Biochemistry Team 435

جامعة الملك سعود
King Saud University

CARBOHYDRATES: STRUCTURE AND FUNCTION

- Color index:
  - Very important
  - Extra Information.

"STOP SAYING I WISH, START SAYING I WILL"

435 Biochemistry Team

*هذا العمل لا يغني عن المصدر المذاكرة الرئيسي

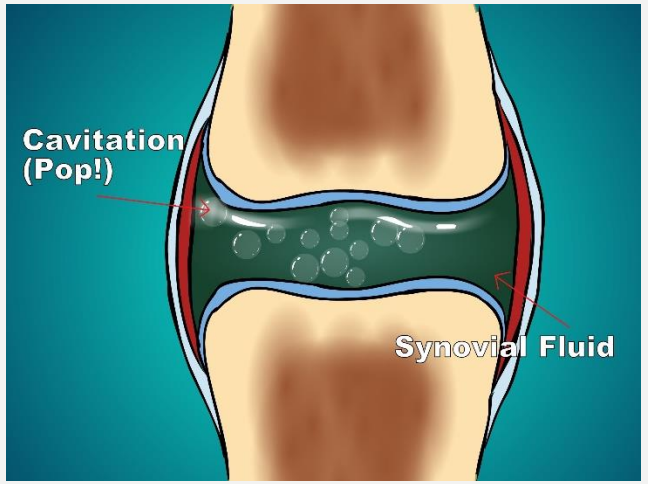
OBJECTIVES:

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

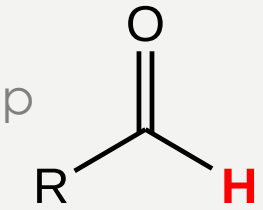
extra information that might help you

1-synovial fluid:

- It is a viscous, non-Newtonian fluid found in the cavities of synovial joints.
- the principal role of synovial fluid is to reduce friction between the articular cartilage of synovial joints during movement



2- aldehyde = terminal carbonyl group (RCHO)



3- ketone = carbonyl group within (inside) the compound (RCOR')

the most abundant organic molecules in nature

Carbohydrates

Formula

$(CH_2O)_n$

hydrate of carbon

Function

1-provides important part of energy in diet .

2-Acts as the storage form of energy in the body

3-structural component of cell membrane.

Diseases caused by disorders of carbohydrate metabolism

1-Diabetesmellitus.
2-Galactosemia.
3-Glycogen storage disease.
4-Lactoseintolerance.

Classification of carbohydrates

monosaccharides

simple sugar

- No. of carbon atoms they contain
- Type of carbonyl group they contain
  - Ketone or aldehyde
    - **Ketose**
      - Contains: ketone group.
    - **aldose**
      - Contains: aldehyde group

Type of carbonyl / No. of C	Aldose	Ketose
Triose	Glyceraldehyde	Dihydroxyacetone
Pentose	Ribose	Ribulose
Hexose	Glucose	Fructose

disaccharides

Two monosaccharides units

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

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

oligosaccharides

3-10 sugar units

polysaccharides

more than 10 sugar units

- Homopolysaccharides
  - Homo= same type of sugars
    - branched
      - **Examples:** **Glycogen and starch** **(α-glycosidic polymer)**
    - unBranched
      - **Example:** **Cellulose** **(β-glycosidicpolymer**
- Heteropolysaccharides
  - Hetero= different types of sugars
  - **-Example:**
  - glycosaminoglycans (GAGs)

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Monosaccharides

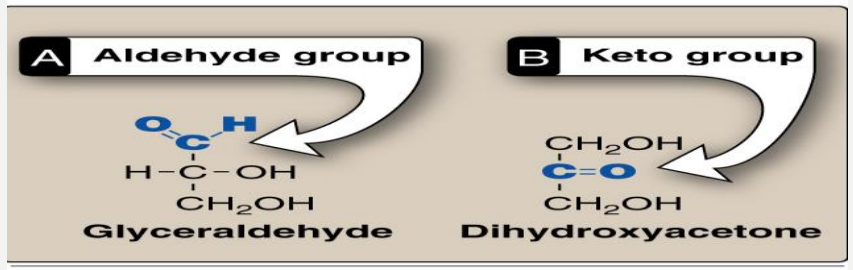
- Monosaccharaides is basic unit of carbohydrate (simple sugar)

