Biochemistry of Carbohydrates I

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الساعات المكتبية

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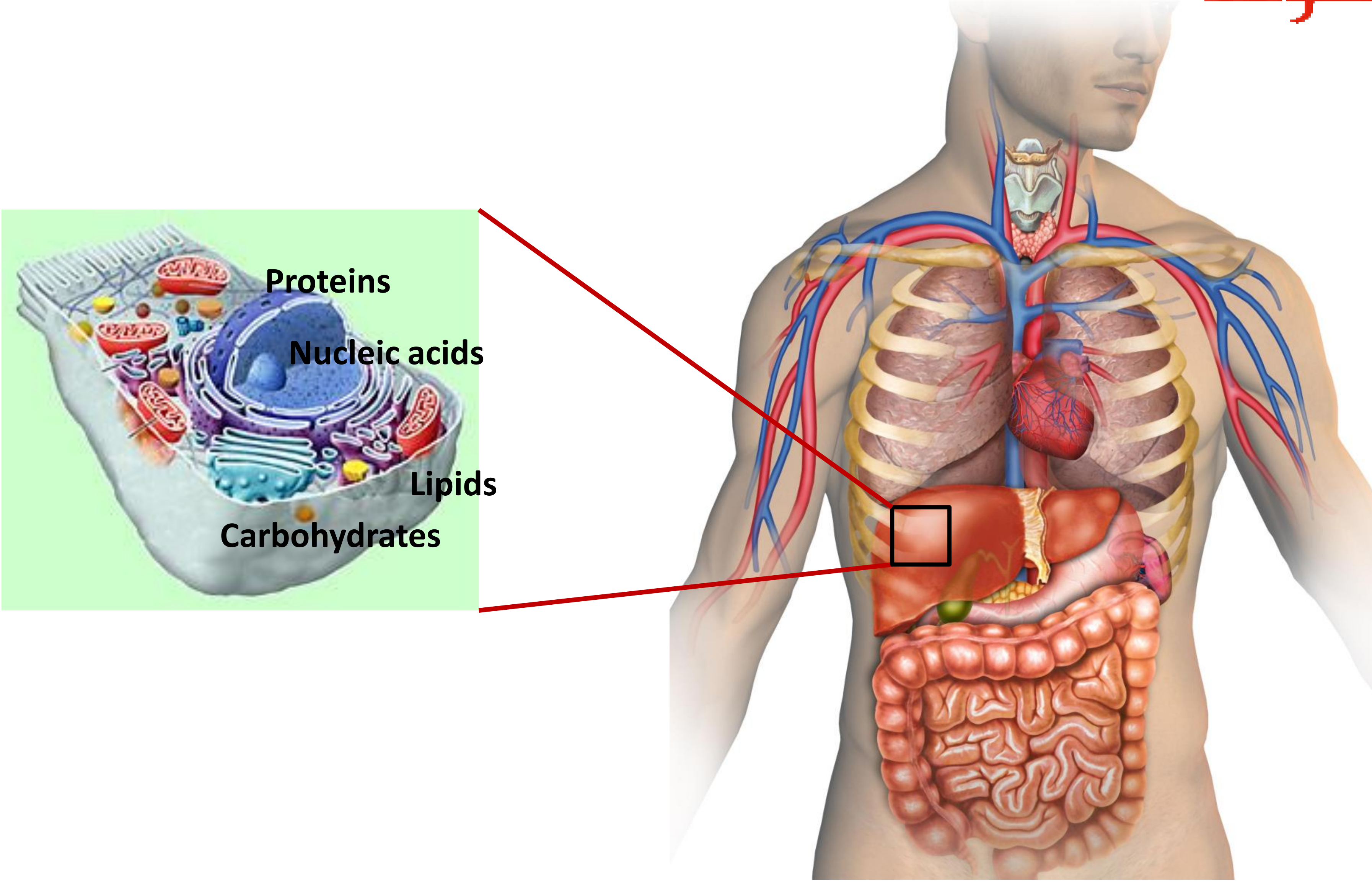
ثلاثاء 12-10

Major Types of Macromolecules



Carbohydrates

- Carbohydrates are "Sugars" or "Saccharides" consist of the empirical formula $(CH_2O)n$ where $n \geq 3$.
- Empirical formula, Molecular formula, Structural formula

Carbohydrates

C

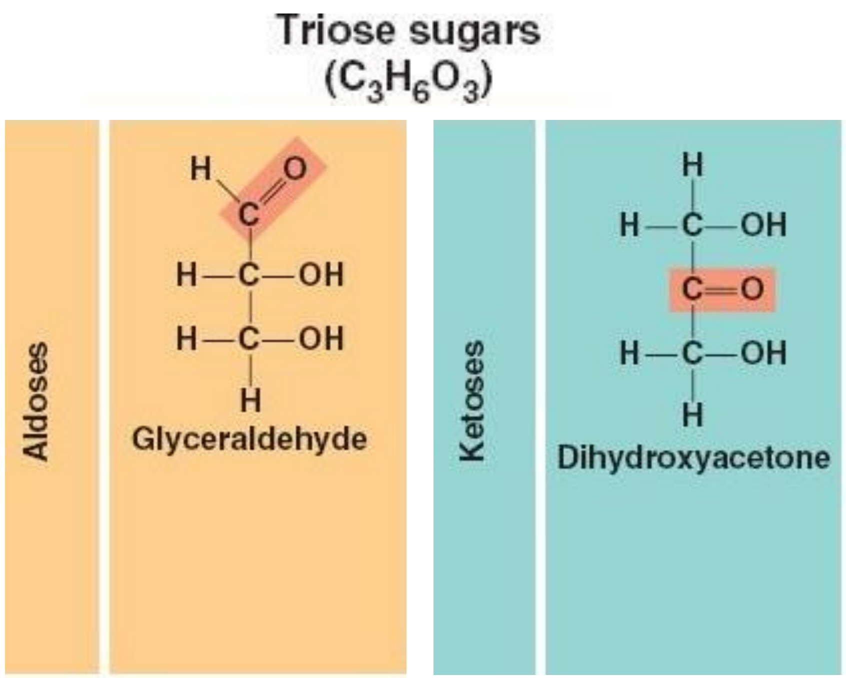
H2O

Carbohydrates

- Empirical formula: glucose, ribose and glyceraldehyde have same empirical formula $(CH_2O)n$

