Basic Biochemistry lecture 1 and 2

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Carbohydrates, also called **saccharides** (Greek: *Saccharon* means sugar), are the most abundant biological molecules containing C, H and O, which are they may be defined as **ketone derivatives** which are combined in the ratio of 1 : 2 : 1, i.e. as (CH2O)n, where n is 3 or more.

Functions of Carbohydrates

Carbohydrates have many important jobs in the body. The simplest form, called **monosaccharides**, gives us quick energy, and **glucose** is the most common one used by the body. Besides providing energy, they also help build other important substances.When the body doesn't need sugar right away, it stores it for later. In animals, sugar is stored as **glycogen** in the liver and muscles. In plants, it is stored as **starch**.

If there is too much carbohydrate in the body, it can be turned into **fat** for long-term storage.

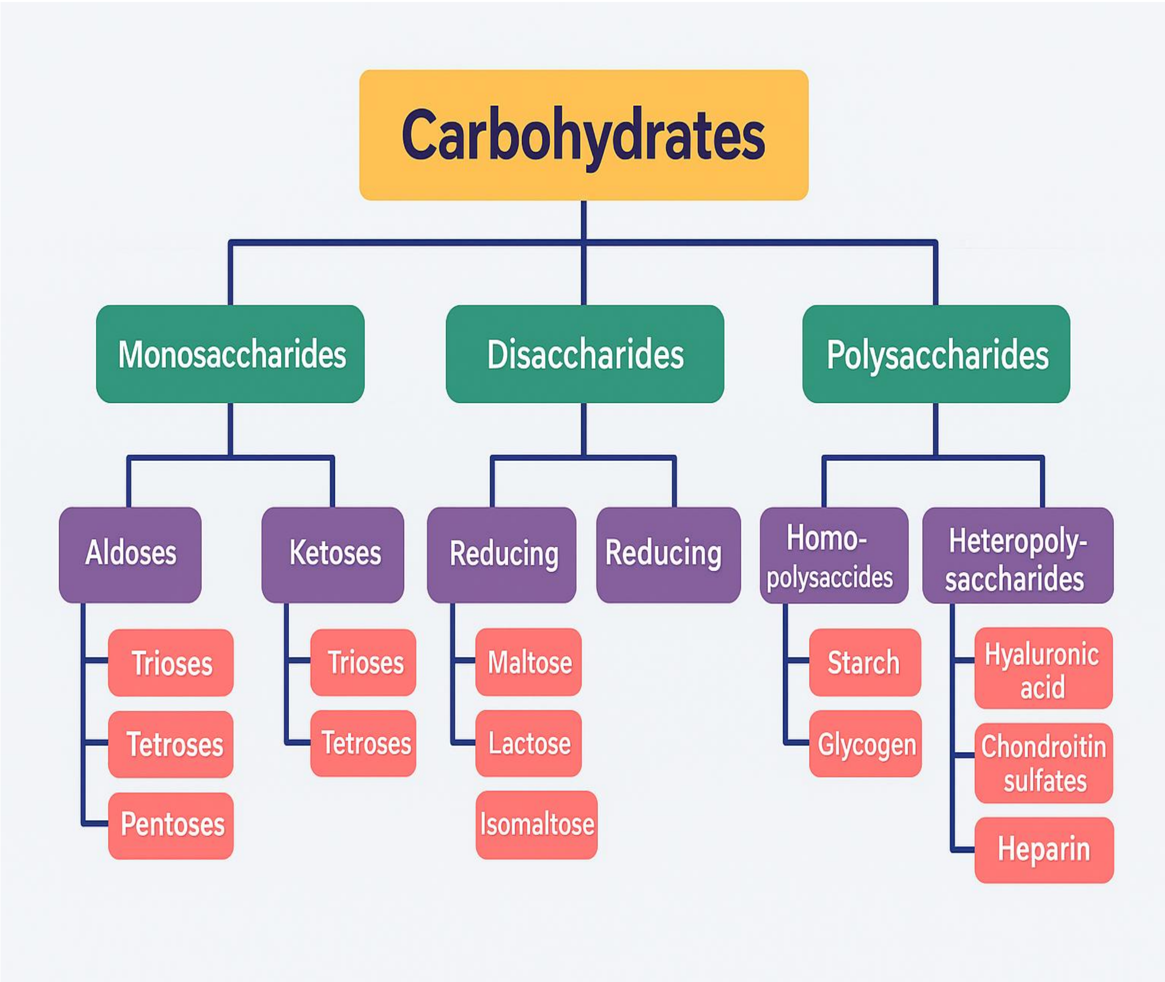
Carbohydrates also have other special uses:

- **Ribose** is a sugar found in **RNA**.
- **Deoxyribose** is found in **DNA**.
- **Galactose** is part of **lactose**, the sugar in milk.
- **Mannose** helps in making some proteins in the body.
- **Fructose**, found in fruits, is absorbed easily, processed in the liver, and is also present in **semen**.

Classification of Carbohydrates

Carbohydrates are grouped based on how many sugar units they have:

1. **Monosaccharides** – simple sugars with one unit (like glucose).
2. **Disaccharides** – made of two sugar units (like sucrose and lactose).
3. **Oligosaccharides** – made of 3 to 10 sugar units.
4. **Polysaccharides** – made of many sugar units (more than 10) joined together (like starch and glycogen).



Monosaccharides (Simple Sugars)

Monosaccharides are the simplest form of sugar. They are made from straight chains of carbon atoms with many –OH (hydroxyl) groups and either an **aldehyde** or a **ketone** group. These sugars have at least **three carbon atoms**.

Monosaccharides can join together to form bigger sugars like:

- **Disaccharides** (2 sugar units)
- **Oligosaccharides** (a few sugar units)
- **Polysaccharides** (many sugars units

Monosaccharides are grouped in two main ways:

1. Based on the Type of Carbonyl Group

- **Aldoses**:
  These have an **aldehyde group (–CHO)** on the **first carbon atom**.
  Example: *Glucose*
- **Ketoses**:
  These have a **ketone group (–CO)** on the **second carbon atom**.
  Example: *Fructose*

2. Based on the Number of Carbon Atoms

Monosaccharides are also named based on how many carbon atoms they have:

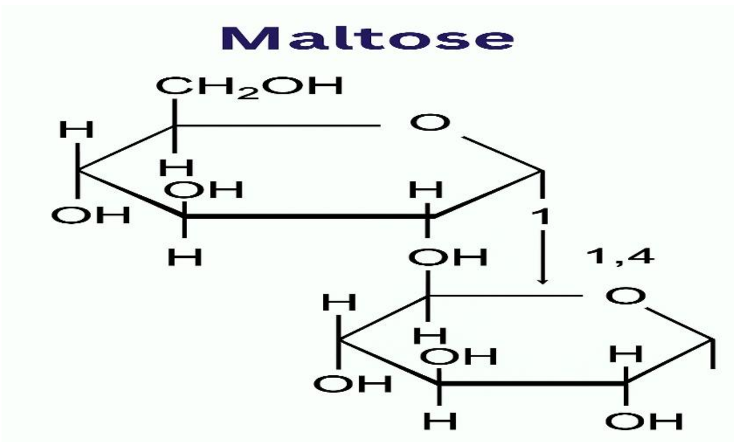
- **Trioses** – 3 carbon atoms:
- **Tetroses** – 4 carbon atoms:
- **Pentoses** – 5 carbon atoms
- **Hexoses** – 6 carbon atoms

Classification of monosaccharides			
Mono-saccharides	Number of carbons	Aldoses	Ketoses
Trioses	3	Glyceralde-hyde	Dihydroxy-acetone
Tetroses	4	Erythrose	erythrulose
Pentoses	5	Ribose	Ribulose
Hexoses	6	Glucose	Fructose

Disaccharides are sugars made of two single sugar units (monosaccharides). These two units can be the same or different and are connected by a **glycosidic bond**. Common examples include **maltose, lactose, and sucrose**.

