



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



# *Biochemistry*

## **Lecture 5**

### **Carbohydrates**

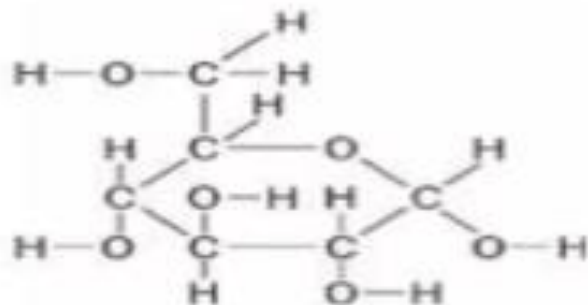
**By**

*Dr. Assel Amer Hadi*

# Carbohydrates



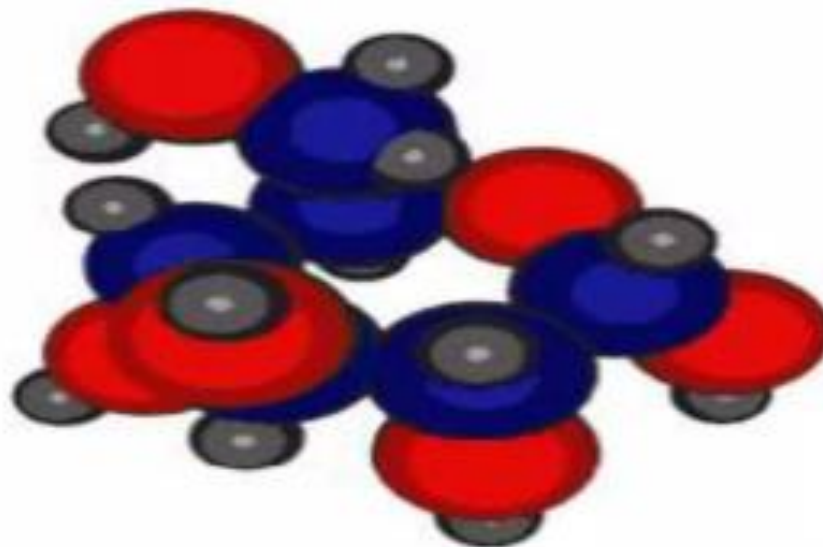
## Molecular Construction of Glucose



● Hydrogen

● Carbon

● Oxygen

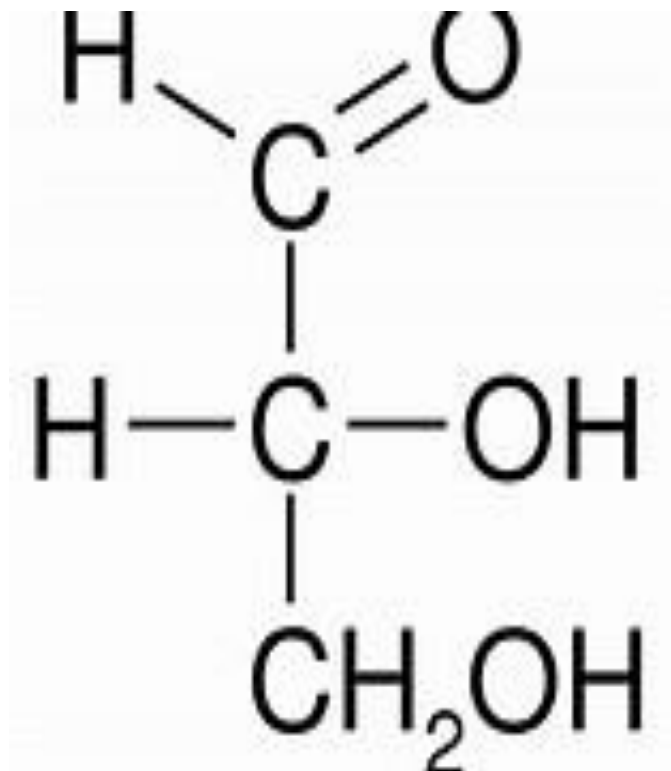


### DEFINITION

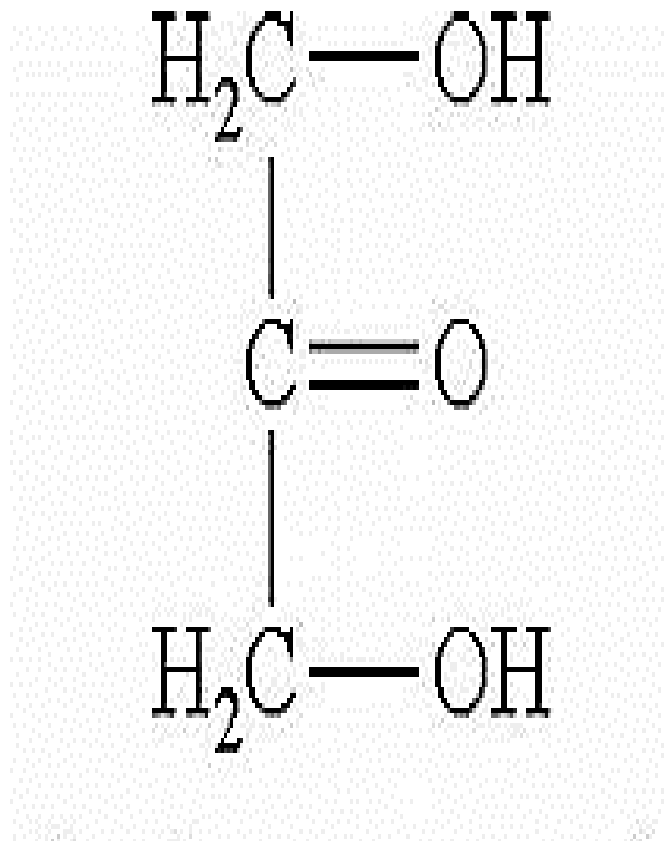
Carbohydrates are polyhydroxy aldehydes or ketones or compounds which yield these on hydrolysis.

Have the empirical formula (  $\text{CH}_2\text{O}$  )<sub>n</sub>

like glyceraldehyde , dihydroxyacetone



glyceraldehyde



dihydroxyacetone

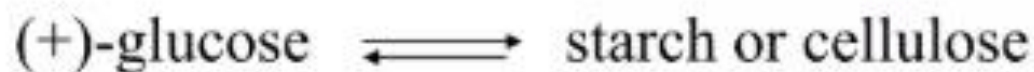
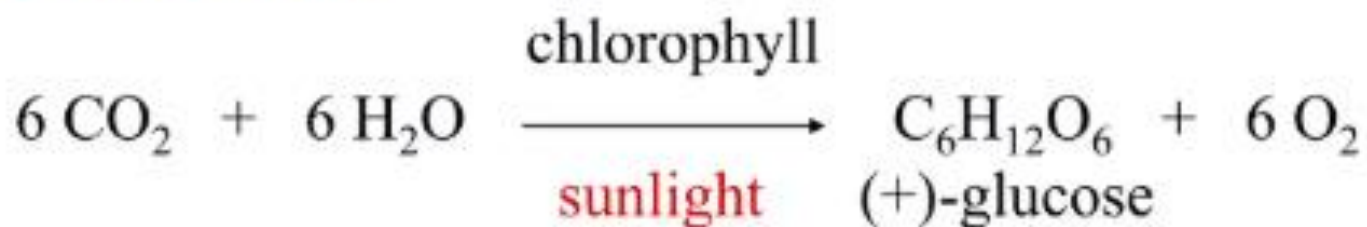
# Carbohydrates - Functions

- 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)

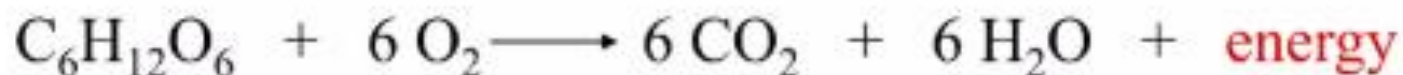
Glucose (a monosaccharide)

Plants:

photosynthesis



respiration



# Classification of Carbohydrates

**Carbohydrates** – polyhydroxyaldehydes or polyhydroxy-ketones of formula  $(\text{CH}_2\text{O})_n$ , 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.



