

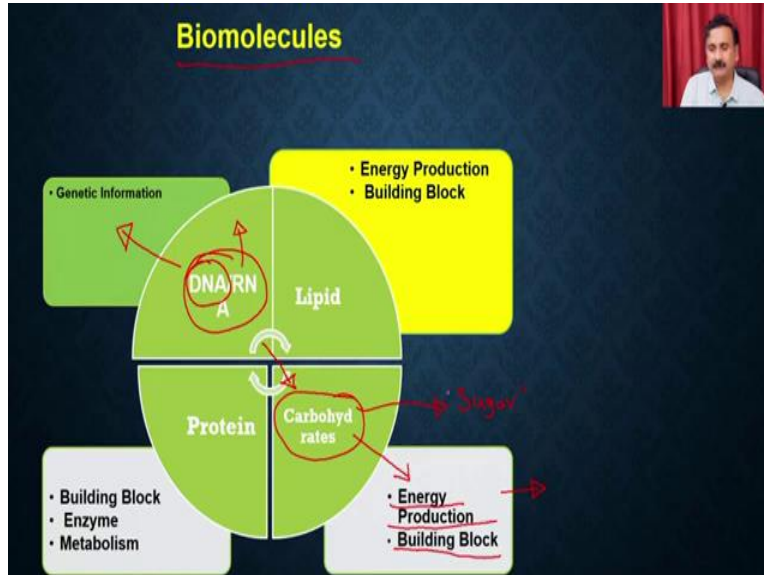
Basics of Biology
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Lecture 16
Carbohydrates (Part 1)

Hello everyone. This is Doctor Vishal Trivedi from Department of Biosciences and Bioengineering, IIT Guwahati. And what we were discussing? We were discussing about the living organisms. And in this context so far what we have discussed? We have discussed about the classification of the living organisms. And then we have also discussed about the evolution of these organisms.

So, and in the previous module we have also discussed about the cells. So, we have discussed about the prokaryotic cells or the eukaryotic cells. While we were discussing about the prokaryotic or eukaryotic cells we could understand that the cellular functions are being performed by the tiny biomolecules which are present in the cells. And so to understand the activity or to understand the cellular functions it is important for us to understand the biomolecules. And in that context, this particular module we are discussing about out the different types of biomolecules.

And if you recall, in our previous lecture we were discussing about the nucleic acids. So, we have discussed about the DNA as well as the RNA. And we have discussed about the structure as well as the different functional properties of the nucleic acids. And the nucleic acid is required for maintaining the genetic information. So, mostly the DNA is the major form of genetic genomic DNA. Or it is the form which actually carries the genetic information from one generation to the next generations. But there are exceptions, where in some cases; the RNA is also been the major molecule which is utilized for carrying the genetic information.

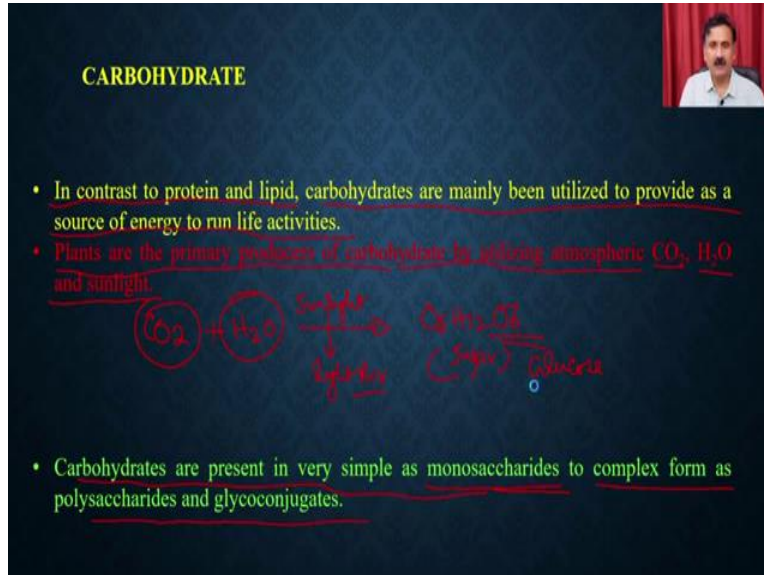
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So, in today's lecture we are going to discuss about another biomolecule. And another biomolecules what we are going to start discussing about, the carbohydrate. So, let us start discussing about the carbohydrates. And so what we were discussing? We were discussing about the different types of biomolecules. And we have discussed about the DNA and RNA. And DNA RNA is required for storing and as well as maintaining the genetic information from the one generation to the next generations, except viruses. The DNA is the major molecule which is responsible for storing the genetic information in most of the organisms.

Now, in today's lecture we are going to start discussing about the carbohydrate. So, when we say about the carbohydrate, the carbohydrate is required for mainly for the energy production. But in some cases the carbohydrates are also been part of the building blocks. They are also responsible for modifying the some of the proteins and some of another biomolecules. Like for example, the carbohydrates are important for generating the glycoproteins and all those kinds of molecules. And these glycoproteins have a significant role in the various types of biological activities, like whether it is for the biological regulations are other kinds of things. So, let us start discussing about the carbohydrates. So, carbohydrates are commonly been called as the sugar.

