Lecture : #10- sections 4,5,6

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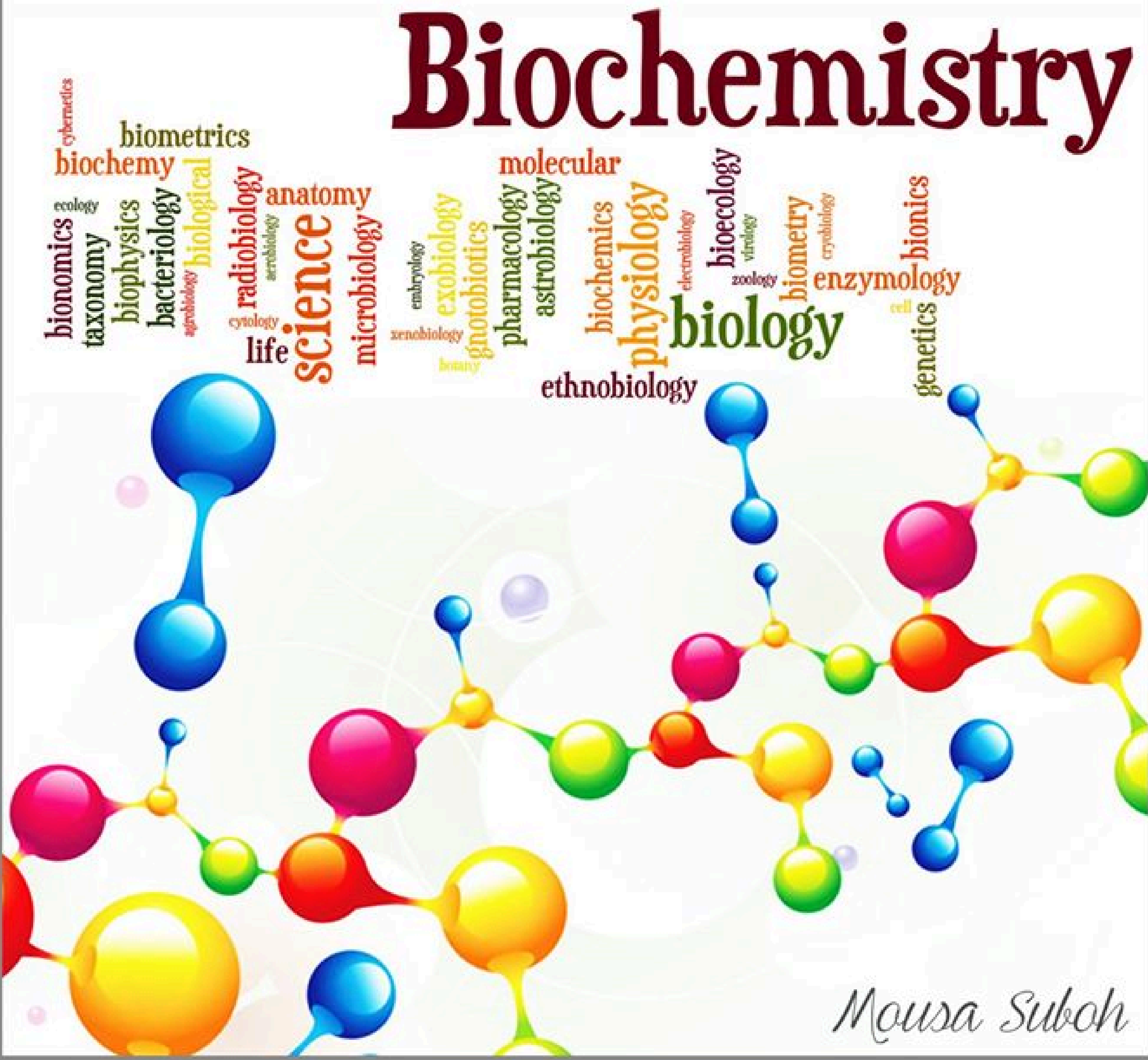
☐ Slide ■ Sheet