- Molecular formula: glucose $(C_6H_{12}O_6)$ and ribose $(C_5H_{10}O_5)$

- Structural formula:

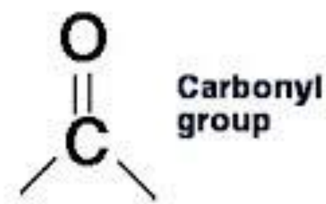


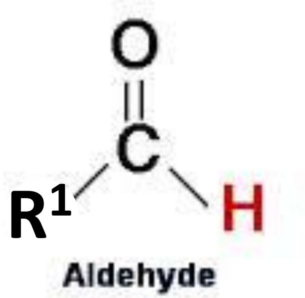
Classification of Carbohydrates

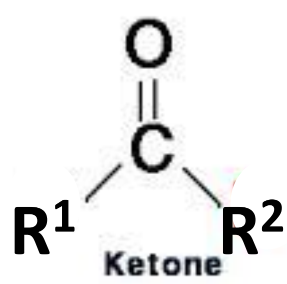
- **Monosaccharides:** The basic units of CHO which cannot be hydrolyzed into smaller sugars like glucose, galactose and fructose
- **Disaccharides:** contain two monosaccharides covalently linked by glycosidic bond like sucrose which consists of glucose and fructose
- **Polysaccharides:** are polymeric molecules composed of long chains of monosaccharides linked together via glycosidic bonds like starch, cellulose and glycogen

Monosaccharides

- They are classified according to the number of carbon atoms: trioses, tetroses, pentoses, **hexoses** …..etc
- Also classified according to the chemical nature of the carbonyl group C=O either to Aldoses (the carbonyl group is an aldehyde) or Ketoses (the carbonyl group is a ketone)







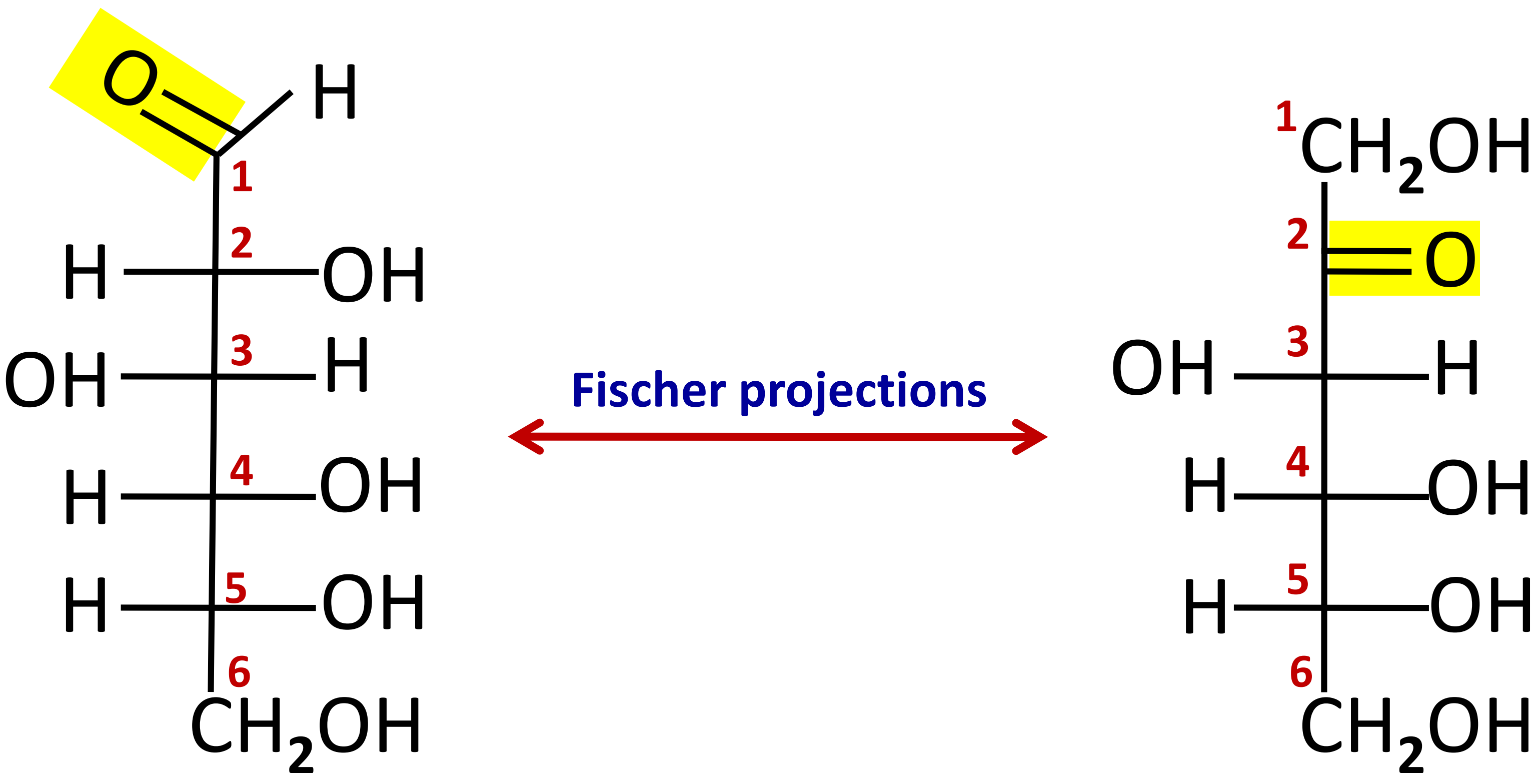
Aldehyde: R^1 **= alkyl or aryl**

Ketone: R^1 **and** R^2 **= alkyl or aryl**

Monosaccharides

Hexose $C_6H_{12}O_6$

Hexoaldose\Aldohexose



Hexoketose\Ketohexose

D-glucose

"grape or blood sugar"

