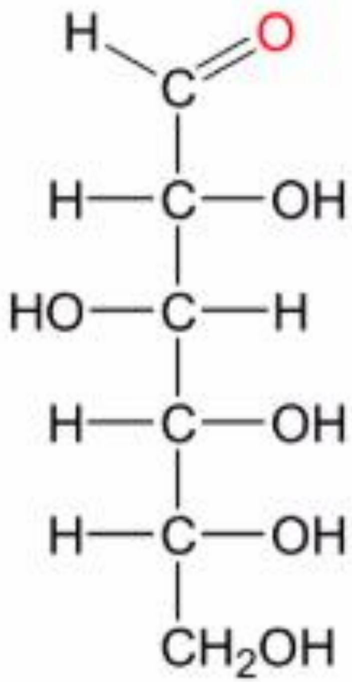
Glucose

- The chemical formula for glucose is $C_6H_{12}O_{6.}$
- It is a six sided ring.
- The structure on the left is a simplified structure of glucose



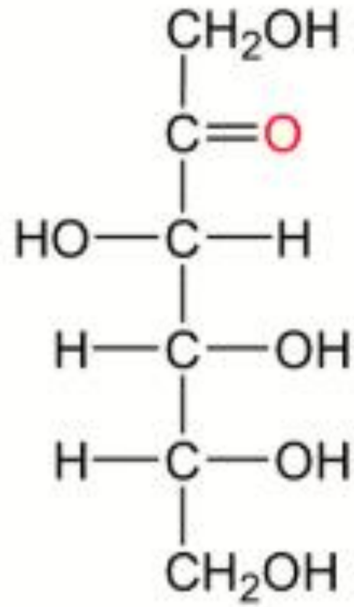
Monosaccharides

Aldoses (e.g., glucose) have an aldehyde group at one end.



D-glucose

Ketoses (e.g., fructose) have a keto group, usually at C2.



D-fructose

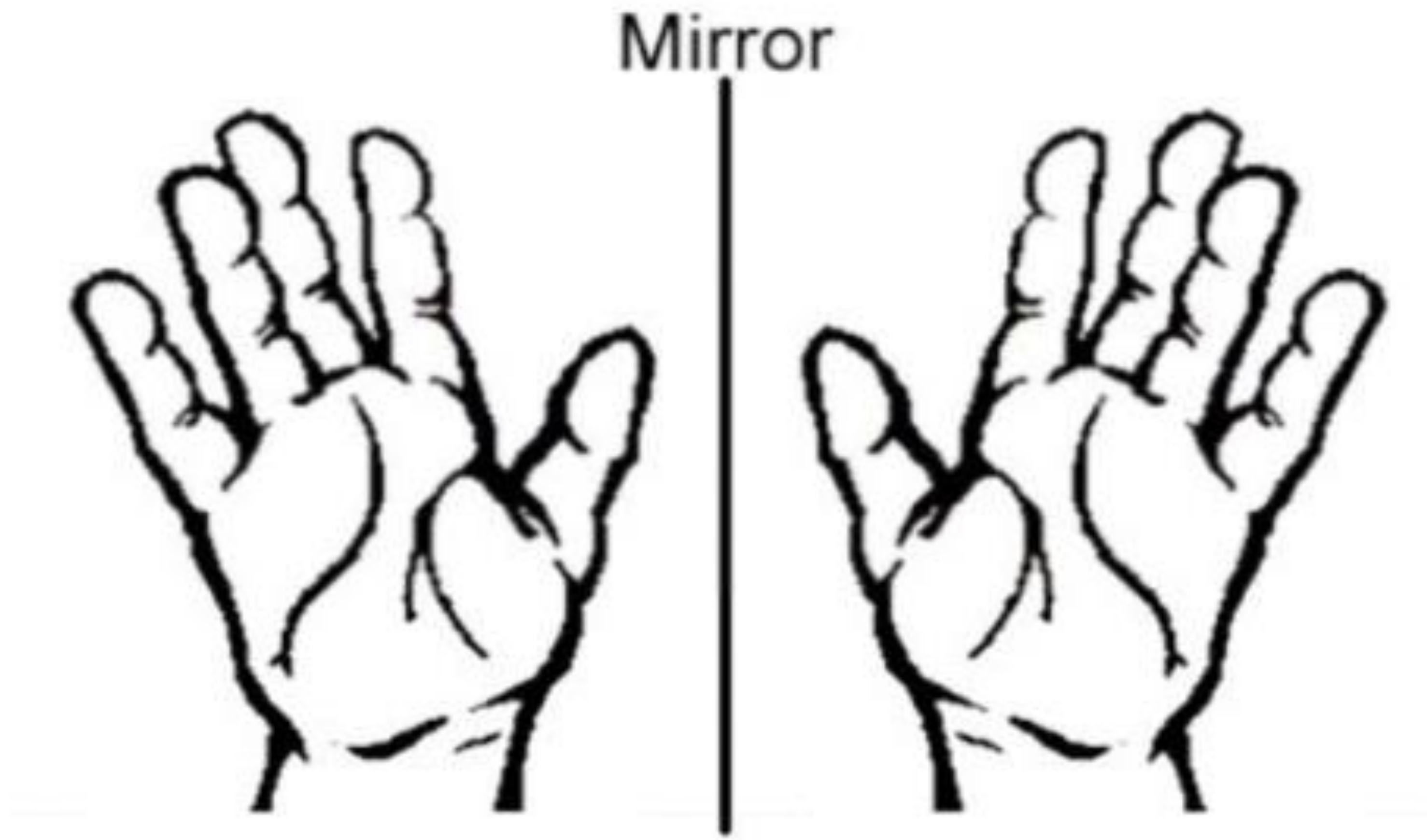
Asymmetric carbon

- A carbon linked to four different atoms or groups farthest from the carbonyl carbon.
- Also called **Chiral** carbon.

chiral centers by definition are C atoms which have 4 DIFFERENT atoms bonded to it

- **Compounds having same structural formula, but differ in spatial configuration.**
- **Asymmetric Carbon atom:Attached to four different atoms or groups.**

- **Vant Hoff's rule: The possible isomers (2n) of a given compound is determined by the number of asymmetric carbon atoms (n).**
- **Reference C atom: Penultimate C atom, around which mirror images are formed.**

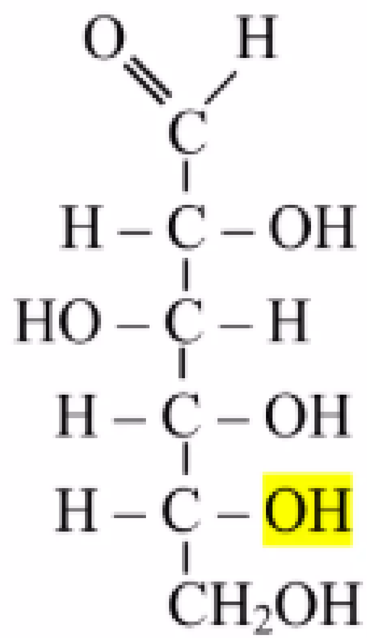


The mirror image of a chiral substance cannot be superimposed on the original image. Hands are chiral, as are sugars and amino acids.

