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Carbohydrates: Structure and Function

Color index :

Main text

IMPORTANT

Extra Info

Drs Notes

Foundation Block - Biochemistry Team

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MED439

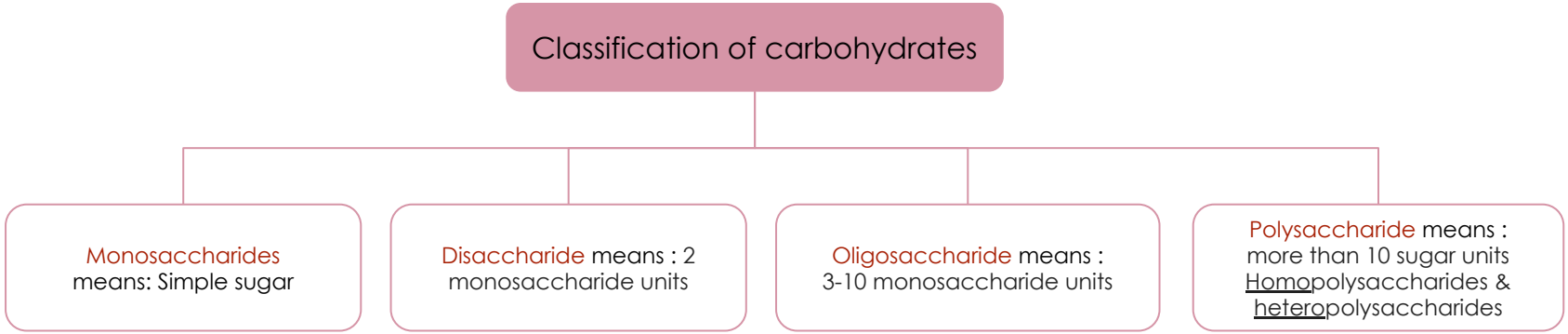
Objectives:

- The structure of carbohydrates of physiological significance.
- The main role of carbohydrates in providing and storing of energy.
- The structure and function of glycosaminoglycans.

Overview of carbohydrates

- The most abundant organic molecules in nature.
- The empiric formula is $(CH_2O)n$, "hydrates of carbon"
- Provide important part of energy in diet.
- Act as the storage form of energy in the body.
- Are structural component of cell membranes.
- Many diseases associated with disorders of carbohydrate metabolism including:

  - Diabetes mellitus a chronic disease associated with abnormally high levels of the sugar glucose in the blood.
  - Galactosemia condition in which the body cannot process or 'metabolise' the sugar galactose. Which means High galactose level in the blood. عنده مشكلة في تحويل المركب
  - 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 is the inability of adults and children to digest lactose حساسية في مركبات اللاكتوز



A helpful video

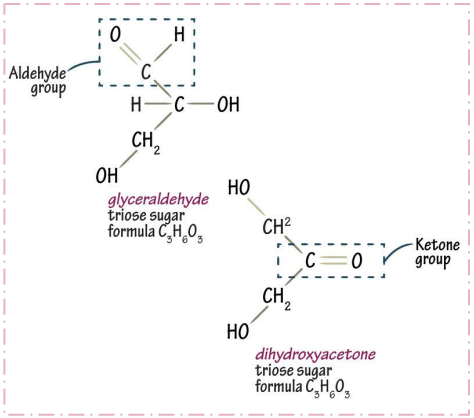
a) Monosaccharides

Monosaccharides classified according to:

No. of carbon atoms.

Generic names	Examples
3 carbons : trioses	Glyceraldehyde
4 carbons : tetroses	Erythrose
5 carbons : pentoses	Ribose
6 carbons : hexoses	Glucose
7 carbons : heptoses	Sedoheptulose
9 carbons : nonoses	Neuraminic acid

Functional sugar group : Aldehyde (aldoses) and keto (ketoses).

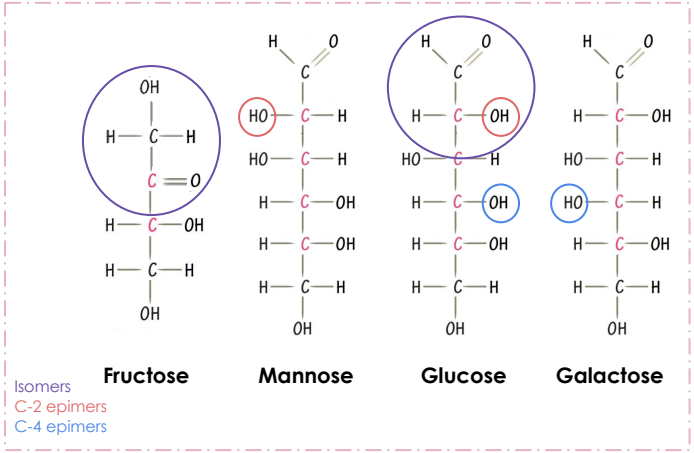


a) Monosaccharides, contd..