Medical Committee
The University of Jordan



إذا غامَرْتَ في شرف مروم فلا تقنع بما دون النجوم

لا تحسبنَّ المجد تمراً أنت آكله لن تبلغَ المجدَ حتى تلعق الصَّبِرا

Modified sugars

Let's Remember

Monosaccharides can be divided into:

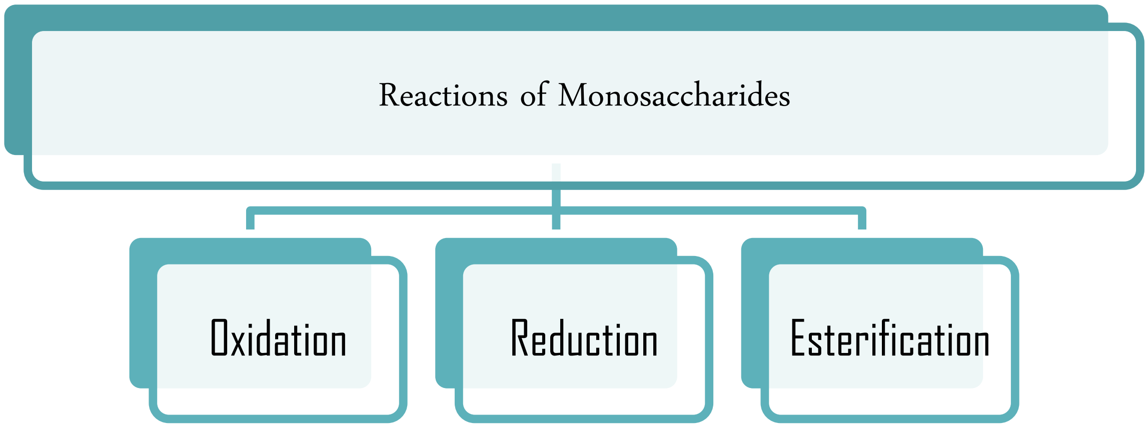
- Trioses (the simplest sugars) :
  a) Glyceraldehyde which is an aldotriose.
  b) Dihydroxyacetone which is a ketotriose.

- tetroses: Threose and Erythrose.

- Pentoses: Ribose ,which is found in DNA (as Deoxyribose) and RNA.

- Hexoses: Fructose , Mannose, Glucose, and Galactose.

I <u>Reactions of Monosaccharides</u>



1) <u>Oxidation :</u>

Oxidation can occur either by opening the ring of the monosaccharide to form a carboxylic **<u>acid</u>** or by forming a double bond between oxygen and the monosaccharide's anomeric carbon.

*When a cyclic hemiacetal is oxidized by double bonding the anomeric carbon with oxygen , a "LACTONE "structure is formed.

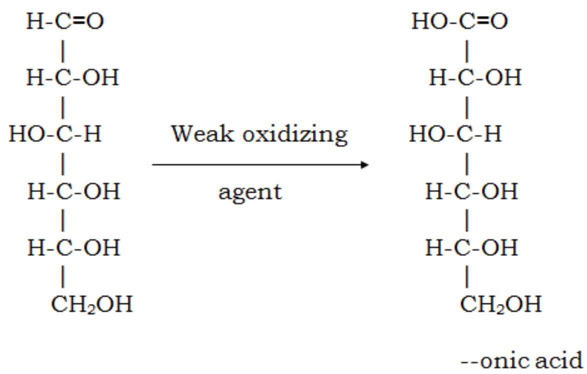
*Another point to mention is that Carbohydrates can be oxidized by a weak oxidizing agent or a strong oxidizing agent.

*Aldoses have 2 peripheral groups which are an aldehyde group and an alcoholic (-OH) group.

*If we used a **weak** oxidizing agent, only the carbonyl group (aldehyde group) will be oxidized to a carboxylic acid because the aldehyde group is easier to be oxidized and is more reactive.

