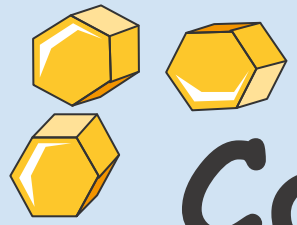
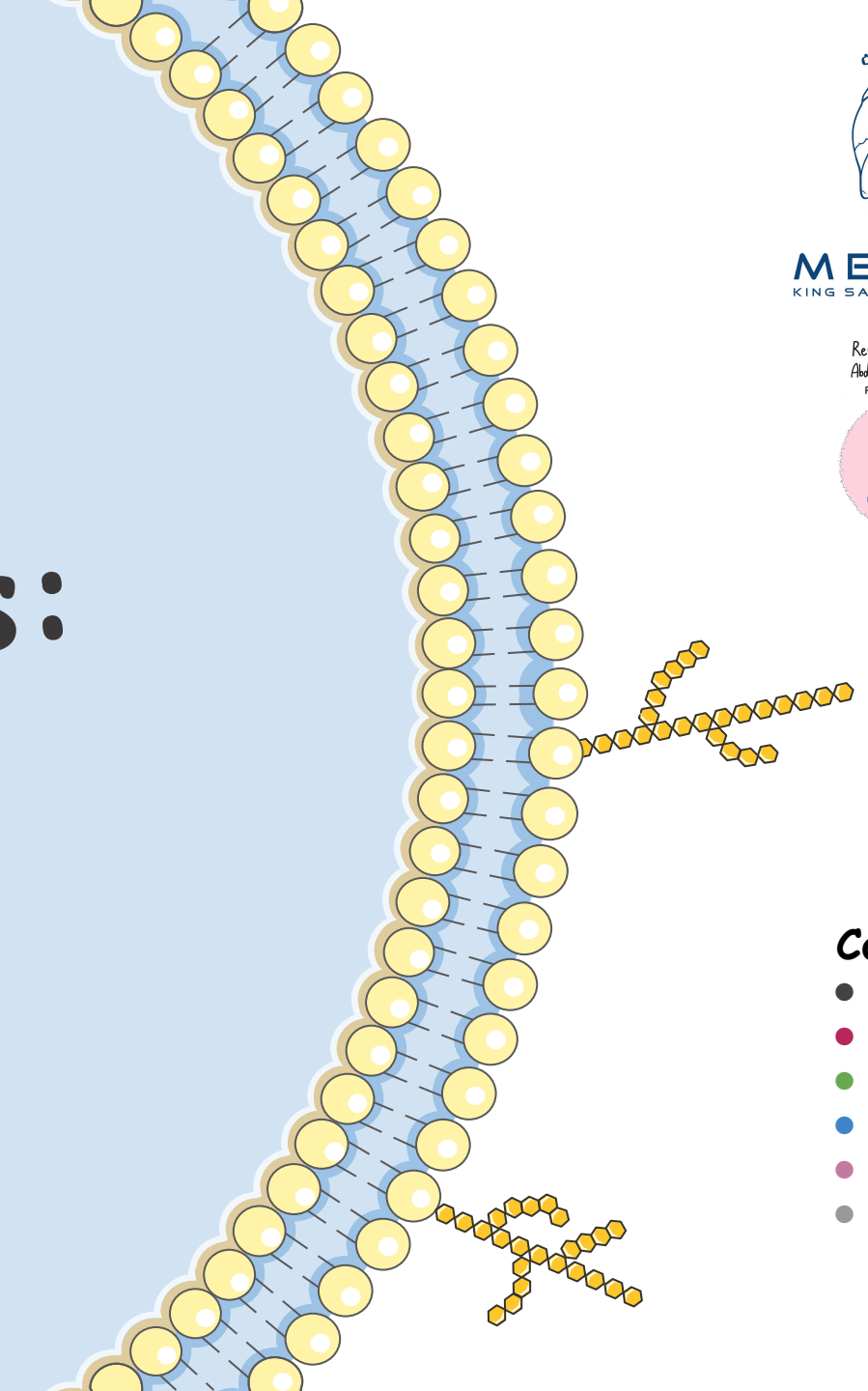


