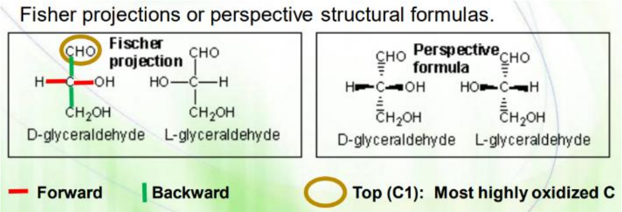
CARBOHYDRATES:

DEFINITION:

(Saccharides) are polyhydroxy aldehydes or ketones, **thus they are** highly soluble.

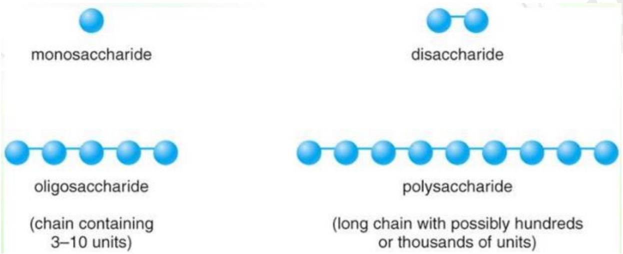


FUNCTIONS:

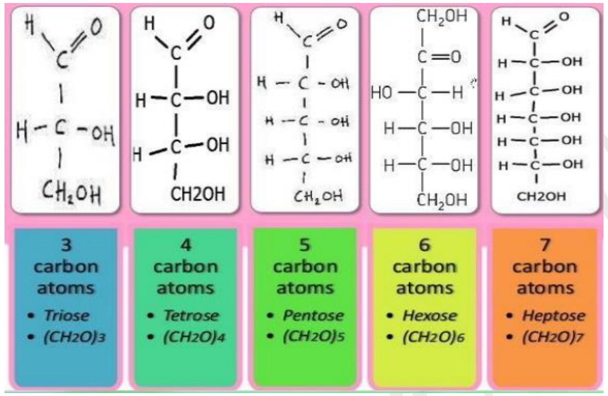
- **Source of energy**; the main and quickest source.
- **Structure (cellulose and chitin)**; <u>cellulose</u> in plants and <u>chitin</u> for the exoskeleton in insects.
- **Building blocks**
- **Cellular recognition**, **i.e.** immune cells recognizing self and non-self-cells.
- **Signaling**; from outside the cell to the inside.

CLASSIFICATIONS:

According to Number of Monosaccharide Molecules:



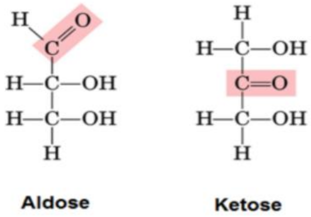
For Monosaccharides, *According to* Number of Carbons:



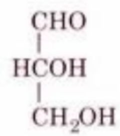
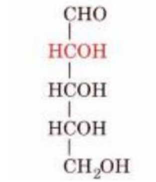
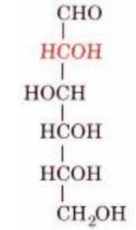
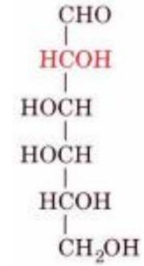
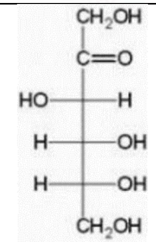
For Monosaccharides, *According to the* Functional Group:

If Aldehyde (طرفية), then aldose

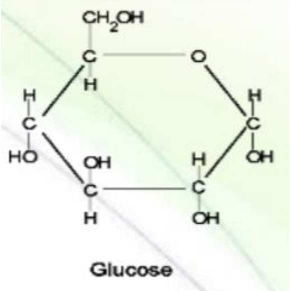
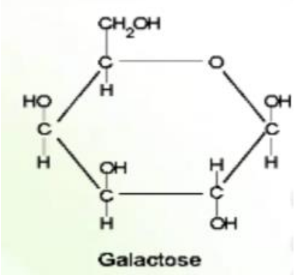
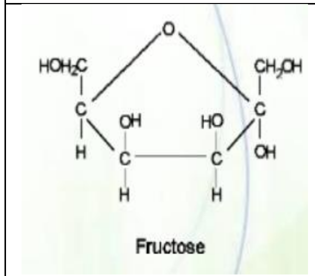
If Ketone (وسطية على الكربونة رقم 2), then ketose



-Structures to MEMORIZE:

Name	Type	Structure
D-Glyceraldehyde	Aldose <u>Tri-</u>	
D-Ribose	Aldose <u>Penta-</u>	
D-Glucose	Aldose <u>Hexa-</u>	
D-Mannose	Aldose <u>Hexa-</u>	
D-Galactose	Aldose <u>Hexa-</u>	
D-Fructose	Ketose <u>Hexa-</u>	

COMMON MONOSACCHARIDES:

Name & Structure	Features
	-Mild sweet flavor -Known as blood sugar -Essential energy source -Found in every disaccharide and polysaccharide **either** in original **or** modified form
	-Hardly tastes sweet -Rarely found naturally as a single sugar (Usually with proteins)
	-The sweetest sugar -Found in fruits and honey -Added to soft drinks, cereals and desserts

LOCATIONS (WHERE TO FIND THEM?):

Most carbohydrates are found naturally in bound form rather than as simple sugars.

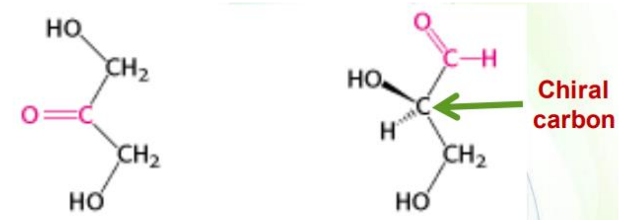
- **Polysaccharides**, **i.e.** starch, cellulose, inulin, gums, glycogen, …
- **Glycoproteins and Proteoglycans**, **i.e.** hormones, blood group substances, antibodies, …
- **Glycolipids**, **i.e.** cerebrosides, gangliosides
- **Glycosides**; modified sugars by adding methyl/ethyl/amino groups, **i.e.** Glycosaminoglycans (GAGs)
- **Mucopolysaccharides**, **i.e.** hyaluronic acid
- **Nucleic acids** (DNA, RNA)

CHIRALITY AND ITS EFFECT ON SUGARS:

RECALL:

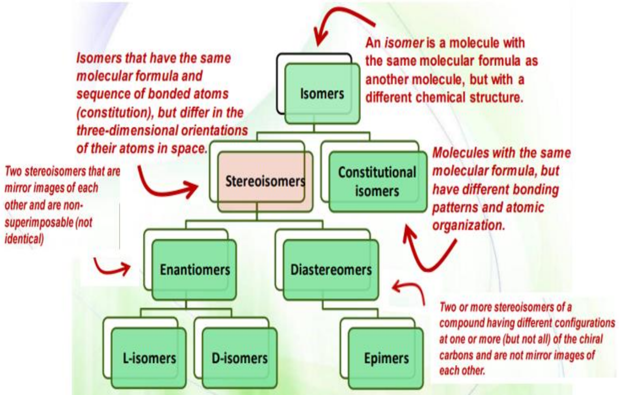
Chiral Carbon: the carbon that is connected with 4 different groups.

