# COURSE TITLE: Biomolecules and Microbial Metabolism

## Course Code: 24MICCC2

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# Carbohydrates: (Monosaccharides ,Disaccharides and Polysaccharides )

- A carbohydrate is a biomolecule consisting of **carbon** (C), **hydrogen** (H) and **oxygen** (O) atoms, usually with a hydrogen–oxygen atom ratio of 2:1 (as in water) and thus with the empirical formula Cm(H2O)n.
- Carbohydrates are also called **Saccharides**, a group that includes sugars, starch, and cellulose.
- The saccharides are divided into four chemical groups: monosaccharides, disaccharides, oligosaccharides, and polysaccharides.

# Classification of Carbohydrates

**Based on number of carbohydrate units**

- **Simple carbohydrates**
  - **Monosaccharides** (Simple/single sugars - one carbohydrate unit with 3-9 'C' atoms)
  - **Disaccharides** (Double sugars - two mono saccharide units)
  - **Oligosaccharides**: Few (1-10) monosaccharides units

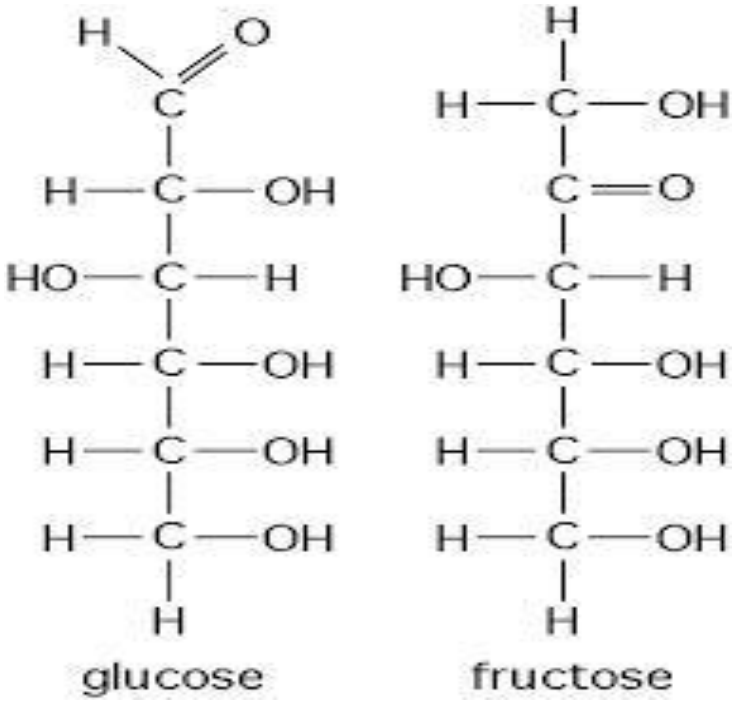
- **Complex carbohydrates**
  - **Tri-saccharides** : Three monosaccharides units
  - **Polysaccharides** :(Many sugars/monosaccharides)

# Monosaccharides

- Monosaccharides (from Greek monos: single, sacchar: sugar), also called simple sugars, are the simplest forms of sugar and the most basic units (monomers) from which all carbohydrates are built.
- They are usually **colorless**, **water-soluble**, and **crystalline organic solids**.
- Contrary to their name (sugars), only some monosaccharides have a **sweet taste**.
- Monosaccharides are the building blocks of disaccharides (such as sucrose, lactose and maltose) and polysaccharides (such as cellulose and starch).
- Examples of monosaccharides include **glucose** (dextrose), **fructose** (levulose), and **galactose**.
- Monosaccharides are classified as aldoses or ketoses based on the type of functional group they contain.

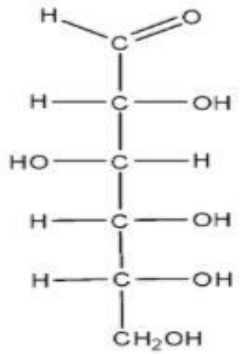
- **Aldoses**
- Contain an **aldehyde functional group**, with the carbonyl group at the end of the carbon atom. Aldoses are primarily found in plants.