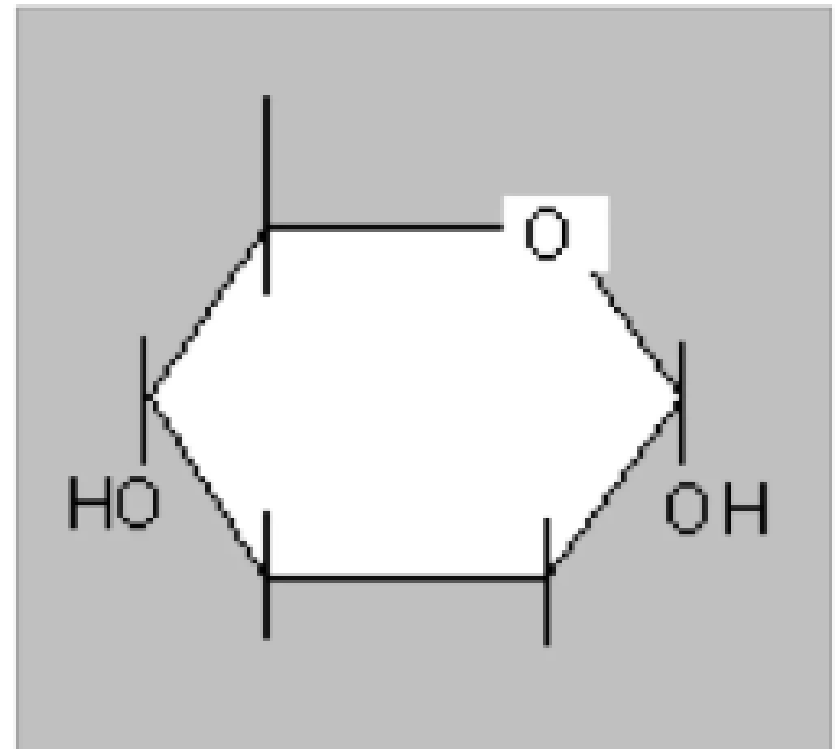
# Monosaccharides

- 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 ose (glucose, galactose, ribose, lactose, etc...)



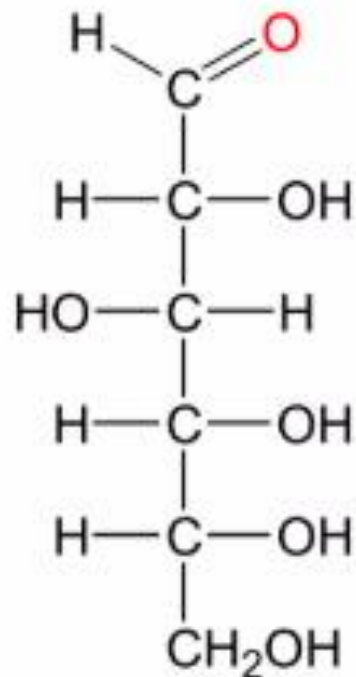
# Glucose

- 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



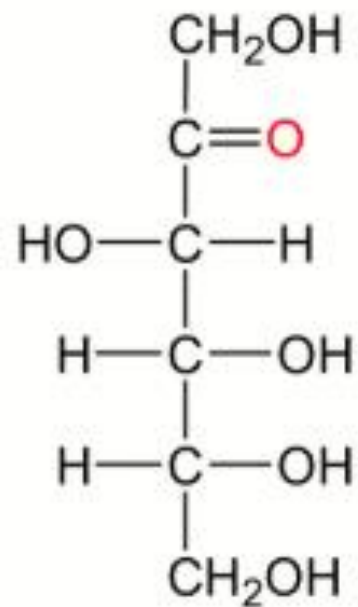
# Monosaccharides

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



**D-glucose**

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



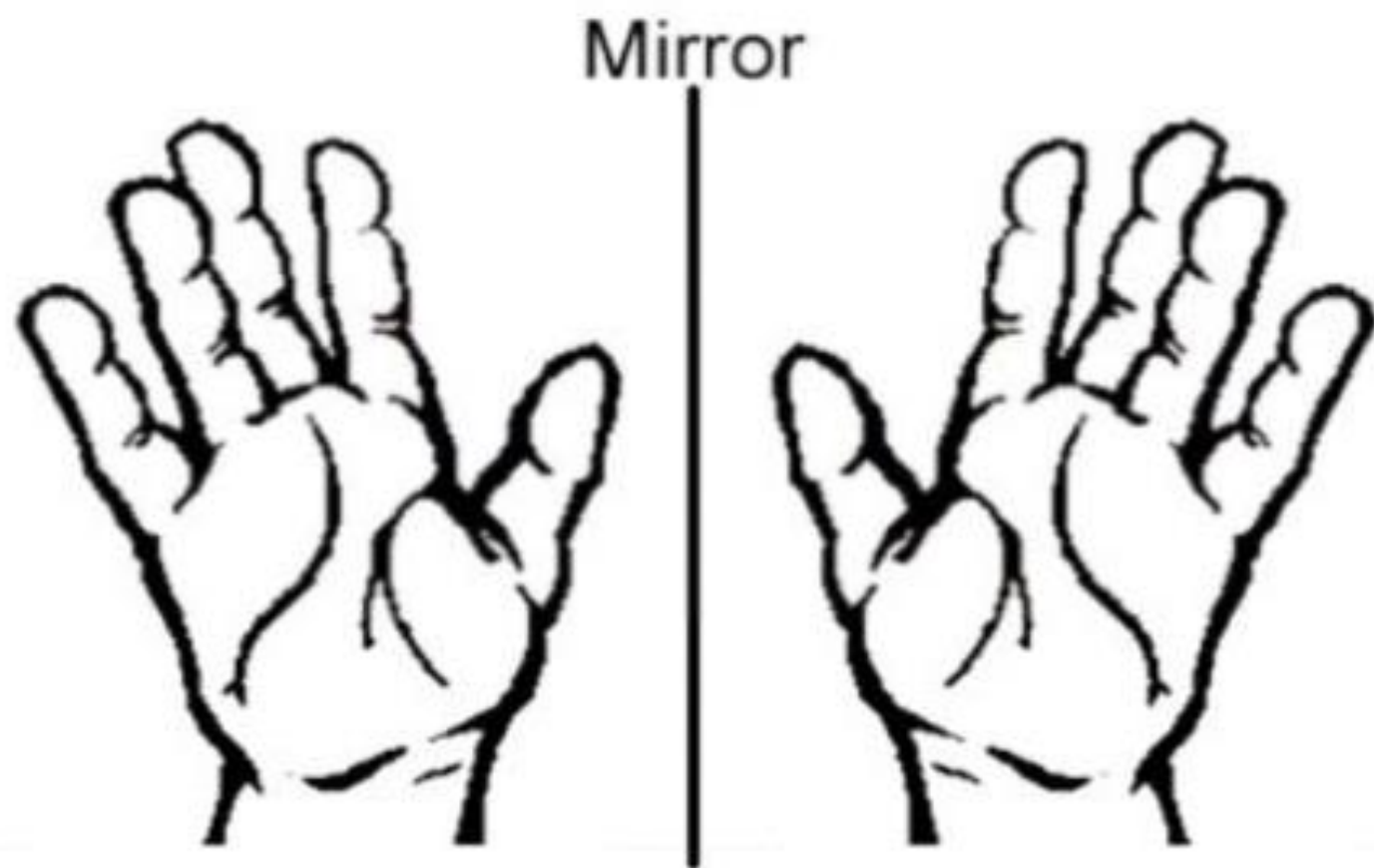
**D-fructose**

## 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 ( $2^n$ ) 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.**

