6

BIOCHEMISTRY

faculty of medicine - JU2017

◉ Sheet ○ Slides

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Carbohydrates:

Q) What are carbohydrates?

A) They are polyhydroxy aldehydes or ketones, a chain of carbon that contains a lot of hydroxyl groups, and with the functional group being a ketone or an aldehyde.

Priority order from the highest to the lowest in naming is: carboxyl group, followed by carbonyl group (carbonyl, ketones, and aldehydes).

Another word for carbohydrates is saccharides. They have many functions including, source of energy, structure (will be discussed later on), functions in cellular recognition (some cells surfaces have proteins and carbohydrates, those carbohydrates give the immune cells information on what the cell is and what's its function), and used as building blocks. A building block is a common name used in biochemistry and molecular biology, referencing to the basic unit of the structure (just like a brick is the basic unit for building a wall).

Classification of carbohydrates:

There are many ways to classify carbohydrates; one of those ways includes counting the number of sugar molecules in the carbohydrate. The simplest one would be monosaccharide (one sugar molecule), like glucose, fructose, and galactose.

When we add two monosaccharides together we get a disaccharide, adding one more monosaccharide gives us a trisaccharide, and so on. A short chain of Carbohydrates containing three to ten monosaccharides is called oligosaccharides (oligo means short). Polysaccharide refers to a carbohydrate with more than ten monosaccharides(a repetitive sequence of mono saccharine). Those carbohydrates (monosaccharide, disaccharides, trisaccharides, and polysaccharides) can be given different names.

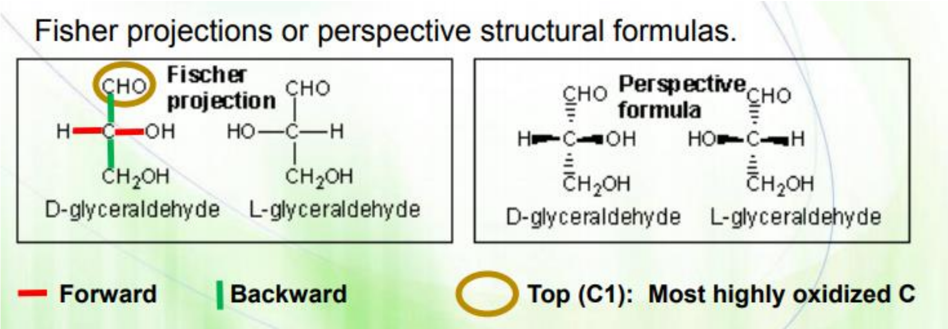
For example, glycogen, cellulose, and starch are all named polysaccharides as they are made of a single chain of monosaccharides, and everyone of them has its own function and purpose.

Glycoproteins, proteins with a small amount of sugar on them(they are important for cell recognition). Glycoproteins,though, differ from proteoglycans. A proteoglycan is a molecule with a huge sugar structure with some small protein structures, and with small amounts of peptides and amino acids tied up together.

Glycoproteins can be hormones, proteins on the cell surface ,blood group substances , or antibodies. Proteoglycans form the extracellular matrix.

Glycolipid is lipid structure with a little bit of sugar molecules associated with them. Mucopolysaccharides, like hyaluronic acid, can also be found outside of the cell, in the ECM. We also have nucleic acids, like DNA and RNA, which can change sugar molecules, which are important.

Now we will start with monosaccharides. Their functional group is (CH2O)n and they contain two or more hydroxyl groups. Their structure is a carbon with an carbonyl group, hydroxyl group, and you can have a chain of carbons with hydroxyl groups. They can be represented by two ways, Fischer projection and Perspective formula.



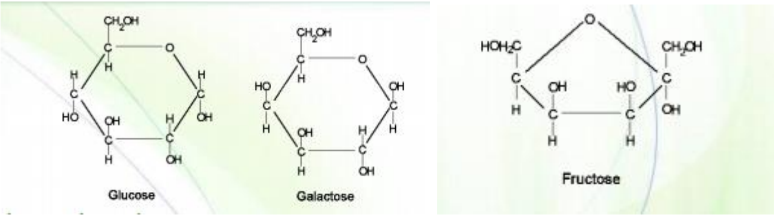
For the Fischer projection the aldehyde group must be on top in sugars(on the C1) and the ketone group must be on the top of the sugar on C2, the red lines (right and left) are forward and the green ones (upper and lower lines) are backwards.