  Glucose is an aldohexose.
- **Ketoses**
- Contain a **ketone functional group**, with the carbonyl group away from the end of the carbon atom.
- Ketoses are used in processed foods.
- Ffructose is a ketohexose.
- The Seliwanoff's Test can be used to distinguish between aldoses and ketoses. Aldoses turn light pink, while ketoses turn deep cherry red.

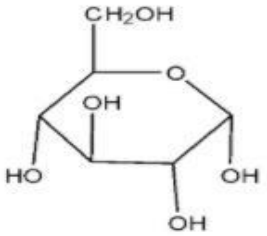


# Glucose

- Glucose is a monosaccharide containing six carbon atoms and an aldehyde group, and is therefore an aldohexose.
- The molecular formula for glucose is $\mathbf{C_6H_{12}O_6}$.
- Glucose is overall the most abundant monosaccharide, a subcategory of carbohydrates.
- In energy metabolism, glucose is the most important source of energy in all organisms.
- Glucose for metabolism is stored as a polymer, in plants mainly as amylose and amylopectin, and in animals as glycogen.
- Glucose circulates in the blood of animals as blood sugar.
- The naturally occurring form of glucose is d-glucose, while its stereoisomer l-glucose is produced synthetically in comparatively small amounts and is less biologically active.
- The glucose molecule can exist in an open-chain (acyclic) as well as ring (cyclic) form.



D-glucose
(Fischer projection)



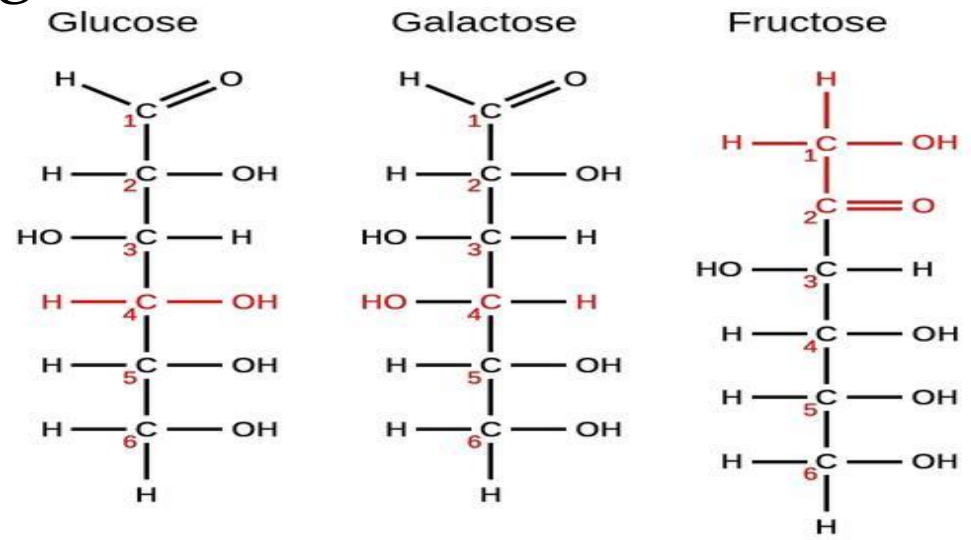
D-glucose
(Haworth projection)

# Fructose

- Fructose or **fruit sugar**, is a ketonic simple sugar found in many plants, where it is often bonded to glucose to form the disaccharide sucrose.
- It is one of the three dietary monosaccharides, along with glucose and galactose, that are absorbed by the gut directly into the blood of the portal vein during digestion.
- The liver then converts both fructose and galactose into glucose, so that dissolved glucose, known as blood sugar, is the only monosaccharide present in circulating blood.
- Pure, dry fructose is a **sweet**, **white**, **odorless**, **crystalline solid**, and is the most water-soluble of all the sugars.
- Fructose is found in honey, tree and vine fruits, flowers, berries, and most root vegetables.
- Commercially, fructose is derived from sugar cane, sugar beets, and maize.
- It is a 6 carbon compound containing ketone group as functional group, hence called ketohexose.