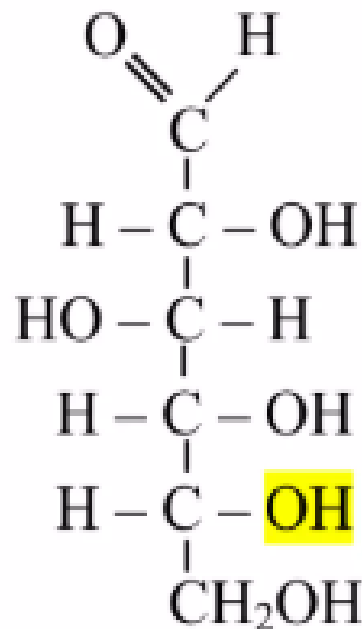


The mirror image of a chiral substance cannot be superimposed on the original image. Hands are chiral, as are sugars and amino acids.

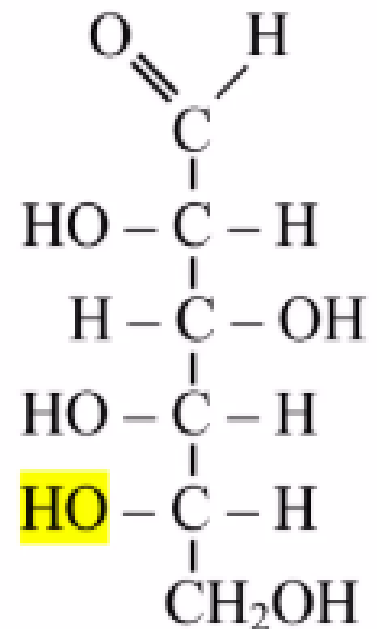
# Sugar Nomenclature

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

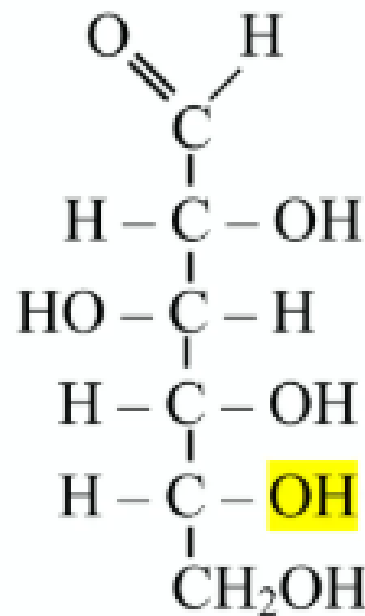


L-glucose

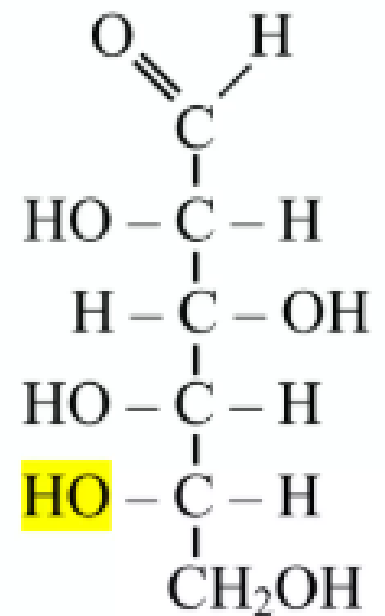
D & L sugars are mirror images of one another.

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 **2<sup>n</sup>**, where **n** is the number of asymmetric centers.

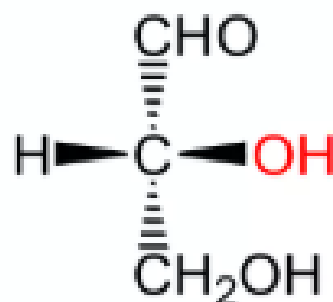
The 6-C aldoses have 4 asymmetric centers. Thus there are **16 stereoisomers** (8 D-sugars and 8 L-sugars).



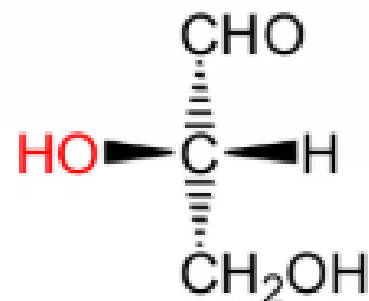
# D vs L Designation

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

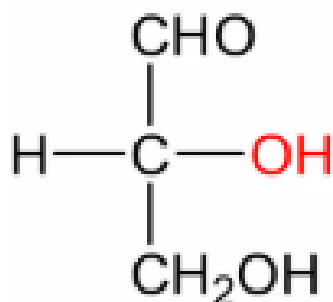
The lower representations are **Fischer Projections**.