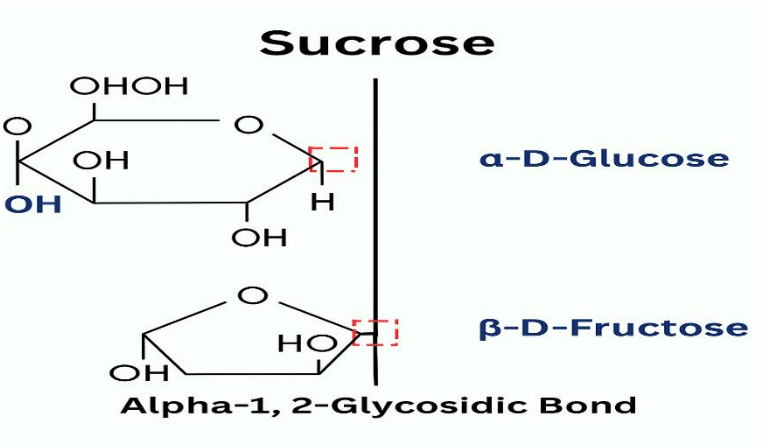
Maltose

Maltose is made of two **glucose** molecules joined by a special bond called **α-1,4-glycosidic bond**. It is formed when bigger sugars like **starch** or **glycogen** break down. An enzyme called **maltase**, found in the small intestine, breaks maltose into two glucose molecules.

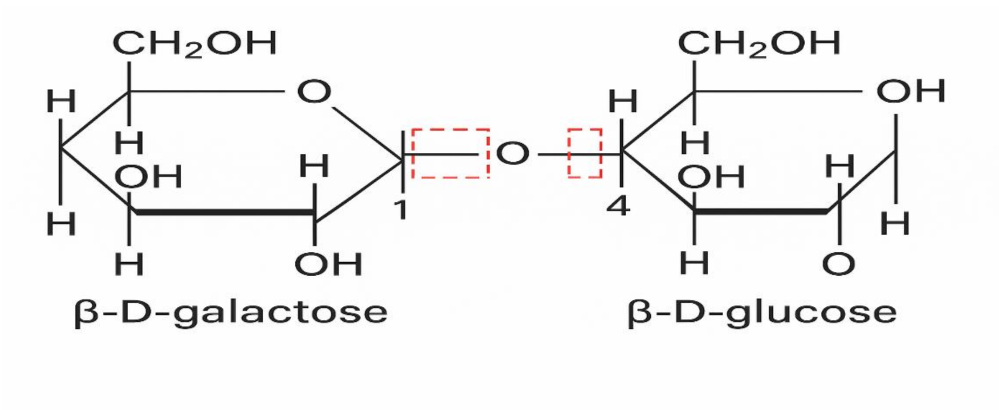


Sucrose (Table Sugar)

Sucrose is a sugar made of two smaller sugars: **glucose** and **fructose**. These two are linked together by a bond called **an α-1,2-glycosidic bond**. Because of this bond, sucrose does **not** have a free carbonyl group, so it is a **non-reducing sugar**. Sucrose is also called **table sugar**, **cane sugar**, or **invert sugar**. In the small intestine, an enzyme called **sucrase** (also known as **invertase**) breaks sucrose into glucose and fructose.



Lactose is a sugar made of two smaller sugars: **galactose** and **glucose**. These two are connected by a special bond called an **α-1,4-glycosidic bond**. Lactose is a **reducing sugar** and is naturally found in **milk**, so it is also called **milk sugar**. In the body, an enzyme called **lactase** breaks down lactose into **glucose** and **galactose** so they can be absorbed.



Oligosaccharides

Oligosaccharides are carbohydrates made up of 3 to 10 simple sugar units (monosaccharides) linked together by glycosidic bonds.
Examples are maltotriose and raffinose.Some oligosaccharides help build structures in the body. Most of them cannot be digested by humans.