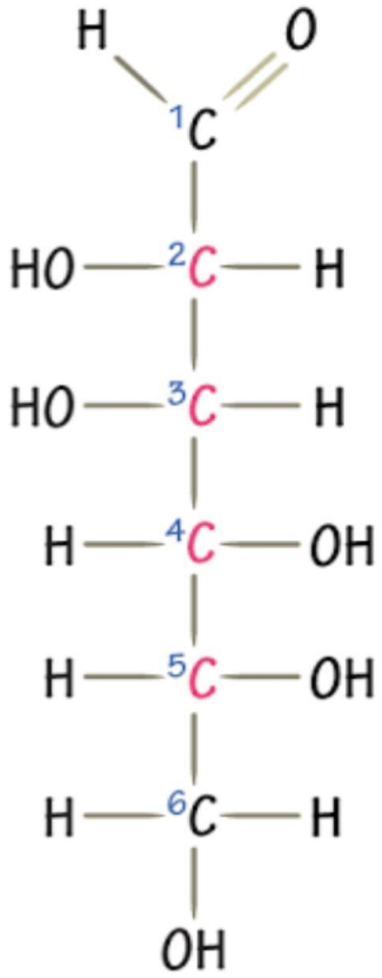
# Galactose

- Galactose is a monosaccharide and has the same chemical formula as glucose, i.e., $C_6H_{12}O_6$.
- It is similar to glucose in its structure, differing only in the position of one hydroxyl group.
- This difference, however, gives galactose different chemical and biochemical properties to glucose.
- **Galactosemia** is an extraordinary metabolic disorder in which affected infants are unable to utilize galactose found in milk.



# Mannose

- Mannose is a sugar monomer of the aldohexose series of carbohydrates. It is a **C-2 epimer** of **glucose**. Mannose is important in human metabolism, especially in the glycosylation of certain proteins. Several congenital disorders of glycosylation are associated with mutations in enzymes involved in mannose metabolism.

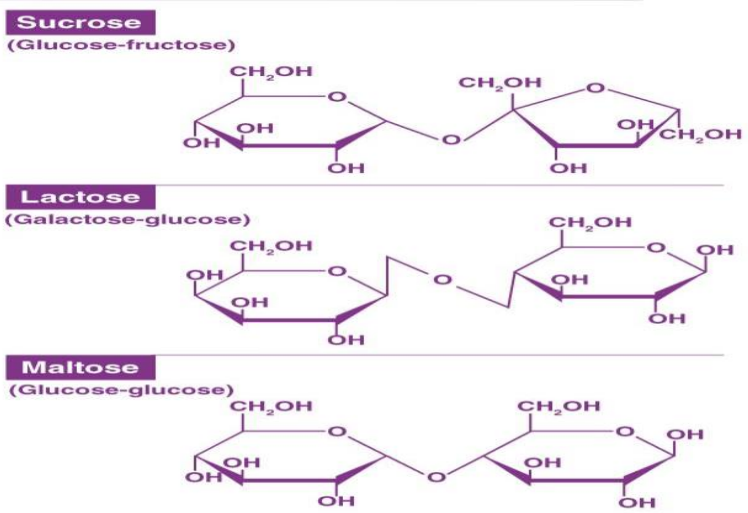



*D-mannose*
commonly used
in glycosylation
of proteins

# Disaccharides

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

- Disaccharides are those carbohydrates that on hydrolysis with **acids** or **enzymes** give two molecules of **monosaccharides** which can either be the same or different.
- Breaking apart a double sugar into its two monosaccharides is accomplished by **hydrolysis** with the help of a type of enzyme called a **disaccharidase**.
- The joining of monosaccharides into a double sugar happens by a condensation reaction, which involves the elimination of a water molecule from the functional groups only.