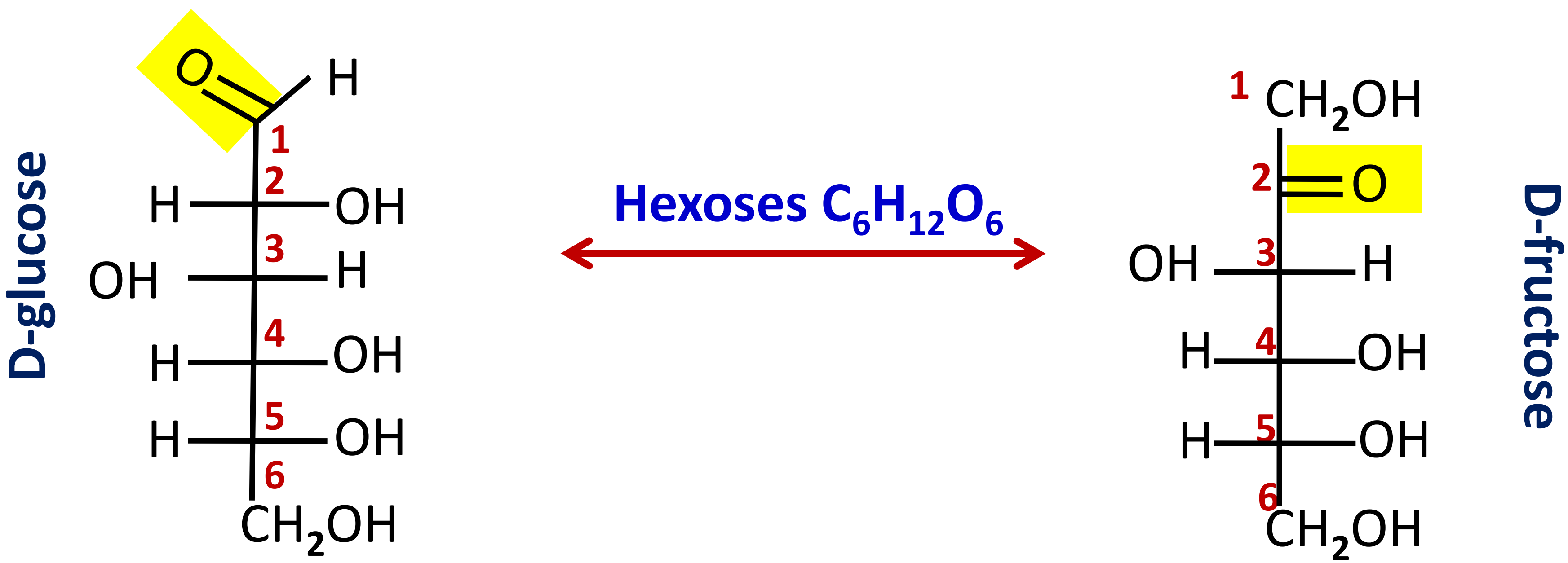
D-fructose

"fruit sugar"

Isomerization

- Isomers: are molecules with same molecular formula but different chemical structures

1. Constitutional (structural) isomers: atoms and functional groups bind together in different ways (e.g. glucose and fructose)



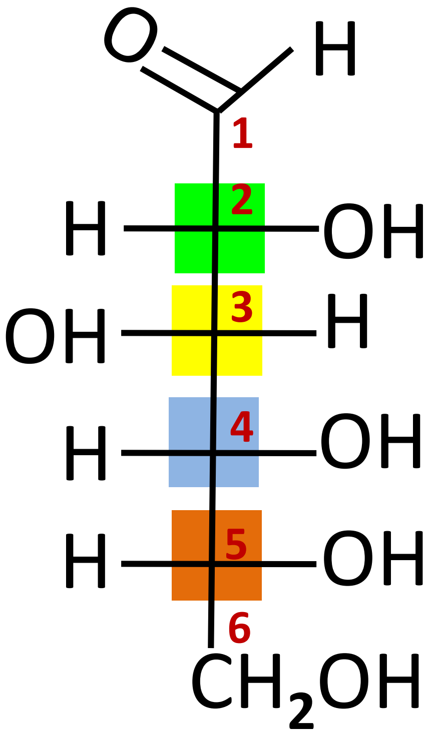
Isomerization

- Isomers: are molecules with same molecular formula but different chemical structures

1. Constitutional (structural) isomers: atoms and functional groups bind together in different ways (e.g. glucose and fructose)
2. Stereroisomers (spatial isomers): differ in the configuration of atoms in space rather than the order of atomic connectivity

   - Chiral carbon: asymmetric carbon atom attached to 4 different groups of atoms
   - The number of stereoisomers for any given molecules = $\mathbf{2^n}$ where n represents the number of chiral centers