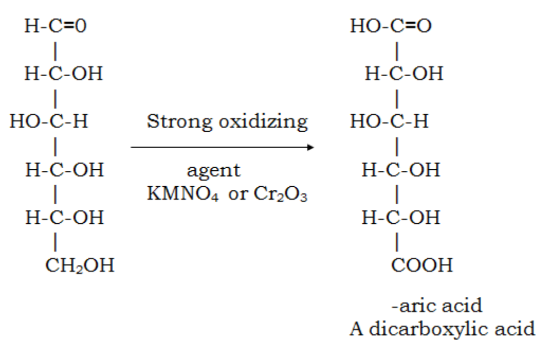
Done by Raneem Bader

a. Weak oxidizing agent



*On the other hand, **strong** oxidizing agents are able to Oxidize both aldehyde group and alcoholic group, so you will get a dicarboxylic acid.

b. Strong oxidizing agents



However, what can we use if we only want to oxidize The alcoholic group?
To accomplish that we should, in one way or another, Protect the aldehyde group and this is accomplished by Certain enzymes because it is a selective process.

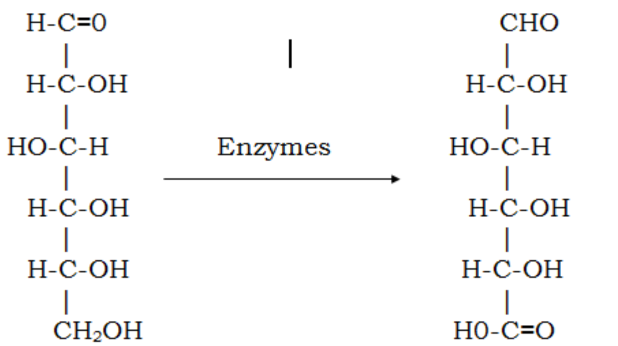
Keep in mind:

*When using a **weak** oxidizing agent, you should add the suffix **"onic"** to the carbohydrate's name, e.g.: Gluconic acid.

*When using a **strong** oxidizing agent, you should add suffix **"aric** "to the carbohydrate's name, e.g.: Galactaric acid.

*When using **enzymes** to oxidize only alcoholic group , you should add suffix **"uronic "** to the carbohydrate's name .

c. Oxidation of primary alcohol end in biological systems



-uronic acids

**Important:

You should be able to differentiate between :

1) Glucuronic acid
2) galactaric acid
3) gluconic acid

Which sugars are "reducing sugars"?

- All Monosaccharides (Aldoses and ketoses) are reducing sugars.
- Monosaccharides isomerize between ketoses and Aldoses , so ketoses can be oxidized indirectly by becoming aldoses first.
- Most disaccharides are reducing sugars except sucrose. Sucrose isn't a reducing sugar because the anomeric carbons of both monosaccarides that make it (fructose and glucose) are engaged in a glycosidic bond.
- The presence of free anomeric carbon makes a sugar a "reducing sugar".
- Oxidation of ketoses to carboxylic acids **directly** does not occur.

Did you know?

- Vitamin C (ascorbic acid) is an unsaturated lactone
- Lactone is an organic compound containing an ester group —OCO— as part of a ring.
- Fruits and vegetables can be oxidized when exposed to too much oxygen. And this results the brown spots on them.
  Also they will lose some of their nutrients and vitamins.
- Air oxidation followed by hydrolysis of the ester bond, leads to loss of activity
- A lack of fresh food can cause vitamin C deficiencies, which, in turn, can lead to the disease scurvy

Tests for Reducing Sugars

We can use 3 different tests to conclude if we have a reducing sugar or not.

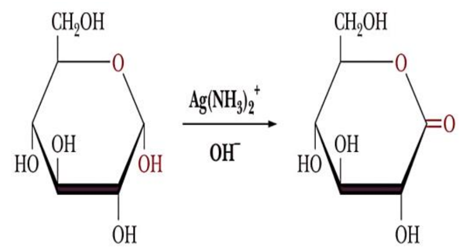
These tests are:

a) Tollens' solution

b) Glucose oxidase

c) Benedict's reagent:

a) Tollens solution (oxidizing agent)



-It is used To test the ability of a saccharide to form a lactone ring .