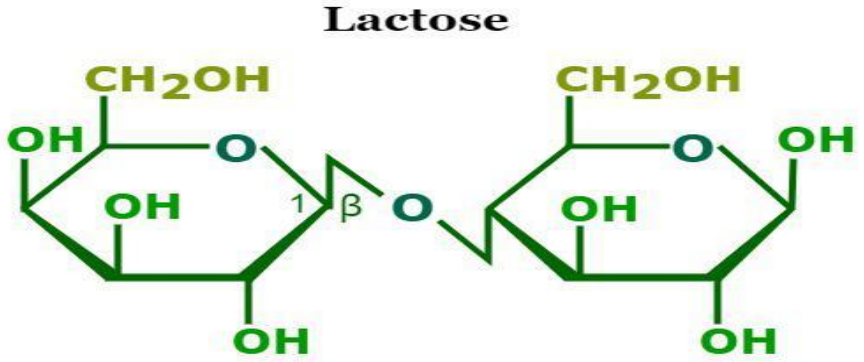
# Sucrose

- Sucrose is a naturally occurring sugar found in various amounts in plants like fruits, vegetables and nuts. Sucrose is also produced commercially from sugar cane and sugar beets.
- Sucrose is also known as **table sugar**, granulated sugar or just plain "sugar.
- Sucrose is a type of carbohydrate, a disaccharide made of equal parts of two monosaccharides: **glucose** and **fructose**.
- This type of linking of two monosaccharides called **glycosidic linkage**. Sucrose has a monoclinic crystal structure and is quite soluble in water. It is characterized by its sweet taste.
- There are no anomeric hydroxyl groups in a sucrose molecule. It can, therefore, be classified as a non-reducing sugar (since it does not act as a reducing agent).

- **Uses of Sucrose**
- Sucrose is one of the most important components of **soft drinks** and other **beverages**.
- This compound is used in many **pharmaceutical products**.
- It serves as a **chemical intermediate** for many emulsifying agents and detergents.
- It also serves as a **food thickening agent** and as a food stabilizer.
- The **shelf lives** of many food products, such as jams and jellies, are extended with the help of this compound.
- The use of sucrose in baking results in the brown colour of the baked products.
- This compound also serves as an antioxidant (a compound that inhibits oxidation).
- Sucrose is widely used as a **food preservative**.

# Lactose

- Lactose, or milk sugar, is a disaccharide composed of **galactose** and **glucose** and has the molecular formula C12H22O11.
- The compound is a white, **water-soluble**, **non-hygroscopic solid** with a mildly sweet taste. It is used in the food industry.
- Lactose is a disaccharide composed of galactose and glucose, which form a β-1→4 glycosidic linkage.
- Detection reactions for lactose are the Wöhlk-and Fearon's test.
- Lactose is hydrolysed to glucose and galactose .Lactulose is a commercial product, used for treatment of constipation.