Isomerization

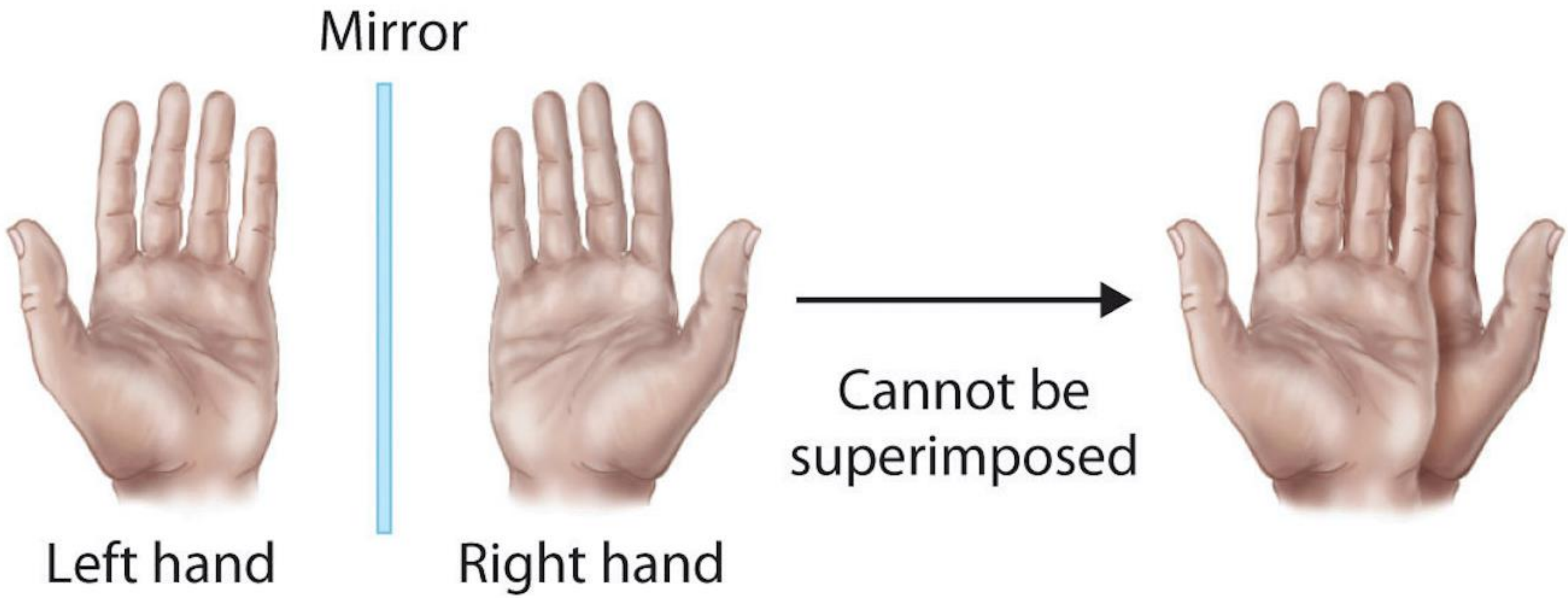


D-glucose

Number of stereoisomers = 2^4

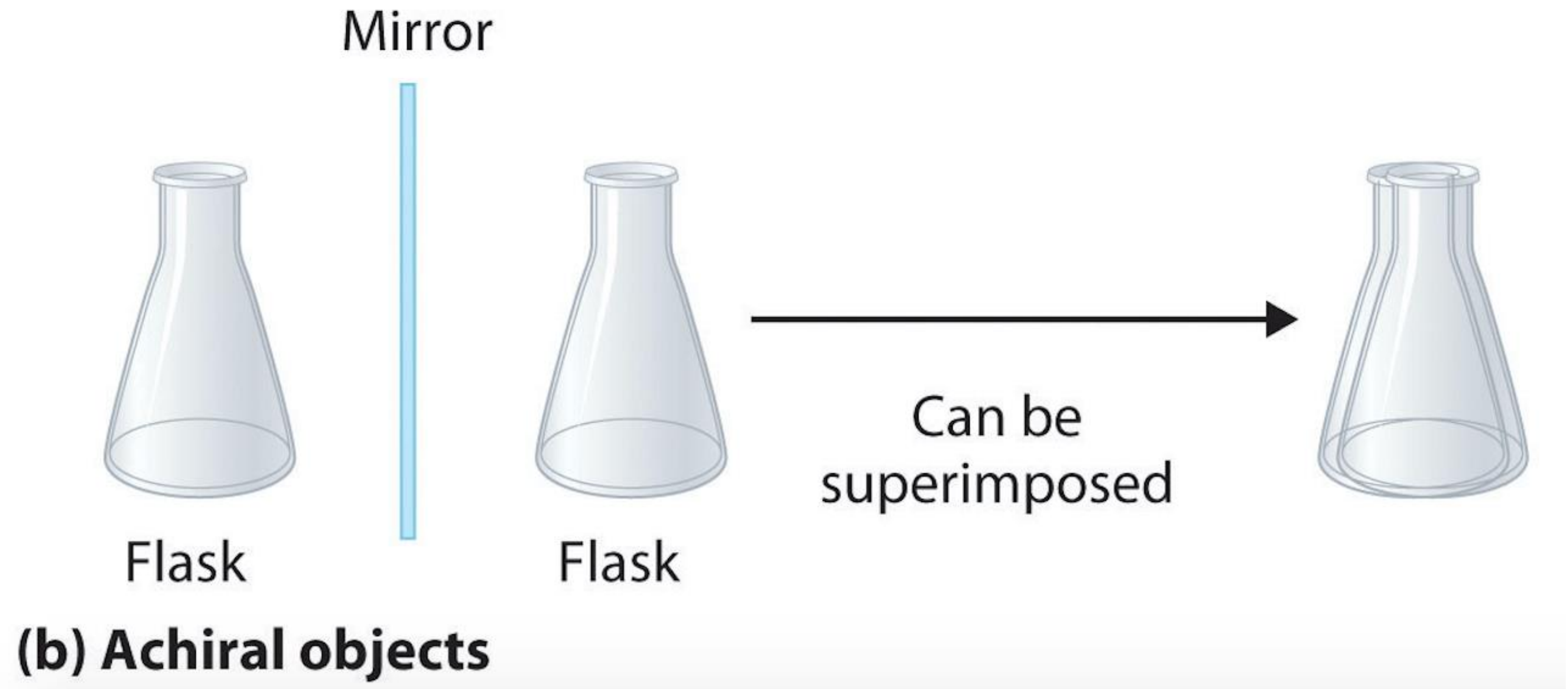
= 16

Chirality & Chiral Object



(a) Chiral objects

Chirality & Chiral Object

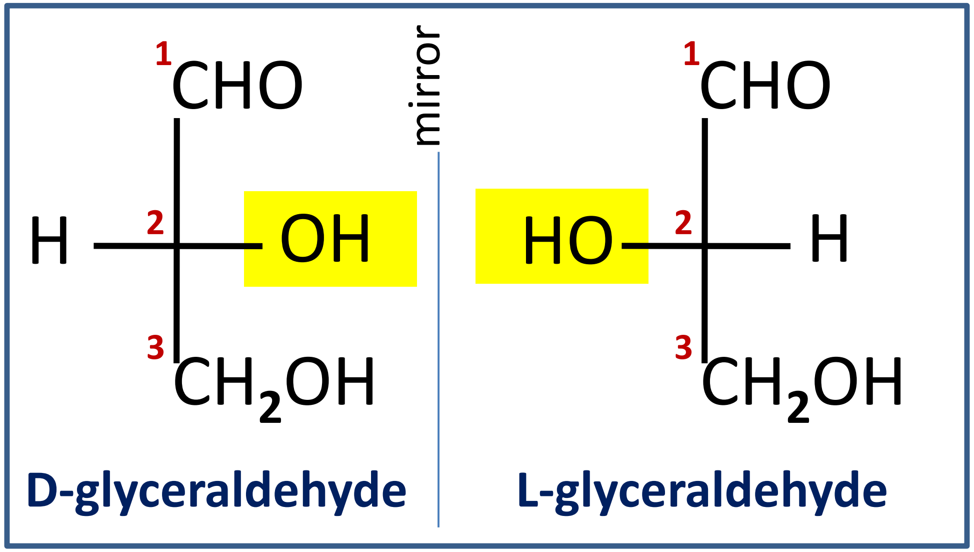


