WEEK 5

UNIT 2-2_CARBOHYDRATES	**Where? How long?**	***Explanations /Questions***
Introduction Carbohydrates are organic molecules produced by photosynthetic organisms; they are synthesized from inorganic molecules: water and carbon dioxide. They are found on outer part of the cell surface form the cell coat and intervene in various cellular functions such as cellular communication, recognition, attachment and so on. Inside the cell, carbohydrates serve as cellular fuel; they are the main source of energy in the cell. ***Expectation*** In this lesson, we'll be talking about carbohydrates. The word 'carbohydrate' comes from the atom carbon and hydrate, or water, because the first carbohydrates that were discovered consisted of carbon, oxygen, and hydrogen atoms. To give you an idea of what these look like, well, first we'll introduce four sugars that you come across often in biology, and then we'll move on to discuss how they can come together to form larger polysaccharides ***Course outline*** Monosaccharides Disaccharides Polysaccharides	10 minutes	Where is this from? Explain here what it is they are going to be learning and ***why*** they need to know about Carbohydrates Also what the expectations are in terms of time commitment, tutor support and so on.
Learning outcomes At the end of this unit, you should be able to: • Explain the classification and the structure of carbohydrates • List common monosaccharides, disaccharides, and polysaccharides • Describe how the chemical structure of monosaccharide leads to the formation of complex and branched carbohydrates.		

ACTIVITY AHEAD OF LESSON :CARBOHYDRATES		30 minutes	
Purpose:	Carbohydrates are also called saccharides to mean sugars. They exist as monosaccharide, single sugar unit, and also as metabolic intermediates with a large variety of function. They also exist as oligosaccharides, when two to ten units are linked and as complex polymers called polysaccharides or complex carbohydrates for more than ten units linkage.		
Over to you:	Watch this video and read this course about structure of carbohydrates ***Be certain to note anything that you don't understand***		
Activity:	Complete the assignment about carbohydrates in order to organize the new information you have learned **Submit the assignment in the LMS system before the end of week 7**.		

CARBOHYDRATES	20 minutes	Notes to tutor
Carbohydrates can be represented by group of molecules that all contain carbon, hydrogen, and oxygen in the molar ratio 1:2:1. Their empirical formula is $(CH_2O)_n$, where *n* is the number of carbon atoms. Carbohydrates are classified into three subtypes: monosaccharides, disaccharides, and polysaccharides.		

MONOSACCHARIDES

- Structure

Monosaccharide are simple sugars with multiple OH groups.
In monosaccharides, the number of carbons usually ranges from three to seven.
Based on number of carbons (3, 4, 5, 6), a monosaccharide is a triose, tetrose, pentose or hexose.
They contain either aldehyde function or ketone function.

Formula of monosaccharides: $C_X (H_2O)_X$
Glucose ($C_6H_{12}O_6$) : the most common monosaccharides

Fructose ($C_6H_{12}O_6$)
Ribose ($C_5H_{10}O_5$)
Galactose ($C_6H_{12}O_6$)
Glyceraldehyde ($C_3H_6O_3$)

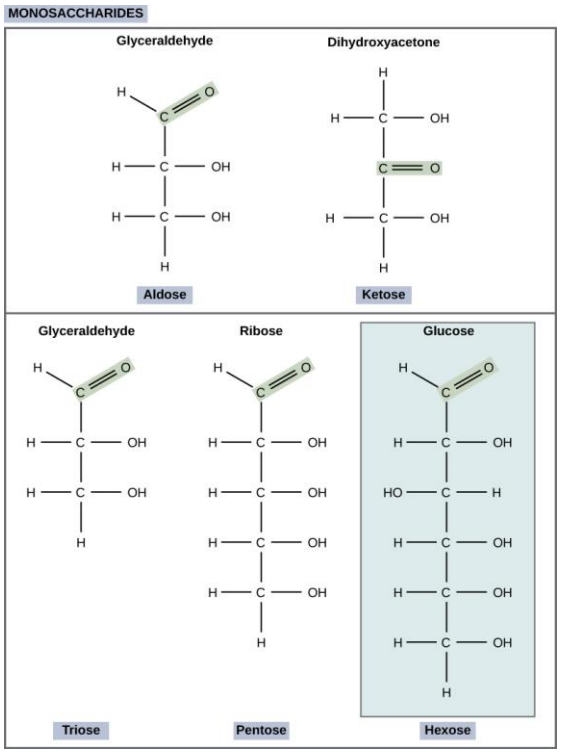

Figure 2.4 : Monosaccharides are named by the type of function and the number of carbon. In aqueous solutions, open-chain form is interconverted with the cyclic form
OpenStax Biology 2nd Edition, Biology 2e. OpenStax CNX. Feb 13, 2019,accessed February 14, 2019. https://cnx.org/contents/jVCgr5SL@15.3:pKmvmCbd@10/3-2-Carbohydrates

Make sure students remember what is an aldehyde and a ketone.