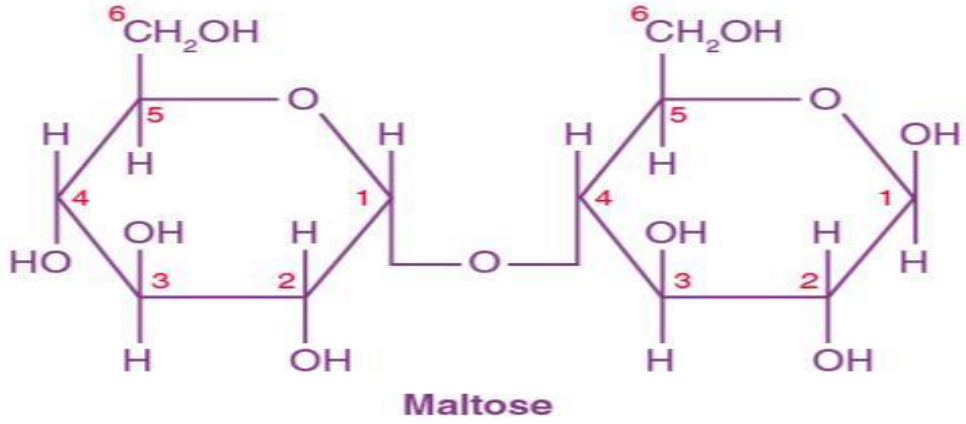
# Lactose intolerance

- People with lactose intolerance are unable to fully digest the sugar (**lactose**) in milk. As a result, they have **diarrhea**, **gas** and **bloating** after eating or drinking dairy products. The condition, which is also called **lactose malabsorption**, is usually harmless, but its symptoms can be uncomfortable.
- Too little of an enzyme produced in your small intestine (**lactase**) is usually responsible for lactose intolerance. You can have low levels of lactase and still be able to digest milk products. But if your levels are too low you become lactose intolerant, leading to symptoms after you eat or drink dairy.

# Maltose

- Maltose , also known as **maltobiose** or **malt sugar**, is a disaccharide formed from two units of glucose joined with an α(1→4) bond. In the isomer isomaltose, the two glucose molecules are joined with an α(1→6) bond.
- When beta-amylase breaks down starch, it removes two glucose units at a time, producing maltose. An example of this reaction is found in germinating seeds, which is why it was named after malt. Unlike sucrose, it is a reducing sugar.

The other disaccharides which are less commonly known are lactulose, trehalose, and cellobiose.



Maltose

- The bond that joins two alpha glucose units is called alpha 1,4 glycosidic linkage.

# Polysaccharides

- Polysaccharides are major classes of biomolecules. They are long chains of carbohydrate molecules, composed of several smaller monosaccharides.
- These complex bio-macromolecules functions as an important source of energy in animal cell and form a structural component of a plant cell.
- It can be a **homopolysaccharide** or a **heteropolysaccharide** depending upon the type of the monosaccharides.
- Polysaccharides can be a straight chain of monosaccharides known as linear polysaccharides, or it can be branched known as a branched polysaccharide.
- **Polysaccharides are categorized into two types**:

  Homopolysaccharides (Glycogen, Starch, Cellulose, Inulin)

  Heteropolysaccharides (Hyaluronic acid, Heparin, Gamma globulin etc.)

# Glycogen

- Glycogen is the stored form of glucose that's made up of many connected **glucose molecules**.
- Your body gets glucose from the food you eat (mostly from carbohydrates) and uses it as fuel for your cells. If you have extra glucose in your blood, your body stores it as glycogen for later use.
- Glycogen is a **multibranched** polysaccharide of glucose that serves as a form of energy storage in animals,fungi, and bacteria.
- It is the main storage form of glucose in the human body.

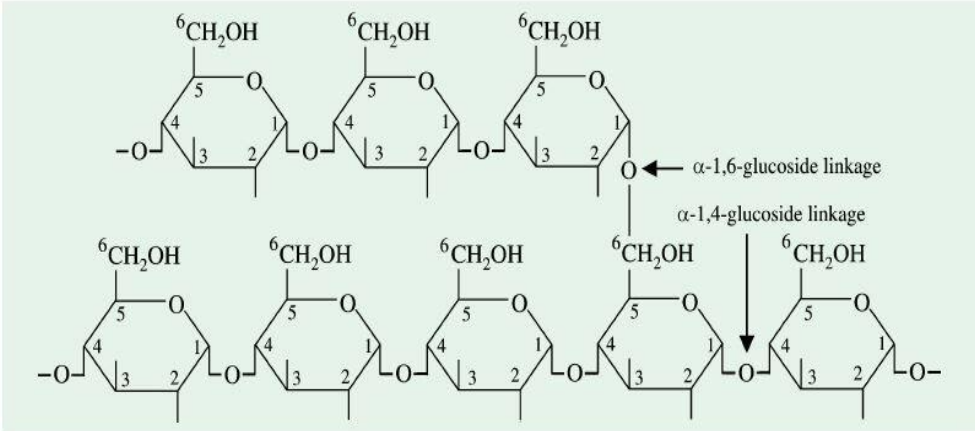
## Bonds

**Alpha-1,4 glycosidic bonds:** These bonds link glucose residues together in linear chains.

**Alpha-1,6 glycosidic bonds**: These bonds link glucose residues at branch points It's stored in the liver and muscle cells, and when animals fast, they use their glycogen reserves to maintain metabolic balance.

