AL-Mustaqbal University
College of Sciences
Department of Biochemistry Sciences

Biochemistry

Dr. Ghada Ali
ghada.ali@uomus.edu.iq

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Introduction to Carbohydrates

Carbohydrates

- Carbohydrates are the most abundant organic molecules in nature.

- Organic compounds containing C, H and O.

- The empiric formula for many of the simpler carbohydrates is $(CH2O)n$, hence the name "**hydrate of carbon.**"

Carbohydrates functions

- Carbohydrates serve as **energy source**.
- Ribose and deoxyribose **sugars form** part of RNA and DNA.
- Polysaccharides are **structural elements in the cell** .
- Carbohydrates are linked to many **proteins and lipids**, forming different molecular classes are the proteoglycans, the glycoproteins and the glycolipids.

Carbohydrates Classification

- Carbohydrates Classified based on:

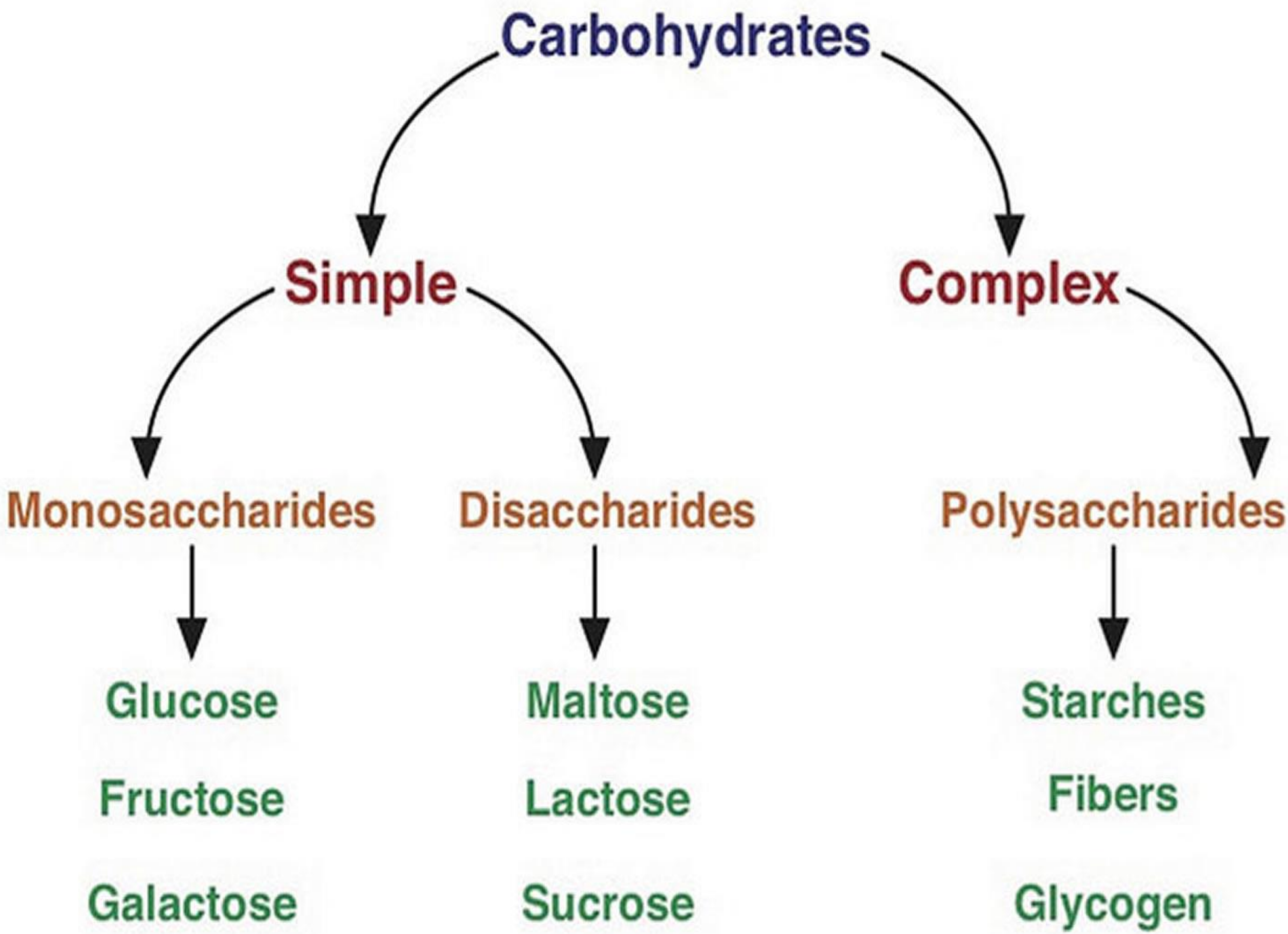
1. Number of sugar units
2. Size of base carbon chain
3. Location of C=O group
4. Stereochemistry

Types of Carbohydrates

- Classifications based on **number of sugar units in total chain.**

- Monosaccharide : Single sugar unit
- Disaccharides: Two sugar units
- Oligosaccharides: 3 to 10 sugar units
- Polysaccharides: More than 10 units

- Chaining relies on ‘bridging’ of oxygen atoms glycoside bonds


Carbohydrates
Simple
Complex
Monosaccharides
Disaccharides
Polysaccharides
Glucose
Fructose
Galactose
Maltose
Lactose
Sucrose
Starches
Fibers
Glycogen

Monosaccharide

- Monosaccharides are those carbohydrates which can not be hydrolyzed further into more simple carbohydrates.
- Thus, they are the Simplest form of Carbohydrates.