The natural sugar found in fruits is fructose

e s

Notes to tutor

In fact, in aqueous solution, all monosaccharides with five or more carbon atoms can undergo a reaction in which they **rearrange** their bonding pattern to form **cyclic** structures. It is a **reversible** reaction in which the **open-chain form** is interconverted with the **cyclic form** in the backbone, process called **mutarotation**.

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Isomers α or β will be formed. The carbonyl carbon in cyclic form is called anomeric carbon and the two cyclic forms are called anomers. **Anomers t**hey are classified, based on the orientation of the **hydroxyl group** (**OH**) on the anomeric carbon, as the **α-anomer** or the **β-anomer**. The **α-anomer** has the **OH** on the anomeric carbon oriented **downward** from the ring while the **β-anomer** has the **OH** on the anomeric carbon oriented **upward** from the ring.

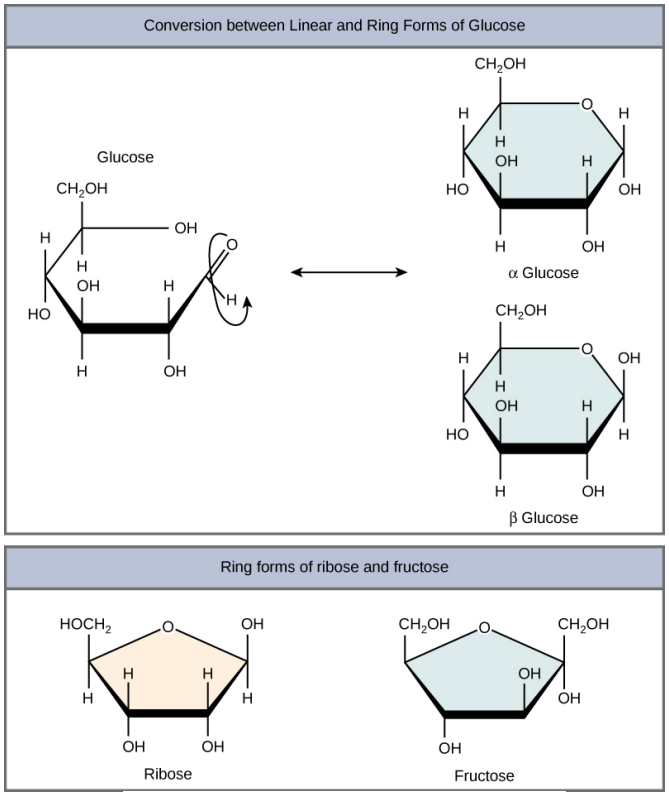

Figure 2.5 : Five and six carbon monosaccharides exist in equilibrium between linear and ring forms. When the ring forms, the side chain it closes on locks into an *α* or *β* position. Fructose and ribose also form rings, although they form five-membered rings as opposed to the six-membered ring of glucose.
OpenStax Biology 2nd Edition, Biology 2e. OpenStax CNX. Feb 13, 2019,accessed February 14, 2019.
https://cnx.org/contents/jVCgr5SL@15.3:pKmvmCbd@10/3-2-Carbohydrates

Explain that:

Cyclic sugar structures are more accurately repre- sented in **Haworth perspective formulas** than in the **Fischer projections** commonly used for linear sugar structures.

In Haworth projections the six-membered ring is tilted to make its plane almost perpendicular to that of the paper, with the bonds closest to the reader drawn thicker than those farther away, as in Figure 2.5 (Glucose).

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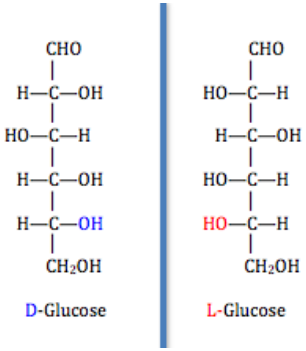
IN CLASS ACTIVITY: ISOMERS AND STEREOCHEMISTRY

20 minutes

Purpose:	To define stereochemistry and differentiate isomers, epimers and enantiomers.		
Over to you:	Using a laptop make a research of above terms.		
Activity:	Draw the Haworth perspective formulas for D-mannose and D-galactose. Draw the Haworth perspective formulas for α -D-mannose and β -L-galactose		