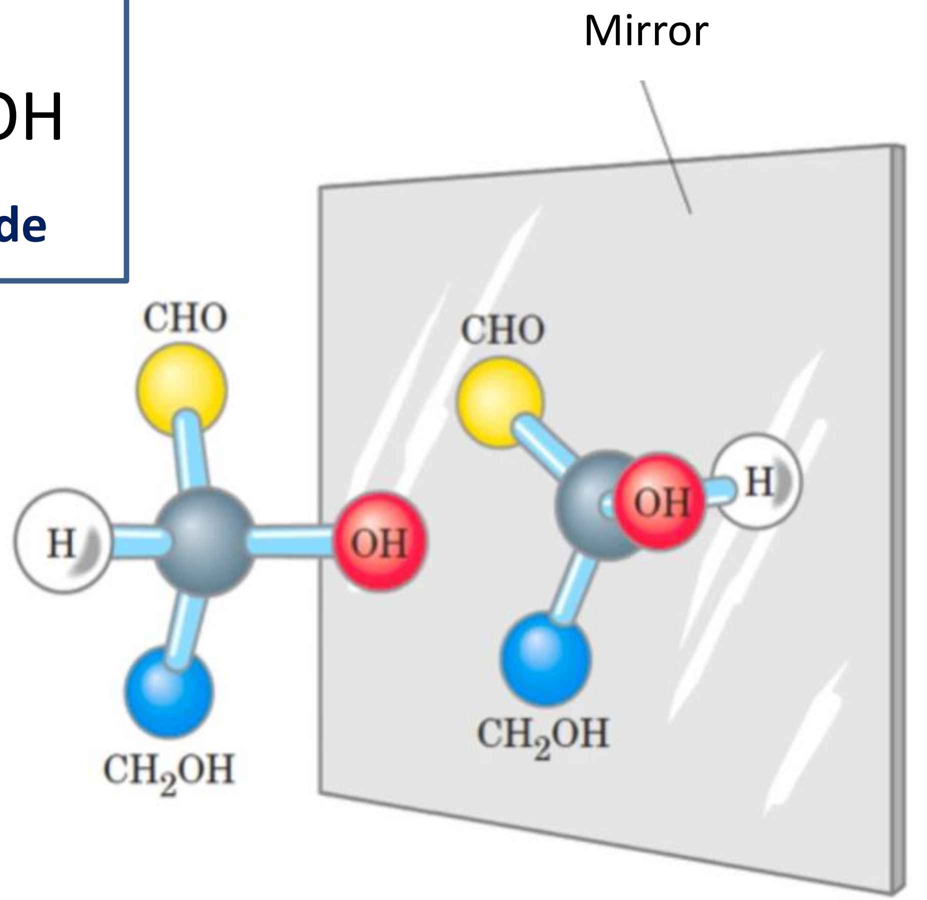
- Chiral molecules should contain at least one chiral center (**usually chiral carbon atom**)

Stereoisomers

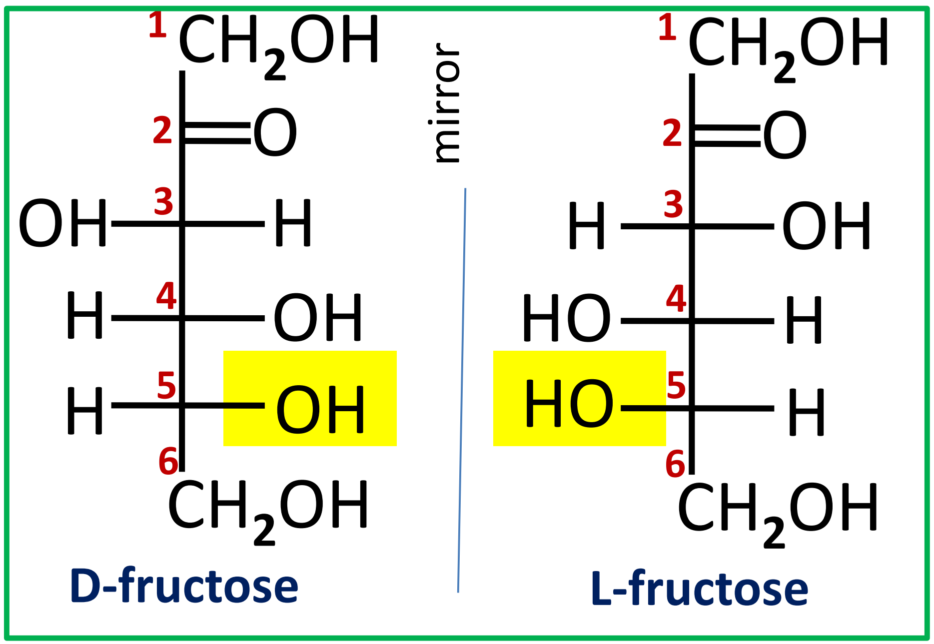
- Enantiomers: are two stereoisomers that are mirror images to each other but not superimposable