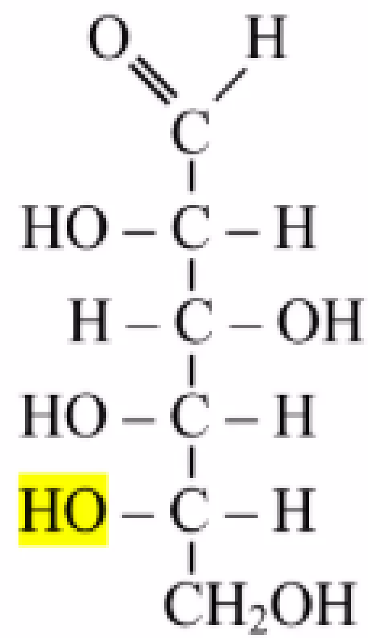
Sugar Nomenclature

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-glucose

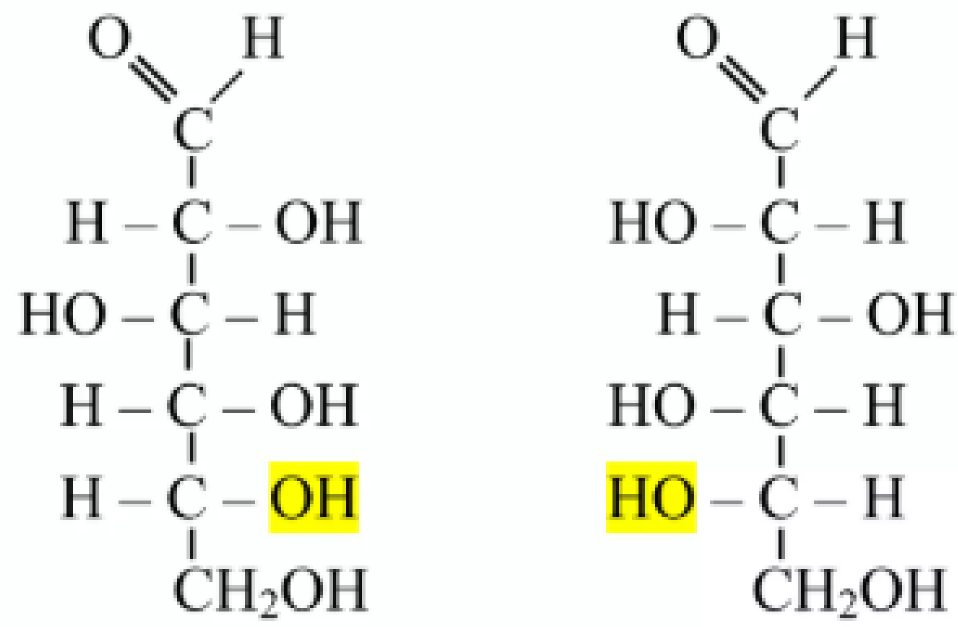


L-glucose

D & L sugars are mirror images of one another.

They have the same name, e.g., D-glucose & L-glucose.

Other stereoisomers have unique names, e.g., glucose, mannose, galactose, etc.



D-glucose L-glucose

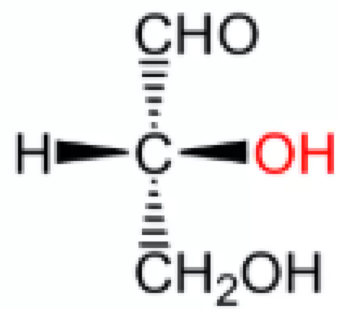
The number of stereoisomers is $\mathbf{2^n}$, where n is the number of asymmetric centers.

The 6-C aldoses have 4 asymmetric centers. Thus there are 16 stereoisomers (8 D-sugars and 8 L-sugars).

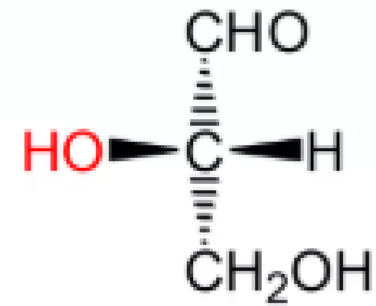
D vs L Designation

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

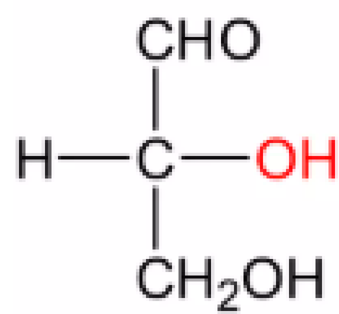
The lower representations are Fischer Projections.



