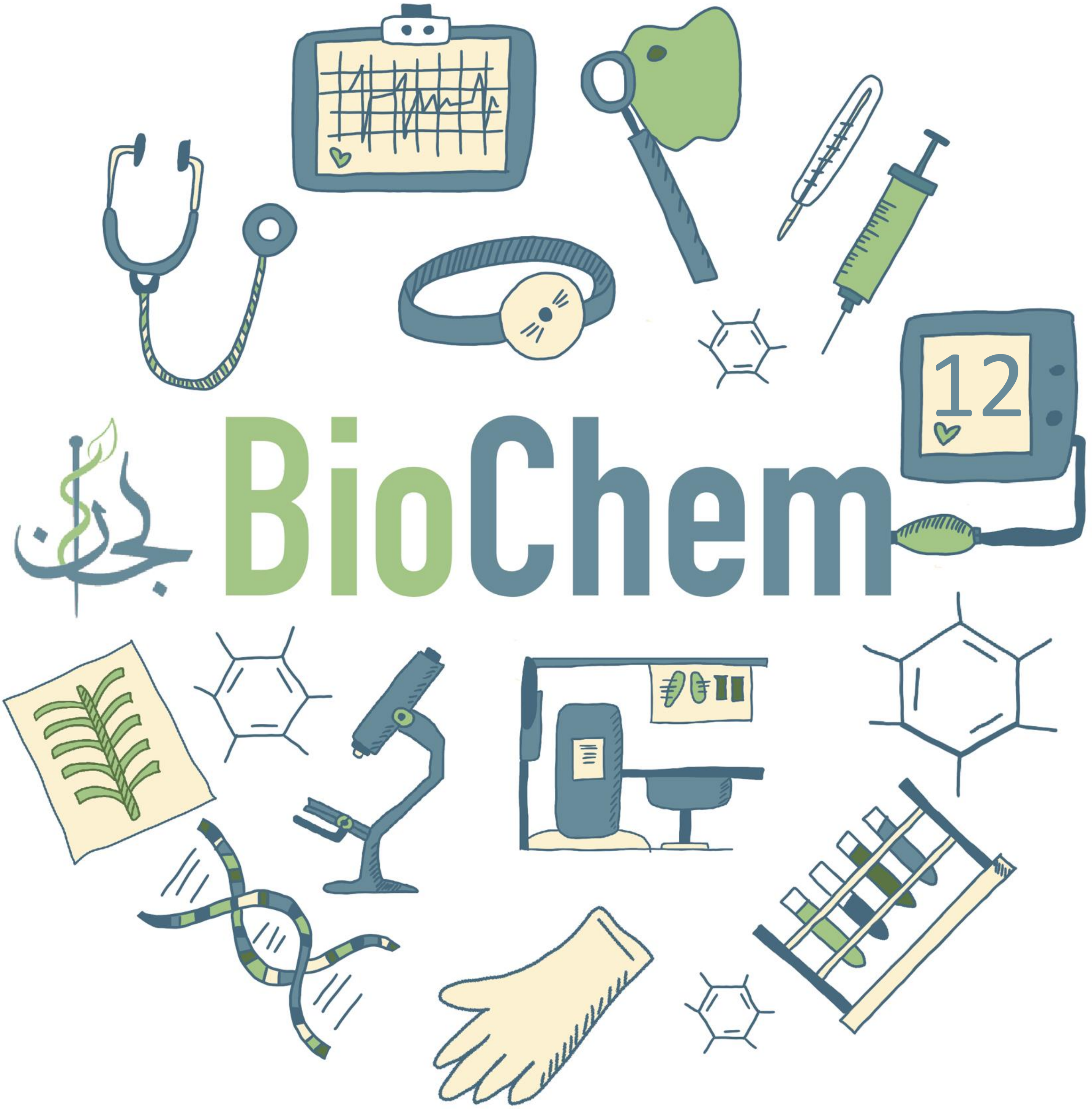


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**Science:** Moath Fateh

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# disaccharides and oligosaccharides

- **Disaccharides** are sugars that are made up of two monosaccharides connected to each other by a glycosidic bond.
- **oligosaccharides** are sugars that are made up of more than two monosaccharides (from 3 to 10).
  ** "oligo" means short, "saccharides" means sugar.

