Biochemistry
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Lecture - 21
Carbohydrates - I

We will begin our lecture on carbohydrates today. We will have 2 lectures on carbohydrates and we will see how important they are in the processes that occur in our body later on especially when we do bioenergetics where we will be studying the metabolism of these carbohydrates.

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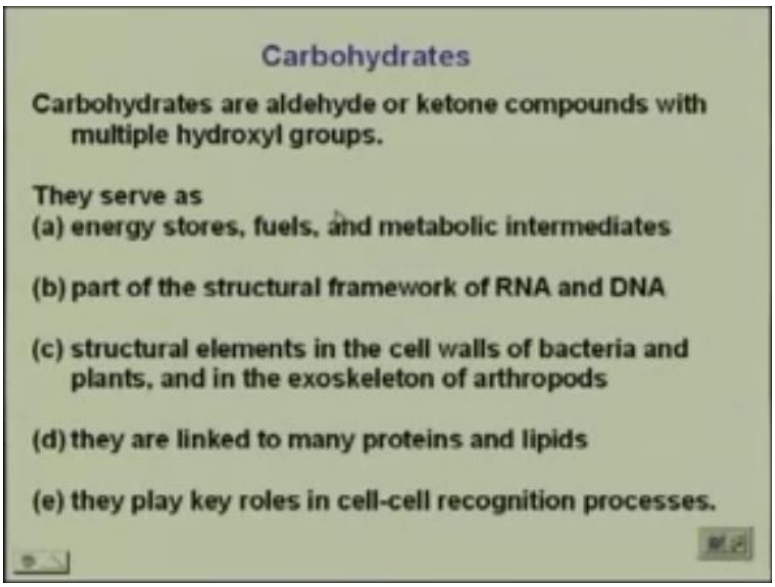

Now, the first thing that we want to know is what are carbohydrates? Carbohydrates are actually aldehyde or ketone compounds with multiple hydroxyl groups. And they have a lot of functions in our body. And the main functions are, the first one which is most important is as energy stores in the body, as fuel and metabolic intermediates that give us our basic energetics that the energy that we need actually to get along.

The next important thing is that they form the part of the structural framework of RNA and DNA, the essential molecules for life. Remember when we consider the central dogma of biology; it was to go from DNA to RNA to protein. Now, these carbohydrates actually form the basic structural framework of RNA and DNA and when we do the structures of nucleic acids and their components, we will see how this actually comes into the picture.

They also form the structural elements in the cell walls of bacteria and plants and in the exoskeleton of arthropods. This is what forms the chitin which you probably have heard about, the exoskeleton of these arthropods like cockroaches and it is their hard shell that is formed that is also a polysaccharide, which also is basically a carbohydrate. They are also linked to many proteins and lipids.

When we studied the lipids and the fluid mosaic membrane of the lipids, we found out there were proteins, which we called glycoproteins that had sugar attached to lipid moieties that were part of the fluid mosaic membrane that allowed the transfer of material from the inside to the outside of the cell. They also play a key role in the cell-cell recognition processes. So these are the major functions of these carbohydrates that are basically aldehyde or ketone compounds that have multiple hydroxyl groups.

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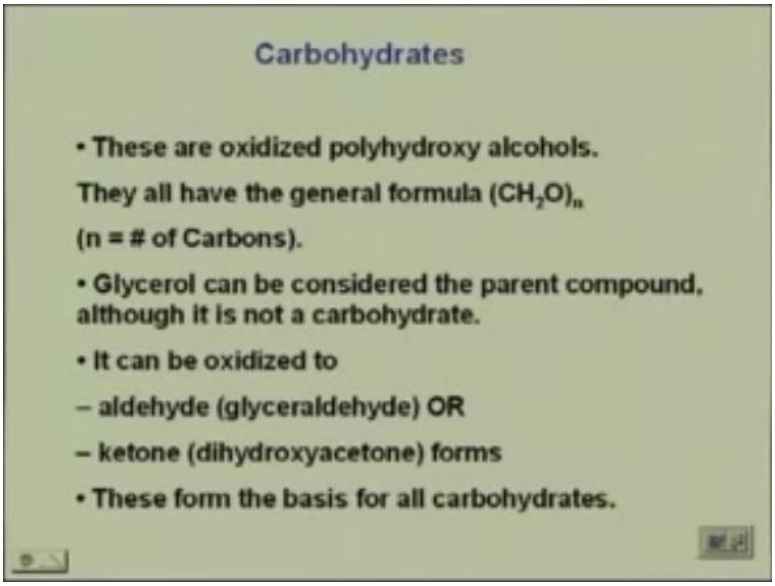

Now, basically these polyhydroxy alcohols as you probably might all know, they have the general formula (CH2O) the whole n. And what is this n? It is the number of carbon atoms that is present. For example, glycerol which was something we also used in the lipids. In this, here also glycerol can be considered to be the parent compound even though it itself is not a carbohydrate. What can happen to this glycerol is, it can be oxidized. It can be oxidized to form an aldehyde or a ketone and these actually form the basis for all carbohydrates.

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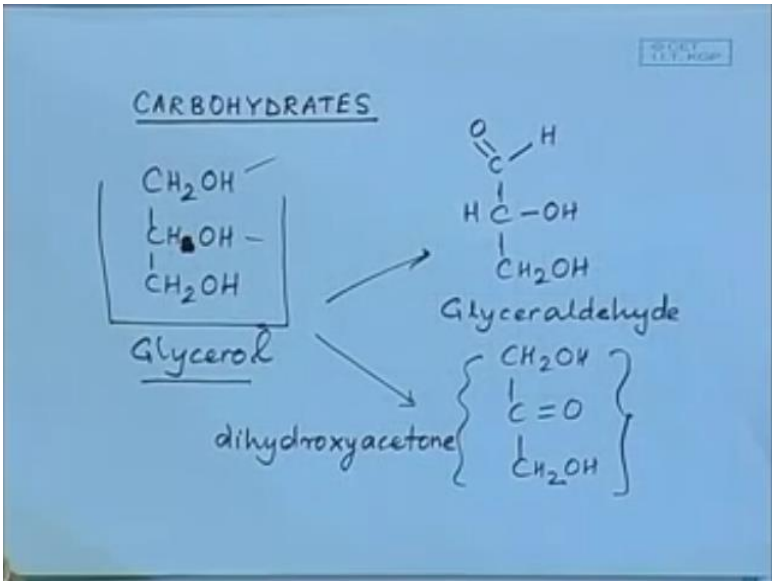

So, if we just go to look at the structure of glycerol, this is what glycerol is (CH2OH) - (CH2OH) - (CH2OH). So, this is glycerol and when we studied the fatty acids and the lipids, we found out that these formed actually, they were linked to fatty acids forming an ester and then we had a phosphate linkage and then some extra linkages here that actually gave us the polar head group and the 2 hydrophobic tails of our lipid molecule.

And, when we come to carbohydrates again, we see that glycerol again here is the parent compound. What is happening here is there is oxidation. Oxidation to form glyceraldehyde, this is CHOH. So, this is actually glycerol. So we have glycerol here and we have, what is this? This is glyceraldehyde. We can also form (CH2OH) – (C=O) – (CH2OH), which is called dihydroxyacetone. So, we know that acetone is (CH3) – (C=O) – (CH3). This is dihydroxyacetone.

So, we have again the parent compound being glycerol and from this we can get these 2 aldehyde and ketone components that actually form the basis for all carbohydrates. So, we have carbohydrates that contain an aldehyde like glyceraldehyde that are called aldoses and glyceraldehyde is an aldotriose because it has 3 carbon atoms, an aldose with 3 carbon atoms.

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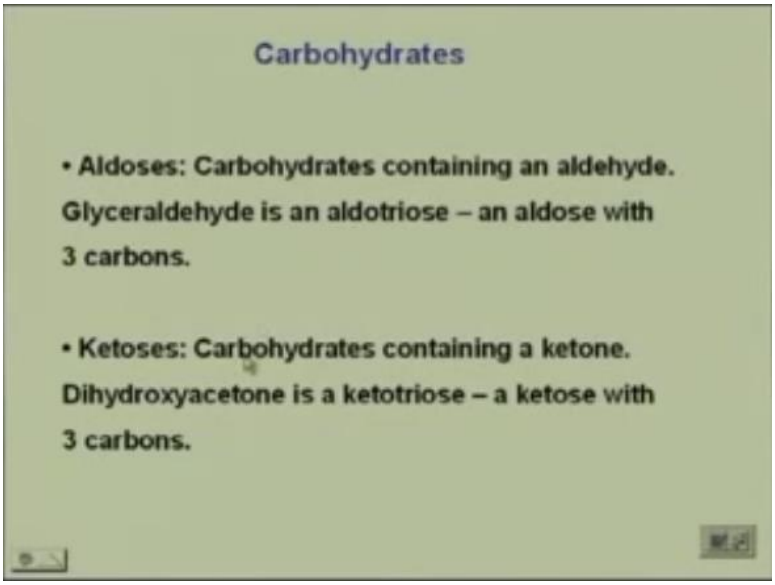

We have ketoses, like the one that I just drew. Dihydroxyacetone, where the carbohydrate contains a ketone, it is a ketotriose. So, it is a ketose with 3 carbon atoms. This is just the nomenclature that you would look at. So, you have an aldose. In this case, glyceraldehyde is an aldotriose. We have ketoses. Dihydroxyacetone is a ketotriose.