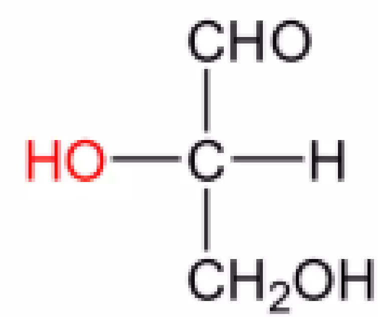
D-glyceraldehyde



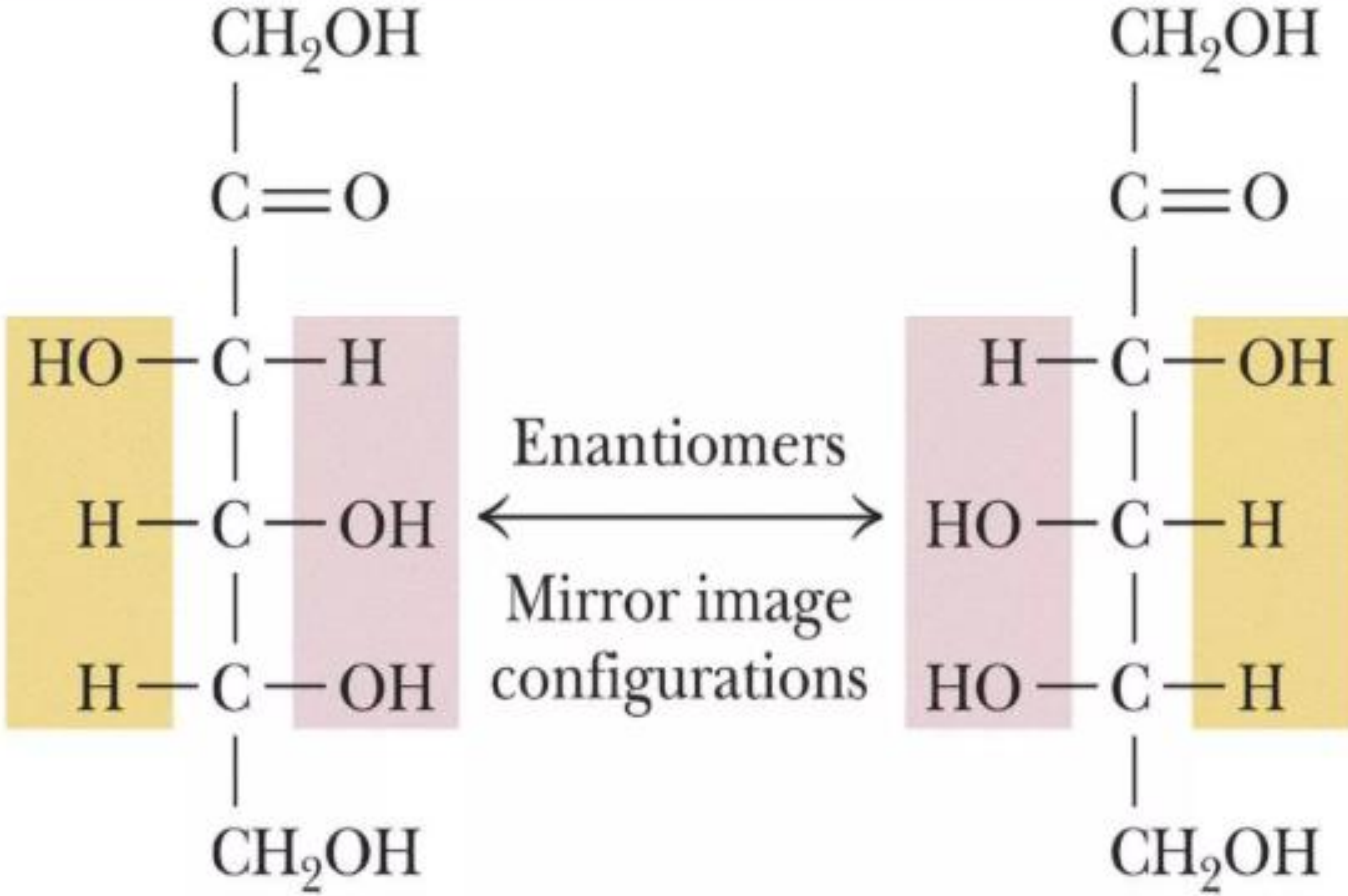
L-glyceraldehyde



D-glyceraldehyde



L-glyceraldehyde



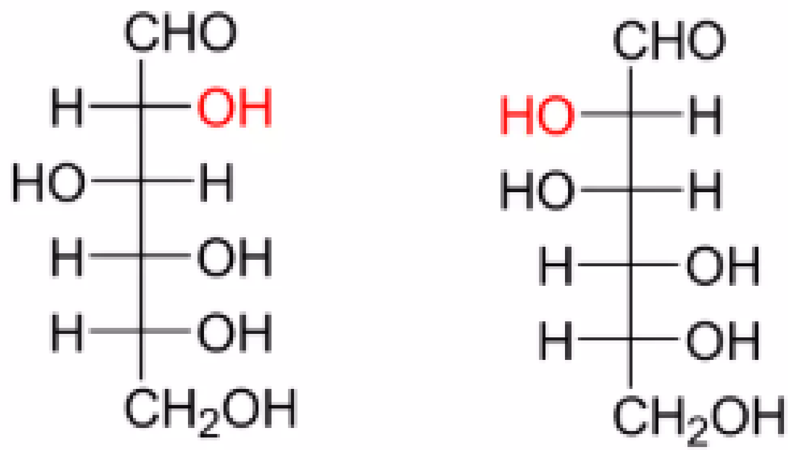
D-Fructose **L-Fructose**

Enantiomres

A special type of isomerism is found in the pairs of structures that are mirror images of each other. These mirror images are called **enantiomers, and the two members of the pair are designated as a D- and an L-sugar**

two monosaccharides differ in configuration around only one specific carbon atom (with the exception of the carbonyl carbon, see below), they are defined as **epimers of each other.**

Epimers – stereoisomers that differ only in configuration about <u>one</u> chiral center.