We have two structure for sugars, either an aldose or a ketose, when we have a sugar molecules we will call them using the suffix "*ose*" (examples: glucose, fructose, sucrose, etc.). The functional group can be either an aldehyde or a ketone as mentioned before. So if the functional group is an aldehyde we will call the sugar aldose and if the functional group is a ketone we will call the sugar a ketose.

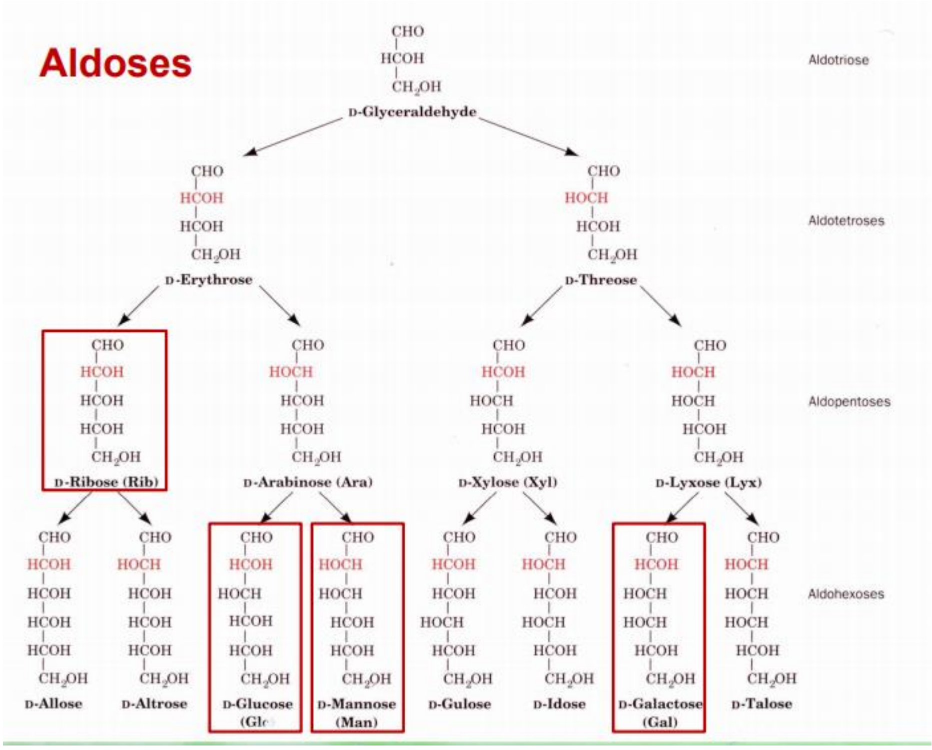
Common monosaccharides: 1) Glucose :(which is the most common polysaccharide) has a mild sweet flavor (that's why it isn't used in the industry). It is also known as blood sugar (when we talk about diabetes, we also mean a problem in glucose), it is essential for energy, and found in every disaccharide and polysaccharide.

2) Galactose: Hardly tastes sweet, and is rarely found naturally as a single sugar.

3) Fructose: Very sweet, found in honey and fruits. Can be found as an industrial sweetener. Added to soft drinks , cereal, and desserts.(such as cola and the gum)



Aldoses: The simplest aldose is glyceraldehyde, learn the four structures (Ribose, Glucose, Mannose, and Galactose) that are in boxes **as they are found in DNA and RNA (the doctor didn't talk about that on the lecture??)** and need to know the differences between them.



Ketoses: The simplest ketose is dihydroxyacetone. You need to know the structure of fructose, others are not needed but just read their names.

The functional group is the ketone, and if is has a chain like fructose, the ketone group must be on top (on C2).