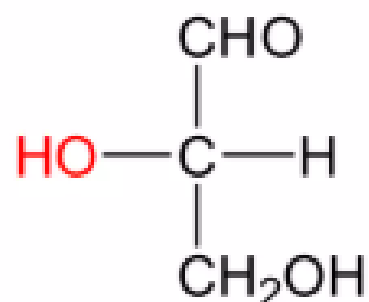
D-glyceraldehyde



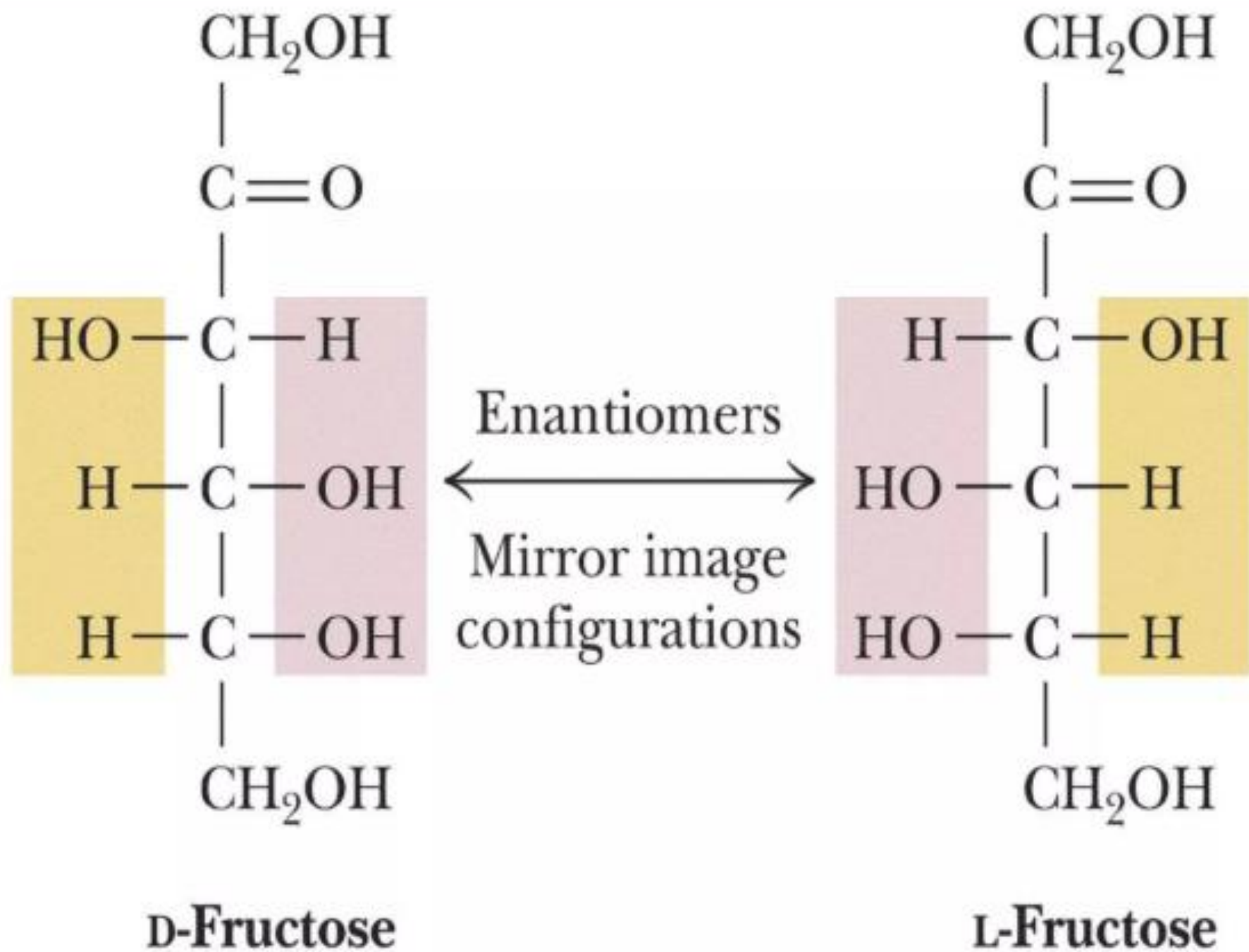
L-glyceraldehyde



D-glyceraldehyde



L-glyceraldehyde

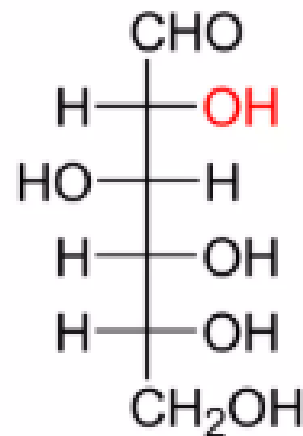


## **Enantiomers**

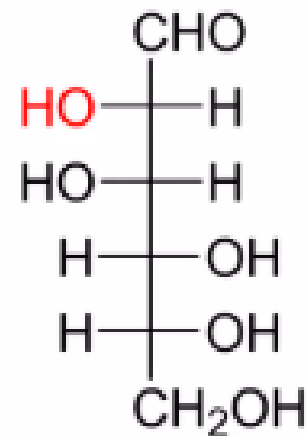
A special type of isomerism is found in the pairs of structures that are mirror images of each other. These mirror images are called **enantiomers**, and the two members of the pair are designated as **a D- and an L-sugar**

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 one chiral center.