Monosaccharide are further classified on the basis of:

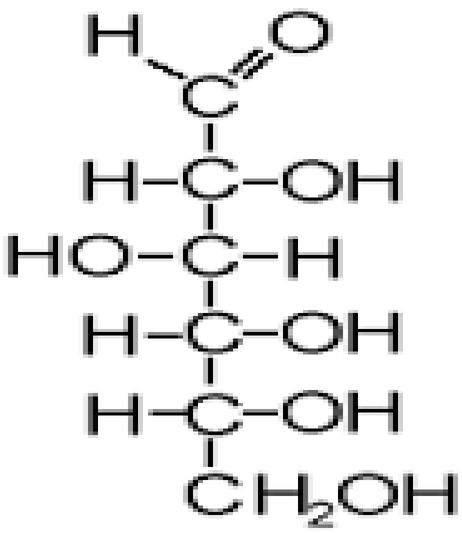
- **Aldehyde or Ketone :**
  - **Aldomonosaccharides (Aldoses).**
  - **Ketomonosaccharides (Ketoses).**
- **Carbon Chain Length.**
  - **Trioses.**
  - **Tetroses.**
  - **Pentoses.**
  - **Hexoses.**
  - **Heptoses.**

Monosaccharide Classification

- The first classification, is Based on location of functional group .
- The functional group is the carbonyl group C=O which may be either

Aldose

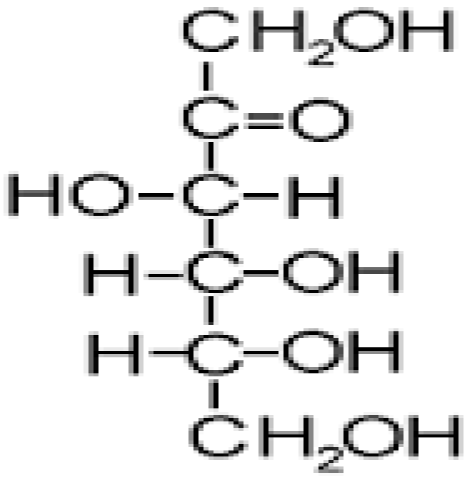
Aldehyde C=O



Glucose

Ketose

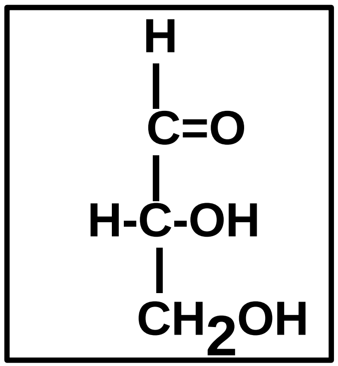
ketone C=O



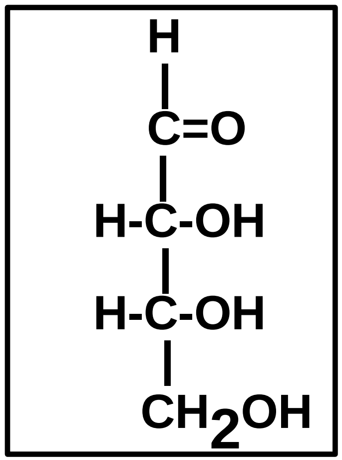
Fructose

Monosaccharide classifications

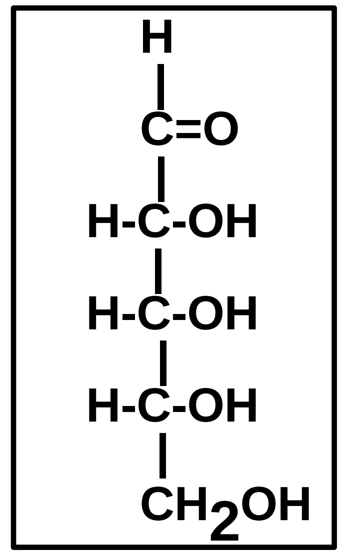
- Number of carbon atoms in the chain



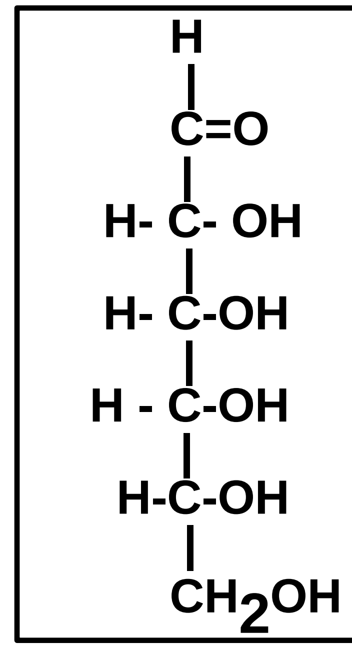
Triose



Tetrose



Pentose



Hexose

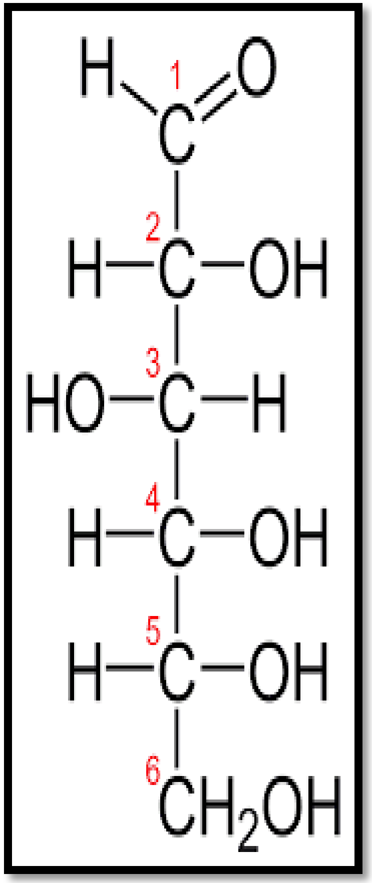
- Can be either aldose or ketose sugar.

Examples of Monosaccharide

No. of carbon atoms	Aldo	keto
3c trioses	Glyceraldehyde	Dihydroxyacetone
4c tetroses	Erythrose	Erythrulose
5c pentoses	Ribose, Xylose	Ribulose, Xylullose
s6c hexose	Glucose, Galactose, Mannose	Fructose
7c heptoses	_______	Psedheptulose

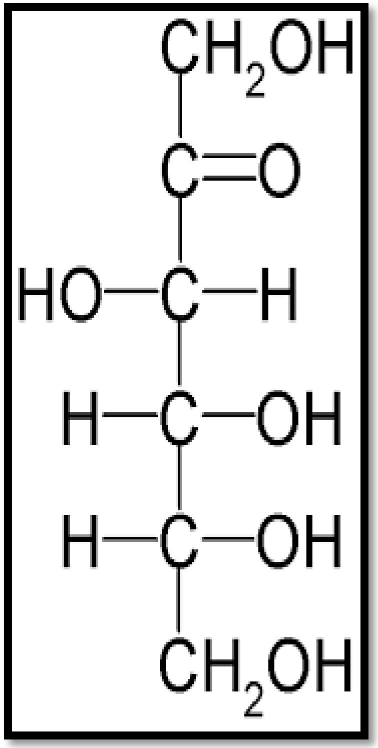
D-glucose

- Glucose is an aldohexose sugar.
- Common names include dextrose, grape sugar, blood sugar.
- Most important sugar in our diet.
- Most abundant organic compound found in nature.
- Level of fasting blood glucose (65-110 mg/ dl)



D-Fructose

- Another common sugar.
- It is a ketohexose.
- Sweetest of all sugars.