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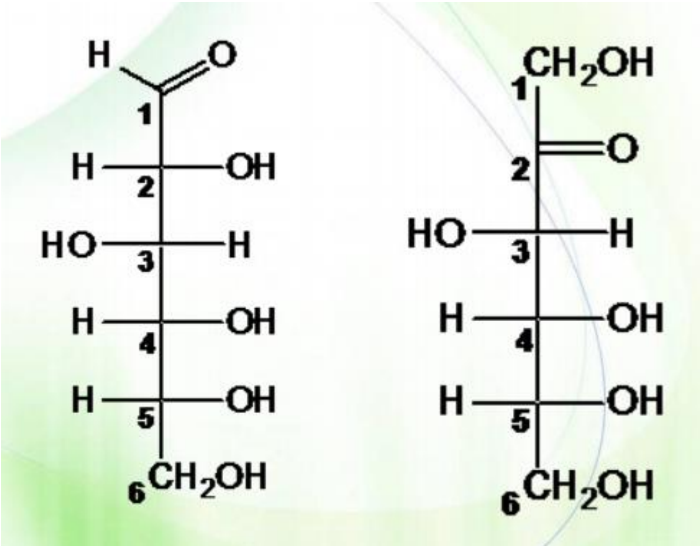
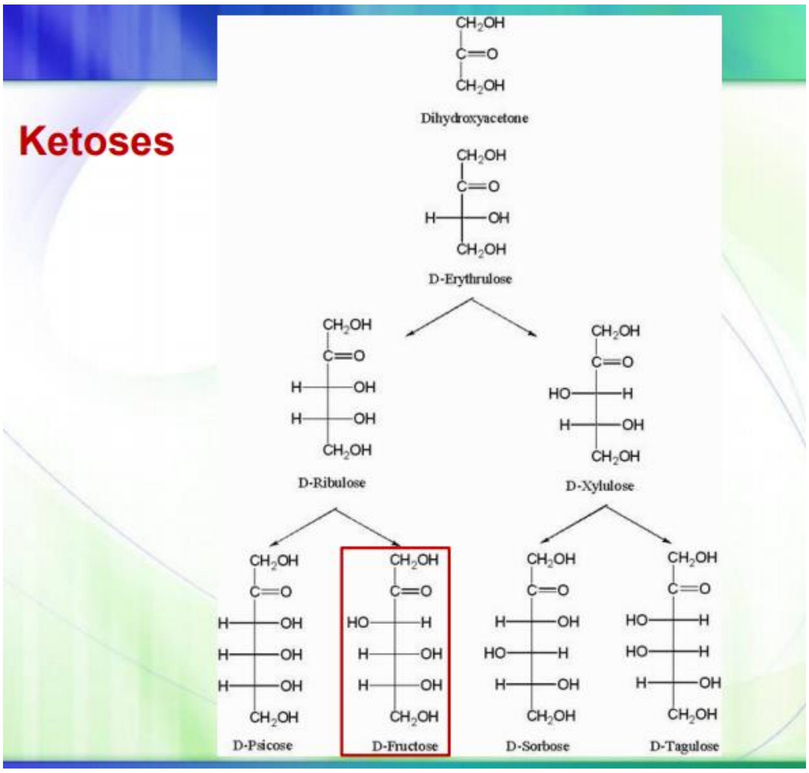
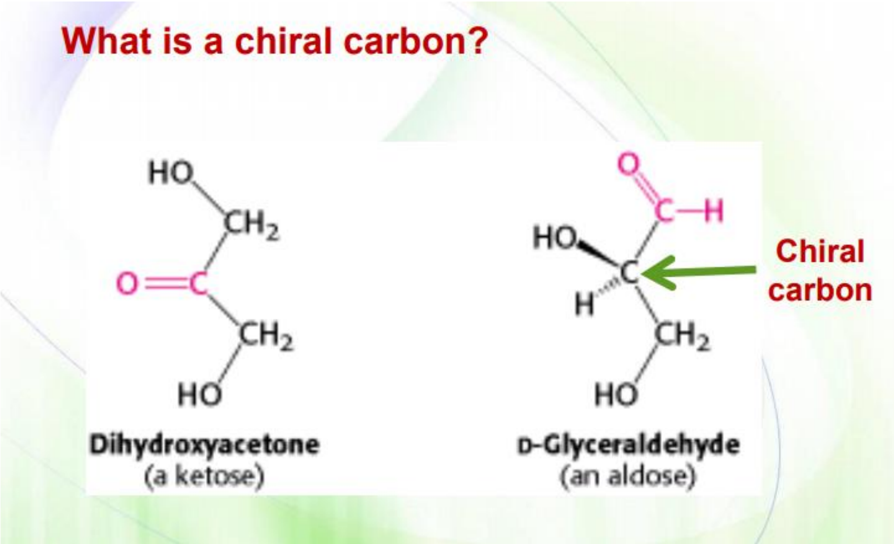
The other way for classifying carbohydrates, especially the monosaccharides, is counting the number of carbons in the carbohydrate (How many carbons do they contain?). The simplest one is the one with just three sugars, trioses. If there was four carbons in the carbohydrate then it's called tetrose, five carbons = pentose (ribose is a pentose sugar). Fructose, glucose, galactose, are all hexoses, as they contain six carbons. Counting always starts from the functional group; notice how every carbon contains a hydroxyl group, if any of these groups is changed/modified, then the carbohydrate becomes a modified sugar (not a sugar). For ketoses, the ketone group must be the second carbon not the first, and we draw it on top as well.