Thus, if we apply this concept upon the known triose sugars: Dihydroxyacetone and D-Glyceraldehyde, we will find the following:

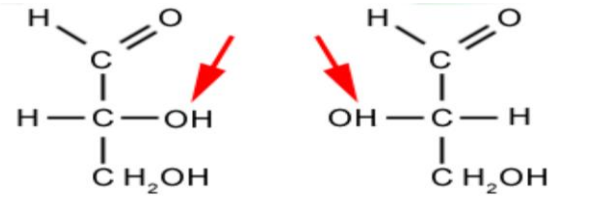


Dihydroxyacetone (a ketose) **D-Glyceraldehyde** (an aldose)

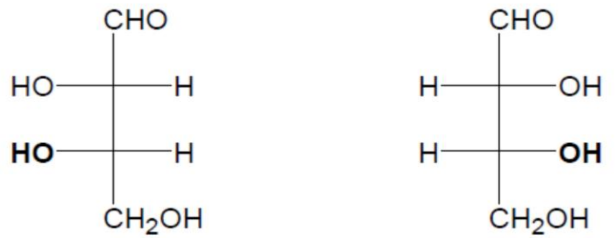
***Isomerism:**



◊ Enantiomers [L- and D-]:



D-Glyceraldehyde L-Glyceraldehyde



L-erythrose D-erythrose

How to know if it is either L- or D-?

You must look upon the hydroxyl group attached to the chiral carbon that is farthest from the functional group.

If the -OH is on the left → L-

If the -OH is on the right → D-

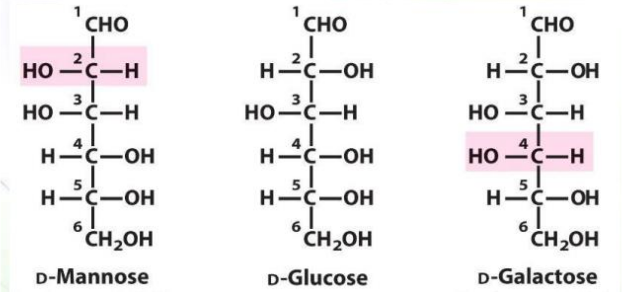
◊ Diastereomers [Epimers]:

What are Epimers?

They are diastereomers that differ from each other in the orientation of one hydroxyl group on one chiral carbon.

NOTE:

When we describe epimers, we have to mention the carbon that has different -OH orientations in the two molecules.



-Describe the relationship between:

•D-Glucose and D-Mannose

Stereoisomers/ Diastereomers/ Epimers at C-2

•D-Glucose and D-Galactose

Stereoisomers/ Diastereomers/ Epimers at C-4

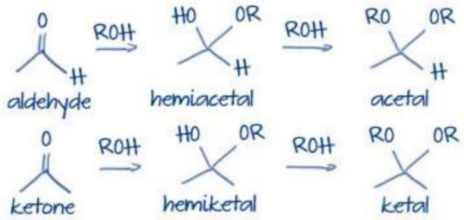
•D-Mannose and D-Galactose

Stereoisomers/ Diastereomers

- Is L-glucose an epimer with D-mannose and D-galactose?

No

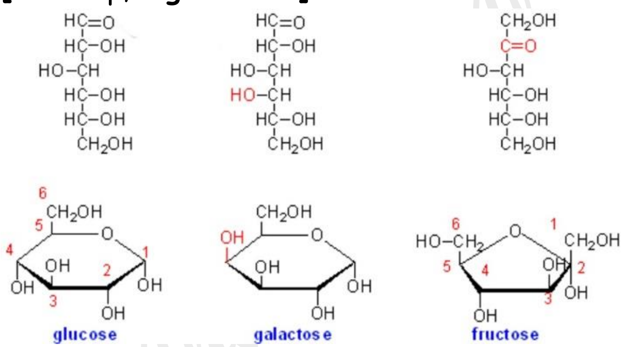
RECALL: From Organic Chemistry



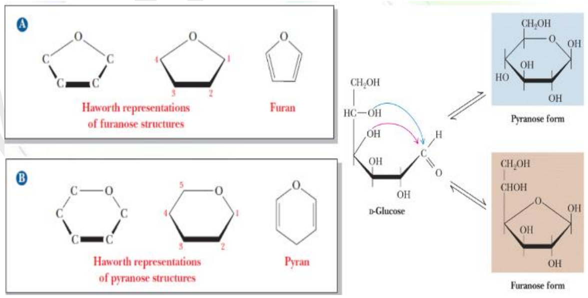
FORMATION OF A RING STRUCTURE:

***What Goes UP and What Goes Down?**

[Left-up, **Right-**down**]**



***Pyranose vs. Furanose:**



The Preferred Form is Pyranose, **because** it is more stable.

*Anomers:

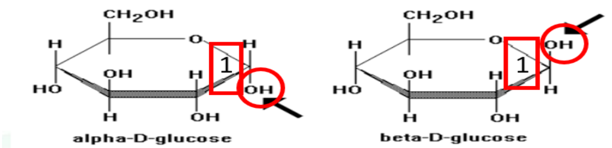
Different forms of a certain sugar enantiomer (either L- or D-), **which differ by** the orientation of OH group on C-1 [in Pyranoses] or C-2 [in Furanoses].

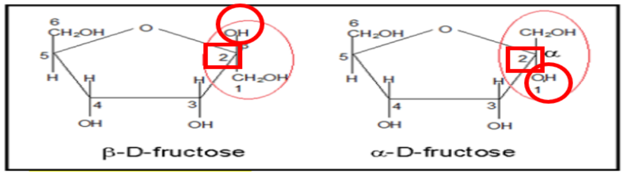
The Carbon that has the OH of interest is called an anomeric carbon.

The OH on the anomeric carbon rotates to form 2 different molecules each time **with a phenomenon called** muta rotation.

Alpha (α) = OH on the anomeric carbon is **down**

Beta (β) = OH on the anomeric carbon is **up**





NOTES:

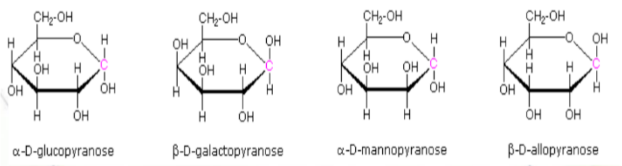
-Anomers can be presented in Fischer's projection, but it is not that common.

-Cyclic glucose is more stable than **acyclic (chain) glucose.**

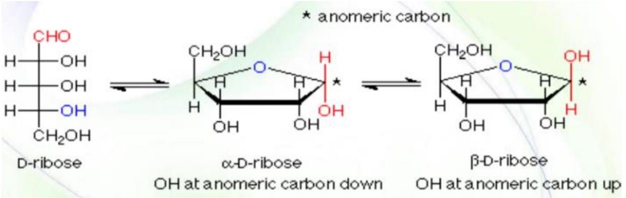
-D-Sugars are the main naturally found sugars. **[L-Sugars** are less common, but they exist, especially in bacteria**]**

Exercise:
Discover all relationships between each two sugars.