	Aldose	Ketose
Triose	Glyceraldehyde	Dihydroxyacetone
Pentose	Ribose	Ribulose
Hexose	Glucose	Fructose

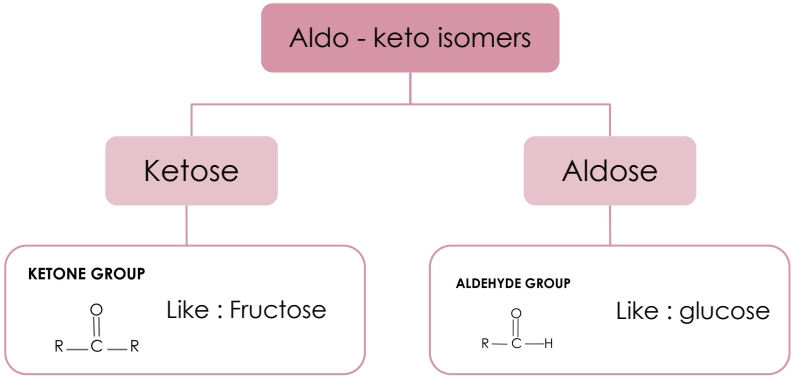
Isomerism

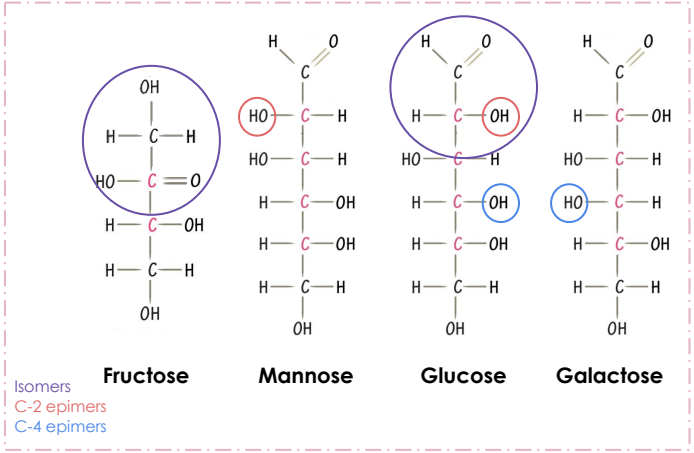
- Compounds having the same chemical formula but different structural formula.
- Because the position of individual atoms within a sugar molecule varies, many monosaccharides are isomers of one another. For example, glucose and fructose share the molecular formula C6H12O6, but are structurally different. Differences between isomers are not always as readily apparent as in structural isomers like glucose and fructose.



Isomerism , contd..

1) isomers





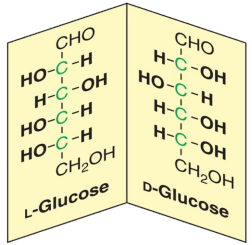
2) Epimers

- CHO dimers that differ in configuration around only one specific carbon atom
  - Glucose and galactose, **C4**
  - Glucose and Mannose, **C2**
- Galactose and mannose are **not epimers**.
- glucose & mannose are epimers in C2 , in the second carbon the position of H & OH varies , Glucose (OH)→ right and Mannose(OH)→ left

Isomerism , contd..

A helpful video

3) Enantiomers (D- and L-Forms)

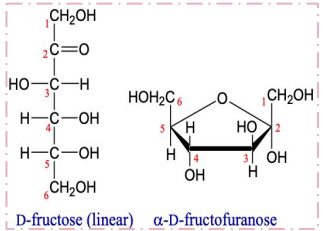


- Structures that are mirror images of each other and are designated as D- and L- sugars based on the position of –OH group on these conditions :

  - an asymmetric carbon group .