D-glucose

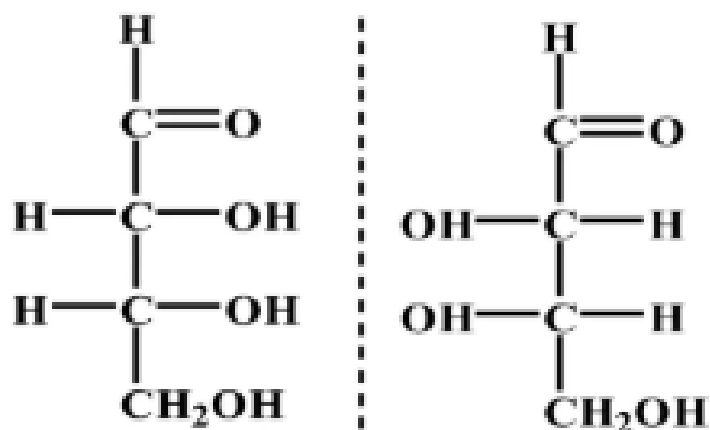


D-mannose

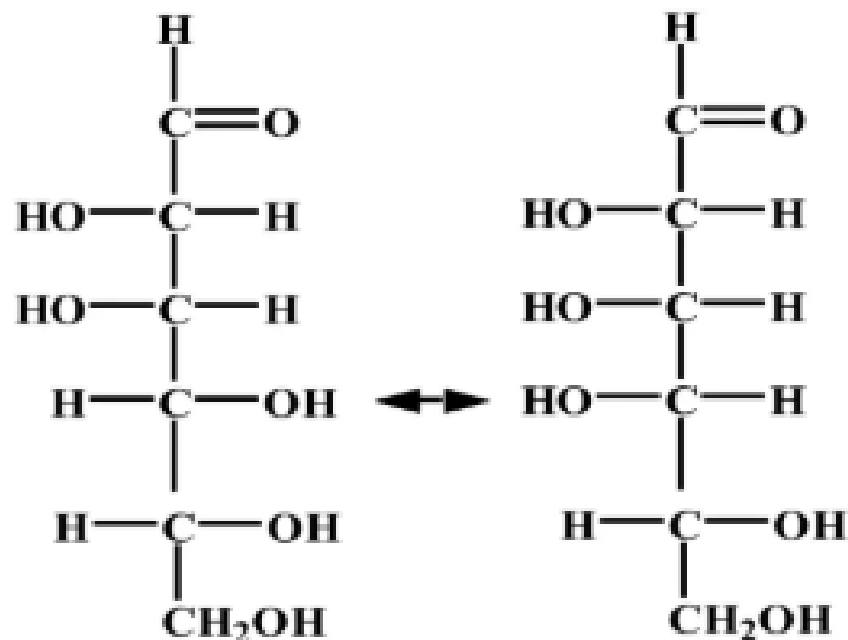
epimers

**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 carbon  
(carbon 4)

# **Modified Fischer Projection Formula**

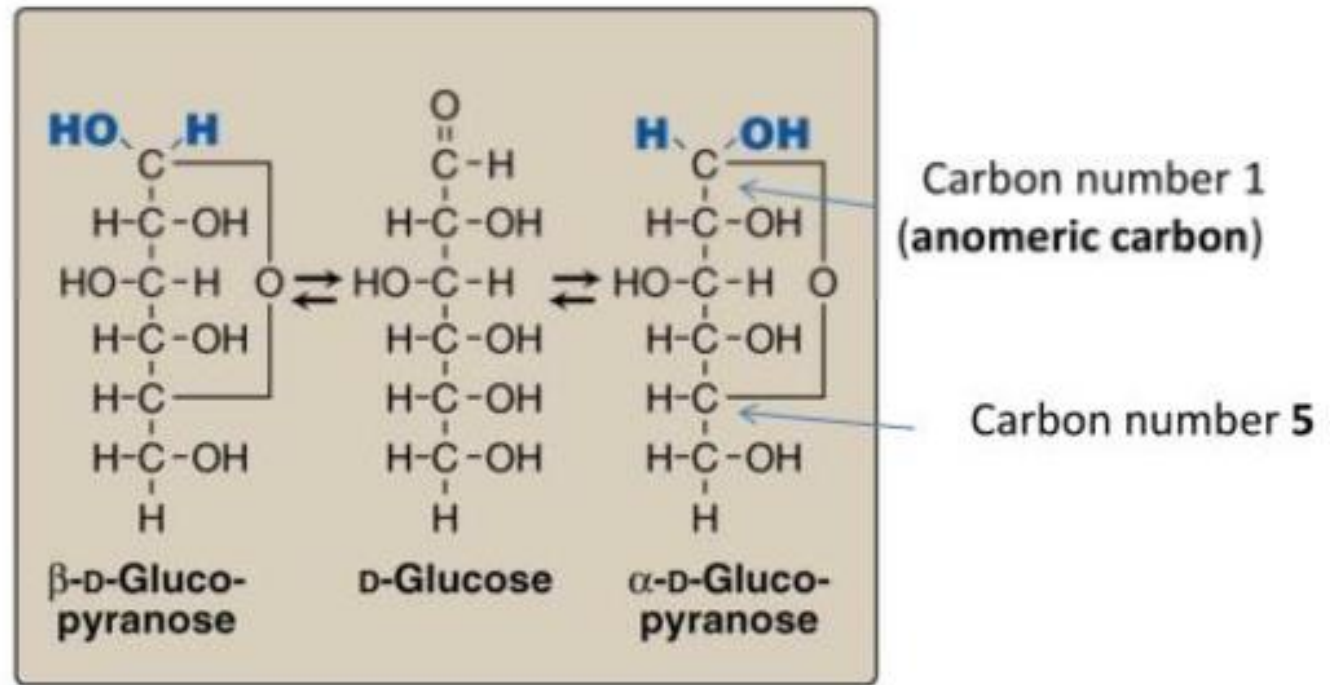


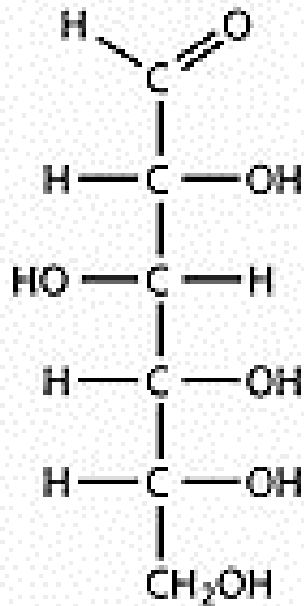
Figure 7.6

The interconversion of the  $\alpha$  and  $\beta$  anomeric forms of glucose (mutarotation).

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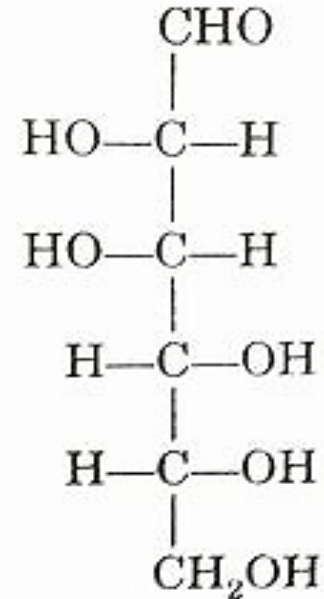
## Example:

D-Glucose give two epimers are show projection formulas.