Isomers and Epimers

- **<u>Isomers:</u>**

  Compounds that have the same chemical formula but have different structures are called isomers. For example:

  - fructose, glucose, mannose, and galactose are all isomers of each other, having the same chemical formula, $C_6H_{12}O_6$.

Isomers and Epimers

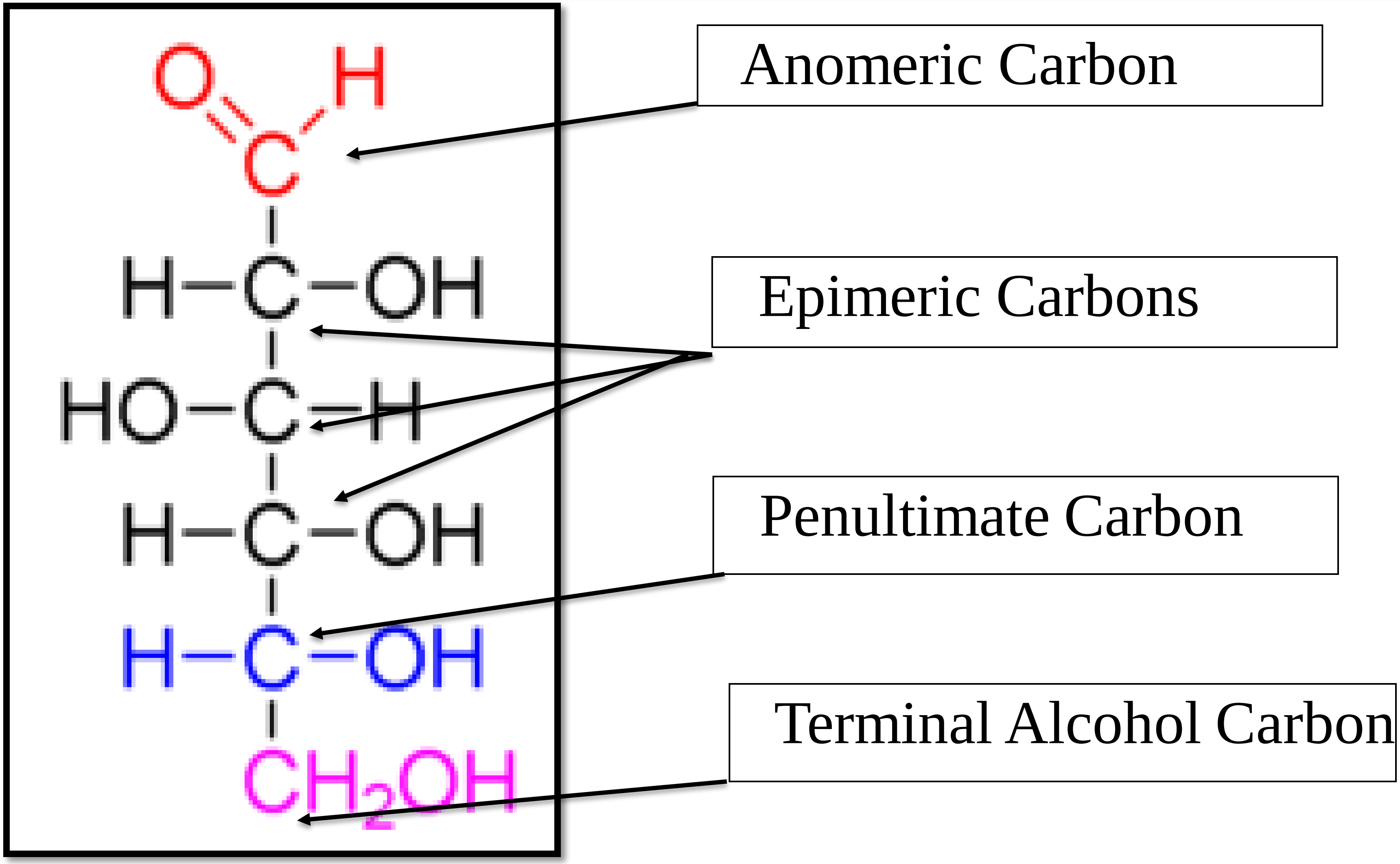
Epimers:

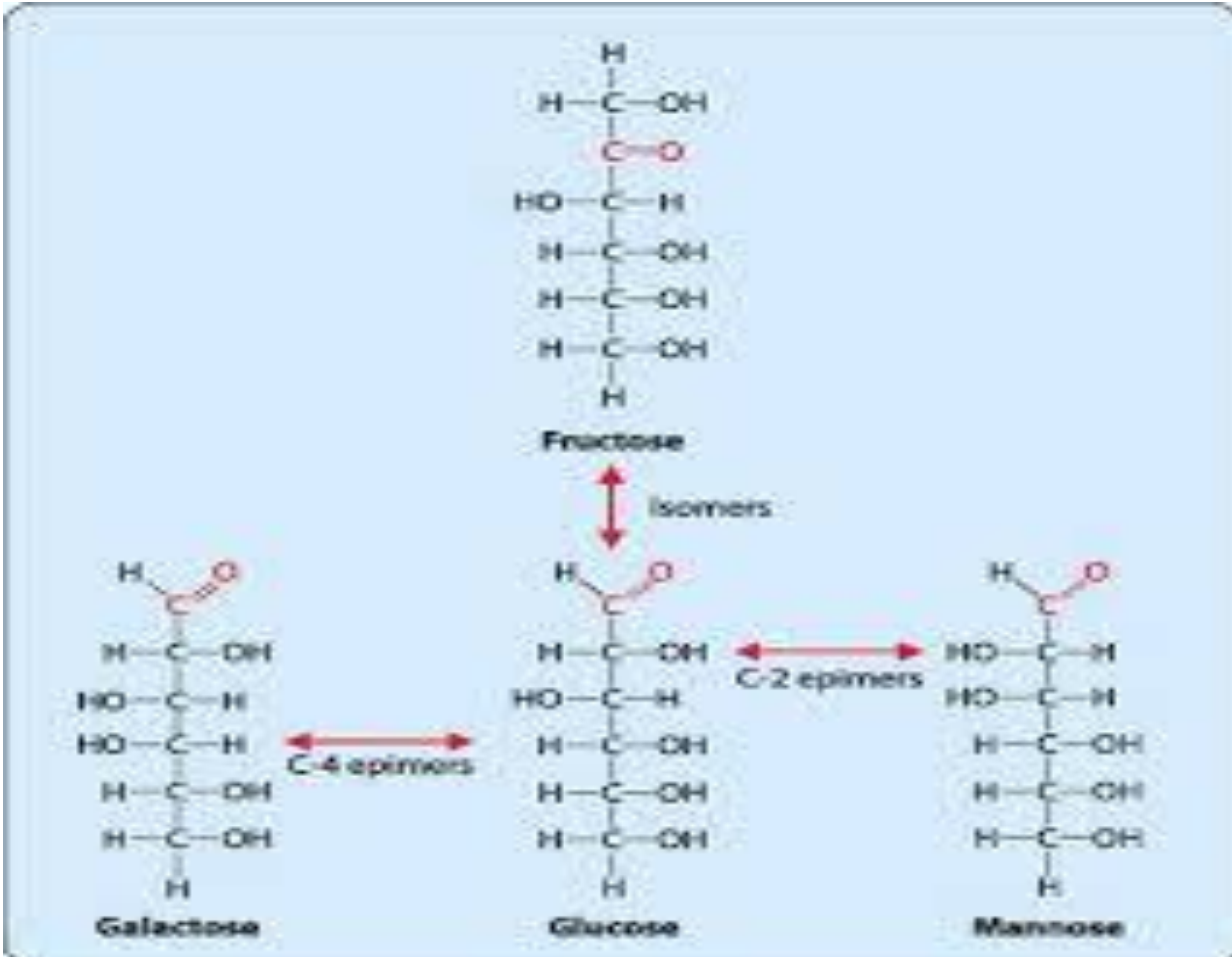
Carbohydrate isomers that differ in configuration around only one specific carbon atom (with the exception of the carbonyl carbon) are defined as epimers of each other. Example:

Glucose and galactose are C-4 epimers (their structures differ only in the position of the –OH group at carbon 4).

Glucose and mannose are C-2 epimers.

Straight Chain Structure of Typical Monosaccharide (Glucose)

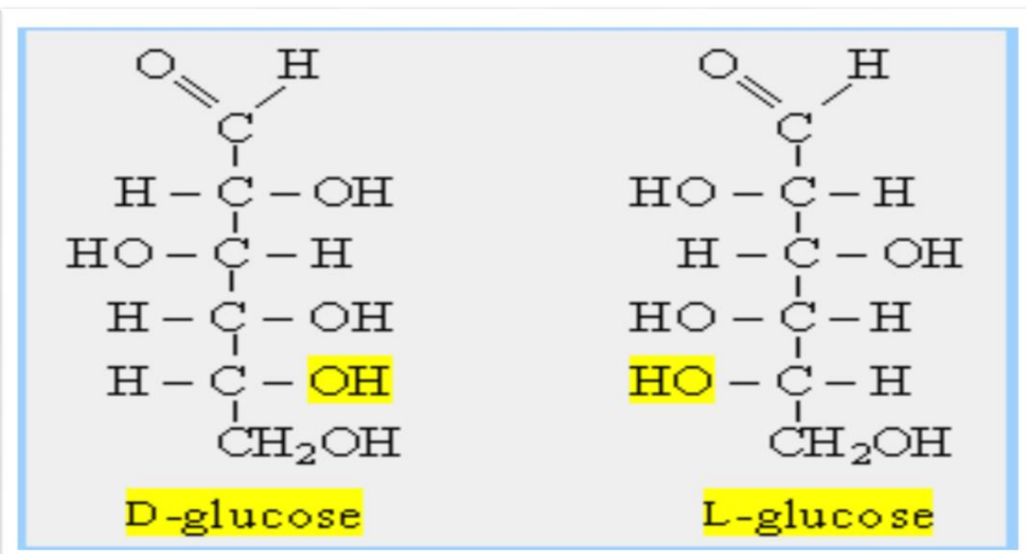


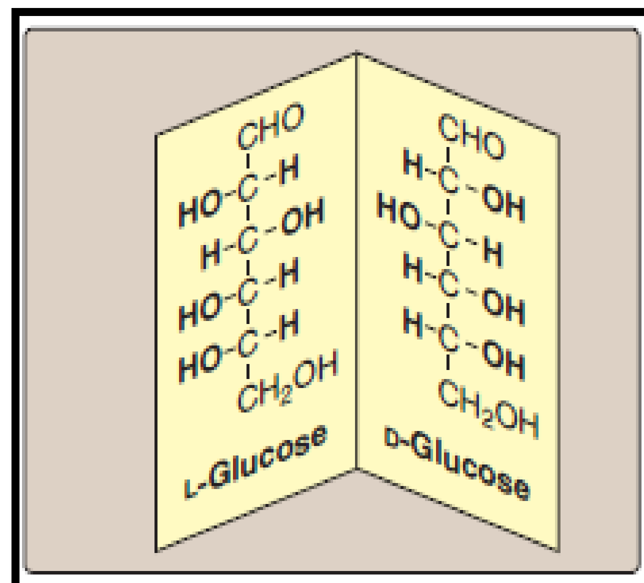


Fructose
Isomers
C-2 epimers
C-4 epimers
Galactose
Glucose
Mannose

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 .
- The vast majority of the sugars in humans are D-sugars.
- In the **D isomeric** form, the –OH group on the asymmetric carbon (a carbon linked to four different atoms or groups) farthest from the carbonyl carbon is on the **right**, whereas in the **L-isomer** it is on the **left.**