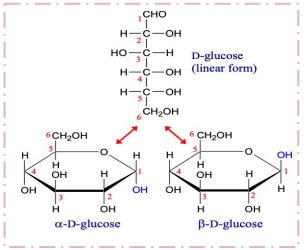
  - the farthest carbon from the carbonyl carbon.

- Majority of sugars in humans are D-sugars and majority of amino acids in humans body are found in L- configuration.
- **D**: OH group on the Right , **L**: OH group on the Left
- D- and L- sugars are MIRROR IMAGES of each other (OH group in each carbon are on the opposite side of the enantiomer) but based on the position of –OH group on the asymmetric carbon farthest from the carbonyl carbon , We can recognize whether it is D or L



4) α & β forms

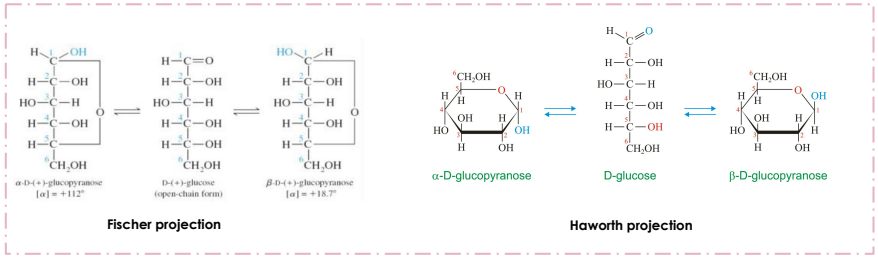
- Cyclization of monosaccharides with 5 or more carbon are predominantly found in the ring form.
  - The aldehyde or ketone group reacts with the –OH group on the same sugar.
  - Cyclization creates an anomeric carbon (former carbonyl carbon) generating the α up and β down configurations.
- the structure of these carbohydrates might show that they are an open chain in fact carbs with 5+ carbons are cyclic.
- For monosaccharide in the D-series: the OH group is down in α anomer, up in β anomer



Mutarotation

A helpful video

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

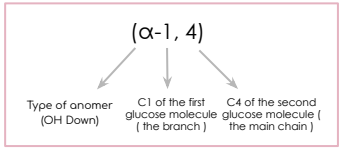


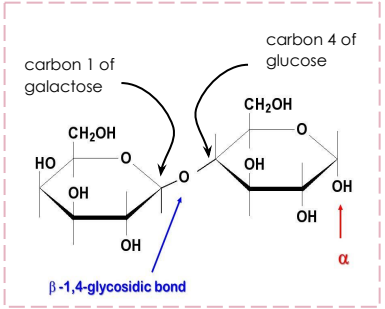
السكر في حالته الطبيعية دائما ياخذ الشكل الحلقي " Haworth projection " ولكن عندما يوضع السكر في محلول تفتح الحلقة ويصبح شكله سلسلة مفتوحة " Fischer projection " فبالتالي موضع OH يتغير مايكون ثابت مرات لتحت α ومرات لفوق β