◊ **Cyclic Aldohexoses:**



◊ **Cyclic Ribofuranose:**



MODIFING SUGARS:

***Oxidation Producing Sugar Acids:**

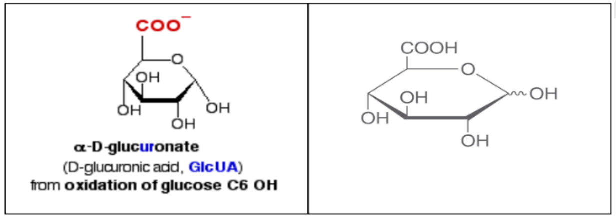
FOR ALDOSES

◊ **Using Enzymes Producing (-uronic acid):**

The oxidation of glucose (hydroxyl to carboxyl) at C-6 producing glucuronate (in the ionized form COO^-) **or glucuronic acid** (in the COOH form).

Hydroxyl (OH) → Carboxyl (COOH)

[Thus, glucuronate is the conjugate base of glucuronic acid]

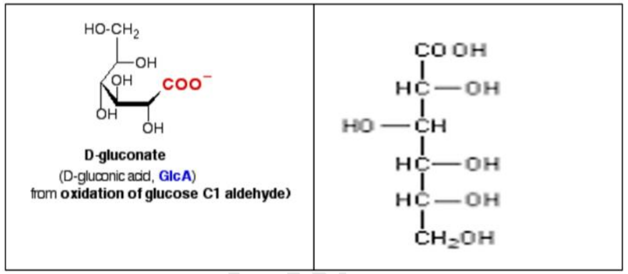


◊ **Using a Weak Oxidizing Agent Producing (-onic acid):**

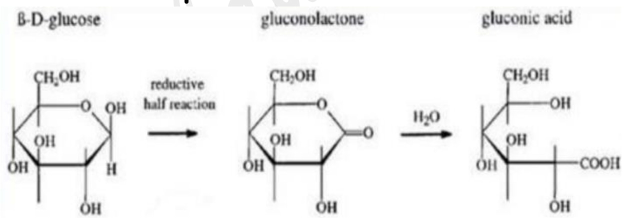
The oxidation of glucose (aldehyde to carboxyl) at C-1 (The Anomeric Carbon) producing gluconate (in the ionized form COO^-) **or gluconic acid** (in the COOH form).

Aldehyde (H-C=O) → Carboxyl (COOH)

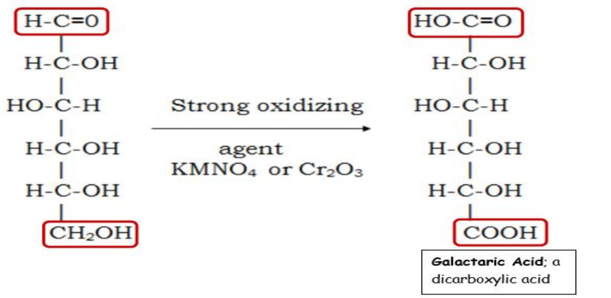
[Thus, gluconate is the conjugate base of **gluconic acid]**



It is a 2 steps reaction;

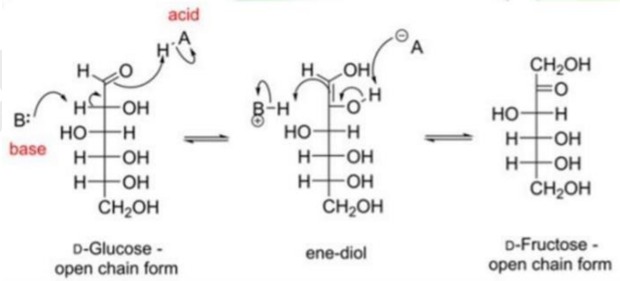


◊ **Using a Strong Oxidizing Agent Producing (-aric acid):**



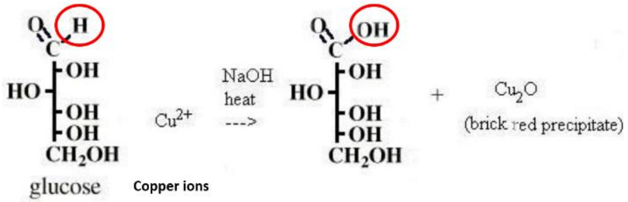
FOR KETOSES

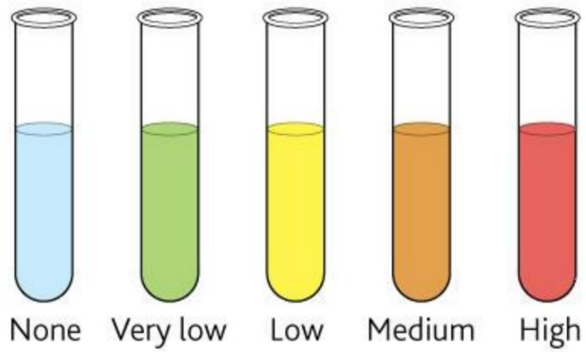
Oxidation of ketoses to carboxylic acids does not occur, but they can be oxidized because of formation of enediol form.



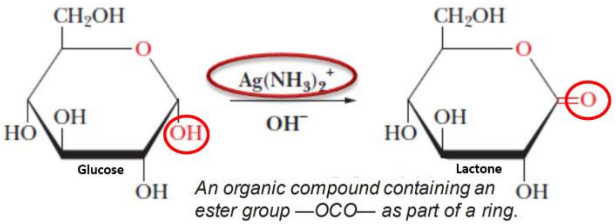
TESTING REDUCING SUGARS AND THEIR STRENGTH:

◊ **Benedict's Test:**

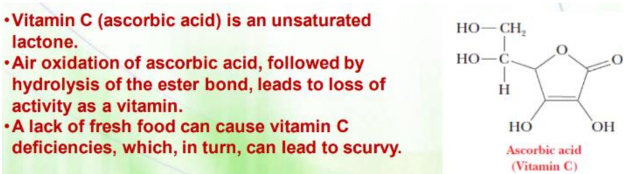




◇ Tollens's Test:



NOTE:



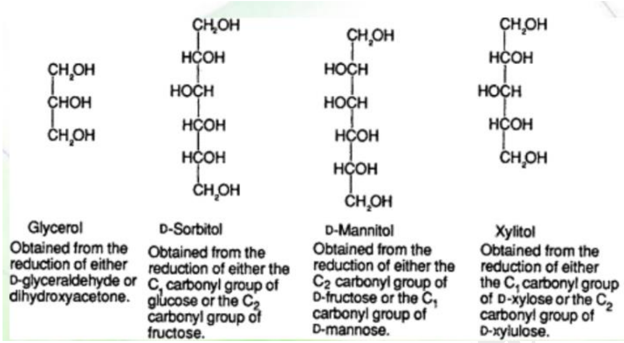
◇ Using Glucose Oxidase:

Specific for glucose and no other sugar.

*Reduction;

◇ Producing Sugar Alcohols

(Carbonyl (C=O) → Hydroxyl (OH)):



Used to sweeten food.

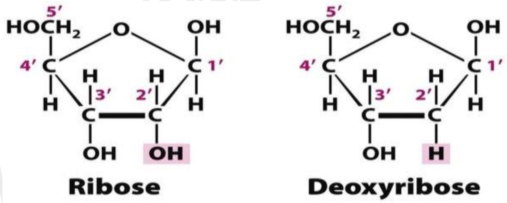
◇ Producing Deoxy Sugars

(Hydroxyl (OH) → Hydrogen (H)):

i.e.

