Structure & Function of Carbohydrates

Editing File

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- Female Slides (Pink)
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- Important (Red)
- Dr's Notes (Green)
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Objectives

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

Overview of Carbohydrates

Carbohydrates:

- Most abundant organic molecules in nature.
- The empirical formula for carbohydrates is $(CH_2O)n$---> lowest number of n is 3.
- They are also called "hydrates of carbon".

Overview of Carbohydrates

Functions of Carbohydrates:

- Provide important part of energy in diet.
- Act as the storage form of energy in the body--> ex: glycogen in the liver.
- Are structural component of cell membranes.

Overview of Carbohydrates

Many diseases associated with disorders of carbohydrate metabolism including:

- **Diabetes mellitus(DM)**
- **Galactosemia-->** “Meaning galactose in the blood" so people who have it can't digest due to the blockage of processing galactose, so it ends up building up in their blood.
- **Glycogen storage disease-**-> The result of defects in the processing of glycogen
synthesis or breakdown within muscles, liver, and other cell types.
- **Lactose intolerance-->** The inability of the body to digest lactose.

Classification of Carbohydrates:

Monosaccharides

01

Simple sugar
Ex: Glucose

Disaccharides

02

2 Monosaccharides units
Ex: Lactose

Oligosaccharides

03

3-10
Monosaccharide units

Polysaccharides

04

More than 10 monosaccharide units

Heteropolysaccharides: monosaccharides are different

Homopolysaccharides: monosaccharides are identical

Monosaccharides Are Further Classified Based On:

1- Number of carbon atoms

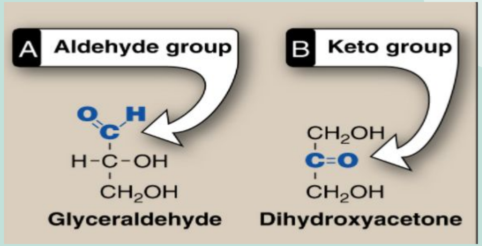
It's important to memorize an example for each type.

2- Functional sugar group

441 Note:
-Keto sugar: The carbonyl group is within the chain.
-Aldehyde sugar: Carbonyl group is at the end of the chain.

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

	Aldose	Ketose
Triose	Glyceraldehyde	Dihydroxyacetone
Pentose	Ribose	Ribulose
Hexose	Glucose	Fructose



Types of Isomerism:

01 Isomers

02 Aldo-Keto Enantiomers Isomers

03 Epimers

04 Enantiomers

05 (α - β) Forms

Types of Isomerism:

Isomers:

- Isomers are compounds that have the same chemical formula but different structural formulas.

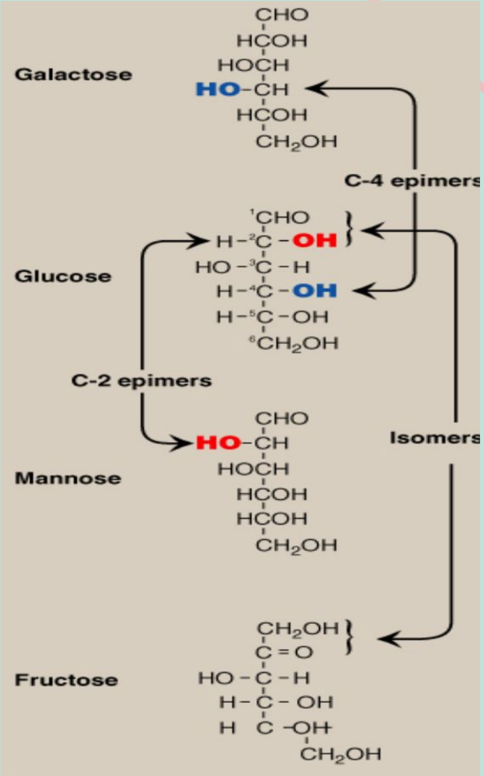
Aldo-Keto Isomers:

- Aldo-Keto Isomerism is a type of isomerism, 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.

441Note: Fructose and Glucose both share the same chemical formula (C6H12O6) but different structural formula.

