Doctor 022

Biochemistry

Sheet no. 7

Writer: Al-Razi Node Team

Corrector: Al-Razi Node Team

Doctor: Dr.Diala, Dr.Mamoun

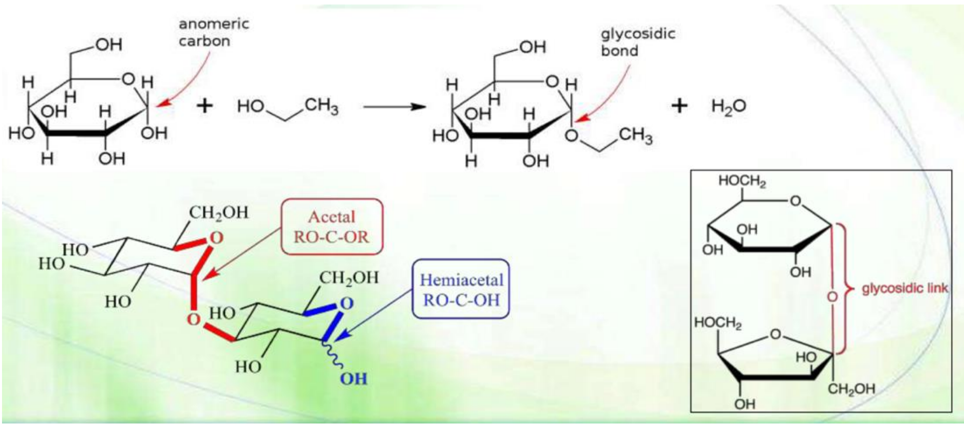
The formation of glycosides:

In the previous lecture we talked about several modifications of sugars, such as oxidation, reduction, and esterification.
For today's lecture we are going to discuss another type of sugar modification which is the formation of glycosides. A glycoside is any molecule by which a sugar group is bonded through its anomeric carbon to another group (such as another sugar group) via a glycosidic bond.

What is the reacting functional group? Where does it react? What are the end products? Where are they used?

How can they react?

The first sugar interacts through its anomeric carbon (aldehyde, ketone), while the second sugar interacts with the hydroxyl group as an alcohol.
The first sugar acts as a hemi (acetal, ketal), and the second sugar acts as an alcohol. For simplicity, we will use ethanol as an example.



—Read the bullet points below to understand the image—

- **The connection between the anomeric carbon and the alcohol occurs through a chemical reaction called glycosidic bond formation by which OR replaces the OH in the acid (R= the sugar with the anomeric carbon). This reaction involves the loss of a water molecule (H_2O: -OH from the alcohol or the sugar which acts as an alcohol in the reaction, and H+ from the atom attached to the anomeric carbon in the other sugar molecule) and the formation of a covalent bond between the two sugars.**

- **Specifically, the anomeric carbon, which is the carbon atom that is a part of the hemi (acetal or ketal) group, reacts with the hydroxyl group** of the second sugar. This reaction results in the formation of a **glycosidic bond**, which joins the two sugars together.

- The formation of the glycosidic bond is typically catalyzed by enzymes or through chemical reactions under specific conditions. It is an important process in the synthesis of various complex carbohydrates, disaccharides, and polysaccharides in living organisms.

- Glycosidic bonds which occur through oxygen are referred to as O-glycosides. The process of forming glycosides involves the transfer of the hemi(acetal/ketal) to acetal/ketal.

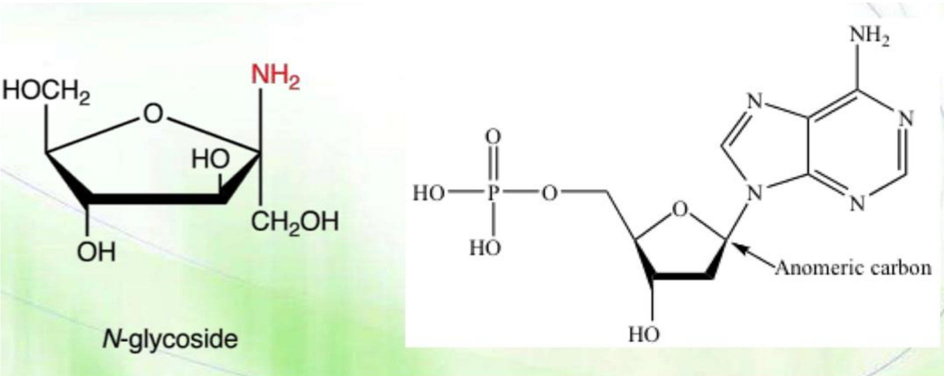
- The first sugar interacts through its anomeric carbon, while the second sugar interacts through the hydroxyl group as a regular alcohol. It is possible to find two sugars interacting with each other through their anomeric carbons. We will discuss this phenomenon later on.

N- glycosides:

- What is the reacting functional group?
- Where does it react? What are the end products?
- Where are they used?

-Examples: nucleotides (DNA and RNA).