Classification of Monosaccharaides according to

No. of carbon atoms they contain

No. of carbon atoms	Generic name	example
3	trioses	**Glyceraldehyde**
4	tetroses	Erythrose
5	pentoses	Ribose
6	hexoses	Glucose
7	heptoses	Sedoheptolose
9	nonoses	Neuraminic acid

Type of carbonyl group they contain



Functional sugar group:

- Aldehyde group – **aldoses** (carbonyl group is terminal (at the end of chain))
- Keto group – **ketoses** (carbonyl group is within the chain)

Type of carbonyl / No. of C	Aldose	Ketose
Triose	Glyceraldehyde	Dihydroxyacetone
Pentose	Ribose	Ribulose
Hexose	Glucose	Fructose

DISACCHARIDES

Joining of 2 monosaccharide's by o-glycosidic bond

Examples:

C4 of the second glucose

1- Maltose (a-1, 4)= glucose + glucose

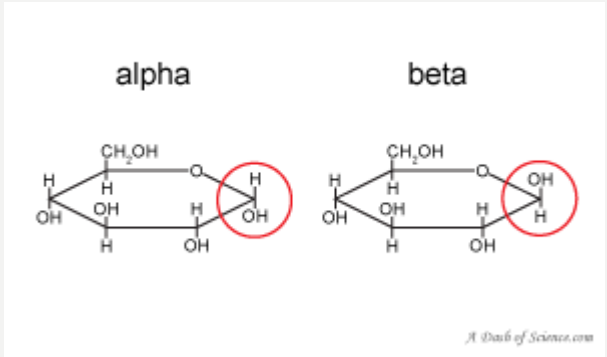
OH toward down

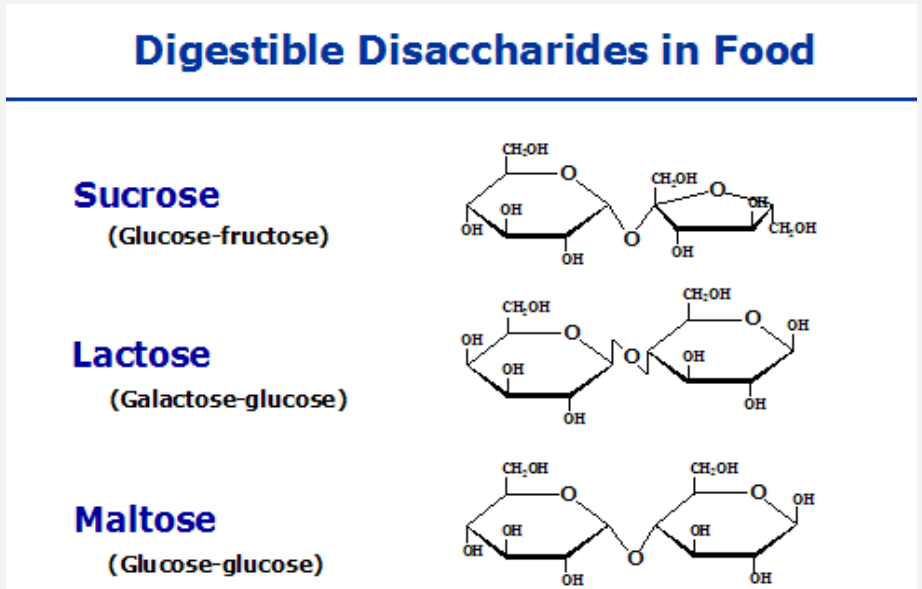
C1 of the first glucose

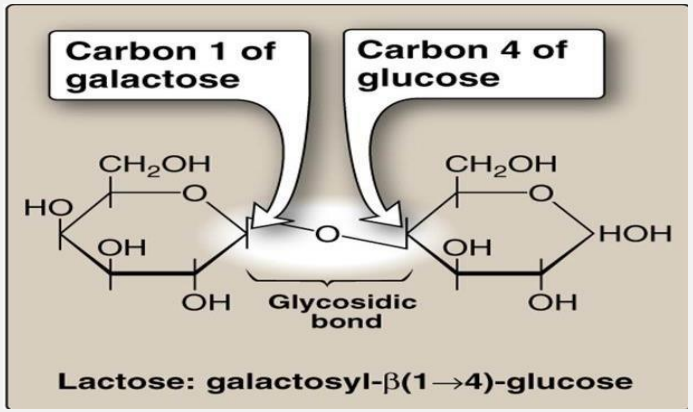
2- Sucrose (a-1,2)=glucose + fructose

3- Lactose (β-1,4)=glucose + galactose

Note:
a= OH down
B= OH up







polysaccharides

Homopolysaccharides