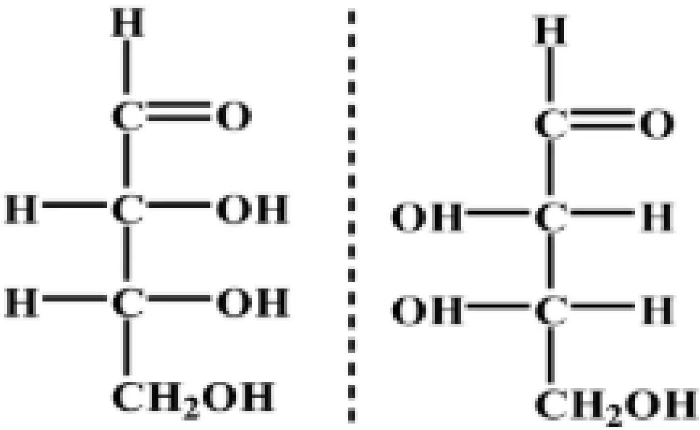


D-glucose D-mannose

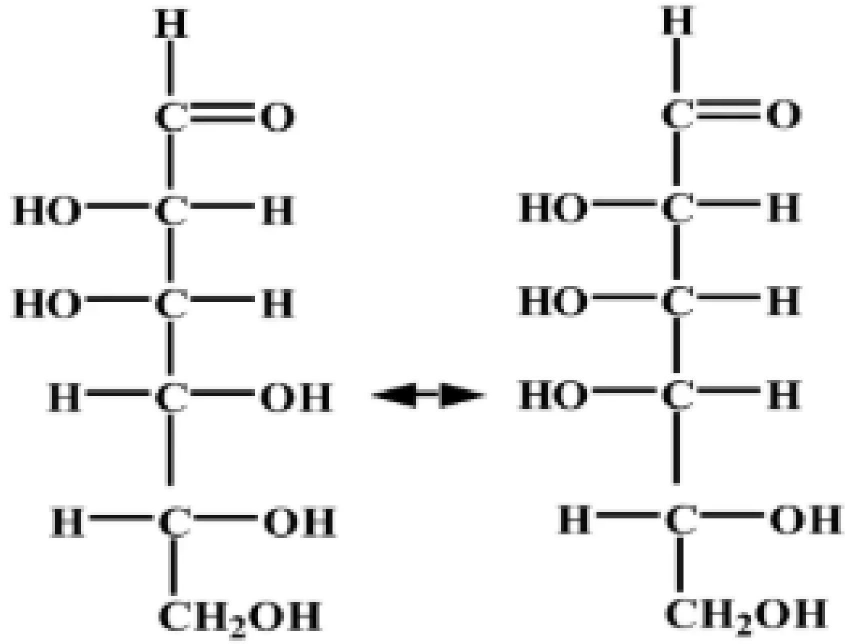
epimers

Sugars are different from one another, only in configuration with regard to a single C atom (other than the reference C atom).

Enantiomers and epimers

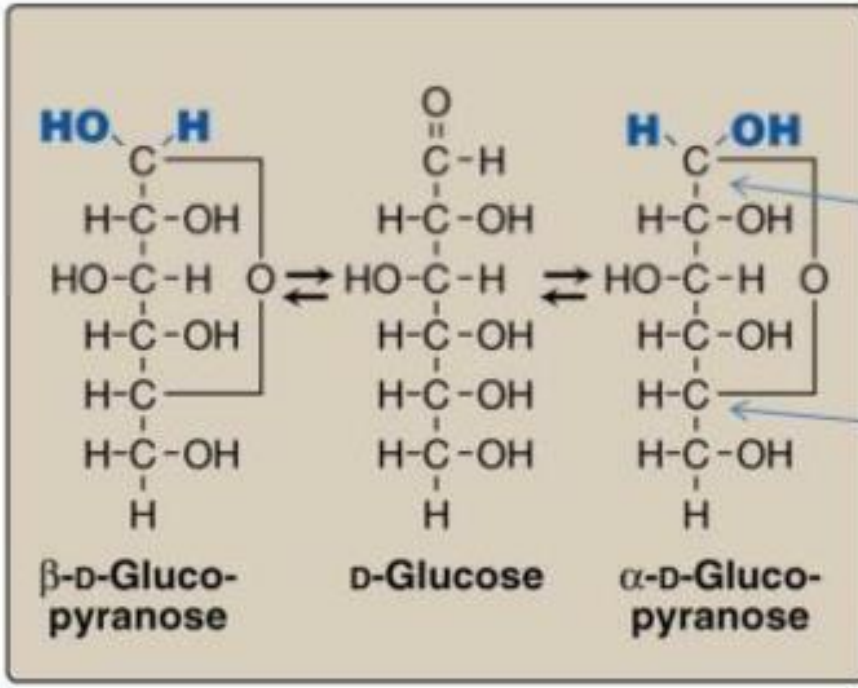


these two aldotetroses are enantiomers. They are stereoisomers that are mirror images of each other



these two aldohexoses are C-4 epimers. they differ only in the position of the hydroxyl group on one asymmetric carb (carbon 4)

Modified Fischer Projection Formula



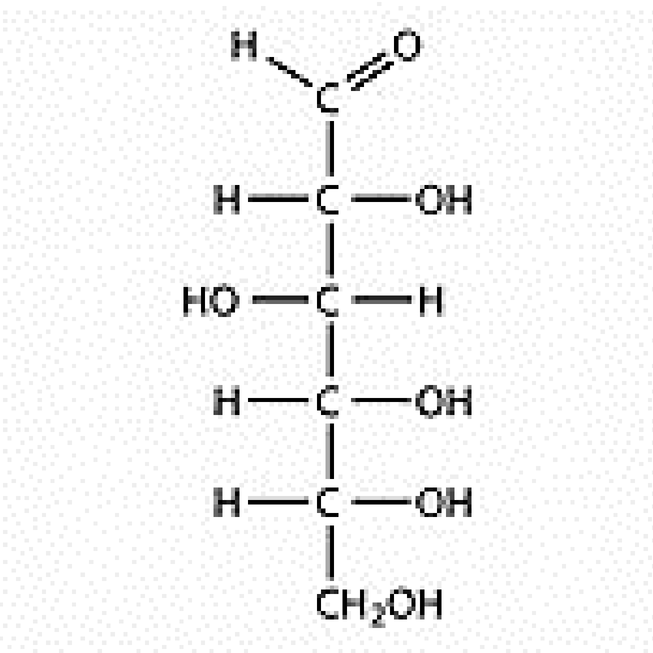
Carbon number 1
(**anomeric carbon**)

Carbon number **5**

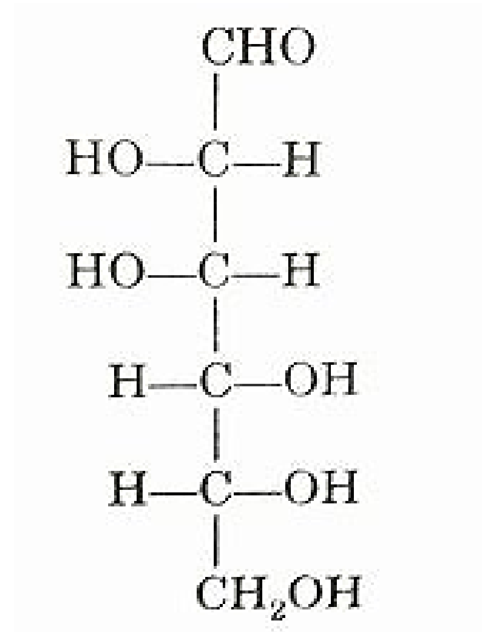
Figure 7.6
The interconversion of the α and β anomeric forms of glucose (mutarotation).

Example:

D-Glucose give two epimers are show projection formulas.