(N)" refers to a connection through nitrogen, and the figure below provides examples with:



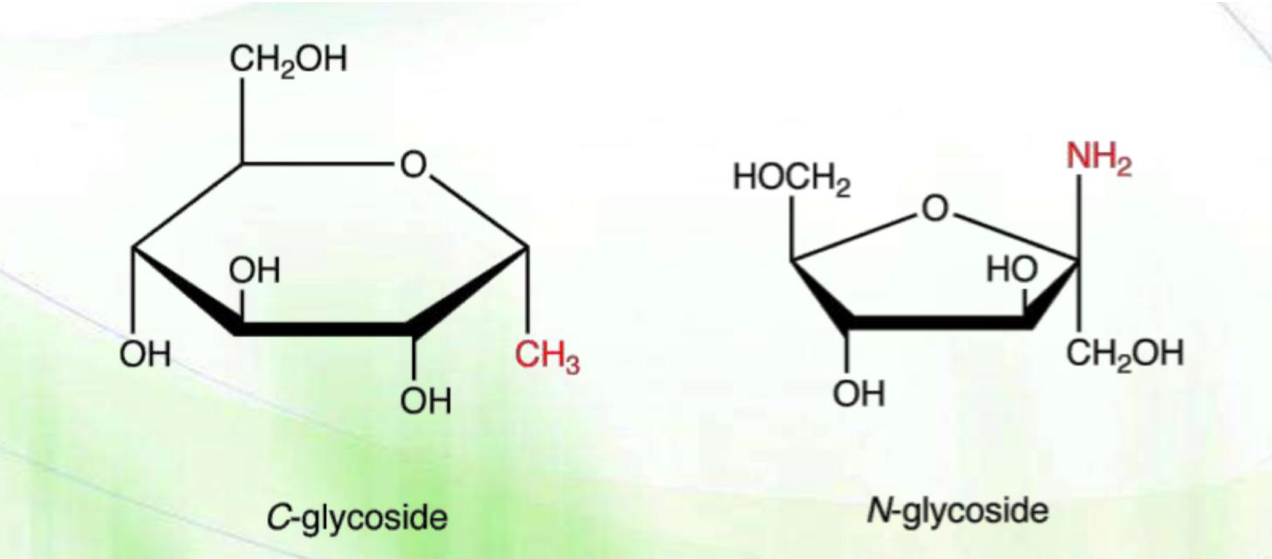
—NH_2–   —Nitrogenous base—

There is another type of glycosides known as C-glycosides, which are classified based on the carbon atom acting as the connection point between the sugar and another molecule or another sugar.

It is not mandatory(essential) for the connection to be with sugars; it can involve different molecules such as NH2, as we mentioned previously.

Note:

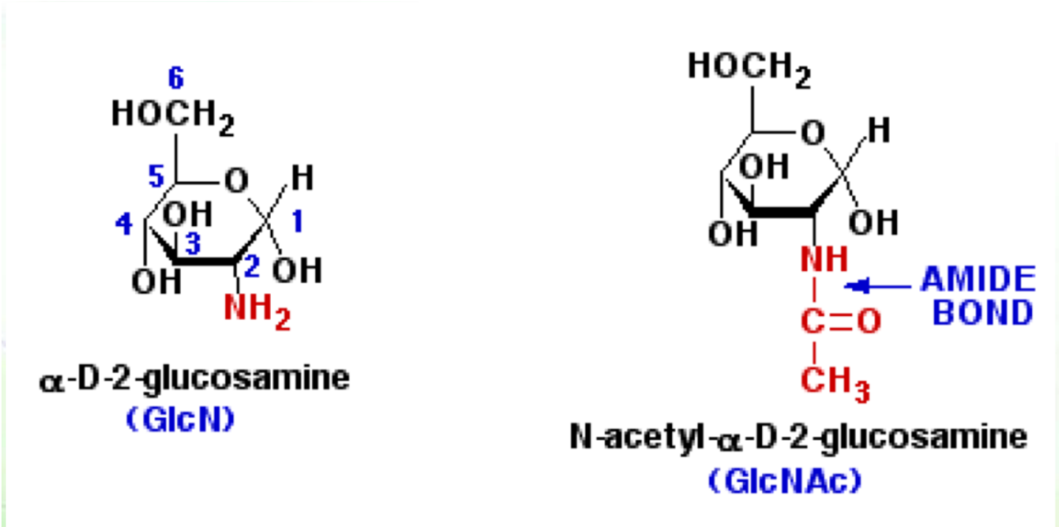
- Glycosides derived from furanoses are called furanosides, and those derived from pyranoses are called pyranosides, regardless if they are N- or O- linked.



Amination of sugers(formation of amino sugers) :

The last modification we will discuss is the amination of sugars.

- **What is the reacting functional group? Where does it react? What are the end products? Where are they used?**
- **Further modification by acetylation .**



The main goal of this process is to form more polar sugars that can be utilized in various locations, functions, and pathways **(in cellular physiological conditions the carboxylic group (—COOH) loses its proton becoming carboxylate(—COO^-), and the amine group (—NH_2) accepts proton becoming alkylammonium (—NH_3^+))** **.**

Specifically, amino sugars are important components of the extracellular matrix, particularly as constituents of glycosaminoglycans.

- **Structure: GAGs are composed of repeating disaccharide units (GAGs are polysaccharides). Each disaccharide unit consists of an amino sugar (either glucosamine or galactosamine) and a uronic acid (such as glucuronic acid or iduronic acid). The disaccharide units can undergo further modifications.**

- **Diversity: There are several types of GAGs, including heparan sulfate, chondroitin sulfate, dermatan sulfate, keratan sulfate, and hyaluronic acid. Each type has a specific pattern of disaccharide units and different functions in the body.**

The doctor described the amino sugars location as being on brush-like bristles, which we will discuss in more detail later.
As their modification increases ➔they become more polar ➔leading to a stronger attraction to water molecules.

The formation of a gel-like structure by glycosaminoglycans can serve as a shock absorber and also function as a pressure sensor. This gel-like structure possesses viscoelastic properties, allowing it to absorb and distribute forces, thereby acting as a cushion or shock absorber in various tissues. Additionally, the structure can sense changes in pressure and transmit these signals to cells, enabling them to respond appropriately to mechanical stimuli.