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CARBOHYDRATE

- In contrast to protein and lipid, carbohydrates are mainly been utilized to provide as a source of energy to run life activities.
- Plants are the primary producers of carbohydrates by utilizing atmospheric CO₂, H₂O and sunlight.

$$\text{CO}_2 + \text{H}_2\text{O} \xrightarrow{\text{Sunlight}} \text{C}_6\text{H}_{12}\text{O}_6 \text{ (Sugar)} + \text{O}_2 \text{ (Oxygen)}$$

- Carbohydrates are present in very simple as monosaccharides to complex form as polysaccharides and glycoconjugates.

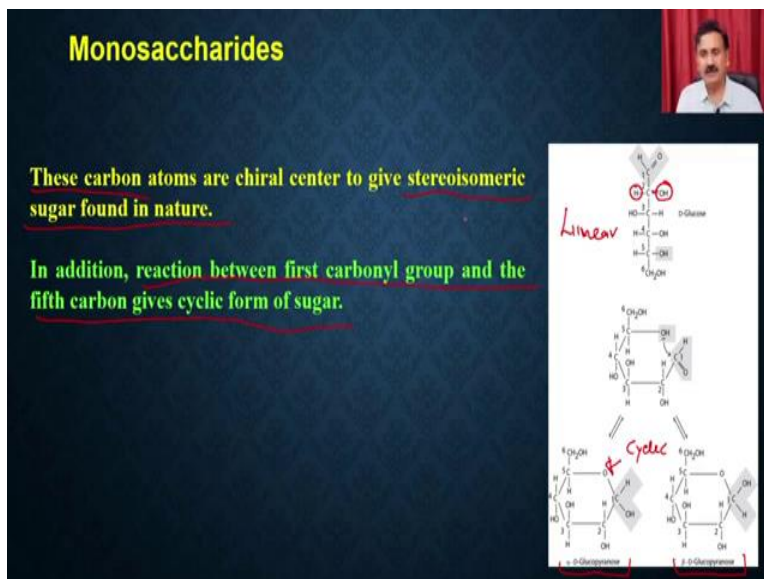
And so carbohydrates, in contrast to the protein and lipids, the carbohydrates are mainly utilized to provide as a source of energy to run the biological activities. Plants are the primary production of the carbohydrates by utilizing the atmospheric carbon dioxide, water and the sunlight. If you recall, we have discussed about this when we were discussing about the chlorophyll, or when we were discussing about the chloroplast.

So, what we have discussed is that the carbohydrate, the plants are actually sequestering the carbon dioxide from the atmosphere. And that is how they are mixing that with the water and in the presence of the sunlight it is actually giving the sugar molecule. So, it is actually giving the sugar molecule. And this is the sugar. And why it is required, the sunlight? Sunlight, it is required for running the light reaction. And it is sequestering the carbon as well as the water molecule to generate the simple sugar molecules.

So, carbohydrates are present in very simple as the monosaccharides to the complex form as the polysaccharides as well as the glycoconjugates. So, let us first start discussing about monosaccharide which is the simplest sugar. This is the monosaccharide commonly known as the glucose.

So, what you see here is that single carbon examples like the glycerol or the 2 carbon examples such as the D- erythro or the D- threo. And the three carbon examples like rabino, lyxo, ribo. And then it is also the 3 carbon examples. So, I have given the many examples. And then it is the 4 carbon examples where you have the D-ello and the D-galacto. So, this is the 5 carbon. And so these are the simple monosaccharide sugars what it present.

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And so these carbon atoms which are chiral centers to give the stereochemistic sugar found in the nature. If you see a simple carbon sugar, what you see here is that all the carbon atoms are actually having attached to the different type of groups. Different, for example, on one side it is attached to the hydroxyl group, one side on to the H group, and the other side it is actually adding with the aldehyde group.

So, this is actually another, first chiral center, second chiral center, third chiral center, fourth chiral center. So, this actually gives the stereochemistry which is found in the nature. And because of it, the carbonyl which is present on to the first carbon is actually been attached on to the last hydroxyl group. And that is how it is actually going to give you the cyclized products.

So, it can actually give you the two different kinds of cyclized products. So, the reaction between the first carbonyl group and the fifth carbon gives the cyclized form of the sugar. And that's how the sugar can actually exist in the three different forms. It can actually exist in the linear form or

it can actually be able to exist in the two different types of cyclized form. Either it can be the alpha form or it can be a beta form. Apart from that we are going to discuss other kinds of these, because it has stereoisomeric carbons. That is why it has many different types of stereoisomers.

(Refer Slide Time: 10:44)

PROPERTIES OF MONOSACCHARIDES

Hemiacetal or Hemiketal formation

Hemiketal formation

The linkage between keto group and alcohol is called as 'ketal linkage'. Forming 5 member furanose ring

D-Fructose D-Fructose D-Fructofuranose

PROPERTIES OF MONOSACCHARIDES

Hemiacetal or Hemiketal formation

The linkage between aldehyde group and alcohol is called as 'hemiacetal' linkage. Forming 6 member pyranose ring.