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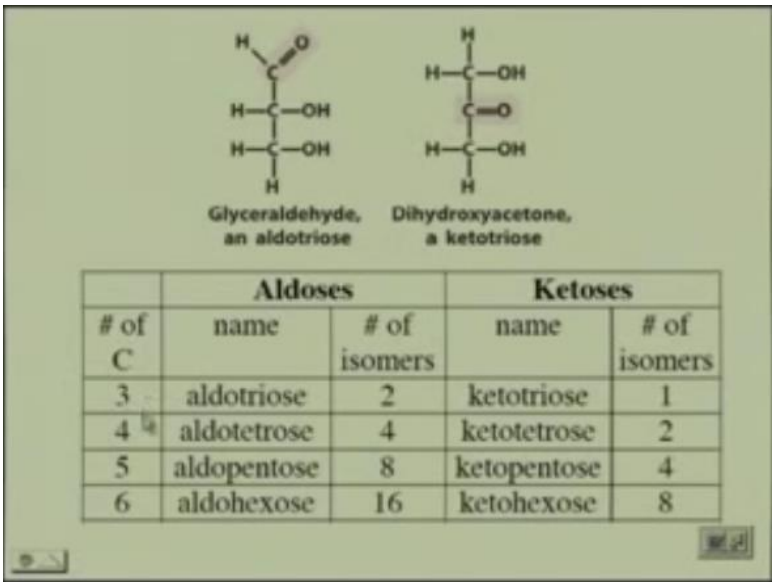

	Aldoses		Ketoses	
# of C	name	# of isomers	name	# of isomers
3	aldotriose	2	ketotriose	1
4	aldotetrose	4	ketotetrose	2
5	aldopentose	8	ketopentose	4
6	aldohexose	16	ketohexose	8

Now, these are the structures that we just looked at. We have our glyceraldehyde, an aldotriose and we have dihydroxyacetone, a ketotriose. Now, if we look at the carbon atoms here, this carbon atom, the one that is in the center here, is an asymmetric carbon atom, why because it has 4 different groups attached to it. We can form therefore, an isomer of glyceraldehyde if the OH is on the other side.

If the OH is on the left, the OH is on the right here; if the OH is on the left then we form an isomer. But, that is not true in the case of the ketotriose. We do not have a chiral center here, because we have identical groups. There is no carbon atom that has 4 different groups attached to it. So, when we look at aldoses and ketoses, the numbers of isomers are different depending on the number of carbon atoms present.

So, if we have 3 carbon atoms like in this aldotriose, there is a possibility of 2 isomers being formed because this OH can flip from the right to the left whereas for the ketotriose this is the only isomer that is possible. So, depending on the number of, when we have the aldotetrose, we have 4 carbon atoms and we have 4 isomers possible. Similarly, when we have a ketotetrose, what does that mean?

A ketone with 4 carbon atoms in that case, you could have a possibility of 2 isomers depending on the number of chiral carbon that you would have and where you could place the OH in 3D structure.

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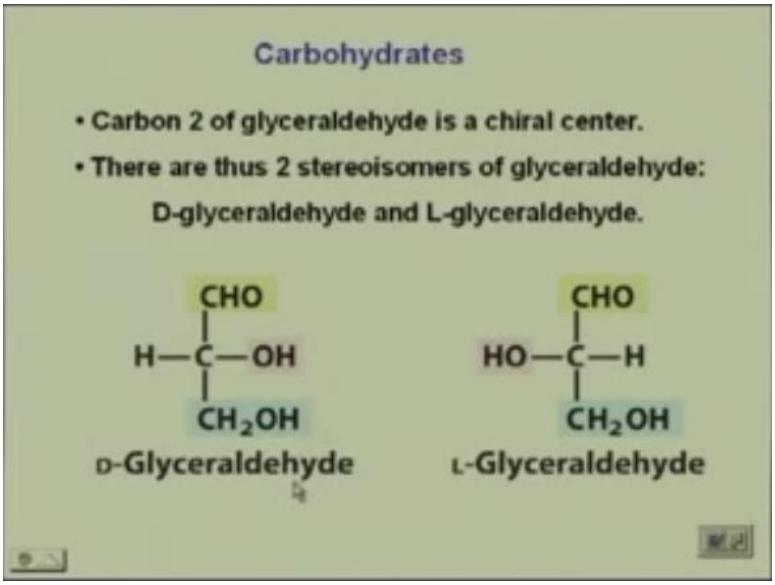

So, if we look at glyceraldehyde once more, we have these 4 different groups attached to it. 4 different groups attached to it means that there are 2 such stereo isomers of glyceraldehyde possible. One is D-Glyceraldehyde and the other is L-Glyceraldehyde. In the L-Glyceraldehyde, the OH is on the left. In D-Glyceraldehyde, OH group is on the right.

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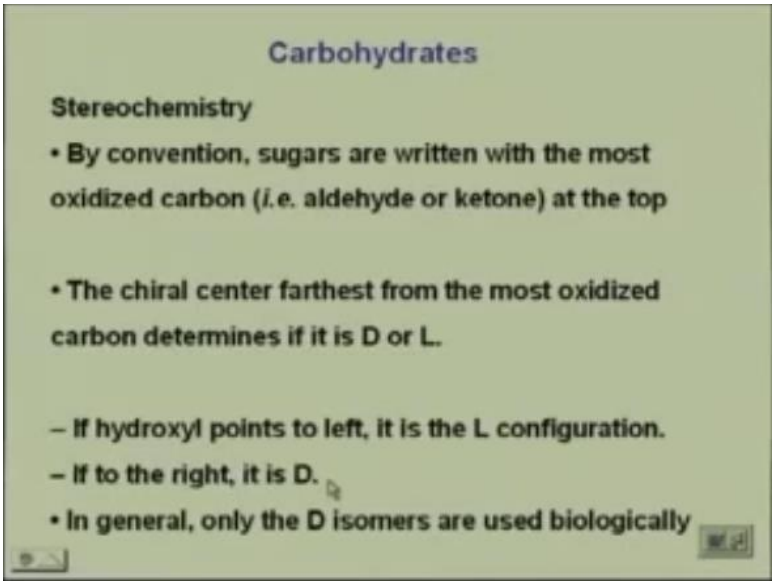

So, this is the stereochemistry that is followed by convention for all carbohydrates. By convention, the sugars are written in such a manner that the most oxidized carbon that is the aldehyde or ketone is written to the top of the structure, at the top. The chiral center that is the farthest from the oxidized group is the one that decides whether it is D or L, not any other OH group.

So, what we have is, we have the sugars written with the most oxidized carbon that is the aldehyde or the ketone at the top and the chiral center that is farthest from the oxidized carbon will determine whether it is D or L, if the hydroxyl group is towards the left, it is the L configuration, if it is to the right, it is the D configuration and in general, we use D isomers in biological compounds, mostly.

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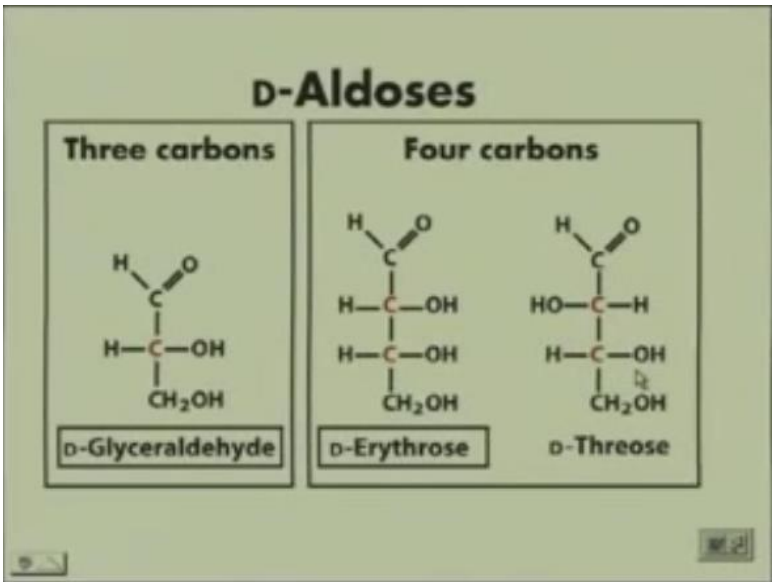

So, we have some other aldoses that we can consider there. So, this is 3 carbon atoms. We have D-Glyceraldehyde. When we look at 4 carbons, we have D-Erythrose, why is this D? The most oxidized carbon is at the top. The carbon atom that is chiral, that is farthest away from the oxidized carbon, has the OH to the right, which means, this is D-Erythrose. This is also D-Threose because the OH attached to the chiral carbon farthest away from the oxidized carbon is on the right. So, that is your nomenclature.

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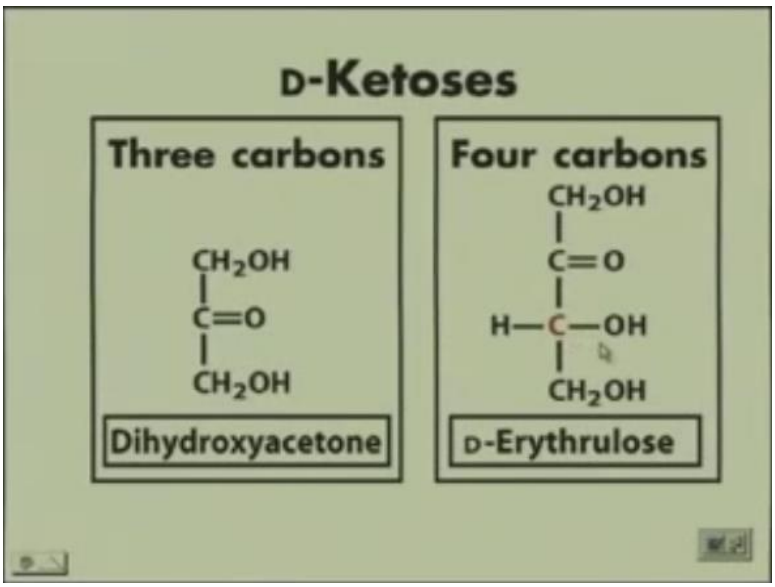

In D-Ketoses, we have, what we have looked at before, with 3 carbons you have dihydroxyacetone. When we are looking at 4 carbons, again we have something, a carbohydrate called D-Erythrulose where we have, what is this? This is a ketotetrose. It has 4 carbon atoms and it is a ketose. We have now, the oxidized carbon as farther to the top as possible. We have the chiral carbon with the OH to the right. So, it is a D- Erythrulose.