-If the test has a positive result then you can notice some silver precipitations on the beaker's wall or the test tube. If there is no silver precipitation ,then it is a negative Tollens' test.

-A negative result can occur when the anomeric carbon is involved in a glycosidic linkage.

The Oxidizing agent : $Ag(NH_3)^{2+}$

Reducing sugar + $Ag(NH_3)^{2+}$ **+OH^-** ⟶ Ag + lactone

b) Glucose oxidase :

It is only specific for glucose and not any other reducing sugar. It is widely used for the determination of free glucose in blood and used in glucose biosensor for the control of diabetes.

How it is used in the control of diabetes?

People with diabetes mellitus need to constantly monitor their blood glucose levels in order to detect fluctuations in glucose level that could lead to hyperglycemia (high blood glucose levels) and hypoglycemia (low blood glucose levels) so as to control the disease. Currently, such monitoring is done using finger-prick blood samples and a portable meter several times a day.

Biosensors are also being developed to measure blood glucose levels. Glucose oxidase is one of the possible enzymes that a biosensor can use.

Glucose oxidase oxidizes the drop of blood and as a byproduct hydrogen peroxide is produced. After that another enzyme found in the biosensor reduces it. The byproduct of the process can be measured. The resultant peak can clearly show if the concentration of glucose is high or low (the higher the peak, the higher the glucose concentration).

c) Benedict's reagent

Benedict's reagent contains blue copper (II) ions (Cu^{2+}) which are reduced to copper (I) ions (Cu^{+}). These are precipitated as red copper (I) oxide (which is insoluble in water) in the presence of a reducing sugar. A positive test with Benedict's reagent is shown by a color change from **clear blue** to a **brick-red precipitate**. The color of the obtained precipitate gives an idea about the quantity of sugar present in the solution.

- ✓ A **greenish** precipitate indicates about **0.5%** concentration.
- ✓ A **yellow** precipitate indicates **1%** concentration.
- ✓ An **orange** precipitate indicates **1.5%.**
- ✓ A **red** precipitate indicates **2%** or higher concentration.

2) Reduction :

$$-OH \underset{\text{reduction}}{\overset{\text{oxidation}}{\rightleftharpoons}} C=O$$

There are two types of reduction:

a) Reduction of the carbonyl group to a hydroxyl group by a variety of reducing agents (e.g. $NaBH_4$)

** Notice: add the suffix "ol"

Keep in mind:
- Reduction: removing Oxygen
- Oxidation: adding Oxygen

Examples:

- Sorbose (a ketohexose) is reduced into Sorbitol.
- Xylulose (a ketopentose) is reduced into Xylitol.

Sorbitol and Xylitol have some commercial importance. They are used as sweeteners in sugarless chewing gum & candy since they give a sweet taste but are not broken down in our body so they don't fatten the body.

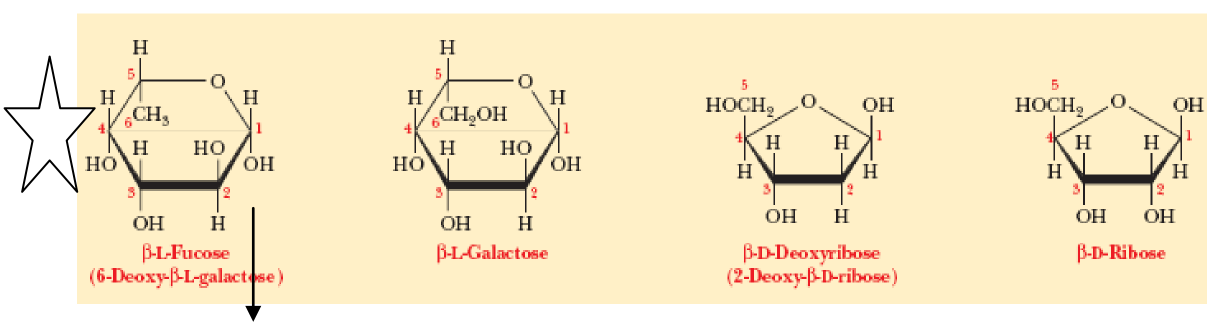
b) The second type of reduction is accomplished by substituting one of the hydroxyl groups of the sugar with a hydrogen atom.