- **Hetro- vs Hemo-**
  - If the two monosaccharides are the same, we call it **hemo disaccharide**.
    As in maltose (glucose + glucose)
  - If one of the two monosaccharides is different, we call it **hetro disaccharide**.
    As in sucrose (glucose + fructose)

  *the same thing with oligosaccharides.

- **Residue**: monomer when it is part of a polymer chain (part of a large complex of similar molecules) for example:
  - each amino acid in the protein.
  - each monosaccharide in the oligosaccharide, disaccharide or polysaccharide.

  But if we have a single monosaccharide, we call it just monosaccharide.

- The formation of disaccharides is an enzymatic reaction, catalyzed by enzymes known as **glycosyltransferases**.

- The formation of disaccharides is a **condensation reaction** where the linkage of two monosaccharides results in the release of water.

- The link between two monosaccharides is very stable.

- Once you have a glycosidic bond (connection between two monosaccharides), the involved anomeric carbon doesn't undergo mutarotation, meaning that the hydroxyl group doesn't flip up and down; its attachment to the anomeric carbon is fixed.

  **Remember
  mutarotation: rotating the hydroxyl group of the anomeric carbon (from α to β and vice versa).

## Distinctions of disaccharides

Whenever you need to identify a disaccharide, you look at the residues one by one starting from the one on the left side, with certain distinctions to identify:

1. The 2 specific sugar monomers involved and their stereo configurations (D- or L-)
   - We need to define and distinguish if the residues are in the D or L stereo configuration.
   - We are not going to talk about residues in the L- configuration.

2. The carbons involved in the linkage (C-1, C-2, C-4, or C- 6).
   - We need to identify the carbons that are involved in linkage for both molecules.
   - We need to know the order of these residues starting with the one on the left.

3. The order of the two monomer units, if different (hetro disaccharide), (example: galactose followed by glucose)
   - We need to know the identity of these sugars (glucose, galactose, or fructose…..)

4. The anomeric configuration of the OH group on carbon 1 of each residue (α or β)
   - We need to identify the orientation of the anomeric carbon for both residues especially the one that is involved in the covalent bond.

**Remember: The covalent bond that involves an anomeric carbon is called a glycosidic bond.

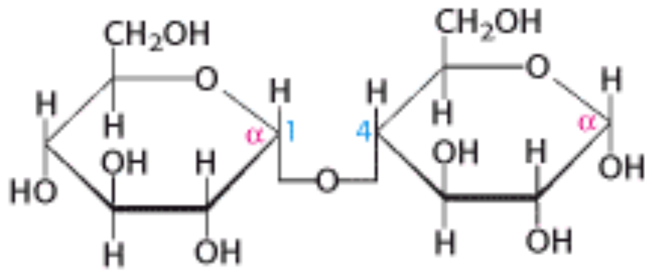
**Remember: The pyranose sugars that we've learned are three:

- Galactose
- Glucose
- Mannose

# Abundant disaccharides

## 1. Maltose (present in malt)

- The 1st residue is a pyranose, hexose sugar.
- OH groups in carbons 2,4 are going downward, while the OH in carbon 3 is going upward, so it's ***glucose*** (glucopyranose). Since it's involved in a linkage, it's called glucopyranosyl.

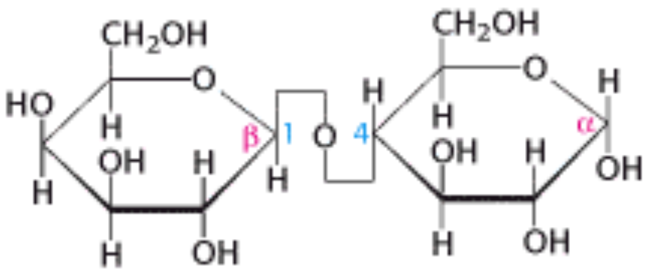


**Maltose**
**(α-D-Glucopyranosyl-(1→4)-α-D-glucopyranose**

- The OH group on the anomeric carbon is going downward, so it's in α orientation.
- The same applies to the 2nd residue.
- The glycosidic bond is between carbon 1 in the 1st residue and carbon 4 in the 2nd one.