# Starch

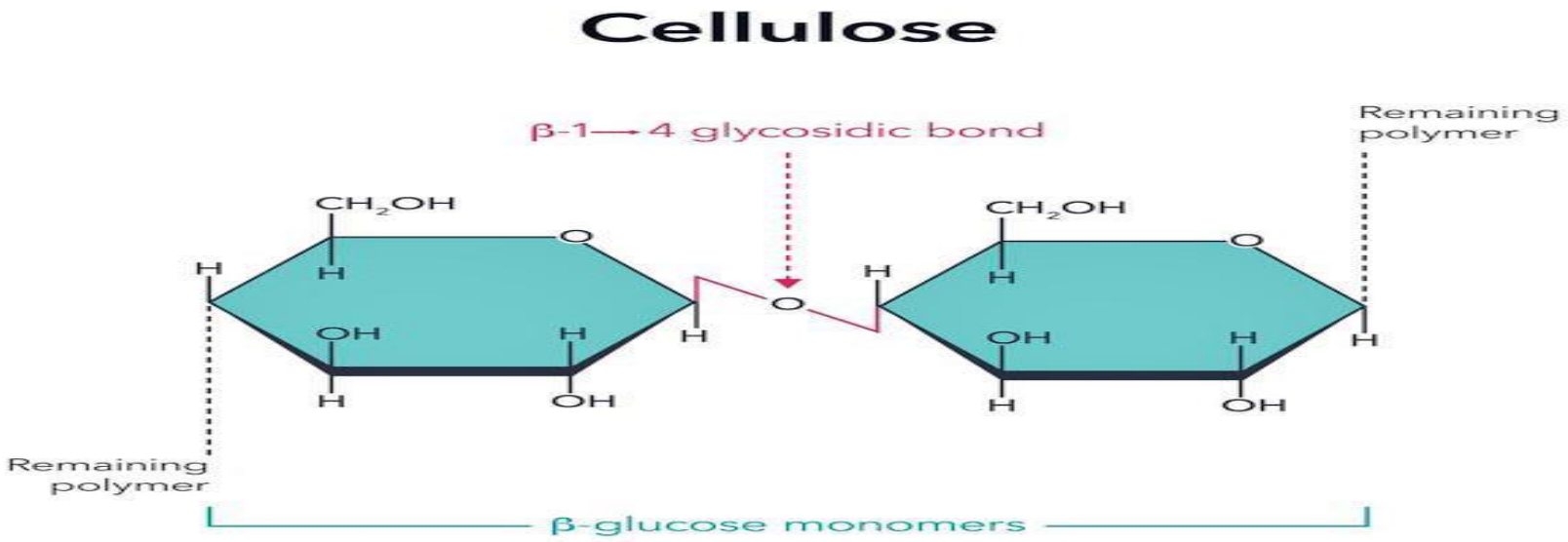
- Starch is a polysaccharide made up of 1,4 linkages between **glucose** monomers. The chemical formula of the starch molecule is $(C_6H_{10}O_5)n$.
- The linear polymer amylose is the most basic form of starch, while amylopectin is the branched form.
- The primary role of starch is to help plants in **storing energy**. In an animal's diet, starch is a source of sugar.
- **Amylase**, an enzyme contained in saliva and the pancreas that breaks down starch for energy, is used by animals to break down starch.