Carbohydrates: Structure and function



MED441
KING SAUD UNIVERSITY

Revised & Reviewed by Abdulaziz & Bahammam Faye Wael Sendi

5
V1

Foundation Block - KSU

Color Index:
- Main text
- Important
- Notes
- Boys slides'
- Girls slides'
- Extra

Editing File

Objectives

- To understand the structure of carbohydrates of physiological significance
- To understand the role of carbohydrates in providing and storing energy
- To understand the structure and function of glycosaminoglycans

Overview of carbohydrates

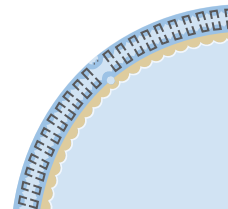
Carbohydrates:

- They are the most abundant organic molecules in nature
- The empirical formula for carbohydrates is $(CH_2O)n$
- They are also named: hydrates of carbon
- Functions of carbohydrates include:
  -Provide important part of energy in diet
  -Act as the storage form of energy in the body.
  -They are structural component of cell membranes

NOTE:
n = number in atoms.
n >= 3 (3 is the minimum)

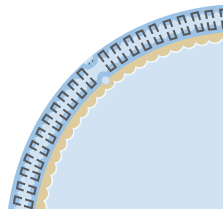
Many diseases associated with disorders of carbohydrate metabolism including:

- Diabetes mellitus (DM)
- Galactosemia (which means "galactose in the blood,"When people with galactosemia ingest foods or liquids containing galactose, undigested sugars build up in the blood because the body's ability to process galactose is blocked)
- Glycogen storage diseases (is the result of defects in the processing of glycogen synthesis or breakdown within muscles, liver, and other cell types)
- Lactose intolerance (disorder caused by the inability to digest lactose, the main carbohydrate in dairy products)



Classification of carbohydrates

1. **Monosaccharides:** Simple sugar
2. **Disaccharides:** 2 monosaccharide units
3. **Oligosaccharides:** 3-10 monosaccharide units
4. **Polysaccharides:** more than 10 monosaccharide units.
   - Heteropolysaccharides: monosaccharides are different
   - Homopolysaccharides: all the monosaccharides are identical