Examples:

- Carbon no. 6 of **Galactose** has an OH group which is reduced to H. When reduced, L- galactose is converted to L- **Fucose.**

Fuscose is a reduced monosaccharide from of galactose. Also , it plays a role in determining the ABO blood group since it is found in some glycoproteins including the ABO blood-group antigens.

- The sugar Ribose can be also reduced to Deoxyribose by replacing the OH group on C no. 2 with H.
- Deoxyribose plays a vital role in DNA.



GOOD POINT ☺

Notice in the figure above that galactose is in the L –β configuration.

How can you know ?

Draw D-galactose , then put its mirror image and convert it to Haworth projection , remember .. Left is above and right is below.. and you will reach to the shape drawn above ☺.

In D- β galactose … the –OH groups at carbon 2…3…4 are (below , above , above , respectively) and the –OH group on the anomeric carbon and the carbon #6 are in cis configuration.

In L- β galactose… the –OH groups at carbon 2…3…4 are (above, below , below , respectively) and the –OH group on the anomeric carbon and the carbon #6 are in cis configuration.

3) Esterification :

-Phosphoric esters are the best example .

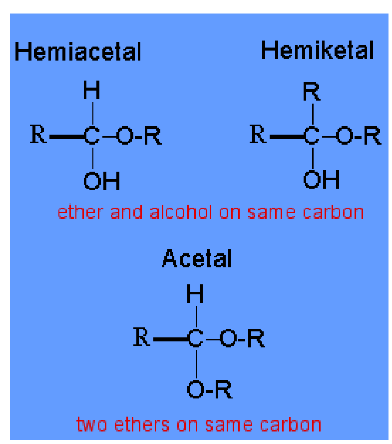
This type of reaction is done by adding a phosphate group to the (-OH) of carbohydrates. The most common donor of this phosphate group is ATP. When ATP donates its phosphate group it will become ADP.

When we eat a meal, glucose will be absorbed by intestine and then goes to blood and will enter the cells. The first step to be taken is "Phosphorylation", which the first step in glycolysis. Glucose is converted to glucose-6- phosphate , (because the phosphate group is added to carbon #6) which makes it negatively charged in order to prevent it from getting out of the cell through channels.

II Glycosidic Bond Formation

** Remember:

- ✓ C1 is bonded to C5, to make a cyclic hemiacetal.(pyranose)
- ✓ C2 is bonded to C5, to form a cyclic Hemiketal. (furanose).



** **Glycosidic bond** : is a covalent bond that connects one Monosaccharide to another. Or we can say that it is a bond between the anomeric carbon of a sugar and the -OR group from another molecule . The result of the glycosidic bond formation is the formation of a Full Acetal (which has a carbon that is linked to two OR groups).

When a monosaccharide makes a Glycosidic bond , it is now a glycoside. We have **Two Types of it :

- **Furanosides** are derived from **Furanoses** (5-memebered ring)
- **Pyranosides** are derived from **Pyranoses** (6-memebered ring)

**This type of bond is the basis of forming (di/oligo/poly) saccharides.

**Glycosidic bond varies depending on types and linkages (α or β) and the # of carbons that are connected.

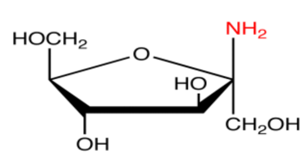
***Glycosides can be linked by: (depending on the atom that is attached o the monosaccharide:**

1) O- (an O-glycoside) (in case of formation of di /oligo/poly , or addition of CH_3)
2) N- (a glycosylamine)
3) S-(a thioglycoside)
4) C- (a C-glycoside)
5) Amino sugars

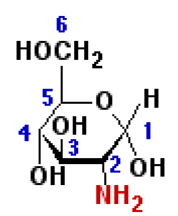
- The glycosidic bond is not necessary an ether bond, as it may not contain (-O-), as in case of glucosamine.