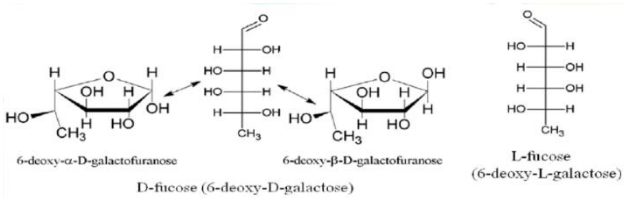
- **Deoxyribose**

A constituent of DNA.

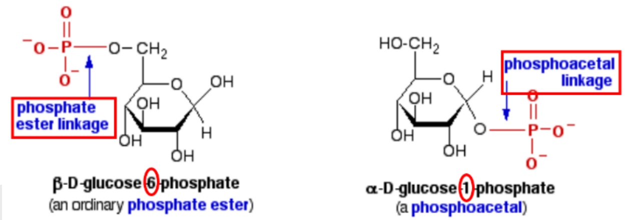


- **L-fucose (L-6-Deoxygalactose)**

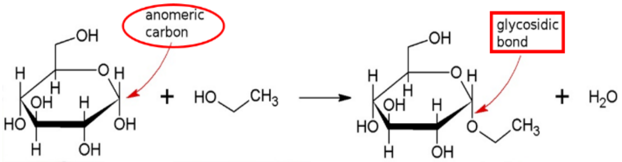
Found in the carbohydrate portions of some glycoproteins.



*Esterification:

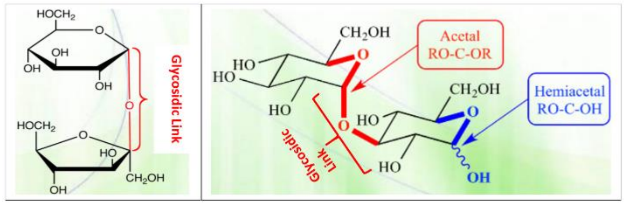


*O-Glycosylation:



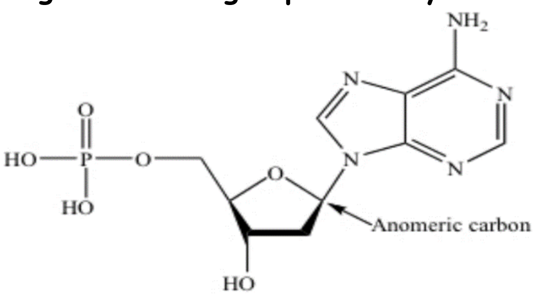
- **Glycosidic Bond:** a bond that is formed at the anomeric carbon and used to link two monosaccharides to form a disaccharide.

Thus, it ends up being like this:



*N-Glycosylation:

Sugar + Amino group → N-Glycoside



***C-Glycosylation:**

Sugar + Alkyl group → C-Glycoside

NOTE:

-**Glycosylation** is simply replacing the hydroxyl group at the *anomeric carbon* with something.

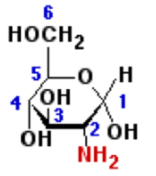
-Glycosides derived from **furanoses** are called **furanosides**, and those derived from **pyranoses** are called **pyranosides**, regardless if they are O-, N- or C- linked.

***Adding Amines**:

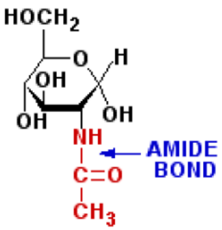
is simply replacing the hydroxyl group at any *non-anomeric carbon* with amines.

NOTE:

Further modification by Acetylation.



α-D-2-glucosamine
(GlcN)



N-acetyl-α-D-2-glucosamine
(GlcNAc)

WRAP UP:

<table>
<tr><th>Modification</th><th>Oxidation of Aldoses | Using Enzymes in Biological Systems</th><th>Oxidation of Aldoses | a Weak Oxidizing Agent</th><th>Oxidation of Aldoses | Using a Strong Oxidizing Agent</th><th>Oxidation of Ketoses</th><th>Reduction [to Sugar Alcohols]</th><th colspan="2">Reduction [to Deoxy Sugar]</th></tr>
<tr><td>The reacting functional group</td><td>(For Glucose) Hydroxyl (OH) group</td><td>(For Glucose) Aldehyde (H-C=O)</td><td>(For Glucose) Hydroxyl + Aldehyde</td><td rowspan="4">Oxidation of ketoses to carboxylic acids does not occur, but they can be oxidized because of formation of enediol form</td><td>Carbonyl Group (C=O)</td><td colspan="2">Hydroxyl Group (OH)</td></tr>
<tr><td>Where does it react?</td><td>(For Glucose) At C-6</td><td>(For Glucose) At C-1</td><td>(OH) → C-6
(H-C=O) → C-1</td><td>At the Anomeric C</td><td>(For Ribose) At C-2</td><td>(For Galactose) At C-6</td></tr>
<tr><td>End Products</td><td>Sugar Acid (-uronic acid)</td><td>Sugar Acid (-onic acid)</td><td>Sugar Acid (-aric acid)</td><td>Sugar Alcohol</td><td>Deoxyribose</td><td>L-Fucose</td></tr>
<tr><td>Where are they used</td><td>---</td><td>---</td><td>---</td><td>Sweeting Food</td><td>In DNA</td><td>In glyco-proteins</td></tr>
</table>

<table>
<tr><th>Modification</th><th colspan="2">Esterification [to Sugar Esters]</th><th>O-Glycosylation</th><th>N-Glycosylation</th><th>C-Glycosylation</th><th>Adding Amines</th><th></th></tr>
<tr><td>The reacting functional group</td><td colspan="2">Hydroxyl (OH) group</td><td>Hydroxyl (OH) group</td><td>Hydroxyl (OH) group</td><td>Hydroxyl (OH) group</td><td>Hydroxyl (OH) group</td><td></td></tr>
<tr><td>Where does it react?</td><td>(For Glucose) At C-1</td><td>(For Glucose) At C-6</td><td>At the Anomeric C</td><td>At the Anomeric C</td><td>At the Anomeric C</td><td>Anywhere except at the Anomeric C</td><td></td></tr>
<tr><td>End Products</td><td>Glucose-1P</td><td>Glucose-6P</td><td>O-Glycoside</td><td>N-Glycoside</td><td>C-Glycoside</td><td>Sugar amine</td><td></td></tr>
<tr><td>Where are they used</td><td colspan="2">In metabolism</td><td>The glycosidic bond is used in forming Disaccharides</td><td>(For Ribose) In nucleotides DNA/RNA</td><td>---</td><td>---</td><td></td></tr>
</table>

→ Definitions:

-Disaccharide: a sugar molecule that is made of the *condensation* of 2 monosaccharides.

-Oligosaccharide: a sugar molecule that is made of the *condensation* of 3 - 10 monosaccharides.

-Polysaccharide: a sugar molecule that is made of the *condensation* of more than 10 monosaccharides.

-Homo-: the *condensed* monosaccharides of a molecule are exactly the same.

-Hetero-: the *condensed* monosaccharides of a molecule are different -Even if only one is different-.

-Residue: a thing that is part of bigger thing.

i.e.

Glucose molecule = an alone glucose molecule

Glucose residue = a glucose molecule that is part from of a bigger molecule (**i.e.** Di-/Oligo-/Poly- saccharide) containing this glucose molecule

→ What is the Type of Reaction?