Numbering: functional group gets smallest number when counting.



Types of Isomerism:

Epimers:

Epimers are CHO dimers that differ in configuration around only one specific carbon atom, and the rest of the Carbons are the same.

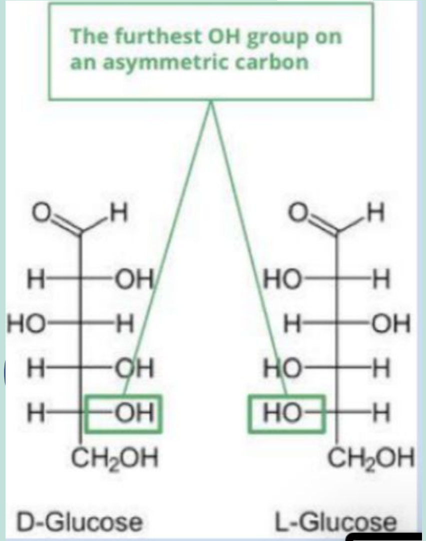
E.g:
- Glucose and Galactose, C4
- Glucose and Mannose, C2
- Galactose and Mannose are NOT epimers (because they differ in configuration around more than one carbon, so they are only isomers).

Types of Isomerism:

Enantiomers (D- & L-Forms):

Enantiomers 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 furthest asymmetric carbon from the carbonyl carbon.

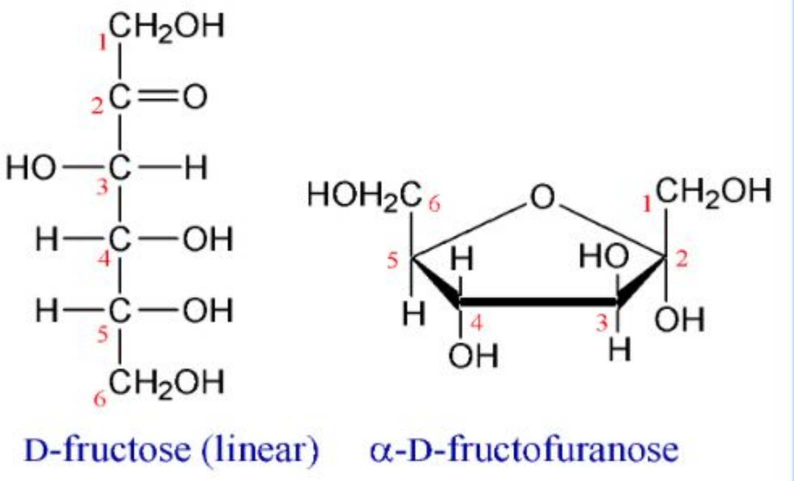
- Majority of sugars in humans are D-sugars.
- Most of amino acids in humans body are L-configuration.
- A carbon is asymmetric when it's attached to four different types of atoms
or groups of Atoms.
-Asymmetric carbons are optically active.

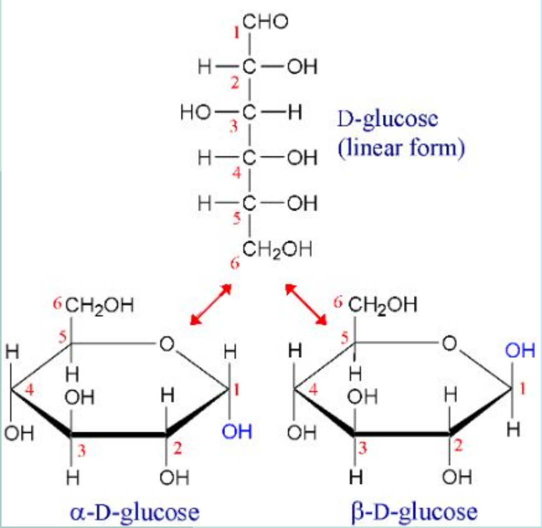


Types of Isomerism:

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 and 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.