**D-Glucose**

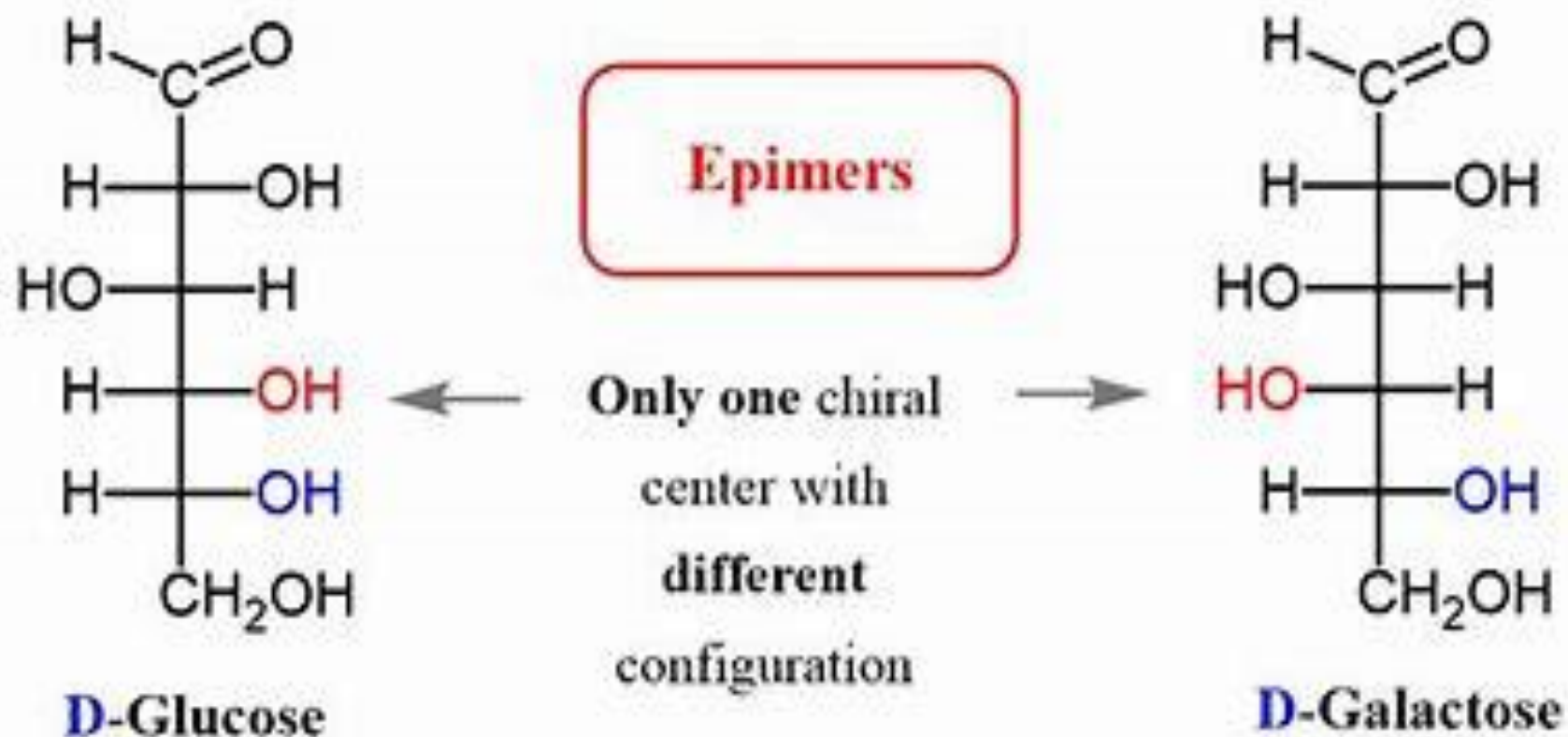
Epimers



**D-Mannose**



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

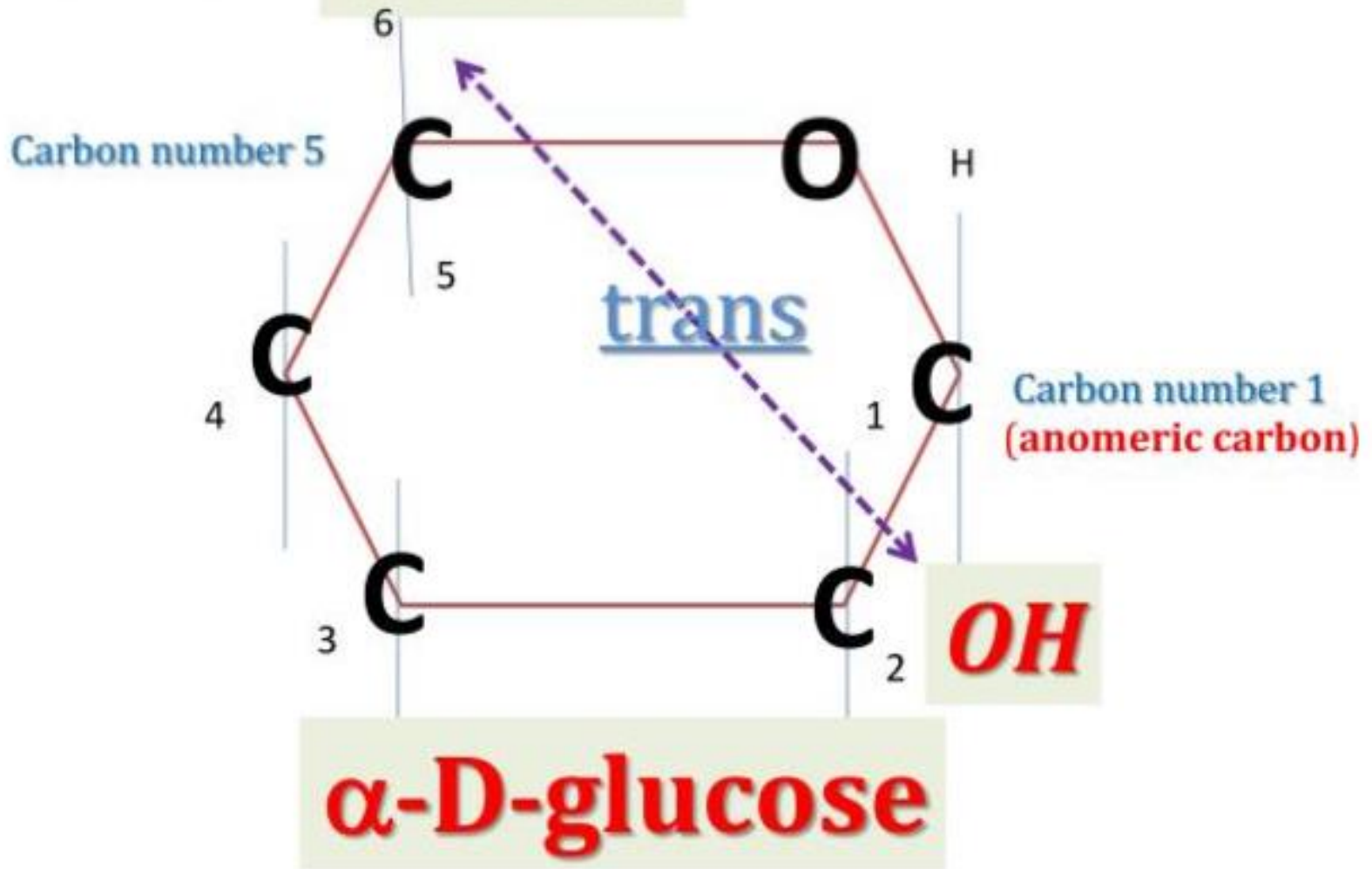


## ***Haworth Formula:***

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

Carbon number 6 ← **CH<sub>2</sub>OH**



# Hawroth Projection Formula

Carbon number 6 ←

**CH<sub>2</sub>OH**

cis

Carbon number 5

**C**

**O**

**OH**

4

**C**

5

1

**C**

Carbon number 1  
(anomeric carbon)