Homo= same type of sugars

Branched

-One chain but it has a branch on it

Examples:

Glycogen and starch (α-glycosidic polymer)

unBranched

-Single chain

Example:

Cellulose

(β-glycosidicpolymer)

Heteropolysaccharides

Hetero= different types of sugars

-Example:

glycosaminoglycans (GAGs)

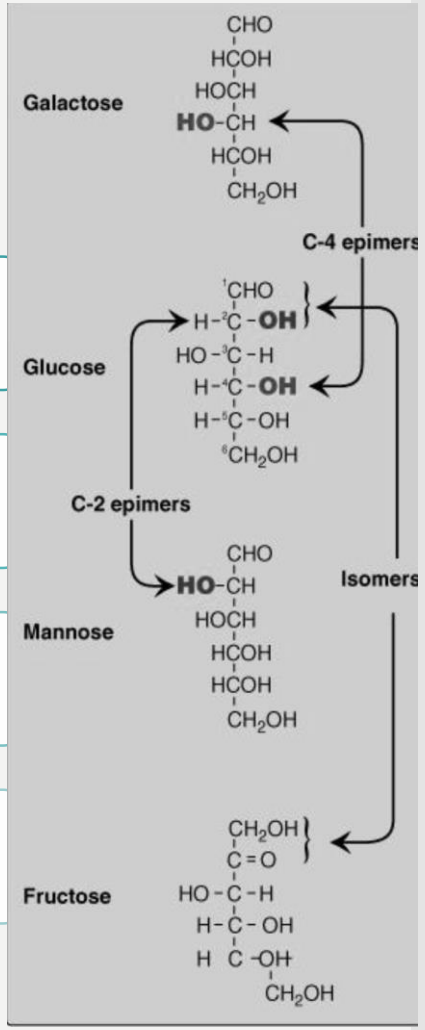
#Isomers:

Compounds with the same chemical formula but with a different structural formula.

Note: Galactose, Glucose, Mannose, and Fructose are all isomers of each other
*The chemical formula is: $C_6H_{12}O_6$

#Types:

- **Aldo-Keto**
  - Same → formula •
  - Different → functional Group •
- **Epimers**
  - Same → formula •
  - Different → configuration around a *single* carbon atom. •
- **D- and L-forms**
  - Same → molecular formula •
  - Different →position of OH group on the *asymmetric carbon* farthest from carbonyl group. •
- **α- and β-anomers**
  - Same → molecular formula •
  - Different → position of OH around anomeric carbon •



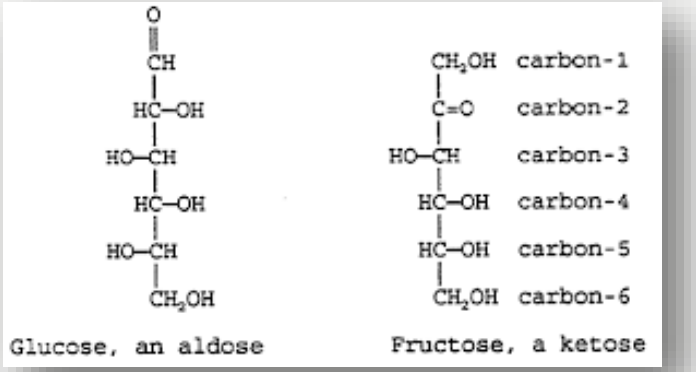
#Aldo-Keto Isomers (Functional group isomerism):