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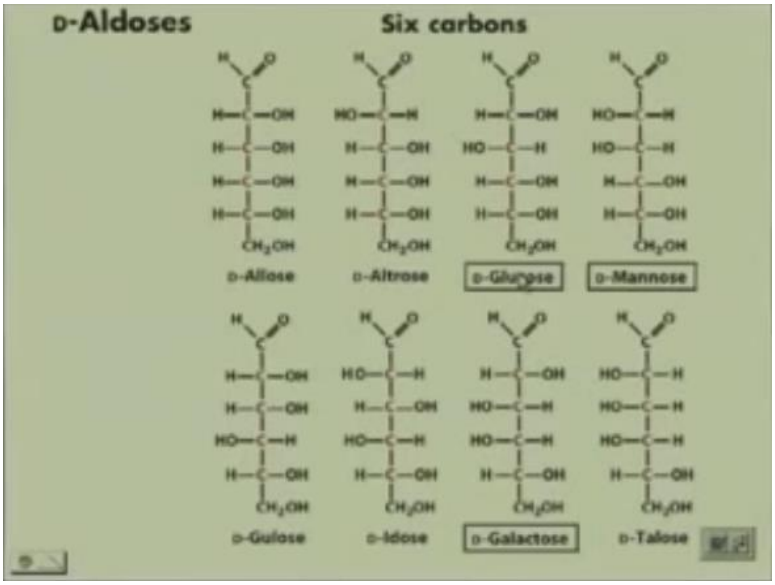

We can also have other types of D-Aldoses, where when we look at the 6 carbons that we are going to consider, we have aldose, altrose, glucose, mannose, glucose, idose, galactose and talose. But, what we need to know is, what is important for most biological carbohydrates are glucose, mannose and galactose. Now when we have this, so what do we see? We see that all of these are actually D structures that have been drawn here.

So, the most oxidized carbon is at the top, the farthest chiral center away from the oxidized carbon has the OH on the right, so this is a D-Glucose. The glucose one is the one that we are going to be most interested in and we will look at the structure in much more detail as we go along.

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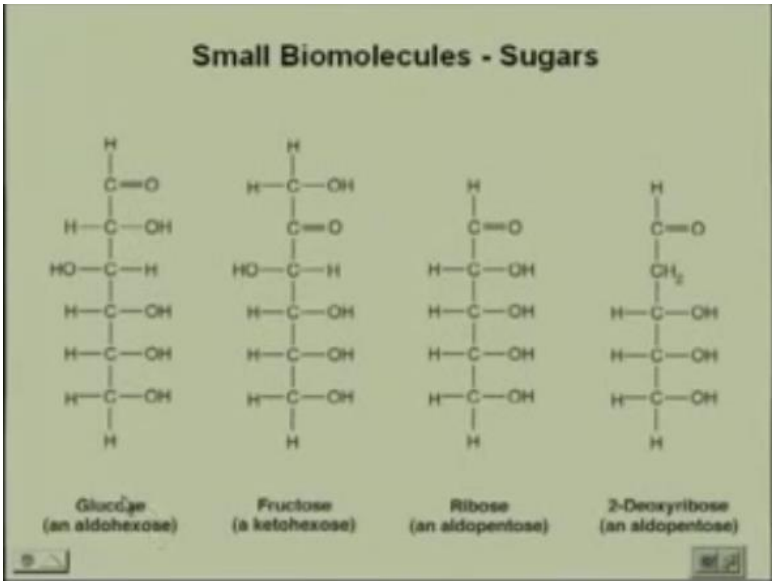

These are other sugars that, these structures are important now, for all of the sugars that we are going to do later. Glucose is an aldohexose. Why? Because it has an aldehyde group and it has 6 carbon atoms. So, it is an aldohexose. Fructose is a ketohexose. It has 6 carbon atoms and it has a ketone group to it. Ribose, which forms the basis of ribonucleic acid, the basic sugar in ribonucleic acid, is an aldopentose.

And the sugar that forms the basis for all DNA molecules is 2-Deoxyribose, where the numbering begins from always the most oxidized carbon atom. So, this is number 1, this is number 2, the deoxy means that it has lost this, so, it has now CH2. So, this is deoxyribose. So, what we have for ribose that is going to form the basis for ribonucleic acid is the ribose sugar which is an aldopentose.

For deoxyribonucleic acid, the basis is 2-Deoxyribose which is missing an OH and we will see how important this is in a lot of structures. For example, when we did the mechanism of ribonuclease, we found out that the ribonuclease because it acts on this 2 prime OH, could not act on DNA and cleave DNA. It could only cleave ribonucleic acid, if you remember when we did enzyme mechanism.

So, these are the small biomolecules that are extremely important or probably the most important ones where we have glucose, fructose, ribose and 2-deoxyribose.

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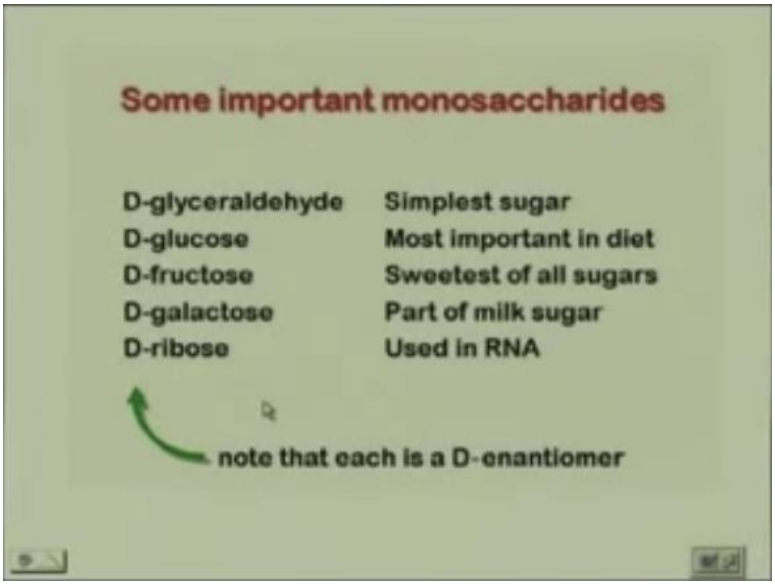

So, these are some other important monosaccharides. D-glyceraldehyde is the simplest of sugars. D-glucose is the most important one in the diet. We will see how this is also stored

and how it is even broken down in the body. Then, we have D-fructose which happens to be the sweetest of all sugars. We have D-galactose that forms a part of the milk sugar and I said as D-ribose that is used in RNA and 2-deoxyribose that is used in DNA.

All of these you see are D-enantiomers. And when we look at the proteins we found that most of them were L amino acids.

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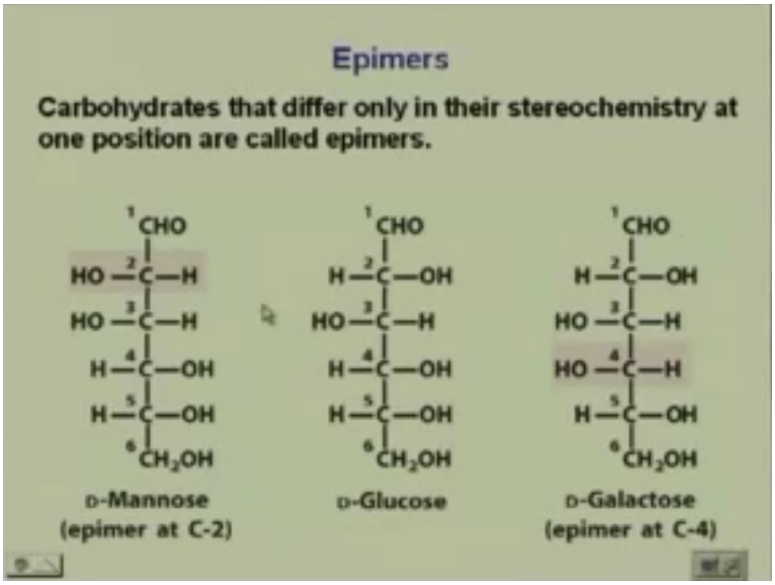

Now, this is what we mean by something called epimers. First of all let us look at the numbering of glucose. If we look at the numbering of glucose, we find that, what is glucose basically? It is an aldohexose. Now, aldohexose has an aldehyde group on the top. This is the way it is written and the rest of the molecule follows. Now, chiral carbon that is number 5 here which is the farthest away from the oxidized carbon will determine whether it is D or L.

This is on the right. So it is D-glucose. We have now 2 other aldohexoses here, D-mannose and D-galactose. Now what we have here is, if you look at the structures carefully, in this case the change in the orientation of the OH is on carbon number 2. The rest is the same. We have the OH on the left in mannose and on the right in glucose. However, for carbon numbers 3, 4 and 5, the OH directions are exactly the same.

The only change that you see is in carbon number 2 between D-glucose and D-mannose. So, what you say is, when you have the difference in the stereochemistry at only one carbon atom, it is referred to as what is called as an epimers. So, this is an epimers at C-2. So, you

would call this an epimers at C-2 meaning that at carbon number 2 this would be an epimer of D-glucose at carbon number 2.

So, since we all have to remember the structure of D-glucose and if it were to be mentioned that, you know the structure of D-glucose and you know that you have D-mannose which is an epimer of D-glucose at carbon number 2. You would know the stereochemistry at carbon number 2 is the only one that is different. So, instead of having the OH on right you would write the OH on the left.

If I say now that there is another epimer of glucose that is an epimer at C-4. That is called D-galactose. So, now since we know the structure of glucose, I know that the only stereochemistry of the carbon that is going to change the stereochemistry is going to be at carbon number 4. So, in carbon number 4, instead of having OH on the right, I am going to have the OH on the left. So, that would be the epimer at C-4 which is D-galactose.

So, all we would remember actually is the structure of glucose and then know that D-galactose is an epimer of glucose at C-4. And D-Mannose is an epimer of glucose at C-2. So, that would be what we would look at. Now, we look at the other structures.