Coming to carbohydrates, the glyceraldehyde carbon is a chiral carbon,:a carbon that is connected to four different groups. The dihydroxyacetone doesn't contain a chiral carbon and has its own structural importance.

Check the slides for a question that might help in identifying the chiral carbons. Slide 12 from Dr. Ahram's third slide.



Classifications for carbohydrates, especially when you have a chiral carbon ,which is an important characteristic, we have isomers, they are molecules that have the same number of atoms, same number of carbon, hydrogen, and oxygen, but they can still have different arrangement and connectivity between their atoms. These isomers could be stereoisomers (Are molecules with same number of atoms, they are connected the same way, but they have different three dimensional structures), or constitutional isomers (same number of atoms but they are connected differently. For example, we have fructose and glucose, that have the same number of atoms but have different arrangements (connected in different ways)). This is what makes biochemistry different from other sciences; you need to think about molecules in three dimensions not just two. So a group maybe forward in one molecule but backward in other. (Two different molecules).One of them could be very sweet in taste, but just by changing the orientation (angle of the bond) it will become very bitter. Same thing is applied to spearmint or peppermint in gum, it could have the taste of mint but by changing the structure, it may change the taste.

How should we know how many isomers or stereoisomers are for a molecule?

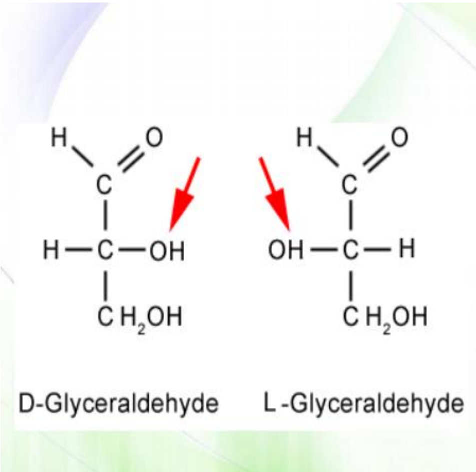
Simply by using 2^n; *"n"* is the number of chiral carbons.So for example here in the first molecule, we can see that carbon one isn't a chiral carbon, whereas carbons 2 to 5 are. Carbon 6 isn't a chiral carbon as it has two hydrogens bonded to it. So to calculate the number of isomers this molecule could have we use the formula 2^n, so it is 2^4 giving us 16 isomers. Just for practice try to find which ones of these molecules are glucose, galactose, and which one of them is mannose.

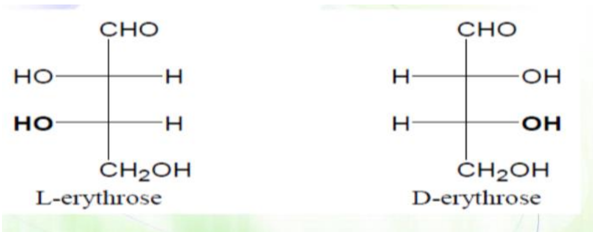
Stereoisomers can be classified into two more classes, enantiomers and diastereomers. Enantiomers are two stereoisomers that are mirror images of each other. As for practice go back to the previous page and try to find a molecule and its enantiomer. For example, glucose and its enantiomer.

