BIOMOLECULES

- Biomolecules are the most essential organic molecules, and the building blocks of all the living organisms.
- They range from small molecules such as primary and secondary metabolites, vitamins and hormones to large macromolecules like proteins, nucleic acids, carbohydrates, lipids **(Figure1).**

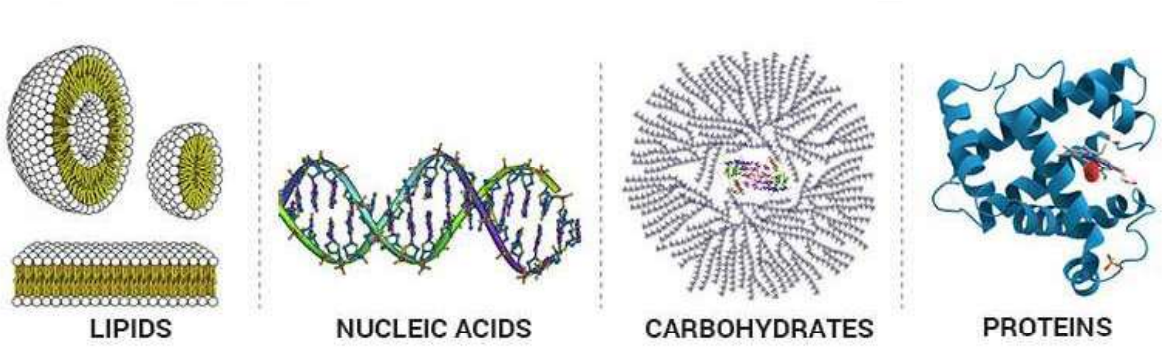


Figure1: Biomolecules

Carbohydrates

- Carbohydrates (saccharides) are the most abundant organic molecules in nature .
- They have a wide range of functions , including :
  - Providing a significant fraction of the dietary calories for most organisms.
  - Acting as a storage form of energy in the body .
  - Serving as cell membrane components that mediate some forms of intercellular communication.
  - Serve as a structural component of many organisms including the cell walls of bacteria, and the fibrous cellulose of plants .

- The general formula for many of the simpler carbohydrates is $(CH_2O)_n$, where n ≥ 3, hence the name "hydrate of carbon."

Classification of Carbohydrates

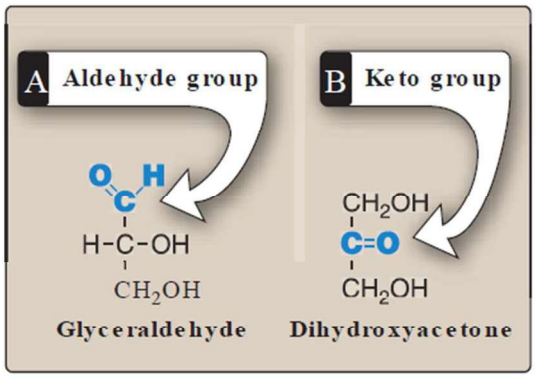
- Carbohydrates are classified according to number of sugar units as:
  - Monosaccharides: 1 sugar unit.
  - Disaccharides: 2 sugar units.
  - Oligosaccharides: 3-9 sugar units.
  - Polysaccharides: 10 or more sugar units.

Monosaccharides

- Monosaccharides (simple sugars) can be classified according to the number of carbon atoms they contain.
- Examples of some monosaccharides commonly found in humans are:

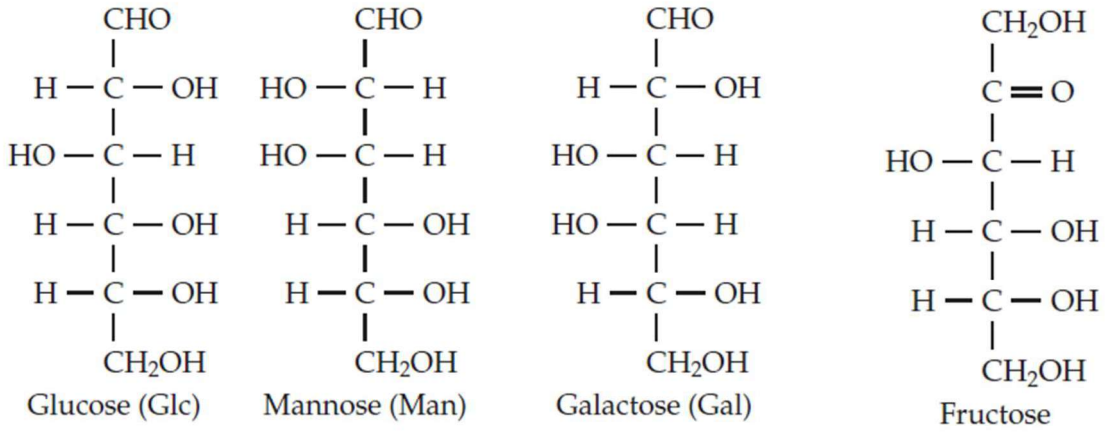
Generic names	Examples
3 Carbons: trioses	Glyceraldehyde
4 Carbons: tetroses	Erythrose
5 Carbons: pentoses	Ribose
6 Carbons: hexoses	Glucose
7 Carbons: heptoses	Sedoheptulose
9 Carbons: nonoses	Neuraminic acid

- They can also be classified by the type of carbonyl group they contain.
- Carbohydrates with an aldehyde as their carbonyl group are called “aldoses” (glucose, galactose, mannose), whereas those with a keto as their carbonyl group are called “ketoses” (fructose).



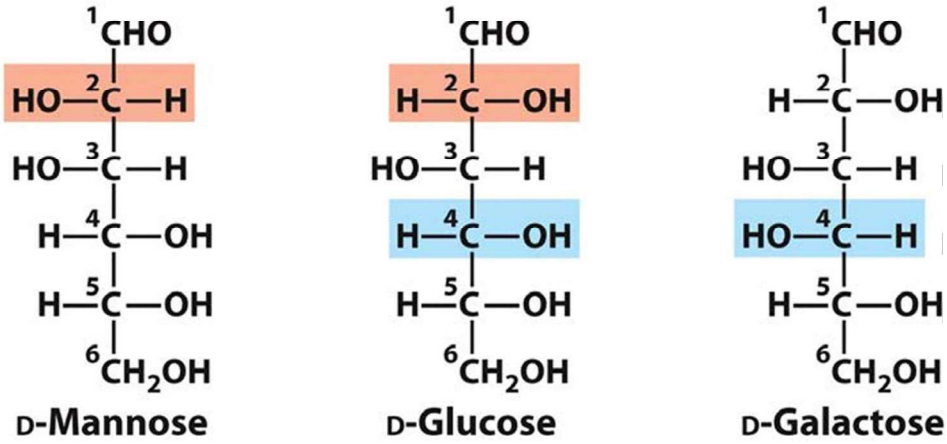
Isomers

- 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, $C_6H_{12}O_6$.



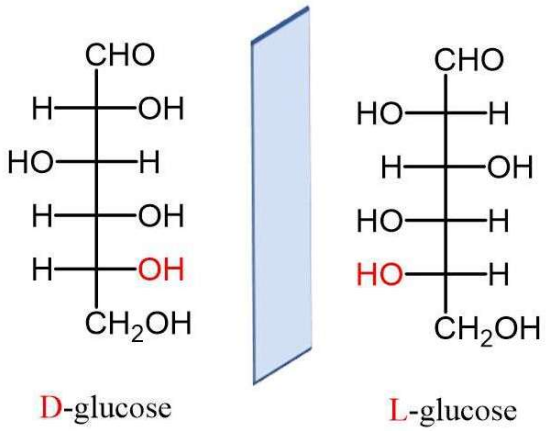
Epimers

- 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.
- Glucose and galactose are C-4 epimers because their structures differ only in the position of the–OH group at carbon 4.
- Glucose and mannose are C-2 epimers .