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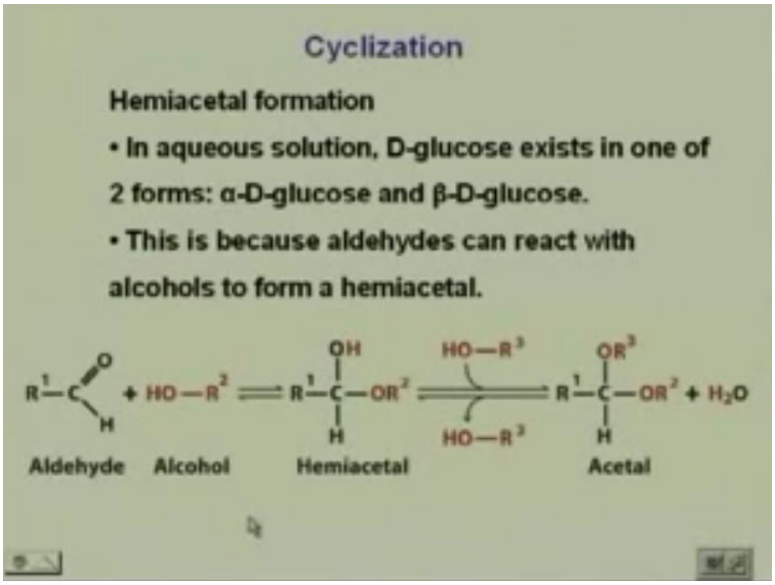

So, now we will look at other structures of glucose. We have what is called Hemiacetal formation. This is something that you probably have studied before also but nevertheless we will go through it because it is going to be important in understanding of what goes later on in

terms of its breakage and cleavage. We have an aldehyde and aldehyde reacts with an alcohol.

Now, when it reacts with this alcohol, then it can form what is called hemiacetal. What is this hemiacetal? It has an OH and it has an OR2. Now, what is attached here is the rest of the chain. We have the aldehyde group and we have an alcohol group here. What happens here is this OR2, the lone pair on the oxygen is going to attack this carbon. In doing so, that acts this carbon. So, what happens here? This goes and takes up this proton.

So, it forms, you see this proton is marked in red which actually come from the alcohol. And the OR2 is now linked to the carbon to form what is called hemiacetal. So, we can also form an acetal. What is going to happen to the acetal now? We are going to have again this attack, on carbon here. And what is going to be released now, the OH. The OH is now going to take up this H and form H2O and an acetal.

So, this is extremely important in cyclisation of glucose, which we will see in a moment. And we have two such forms of glucose called an alpha form and beta form. Basically, what is happening in the glucose structure we have not only an aldehyde group, but we also have an alcohol group? So, what does it actually look like?

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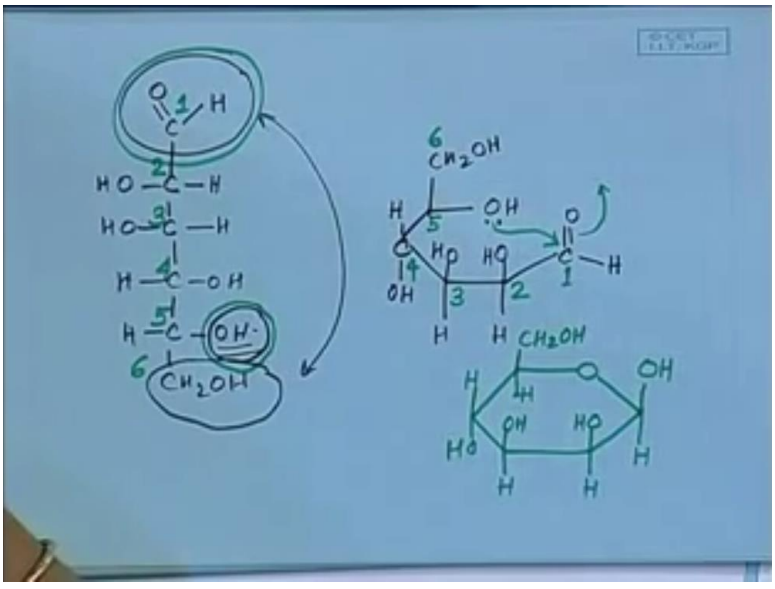

We have here not only an aldehyde group. So, we have C. This is what we have. So, if we write this actually in a different fashion. Just write it out straight first. This is just an example, where we are showing how we can actually have. So, where is our aldehyde? Our aldehyde is

sitting here. And where is our alcohol? It is here. So, what can actually happen? I can have cyclisation. So, if we write this in a manner that is going to be like this. Actually it is not this one. It is this one that actually reacts. This alcohol.

So, we have OH, CH2OH, C OH. This will be parent when I show the slide also, but you should draw yourself once. So, we have an H also sticking here. So let us number the carbons. Let us be careful in our numbering. We have this as carbon number 1, 2, 3, 4, 5 and 6. When we look at the carbons here, this is 1, 2, 3, 4, 5 and 6. So, which is the alcohol that is actually forming the hemiacetal? It is this alcohol with this aldehyde, because, this CH2OH is up there, number 6.

So, the numbering is 1, 2, 3, 4, 5 and 6. So, now if we have this same reaction going on, what is going to happen? Is this from the oxygen is going to come here and what is this going to do? It is going to take up this proton. And what we are going to form? We are going to form. And CH2OH. The rest are all hydrogens. So, that is what we have found. So, what have we actually done, if we go back to the hemiacetal formation here?

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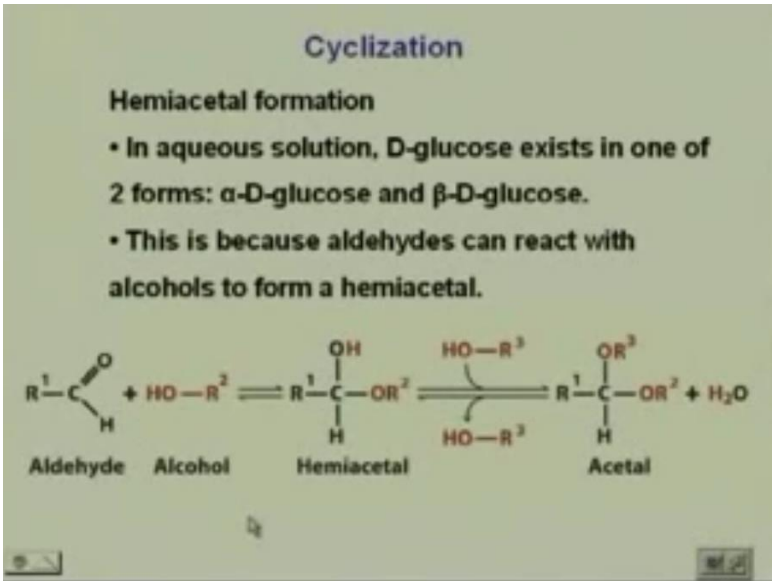

We have the aldehyde with the alcohol forming a hemiacetyl.

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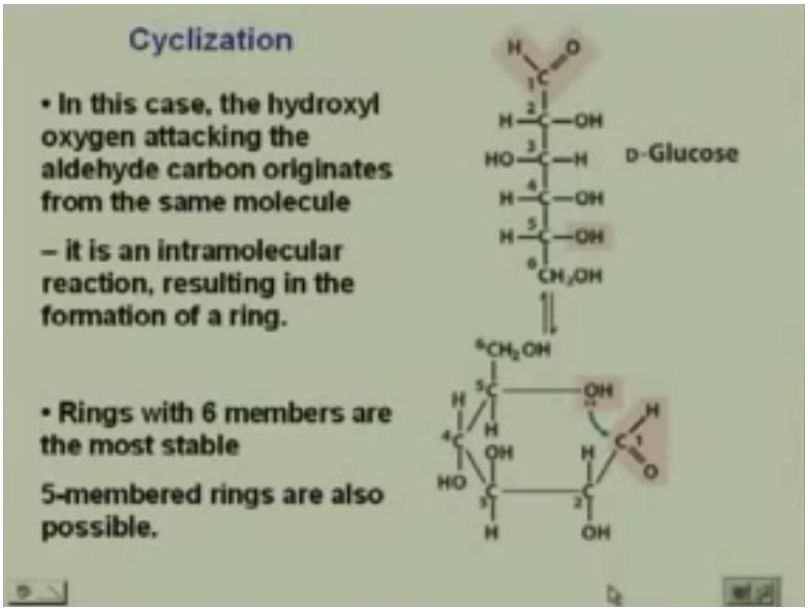

This is what is happening. We have the cyclization, where it is this OH attached to 5 that is doing what? Participating with the aldehyde, so the hydroxyl oxygen and the aldehyde of carbon number 1 is going to do what? Cyclise and what we will have? We will get six-member ring here. One of the members is going to be the oxygen. A six-member ring CH2OH, being the sixth carbon. We can also have five member rings, because, we can also have the cyclisation of D-fructose. We will look at what those rings look like in a moment.

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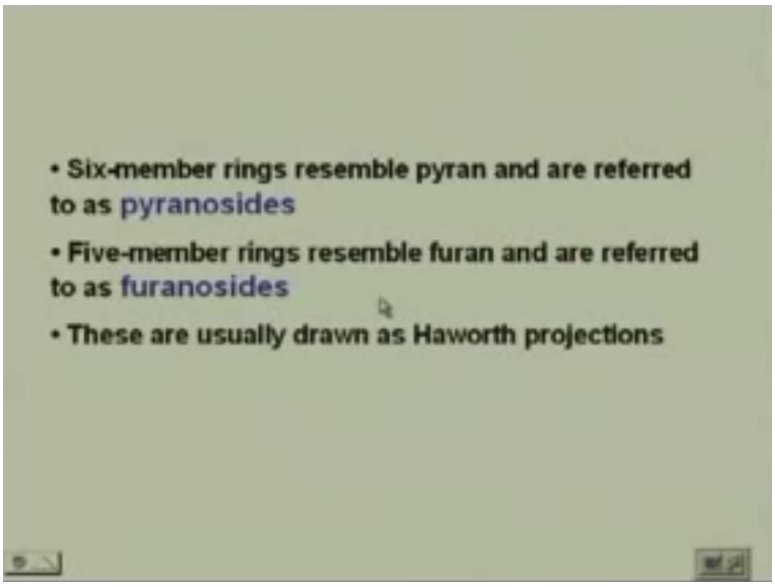

So, since these six member rings resemble pyran, they are called Pyranoxides. So, glucose is also called glucopyranosides. Furanosides are five member rings with oxygen because they resemble furan. And, we usually have them drawn as Haworth projections as was shown before. So, what do we have? We have six member rings and five member rings that

resemble pyran and furan, so they are also called pyranosides and furanosides. So, this is what we have.