10:00-----20:00

For example, the simplest sugar aldose, has a chiral carbon, the mirror image of the aldose would be its enantiomer. As it's the only chiral carbon, we give them designations of *L* and *D*; *L* for Levo and *D* FOR Dextro. For simplicity, lets consider L as left and D as right, used for the hydroxyl group that is bonded to the chiral carbon. Look for the OH in the molecule and if it's on the left then we call it a L-sugar, same goes to D. For glyceraldehyde the enantiomers are D and L, as we used the OH group that is bonded to the chiral carbon to know the L and D molecules.

Is the dihydroxyacetone considered as an enantiomer? No, because it doesn't contain a chiral carbon.

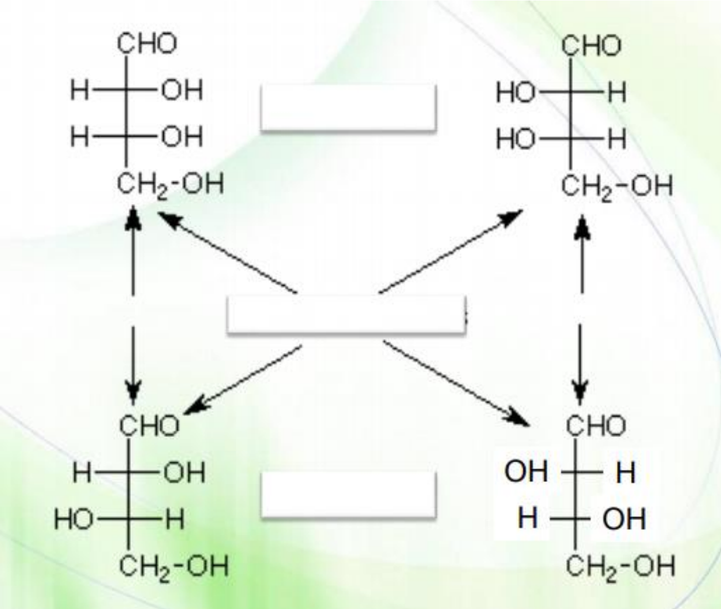




Looking at this molecule we can see there are two chiral carbons, carbons 2 and 3. So which one of them is L and which one is D? Let's repeat the definition. It depends on the position of the hydroxyl group that is connected to the chiral carbon that is furthest to the functional group (aldehyde or ketone).

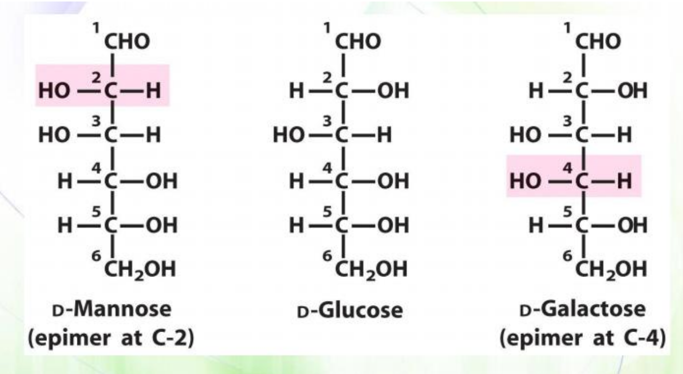
Go to page five and find which ones are L and D from the fifteen isomers of glucose.

Diastereomers, are stereoisomers that are not mirror images of each other. (So, when they are mirror images of each other they are enantiomers and when they are not mirror images of each other they are diastereomers.) And they are non-superimposable (لا يتطابقوا على بعضهم البعض), if they are superimposable on each other then they are the same molecule.



The ones on the top left and right are enantiomers, as they are isomers, stereoisomers, and they are mirror images of each other. Same thing goes to the down- right and left. Whereas the top left and down-right and diastereomers to each other, top- right and down- left are also diastereomers to each other.