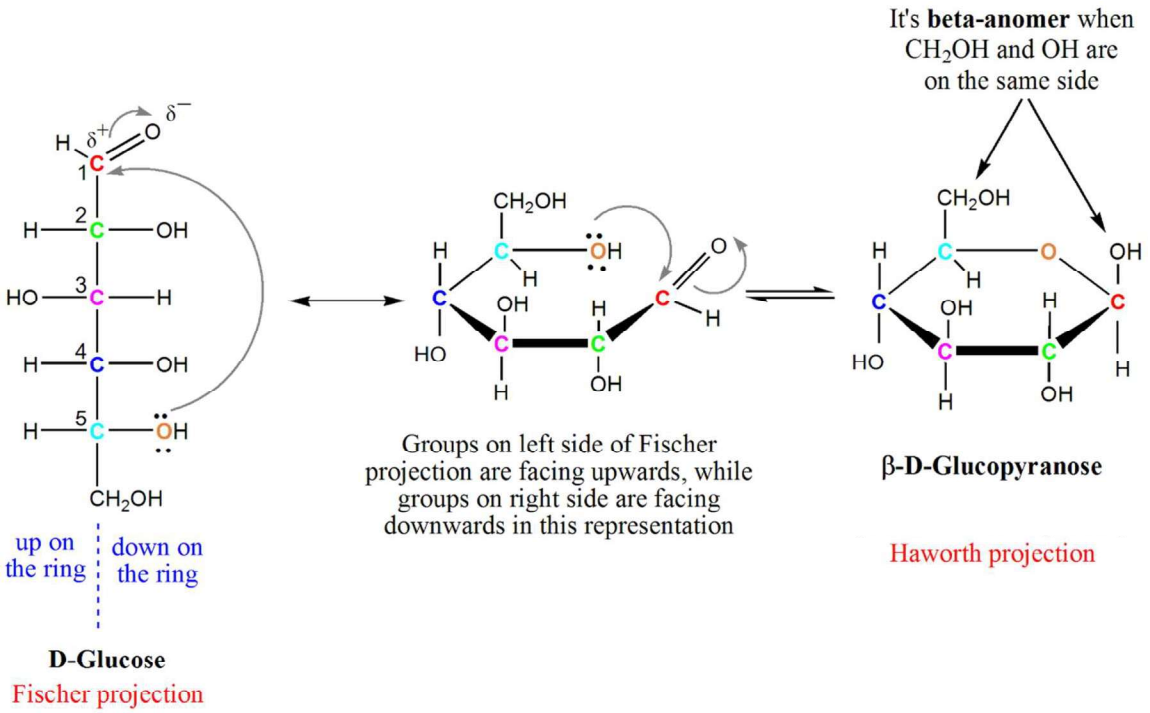
Enantiomers

- 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 Monosaccharides

- Less than 1% of each of the monosaccharides with five or more carbons exists in the **open chain (a cyclic) Fischer projection formula** in solution.
- **Rather, they are predominantly found in a ring (cyclic) Haworth projection formula.**
- In which the aldehyde (or keto) group has reacted with an **alcohol group** on the same sugar, making the carbonyl carbon (**C1** for an aldose , **C2** for a ketose) a symmetric.
- This **asymmetric carbon** is referred to as the **anomeric carbon.**