3

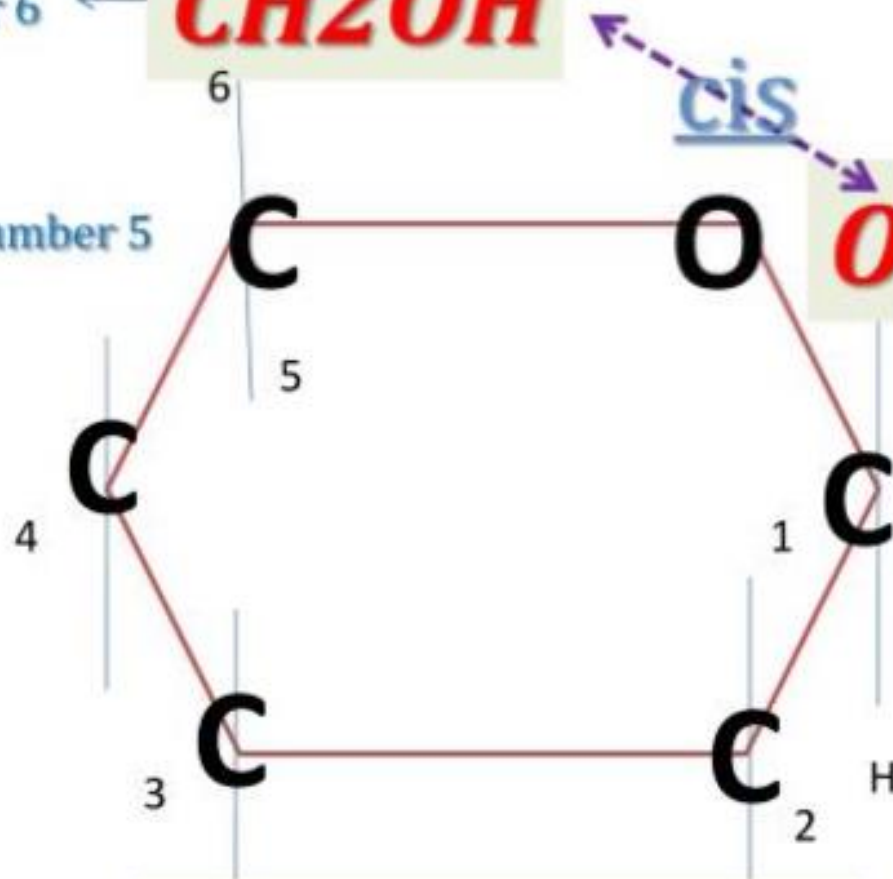
**C**

2

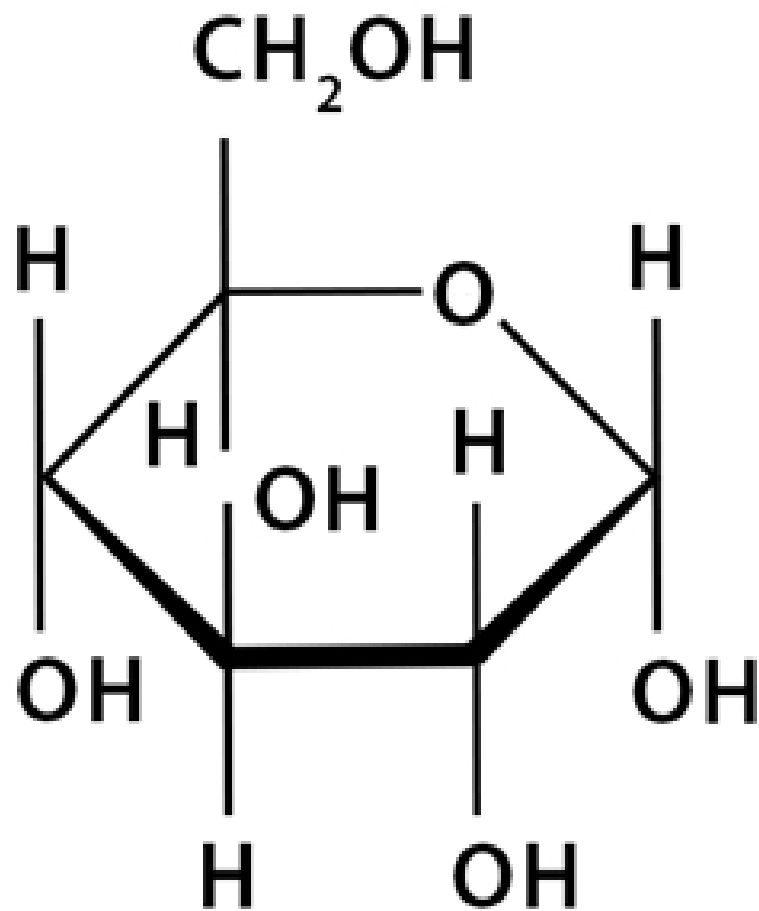
**C**

H

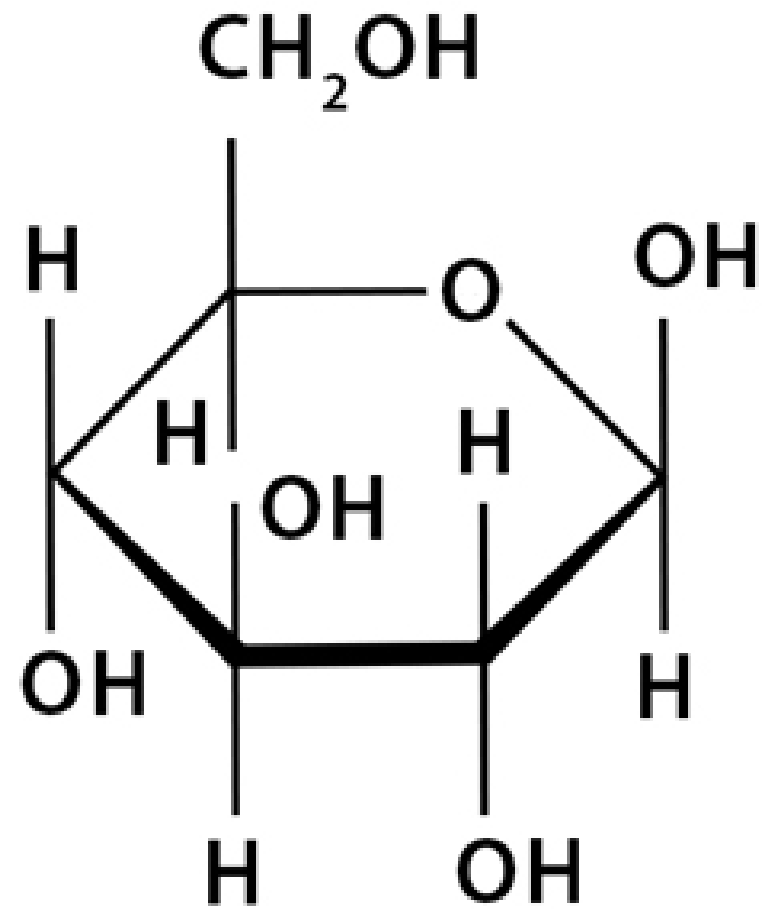
**β-D-glucose**



# Haworth Projection



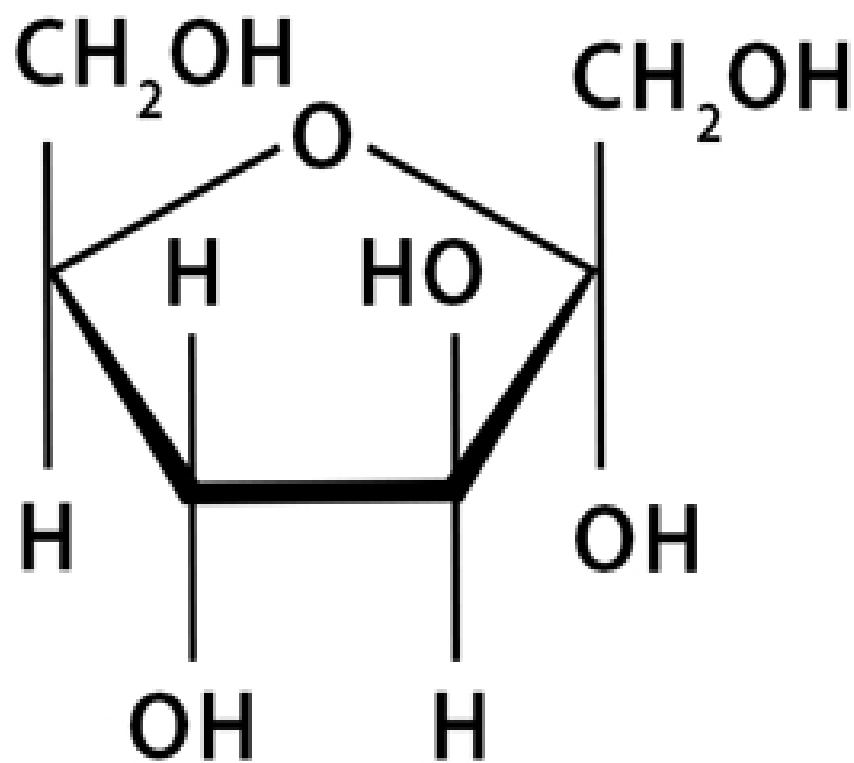
$\alpha$ -D-Glucopyranose



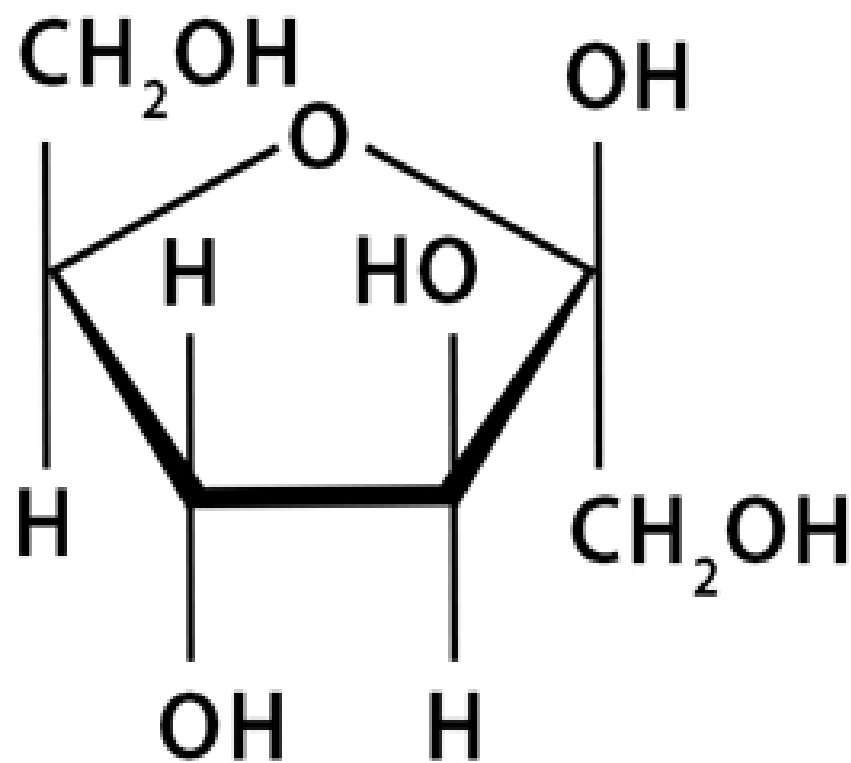
$\beta$ -D-Glucopyranose

# Haworth Projection

## Fructose



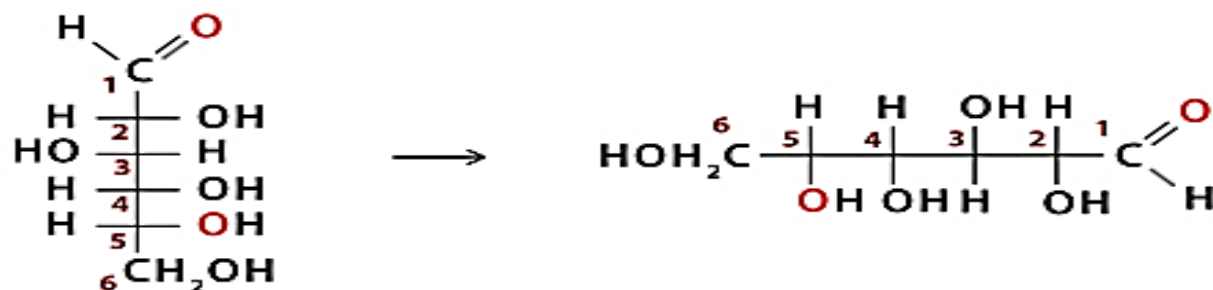
$\alpha$ -D-Fructofuranose



$\beta$ -D-Fructofuranose

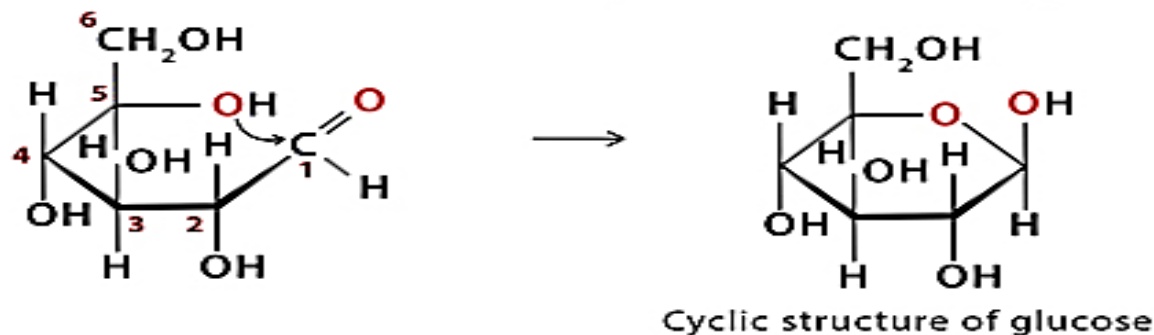