One of the crucial positions for adding an amine group to the sugar molecule is carbon number 2 (C2) in glucose and galactose. For instance, the addition of an amine group to galactose results in the formation of galactosamine (or 2-galactosamine), while adding an amine group to glucose yields glucosamine (or 2-glucosamine), and so on.

By acetylating this amino group, additional functional group can be introduced. When acetic acid reacts with the amino group, it forms an amide bond, resulting in the molecule known as N-acetyl-alpha-D-glucosamine (GlcNAc) as can be seen from the image above. GlcNAc is commonly found in glycosaminoglycans (GAGs) and serves as a building block for their synthesis, providing structural diversity and functional properties to the GAG molecules.

Note:
to differentiate between amino sugars and N-glycosides:
A modified sugar molecule can be considered
N-glycoside when an amine group (such as purines, pyrimidines or just ammonia) is attached to the anomeric carbon in the monosaccharide.
But when an amine group is attached to any carbon other than the anomeric carbon, then the modified sugar is considered an amino sugar

Disaccharides:

-now after we finished examining monosaccharides (simple sugars), we move to more complex sugars, which are disaccharides

-Disaccharides are composed of two simple sugars (The prefix di- is of Greek origin and means " two, double, twice, twofold ") **,from a reaction by which two sugars reacted , the first sugar reacted by its anomeric carbon , and the second sugar reacted by its normal carbon as an alcohol (by its OH group.** note that it's not an alcohol, it just reacted as an alcohol**) forming an O-glycosidic linkage.**

-Different sugars can make a large number of disaccharides, but we will focus on a few numbers of them (this doesn't mean that they are the only ones).

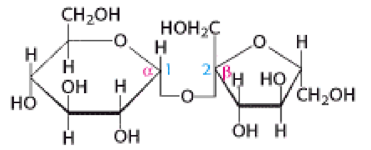
-now, what determines the disaccharide?

- **The 2 specific sugar monomers (monosaccharides) involved and their stereoconfigurations (D- or L-)**
- **The carbons involved in the linkage (C-1, C-2, C-4, or C-6)**
- **The order of the two monomer units, if different (example: galactose followed by glucose)**
- **The anomeric configuration of the OH group on carbon 1 of each residue (α or β)**

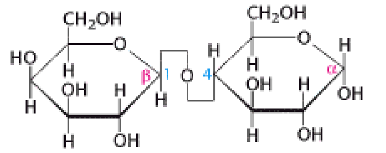
The type of disaccharide is determined by the orientation of the two sugars, between which two carbons is the linkage and the type of monomers in the disaccharide, are those monomers the same or different? (Note that if the monomers are the same, for example: glucose +glucose, we call it a Homo-disaccharide and if the monomers are different we call it a Hetero-disaccharide).

based on that the disaccharide, its properties and its functions are determined.

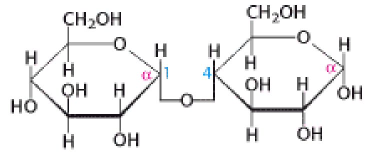
-note that all disaccharides have the same main type of linkage (o-glycosidic), but the difference is which two carbons are linked and is the linkage α or β.



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



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



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

Most abundant disaccharides:

-Now let's examine the three most important disaccharides.

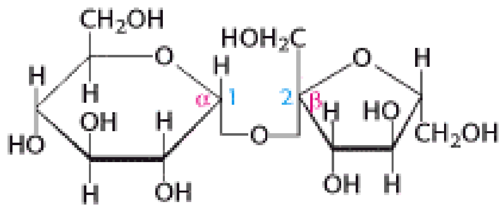
1. <u>Sucrose</u>: (common table sugar)

2. <u>Lactose</u>: (milk sugar)

3. <u>Maltose</u>: (malt sugar, found in any fermented substance)

-now let's examine the properties of each one of them:

<u>1. Sucrose</u>: (we get sucrose from sugarcane) it is composed of <u>D-glucose</u> and <u>D-fructose</u> (as noted by the doctor all sugars in the human body are D sugars) , the linkage is between the carbon number 1 (which is α) of glucose and the carbon number 2 (which is β) of fructose (note that the fructose ring in the figure in flipped so carbon number 2 is on the left) , and the linkage is from the same side (below).



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

So, the bond is called <u>α (1,2) linkage</u>, because the first monosaccharide (glucose in here) is alpha connected.
Or <u>anomeric (1,2) linkage</u> (anomeric because both carbons are anomeric)

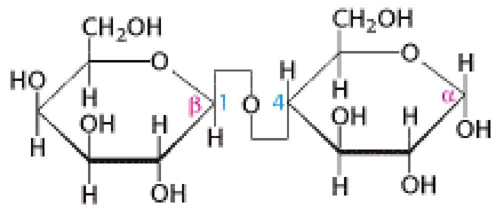
-Note the systematic name below the common name in the image above

-As we studied earlier , anomeric carbon is the easiest carbon to oxidize (because it's a one-step reaction➔as it can be oxidized directly from aldehyde to carboxylic acid) , but if you look closely to the sugars making the sucrose, you will notice that the anomeric carbon of each building sugar is linked to the other , which makes them occupied and unable to be oxidized (the bond is a covalent bond which is very strong) , according to this we call sucrose a non-reducing sugar (because when a molecule or an atom gets oxidized it also reduces another molecule or atom , so because sucrose cant be oxidized, therefore it can't reduce and can't work as a reducing agent)

-Sucrose has moderate sweetness, between fructose (which is super sweet!) and glucose (mild sweetness)

-Artificial sweetness use very sweet sugars, so the person using it will feel the sweetness even by using few sugars amounts.