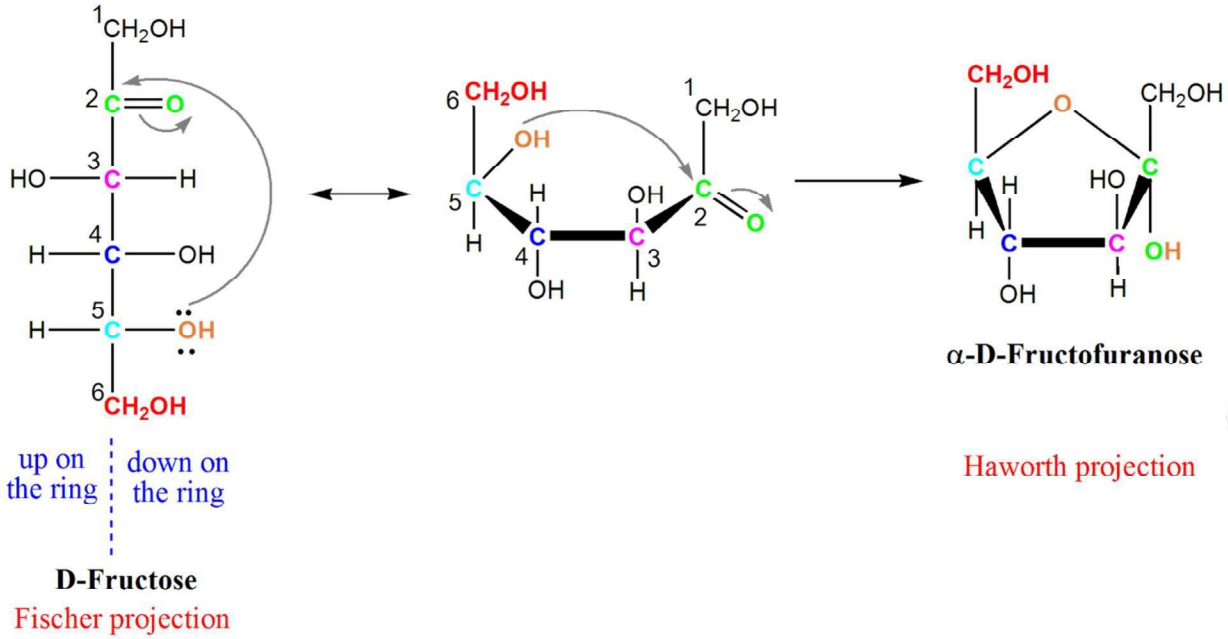


D-Glucose

Fischer projection

β-D-Glucopyranose

Haworth projection



D-Fructose

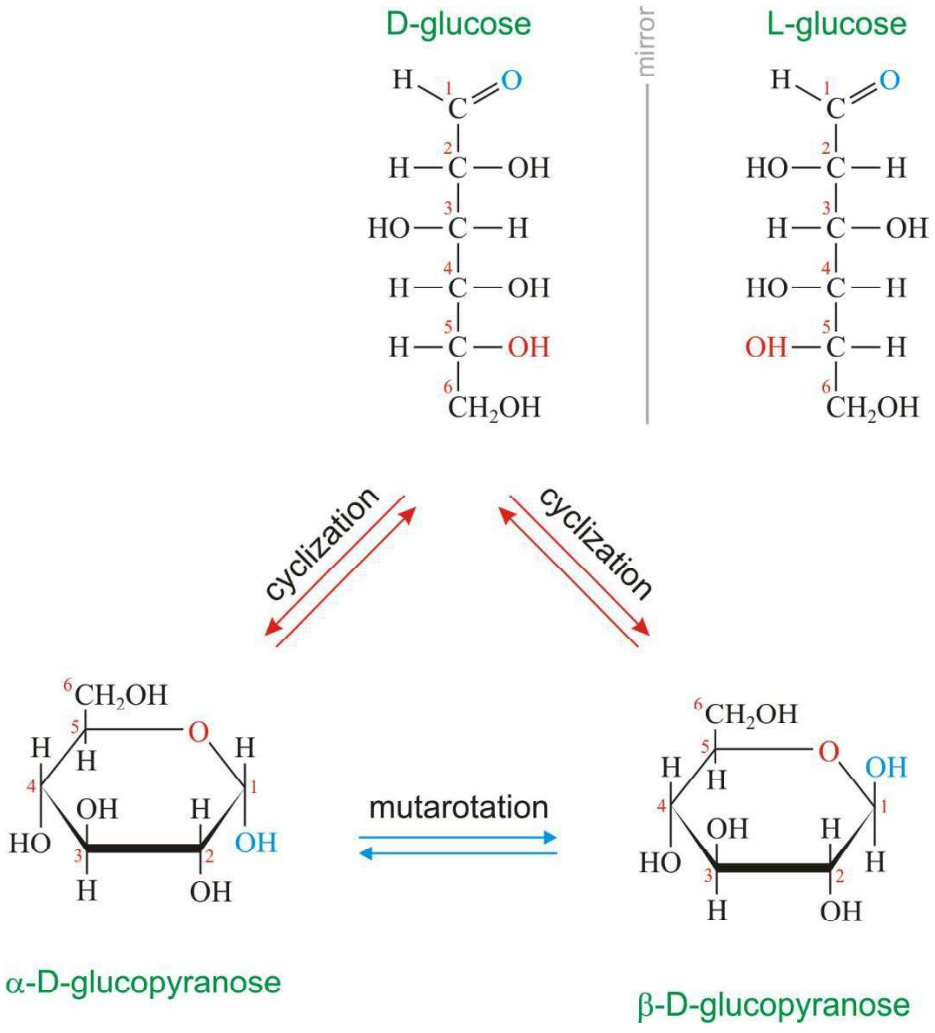
Fischer projection

α-D-Fructofuranose

Haworth projection

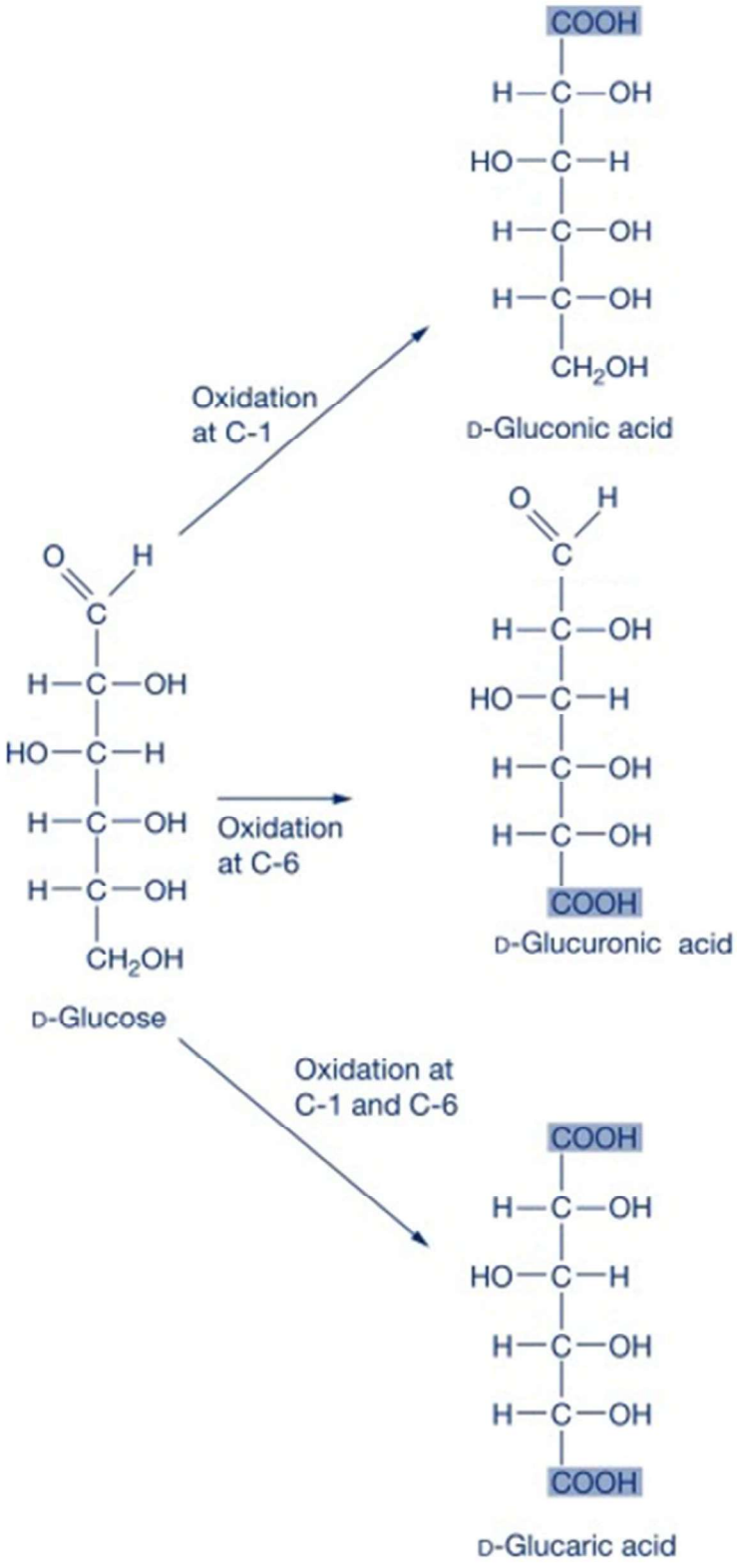
Anomers

- Creation of an anomeric carbon, generates a new pair of isomers, the α and β configurations of the sugar (α-D-glucopyranose and β-D-glucopyranose), that are anomers of each other.
- The cyclic α and β anomers of a sugar in solution spontaneously (but slowly) form an **equilibrium mixture** , a process known as **mutarotation.**
- The **α and β forms are not mirror images** , and they are referred to as **diastereomers.**