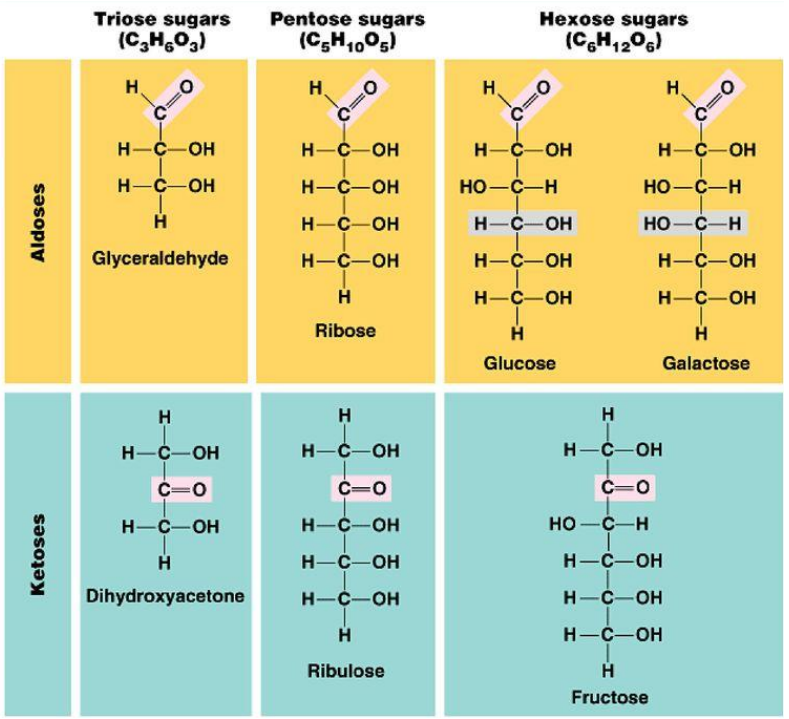
Monosaccharides

Classification of Monosaccharides

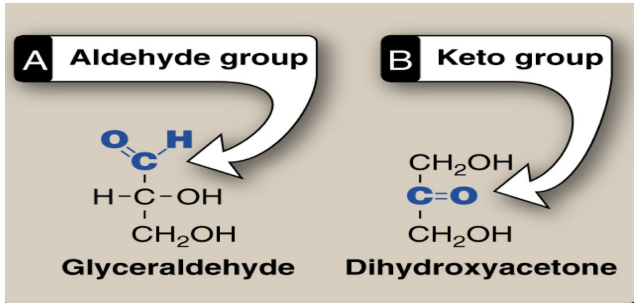
- **No. of carbon atoms**
- **Functional sugar group**

No. of Carbons	Generic name	Example
3	Triose	Glyceraldehyde
4	Tetrose	Erythrose
5	Pentose	Ribose
6	Hexose	Glucose
7	Heptose	Sedoheptulose
9	Nonose	Neuraminic acid

Ketose		Aldose
Dihydroxyacetone	Triose	Glyceraldehyde
Ribulose	Pentose	Ribose
Fructose	Hexose	Glucose



-Keto sugar: the carbonyl group within the chain.
-Aldehyde sugar: the carbonyl group at the end of the chain.

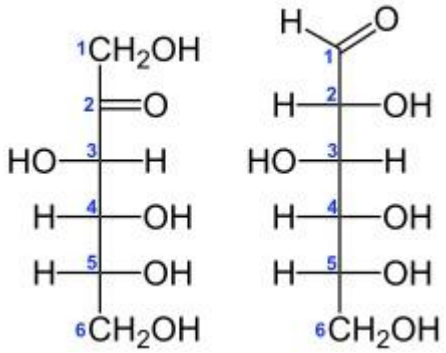


Ways of Isomerism:

Isomers | Aldo-Keto Isomers | Epimers | Enantiomers | (α - β) Anomers

1- Isomers compounds having the same chemical formula but different structural formula.

- A type of Isomers are Aldo-Keto Isomers, which happens when one compound is an Aldose (has Aldehyde as a functional group) and the other compound is a Ketose (has a Ketone as a functional group)...
- E.g: Fructose (Ketose) and Glucose (Aldose) which are Aldo-Keto Isomers, because they both share the same chemical formula ($C_6H_{12}O_6$) but different structural formula, and they are an Aldose and a Ketose.



Fructose **Glucose**

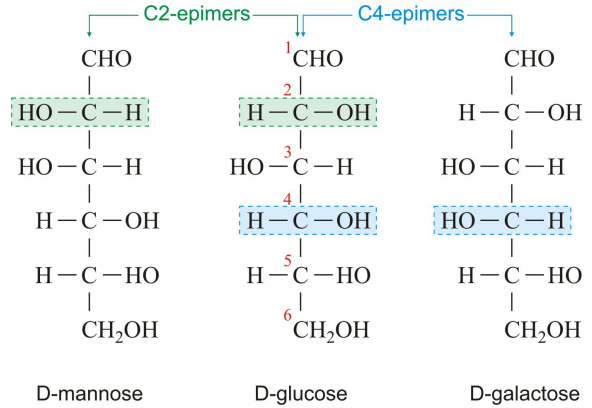
Isomerism

Helpful Video

Isomers | Aldo-Keto Isomers | Epimers | Enantiomers | (α - β) Anomers

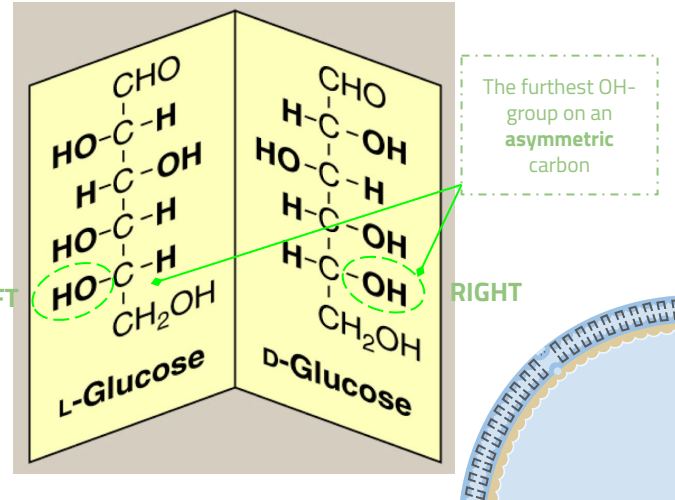
2- Epimers are CHO dimers that differ in configuration around **one** specific Carbon atom, and the rest of the Carbons are the **same**.