2. Lactose: it is composed of D-galactose and D-glucose, the linkage is between carbon number 1 of galactose (which is β) and carbon number 4 of glucose (which is bonded to a hydroxyl group oriented in the opposite direction from the galactose's hydroxyl group) so it is called β (1,4) linkage , and the linkage is from opposite sides (upward from the galactose and downward from the glucose)



Lactose

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

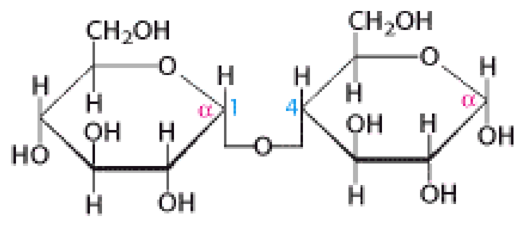
-Note the systematic name below the common name.

-Unlike sucrose, lactose can be oxidized because the anomeric carbon of glucose is free and therefore it can be oxidized, so it can work as a reducing agent, and it can be called a reducing sugar.

-Now regardless if the bond is on the same side or on the opposite side, it can be digested by the human digestive system in the small intesine (sucrose by sucrase, lactose by lactase and maltose which we will study next by maltase)

-We need those enzymes because human body (cells) can't absorb disaccharides (or to be exact, it can't absorb any thing more complex than monosaccharides) in its form, so it must be broken down to monosaccharides (simple sugars).

3. Maltose: it is composed of two D-glucose molecules the first connected by its carbon number 1 (which is α) and the second by its carbon number 4 (which is bonded to a hydroxyl group oriented in the same direction as the hydroxyl group in the other glucose monomer) , the linkage is at the same side (from below , which looks like the number 7 in Arabic) , this bond is called α (1,4) linkage.

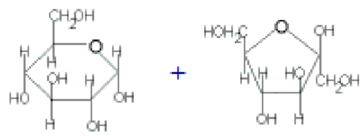
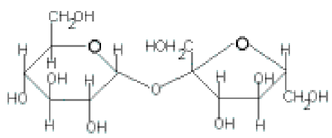
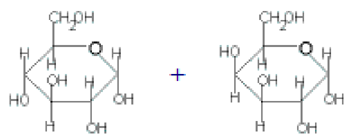
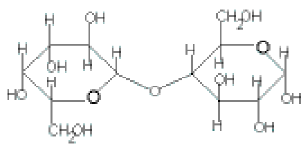
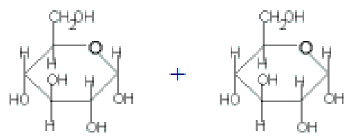
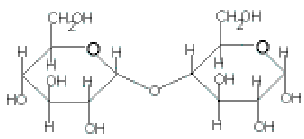


Maltose
(α-D-Glucopyranosyl-(1→4)-α-D-glucopyranose

-Note the systematic name below the common name.

-Unlike Sucrose, Maltose can be oxidized because the anomeric carbon of glucose is free and can be oxidized, so it can work as a reducing agent and therefore it can be called a reducing sugar.

Note: the monosaccharides alone are relatively easier to oxidize compared to lactose and maltose, because these disaccharides have a covalently bonded anomeric carbon in addition to the free anomeric carbon.

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  الدكتورة حكت انه الأصح ينحط الغالاكتوز بالأول	---> lactose + H_2O 
maltose	$C_{12}H_{22}O_{11}$	glucose + glucose 	---> maltose + H_2O 

- The

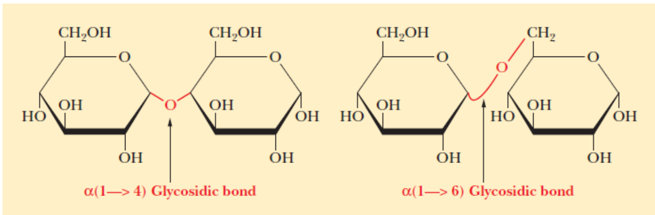
Reaction of the formation of the glycosidic linkage which makes disaccharides is a dehydration reaction , a Hydrogen ion (+H) is eliminated from one sugar

and a hydroxyl group (OH-) is eliminated from the other molecule , which means we eliminated a water molecule (H2O) , these type of bonds which are created by eliminating a water molecule can be broken or disturbed by hydrolysis (the addition of water) ,but usually water alone isn't enough and we need enzymes that are found in the digestive system.

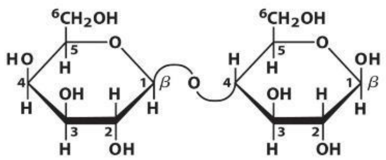
-As we mentioned earlier those are not the only disaccharides but rather the most important ones, we have diverse disaccharides because we can have different types of bonds for the same monomers, for example:

. The glycosidic bond in (glucose+glucose) can be:

. α (1,4) or α (1,6).

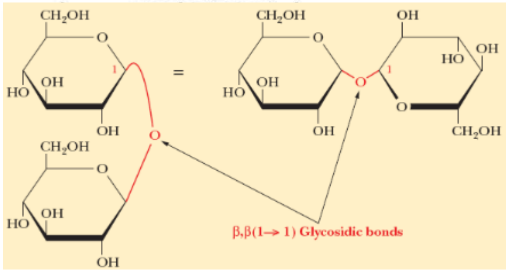


. It can be β (1,4).