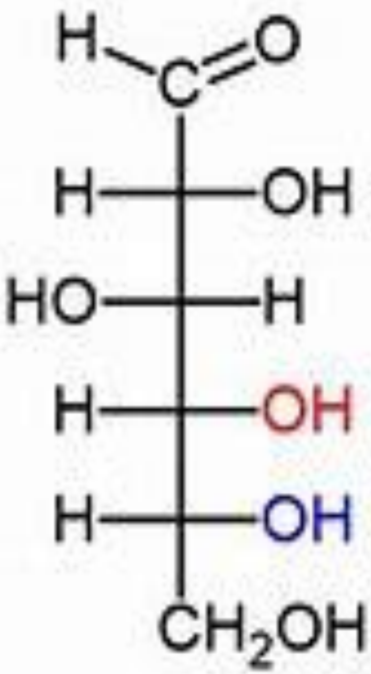
Epimers



D-Glucose

D-Mannose

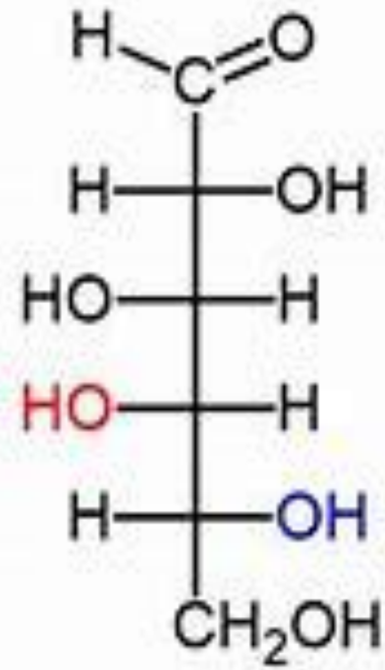
D-glucose and D-galactose are epimeric at carbon-4



D-Glucose

Epimers

Only one chiral center with **different** configuration

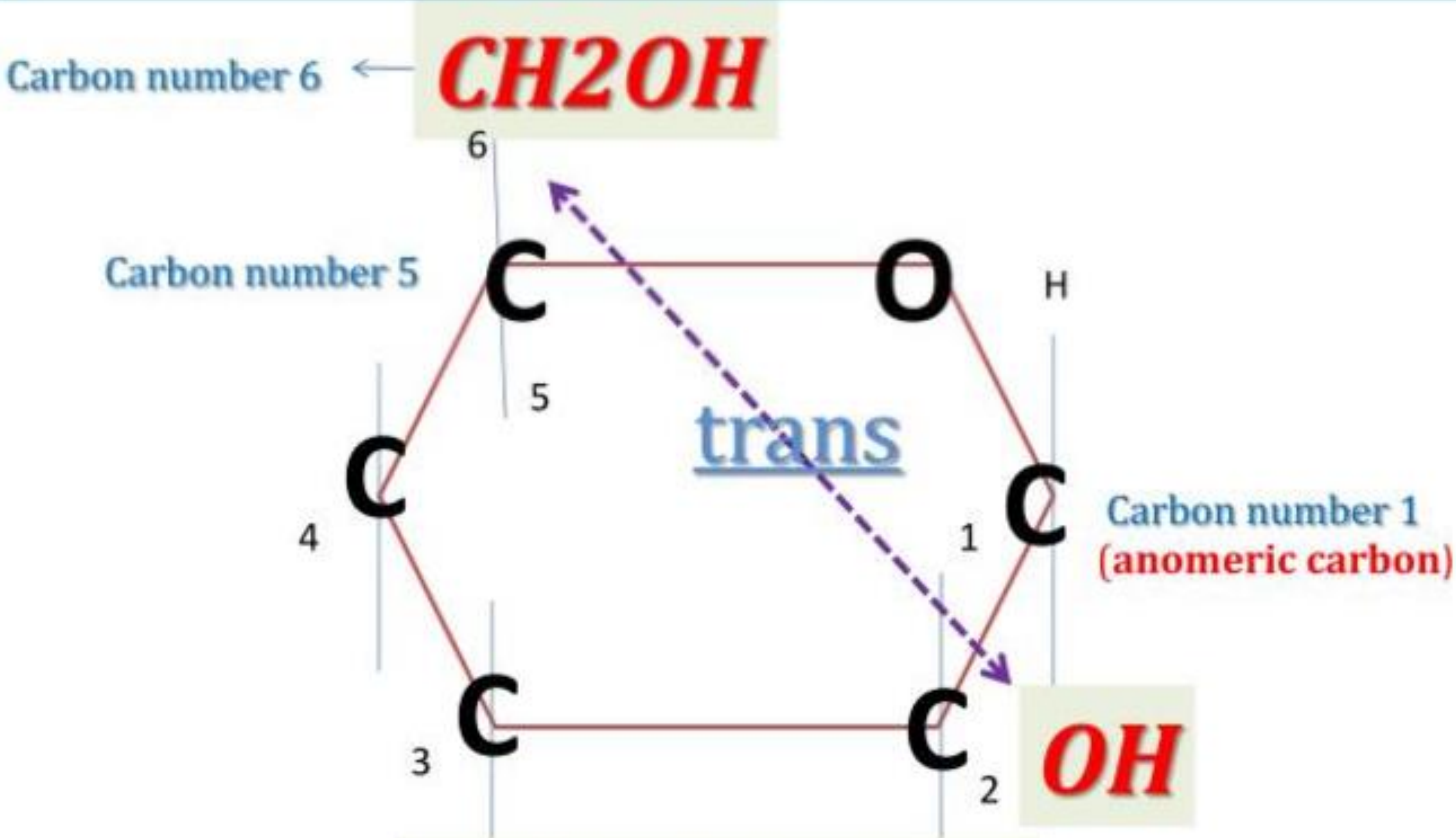


D-Galactose

Haworth Formula:

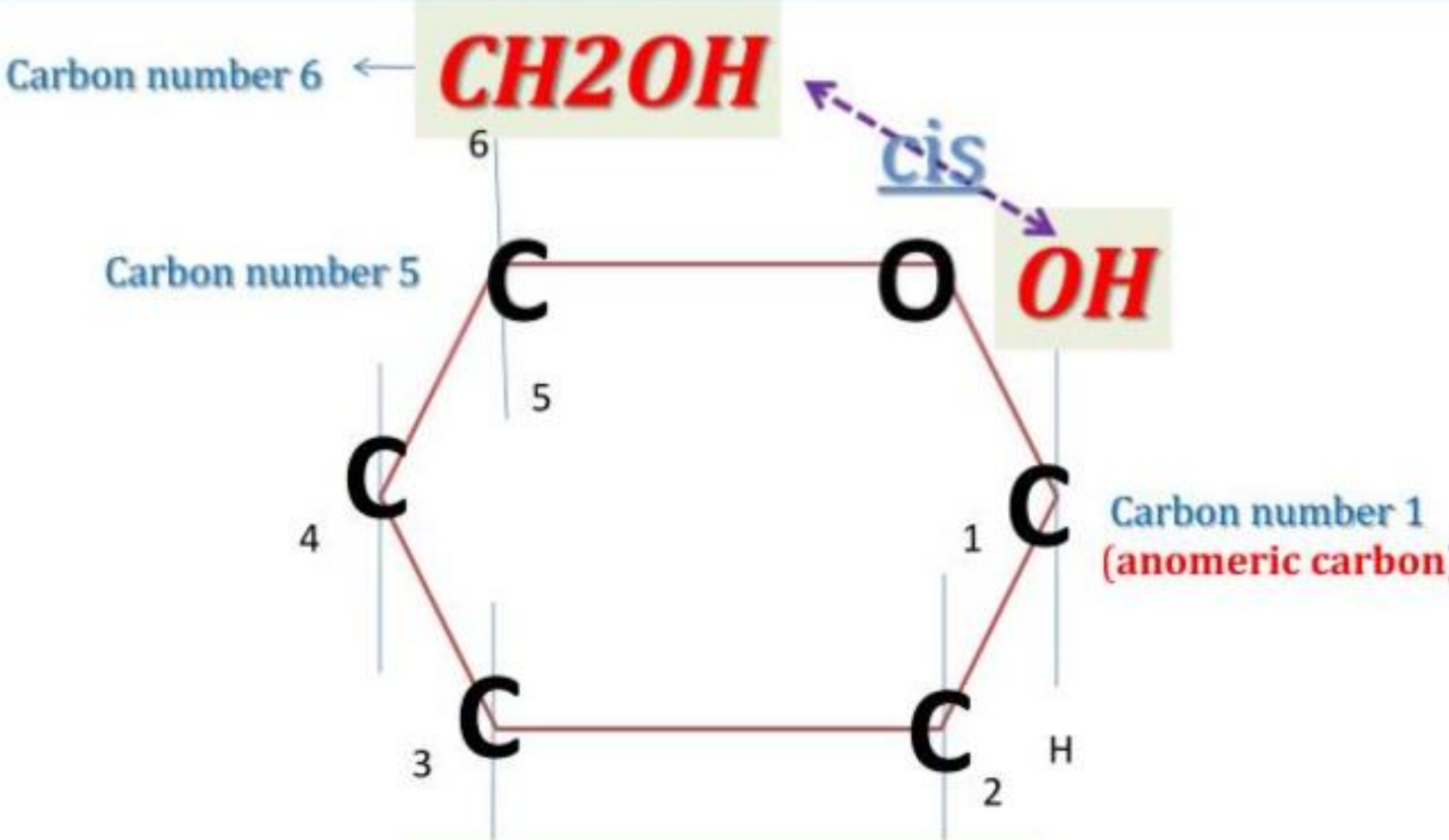
It is the conversion of the open Fisher formula into a ring formula known as Haworth formula. Results from the union of the carbon atom of Carbonyl No. (1) with the OH around carbon atom No.(5) to give two different ring structures: alpha and beta. Haworth relied on the **Pyran** and **Furan** ring to form a ring indicating his formula.