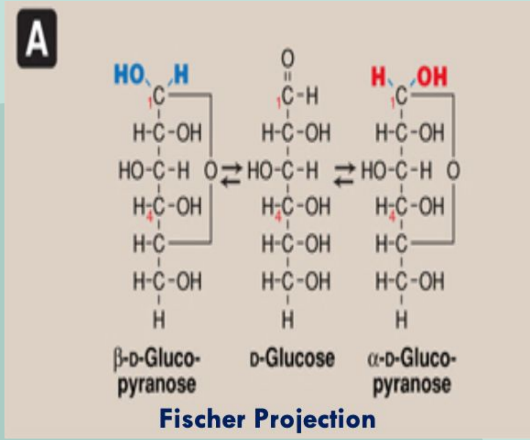

CH_2OH
$C=O$
HO—C—H
H—C—OH
H—C—OH
CH_2OH
HOH_2C
O
CH_2OH
H
HO
H
OH
OH
H
D-fructose (linear)
α-D-fructofuranose

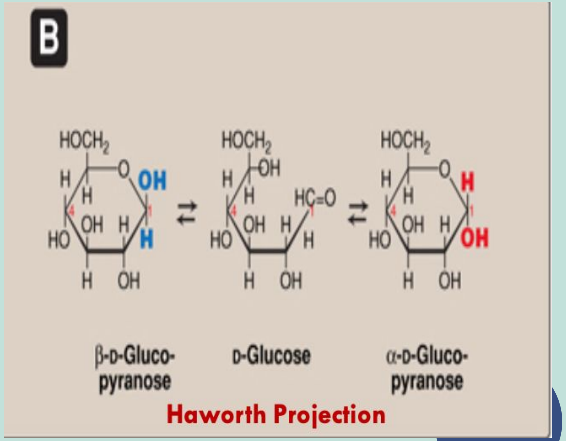

CHO
H—C—OH
HO—C—H
H—C—OH
H—C—OH
CH_2OH
D-glucose
(linear form)
CH_2OH
O
OH
H
CH_2OH
O
OH
H
α-D-glucose
β-D-glucose

Mutarotation

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

441Note: In Fischer Projection: We add the α configuration when the OH group is near the O atom, and the β group when the OH group is far from the O atom. (Look at the arrows).





439Note: Sugar in its 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 the -OH location changes and isn't stable.

Disaccharides

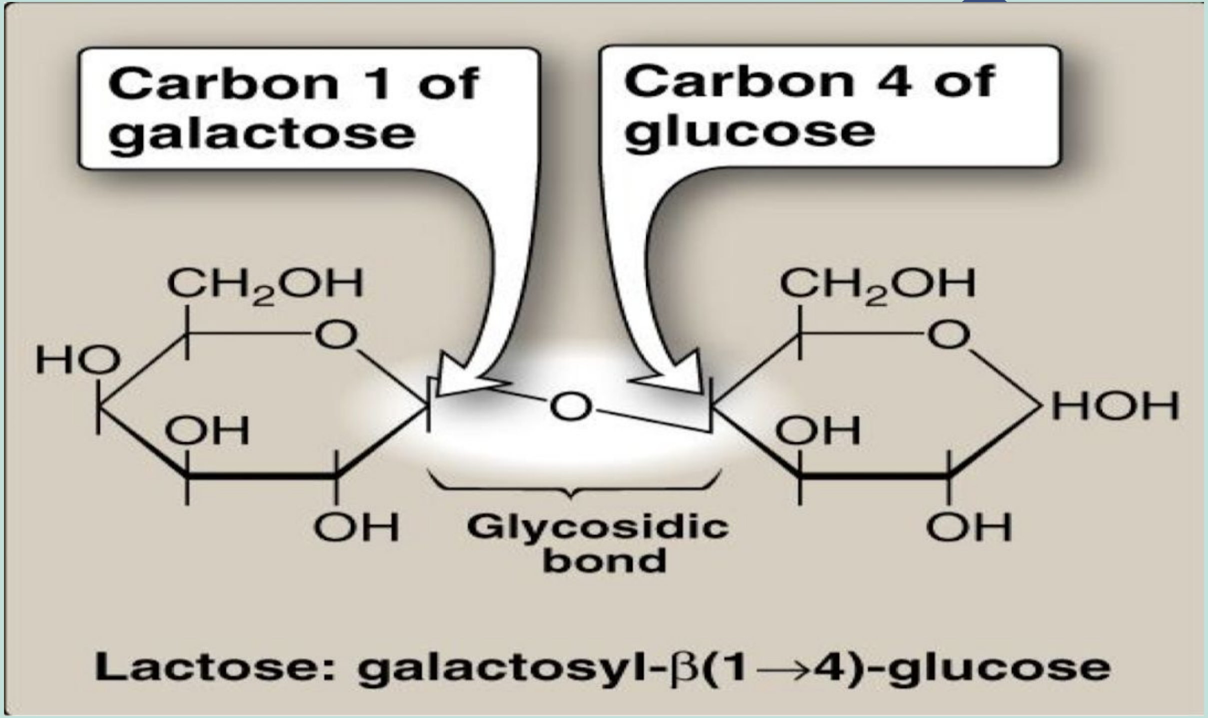
Definition: Disaccharides are 2 monosaccharides joined by a O-glycosidic bond.