D-Glucose D-Glucose (Fisher formula) D-Glucopyranose (Haworth formula)

As far as the cyclization is concerned it can actually be able to form the two different types of cyclization products. The first product which is called as the hemiacetal or hemiketal formation that is occurring between, a duct formation between the carbon and the aldehyde group. So, the

linkage formed between the aldehyde group and the alcohol is called as the hemiacetal linkage and this is present in the six-membered pyranose rings.

So for example, this is the glucose, if the one or fifth, if 1 is actually making a cyclization product with the 5 then it is actually be able to form the cyclization product. So, if this is the aldehyde group and if it is attached onto the fifth carbon so that is how it is actually going to form the hemiacetal formations. And that hemiacetal form can be represented in two different forms.

So, what you see here is actually the Fischer formula where the carbon is connected to this one or it can be actually be able to shown into the Haworth formula. So, this is the Haworth formula where the hydroxyl as well as the hydrogen groups are being placed on to a plane and it is actually going to show you to which one is going up on the top of the plane or which are on the bottom of the plane. So, once you actually going to have the carbonyl group which is attached onto the fifth carbon and it is going to form the hemiacetal groups or hemiacetal linkage that can be represented by the two formula, Fischer formula as well as the Haworth's formula.

Same is true for the another one where you can actually have the hemiketal formations. So, hemiketal formation, the linkage between the keto group and alcohol is called as the ketal linkage. This is forming in the 5 member ring as the furanose ring. So, what will happen? When you have the carbonyl group or when you have the keto group and that keto group is present onto the second carbon so that keto group is actually going to attach onto the fifth carbon.

And that's how it is actually going to form the hemiketal formations, and that is how it is actually going to have the two different forms. This is the Fischer's formula and this is Haworth's formula. So, same way, it is going to show you the 5-member ring and it is going to show you the placement of different groups, either on top of the plane or the bottom of the plane.

(Refer Slide Time: 13:29)

Monosaccharides

The cyclization generates additional chiral center and contribute into stereochemical complexity of the molecule.

Optical activity the ability of a sugar to rotate plane polarized light

➤ Orientations
-right - dextrorotatory '+ sign or 'd' indicates dextrorotation
-left -levorotatory. '- sign or 'l' indicates levorotation of a sugar.

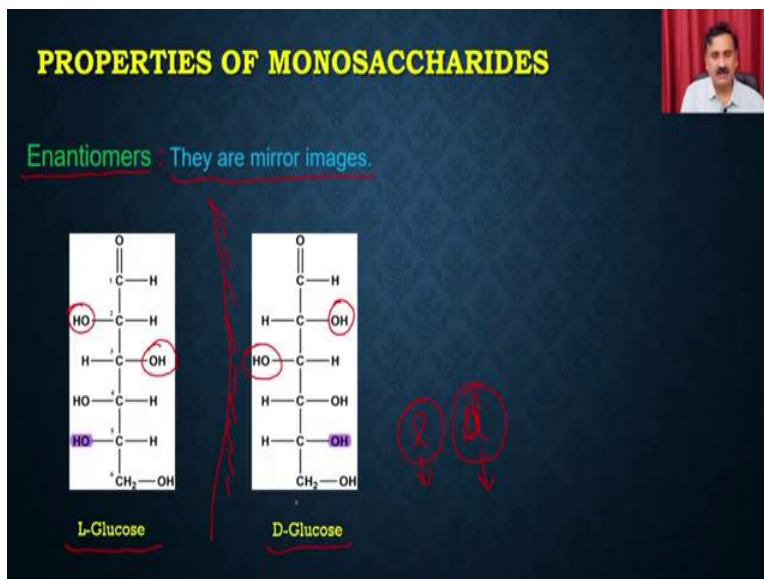
The cyclization actually generates the additional chiral centers and that contributes into the stereochemical complexity of the molecule. For example, this is the glucose molecule where you have the carbonyl group which is on the number 1. Then you have the number 2, 3, 4, 5 and 6. So, all these, when there is a cyclization product between this and this, that is actually going to form this cyclization product. So, that actually is going to give you the additional chiral center, because initially this one, the first carbon is actually not having any chirality. It is actually been attached to the oxygen on one side, hydrogen on one side.

So, this one is not... this is achiral molecule. But when there will be a cyclization product and this is going to be connected like this then it is actually also going to acquire the chirality. So, because of that this actually has 2 OH on this side and H on that side. So, that is how it is actually going to be represented like this. So, now you see this is an additional chiral center what is going to be developed onto the glucose molecule. And because this can be represented in two different ways it can be either the OH on the bottom side or OH on the top side and that's how it can be actually able to adopt either the alpha form or the beta form.

So, depending on the rotation of the different kinds of groups or the ability of the sugar to rotate the plane polarized light it can either be represented by... it can be actually be able to have the dextrorotatory sugar or to the levorotatory sugar. And this dextrorotatory sugar is represented by a plus sign or to the small d sign, whereas the levorotatory sugar is actually going to be

represented by the negative sign or through the small l sign. Because it has different kinds of chiral centers it can acquire the ability to rotate the plane polarized light it actually can have the different types of stereoisomers.