## 2. Lactose (milk sugar)

- The 1st residue is a pyranose, a hexose sugar.
- OH group for carbon 2 going downward, while for carbons 3,4 upward, so it's ***galactose***. (galactopyranosyl) since it's involved in a linkage.
- The OH group on the anomeric carbon is going upward so it is in β orientation.

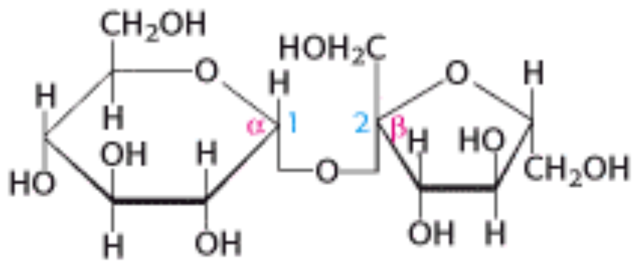


**Lactose**
**(β-D-Galactopyranosyl-(1→4)-α-D-glucopyranose**

- The 2nd residue is a pyranose, a hexose sugar. The OH group for carbons 2,4 is going downward, while for carbon 3 upward so it's ***glucose*** (glucopyranose).
- The OH group on the anomeric carbon is going downward so it is in α orientation.
- The glycosidic bond is between carbon 1 in the 1st residue and carbon 4 in the 2nd one.

## 3. Sucrose (table sugar)

- The 1st residue is a pyranose, a hexose sugar.
- The OH group for carbons 2,4 is going downward, while for carbon 3 upward, so it's ***glucose*** (glucopyranose) since it's involved in a linkage it's called (glucopyranosyl).



**Sucrose**
**(α-D-Glucopyranosyl-(1→2)-β-D-fructofuranose**

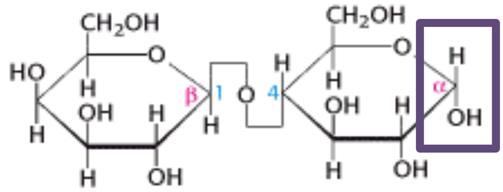
- OH group on the anomeric carbon going downward so it's in α orientation.
- The 2nd residue is a ***fructose,*** but actually a flipped fructose, so it's in β orientation.
- The glycosidic bond is between carbon 1 in the 1st residue and carbon 2 in the 2nd one

**Note**: Some sugars can reduce other molecules, while the sugar itself gets oxidized; we call these sugars reducing sugars.

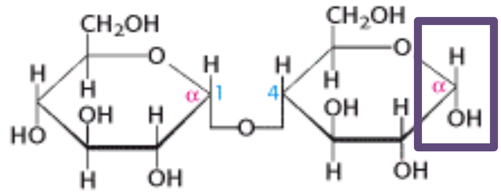
**reducing sugar** is a sugar that has a free anomeric carbon.

** all monosaccharides are reducing sugars.

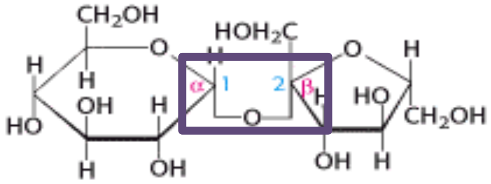
Both maltose and lactose are considered **reducing sugar** because they have a free anomeric carbon, which means that these two disaccharides can be involved in "reduction-oxidation reaction", specifically by reducing other molecules while getting oxidized themselves.