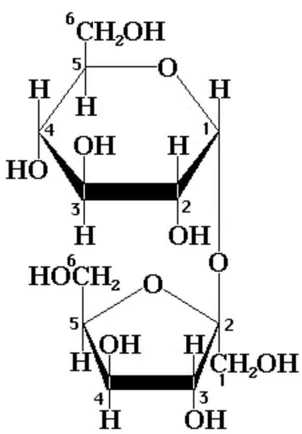
Lactose (β form)

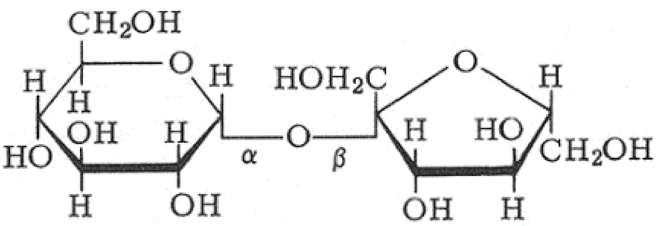
. And It can be β (1,1).

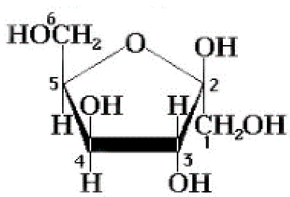


-(and each of these bonds will give a uniqe disaccharide)

-Sucrose can be represented by two ways to show the bond between the two anomeric carbons, the fructose can either be flipped so the anomeric carbon will face the other anomeric carbon , or it can be placed bellow the glucose so the anomeric carbon will be below the other anomeric carbon , and therefore by either representation the bond can be shown .



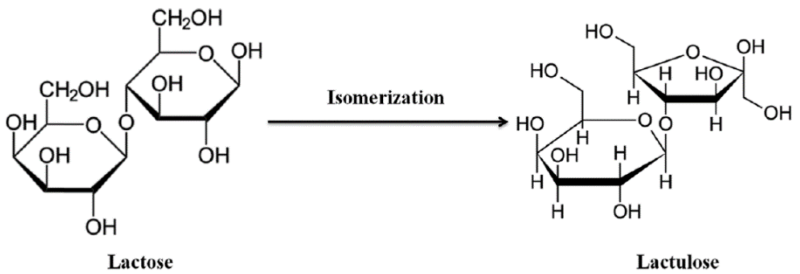




Applications on Disaccharides

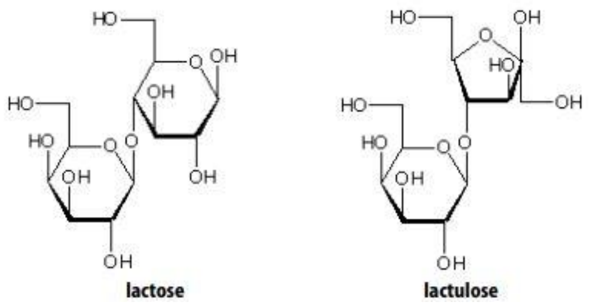
-Now let's look at some applications in medical fields regarding Disaccharides:

1. Lactulose: It is formed by the isomerization of lactose either chemically or enzymatically.



-The figure might be complex at first look, but just note the important differences and that lactose underwent isomerization.

-Carbon number 5 moved out of the ring and is now connected downwards to carbon number 4, while the hydroxyl group (OH-) is now upward to carbon number 4 instead of downwards.



-Lactulose has some health benefits:

1. It is used in treating constipation by increasing water absorption in the colon.

- (This figure is from the internet and not from the slides, but I felt that it was more simple and easier to note the differences in it.)

-when we consume Lactulose, just like most molecules, it will reach the intestine where the enzyme lactase will recognize the differences (the differences between lactose and lactulose) and will be unable to digest it to simple sugar, and as humans we don't have enzymes specific for lactulose, so it will remain a disaccharide(and if you remember the human body can't absorb disaccharides) which will not be absorbed and therefore accumulates in the intestine. Lactulose will act as a solute, increasing the osmotic pressure inside the intestine, and because Lactulose can't be absorbed and transported, water will move through the walls of the intestine towards the intestine to dilute the lactulose and decrease the osmatic pressure, therefore returning it to normal levels. This process will increase the levels of water inside the intestine, which in turn will increase its output(excretions) and make it more watery (more loose), treating constipation.

2. It promotes the growth of health-promoting gut bacteria.

-Lactulose also provides a healthy environment for gut bacteria (essential bacteria in the human digestive system), which uses Lactulose as an energy source (The interaction between these bacteria and the contents of our body is what maintains our health).

3. It increases the production of small-chain fatty acids and the removal of toxic ammonia.

-If ammonia toxins reach our body through Pesticides and fertilizers, Lactulose can help the human body get rid of it and remove it (as we discussed earlier, it stimulates the intestine and treats constipation, so toxins will not spend a significant amount of time inside the intestine, therefore very few toxins will be absorbed by the intestine and most of it will be Excreted outside the body)

4. It modulates the immune system.

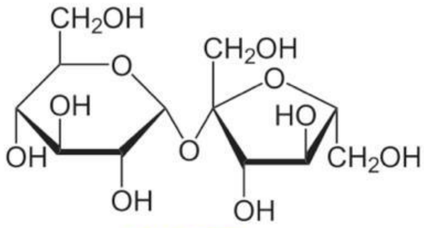
-It does so by getting rid of bacteria and microbes inside the intestine (by the same mechanism of removing toxins).

-Because the digestive system (gastro-intestinal tract) is a system that is exposed to the outer environment, it's susceptible to invasion (unlike blood which is relatively unexposed or unopened to the environment surrounding the body).

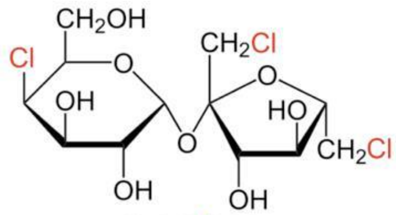
2.Sucralose (artificial sweetener)

-It is formed by the addition of (cl) at different sites on the sucrose molecule.