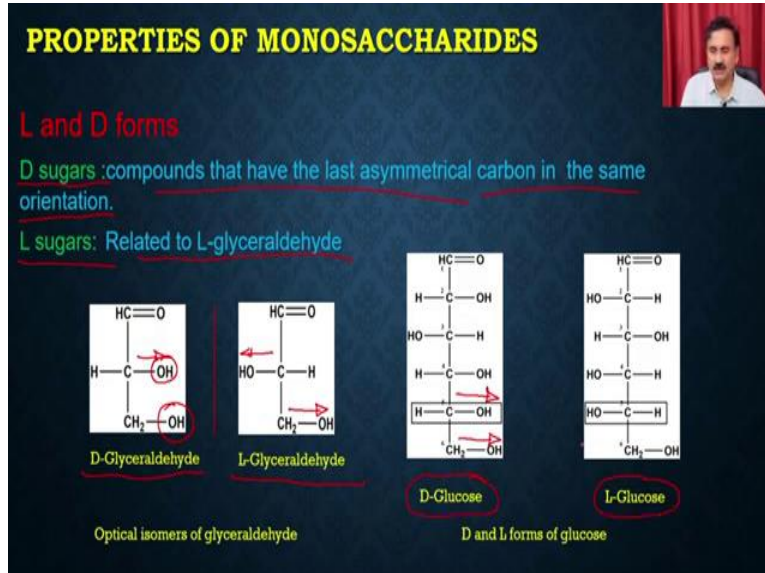
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Now, one of stereoisomers is the enantiomers. So, enantiomers are actually the mirror image to each other. So, if you keep a mirror here what you will see? In this one is actually going to be the mirror image of this. So, you know that all the groups are going to be flipped to the 180 degrees. So, for example in this one, except the first group all other groups... like see the OH is on this side, on this one the OH is on this side. The OH is in this side, this is OH in this side.

So, that's how all these are actually been flipped by the 180 degree. And that's why this form is called as the L form and this one is called as the D form. So, what I say is, don't get confused when you see the L and D versus the small l and small d. This small l is actually levorotatory and this d is actually called as the dextrorotatory, whereas here we are actually going to show you the enantiomers where you have the capital L form or the capital D form.

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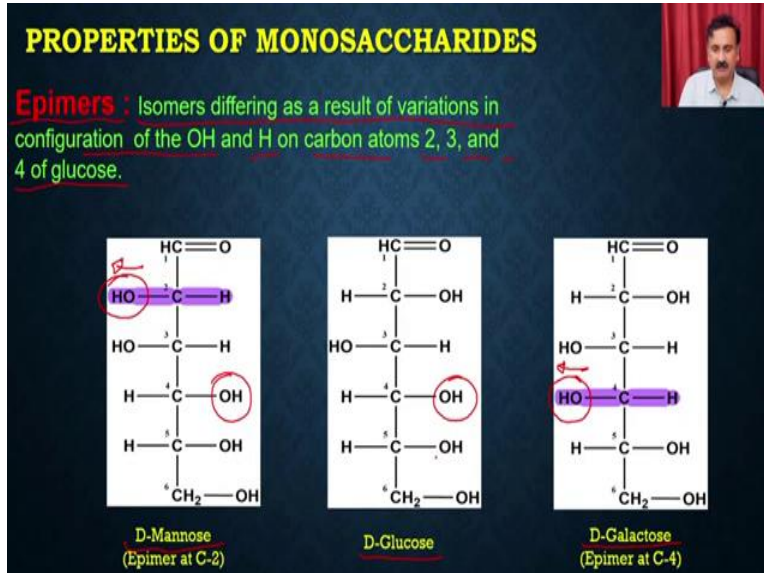


So, this is what explained here. So, D sugar, compound that have the last asymmetrical carbon in the same orientation, that is called as the D form, whereas the L form it is related to the L-glyceraldehyde. So, what you see here is the if the last asymmetrical carbon is actually having the groups on to the same side, you see this one has the functional group which is on this side, and this one also has the functional group on to this side then this is called as the D form.

Whereas in the L form it is actually going to be in the reverse orientation. So, the group is actually on to the this side where as the last carbon has the group on the side. So, they are actually been presented in the two different modes. And that is why these two are actually going to be the mirror image as well. So, this is the D form and this is the L form.

Same is true for the glucose also. In the glucose this is the last asymmetrical carbon. So, if the last asymmetrical carbon the groups are on this side, and if this one also has the group on the side then this is called the D form whereas in L form it is actually going to be on the reverse orientation.