Hawroth Projection Formula



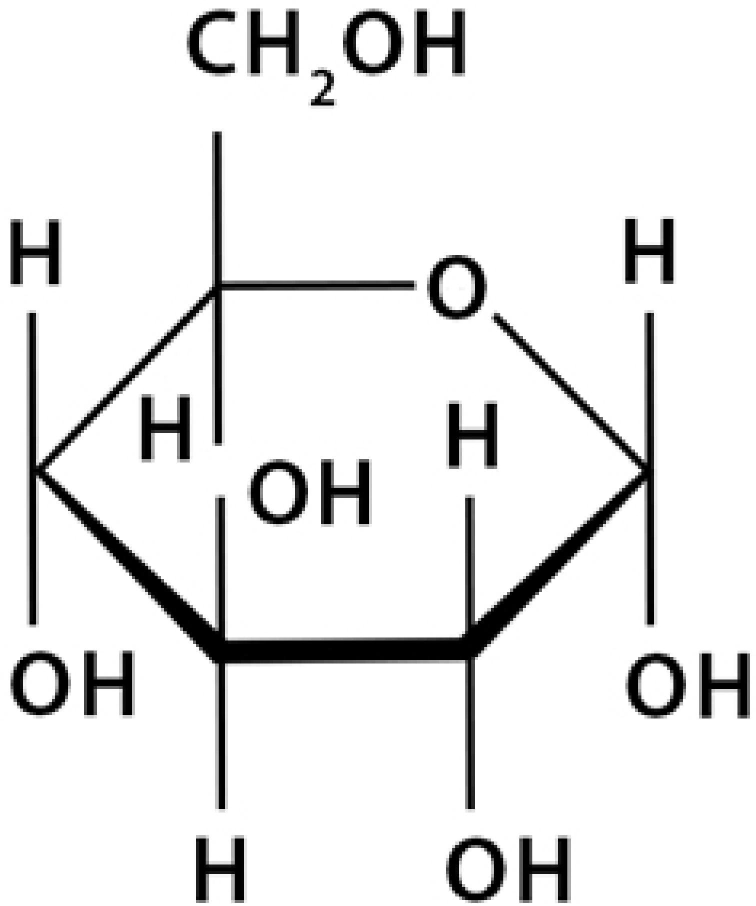
α-D-glucose

Hawroth Projection Formula

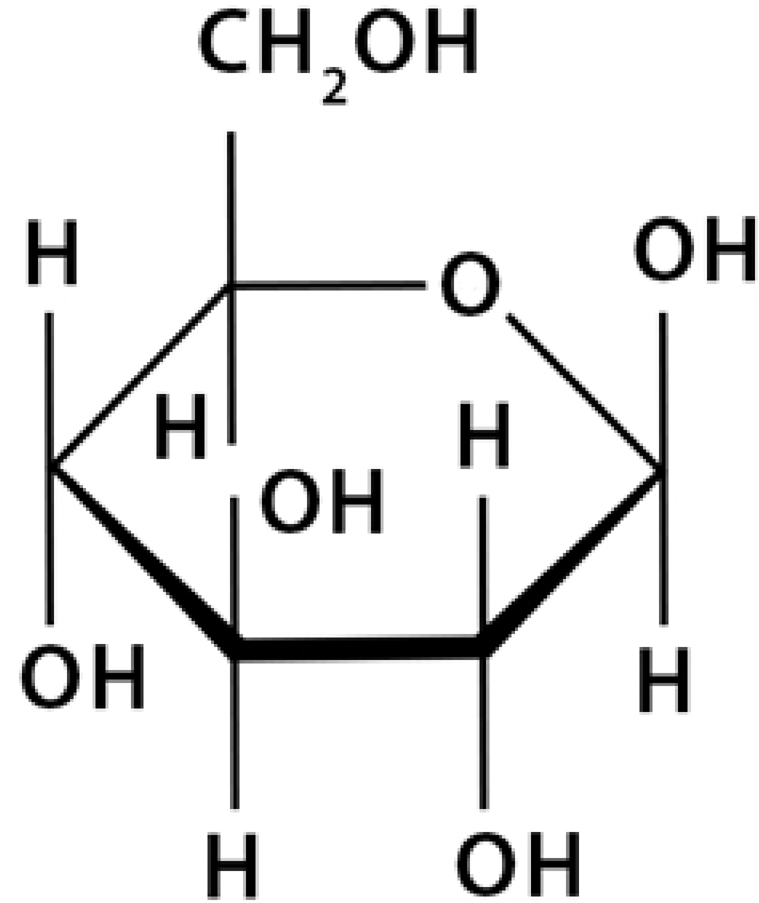


β-D-glucose

Haworth Projection



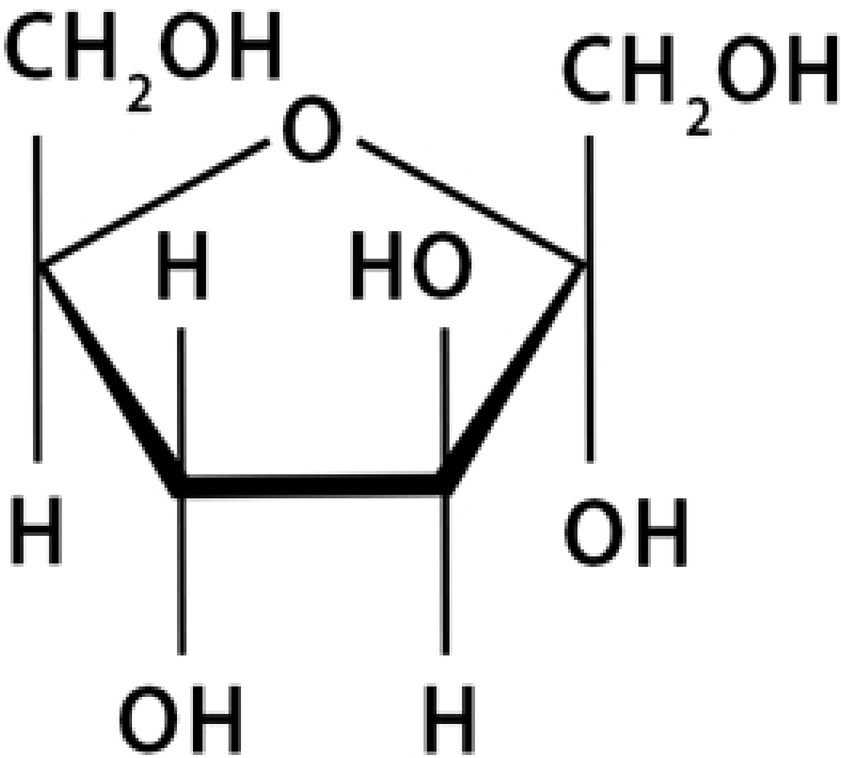
α-D-Glucopyranose



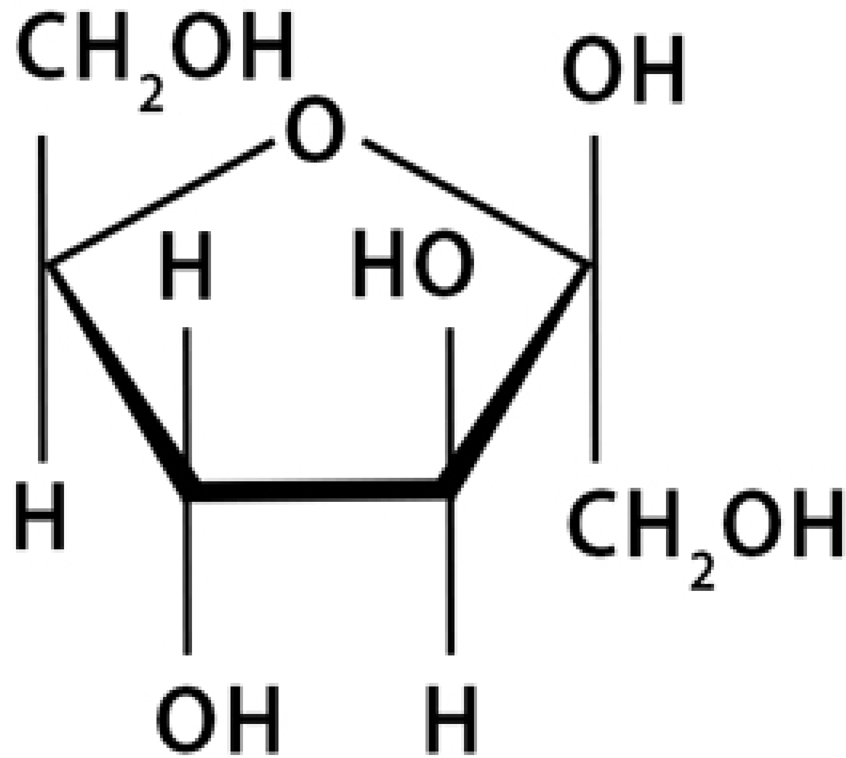
β-D-Glucopyranose

Haworth Projection

Fructose



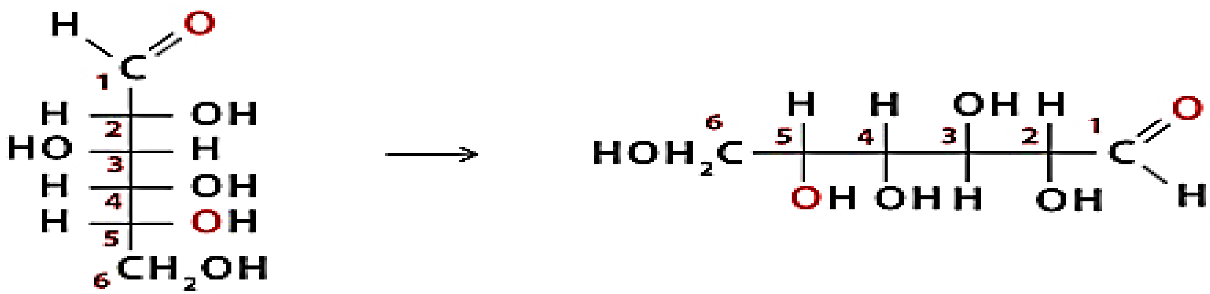
α-D-Fructofuranose



β-D-Fructofuranose

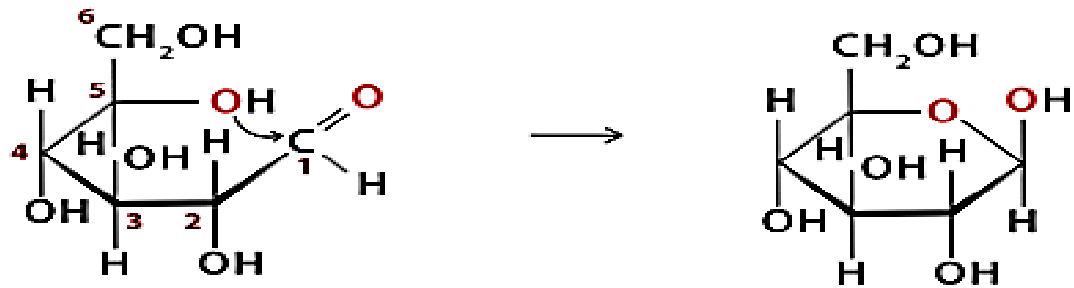
Conversion of Fischer Projection to Haworth Projection

Step 1: Number the carbon atoms and turn Fischer projection by 90°