**** Important:**

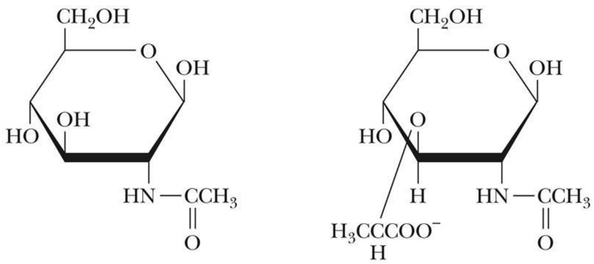
The Nitrogen in Glycosylamine is attached to the anomeric carbon. But the Nitrogen in amino sugars is attached to any other carbon.



N-glycoside



α-D-2-glucosamine (GlcN)



N-Acetyl-β-D-glucosamine N-Acetylmuramic acid

In the figure above.. what is the difference between the two sugars?

- N-Acetyl-β-D-glucosamine ...amino group is added to carbon#2 and an acetyl group is added to it. (acet is 2 carbon atoms)
- N-Acetylmuramic acid .. same modification to the previous molecule in addition to the lactate added to C#3 to make it negative.

III <u>Disaccharides</u>

-Disaccharides are Pairs of monosaccharides (always one of them must be glucose) -
-They are formed by Condensation reactions (forming the glycosidic bond) & Hydrolyzed by hydrolysis reactions (breaking the glycosidic bond).

- ❖ Maltose is a disaccharide that is produced during the germination of seeds and fermentation . It is found in malt.
- ❖ Also, Sucrose is a disaccharide that is refined from sugarcane, tastes sweet, and is readily available.
- ❖ Lactose is found in milk & milk products .

<u>Naming and Classification of Disaccharides:</u>

To name a disaccharide, you can use either the common name or the scientific name. Sucrose, Maltose, and Lactose are all common names.

In order to name the disaccharide with its scientific name, you should have 2 Monosaccharides. Keep in mind that the sequence used in naming is important.

Rules to name :

- Start from left to right and identify the two monosaccharides
- Determine whether the monosaccharides is β or α.
- Determine if it D or L … (all are D)
- Put name of the monosaccharide and add pyranose if it is 6-membered ring and furanose if it is 5-membered ring.(for example galactopyranose)
- For the first monosaccharide add (yl)
- Name the bond β or α (according to the first monosaccharide) ,and the numbers of carbons engaged in it .

Common name	**Scientific name**	**Components**	**Glycosidic bond**
Sucrose (Table sugar)	α-D-glucopyranosyl-(1→2)-β-D-fructofuranose	D-glucose & D-fructose	α 1,2-glycosidic bond
Lactose (Milk sugar)	β-D-galactopyranosyl-(1→4)- α D-glucopryanose	D-galactose & D-glucose	β 1,4-glycosidic bond
Maltose (Malt sugar)	α-D-glucopyranosyl-(1→4)- α-D-glucopryanose	Two units of D-glucose	α 1,4-glycosidic bond

** Galactose is a C-4 epimer of glucose .

Notes about the table above :

In sucrose : glucose is in α conformation and fructose is in β conformation

In maltose : 2 glucoses are in α conformation

In lactose : galactose is in β conformation and glucose is in α conformation

IV Oligosaccharides

Oligosaccharides are formed when 3 or more Monosaccharides (3- 10) are attached to each other.

Raffinose :

It is an oligosaccharide that is composed of galactose , glucose and fructose (trisaccharide).

So you can say it is galactose linked by α 1-6 glycosidic linkage to sucrose.

It is found in beans and causes bloating .... Why ?

**Because beans contain high amount of raffinose. Raffinose itself is indigestible as animals and humans don't have the enzyme needed for that (α -galactosidase), which separates galactose from sucrose. This enzyme is found in the bacteria that are present in the large intestine. They degraded it and The byproducts are methane and CO_2, and that's why peas cause bloating.

***Another important application for Oligosaccharides is its usage in drugs:**

- **Streptomycin** (3 monosaccharides with amino modification) and **Erythromycin** are important antibiotics.
- **Doxorubicin** is used in cancer chemotherapy, especially breast cancer.
- **Digoxin** is used in cardiovascular disease and heart failure.