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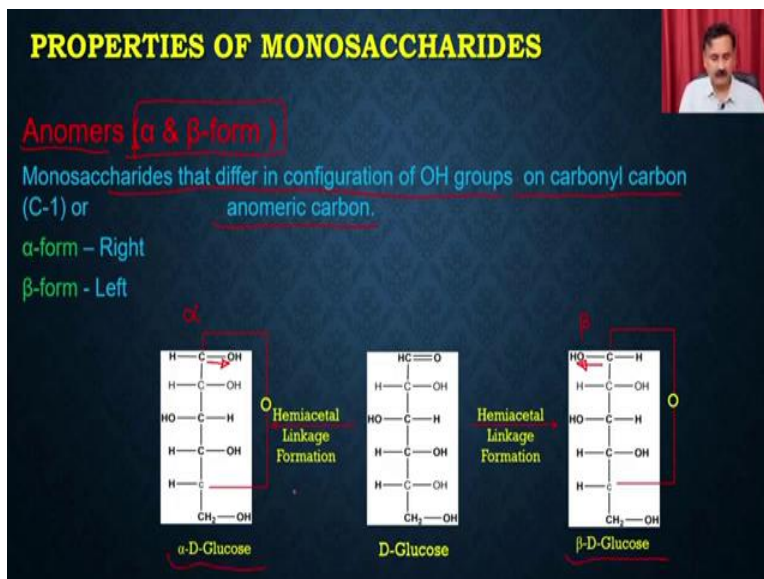


Now, we can have another kind of isomerism that is called as the epimers. So, the isomers differ as a result of variation in the configuration of the OH and H on the carbon atoms as 2, 3 and 4 glucose molecule. So, you can see in a glucose molecule, at 2, 3, 4 and 5 you have the hydroxyl groups. And that is why the positioning of the hydroxyl as well as the H group on the different carbon atoms or the differences between the different orientation of the OH and H on the different carbon atom you can have the different types of epimers.

For example, this is the D-Mannose because you have the epimerization of the OH groups. So, OH is on this side. So, this is called as the epimer at carbon 2 and that is present in the D-Mannose. Similarly you can have the epimerization in D-Glucose. So, here also you can have the epimerization at carbon 3. So, you have the carbon 3 at different orientation. This is the standard molecule where you have the epimerization, and this is going to be used.

Then in the case of D-Galactose, you see the D-Galactose at the carbon 4 the orientation of the OH is on this side. So, this is actually be going to be different from the other sugars. For example in this one you have the OH on this side, in this one also you have the OH on this side. So, in the glucose what you see here is this is the standard molecule. So, this is going to be used for comparison purposes.

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Then we have the anomers. So, anomers are actually been orientation of the alpha or, anomers means alpha or beta forms. So, anomers are monosaccharides that differ in the configuration of the OH group on to the carbonyl carbon or to the anomeric carbon. So, you can see that this is the linear chain D-Glucose molecules and when it is actually going to go through with the hemiacetal linkage formation it actually can going to generate the additional chiral center on to this first carbon. So, on to the first carbon if the OH is on to the right side then it is actually going to be called as alpha form, whereas if the OH is going to be on to the left side then it is actually going to be called as beta form. So, this is the alpha D beta form. This is the beta D beta form.

(Refer Slide Time: 20:45)

PROPERTIES OF MONOSACCHARIDES

Mutarotation

Monosaccharides containing asymmetric carbon atom rotate plane polarized light.

The change in optical rotation when either form of glucose is allowed to stand in solution is mutarotation

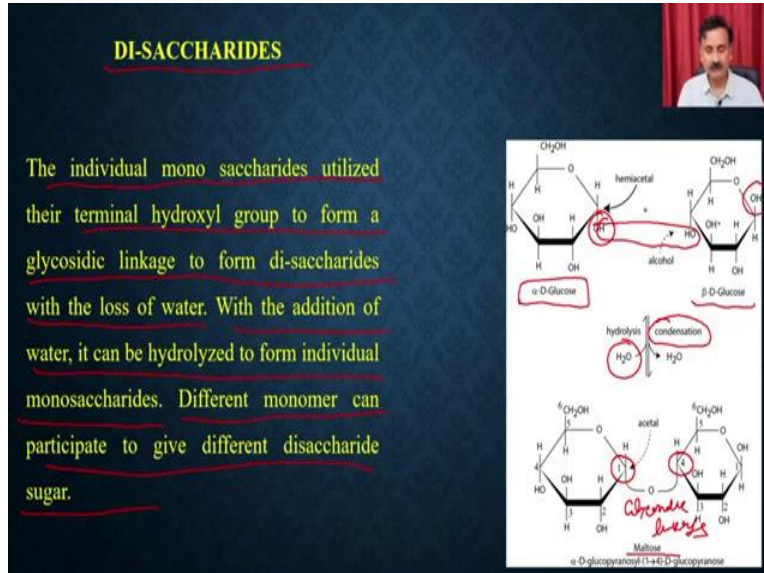
α -D-Glucose +112°

D-Glucose (Acyclic form) +52.5°

β -D-Glucose +19°

Then we have the mutarotation. So, monosaccharides containing the asymmetrical carbon atom rotate the plane polarized light. The change in the optical rotation when either form of the glucose is allowed to stand in a solution is the called as mutarotation. So, you can see here is this is the alpha form, and this is the beta form. So, in the alpha form you see the optical rotation is plus 112 degree. But if you allow this sugar to stand into the solutions what will happen is it is going to return back to the linear form. So, with the conversion of this particular sugar into a linear form which is the D- Glucose form it is actually going to change its optical rotation. So, it is going to have the optical rotation of plus 52.5 degrees. Whereas same is true for this one also. If you see the beta form, the beta form has the optical rotation of plus 19 degrees, but on standing the sugar into the solution it is actually going to get converted into the linear chain. And that is how the optical rotation is going to be changed to 52.5 degree.