Reducing Sugars

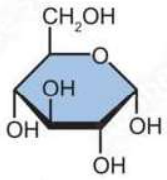
- If the hydroxyl group on the anomeric carbon of a cyclized sugar is not linked to another compound by a glycosidic bond, the ring can open.
- The sugar can act as a reducing agent and is termed a reducing sugar.
- Such sugars can react with chromogenic a gents (Benedict reagent) causing the reagent to be reduced and colored, with the aldehyde group of the a cyclic sugar becoming oxidized.
- All monosaccharides but not all disaccharides , are reducing sugars .
- Glucose can have its **terminal hydroxyl group** oxidized to a **carboxyl group**, forming **glucuronic acid**, or its **anomeric carbon** oxidized forming **gluconic acid**, or **both oxidized forming glucaric acid.**



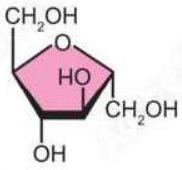
Glucose Oxidation

Disaccharides

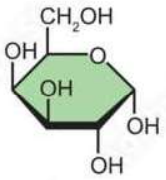
- A disaccharide (also called a double sugar) is the sugar formed when two monosaccharides (simple sugars) are **joined** by **glycosidic linkage**.
- The oxide linkage is formed after the loss of the water molecule and then the two monosaccharides are formed by that linkage.
- Like monosaccharides, disaccharides are soluble in water.
- Three common examples are sucrose, lactose, and maltose.