Notice that :

*Streptomycin and Digoxin are oligosaccharides with some modifications.

* Doxorubicin and Erythromycin are not oligosaccharides, they just contain Monosaccharides.

V Polysaccharides

Polysaccharides are made from more than 10 Monosaccharides .

*There are two types of Polysaccharides:

1) **Homopolysaccharide** (most common): made from one repetitive monosaccharide.
2) **Heteropolysaccharide:** made from 2 different repetitive Monosaccharides. (i.e. :disaccharide that is repeating) .

Note

Glucose is the most common monomer (it is found in all disaccharides and polysaccharides)

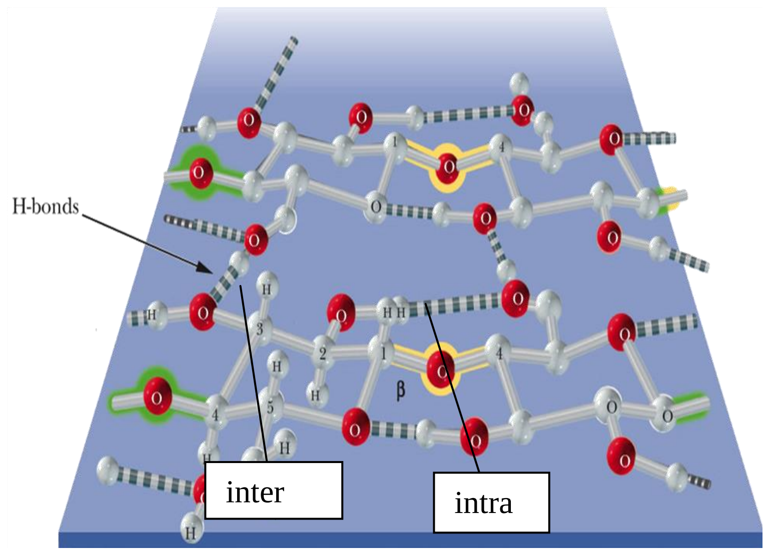
*Cellulose, chitin, Starch and glycogen are examples on polysaccharides.

- Cellulose & chitin: β-glycosidic linkages; Polysaccharides
- Starch & glycogen: α-glycosidic linkages; storage polymers in plants & animals, respectively

Keep in mind:

- Beta is harder than alpha.
- Beta is for structural Polysaccharides.
- Alpha is for storage (makes it more compact and easy to break).

❖Cellulose



- Its monosaccharide is β D-glucose.
- Major structural component of plants, especially wood and plant fibers.
- A linear polymer (not branched)(≈ 2800 D-glucose units per molecule)
- β-1,4-glycosidic bonds
- Extensive intra- & inter-molecular hydrogen bonding between or within chains. Hydrogen bonding makes cellulose stronger.
- Cellulose Can't be digested be animals since they don't have the enzyme Cellulase.

❖ Dextran:

- A branched storage polysaccharide.
- Found in yeast and bacteria.
- Its monosaccharide is ɑ- D-glucose.
- The most important feature is that it is not so long, but can branch (1, 2 branch \ 1, 3 branch\ 1, 4 branch) and this provides it with more strength.
- *A striking fact* about it that its straight chain consists of ɑ-1,6 Glycosidic linkages between glucose molecules, while branches begin from ɑ-1,2.. ɑ-1,3 ɑ-1,4…linkages.

❖ Starch :

- Energy storage in plants.
- A polymer of α-D-glucose units, why ?