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Then the sugars actually can come together and they can be able to form the disaccharides. So, when you have the two different sugars you can have the hemiacetal formation. So, on both the sugar, so what will happen is that there will be a dehydration reaction. So, there will be a dehydration reaction, and because of that there will be a loss of water molecule and there will be a linkage which is going to be formed between this and this.

So, what will happen is there will be loss of water and this is actually going to lose, then there will be a linkage which is going to be formed. This is going to be called as the glycosidic linkage. And the disaccharide what is going to be formed, you can rate this as alpha D-glucopyranocyl 1-4 galactocytase. Why it is called as 1-4? Because you are actually making a linkage between the first carbon and the fourth carbon. So, the OH what is present onto the fourth carbon and the first carbon is involved into the formation of the glycosidic linkages.

So, the individual monosaccharides utilize their terminals hydroxyl group to form a glycosidic linkage to form the disaccharides with the loss of water. With the addition of the water it can be hydrolyzed to form the individual monosaccharides. Different monosaccharides can participate to give you the different types of sugar.

Same is true, like if you take the disaccharide, for example this is the Maltose. So, if you take the Maltose and if you add this water then what will happen is the water is actually going to

hydrolyze this particular bond and that is how you are actually going to have the two sugar molecules. So, you are going to have the alpha D-Glucose. See the OH is on to the lower side and you are going to have the beta D-Glucose where the OH is on to the top side.

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Glycosidic bond/ linkage

O-glycosidic: When hydroxyl group on anomeric carbon of a sugar reacts with an alcohol (or another sugar). They exist in disaccharides, oligosaccharides and polysaccharides.

N-glycosidic: Hydroxyl group on anomeric carbon of sugar reacts with an amine. They are present in nucleotides, RNA and DNA.

O-Glycosidic bond

N-Glycosidic bond

Glycosidic linkages what is been formed into the sugar could be of two different types. You can have the O- glycosidic linkages or the N- glycosidic linkages. O- glycosidic linkages, when the hydroxyl group on to the anomeric carbon of sugar react with alcohol of the another sugar then that is called as the glycosidic O- linked glycosidic linkages, such as, just now we have seen here in this one also we have seen this is the O- linked glycosidic linkages, means it is actually going to be between the first and the fourth carbon.

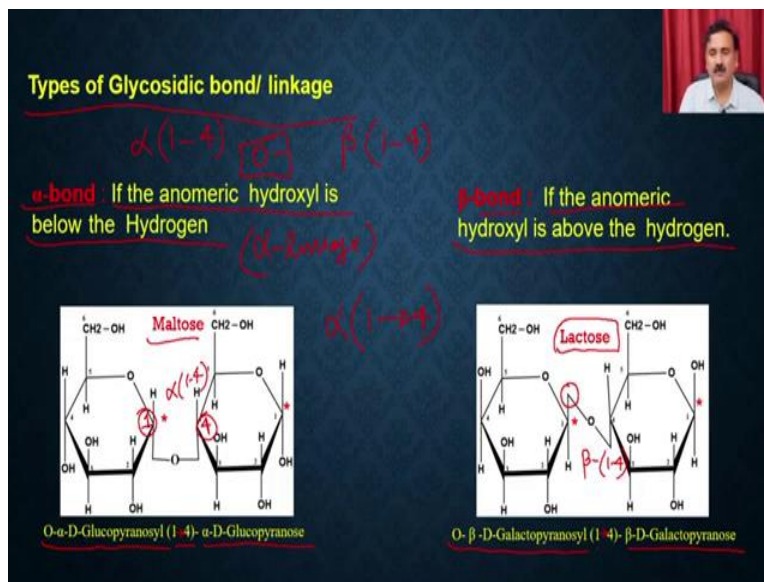
So, this is the anomeric carbon where you have the OH. So, that OH is actually making a condensation with the another OH on to the fourth position, and that is how it is actually going to form the O- linked glycosidic linkages. This kind of linkages are present in the disaccharides, oligosaccharides and they are also present in to the polysaccharides, which means the O- linked glycosidic linkages are mostly been present into the sugar molecules, so sugar to sugar actually.

Then we have the N- linked glycosidic linkages, so hydroxyl groups on to the anomeric carbon of the sugar reacts with an amine. They are present in the nucleotides RNA and the DNA. So,

when you have the sugar and you want to see the N- linked glycosidic bond formations you can see that into the formation of the nucleotides.

So, remember that when we were discussing about the nucleotides, when we were discussing about the nucleic acids, so nucleotides are being formed when the sugar is actually making a linkage with the base. And I said this is the base linkage is actually going to be the glycosidic linkage. So, this is actually going to be the N- linked glycosidic linkage. So, that is actually going to give you the nucleoside, and when it is actually going to make pair with the phosphate then it is actually going to give you to the nucleotides. So, that is what is called as the N- linked glycosylations, N- linked glycosidic bond formations. And that is present in the different types of nucleotides which are present in the RNA or the DNA.