- **Isomers and stereochemistry**  **Figure 2.6 : D-Glucose and L-Glucose are enantiomers because they are mirror images of each other and are not superimposable on one another.**by Milcuana. November 22,2010,accessed February 14, 2019. https://commons.wikimedia.org/wiki/File:Enantiomers-Glucose.png - **Monosaccharide derivatives** There are a number of sugar derivatives in which a hydroxyl group in the parent compound is replaced with another substituent, or a carbon atom is oxidized to a carboxyl group. F*our* classes of monosaccharide derivatives include: **Amino Sugars, Carboxylic Acid Sugars, Alcohol Sugars** and **Deoxy Sugars.** Example: Ribitol, *N*-acetylglucosamine…	20 minutes	**Notes to tutor** Project picture of Glucose enantiomers Discuss with students the differences. the tutor should lead a class discussion reviewing the difference between isomers, epimers and enantiomers. A students volunteer will go to the black board and draw structural isomers of Glucose .

DISACCHARIDE

Disaccharide sugars are formed by a condensation reaction between two monosaccharides. The covalent linkage is called an **O-glycosidic bond** and can be either α or β.
Disaccharides of great importance include maltose (made by 2 glucose units), lactose (made by glucose and galactose units) and sucrose (made by glucose and fructose units).

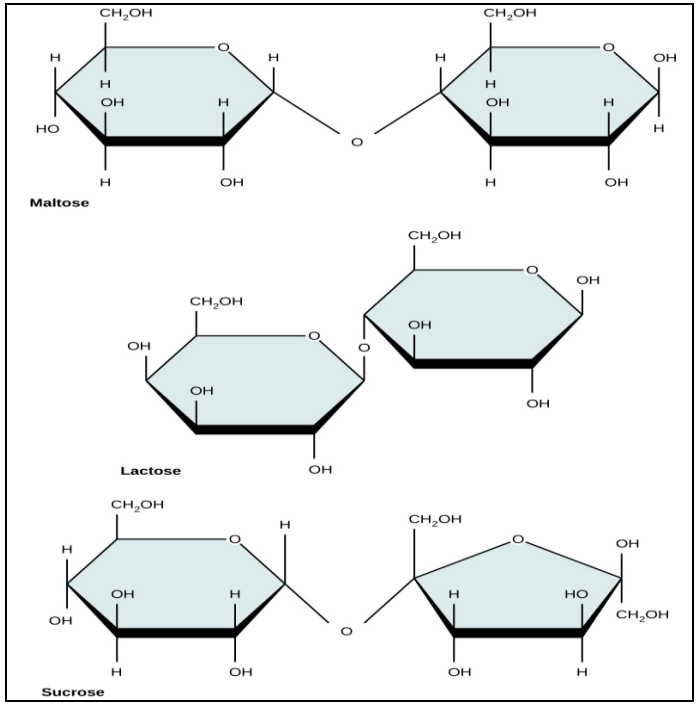


Figure 2.7 : Common disaccharides include maltose (grain sugar), lactose (milk sugar), and sucrose (table sugar).
OpenStax Biology 2nd Edition, Biology 2e. OpenStax CNX. Feb 13, 2019,accessed February 14, 2019.
https://cnx.org/contents/jVCgr5SL@15.3:pKmvmCbd@10/3-2-Carbohydrates

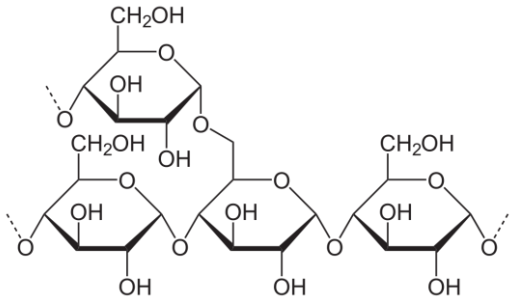
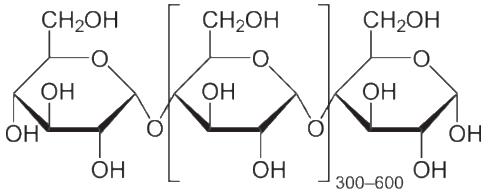
20 minutes

Note to tutor

The natural sugar found in milk is lactose.