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



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

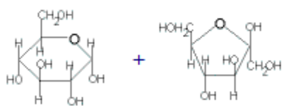
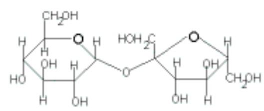
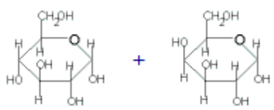
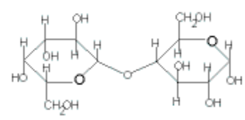
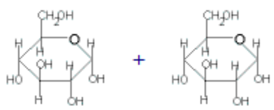
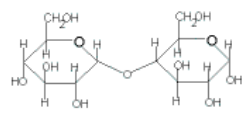


**Sucrose**
(α-D-Glucopyranosyl-(1→2)-β-D-fructofuranose

But in sucrose, both anomeric carbons are involved in the glycosidic linkage, meaning that sucrose isn't a reducing sugar.

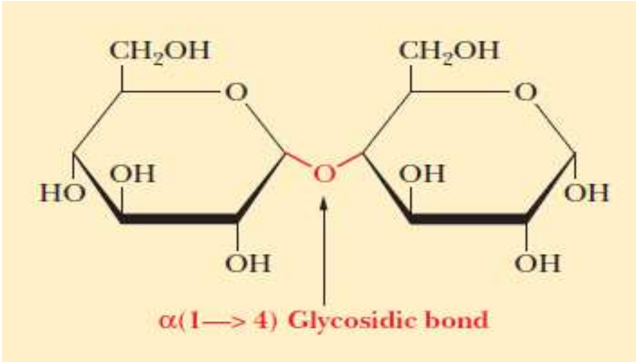
**To sum up:**

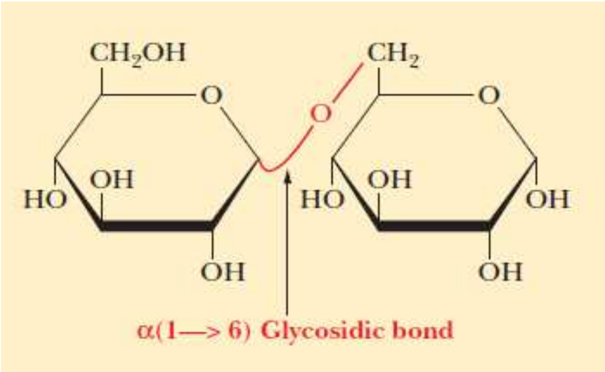
- **sucrose**:
  glucose + fructose (1-2)
  non-reducing sugar
- **lactose**:
  glucose + galactose (1-4)
  reducing sugar
- **maltose**:
  glucose + glucose (1-4)
  reducing sugar

| Name | Formula | Formed from | Structure |
|---|---|---|---|
| sucrose | $C_{12}H_{22}O_{11}$ | glucose + fructose  | ---> sucrose + $H_2O$  |
| lactose | $C_{12}H_{22}O_{11}$ | glucose + galactose  | ---> lactose + $H_2O$  |
| maltose | $C_{12}H_{22}O_{11}$ | glucose + glucose  | ---> maltose + $H_2O$  |

# Different forms of disaccharides

- Both residues are glucose molecules, so each one is glucopyranose.
- Both are in α orientation.
- The glycosidic bond is between carbon 1 and carbon 4 so it's
  α (1-4) glycosidic bond.