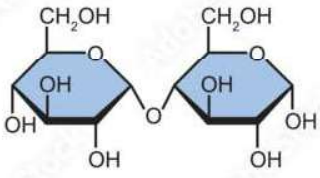
Glucose



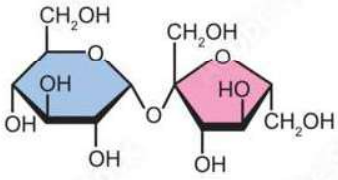
Fructose



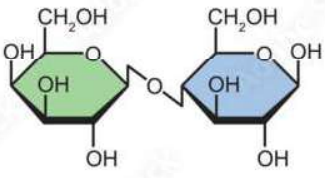
Galactose



Maltose



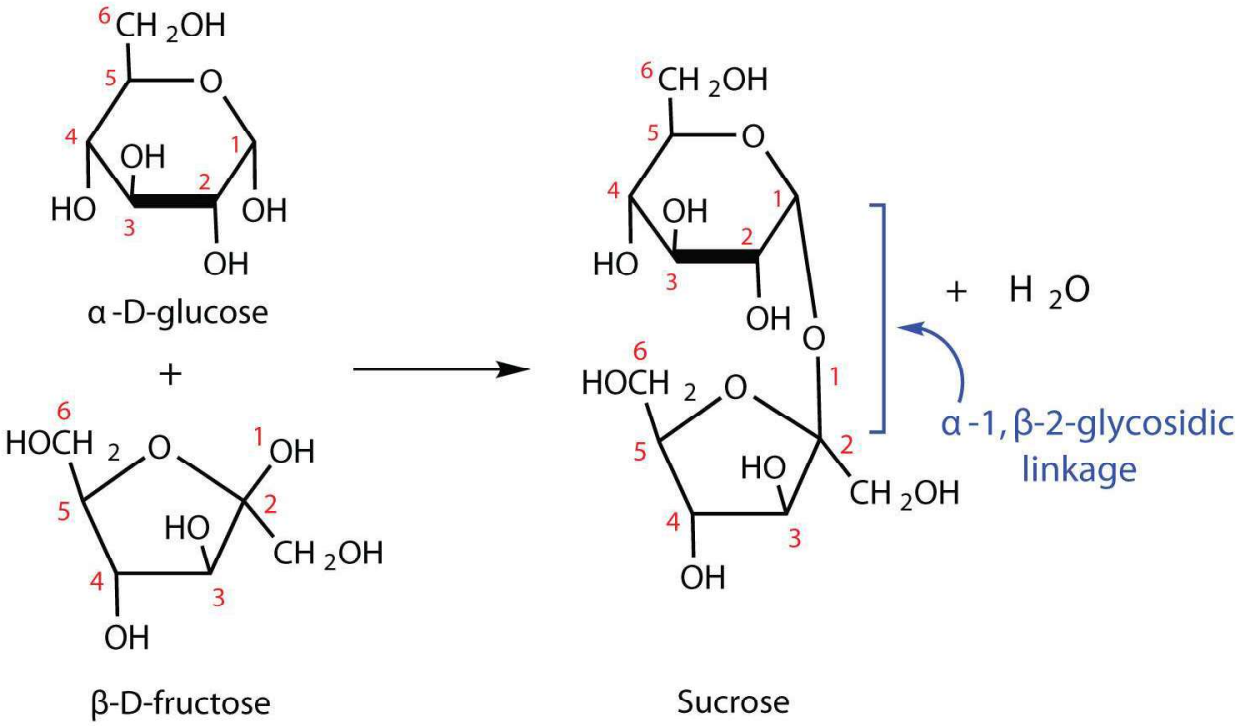
Sucrose



Lactose

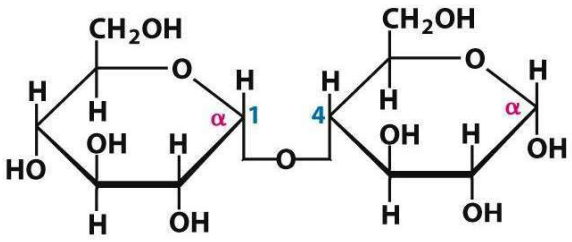
Sucrose (table sugar)

- The most common disaccharide is sucrose which gives D- glucose and D- fructose on hydrolysis.
- Both the monosaccharides i.e. glucose and fructose are connected through the glycosidic linkage between **alpha glucose** and second carbon **beta fructose.**
- **Sucrose is a non-reducing sugar** as both the **reducing groups of glucose and fructose are involved in the glycosidic bond formation.**



Maltose (Malt sugar)

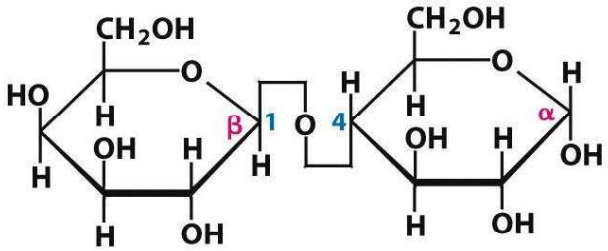
- Maltose is also one of the disaccharides which have two α -D-glucose units which are connected by the first carbon of the glucose and linked to the fourth carbon of another glucose unit.
- In the solution, a free aldehyde can be produced at the first carbon of the second glucose of the solution and it is a reducing sugar as it shows reducing properties.



Maltose
(α-D-Glucopyranosyl-(1→ 4)-α-D-glucopyranose

Lactose (Milk sugar)

- Commonly it is called milk sugar as this disaccharide is found in milk.
- It is made up of β-D-galactose and α-D-glucose. The bond is between the first carbon of galactose and the fourth carbon of glucose.
- This is also a reducing sugar.



Lactose
(β-D-Galactopyranosyl-(1→ 4)- α-D-glucopyranose

Some More Types of Disaccharides

Trehalose

- It is made up of 2 molecules of glucose which are linked differently.
- This can be found in fungi, plants, and insects.

Lactulose

- It is formed from galactose and fructose.
- It is helpful for the treatment of constipation and liver diseases.

Cellobiose

- It is also made up of two glucose molecules which are also arranged differently.
- These can be seen bacteriology which is a form of chemical analysis.

Chitobiose

- It comprises two glucosamine molecules which are linked.
- It is seen in some bacteria, exoskeletons of insects and is also found in fish, octopus, and squid.