- E.g: - Glucose and Galactose, C4.
  - Glucose and Mannose, C2.
- Galactose and Mannose are NOT epimers because they differ in configuration around 2 carbons, so they are Isomers only.



3- Enantiomers (D-L forms) are structures that are mirror images of each other and are designated as D- and L- sugars, based on the position of -OH group on the **asymmetric carbon** and the **furthest from the carbonyl carbon.**

- Majority of sugars in humans are D-sugars.
- Most of amino acids in humans body are L-configuration.
- A carbon is **asymmetric** when it's attached to **four** different types of atoms or groups of atoms.

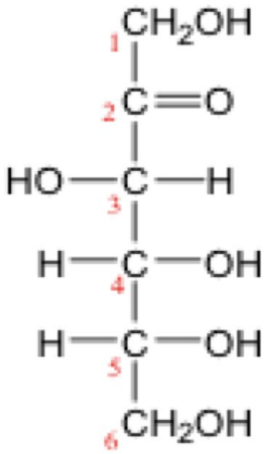


Isomerism

Isomers | Aldo-Keto Isomers | Epimers | Enantiomers | (α - β) Anomers

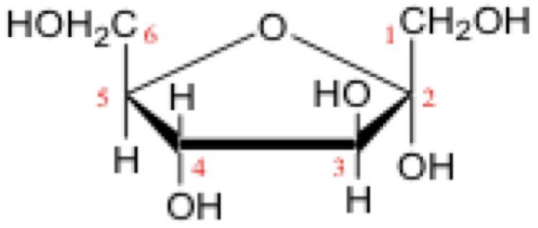
4- α & β configurations.

- Cyclization of monosaccharides with 5 or more carbons are predominantly found in the ring form.
- The Aldehyde or Ketone group reacts with the -OH group on the same sugar.
- Cyclization creates an anomeric carbon (former carbonyl carbon) generating the **α - β** configurations.
- We add the configuration **β** when OH- is **above**, and we add **α** when OH- is **below.**
- The structure of these carbohydrates might show that they are an open chain in fact most of the carbs with 5+ carbons are cyclic.



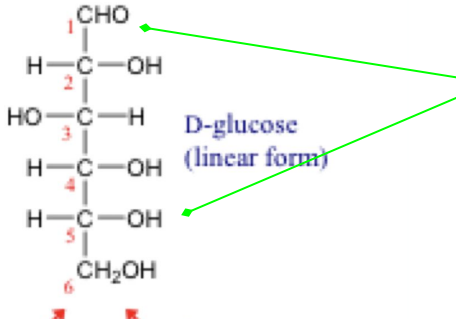
The furthest OH- group on an **asymmetric** carbon on the **RIGHT SIDE**

D-fructose (linear)



α-D-fructofuranose

anomeric carbon is C num 1 in glucose and C num 2 in fructose (former position of the carbonyl group)

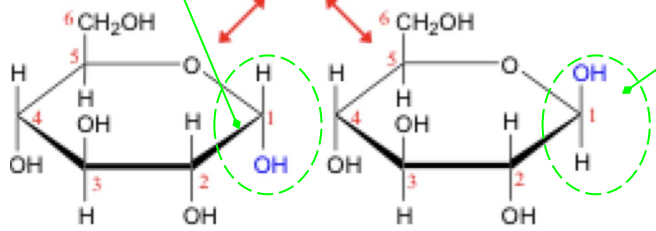


D-glucose (linear form)