-It is very close to the structure of sucrose and very sweet.



sucrose



sucralose

-A very recent study (2023!) showed that sucralose leads damages DNA and leads to a leaky Gut (The doctor didn't focus on it, but here is a brief explanation if you are interested,

Leaky gut, also known as increased intestinal permeability, is a condition that refers to a compromised or damaged intestinal lining. The intestinal lining is naturally designed to function as a barrier, selectively allowing nutrients and beneficial substances to pass through while preventing harmful substances from entering the bloodstream. However, in the case of leaky gut, the tight junctions between the cells of the intestinal lining become loose or damaged, leading to gaps or "leaks" in the barrier.)

Sucralose, a Common Artificial Sweetener, May Increase Cancer Risk

News > WebMD Health News

Sucralose Damages DNA, Linked to Leaky Gut: Study

Lisa O'Mary
June 01, 2023

WebMD

Milk problems

1) **Lactose Intolerance: A deficiency of the enzyme lactase (due to a reduction in its amount or a reduction in its activity) in the intestinal villi. So, when you drink milk that contains lactose, this lactose is not going to be digested and it will not be absorbed leading to its accumulation in the intestine which is going to increase the osmotic pressure in the intestine which attracts H2O molecules towards the intestinal lumen which causes diarrhea.**

Accumulation of lactose in the intestine → osmosis and attraction of H20 molecules → Diarrhea.

In addition to that, the Normal flora (a type of bacteria which lives in our intestinal tract) will use the accumulated lactose by metabolizing it, and the metabolize it producing side product, such as: H_2, CO_2, CH_4 and other gases which is going to cause bloating.

Some books say that reduction in lactase amount or activity is caused by aging while other books say that it's due to decrease in number.

1 cup of milk contains around 9 grams of lactose which is going to absorb around 1L of H20 to the intestinal lumen.

Is this intolerance considered a disease? NO it is not, this is actually normal for elderly people as the enzyme's activity decreases by aging.

The activity of the enzyme lactase is at its highest level in babies (less than 6-7 years old).

In kids which are 6-7 years old or more, the activity of the enzyme lactase is almost the same level as in adults (and of course the enzymatic activity varies from individual to another).

Instead of milk you could eat cheese or yogurt to get calcium. And you could use the sunlight to get vitamin D.

Note that yogurt undergoes certain processingg procedures when synthesizing it which make it different than milk.

What about teeth? How is milk important for our teeth?

Actually, when the teeth are developing in the jaw (milk teeth) they need calcium (they complete their development a few years before they come out). After the completion of teeth development, calcium no longer becomes important. Instead, fluoride is what actually improves and strengthens the teeth at that point. That's why elderly people (or adults) don't need to drink milk for their teeth.

Extra info: For lactose intolerant people who can't give up milk:

There is <u>lactose free milk</u>, or <u>lactase supplemented products</u> in order to digest.

2) **Galactosemia: this is an <u>inherited genetic disease</u> that is caused due to the deficiency of a <u>galactose-metabolizing enzyme</u> in cellular galactose-degradation pathway.**

   ⇨ **What happens to patients with galactosemia?**

   Once the galactose gets into the body and gets absorbed into the cells (as a monosaccharide) the cells can't benefit from it. as a result, galactose accumulates in the cells, leading to a high concentration of

galactose within the cells, at this point the galactose is going to be transformed into polyalcohol (galactitol) which cannot use the same protein transporter of galactose to exit the cell. The increased concentration of galactitol in the cells leads to high intracellular osmotic pressure, causing water (H_2O) to be absorbed, resulting in cell swelling and eventual cell rupture or explosion.

Note: monosaccharides are mainly acquired in our body from various sugar sources (such as disaccharides, polysaccharides, etc.…) rather than their pure form. Remember, sugars cannot enter the cells in any form other than monosaccharides, which means that disaccharides, oligosaccharides, and polysaccharides must be hydrolyzed so that their monosaccharide components enter the cells.

- One of the most affected cells due to this disease *are* the neuronal cells (resulting in severe and irreversible retardation).

Recall that galactosemia is a genetic disease➔ which means it accompanies humans when they are born➔ so it makes sense that one of the most affected cells are the neurons.

-Another type of cells that will be mostly affected by galactosemia are the lens cells (which make up the transparent lens of the eye.).
When the lens cells die and rupture, they will release their cellular debris which in turn will affect the transparency of the eye lens, as they will stain it with the color white. So, lens lose their ability to transmit light as the lens is filled with white liquid (cellular debris) which we call cataract (the cloudiness of the eye lens).

Note: Allergies to milk are hard to diagnose➔ as it is hard to detect which component of the milk causes the allergic response in the individual.

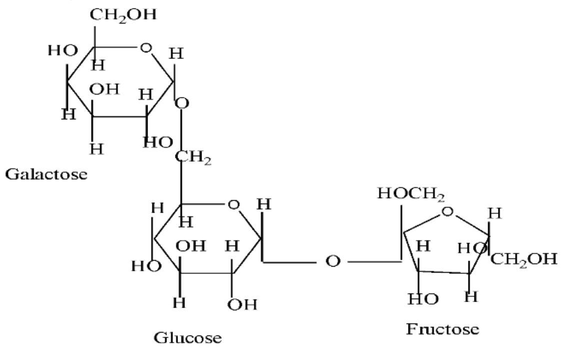
Note: some types of milk allergies are temporary and other types are lifelong allergies.

Note: the carbohydrates we acquire can be used in our cells in anabolic pathways to synthesize various bodily carbohydrates (or organic compounds that aren't carbohydrates).
For example: ECM components such as GAGs, or the lactose in the breast milk which is synthesized in the mammary glands.