D/L Monosaccharides

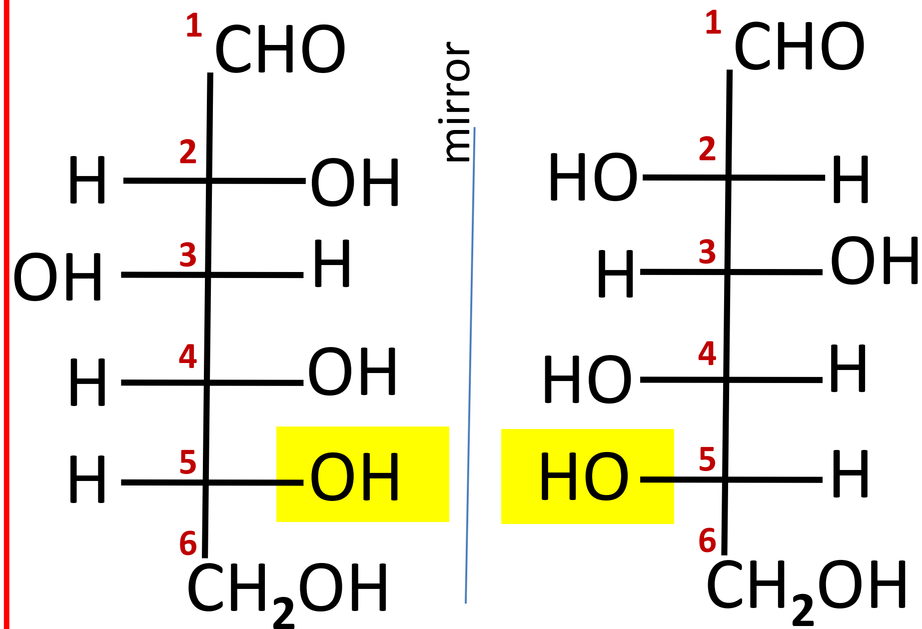




D/L Monosaccharides



D/L Monosaccharides



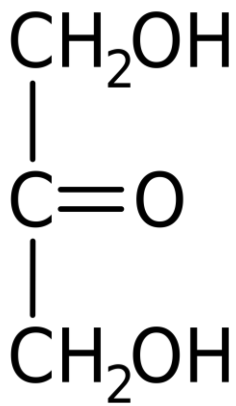
D-glucose L-glucose

Isomerization

- Enantiomers: are two stereoisomers that are mirror images to each other but not superimposable
- **D-** (dexter)/**L-** (laevus) Nomenclature system: commonly used to assign the configurations in sugars and amino acids
  - As a rule of thumb: if the farthest chiral atom from the highest oxidized carbon (i.e. carbonyl group) has –OH group on the right-hand side, the configuration is assigned as **D** but If it is on the left-hand side, the sugar is designated as **L**
- Most naturally occurring sugars are D-isomers (biologically active form)