Ring attachment

OH- is **below**

OH- is **above**



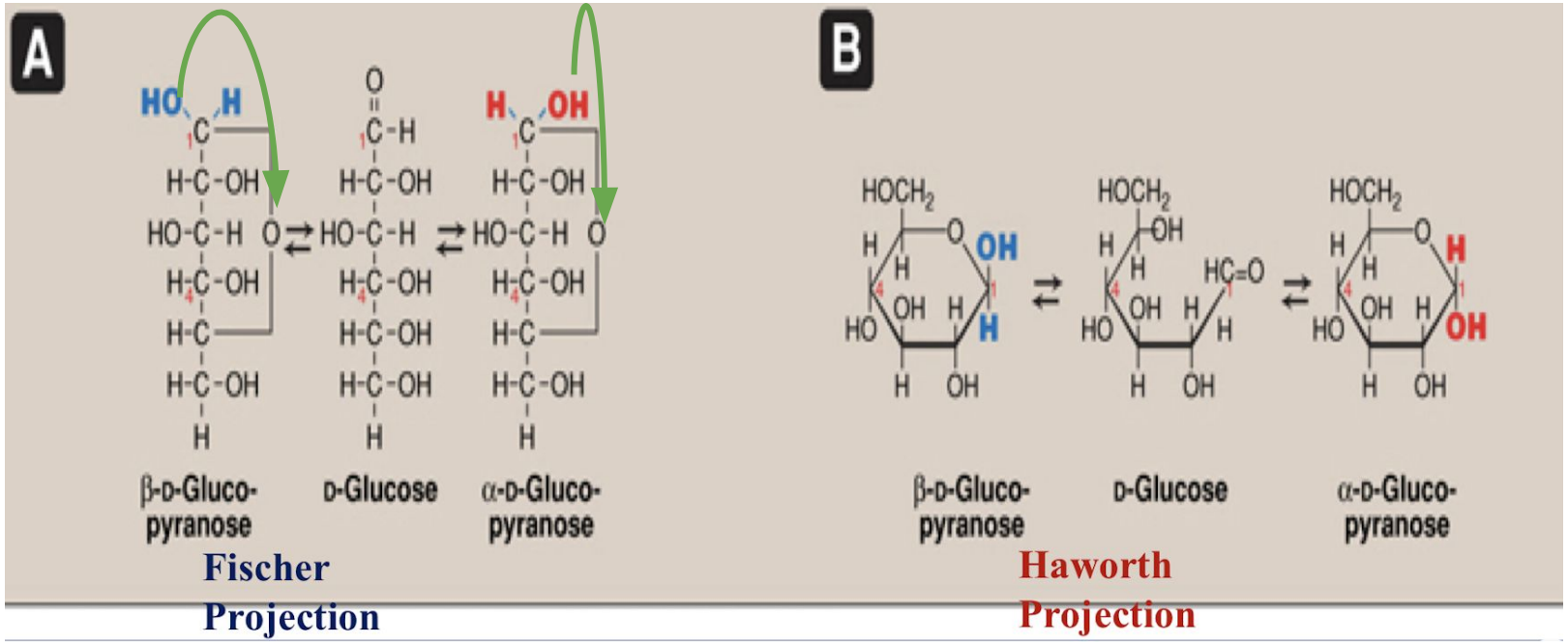
α-D-glucose

β-D-glucose

Mutarotation

Helpful video

- In a solution, the cyclic α and β anomers of a sugar are in equilibrium with each other, and can be interconverted spontaneously.



439Note: Sugar in it's normal condition is always in a ring form (Haworth projection) but when the sugar is put in water the ring is separated and becomes a linear form (Fischer projection) so OH-location changes and isn't stable.