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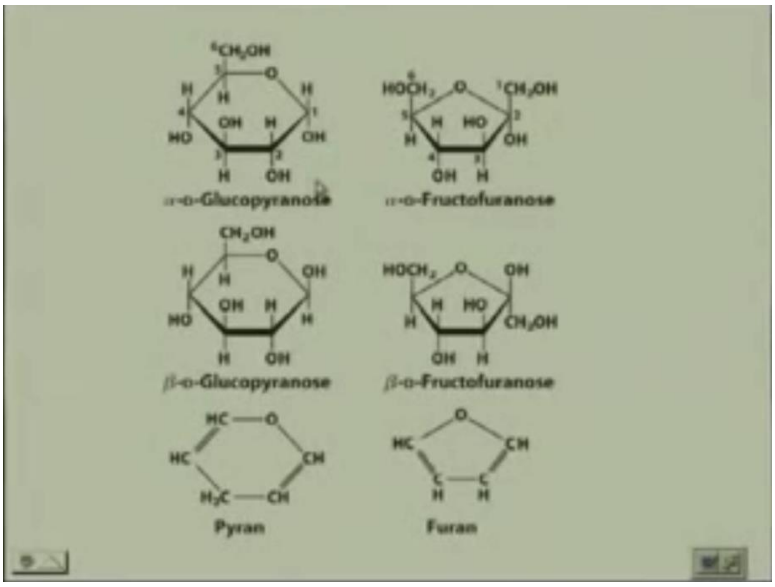

We should try and work out the structure for the case of furanose and see what it looks like. You should get a 5-member ring, in that case, because we have the C double bond O. But, to the C double bond O, we have the CH2OH attached. So, if we now look at the alpha D-glucopyranose, now we will see what is alpha in a moment but for now, we have to know that we have a six-member ring here and we have the oxygen resembling the structure of a pyran.

So, we have glucopyranose. The five-member ring in case of fructose, which is a ketohexose, is forming a fructofuranose. Now, there are something that we can notice here, especially a carbon atom number 1. Carbon atom number 1 in the first diagram, we have the OH that is trans to the CH2OH. In the second diagram, we have the OH cis to CH2OH, which is the sixth carbon.

So, what do we have? We have an alpha anomer and a beta anomer and you form anomers of glucose only, when you have the closed ring structure. So, what do we have? We have in this case the OH on carbon atom number 1 that we have to take care of, if OH is trans to the CH2OH, it is called an alpha anomer. If it is a cis to CH2OH, it is known as a beta anomer. The same goes with fructofuranos. The CH2OH if it is cis to other CH2OH, it is the alpha. If it is trans, then it is the beta form.

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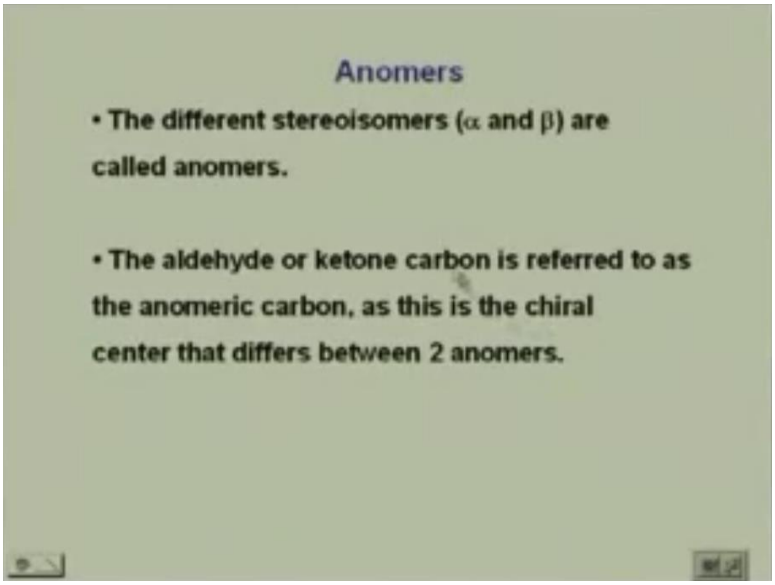

This is what the anomers are. The different stereoisomers alpha and beta are called anomers and we have the aldehyde or ketone carbon, which will give us or decide whether we have the anomeric in the beta position or in the alpha position and you have to remember that this is only possible when there is cyclisation, not before that.

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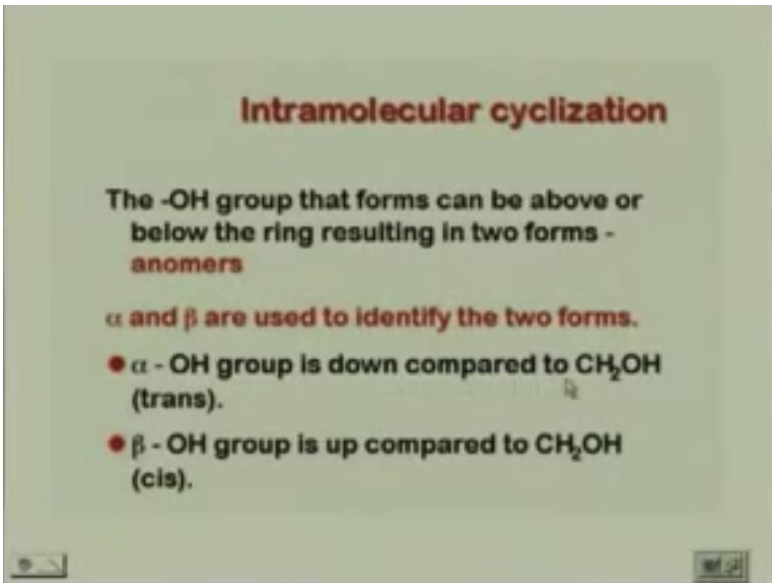

So, we have the alpha OH down compared to CH2OH that is trans. If the beta OH group is up compared to CH2OH, it is basically a cis conformation. And when it is beta and we have the alpha. And we will see how this is going to help us in all the glycosidic linkages that we talk about later on.

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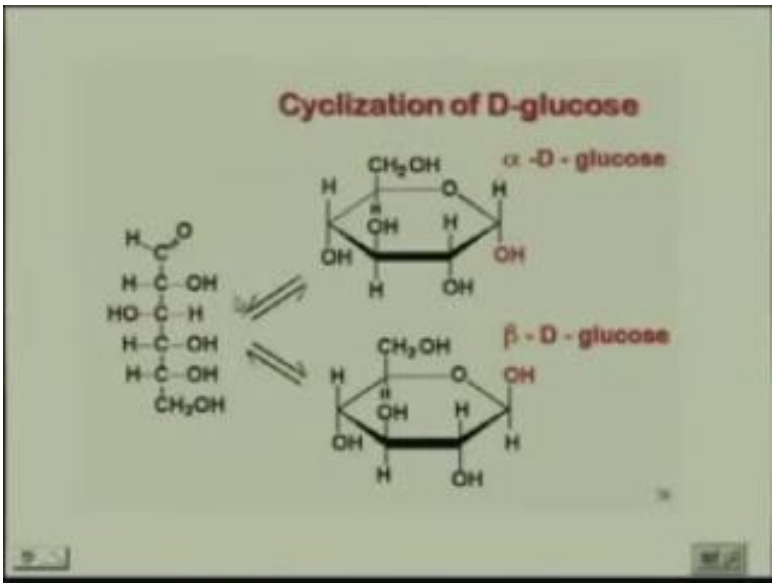

So, this is what we have. We have our glucose here; we have the cyclization. And what is this cyclization leading us to? When we have the OH, transed to the CH2OH, we have alpha D-glucose. When we have the OH cis to CH2OH, it is beta D-glucose.

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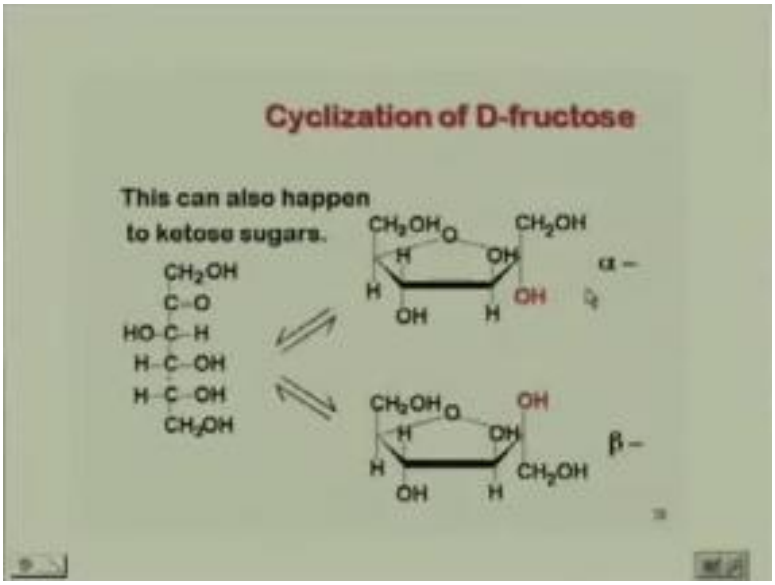

When we have the ketose sugar, what do we have? In this case, they have shown the OH trans to the CH2OH and the OH cis to the CH2OH.