-Examples:

- Maltose: (α-1, 4)= Glucose + Glucose
- Sucrose: (α-1, 2)= Glucose + Fructose
- Lactose: (β-1, 4)= Galactose + Glucose

O-glycosidic bond: an oxygen is shared between the monosaccharides

Lactose



Carbon next to the oxygen is anomeric oxygen taken from galactose free anomeric C= reducing sugar.

Polysaccharides

Homopolysaccharides

- Branched: Glycogen and Starch (α-glycosidic bond)
- Unbranched: Cellulose (β-glycosidic bond)

Heteropolysaccharides

- Glycosaminoglycans

Reducing Sugars

If the O on the anomeric carbon is 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.

Reducing Sugars

If the O on the anomeric carbon is free; that sugar can act as a reducing agent.

-Examples:

- Monosaccharides.
- Maltose and Lactose.

Sucrose is non-reducing because both anomeric carbons are busy (due to the linkage they have '(α-1, 2) glucose + fructose').

Complex

Carbohydrates attached to non-carbohydrate structures via glycosidic bonds.

-Examples:

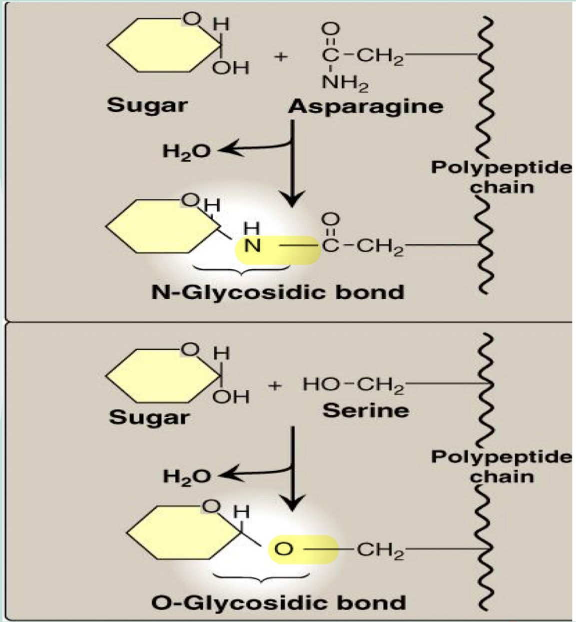
- Purine and Pyrimidine bases in nucleic acid.
- Bilirubin.
- Proteins in glycoproteins and proteoglycans.
- Lipids in glycolipids.

Complex

Carbohydrates attached to non-carbohydrate structures via glycosidic bonds.

-Glycosidic Bonds:

- N-Glycosidic: attachment happens at N atom (e.g., Asparagine).
- O-Glycosidic: attachment happens at O atom (e.g., Serine).



Glycosaminoglycans

Large complexes of negatively charged heteropolysaccharide chains.

- Associated with a small amount of protein to form proteoglycans which are 95% carbohydrates.

- Bind with large amounts of water; forming the gel-like matrix that forms body's ground substance.

- GAGs also gives mucous secretions its viscous and lubricating properties. They were originally named mucopolysaccharides.