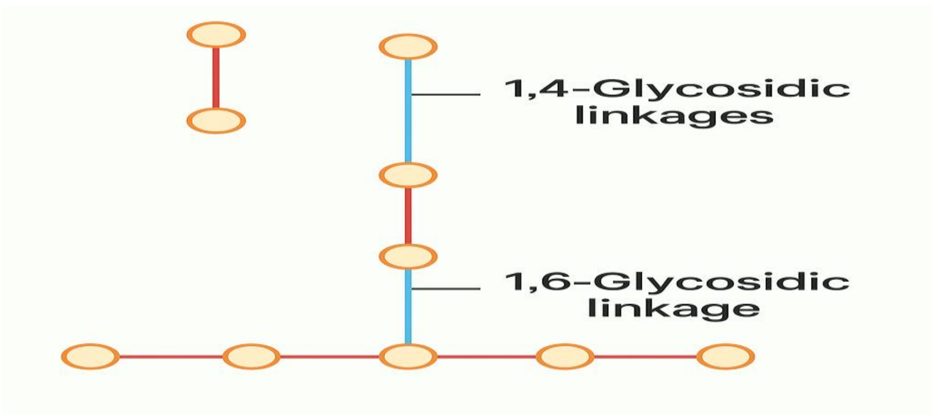
Polysaccharides

Polysaccharides, also called glycans, are made from a large number of simple sugars joined by glycosidic bonds. They can be either straight chains or branched chains and are divided into two main types:

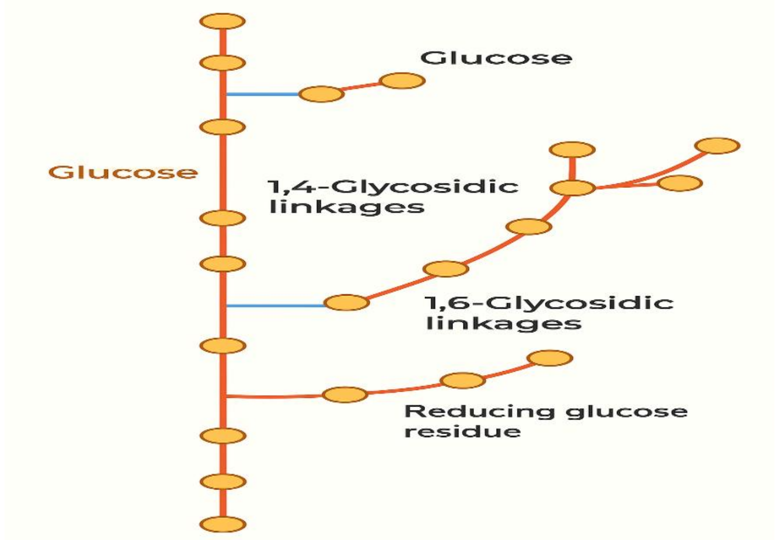
1. Homopolysaccharides

Also called homoglycans, these are made from the same type of simple sugar units.

- Starch
- Glycogen
- Cellulose (all made from glucose)
- Inulin (made from fructose)



Starch



Collagen

Heteropolysaccharides are complex carbohydrates made up of different kinds of simple sugar units. A special group of these is called glycosaminoglycans (GAGs), which were earlier known as mucopolysaccharides. These molecules are large and carry a negative charge. They usually combine with small amounts of protein to form structures called proteoglycans. One well-known example is hyaluronic acid, which is made from repeating pairs of two sugars: D-glucuronic acid and N-acetyl-D-glucosamine.

Digestion and Absorption of Carbohydrates

Carbohydrate Digestion:

1. **Carbohydrate digestion starts in the mouth**, where the enzyme **salivary amylase** begins breaking down **starch** into smaller units like **maltose** and shorter polysaccharides.
2. **Chewing** increases saliva production, mixing food with salivary amylase. However, only about **5% of starch** is digested here. Once

the food reaches the **stomach**, the **acidic environment (low pH)** inactivates salivary amylase.