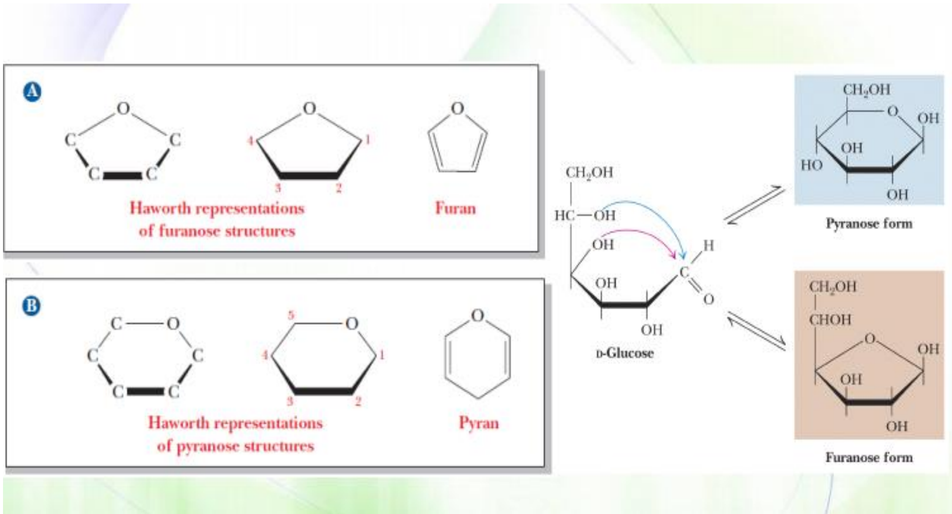
Stereoisomers can be diastereomers, from those diastereomers there might be some epimers. Epimers are stereoisomers that aren't mirror images of each other and they differ in the position of only one hydroxyl group. (So it's a type of disagreements)



As we can see here, that mannose and glucose only differ in the position of one hydroxyl group, that is bonded to carbon two. So, mannose and glucose are epimers of each other at carbon number two. Galactose and glucose are epimers of each other at carbon four. Galactose and mannose are diastereomers to each other. L glucose (when we change the position of hydroxyl group from the right to the left on the last chiral carbon which is carbon 5 in glucose) and D galactose are diastereomers(Note: human's body couldn't digest L-sugar, whereas the bacteria could digest L and D sugar). In organic chemistry, when aldehyde reacts with alcohol, it results in hemiacetal. If the reaction continues and alcohol reacts with hemiacetal it forms acetal. Hemiacetal is when we have a carbon with OH, H, OR, and R. Having another reaction will remove the OH group producing OR, OR, H, and R. If a ketone reacts with alcohol it becomes a hemiketal OR, OH, R, and R. Aldehyde is terminal but ketone isn't, so the aldehyde contains OH group while the ketone contains R group instead. Having another reaction produces ketal OR, OR, R, and R.

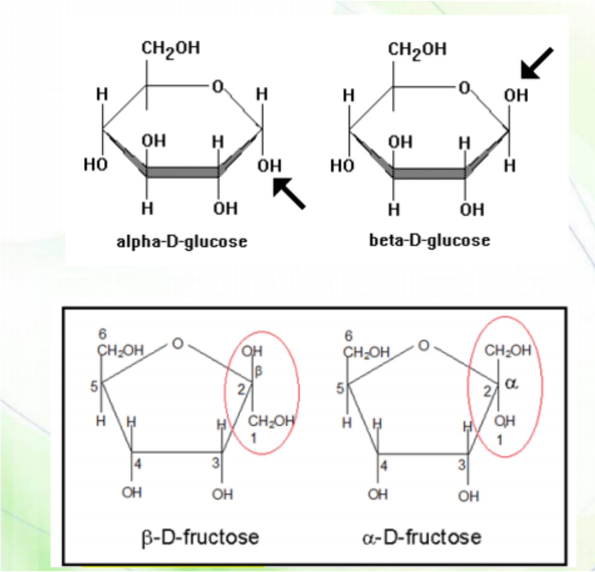
20:00----30:00

We say this as the sugar molecule has many hydroxyl groups and has aldehyde groups, a reaction might take place within the same molecule, between the aldehyde and hydroxyl groups on carbon number five, for example. Producing a ring structure. If we have a solution of glucose 99% of the glucose would be in a ring structure and just 1% would be in chain structure, as the ring structure is more stable.