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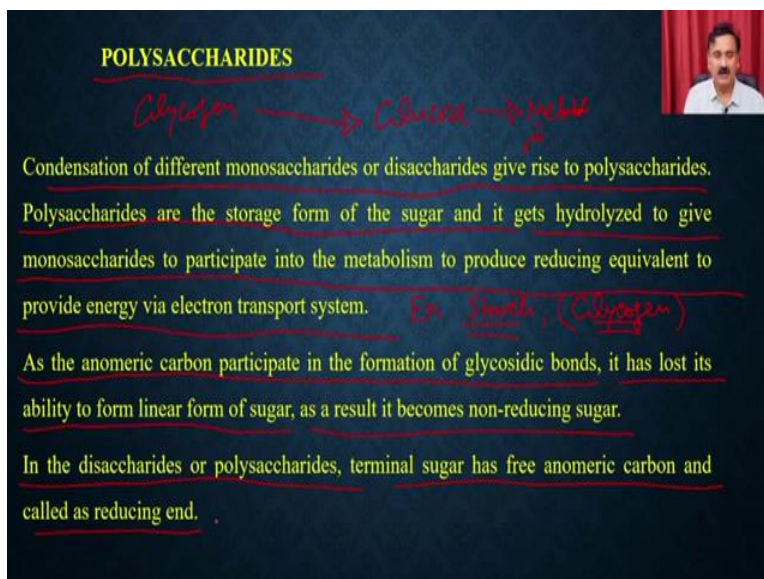


Then type of glycosidic bond or linkages, so you can have the two different types of bonds. You can have the alpha bonds, alpha 1-4 linkages just now we have seen. Or you can have the beta 1-4 linkages. So, if the anomeric hydroxyl is below the hydrogen, then it is actually going to be called as alpha glycosidic linkage. So, it still be O- linked glycosylation, O- linked glycosidic bond formation. But it is going to be called as alpha linkage which means it is going to be called as alpha 1-4 linkage.

So, for example in this case, this is the Maltose. So, what we have the OH on to the lower side. This is the alpha form. So, then if it is reacting with the another OH on to the fourth position, so this is the number 1 position which is the anomeric carbon, and this is the fourth position then it is actually going to be called as alpha D-glucopyranocyl 1-4 alpha D-pyranose. So, this is actually going to be alpha 1-4 linkage. And why it is called as alpha 4? Because the OH what is been involved into the formation of glycosidic linkage is actually present in the alpha conformation.

Then we have the another kind of thing where you have the Lactose. So, here OH is present in the beta conformation. What is the beta bond? If the anomeric hydroxyl is above to the hydrogen. So, if the hydroxyl group is present into the beta conformation or beta form and if it is involved into the glycosidic bond formation then that will be called as beta linkage. And for example here we have the beta 1-4 linkage. So, here what we have is beta D-Galactopyraonsyl, 1-4 beta D-Galactopyraonsyl. So, here this is the structure of the Lactose. Same kind of glycosidic bond are actually going to be formed to give rise to the polysaccharides.

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POLYSACCHARIDES

Glucose → Sucrose → Maltose

Condensation of different monosaccharides or disaccharides give rise to polysaccharides.

Polysaccharides are the storage form of the sugar and it gets hydrolyzed to give monosaccharides to participate into the metabolism to produce reducing equivalent to provide energy via electron transport system. Ex. Starch, (Glycogen)

As the anomeric carbon participate in the formation of glycosidic bonds, it has lost its ability to form linear form of sugar, as a result it becomes non-reducing sugar.

In the disaccharides or polysaccharides, terminal sugar has free anomeric carbon and called as reducing end.

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So, these are the polysaccharides. So, here, the condensation of the different monosaccharides or disaccharides will give rise to the polysaccharides. Polysaccharides are the storage form of sugar and it gets hydrolyzed to give the monosaccharides to participate into the metabolism to produce the reducing equivalent to provide the energy by the electron transport chain.

The examples are like the starch which is the storage polysaccharides present into the plants, or we have the glycogen which is the storage polysaccharide what is present into the animals. Both the starch or the glycogen are actually being stored in the form of the food and that's how they are actually going to be used for the energy production.

So, what will happen is that polysaccharide, whether it is the glycogen for example, so glycogen is actually, whenever there is a requirement of the energy e the glycogen is actually going to be converted into the glucose and then the glucose will go into the metabolism and it is actually going to produce the energy.

Same is true for the starch also. As the anomeric carbon participates in the formation of glycosidic bond it has lost its ability to form the linear form of sugar. As a result it becomes a non-reducing sugar. In the disaccharides or the polysaccharides, the terminal sugar has the free anomeric carbon and called as the reducing sugar. So, if I want to know whether a particular sugar is, so you can have two different types of sugar. You can have the sugar which is reducing sugar, or you can have the sugar which is non-reducing sugar.