Oligosaccharides

Raffinose: it is found in beans and vegetables like cabbage, Brussels, sprouts, broccoli, and asparagus.

All of these contain galactose, glucose, and fructose (raffinose components which is a trisaccharide)



Note that the bond between Galactose and Glucose is (1-6 bond)

While the bond between Glucose and Fructose is (1-2 bond)

Humans lack the alpha-galactosidase enzyme that is needed to break down raffinose, but intestinal bacteria can ferment it into hydrogen, methane, and other gases.

Note: raffinose causes bloating in the intestinal tract.

➔which causes intestinal bloating

Note: this is not a mutation nor a disease, all human beings lack this enzyme that breaks down this alpha-glycosidic bond.

⇨ **Two reasons why raffinose cause bloating:**

1) **The alpha (1-6) glycosidic linkage between galactose and glucose can't be broken because-as humans- we lack the enzyme which digest it, so the sugar accumulates in the intestinal lumen, which will increase the osmotic pressure there, then it will attract water.**
2) **The bacteria in our intestinal tract utilizes it in its metabolism and then release gases such as carbon dioxide, methane, etc.…**

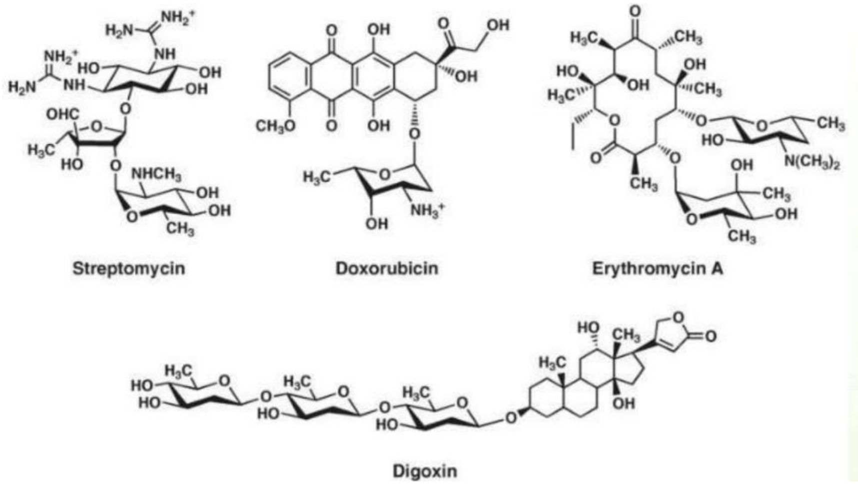
Note: our body also doesn't have enzymes which digest beta (1-4) glycosidic linkage between two glucose molecules as in the polysaccharide cellulose (we don't have cellulose).

Oligosaccharides as drugs (medications)

We are going to discuss oligosaccharides which are drugs or medications that we don't obtain from dietary sources.

An example of oligosaccharides that can be used in drugs (or drugs that contain sugar rings and have a structure very similar to sugars, and so can be considered as oligosaccharides):

1) **<u>Streptomycin and erythromycin</u> which are antibiotics.**
2) **<u>Doxorubicin</u> (cancer chemotherapeutic agent).**
3) **<u>Digoxin</u> (cardiovascular disease drug).**



You don't have to memorize their structure :)

Polysaccharides (hundreds to thousands to millions of residues)

Polysaccharides can be made of the same repeated residue (<u>homopolysaccharide</u> or homoglycan), or they can be made of several different residues (<u>heteropolysaccharides</u>).

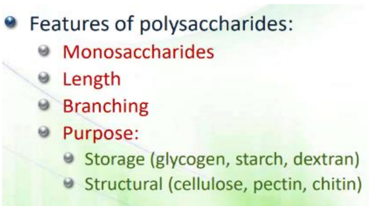
other ways to differentiate polysaccharides:

- The type of linkage between these residues, it could be alpha or beta.

- What are the atoms connected together? Could be 1-2,1-4, or 1-6, And so on...

- Are there branches or not? Is it just linear chain or are there branches?

- The function or purpose of the polysaccharide➔it could be storage molecule (such as starch or glycogen) or a structural molecule (such as the cellulose).

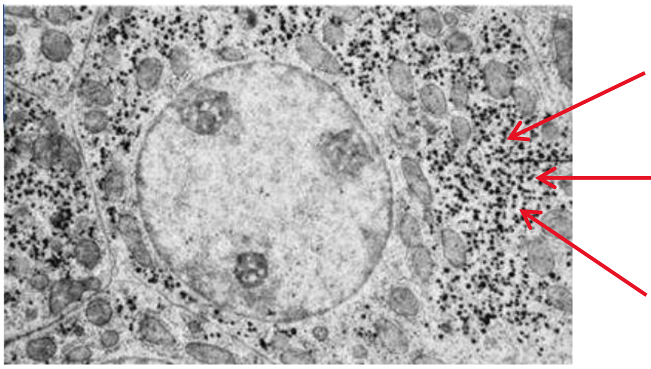


Glycogen (also called animal starch)

Glycogen is the storage form of sugars in animal cells.

We as humans have animal cells, so <u>we can synthesize glycogen</u> to store sugars but not starch (the storage form of plant cells).

Glycogen is stored in all the cells, But the main and largest stores of glycogen are the liver and muscle cells.



All these black dots are glycogen granules.