The reaction between the aldehyde and the hydroxyl group, we have two hydroxyl groups one on the fourth carbon while the other is on the fifth carbon. Producing two ring structures, either a six membered ring or a five membered ring. One of the members is oxygen. If it was a six membered ring then we call it a pyrane, and the sugar is called a pyranose. And if the sugar is a five membered ring it is called furanose. Which one is more stable or more common? The pyranose as it has more space therefore having no van der waal forces, no repulsion, and no steering hindrance (steering means structure and hindrance means something like repulsion or compression).

Once a ring structure is formed for glucose, all of the hydroxyl groups are stable. Their locations and positions do not change, except the hydroxyl group bonded to carbon 1, could be upward or downward, below or above. Designations for these are alpha or beta sugars; if the hydroxyl group is below the ring then the sugar is an alpha sugar, if it is above the ring then the sugar is a beta sugar. The molecules with such configuration are called anomers, and the carbon is called anomeric carbon. So an anomeric carbon is the carbon that was originally the functional group (aldehyde or a ketone), and has the hydroxyl group in free- form and can be below the ring or above the ring.

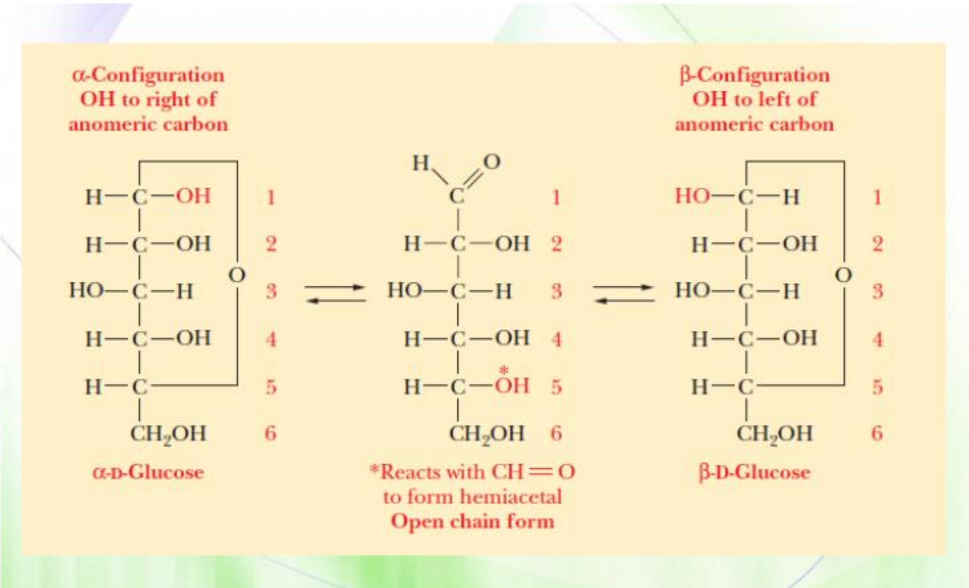


If you are confused and finding it difficult to memorize that alpha is when the hydroxyl group is below the ring, and that the beta means hydroxyl group is above the ring, then try to get it this way:).

Alpha's shape looks like a fish, and fishes swim below the water, therefore alpha mean below!

Reading beta in Arabic sounds like (بيت) which is a house, and houses are of course built above the ground, therefore beta means above!

To know the D/L designation for ring structure we look at the sixth carbon and check whether it is above or below the ring, if above then it's a D, if below then it is a L.



The doctor didn't concentrate much on this slide, and just said that they could be represented with Fischer's projection this way. He added that it is a bad way of doing it.

When a chain structure turns to a ring structure, how will you know which hydroxyl groups are upwards and which are downwards? Simply if it was to the left it will be up, and if it was located at the right it will be to down. Will be discussed next lecture..