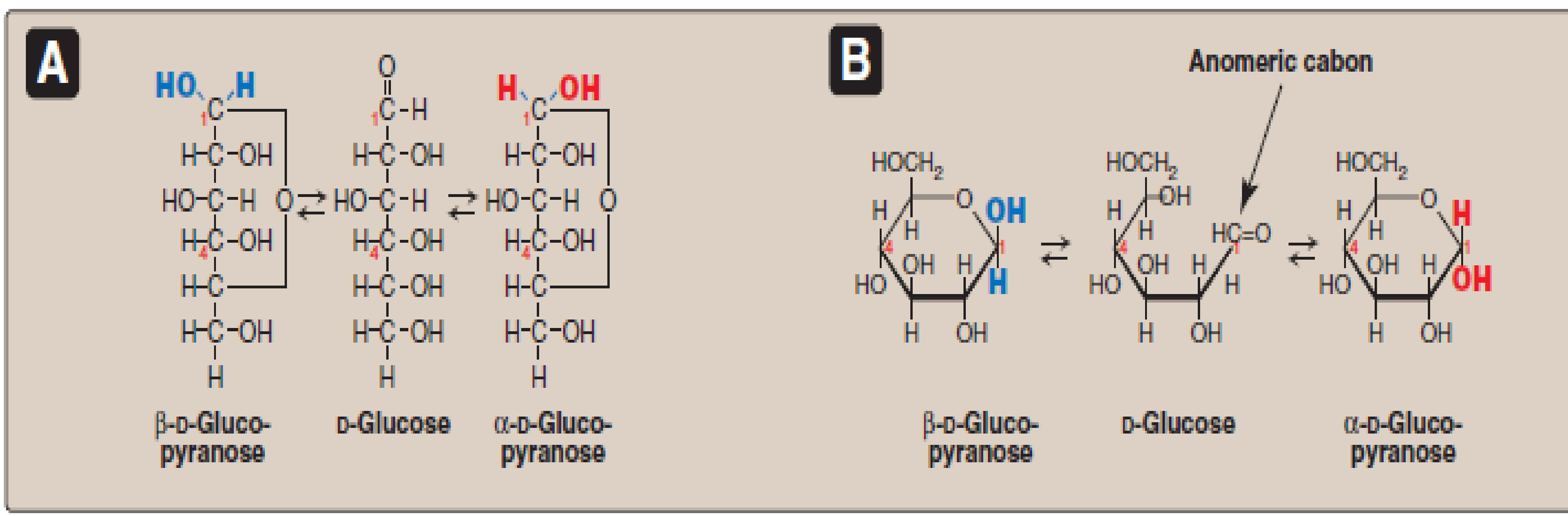


Cyclization of Monosaccharide

- Less than 1% of each of the monosaccharide with five or more carbons exists in the open-chain (acyclic) form.
- Rather, they are predominantly found in a ring (cyclic) form, in which **the aldehyde (or keto) group has reacted with an alcohol group on the same sugar, making the carbonyl carbon (carbon 1 for an aldose or carbon 2 for a ketose) asymmetric.**

<u>**Note:**</u>

- Pyranose refers to a six-membered ring consisting of five carbons and one oxygen, for example, glucopyranose whereas furanose denotes a five-membered ring with four carbons and one oxygen.



Anomeric carbon: Cyclization creates an anomeric carbon

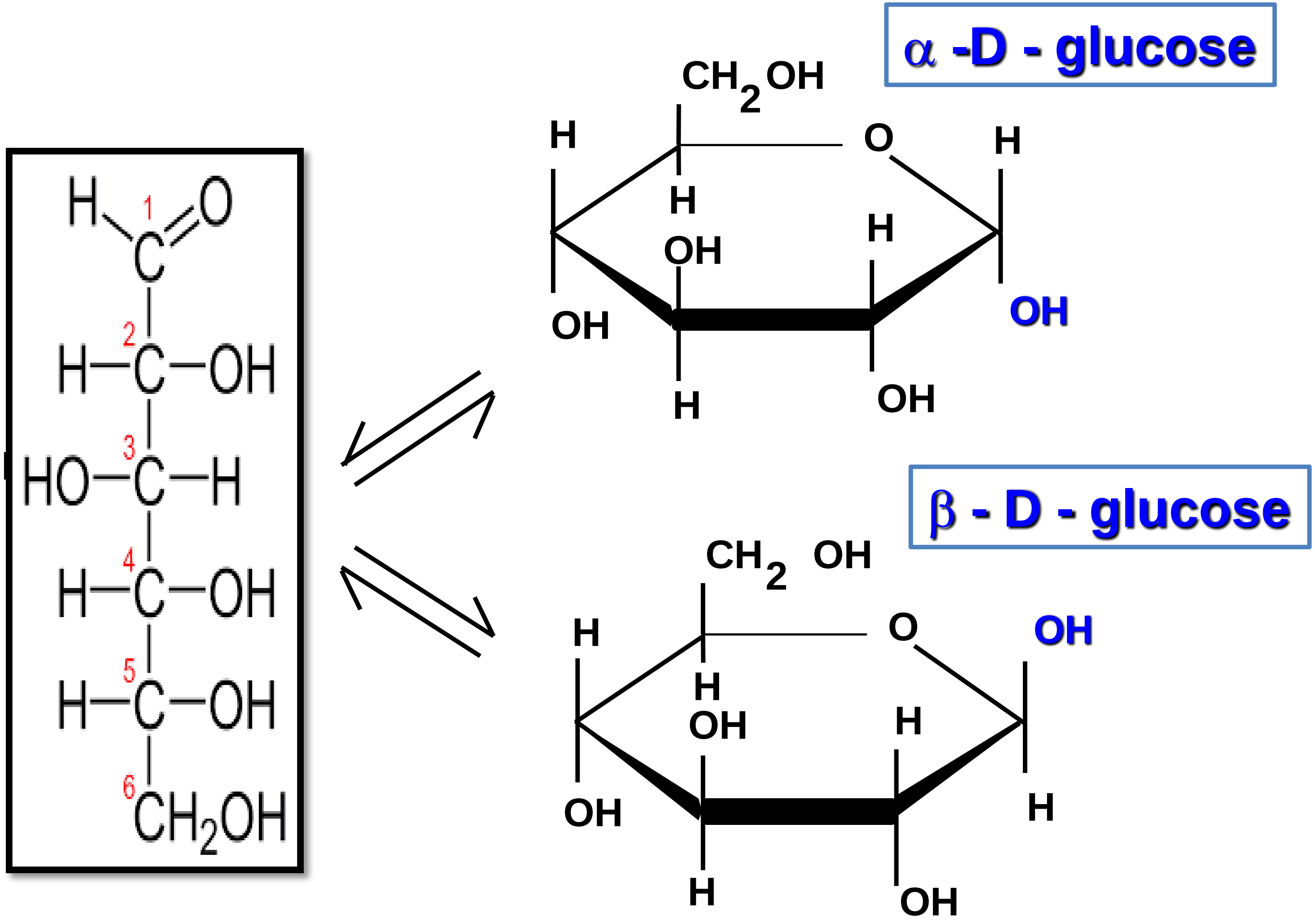
- Anomeric carbon: Cyclization creates an anomeric carbon (the former carbonyl carbon), generating the α and β configurations of the sugar, for example, α-D-glucopyranose and β-D-glucopryanose.
- These two sugars are both glucose but are anomers of each other.