Condensation reaction; each linkage of 2 monosaccharide to each other results in the formation of H_2O molecule per linkage.

→ Formation of a Di-/Oligo-/Poly-saccharide:

-Catalyzed by Glycosyltransferase.

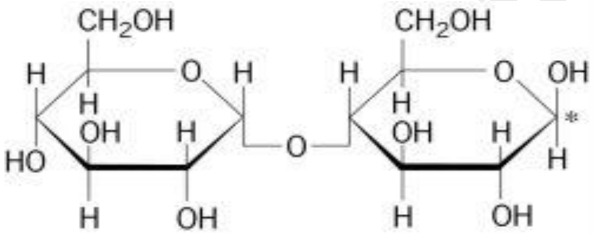
-No muta-rotation of the Anomeric Carbon, **thus** the products are stable.

DISACCHARIDES:

***Naming Disaccharides (Systematic Naming):**

[Reading from Left → Right]

<u>**Example**</u>:



For each monosaccharide residue, we have to identify:

- Name of the residue
- Stereo-configuration (D- or L-)
- α or β

Thus;

On the left: α-D-Gluco<u>pyranosyl</u>

On the right: α-D-Gluco<u>pyranose</u>

Then, we have to identify the carbons involved in the linkage:

1 → 4

Systematic Name is:

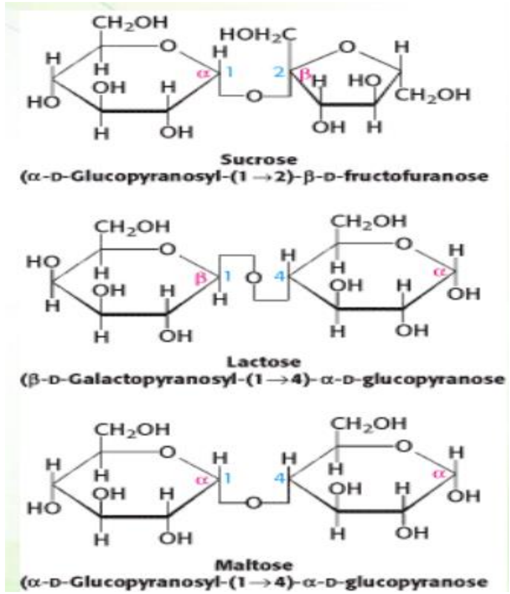
α-D-Glucopyranosyl-(1→4)-α-D-Glucopyranose

***Determining the Reduction Ability of Sugars:**

The anomeric carbon is NOT linked = reducing **(i.e.** Lactose, Maltose**)**

The anomeric carbon is linked = non-reducing **(i.e.** Sucrose**)**

***Common Disaccharides:**



NOTE:

-With the formation of a disaccharide, an H_2O molecule is released.

-Each of the three has a formula of $C_{12}H_{22}O_{11}$ [= (2 x $C_6H_{12}O_6$) – H_2O]

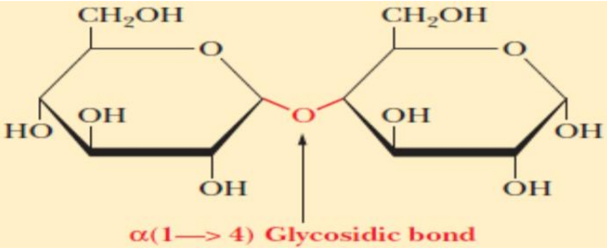
-Where is Each Used?

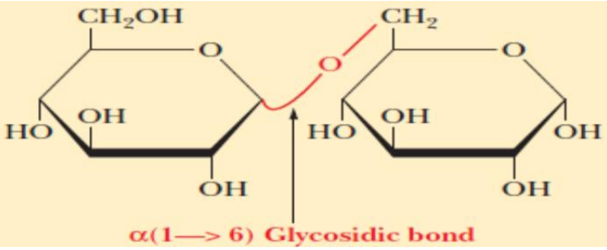
Sucrose = Table sugar

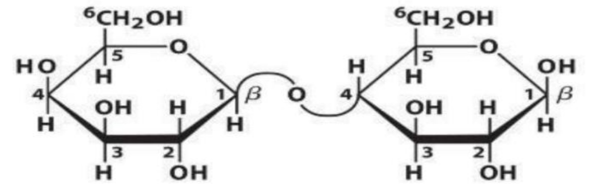
Lactose = Milk

Maltose = Malt (شعير)

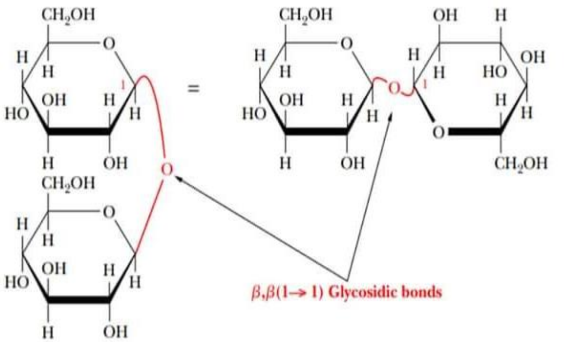
***Check These Disaccharides and the Type of Glycosidic Linkage in Each One:**



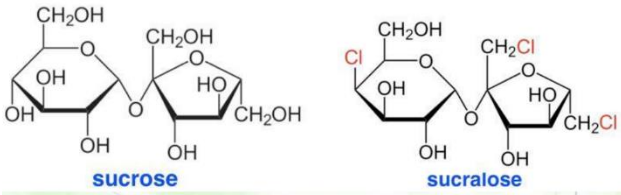




Lactose (β form)
β-D-galactopyranosyl-(1→4)-β-D-glucopyranose
Gal(β1→4)Glc



***Sucralose: An Alternative to Sucrose**



No calories are added to the body because it is indigestible.

***Disorders Related to Disaccharides: Milk Problems**

◊ Lactose Intolerance:

-Case:

A deficiency of the enzyme **lactase** in the intestinal villi allows **lactase of intestinal bacteria** to digest it producing hydrogen gas, carbon dioxide and organic acids, **thus leading to** stomachache, gases and digestive problems (**i.e.** bloating and diarrhea).

-Most Affected:

Old people

(It can be a huge problem for children + people in the old world (Asia, Africa and southern Europe)

-Treatment:

- Eating/Drinking treated milk
- Taking pills that help in the digestion of lactose

◊ Galactosemia:

-Case:

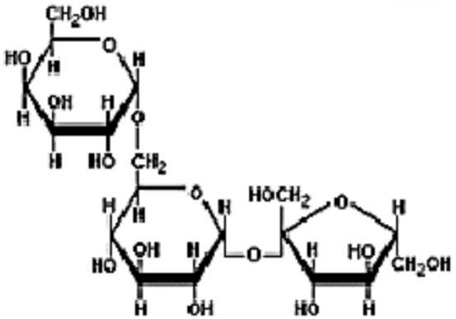
Missing a galactose-metabolizing enzyme can result in **galactosemia**; where nonmetabolized galactose accumulates within cells and is converted to the hydroxy sugar **galactitol**, which cannot escape cells.

Water is drawn into cells and the swelling causes cell damage, particularly in the brain, **resulting in** severe and irreversible retardation.

It also causes cataract.

OLIGOSACCHARIDES:

***Example**: Raffinose*



Recognize the monosaccharides that make up raffinose.