441Note: In **Fischer** Projection: We add the **α** configuration when the OH group is near to the O atom, and we add **β** configuration when the OH group is far from the O atom. (LOOK AT THE ARROWS)

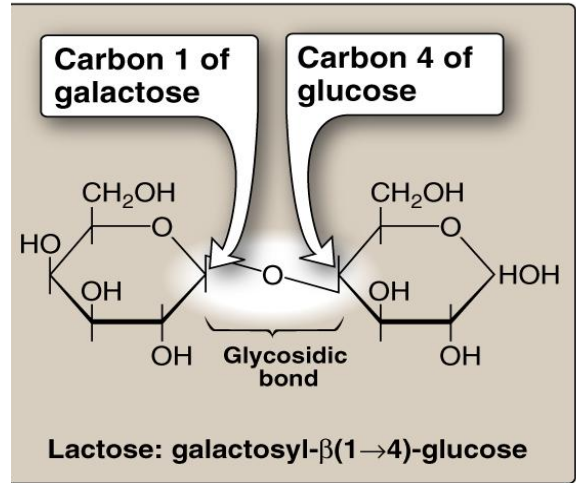
Disaccharides

1- Helpful video

2- Helpful video

- **Definition: It is the joining of 2 monosaccharides by O-glycosidic bond.**
- **Examples:**

Maltose	(α-1, 4)= glucose + glucose
Sucrose "table sugar"	(α-1,2) = glucose + fructose
Lactose	(β-1,4)= galactose + glucose



Polysaccharides

Heteropolysaccharides
Hetero: different types of simple sugars
contain two or more different monosaccharide units

e.g,glycosaminoglycans (GAGs)

Homopolysaccharides
Homo: Same type of simple sugars
All monomers units are the same

Branched:
Glycogen and starch eg;(amylopectin)
(α-glycosidic polymer)

Unbranched:
Cellulose (β-glycosidic polymer)

439Note: Glycogen, Starch, and Cellulose are all made of glucose

Reducing Sugar

Helpful video

- Free anomeric carbon + reducing agent = reducing sugar
- If the O on the anomeric C of a sugar is not attached to any other structure (**Free**), that sugar can act as a reducing agent
- Reducing sugars reduce chromogenic agents like Benedict's reagent or Fehling's solution to give a colored precipitate
- urine is tested for the presence of reducing sugars using these colorimetric tests

Examples:

1-Monosaccharides

2-Maltose (disaccharides)

3-Lactose (disaccharides)

- Sucrose is non-reducing, Why? sucrose is the combination of Glucose and Fructose (each of them combine with the other in the carbonyl group) and therefore none of them have a free aldehyde or ketone group. (the anomeric C is attached) In other words the anomeric carbon is busy. **(439Team)**

Complex Carbohydrates

-Helpful video

- Carbohydrates attached to non-carbohydrate structures by glycosidic bonds (O- or N-type)

Examples:

- Purine and pyrimidine bases in nucleic acids
- Bilirubin
- Proteins in glycoproteins and proteoglycans

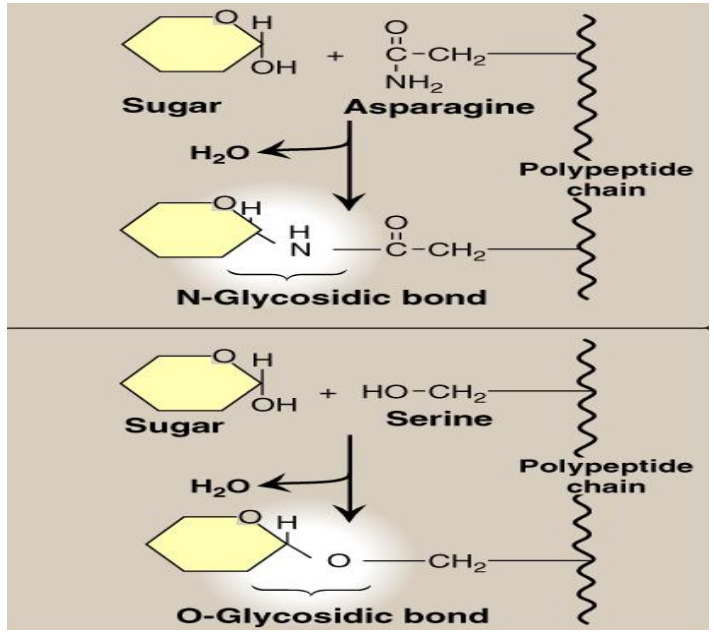
  Glycoproteins are proteins covalently bonded with carbohydrates (more protein).