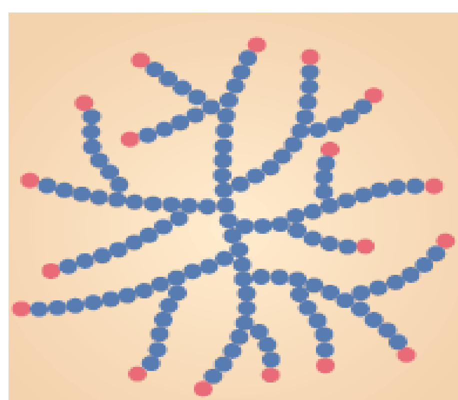
- There are two types of Starch :

1) **Amylose:**
- Continuous, unbranched chain (linear).
- Up to 4000 α-D-glucose units
- α-1,4-glycosidic bonds.
- It can by digested completely by amylases

2) **Amylopectin:**
- Highly branched polymer.
- 24-30 units of D-glucose.
- α-1, 4-glycosidic bonds in the continuous chain & branches created by α-1, 6-glycosidic bonds.

**** Notes:**

- Amylases break amylose and amylopectin by catalyzing hydrolysis of α-1, 4-glycosidic bonds.
- Amylases are found in saliva ☺.
- There are two types of amylase : both of them break α 1-4 glycolysidic linkage.
  a) **β-amylase:** it is an exoglycosidase and cleaves from the non-reducing end of the polymer.
  b) **α-amylase:** is an endoglycosidase and hydrolyzes Glycosidic linkages anywhere along the chain to produce glucose and maltose.
- Amylopectin cannot be completely degraded to glucose and maltose by the two amylases, as they cannot break the **α-** 1, 6 -glycosidic linkage. Therefore some enzymes called <u>Debranching enzymes</u> are needed ,as they catalyze the hydrolysis of α-1,6-glycosidic bonds.



** The endoglycosidase breaks the internal glycosidic linkage.

** The exoglycosidase breaks the peripheral glycosidic linkage.

INFORMATION – SHAKE ☺

Q1 What four categories do carbohydrates come in?

a) Pentose, Ribose, Deoxyribose, hexose
b) Monosaccharide, Disaccharide, Trisaccharide ,tetrasaccharides.

c) Monosaccharide, Disaccharide, oligosaccharide, and Polysaccharide

Q2 What is the Primary source of energy for all cells and what type of carbohydrate is it?

a) Glucose -Monosaccharide

b) Glucose - Disaccharide

c) Glucose - Polysaccharide

d) Fructose - Monosaccharide

Q3 What bond creates a disaccharide?

a) Beta 1:4 Bond
b) Beta 1:5 Bond
c) Phosphorylation Bond
d) Alpha 1:4 Bond

e) Either A or D .

Q4 Name a "dairy" (ألبان)disaccharide and its components.

a) Galactose: Lactose-Glucose
b) Lactose: Galactose-Glucose
c) Sucrose: Glucose-Fructose

d) Maltose: Glucose-Glucose

Q5 What bond(s) creates a polysaccharide?

a) Alpha 1:4
b) Either Beta 1:4 or Hydrogen bonding
c) Either Alpha 1:4 or Beta 1:4
d) Beta 1:4

Q6 Name a polysaccharide that is stored in the liver to increase blood sugar (also name linkage).

a) Glucagon
b) Glycogen
c) Glucose
d) Cellulose

Q7 What polysaccharide makes up plant walls and has a beta 1:4 linkage?

a) Cellulose
b) Glycogen
c) Starch
d) Lactose

Q8 All of the following is monosaccharide except :

a) sucrose
b) fructose
c) glucose
d) Mannose

Q9 Select the storage form of carbohydrate found in mammals.

a) glycogen
b) starch
c) fiber
d) fiber and glycogen

Q10 The digestion of sucrose (table sugar) results in what two Monosaccharides?

a) maltose & glucose
b) glucose & galactose
c) fructose & glucose
d) galactose & fructose

Q11 Oligosaccharides are carbohydrates containing many sugar units (greater than 10) linked together.

a) True

b) False

Q12 Humans are unable to digest

a) Starch
b) complex carbohydrates
c) denatured proteins
d) cellulose

1	2	3	4	5	6	7	8	9	10	11	12
C	A	E	B	C	B	A	A	A	C	B	D

لا تسر في طريق معروف نهايته، وإنما ابحث عن طريق آخر غير ممهد واترك خطاك لتكون دليل لمن يأتي بعدك.

دمتم بخير .... دعواتكم

Done by:

Raneem Bader