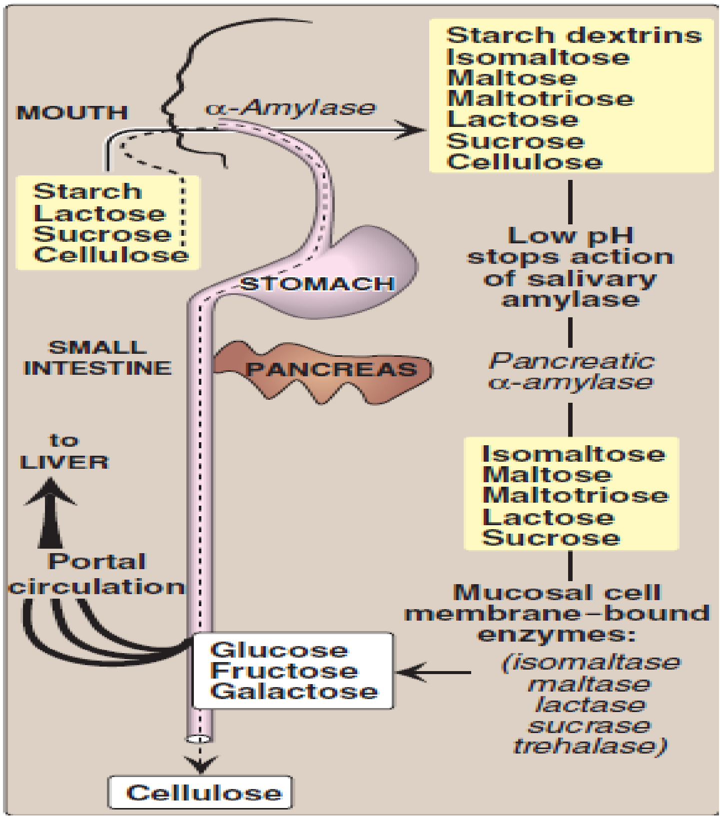
3. In the **small intestine**, the **pancreas** releases **pancreatic amylase** through the pancreatic duct.
4. **Pancreatic amylase** continues starch digestion, breaking it down into **maltose, isomaltose, dextrins**, and both **branched and unbranched oligosaccharides**.
5. **Enzymes on the brush border** of the small intestine (called **disaccharidases**) finish the process by converting **disaccharides into monosaccharides**, which can then be absorbed.

Carbohydrate Absorption

All dietary carbohydrates are ultimately absorbed in the small intestinein the form of monosaccharides. This occurs through two main processes:

1. **Fructose** is taken up by **facilitated diffusion**.
2. **Glucose and galactose** are absorbed through **secondary active transport**, using the **sodium-linked glucose transporter-1 (SGLT-1)**.

After absorption, these monosaccharides travel through the intestinal mucosal cells located in the villi and enter the liver via the portal vein. In the liver, both **galactose and fructose are converted into glucose**.



ISOMERISM IN CARBOHYDRATES

Stereoisomerism refers to molecules with the same chemical formula and structure but that differ in the three-dimensional arrangement of their atoms. This happens when a molecule has either

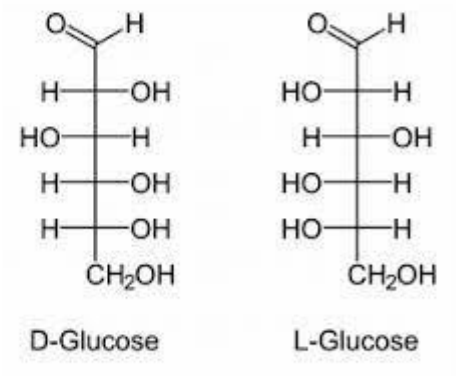
- a double bond, which prevents rotation
- or a chiral carbon, meaning a carbon atom attached to four different groups.

The presence of chiral carbons in carbohydrates leads to stereoisomerism and gives the compound optical activity, allowing it to rotate plane-polarized light. These include:

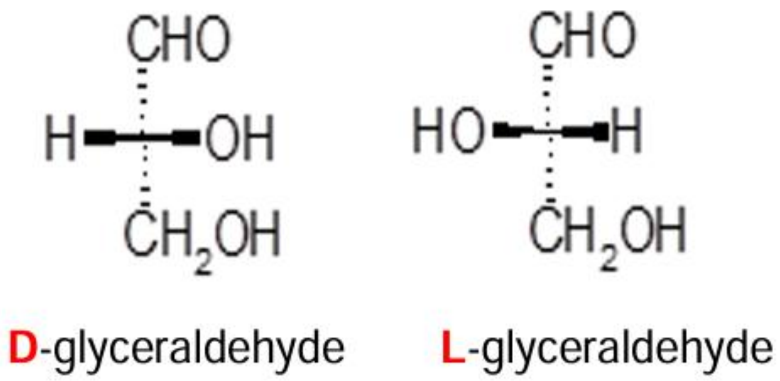
1. **Enantiomers**—molecules that are mirror images of each other. In sugars, these mirror-image forms are known as D- and L-forms. The classification depends on the position of the –OH group on the second-to-last carbon in the molecule:

    - If the –OH is on the right, it's called a D-sugar. Human bodies can only use D-sugars for metabolic processes.