# Conversion of Fischer Projection to Haworth Projection

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



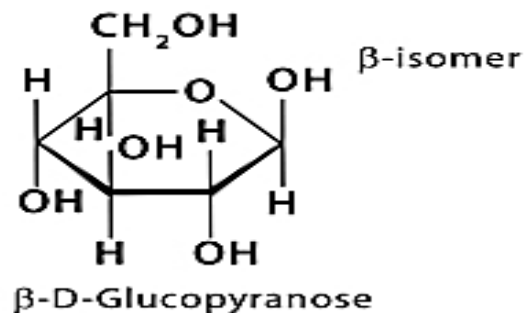
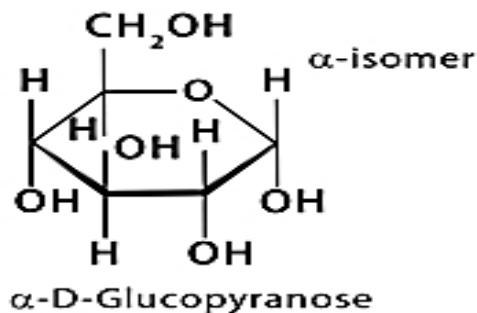
Fischer projection of D-glucose

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



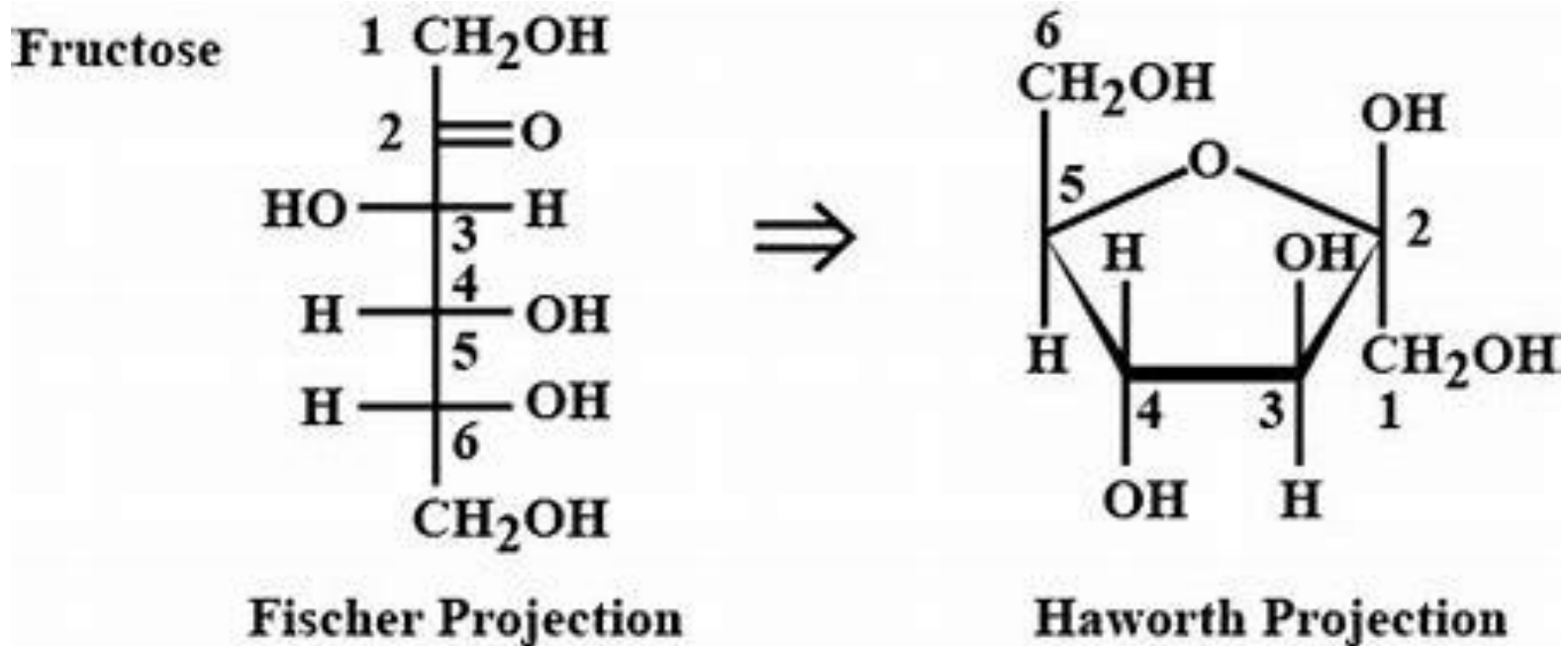
Cyclic structure of glucose

**Step 3:** Draw the bond between the OH group and carbon 1 and indicate the  $\alpha$ - and  $\beta$ -isomer according to the position of OH





# Mutarotations Fructose from Fischer Projection to Haworth Projection.



*Thank  
you*