So, what is meant by the reducing sugar? So, reducing sugar is in the case of disaccharides where the terminal sugar has the free anomeric carbon and called as the reducing sugar, whereas in the case of polysaccharides as the anomeric carbon is also participating into the glycosidic bond it has lost its ability to form the linear sugar. As a result it becomes a non-reducing sugar.

So, let me explain this. For example in the case of disaccharides what will happen is that, suppose this is one of the disaccharide sugar. What will happen is that this is going to be formed. So, this is going to be formed like this. But this is your anomeric carbon where you have the OH. And this is free. So, this, for example, if this is Maltose which is... so I am not showing all other bonds but... this is the alpha 1-4 glycosidic linkage and that is how it is actually going to be, and this OH is free. So, this actually can participate in to the reduction and oxidation reactions. So, this is going to be called as the reducing sugars, whereas in the case of polysaccharides what will happen is that you can imagine that this OH, if I convert the Maltose to a polysaccharide or if you add some more sugar, so what will happen? If this OH is again going to form a bond.

So, if you see the polysaccharides it is like this. So, it is like this. So, this is the anomeric carbon. So, this is your anomeric carbon. This is the 1-4. So, it is 1-4 linkage. This one is actually the fourth linkage. This is the 1, this is 4, this is 1, this is 4. So, you see the anomeric carbon is actually been involved into the formation of this particular bond. So, there is no free OH at the anomeric carbon what is present. So, that is why this is actually going to be called as the non-reducing sugar.

Now, the question is how you actually can be able to know whether the given sugar is actually going to be the reducing or the non-reducing? To know that you can actually be able to test the ability of a sugar to reduce the given compounds.

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PROPERTIES OF MONOSACCHARIDES

Reducing properties

Glucose and other sugars capable of reducing ferric or cupric ion in solution are called reducing sugars.

They reduce and colour Benedict's and Fehling's solution with the aldehyde group of the sugar.

Benedict Test

- Get a clean test tube. Place inside the test tube 1 ml of sample.
- Put about 10 drops of Benedict's reagent in the test tube.
- Bring the solution to heat in a boiling water bath for approximately five minutes.
- Observe for changes in color and watch out for precipitate formation.

Benedict Reagent

- Anhydrous sodium carbonate
- Sodium citrate
- Copper(II) sulfate pentahydrate

Color change diagram: Blue (None) → Green (Traces of reducing sugar) → Yellow (Moderate) → Red (Large amount of reducing sugar)

So, glucose and the other sugars are capable of reducing ferric or cupric ion in the solution and are called as the reducing sugars. They reduce and the color, Benedict's and Fehling's solution with the aldehyde groups on to the sugar. So, what is the Benedict test? So, if you want to know whether the sugar is reducing or non-reducing is you can do a Benedict test. So, Benedict test is actually been very simple test where you can take the Benedict reagents.

So, what is Benedict reagents? Benedict reagent is the combination of anhydrous sodium carbonate, sodium citrate and it has the copper 2 sulfate pentahydrate which means it is actually going to have the copper 2 plus. And this is going to be a blue colored reagent. So, if you don't have a sugar it is going to give you the big blue color reagent.

So, what you have to do is take a clean test tube and place inside that test tube 1 ml of the solution. So, whatever the sugar solution you want to test, whether it is reducing or no-reducing, you take the 1 ml of that particular solution. Then you put the 10 drops of Benedict reagent into the test tube. Bring the solution to heat in a boiling water bath for approximately 5 minutes. So, you can you can take 1 ml solution into the test tube, and then you add with the help of the, so you add the sugar solution and then you add the small amount of the Benedict reagents, and then you are actually going to keep this into a water bath. So, when you boil this in a water bath there will be a reaction between the sugar and the copper that is present into the Benedict reagent. And

as a result you are actually going to see the change in the color into the particular Benedict reagent solution.

So, what you will see is that if there will be no sugar what is present or if the sugar is non-reducing then it is actually going to give you the no change in the color. So, if there will be no change in color that could be because the sugar is non-reducing. Then if it is going to give you a slight green color solution then that will be called as it has a very small amount of reducing sugar. Then if it is going to give you the yellow color then it is going to be a moderate amount of the reducing sugar. And if it gives you the red color then it is actually going to say that you have a large quantity of the reducing sugar. Apart from the Benedict reagents you can also use the Fehling solution then that also is going to give you the similar kinds of results.

So, with this, we have understood the different types of properties of the monosaccharides. We have understood the structure of the carbohydrates and we have also understood how you can be able to distinguish between the reducing and the non-reducing sugar.

Apart from that, in this particular lecture we have also discussed about out the different types of isomerism what is found into the sugar monosaccharides, and how the monosaccharides are coming together to give you the disaccharides. It is actually performing the glycosidic linkages. And these glycosidic linkages could be alpha type or the beta type.

And apart from that we can have the two different types of glycosidic linkages. Either you can have the O- linked glycosidic linkages or to the N- linked glycosidic linkages. So, with this brief discussion about the structure as well as the properties of the carbohydrates I would like to conclude my lecture here. In our subsequent lecture we are going to discuss about the metabolism of the carbohydrates and how the carbohydrates are participating into the energy production.

So, with this I would like to conclude my lecture here. Thank you.