- if it's on the left, it's an L-sugar.



- Glyceraldehyde has a single asymmetric carbon and, thus, there are two stereoisomers of this sugar. D-Glyceraldehyde and L-glyceraldehyde are mirror images of each other (enantiomers)



2. **Anomerism**: is a type of isomerism seen in sugars when they are in **ring form** (not straight chains) in solution.

- **Aldose sugars** (like glucose) usually form **pyranose rings** (6-membered).
- **Ketose sugars** (like fructose) usually form **furanose rings** (5-membered).

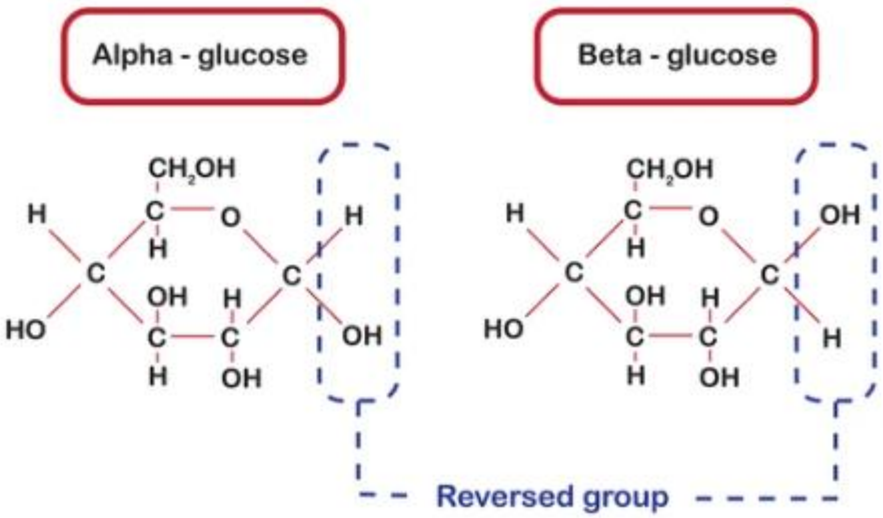
When the sugar forms a ring, the carbon that was part of the carbonyl group (C=O) becomes a new **chiral center**, called the **anomeric carbon**:

- In **aldoses**, it's **carbon 1 (C1)**.
- In **ketoses**, it's **carbon 2 (C2)**.

If two sugars are exactly the same except for the position of the –OH group on the anomeric carbon, they are called **anomers**. These are labeled as **alpha (α)** and **beta (β)** forms.

Examples:

- α-D-glucose and β-D-glucose

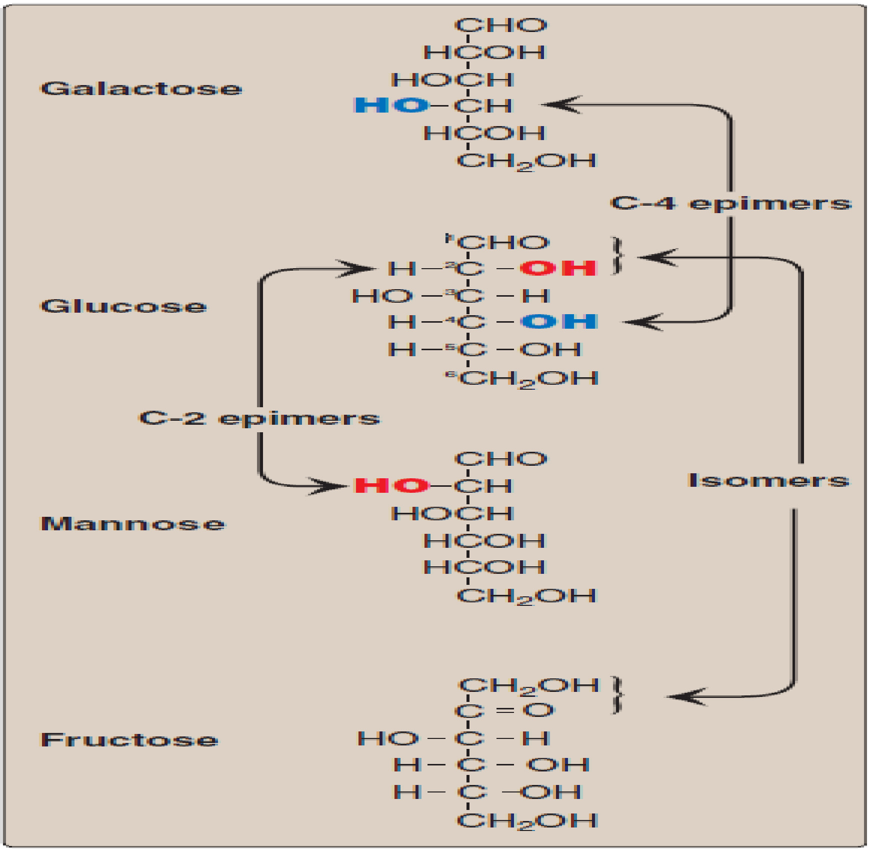


3. **Epimerism** occurs when two sugar molecules differ in the arrangement of –H and –OH around just **one specific carbon atom**.

- For example, **mannose** is an **epimer of glucose** because they differ only at **carbon 2 (C2)**.

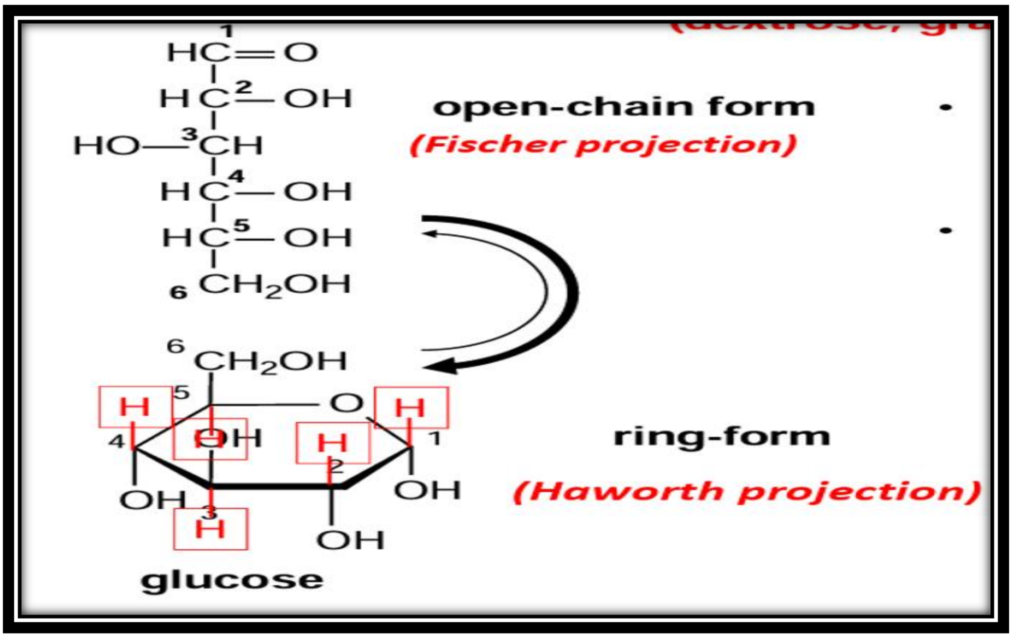
Likewise, **galactose** is an **epimer of glucose** because they differ only at **carbon 4 (C4)**.These types of sugar isomers are called **epimers**.

Stereoisomers have the same chemical formula but differ in the position of the hydroxyl group on one or more of their asymmetric carbons. Epimers are stereoisomers that differ in the position of the hydroxyl group at only one of their asymmetric carbons. D-glucose and D-galactose are epimers of each other, differing only at C4, and can be interconverted in human cells by enzymes called epimerases. D-mannose and D-glucose are also epimers of each other, differing only at C2.



Fischer/Haworth projection

- Glucose in solution exists mostly in the ring form at equilibrium, with less than 0.1% of the molecules in the open-chain form.
- Fischer projections are useful for depicting carbohydrate structures because they provide clear and simple views of the stereochemistry at each carbon center.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open-chain form
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