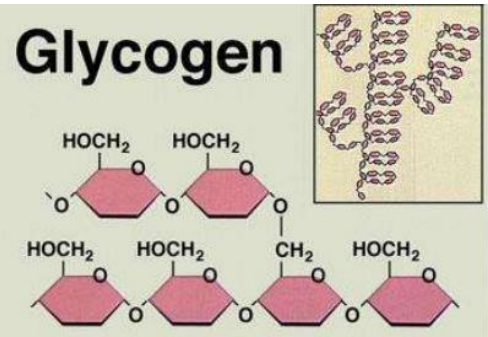
Glycogen is mainly made by glucose monosaccharides, The majority of the glucose monomers in glycogen are linked together by alpha 1-4 glycosidic bonds. This means that the C1 of one glucose molecule is connected to the C4 of the adjacent glucose molecule.

- ⇨ **Unlike cellulose, glycogen and starch are branched polysaccharides.**

Whilst at branch points along the glycogen molecule, there are alpha 1-6 glycosidic bonds (C6 from the glucose molecule in the linear chain with alpha-C1 from the glucose molecule in the branched chain).
These bonds create branches by connecting the carbon 1 of a glucose molecule in the branched chain to the carbon 6 of another glucose molecule within the linear chain. The alpha 1-6 linkages allow for the branching structure of glycogen. And this 1-6 bond forms because the glucose monosaccharide in the linear chain (which is attached to the branched chain with its 6th carbon) is actually connected to other glucose monosaccharide at C1 and C4, so it cannot form another bonds on these carbons →so the best carbon among the ones that are left to form the bond is carbon number 6. Why? Because it is outside the chain, so it <u>reduces Steric hindrance</u>.

So only when glycogen branches the linkage is α-1-6 (at the branching point only!), but within the branch the linkages between the residues are α-1-4 linkages.

Note: Glycogen is extensively branched (almost every 10 residues there's a branch) and the branching occurs in several layers (it could branch 13 times into 13 layers!)

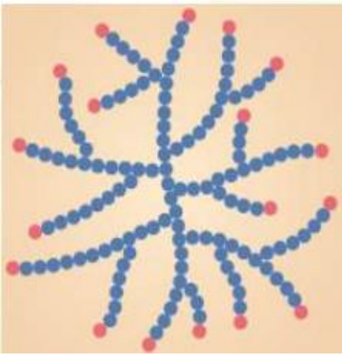


In Glycogen, most terminal residues (at the end of the linear or branched chain) have an atom on carbon number four as the free atom, except for the first (main) residue in the main linear chain, which has an atom at carbon number one as the free atom.

⇨ **Because most of the terminal glucose residues have their C4 free and their anomeric C1 occupied or covalently bonded (except for one glucose residue in the main linear chain which has free anomeric C1 and a covalently bonded C4), their anomeric C1 cannot be oxidized so they are <u>non-reducing agents</u>, so we can consider the overall molecule to be a <u>non-reducing agent.</u>**

Question) What is the importance of all these branches?

Answer) When there are a lot of branches, the enzymes could breakdown the glycogen faster. How?



In this photo, the red dots represent the endpoints of each branch of the <u>glycogen chain.</u> When the glycogen is set to be broken down, a lot of enzymes come and function at the same time with each one of them functioning on a single branch. So, this structure of the glycogen helps to break down the glycogen faster.

That's why glycogen is quick source of glucose (glycogen can last in the body from 12-18 hours)

- **Because most of these ends actually have the free atom at carbon number four, they are considered to be <u>non-reducing</u> ends, because they don't get oxidized. It is worth noting that glycogen is considered to be a Non reducing polysaccharide even though it has one reducing end. (One reducing end can't have a big effect on its own).**

The End of Sheet 7

إِنَّمَا يُوَفَّى الصَّابِرُونَ أَجْرَهُمْ بِغَيْرِ حِسَابٍ

What is edited in v2?

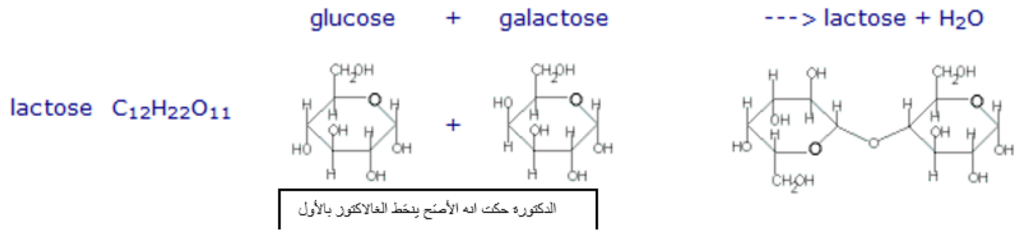
1) **Page 7**:

So, the bond is called <u>α (1,2) linkage</u>, because the first monosaccharide (glucose in here) is alpha connected. ✓

So, the bond is called <u>α (1,2) linkage</u> (because the two monomers are alpha anomers). ✗

2) Page 9:

We added the Arabic text below.



3) Page 13: the photo was covering the text.

Leaky gut, also known as increased intestinal permeability, is a condition that refers to a compromised or damaged intestinal lining. The intestinal lining is naturally designed to function as a barrier, selectively allowing nutrients and beneficial substances to pass through while preventing harmful substances from entering the bloodstream. However, in the case of leaky gut, the tight junctions between the cells of the intestinal lining become loose or damaged, leading to gaps or "leaks" in the barrier.)

Sucralose, a Common Artificial Sweetener, May Increase Cancer Risk

News > WebMD Health News

Sucralose Damages DNA, Linked to Leaky Gut: Study

Lisa O'Mary

June 01, 2023

WebMD

4) **Page 21: we added this text to the last paragraph**:

It is worth noting that glycogen is considered to be a Non reducing polysaccharide even though it has one reducing end. (One reducing end can't have a big effect on its own).

5) **<u>a lot more edits that doesn't affect much, such as: Grammarly edits, replaced a word with a better symptom, change the color of a word, etc....</u>**