Note:

In the α configuration, the OH on the anomeric C projects to the same side as the ring in a modified Fischer projection formula and is trans to the CH2OH group in a Haworth projection formula.

- Enzymes are able to distinguish between these two structures and use one or the other preferentially. For example, glycogen is synthesized from α-D-glucopyranose, whereas cellulose is synthesized from β-D-glucopyranose.
- The cyclic α and β anomers of a sugar in solution are in equilibrium with each other, and can be spontaneously interconverted (a process called mutarotation).

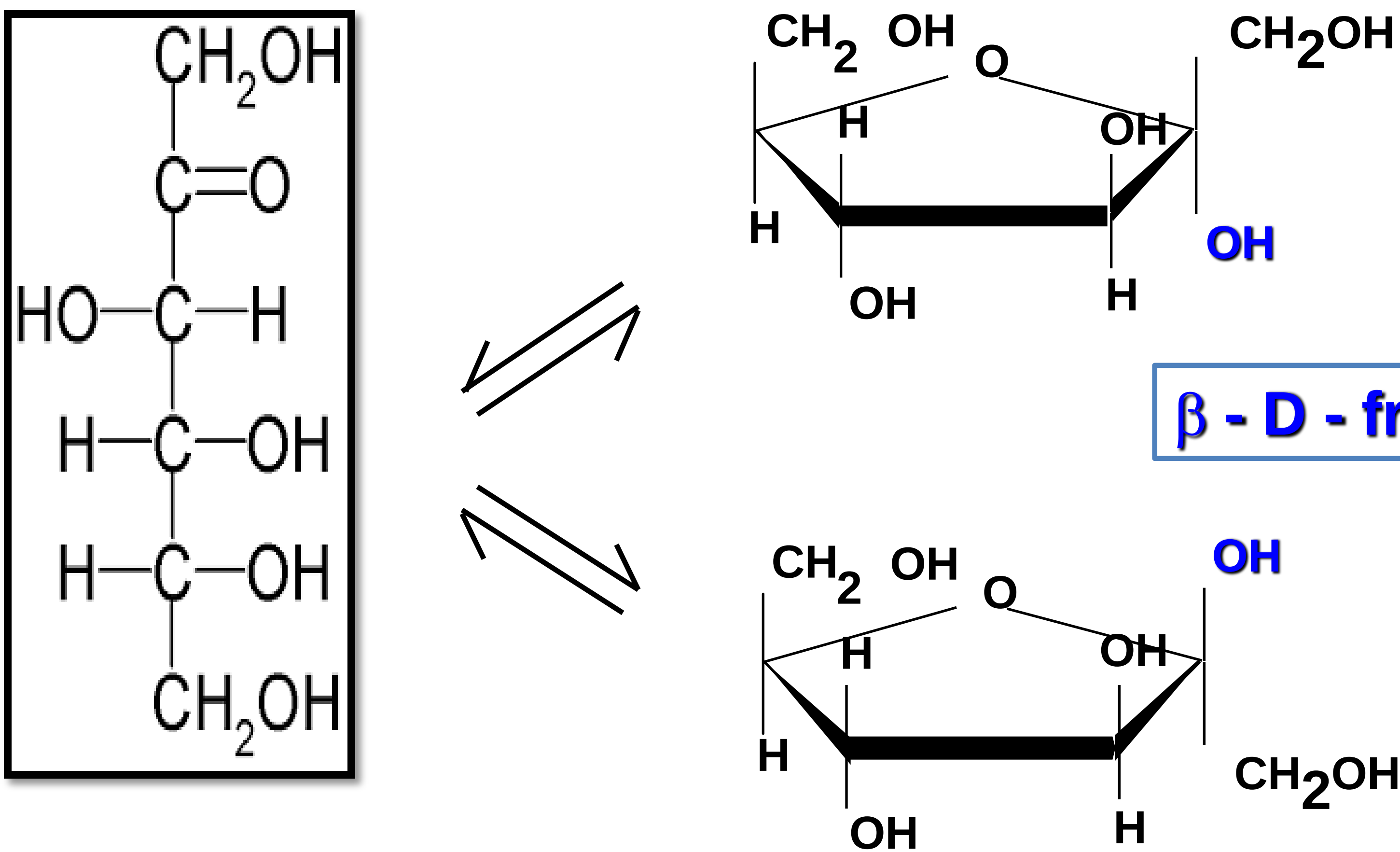
Cyclization of D-glucose
Fischer vs. Haworth projections



Cyclization of D-fructose

α - D - fructose

β - D - fructose



Joining of Monosaccharide

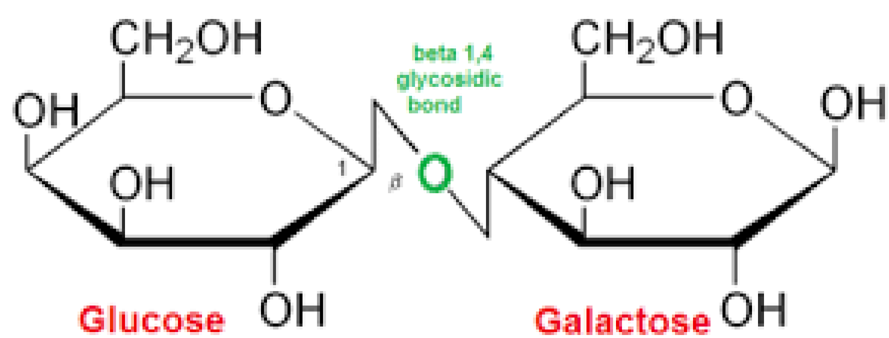
- Monosaccharide can be joined to form disaccharides, oligosaccharides, and polysaccharides.

- The bonds that link sugars are called glycosidic bonds. These are formed by enzymes known as **glycosyl transferase** that use nucleotide sugars such as UDP-glucose as substrates.