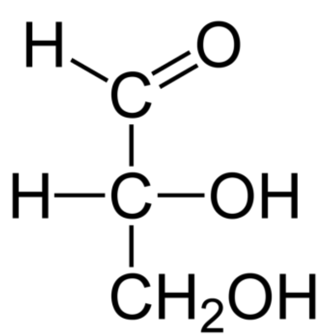
D/L Monosaccharides

Ketotriose or Trioketose



Dihydroxyacetone

Aldotriose or Trioaldose



Glyceraldehyde

1. **How many stereoisomers do we have for dihydroxyacetone?**

Answer: 1

2. Why?

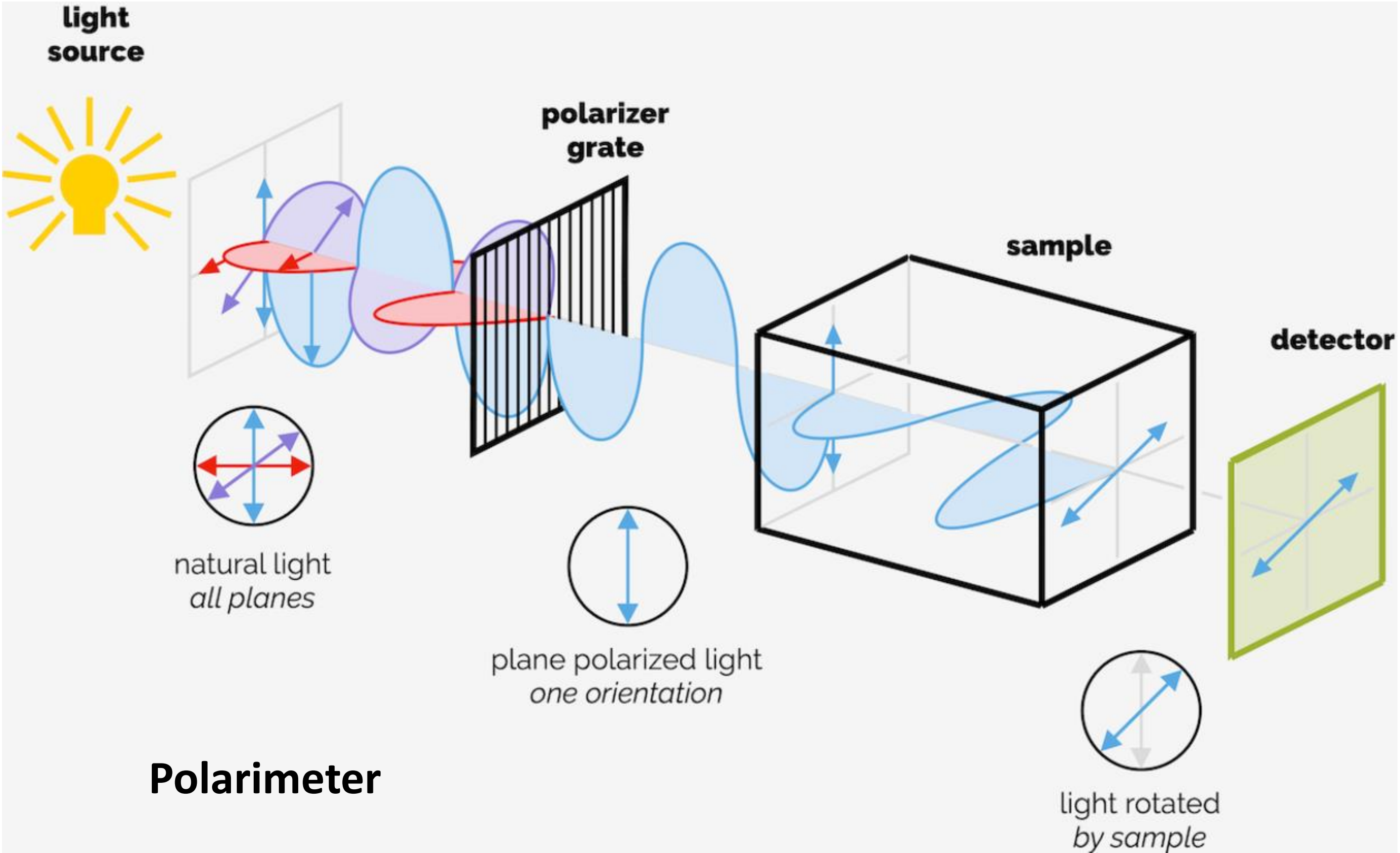
Answer: No chiral carbons (2^0 = 1) Achiral molecule

3. What is the relation between dihydroxyacetone and glyceraldehyde?

Answer: Structrual isomers

Monosaccharides

- Enantiomers are optically active and can rotate the polarized light plane either clockwise or counterclockwise

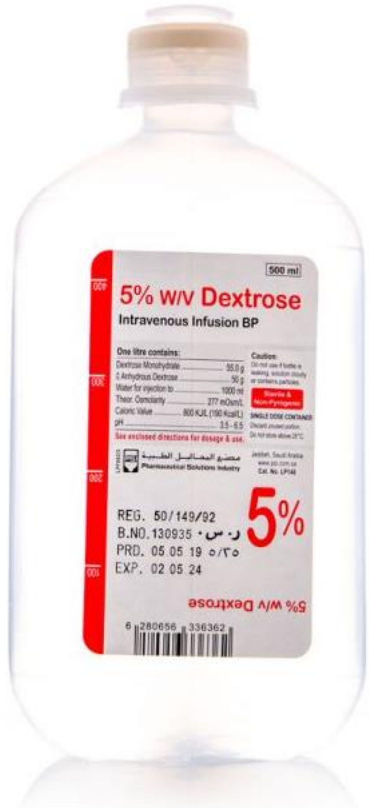


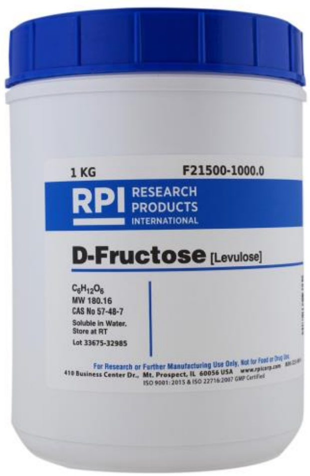
Polarimeter

Monosaccharides

- Enantiomers are optically active and can rotate the polarized light plane either clockwise or counterclockwise
  - (+)/(-) nomenclature system: if one enantiomer rotates the light clockwise, it is labeled (+) or (*d*) (dextrorotatory). The second mirror image enantiomer is labeled (-) or (*l*) laevorotatory [(+)D-glucose, (*d*)D-glucose]
  - by chance, it was found that D-glyceraldehyde is in fact the dextrorotatory isomer.
  - D/L system should not be confused with +/- or *d*/l system. For example, D-fructose (laevulose) is levorotatory whereas D-glucose (dextrose) is dextrorotatory.