Structure of amylopectin (= B-fraction)

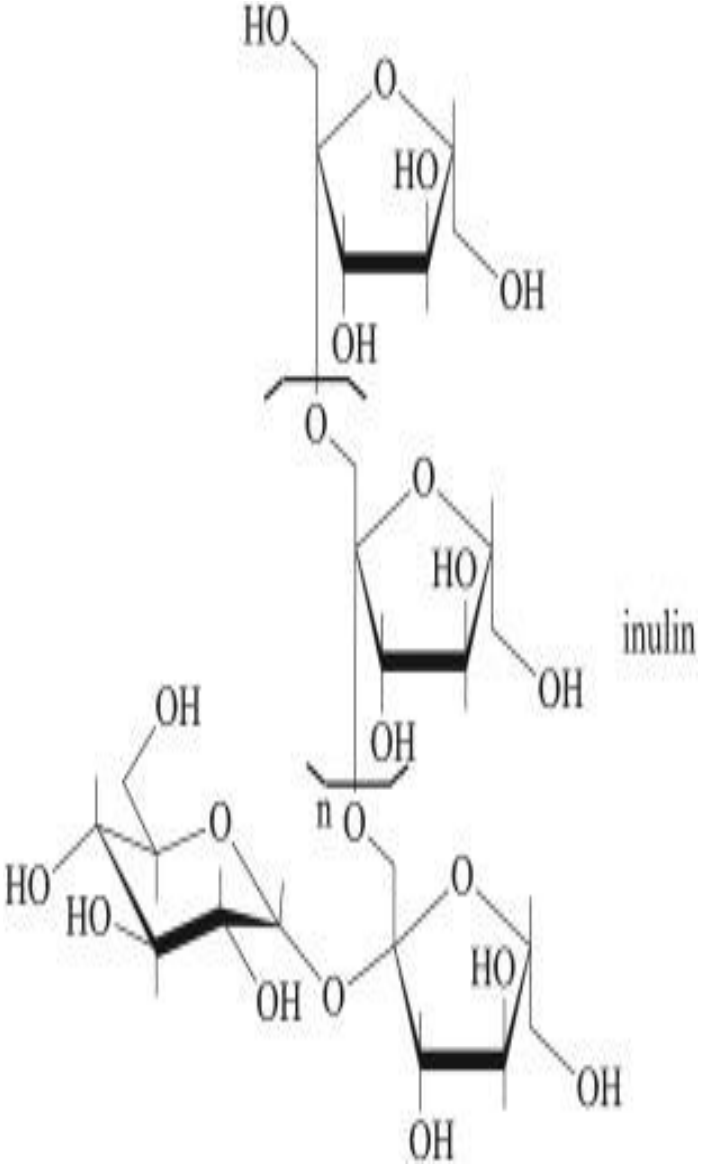
# Cellulose

- Cellulose is a complex carbohydrate and the **most abundant** organic compound on Earth. It's made up of thousands of glucose units linked together by β-1,4 glycosidic bonds.



# Inulin

- Inulins are polymers composed mainly of fructose units (fructans), and typically have a terminal glucose.
- The fructose units in inulins are joined by a β(2→1) glycosidic bond. The molecule is almost exclusively linear, with only a few percent branching.
- Inulin aids digestion by increasing the number of good bacteria in the gut, particularly Bifidobacteria and Lactobacilli. These bacteria help: fend off unwanted pathogens (bad bacteria) prevent infection.



# Hetero polysaccharides

- **Hyaluronic acid** is a naturally occurring anionic polysaccharide which are composed of **N-acetyl-D-glucosamine** and **D-glucuronic** acid, that is a component of connective tissue, skin, synovial fluid in joints, and the vitreous humor of the eye.
- **Heparin** is a linear polysaccharide made up of repeating disaccharide units of **uronic acid** and **D-glucosamine**.
- **Peptidoglycan**
- This heteropolysaccharide is made up of repeating units of **N-acetylglucosamine** a**nd N-acetyl muramic acid.**

## Characteristics of Polysaccharides

They are **not sweet** in taste.

Many are **insoluble** in water.

They are **hydrophobic** in nature.

They **do not** form **crystals** on desiccation.

Can be extracted to form a white powder.

They are **high molecular weight** carbohydrates.

Inside the cells, they are compact and osmotically inactive.

They consist of hydrogen, carbon, and oxygen. The hydrogen to oxygen ratio being 2:1.