Disaccharides

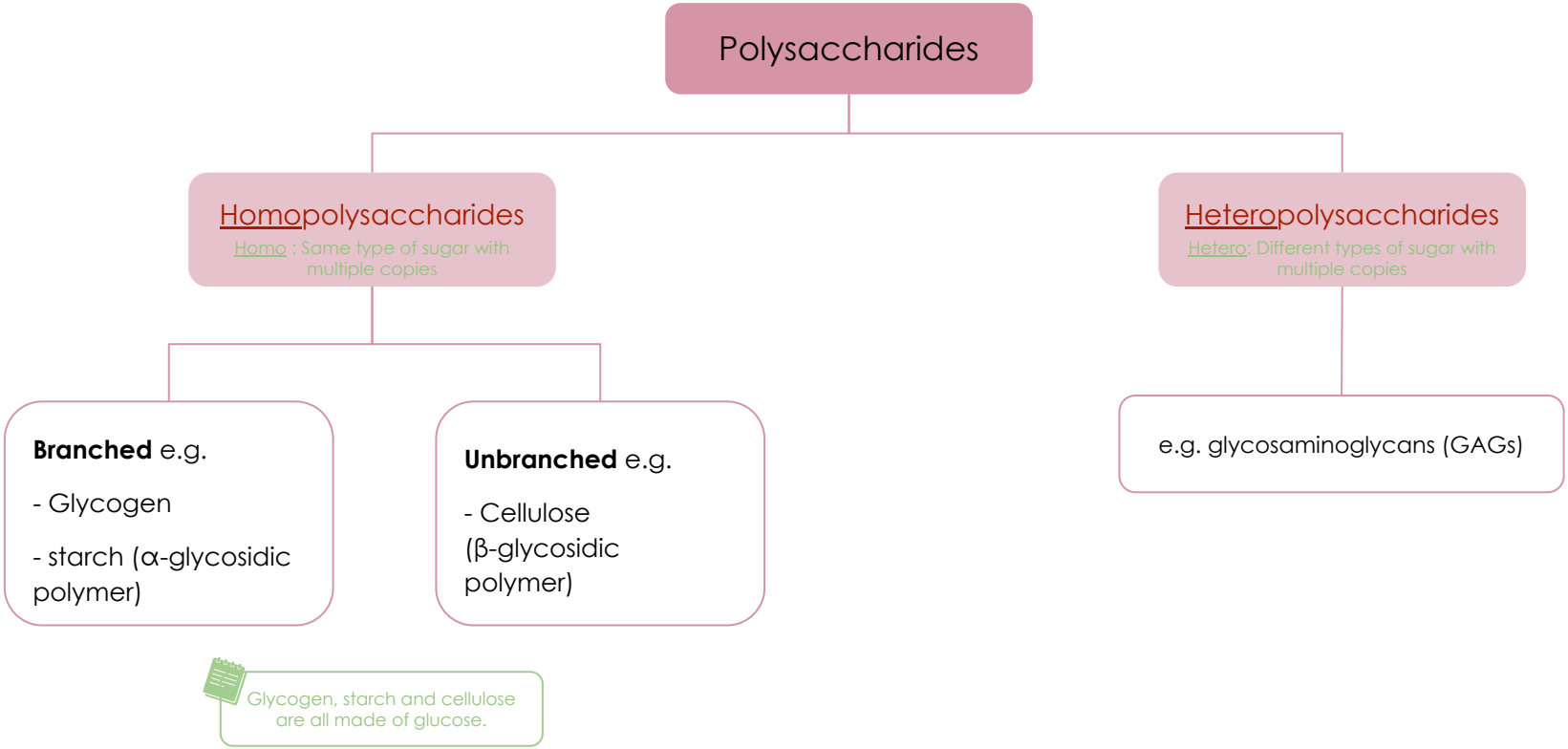
- Joining of 2 monosaccharide by **O-glycosidic bond**:

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





Polysaccharides



Reducing Sugars

Free anomeric carbon + reducing agent = reducing sugar

- **When ?** 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.
- **Where ?** reducing sugars reduce chromogenic agents like Benedict's reagent or Fehling's solution to give a colored precipitate.
- **Why do we need it ?** Urine is tested for the presence of reducing sugars using these colorimetric tests.
- **Examples:**
  - Monosaccharides
  - Lactose (Disaccharides)
  - Maltose (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)

بمعنى آخر الـ anomeric carbon مشغولة

Complex carbohydrates

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

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

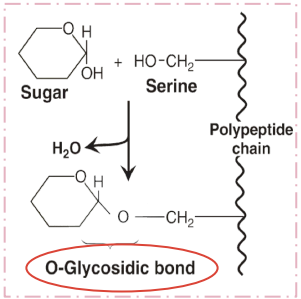
    glycoprotein: proteins that have some sugar attached to it

    proteoglycans: carbohydrate having some protein attached to it.
  - Lipids found in glycolipids.

    Glycolipids:lipids that have some sugar attached to it.

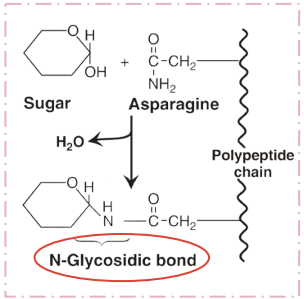
O-Glycosidic

- Attachment happens at a Oxygen atom.



N-Glycosidic

- Attachment happens at a Nitrogen atom.