Glycosaminoglycans

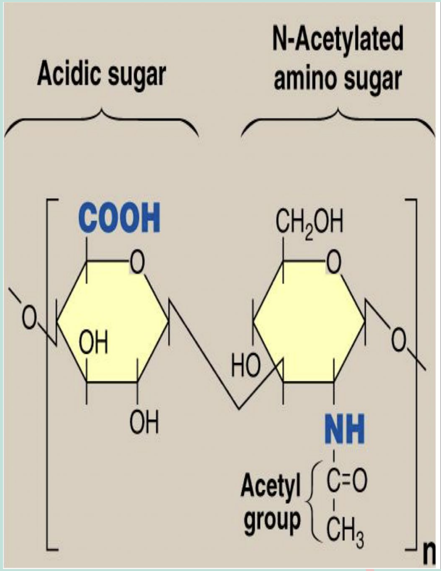
Large complexes of negatively charged heteropolysaccharide chains.

GAGs are linear polymers of repeating disaccharide units: (acidic sugar-amino sugar)n.

Amino sugars (usually sulfated) either:
D-glucosamine or D-galactosamine.

Acidic sugars either:
D-glucuronic acid or L-iduronic acid.

GAGs are strongly negatively charged because of the carboxyl and sulfate groups.



Glycosaminoglycans

Relationship between GAGs structure and functions.

- Because of its negative charge, GAG chains tend to be extended in solutions and repel each other. When brought together they 'slip' past each other.

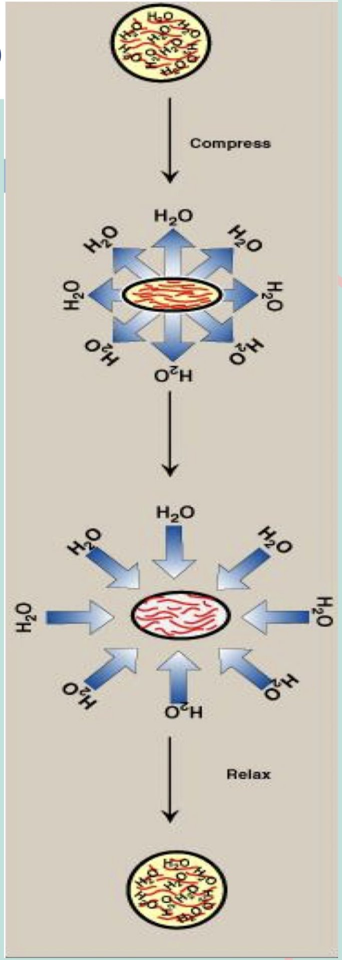
- This produces the slippery consistency of mucous secretions and synovial fluid.

Glycosaminoglycans

Relationship between GAGs structure and functions.

- When a solution of GAGs is compressed; the water is 'squeezed out' and the GAGs are forced to occupy smaller volume. When the compression is released the GAGs spring back to their original volume and gain water back (like a sponge).

- This contributes to the resilience of synovial fluids and vitreous humor of the eye.



Ability to be compressed

Glycosaminoglycans

Examples of GAGs:

- Chondroitin sulfates: Most abundant GAGs.
- Keratan sulfates: Most heterogenous GAGs.
- Hyaluronic Acid: Compared to other GAGs, it is unsulfated and not covalently attached to protein.
- Heparin: Intracellular, is an anticoagulant (stops clotting).

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 functions of GAGs.
- Examples of GAGs: chondroitin sulfate, keratan sulfate, hyaluronic acid and heparin.

Question 1

Which one of these is classified as branched homopolysaccharides?

A Glycogen

B Glycosaminoglycan

C Cellulose

D Maltose

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Question 2

Carbohydrates that have similar structure but differ in configuration at one carbon are:

A Epimers

C Isomers

B Enantiomers

D Anomeric

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Question 3

Fructose structure is classified as:

- A Aldopentose
- B Ketopentose
- C Aldohexose
- D Ketohexose

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Question 4

Cyclization of monosaccharides generates which kind of isomers?

- A Aldo-keto isomers
- B D and L forms
- C Epimers
- D α and β anomers

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