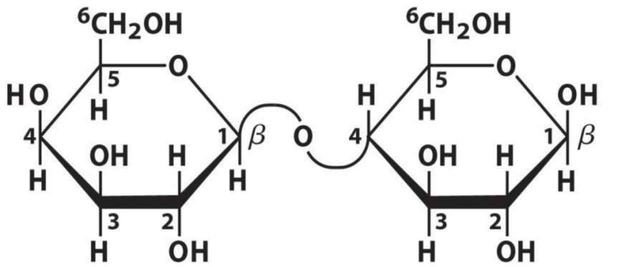


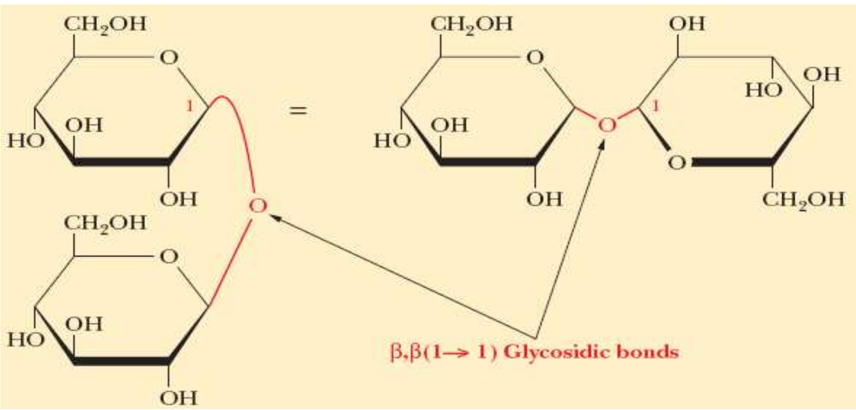

- Both residues are glucose molecules so each one is glucopyranose.
- Both are in α orientation.
- The glycosidic bond is between carbon 1 and carbon 6 so it's
  α (1-6) glycosidic bond.

It is a lactose molecule ...

- The 1st residue is a galactose molecule so it's galactopyranosyal.
- The 2nd residue is a glucose molecule so it's glucopyranose.
- The glycosidic bond is between carbon 1 and carbon 4
- Galactose molecule is in β orientation (OH upward) so it's
  β(1-4) glycosidic bond



**Lactose ($\beta$ form)**
$\beta$-D-**galactopyranosyl-(1→4)**-$\beta$-D-**glucopyranose**
**Gal( $\beta$1→4)Glc**

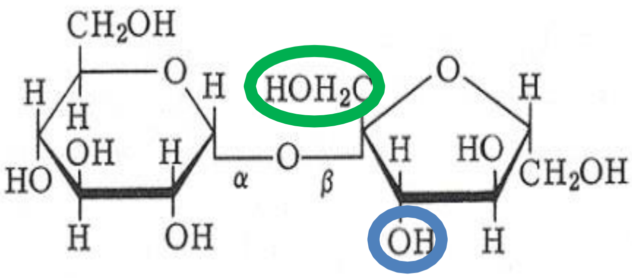


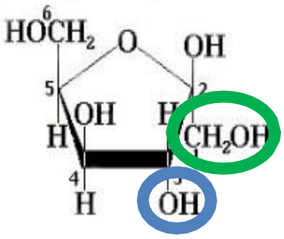

- Disaccharides of two glucose molecules.
- They can be drawn in both ways.
- The glycosidic bond is between carbon 1 and carbon 1.
- Both glucose molecules in β orientation (OH upward ) so the bond is
  β(1-1) glycosidic bond

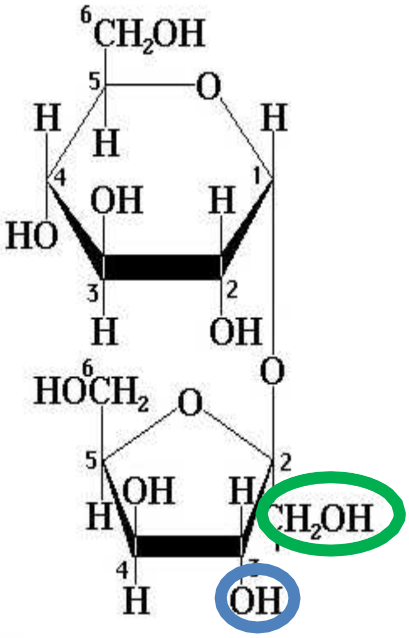
# Sucrose

These pictures show you why fructose is in the β orientation…

(If you are curious).. not important.