Glycosaminoglycans (GAGs)

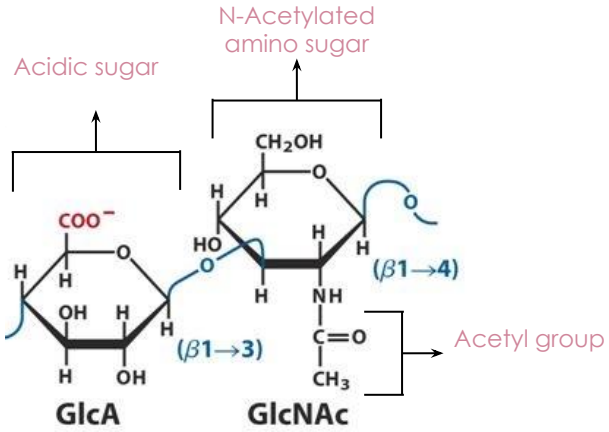
- Glycosaminoglycans (GAGs) are large complexes of negatively charged heteropolysaccharide chains.
- are associated with a small amount of protein, forming proteoglycans, which consist of over 95 percent carbohydrate.
- bind with large amounts of water, producing the gel-like matrix that forms body's 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, lubricating properties of mucous 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

Glycosaminoglycans (GAGs)

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: due to carboxyl groups of acidic sugars and Sulfate groups



Examples of GAGs

01 Chondroitin sulfates: Most abundant GAG.

02 Keratan sulfates: Most heterogeneous GAGs.

03 Hyaluronic acid: Compared to other GAGs, it is unsulfated and not covalently attached to protein.

04 Heparin: Unlike other GAGs, Unlike other GAGs that are extracellular, heparin is intracellular and serves as an anticoagulant

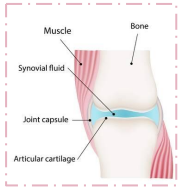
Resilience of GAGs

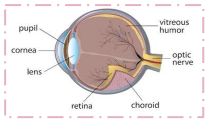
Relationship between glycosaminoglycan structure and function

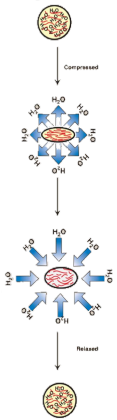
- Because of negative charges, the GAG chains tend to be extended in solution and repel each other and when brought together, they "slip" past each other this produces the "slippery" consistency of mucous "مخاطي" secretions and synovial fluid

- 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 of their negative charges This property contributes to the resilience of synovial fluid and the vitreous humor of the eye

الـ synovial fluid هو سائل يتواجد بين المفاصل ويمنع الإحتكاك اما الـ vitreous humor هو سائل يتواجد داخل العين







Take home messages

- Mono-, Di-, and Poly-saccharides.
- Sugar Isomers: Aldo-keto, epimers, D- and L-, a-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 : Ribulose sugar is			
A) Hixose	B) Triose	C) Pentose	D) Aldose
Q2 : The functional group in fructose is			
A) Aldehyde group	B) Ketone group	C) Carboxylic Acid group	D) Amino Group
Q3 : Maltose is made of two monosaccharide			
A) Glucose + Glucose	B) Glucose + Fructose	C) Galactose + Fructose	D) Galactose + Glucose
Q4 : Carbohydrates attached to non-carbohydrate structures by			
A) Glycosidic bond	B) Covalent bond	C) Hydrogen bond	D) Phosphodiester bond
Q5 : Majority of sugars in humans are ?			
A) D- sugar	B) L- sugar	C) F-sugar	D) G-sugar
Q6 : The empiric formula is :			
A) $(CHO_2)n$	B) $(CHO)n$	C) $(CH_2O)n$	D) $(C_2HO)n$

SAQs :

Q1: What are the isomers ?

Q2: Why do GAG molecules tend to repel each other, and for why is this considered an advantage for mucous secretions and the synovial fluid?

★ **MCQs Answer key:**

1) C 2) B 3) A 4) A 5) A 6) C

★ **SAQs Answer key:**

1) Compounds having same chemical formula but different structural formula

2) They repel each other because they're negatively charged molecules, and like repels like. It is an advantage since it produces the slippery consistency of synovial fluid and mucous secretions.

Girls team:

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Reema Alomar
Reem Alqahtani
Renad Alhumaidi
Shaden Alobaid
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Lama Alahmadi
Sadem Alhazmi
Somow Abdulrahman
Budoor Almubarak
Samar Almohammedi
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Duaa Alhumoudi

Boys team:

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Hassan alshuraf
Abdulrahman almbki
Mohammed alsayari
Abdullaziz alomar
Abdulaziz alrabiah
Saud alrasheed
Abdullah almazro
Hamad almousa
Ahmad alkhayat

"Setting goals is the first step in turning the invisible into the visible"

Shatha Aldhohair

Mishal Althunayan

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