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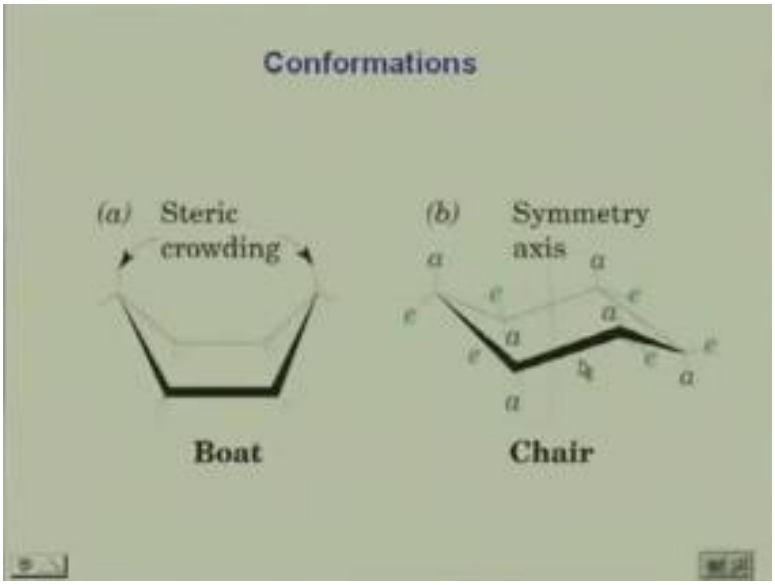

Now, conformations. We have six membered rings for our glucose, which means that we can have either a boat conformation or a chair conformation. This is something you already know with six membered rings. And what do we have is, we have actual bonds or equatorial bonds, depending on the disposition of, why is this shape like this, because this carbon atom is SP3 hybridized, so it has a tetrahedral disposition conformation to it, which means that you can have an actual part and an equatorial part.

And we know, also know that the chair conformation is favored over the boat conformation, because in this case, we have steric crowding.

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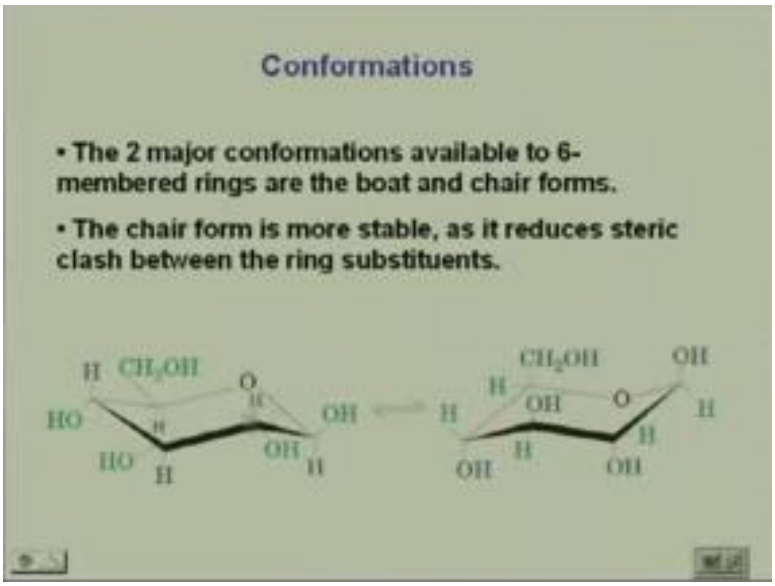

Now, of these two major conformations that are available, so this would be the structure of glucose, we have the six membered ring, which is our pyranose ring, because we have the

oxygen sitting here, we have the OH and we have the OH in this case, it is in the equatorial form. Here, it is in the actual form. So, we have a stable chair conformation because it is obviously going to reduce the steric clash between the ring substituents.

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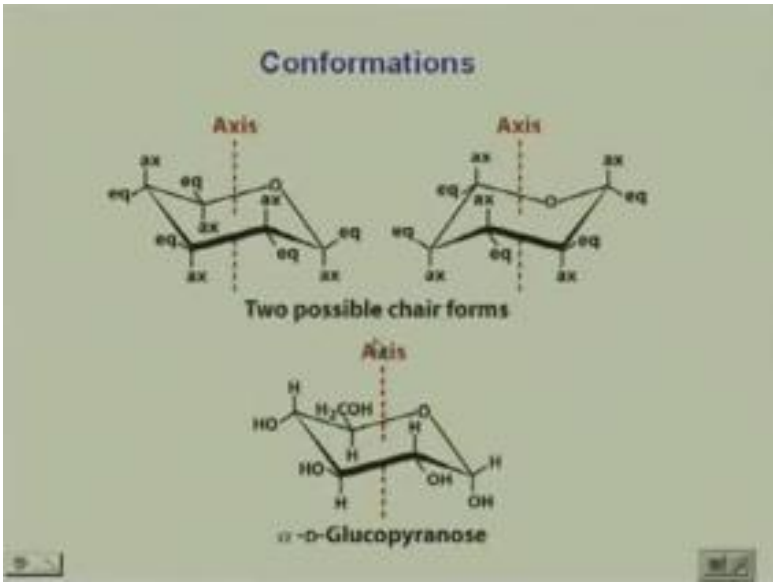

This is something you all know already. So we have here, the actual and equatorial axis. And there are two possible chair conformations, where we have the oxygen here or here. What we can have here, this is alpha D-glucopyranose. Now, you have to look at the name carefully. Pyranose means it has a six-membered ring with oxygen in it. We have the OH trans to the CH 2 OH. So, it is alpha. And why is it D? It is D because the last cyra carbon atom away from the most oxidized carbon atom is having the OH on the right. So, it is alpha D glucopyranose.

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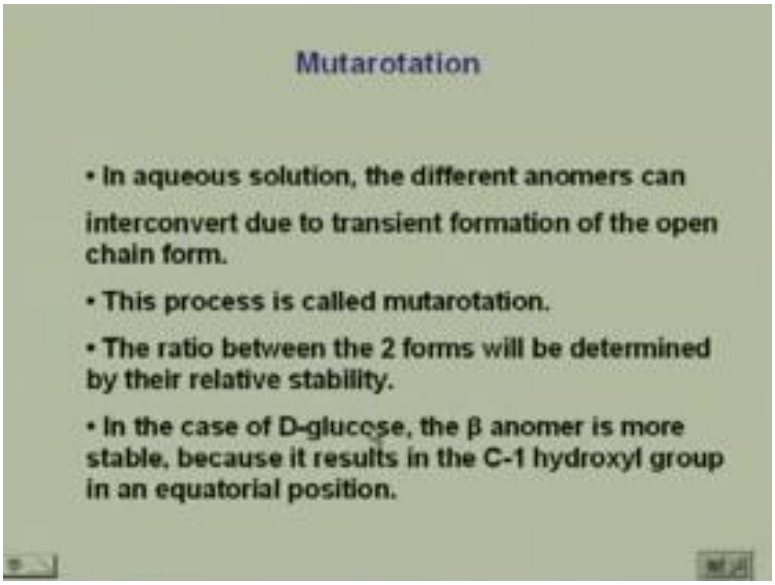

Another thing that we have to consider is, in aqueous solution, the different anomers can actually interconvert between themselves. Now this interconversion, actually gives us a transient formation of the open chain form. Because you realize that once it goes through the reaction, there is going to be a certain intermediate that is going to have the alpha chain in the open conformation.

Now, when it has it in the open conformation, when it closes again, the OH could either be up or down, that is cis or trans to the CH2OH that is on the sixth carbon atom. So, what can happen is, in aqueous solution, when we have the different anomers that can actually interconvert due to the transient formation of the open chain form, this process is known as mutarotation. And the ratio of the two forms is actually determined by the relative stability. And in the case of D glucose, the beta anomer is more stable, because it results in the C-1 hydroxyl group in the equatorial position.

You know that when we have the chair confirmation, first of all between the boat and the chair, we know that the chair conformation is more stable. Now, again when we are looking at the chair confirmation, if you want to look at which of the chair conformations are stable, we know that we have to look at the chair conformation; it has the most bulky substituents at the equatorial positions. So, that is exactly in the case of the beta anomer, where the hydroxyl group is in equatorial position and that will make it the stable form for D-glucose.

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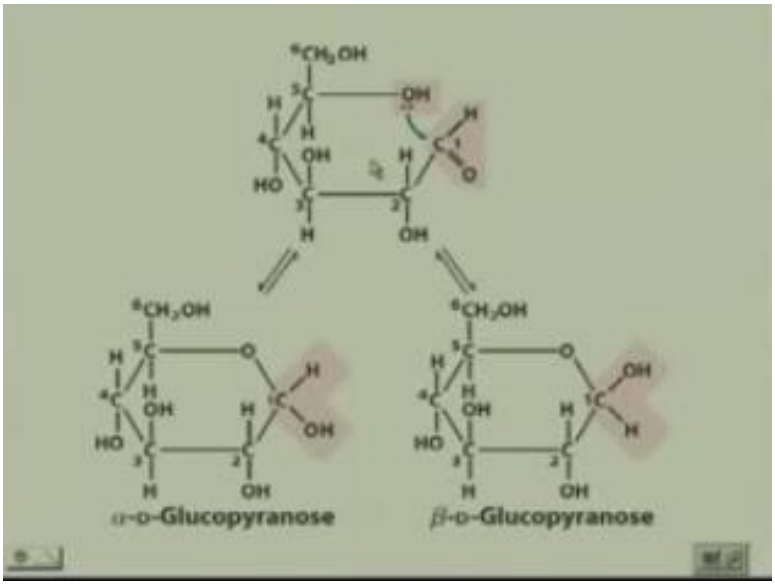

So, this is what we have in looking at the structures of our glucose. We have, basically what are we forming here, we have our aldehyde group, we have the OH that is attached to the

carbon number five. We have the formation or we basically have a cyclisation. In the cyclisation, it is possible that the OH either goes trans to the CH2OH or it goes cis to the CH2OH. We usually use or we refer to these as spranosis because it is based on spran.

And, then we also know that when we look at the chair conformation of this, it would be more convenient to have the OH group at an equatorial position, so that there would be more or basically there will not be any bulky groups at actual positions would fit, would be unfavorable.