Disaccharides serve as effective reservoirs of glucose because the enzymes that normally use glucose in the organism cannot break the bond linking the two monosaccharide subunits. Enzymes that can do so are typically present only in the tissue that uses glucose. **Lactose intolerance** Lactose intolerance is a digestive disorder caused by the inability to digest lactose, the main carbohydrate in milk. Many mammals supply energy to their young in the form of lactose. Adults often have greatly reduced levels of *lactase*, the enzyme required to cleave lactose into glucose and galactose, and thus they cannot metabolize lactose efficiently. This can result in lactose intolerance in humans.	10 minutes	Explain the lactose intolerance and why it is importance to know the structure of biomolecules.

POLYSACCHARIDES A polysaccharide is composed of many monosaccharide units (the monomers) joined together in one or more chains. Two types: – **Homopolysaccharides** composed of one type of monomer – **Heteropolysaccharides** composed of different types of monomers **- Homopolysaccharides** Example of Homopolysaccharides includes starch, glycogen, Cellulose and chitin.	20 minutes	**Note to tutor**

Starch It is one of the most important storage polysaccharide in plant cells. It is especially abundant in tubers, such as potatoes and in seeds such as cereals. It is usually present inside the plant cells as compact insoluble granules which may be spherical, lens-shaped or ovoid, and which have a distinctly layered structure. Starch consists of two polymeric units made of glucose called Amylose and Amylopectin but they differ in molecular architecture. Amylose, which counts for 80% of the starch of a plant cell, is a linear polymer of α-D glucose units joined by α (1-4) glycosidic bond while in amylopctin glucose units are joined by α (1-6) glycosidic bond. **Figure 2: 8: both amylose and amylopectin are polymers of glucose in α(1-4) linkages, but amylase is linear while amylopectin is branched via α(1-6) linkages.** (a) Amylopectin. By Neurotiker, April 29,2008 . Amylopektin[illustration] . Accessed on February 25, 2019. https://commons.wikimedia.org/wiki/File:Amylopektin_Haworth.svg . (b) Amylose. May 3,2007 . Amylose[illustration] . Accessed on February 25, 2019. https://commons.wikimedia.org/wiki/File:Amylose2.svg	 **Amylopectin** **(a)**  **Amylose** **(b)**		Starch and glycogen are form of storage

Glycogen Glycogen is the major glucose storage molecule of animals. It has the same structure as that of amylopectin except that the glycogen contains more and shorter branches. Glycogen is stored in the liver and muscles of animals. **Cellulose** Cellulose occurs in the cell walls of plants where it contributes in a major way to the structure of the organism. It resembles in structure with amylose except that the glucose units are linked together by β-1, 4-glucoside linkages. **Chitin** It is found in fungi but principally among the arthropods (crabs and insects). The excellent mechanical properties of insect skeleton are due to chitin. Chitin is a linear polymer of N-acetyl-D-glucosamine units joined together by β-1, 4-glucosidic linkages. – **Heteropolysaccharides** Example of heteropolysaccharides include glucosaminoglycans, glycoproteins, proteoglycans and peptidoglycans. **Glycosaminoglycans** Glycosaminoglycans (GAGs) also called **mucopolysaccharides** are long unbranched anionic polysaccharides consisting of a repeating disaccharide unit made of an **N-acetyl-hexosamine** and **a hexose or hexuronic acid**. On the basis of their structure units and linkage between disaccharide units; they can be classified in two types. 1. **Non-sulphated GAGs:** For example, hyaluronic acid (HA) 2. **Sulphated GAGs:** For example; chondroitin sulphate (CS), dermatan sulphate (DS), keratan sulphate (KS), heparin and heparin sulphate (HS). They are synthesized in either endoplasmic reticulum and/or Golgi apparatus and are present on the cell surface and in the ECM of animals. For more information about GAGs read this link	20 minutes	Cellulose and Chitin serve as structural role. Explain : N-acetyl-hexosamine Hexose hexuronic

POLYSACCHARIDES

A polysaccharide is composed of many monosaccharide units (the monomers) joined together in one or more chains. Two types:

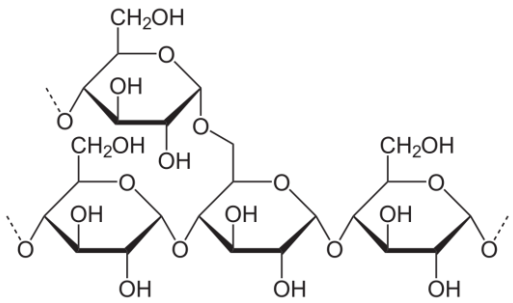
- **Homopolysaccharides** composed of one type of monomer
- **Heteropolysaccharides** composed of different types of monomers

- Homopolysaccharides

Example of Homopolysaccharides includes starch, glycogen, Cellulose and chitin.