  Proteoglycans are a subclass of glycoproteins in which the carbohydrate units are polysaccharides that contain amino sugars. (more carbohydrates).
- Lipids found in glycolipids

  Glycolipids are basically lipids the have some sugar molecules attached to it

N-Glycosidic:
Attachment happens at **N** atom.

O-Glycosidic:
Attachment happens at **O** atom.



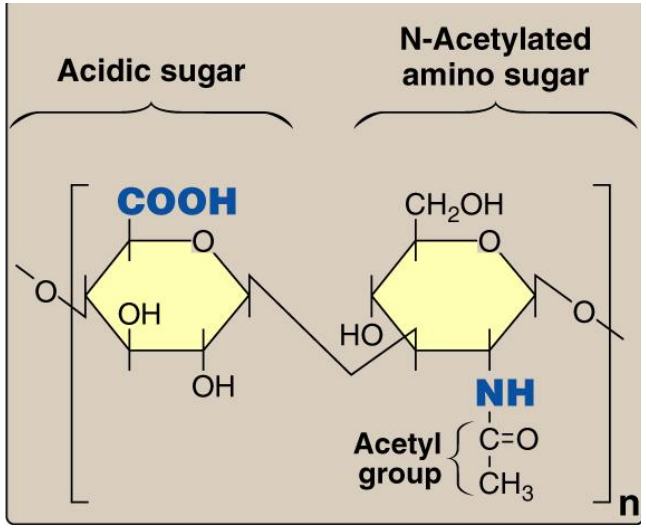
Glycosaminoglycans (GAGs)

Helpful video

- Glycosaminoglycans (GAGs) are large complexes of **negatively** charged **hetero**polysaccharide chains that are associated with a small amount of protein, forming **proteoglycans**, which consist of over 95% carbohydrates.
- They bind with large amounts of water, producing the gel-like matrix that forms the body's ground substance. Ground substance : are the non-fibrous protein of our extracellular matrix (the stuff outside the cell of our bodies) in which the other components are held in place.
- The viscous (لزج), lubricating properties (خصائص تزييت\تشحيم) and mucous (مخاط) secretions also result from GAGs, which led to the original naming of these compounds as Mucopolysaccharides.
- GAGs are linear polymers of repeating disaccharide units: (**Acidic sugar-Amino sugar**)n

The acidic sugar is either:
D-glucuronic acid or L-iduronic acid

The amino sugar (usually sulfated) is either:
D-glucosamine or D-galactosamine



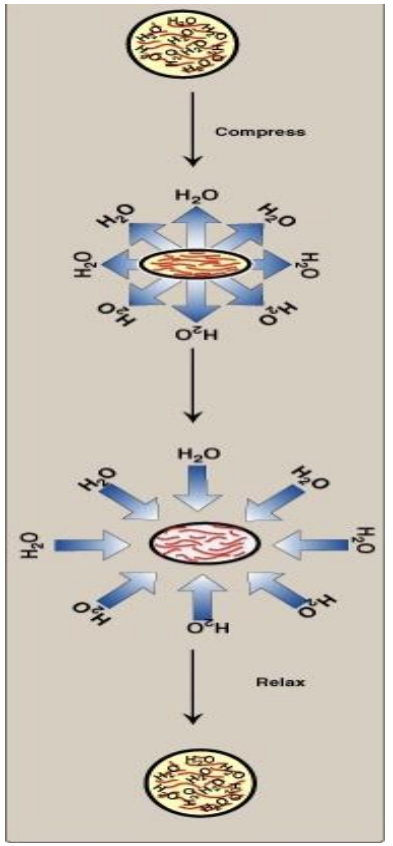
GAGs are strongly negatively charged because of:

- The carboxyl group of the acidic sugar
- The sulfate group
- NH (+) is occupied with the Acetyl group

Resilience of GAGs

Relationship between glycosaminoglycan structure and function:

- Because of negative charges, the GAG chains tend to be extended in solution and repel each other and when brought together, they "slip" past each other. This produces the "slippery" consistency of mucous secretions and synovial fluid.
- When a solution of GAGs is compressed, the water is "squeezed out" and the GAGs are forced to occupy a smaller volume.
- When the compression is released, the GAGs spring back to their original, hydrated volume because of the repulsion (تنافر) of their negative charges.
- This property contributes to the resilience (صمود\مناعة) of synovial fluid and the vitreous humor of the eye.