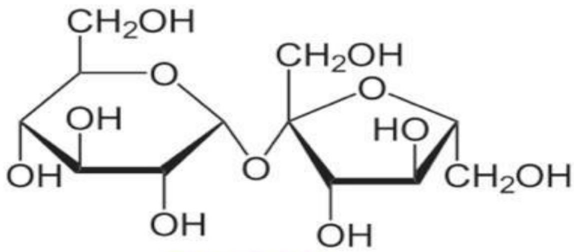




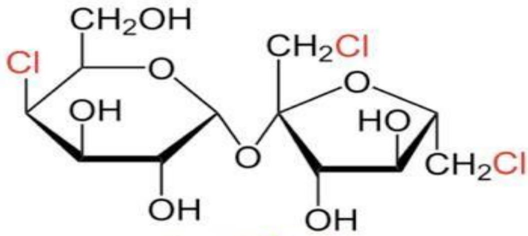
# Sucralose (artificial sweetener)

As we mentioned before Sucrose is a disaccharide made up of glucose and fructose.  It is the table sugar (white sugar) that we use to sweeten our drinks.

Because the white sugar is fattening, bad for our health in general, and harmful to our teeth, people try to avoid it and instead use an artificial, modified, unnatural sweetener scientifically called **sucralose**.



sucrose



sucralose

What is sucralose?

Sucralose is obtained by modifying sucrose. Chloride groups are added to the sucrose at specific positions, which produces **sucralose.**

**Sucralose** is an artificial sweetener that can't be consumed or digested by our bodies, so it doesn't add any Calories.

It's the basic ingredient of this marketed product known as

# Milk problems

As we mention before lactose is the sugar of milk, so milk is manly composed of lactose.

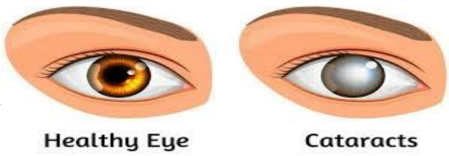
There are two medical cases associated with milk to be discussed:

1. **Lactose Intolerance**
   It occurs due to a deficiency of the enzyme lactase in the intestinal villi. This allows lactase of intestinal bacteria (instead of lactase from the human body) to digest lactose, which produces hydrogen gas, carbon dioxide, and organic acids that lead to digestive problems (bloating and diarrhea).

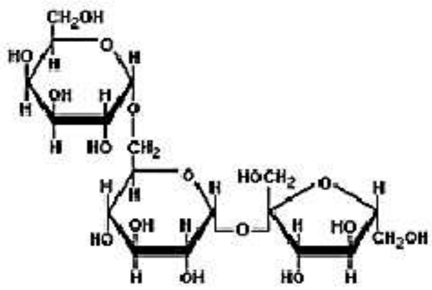
   For more clarification: In order to digest lactose we need an enzyme known as **lactase**. People with lactose intolerance don't produce enough lactase, as a result, they don't benefit from milk, as they can't digest it. Therefore, the lactose stays in their digestive system, where it's fermented by intestinal bacteria (the Flora) producing hydrogen gas, carbon dioxide, and organic acids. This results in major stomach problems such as lots of gases, which can be painful.
   As an alternative, there are some milk products that don't contain lactose, and some people take pills that to help them digest the milk.
   The efficiency of the enzyme lactase decreases with age, so older people might have trouble digesting milk. This seem a problem mainly with people living in the old world (Asia, Africa, and southern Europe)

2. **Galactosemia**
   Missing a galactose-metabolizing enzyme can result in galactosemia where nonmetabolized galactose accumulates within cells and is converted to the hydroxy sugar galactitol, which cannot escape cells. Water is drawn into cells and the swelling causes cell damage, particularly in the brain, resulting in severe and irreversible retardation. It also causes cataract.

   For more clarification: deficiency in the enzyme responsible for the metabolism of galactose, so galactose wouldn't be metabolized in our system, instead it is taken into cells and converted into hydroxyl sugar (galactitol) which is trapped inside the cells. Since galactitol can't escape cells its concentration increases inside the cells.
   Because of the higher concentration of sugar inside the cell, water gets into the cell causing cell swelling, cell damage, and death.
   That can result in **retardation** or **cataract**.