Galactose-Glucose-Fructose

What is the monosaccharide that is attached to what disaccharide?

Galactose-Sucrose

-Humans lack the **alpha-galactosidase enzyme** that is needed to break down **raffinose**, but intestinal bacteria can ferment it into hydrogen, methane, and other gases.

-Found in beans **and** vegetables **like** cabbage, Brussels sprouts, broccoli, asparagus.

-In medicines, used as precursors for drugs. **i.e.**

Streptomycin and Erythromycin (antibiotics)

Doxorubicin (cancer chemotherapy)

Digoxin (cardiovascular disease)

POLYSACCHARIDES:

Features of Polysaccharides:

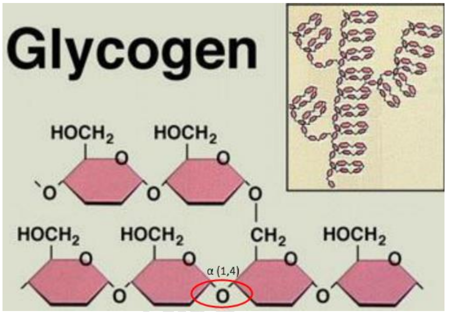
- Residues
- Length
- Branching and the extensivity of it
- Purpose:

Storage, **i.e.** glycogen, starch, dextran

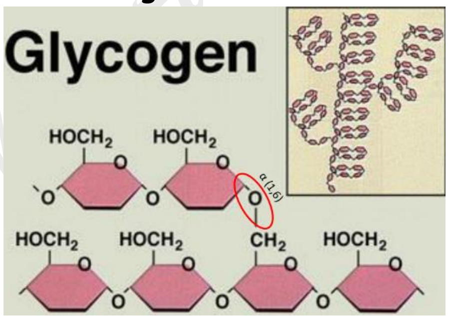
Structural, **i.e.** cellulose, pectin, chitin

Glycogen:

-Residues: α-Glucose [Homo-polysaccharide]

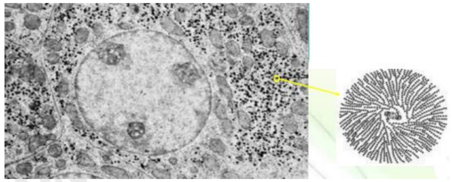


-Branching: It is branched



-Purpose: Storage in animals (and humans)

-Main Storage Organ: Liver

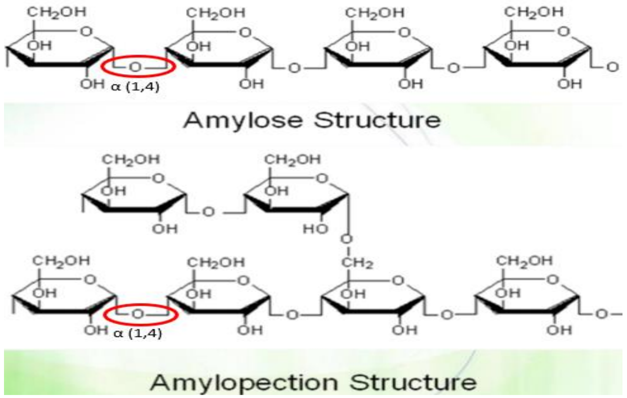


Starch:

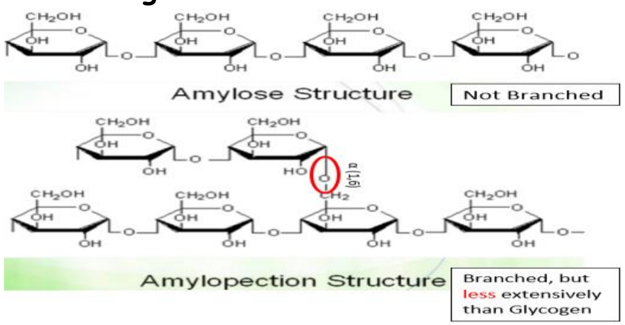
-Forms:

Amylose (10-20%) **|** **Amylopectin** (80-90%)

-Residues: α-Glucose [Homo-polysaccharide]



-Branching:



-Purpose: Storage in plants

-When degraded, maltose and glucose molecules result.

Why is Branching Important?

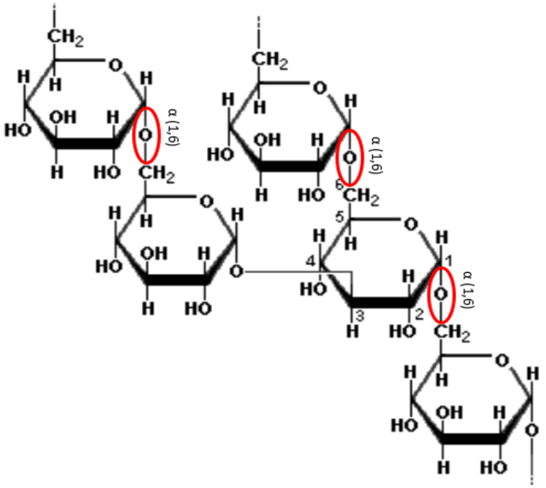
- It makes it more water-soluble and does not crystallize.
- Easy access to glucose residues.

Glycogen vs. Amylopectin:

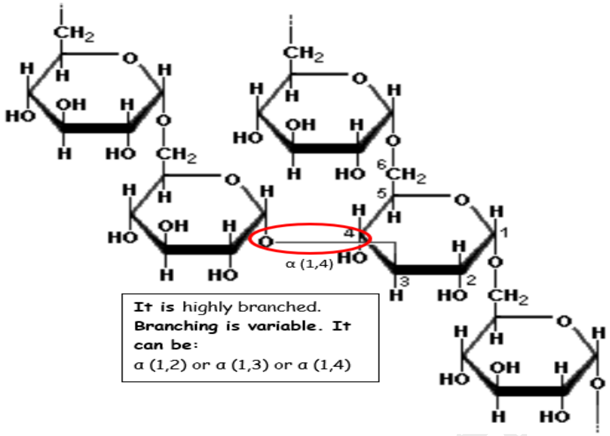
	Glycogen	Amylopectin
Monomer	Glucose	Glucose
Purpose	Storage	Storage
Found in:	Animals	Plants
Branching	Yes	Yes
Extensivity of Branching	Higher; branch points occur about every 10 residues	Lower; branch points occur about every 25 residues

***Dextran:**

-Residues: α-Glucose [Homo-polysaccharide]



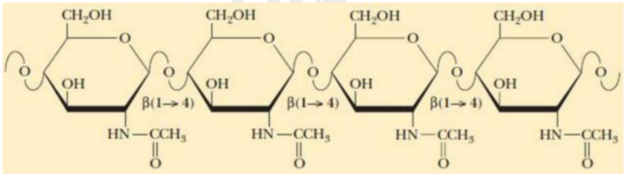
-Branching: It is highly branched



-Purpose: Storage in bacteria and yeast

***Chitin:**

-Residues: N-Acetyl-β-glucosamine [Homo-polysaccharide]



-Branching: It is NOT branched

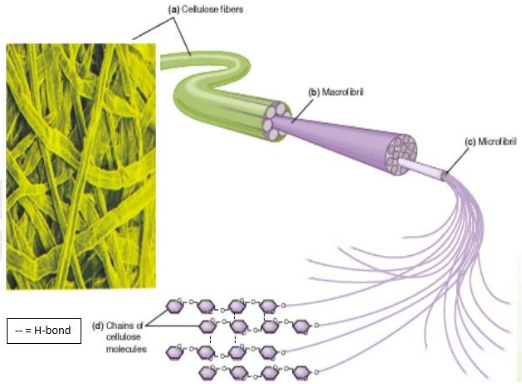
-Purpose: Structure in different organisms (It makes up the **exoskeleton** of insects)

How Does the Structure of Chitin Affect its Function?