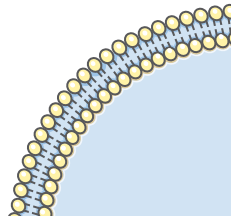


Examples of GAGs are: (439TEAM) ال synovial fluid هو سائل يتواجد بين المفاصل ويمنع الاحتكاك اما ال vitreous humour هو سائل يتواجد داخل العين

- Chondroitin sulfates: Most abundant GAG, it is found in the bones and cartilage.
- Keratan sulfates: Most heterogeneous GAG that exists, It is found in the cornea of the eye.
- Hyaluronic acid: Compared to other GAGs, it is the only one that is unsulfated and not covalently attached to protein.
- Heparin: Unlike other GAGs, that are extracellular, heparin is **intracellular** and serves as an anticoagulant (مضاد تخثر)

Take home Messages

- structure and function of carbohydrates.
- Mono-, Di-, and Polysaccharides.
- Sugar Isomers: Aldo-keto, epimers, D- and L-, α-and β-anomers.
- Complex carbohydrates: e.g., Glycosaminoglycans and Proteoglycans.
- Structure and function of GAGs.
- Examples of GAGs: chondroitin sulfate, keratin sulfate, hyaluronic acid and heparin.



Quiz

Q1: One of the following is NOT an Aldose:							
A	Glucose	B	Ribose	C	Fructose	D	Glyceraldehyde
Q2:Which of the following are epimers?							
A	Mannose-Fructose	B	Galactose-Glucose	C	Glucose-Fructose	D	Mannose-Galactose
Q3: Cyclization of Monosaccharides create:							
A	Asymmetric carbon	B	Carbonyl carbon	C	Epimer	D	Anomeric carbon
Q4:The scientific name for table sugar							
A	Lactose	B	Sucrose	C	Galactose	D	Glucose
Q5: Which one of the following is a non-reducing carbohydrate?							
A	Maltos	B	Sucrose	C	Lactose	D	Fructose

Answer key: 1) C 2) B 3) D 4) B 5) B

Q6:Name the diseases associated with disorders of carbohydrate metabolism:

Q7:What are Enantiomers?

Q8:Very large complexes of negatively charged heteropolysaccharide chains?

Q9: What are three common polysaccharides that are found in nature?

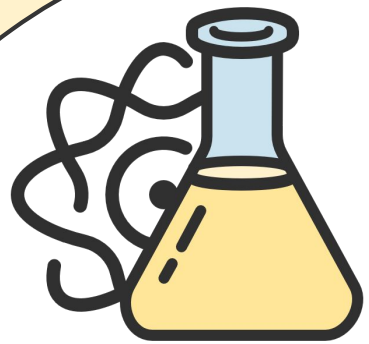
ANSWER:

Q6:
1-Diabetes mellitus
2- Galactosemia
3-Glycogen storage diseases
4- Lactose intolerance Answer

Q7: Enantiomers are structures that are mirror images of each other.

Q8: Glycosaminoglycans (GAGs)

Q9:
1-starch
2-glycogen
3-cellulose



Biochemistry 441

Girls

Boys

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Reema Alrashedi
Wareef Almousa
Joud Alangari
Fay Alluhaidan
Sarah Alhamlan
Arwa Almobeirek
Jumana AL-qahtani
Latifa Alkhdiri
Alanoud Alhaider
Futoon Almotairi
Manal Aldhirgham
Raaoum Jabor
Norah alawlah
Shahad Helmi
Rand Aldajani

Leader: Khalid Alhamdi

Members:

Ahmed Alayban
Sultan Alosaimi
Abdullah Alomran
Bassam Alghizzi
Ibrahim Aljurayyan
Mohammed Almutairi
Turki Alkhalifa
Malik Alshaya
Faisal Alhmoud
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