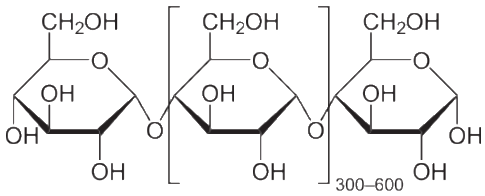
Starch

It is one of the most important storage polysaccharide in plant cells. It is especially abundant in tubers, such as potatoes and in seeds such as cereals. It is usually present inside the plant cells as compact insoluble granules which may be spherical, lens-shaped or ovoid, and which have a distinctly layered structure. Starch consists of two polymeric units made of glucose called Amylose and Amylopectin but they differ in molecular architecture. Amylose, which counts for 80% of the starch of a plant cell, is a linear polymer of α-D glucose units joined by α (1-4) glycosidic bond while in amylopctin glucose units are joined by α (1-6) glycosidic bond.



Amylopectin

(a)



Amylose

(b)

Figure 2: 8: both amylose and amylopectin are polymers of glucose in α(1-4) linkages, but amylase is linear while amylopectin is branched via α(1-6) linkages. (a) Amylopectin. By Neurotiker, April 29,2008 . Amylopektin[illustration] . Accessed on February 25, 2019. https://commons.wikimedia.org/wiki/File:Amylopektin_Haworth.svg . (b) Amylose. May 3,2007 . Amylose[illustration] . Accessed on February 25, 2019. https://commons.wikimedia.org/wiki/File:Amylose2.svg

20 minutes

Note to tutor

Starch and glycogen are form of storage

Glycoproteins A glycoprotein is a biomolecule composed of **a protein** and a carbohydrate (an oligosaccharide). They are found on the cell surface and have a critical role in cellular life. They are structural components of the cell, they act as receptors, and they protect cells from chemical and physical disturbances**.** They also serve to attach cells to cells during tissue formation and finally they are implicated in cell communication and recognition. When a core protein is attached to glycosaminoglycan chain(s), this kind of glycoproteins are called **proteoglycans** and are abundant in the ECM. **Peptidoglycans** *Peptidoglycan is a* polysaccharide made up of repeating units of a disaccharide made by N-acetylglucosamine (GlcNAc) and **N-acetylmuramic acid**, with the N-acetylmuramic acid residues cross-linked to peptides. Thus the name peptidogycan tells us that this structure consists of sugar molecules (glycans) and peptides (peptide: short polymer of amino acids). The monosaccharides in the disaccharide unit are joined by a β(1-4) glycosidic bond. In addition, each N-acetylmuramic acid is bonded to a tetrapeptide, a chain of four amino acids. These kinds of polysaccharides constitute **the bacterial cell walls.** They form rigid structures that give bacteria their shape and serve as the physical boundary for bacterial membranes, thereby protecting the cell from osmotic pressure and lysis	20 minutes	

LABORATORY PRACTICALS : Qualitative analysis of carbohydrates			
Purpose:	Carbohydrates as Reducing Sugars: A reducing sugar is any sugar that, in a solution, has an aldehyde or a ketone group. The enolization of sugars under alkaline conditions is an important consideration in reduction tests. The ability of a sugar to reduce alkaline test reagents depends on the availability of an aldehyde or keto group for reduction reactions. A number of sugars especially disaccharides or polysaccharides have glycosidic linkages which involve bonding a carbohydrate (sugar) molecule to another one, and hence there is no reducing group on the sugar; like in the case of sucrose, glycogen, starch and dextrin. In the case of reducing sugars, the presence of alkali causes extensive enolization especially at high pH and temperature. This leads to a higher susceptibility to oxidation reactions than at neutral or acidic pH. These sugars, therefore, become potential agents capable of reducing Cu^{+2} to Cu^{+}, Ag^{+} to Ag. Most commonly used tests for detection of reducing sugars are Fehling's Test, Benedict's Test and Barfoed's Test.	120 minutes	For lab this exercises make sure materials in the lab manual are available and the lab prepared.
Over to you:	This experiment aims to introduce you with the identification of unknown carbohydrates. To gain maximum benefit, observations should be related, as far as possible, to the structure of the substances examined.		
Activity	Perform the Fehling's test: Fehling's Solution (deep blue colored) is used to determine the presence of reducing sugars and aldehydes. Perform this test with fructose, glucose, maltose and sucrose.		

Anticipated time required for Unit 2.2 activities :
Theory : 2h all activities + 2h self-learning
Practical : 2h