- Naming glycosidic bonds: Glycosidic bonds between sugars are named according to the numbers of the connected carbons, and with regard to the position of the **anomeric hydroxyl group** of the sugar involved in the bond.

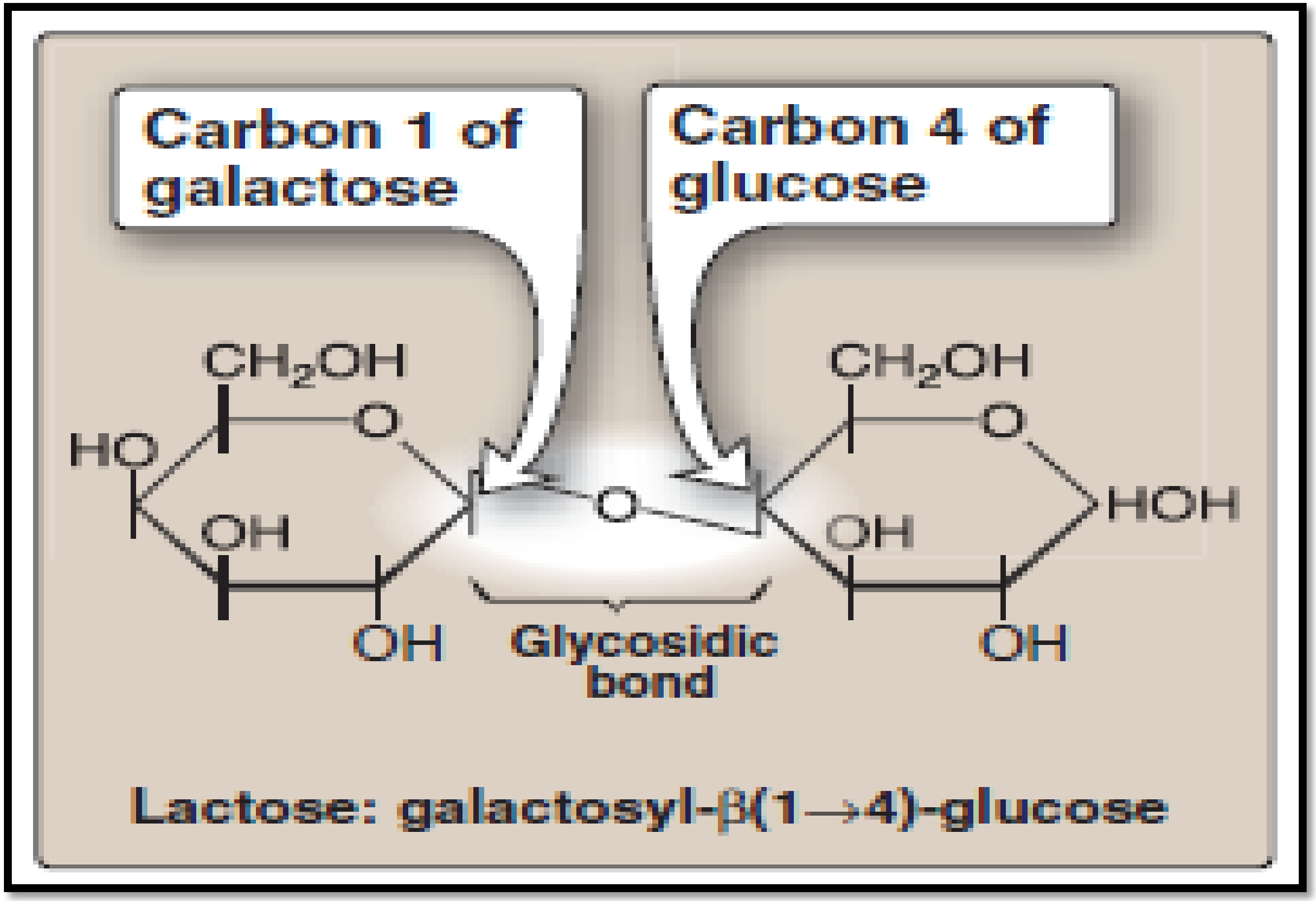
- If this anomeric hydroxyl is in the **α configuration**, the linkage is an **α-bond**. If it is in the **β configuration**, the linkage is a **β-bond.**

- Lactose, for example, is synthesized by forming a glycosidic bond between carbon 1 of β-galactose and carbon 4 of glucose. The linkage is, therefore, a β(1→4) glycosidic bond