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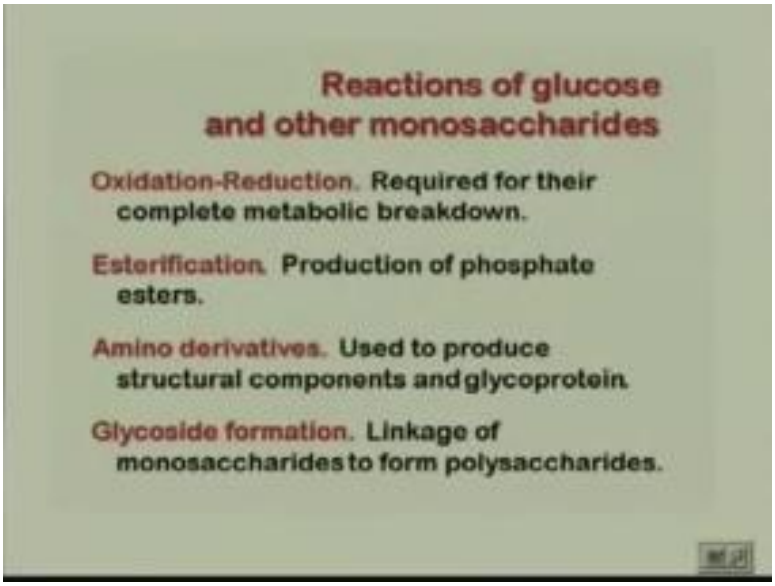

Now, let us look at the reactions of the glucose and other monosaccharaides. There are certain reactions of glucose that are important for the metabolic breakdown of glucose. There is oxidation and reduction that can occur. Oxidation and reduction required for the complete metabolic breakdown of glucose. This is extremely important and another thing important about glucose is storage.

It is not stored as glucose, because glucose breaks down. There is metabolic breakdown of glucose, so when it is stored, it is stored as glycogen. We will see in the next class, what the different types of methodologies are or the different types of linkages are and how we can actually store them. So we have our different reactions, one is oxidation reduction. What is this, oxidation reduction? We require this.

We will see later on when we do bioenergetics and consider the metabolism of carbohydrates and how this is important there. We have esterification, where we have the production of

phosphate esters. We have amino derivatives, where we have the use to produce structural components and glycoproteins. What are these glycoproteins? These glycoproteins are those that have glucose linked to the protein.

And we will see how they are actually linked to the protein. Then, the most important thing that we will be considering for disaccharide formation or polysaccharide formation is glycosidic linkages. So, when we consider glycoside formation, we will understand what these linkages actually are in their formation.

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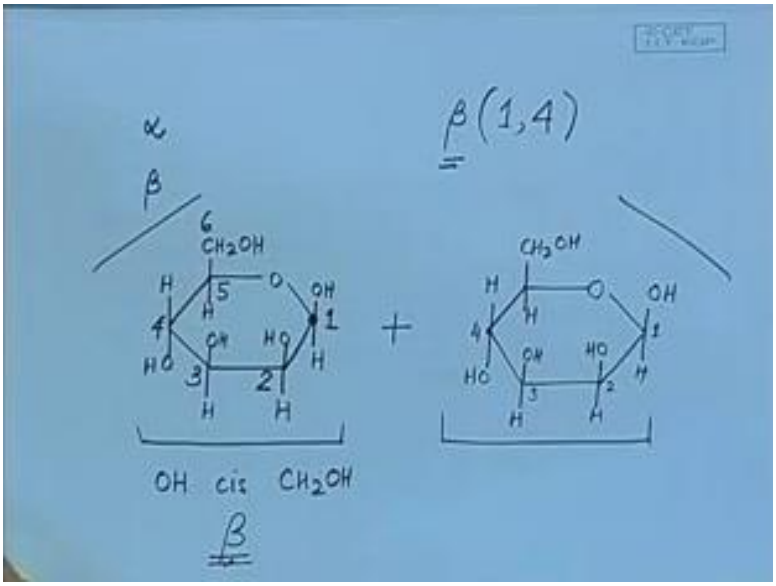

For example, when we consider, we know that we have an alpha form; we know that we have a beta form. Now, if we just look at the structure of glucose, in the different forms then we have OH, CH2OH, H, what is this form? Now, what is happening here, why is that the beta form, because the OH is cis to the CH2OH. So, it is beta. Now, when we talk of these linkages, we have to first of all remember the numbering of the carbon.

What is the number of this carbon? It is number one, this is number two, this is number three, four, five and six. What happened here? We had a hemiacetal formation. Why? Because, we had the aldehyde and the OH of carbon number five linked together. Now, when we have glycosidic linkages, we will see in the next class. We are forming now, from one unit, we are going to link in another unit.

In the linkage of the other unit, we are going to first of all, look at whether this carbon is alpha or beta. Then we are going to determine, what it is linking to or which two carbon

atoms are linked. If you link a 1 and a 4 and the first carbon atom that you are linking is in the beta form, this forms what is called a beta (1, 4) linkage. So, if I were to write, another beta form of this, again I have to number them again, so I have 1, 2, 3 and 4.

If I have now a link between the carbon atom at 1 here and at the carbon atom at 4 in the other monosaccharaide, so this is one monosaccharaide and this is the other one. If I link these two together, it at 1 and 4, I would have a 1, 4, glycosidic linkage. And depending on whether the first monosaccharaide being linked to the second one was in the alpha or beta position, I would have the numbering as, or the basically the type of glycosidic linkage as beta (1, 4).

We will look at this in a bit more detail, when we will do the next lecture. So, what are the reactions the, of these glucose, these are the specific reactions that can actually go on and we looked how we can actually have glycosidic formation. What is this glycosidic formation? If we go back to the slides here, we have the linkage of the monosaccharaides, in this case, what we looked at was the formation of a possible disaccharide.

But, if we keep on linking in this fashion, if we have a series of beta (1, 4) linkages, then obviously I am going to form what is a polysaccharide.

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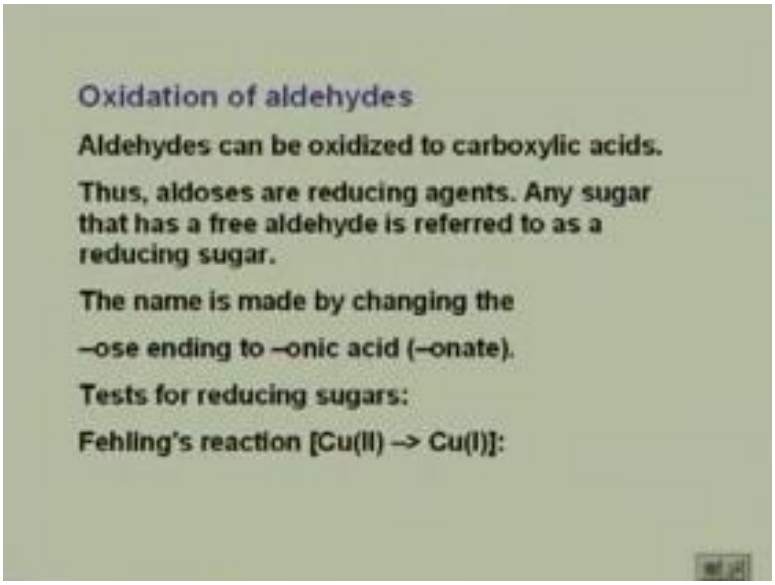

And we will look at the different linkages, as I said in the next class. Now, one of the reactions that is extremely important, when we consider aldehydes is their oxidation to carboxylic acids. In their oxidation, the sugar that has a free aldehyde is usually referred to

as a reducing sugar. So, the sugar with the free aldehyde, for example like glucose. Glucose is the sugar that has a free aldehyde, so all aldoses, what are aldoses? Aldoses are sugars with free aldehyde groups. So, all these aldoses are reducing sugars.

And what happens is actually the name the -ose, when you have the name with the suffix –ose, it refers to as a sugar. So, whether it is a ketose or an aldose, it has the –ose. An aldose is where you would have the sugar, in the aldehyde fond. A ketose is where you would have it in the ketone form. So the name basically is made by changing the –ose ending, that is the –ose, the end of the –ose, to –onate. So if we had glucose, it will become gluconate.

Now, the test for reducing sugars, is something called Fehling's reaction. What happens here, is you have a reduction of copper 2 to copper 1. Now, the basic reaction, this is a reaction for reducing sugars for aldehydes.

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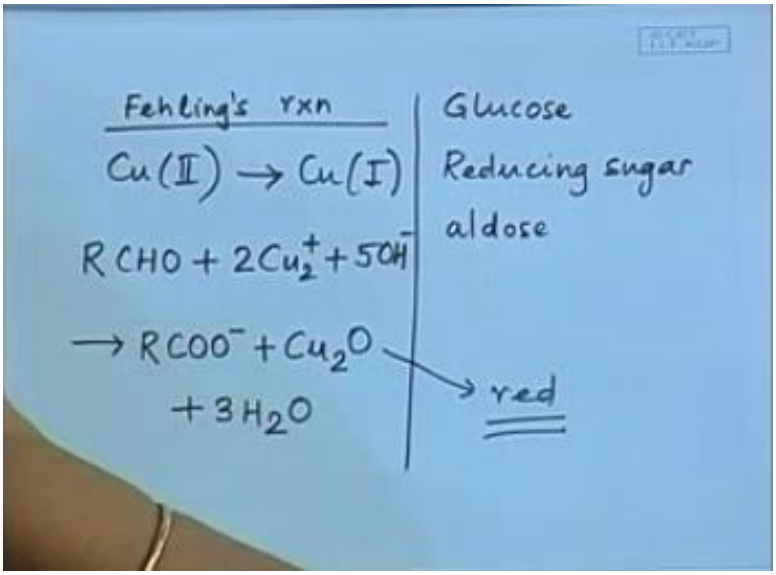

What happens in that case is, this is Fehling's reaction. It is a very common reaction that is used in the determination of whether you have glucose. For example, it can be quantitated even, when you have, say a pathological test or a biochemical test to figure out the, in this case, we are looking at glucose. But it works for any reducing sugar. So, a reducing sugar would be 1 that would have an aldehyde to it.