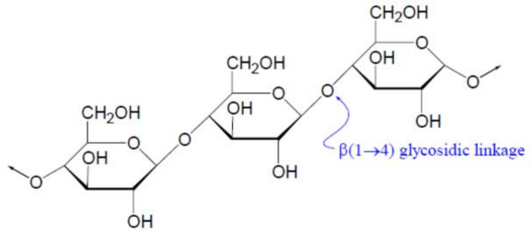
1- β-glycosidic linkage that is rigid and hard to be bent.

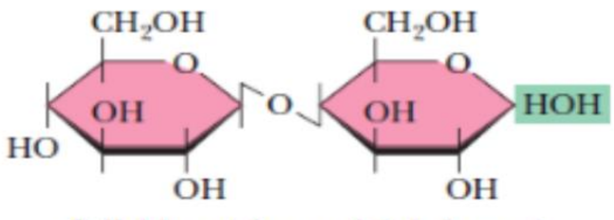
2- Extensive H-bonds between chitin molecules **due to** the presence of modified glucose monomers.

***Cellulose:**



-Residues: β-Glucose [Homo-polysaccharide]





Cellobiose (glucose-β-1,4-glucose)

-Branching: It is NOT branched

-Purpose: Structure in plants

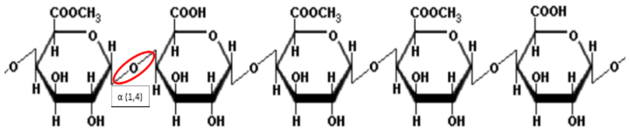
How Does the Structure of Cellulose Affect its Function?

1- β-glycosidic linkage that is rigid and hard to be bent.

2- H-bonds between cellulose chains.

***Pectin:**

-Residues: α-Galacturonic acid



-Branching: It is NOT branched

-Purpose: Structure in plants (Along with **cellulose**)

+ **It is used in** food industry.

*Are Polysaccharides Reducing Sugars?

A sample that contains only a few molecules of a large polysaccharide, each molecule with a single reducing end, might well produce a negative test because there are not enough reducing ends to detect.

PROTEIN – SUGARS LINKING:

GLYCOSAMINOGLYCANS (GAGs):

***What are They?**

They are negatively charged -At least one of the sugars in the repeating unit has a negatively charged carboxylate or sulfate group-, large sugar molecules -**made of** repetitive disaccharides-, **derived from** an amino sugar [**contains** amino groups], either glucosamine or galactosamine, **found** extracellularly, **i.e.:**

Heparin/ Keratan sulfate/Hyaluronic/ Dermatan sulfate/Chondroitin-4-sulfate/ Chondroitin-6-sulfate

***Localization and Function of GAGs:**

GAG	Localization	Comments
Hyaluronate	synovial fluid, vitreous humor, ECM of loose connective tissue	the lubricant fluid, shock absorbing As many as 25,000 disaccharide units
Chondroitin sulfate	cartilage, bone, heart valves	most abundant GAG
Heparan sulfate	basement membranes, components of cell surfaces	contains higher acetylated glucosamine than heparin
Heparin	component of intracellular granules of mast cells lining the arteries of the lungs, liver and skin	A natural anticoagulant
Dermatan sulfate	skin, blood vessels, heart valves	
Keratan sulfate	cornea, bone, cartilage aggregated with chondroitin sulfates	Only one not having uronic acid

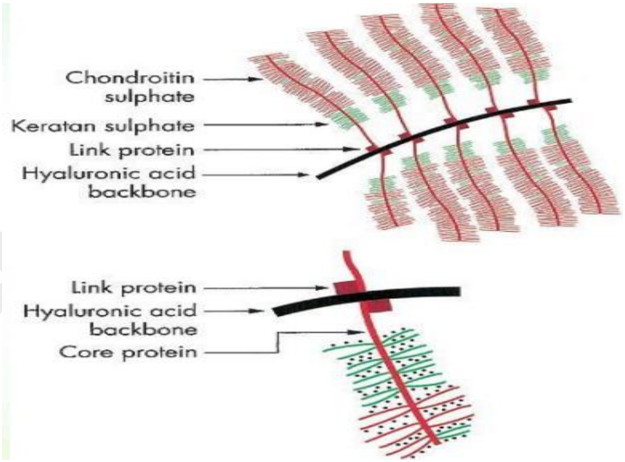
***How Does the Negative Charges Affect the Function of GAGs in Cartilage?**

After being compressed due to a physical action, negative charges repulse from each other; maintaining the structure in its original form.

PROTEO-/PEPTIDO-GLYCANS:

***What are They?**

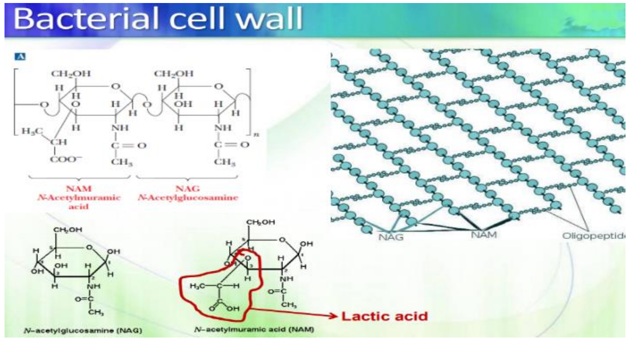
They are GAGs associated with protein/peptide parts in the ECM.



***Functions:**

- Lubricants
- Structural components in connective tissue
- Mediate adhesion of cells to the extracellular matrix, **thus** playing a role in cell signaling and signal transmission
- Store hormones that are released slowly when needed
- Bind factors that stimulate cell proliferation

Example:



GLYCOPROTEINS:

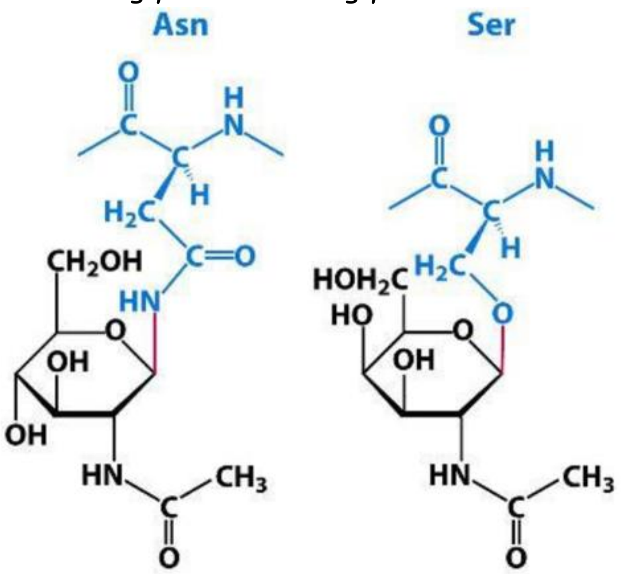
***What is the Difference?**

In Proteoglycans; Sugar (GAGs) > Protein

In Glycoprotein; Protein > Sugar

***Structure:**

The carbohydrates of glycoproteins **are linked to** the protein component **through** either O-glycosidic or N-glycosidic bonds.