Lactose structure

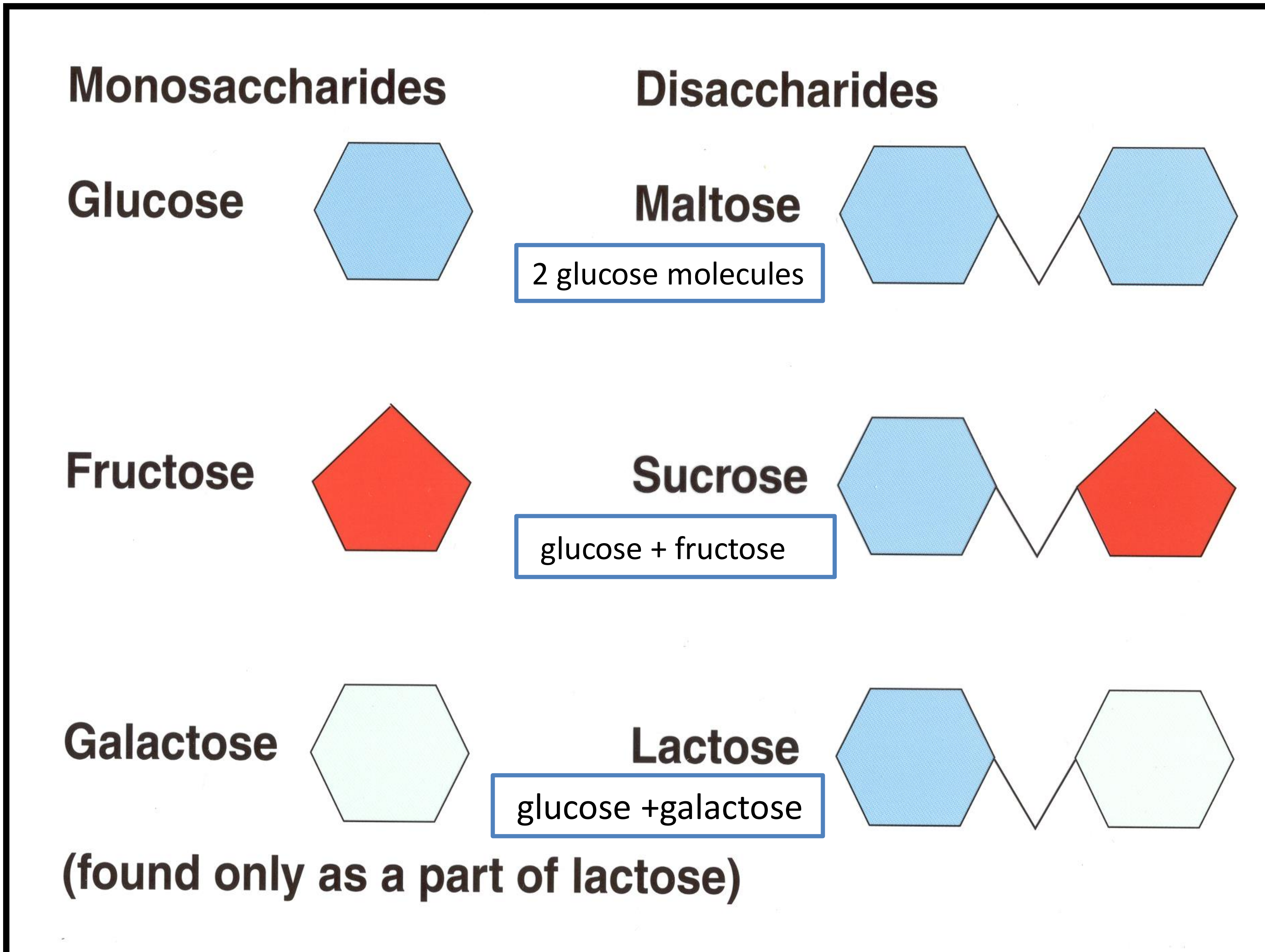
Glycosidic Bonds

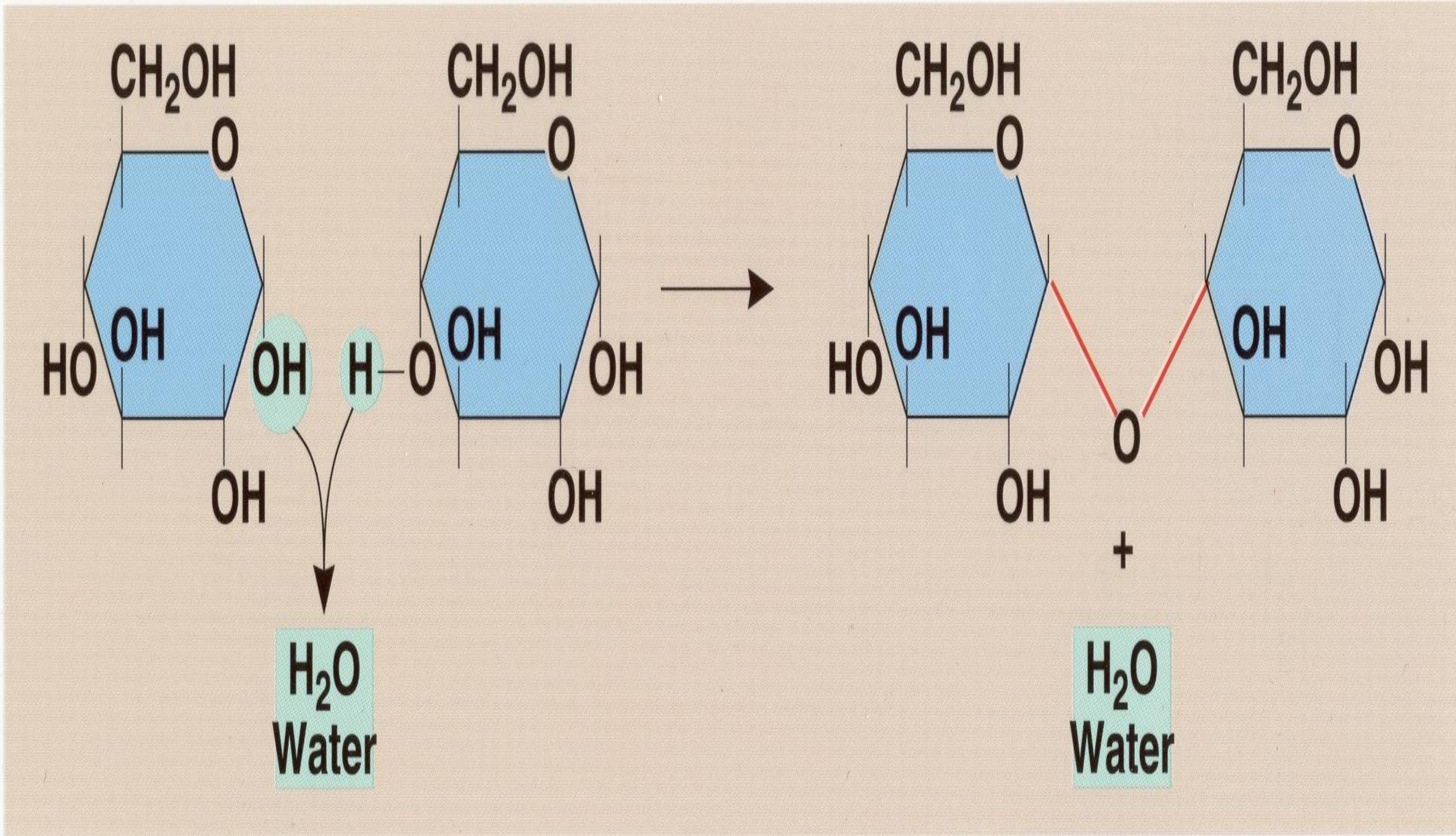


Disaccharides

- Two Joined Monosaccharides, examples:
    - Sucrose: Glucose + Fructose
    - Maltose: Glucose + Glucose
    - Lactose: Glucose + Galactose

The Most Important Disaccharides





Glucose + glucose → Maltose

Oligosaccharides

Composed of:

- Three to ten monosaccharide units.
- E.g. Fructooligosaccharides

Polysaccharides

- Larger than ten monosaccharide units.
- Can reach many thousands of units.
- Examples:
  - Glycogen
  - Starch
  - Fibres (Cellulose)


Thank you