So what would be an aldehyde with the sugar? An aldose. In this case, we are looking at glucose, which is an aldo hexose. So, that is basically all the nomenclature that we would know for a monosaccharaide. What is basically happening here is, in Fehling's reaction, you

are going from Cu (II) to Cu (I). What happens is, you have RCHO + 2Cu2 plus + 5OH minus, it is basically an alkaline medium, where this goes to RCOO minus.

So, what have we formed from glucose? We have formed gluconate + we have Cu2O. Then what happens here? Is this actually gives you a red coloration, to your experiment.

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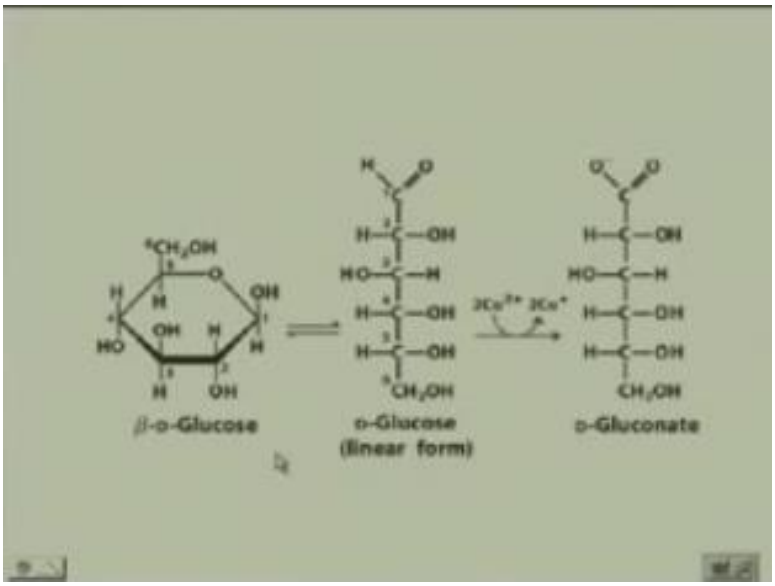

So, what we have in this case here is, this is what happens. In beta D-glucose, now you recognize this as beta D-glucose. So, any structure given to you, you should be recognizable, in terms of where the OH is, where the CH2OH is, where whether it is a fructose or, or rather whether it is a furanose or a pyranose. So, we have a linear form, we have a cyclized form and the Cu2+.

I think in my reaction, I wrote it wrong, right. It must be here. This is what it supposed to be because we have a reduction, right. So the Cu (II) is going to the Cu (I). So, it is 2Cu2 plus. Not here.

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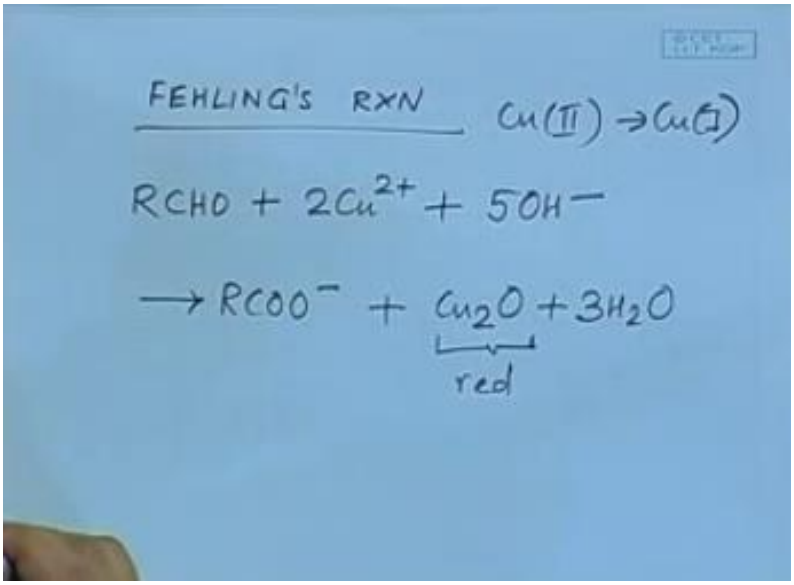

So, for the Fehling's reaction, we have RCHO, the aldehyde + 2 Cu 2plus, because this has to be reduced, going to Cu (I). In the first case, we didn't do that. 5 OH minus, going to, so what are we going to have here, oxidation, Cu2O + 3H2O. And this red coloration is going to be an indicator of the presence of glucose or the presence of a reducing sugar. So, we have our beta D-glucose, the D-glucose in the linear form, forming the gluconate.

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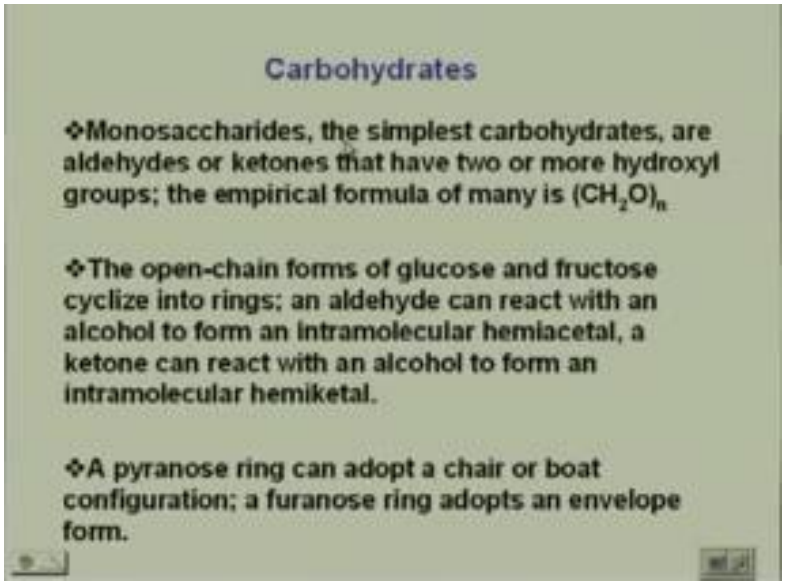

So, this is basically what we did today. We consider the monosaccharaides. The monosaccharaides are the simplest carbohydrates. And we found out that they all are formed from glyceraldehyde. The basic one, the basic form is glycerol and from glycerol, we form glyceraldehyde. And we know that we have two forms of glyceraldehyde, D-glyceraldehyde and L-glyceraldehyde.

What determines, whether it is D or L, it is the disposition of the OH, at the cyral carbon. If it is on the left, it is L-glyceraldehyde. If it is on the right, it is D-glyceraldehyde. Then, we have the aldehydes or ketones that would have two or more hydroxyl groups attached to it basically that would be carbohydrates and the empirical formula is CH2O, whole n, where n is the number of carbon atoms present.

We have aldoses and we have ketoses, depending on whether we have oxidized carbon in the aldehyde form or in the ketone form. The open chain forms of glucose and fructose, cyclize into rings. We looked at that also, where the aldehyde can react with an alcohol to form an intramolecular hemiacetal. We looked at a reaction, where it is possible for the aldehyde and the alcohol to form an hemiacetal.

But in this case, we have the aldehyde and the alcohol, both in the same molecule. Since they are both in the same molecule, we form an intramolecular hemiacetal. And, then a ketone can react with an alcohol to form an intramolecular hemiketal. So, when we formed these structures, we form either a pyranose, depending on whether we have a six membered ring or we formed a furanose, if we have a five membered ring. For the fructose case, we will have a furanose and for the glucose case, we have the pyranose.

Then, we also looked at how the pyranose ring can actually adopt either a chair conformation or a boat conformation. And the furanose actually adopts, what is called an envelope conformation. What is this envelope conformation? I am sure all of you are aware of this.

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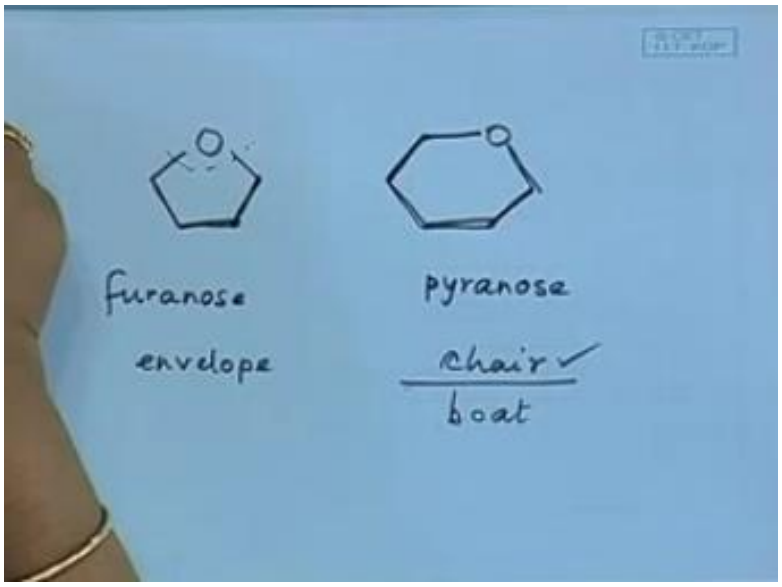

When we have the furanose, it looks like this. When we have the pyranose, it looks like this. So, this would be a pyranose and this would be a furanose. So, what happens in this case is, it is these parts that are level. And in this case, we have either the chair or the boat conformation. But in this case, we have what is known as an envelope conformation. What is the envelope conformation?

The oxygen is slightly lifted up, from the rest of the carbon atoms, like an envelope, like a flap of an envelope. So, like the flap of an envelope, this would adopt an envelope conformation, this would adopt a chair or boat conformation. But, what did we find out? We know that it is going to adopt a chair conformation. Why? because the boat conformation would give it some steric hindrances.

And then, we also found out that the beta conformation would be more stable for glucose. Then, we looked at a certain reaction that could go on or the different reactions that glucose can actually have. Thank you.