## raffinose



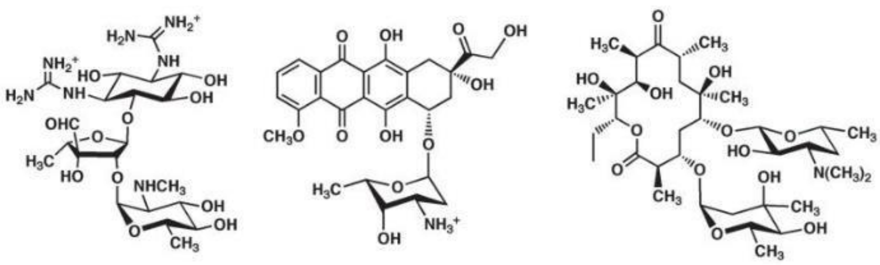
- It’s an oligosaccharide made up of three residues (trisaccharides).
- It’s found in beans and vegetables like cabbage,
  Brussels, broccoli, sprouts, and asparagus.
- We don’t have the enzyme that is responsible for metabolizing raffinose (**alpha-galactosidase**), so intestinal bacteria ferment it producing hydrogen, methane, and other gases.
  *that’s why when we eat “homos and falafel” some people, including most of us, would have trouble.

## Oligosaccharides as drugs

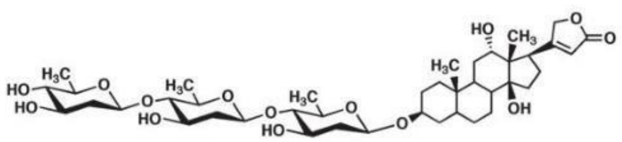
Some oligosaccharides are important because they can be used as precursors for the production of drugs.

Ex.

- ✓ Streptomycin and erythromycin (antibiotics)
- ✓ Doxorubicin (cancer chemotherapy)
- ✓ Digoxin (cardiovascular disease)



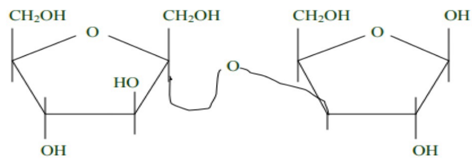
Streptomycin Doxorubicin Erythromycin A



Digoxin

**Allah Ma3akom** ☺

The following disaccharide is named D-fannose



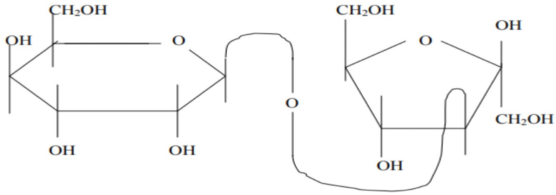
1) This structure

a) is α-D-fannose containing an epimer of D-fructose.
b) is α-D-fannose containing an epimer of D-ribose.
c) is β-D-fannose containing an epimer of D-ribose.
d) is β-D-fannose containing an epimer of D-fructose

2) What type of glycosidic bond exists in this disaccharide?

a) β 1,3
b) β 2,3
c) α 1,3
d) α 2,3

The following disaccharide is named D-avatose



3) What monosaccharides will be produced upon acid hydrolysis of D- avatose?

a) D-galactose and D-fructose
b) D-galactose and an epimer of D-fructose
c) an epimer of D-galactose and an epimer of D-fructose
d) D-fructose and an epimer of D-galactose

4) This structure

a) is α-D-avatose which contains a β 1,3 glycosidic bond.
b) is α-D-avatose which contains a β 1,2 glycosidic bond.
c) is β-D-avatose which contains a β 1,3 glycosidic bond.
d) is β-D-avatose which contains a β 1,2 glycosidic bond:*

5) which of the following can't be linked with drugs ?

A) streptomycin
B) erythromycin
C) doxorubicin
D) digoxin
E) none is correct

# ANSWERS

| Q1 | Q2 | Q3 | Q4 | Q5 |
|---|---|---|---|---|
| C | D | D | C | E |