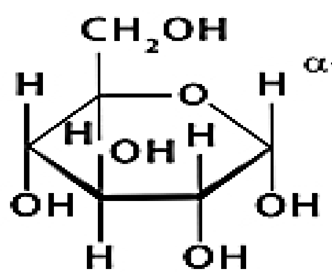
Fischer projection of D-glucose

Step 2: Fold clockwise to make a hexagon and bond the oxygen on C-5 to C-1



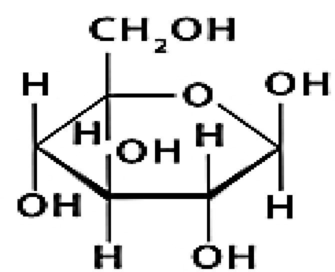
Cyclic structure of glucose

Step 3: Draw the bond between the OH group and carbon 1 and indicate the α- and β-isomer according to the position of OH



α-isomer

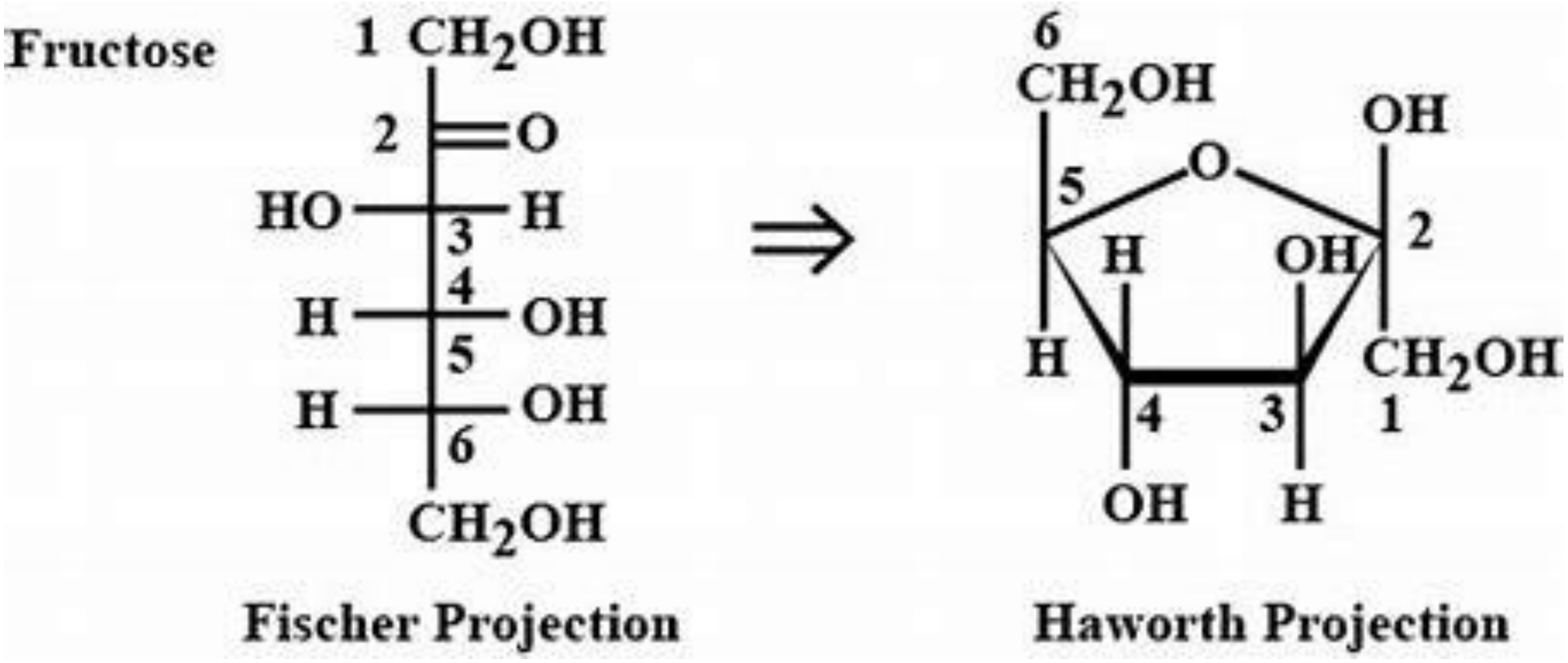
α-D-Glucopyranose



β-isomer

β-D-Glucopyranose

Mutarotations Fructose from Fischer Projection to Haworth Projection.




Thank you