N-linked GlcNAc | **O-linked GalNAc**

The N-glycosidic linkage is through the amide group of asparagine (Asn, N)

The O-glycosidic linkage is to the hydroxyl group of serine (Ser, S), threonine (Thr, T) or hydroxylysine (hLys)

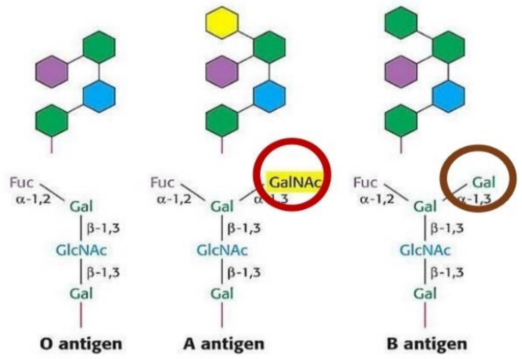
SIGNIFICANCE OF PROTEIN-LINKED SUGARS:

*Either Soluble proteins or membrane proteins;

- Protein folding
- Protein targeting, **i.e.** Lysosomal proteins are attached to mannose residues to be targeted to lysosomes.
- Prolonging protein half-life
- Cell-cell communication [Outside cells]
- Signaling, **i.e.** inositol.
- Affecting the solubility of proteins

***Blood Typing and Glycoproteins:**

Modification of proteins on the cell surface of red blood cells is important for blood typing.



The difference:

N-acetyl galactosamine (for A)

Galactose (for B)

-BOTH- (for AB)

-NONE- (for O)

Blood Type	Gives:	Receive from:
O	O/A/B/AB	O
A	A/AB	O/A
B	B/AB	O/B
AB	AB	O/A/B/AB

SIALIC ACID:

= N-acetylneuraminate

***Precursor:** the amino sugar, neuraminic acid

***Features:**

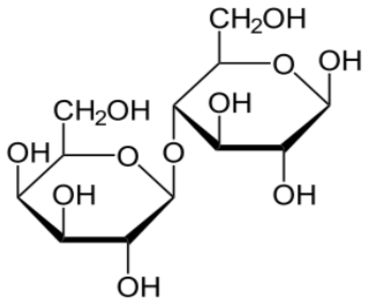
Sugar acid, Acylated, Negatively charged.

***Location:** a terminal residue of oligosaccharide chains of glycoproteins and glycolipids.

Done by: Abdullah Al-Jaouni

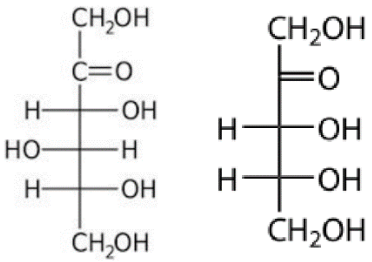
Q-BANK FROM PAST PAPERS:

1) What is true about the following disaccharide's structure?



A) It is a non-reducing sugar
B) It is a homopolysaccharide
C) It has a 1-1 glycosidic linkage
D) All of the above are true
E) None of the above is true

2) Which is false about the two following sugars?



A) They are diastereomers
B) They are both ketoses
C) OH on carbon 4 would be above the ring
D) Benedict's test is positive for both of them
E) More than one of the above

3) To synthesize a human nucleic acid in the laboratory, we use:
A) D sugars only
B) L sugars only
C) Alpha sugars
D) Aldohexoses
E) Penta-ketoses

4) Which best describes glucose?
A) It is mainly in the open chain form
B) It participates in the formation of sucrose
C) It has no epimers
D) It is a ketose
E) More than one of the above

5) What is false regarding GAGs?
A) They are negatively charged
B) They are found extracellularly
C) They can only be made of glucose and fructose derivatives
D) More than one of the above
E) None of the above

6) Why is sucrose a non-reducing sugar?
A) It does not contain a free anomeric carbon
B) Contains two non-reducing monosaccharides
C) It is a disaccharide
D) More than one of the above
E) None of the above

7) Why is cellulose indigestible in our bodies?
A) We lack the enzyme necessary for its digestion
B) It is a large molecule
C) It is left undegraded to aid in bowel movement
D) Bacteria digest it faster
E) More than one of the above

8) Regarding bacterial cell walls, what is incorrect statement?
A) There're NAG-NAM repeats
B) It is mainly made of sialic acid
C) Lactic acid is found within NAM molecules
D) More than one of the above
E) None of the above

9) Which of the following sugars has a beta glycosidic linkage?
A) Chitin
B) Sucrose
C) Lactose
D) More than one of the above
E) None of the above

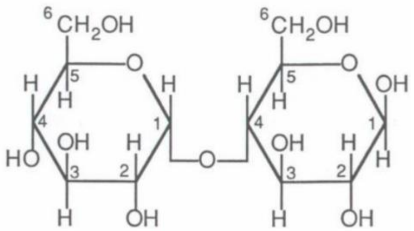
10) How many chiral carbons are there in deoxyribose?

A) 1
B) 2
C) 3
D) 4
E) none

11) What is the wrong statement about D and L configuration?

A) D sugars Exist in abundance in nature
B) All of the amino acid in protein is L configuration
C) They don't differ in the anomeric carbon
D) They are only different in the last chiral center
E) More than one of the above

12) Which of the following is correct about this structure?



A) It is lactose
B) It contains B-glucose
C) It is a non-reducing sugar
D) This is a beta-(1-4) linkage
E) More than one of the above

13) Which of the following is a reduced sugar?

A) 2-deoxyribose
B) Fructose
C) Sucrose
D) Galactose
E) More than one of the above

14) Glycosaminoglycans are characterized by all of the following features EXCEPT:

A) The basic unit is a repeated disaccharide
B) At least, one sugar has an amino group
C) At least, one sugar is negatively charged with acidic group
D) The sugars are derived from glucose or fructose
E) It is attached to proteins forming proteoglycans

15) The polysaccharide in a bacterial cell wall has all the following features EXCEPT:

A) It is a heteropolysaccharide of NAG and NAM
B) It is a homopolysaccharide of sialic acid
C) It is a polysaccharide crosslinked by peptides
D) Sugars are connected directly to tetrapeptides
E) The strands are connected by Gly pentapeptides

16) Which is not correct about glucose?

A) It is an epimer of mannose
B) It is an epimer of galactose
C) Only D-isomer exist in mammalian cells
D) It mainly exists as open chain in solution
E) More than one of the above

17) D-glucose and D-galactose has all of the following except:

A) Hexoaldoses
B) They are Diastereomers
C) They are anomers
D) They are reducing sugars
E) None of the above

18) The polysaccharide which glucose is stored as in animal cells:

A) is stored in the melanocytes and hepatocytes
B) contains Beta-linkage
C) is extremely branched for more efficient energy supply
D) is broken down to glucose and maltose
E) More than one of the above

→ **Answers:**

Q. No.	Ans.	Q. No.	Ans.
1	E	10	B
2	E	11	D
3	A	12	B
4	B	13	A
5	C	14	D
6	A	15	B
7	A	16	D
8	B	17	C
9	C	18	C