Monosaccharides

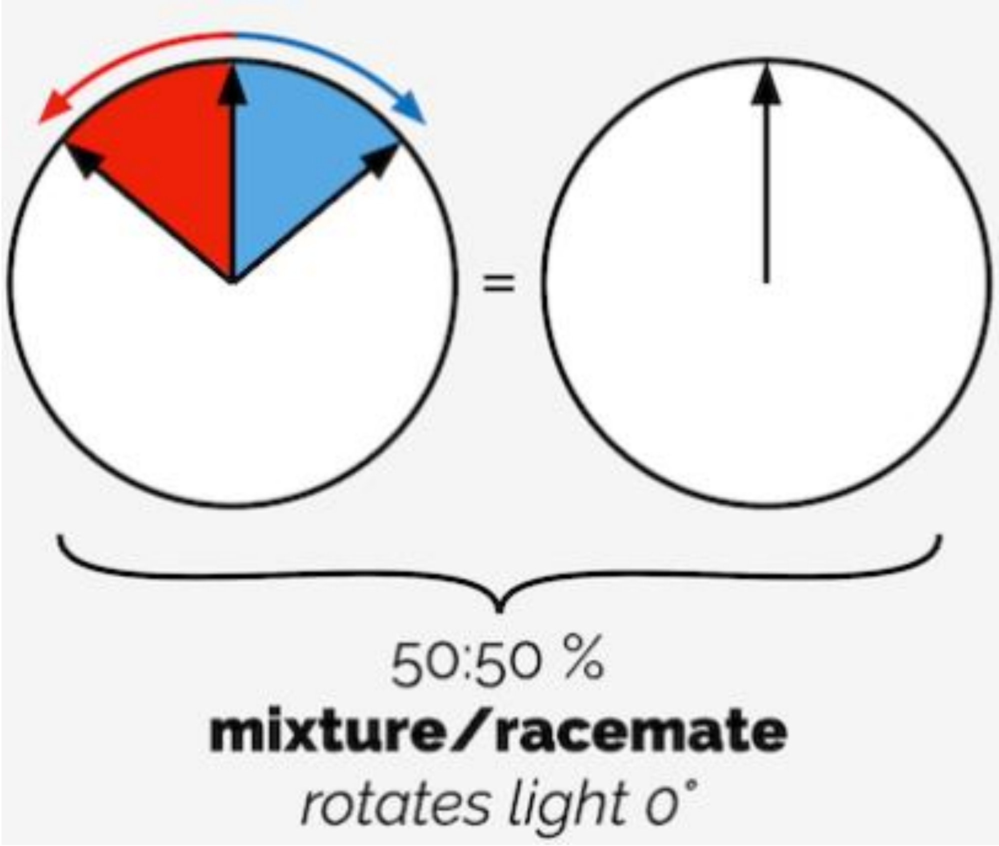




- **Dextrose** is the commercial/trade name of **D-glucose**
- **Laevulose** is the the commercial name of **D-fructose**

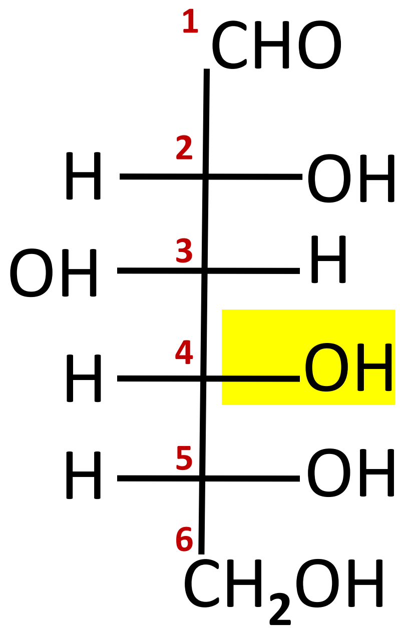
Monosaccharides

- **Racemic mixture** contains equal amounts of each enantiomer (net rotation is zero)

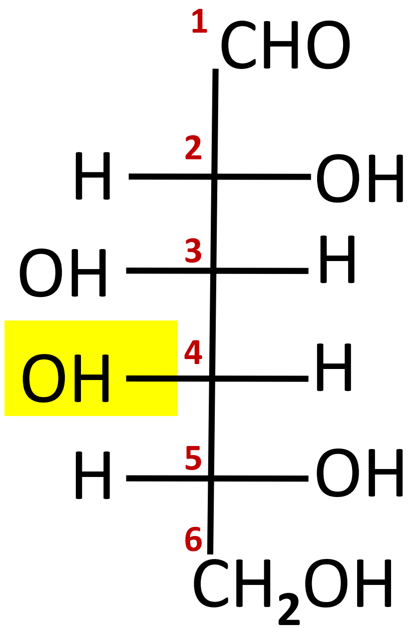


Monosaccharides

- Epimers: are stereoisomers that differ in the configurations of atoms at **only** one chiral center (i.e. chiral carbon in CHO). They are not mirror image isomers.

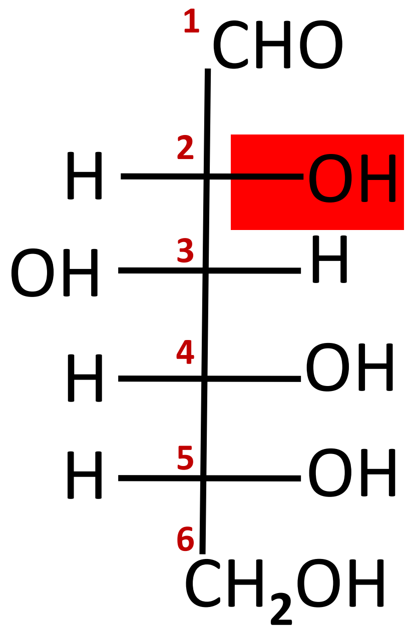


D-glucose

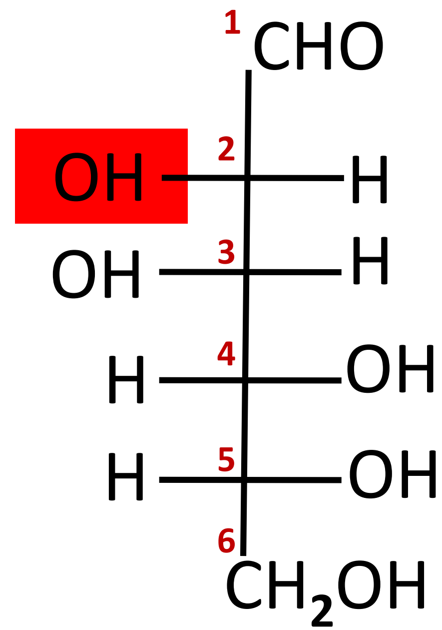


D-galactose

Monosaccharides



D-glucose



D-mannose

- Glucose and galactose are C4 epimers while glucose and mannose are C2 epimers