What are they?

two compounds with the same molecular formula, but different functional group

Example:

Glucose (Aldose) and **Fructose** (Ketose)



Recall

aldose is a monosaccharide (a simple sugar) that contains only one aldehyde (−CH=O) group per molecule.
ketose is a monosaccharide containing one ketone group per molecule

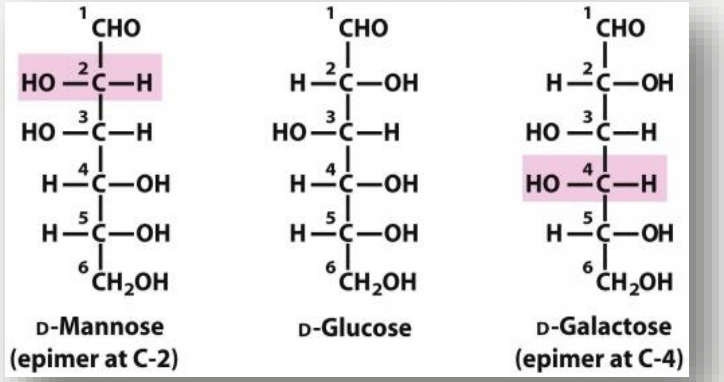
#Epimers:

What are they?

Compounds that have the same chemical formula but they differ only in the configuration around a **single** carbon atom

Examples:

-**Glucose and galactose** (epimers at C4)
-**Glucose and Mannose** (epimers at C2)
* Galactose and mannose are not **epimers**



* Galactose and mannose are not epimers

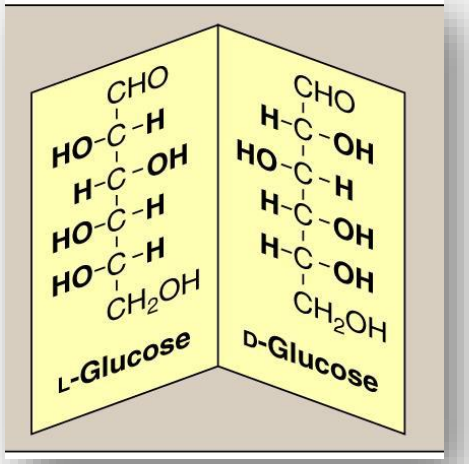
NOTE: when 2 compounds differ in the configuration around more than one carbon they don't considered as epimers .

Enantiomers (D- and L-Forms)

What are they?

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 farthest from the carbonyl carbon

→Majority of sugars in humans are D-sugars ←



NOTES: D and L-forms have to be optically active.

- **asymmetric carbon (chiral carbon) is**: a carbon atom attached to 4 different groups.

- **The basic requirement of structural formula to be optically active** is to has at least one asymmetric carbon atom

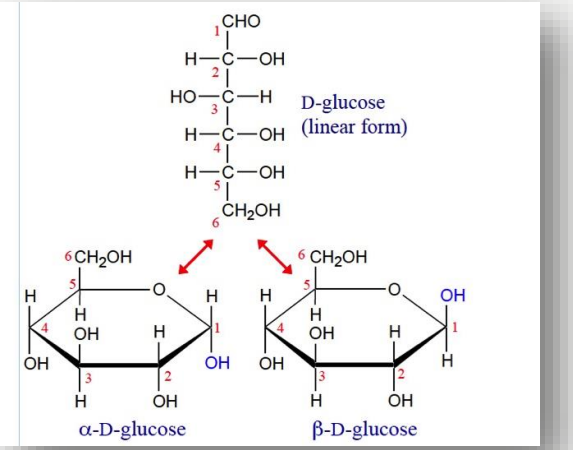
- when the OH group is on the right of the molecule →**D-molecule.**
- when the OH group is on the left of the molecule, → **L-molecule.**

α- and β- Forms (Anomers)

- **Cyclization of Monosaccharides** with 5 or more carbon are predominantly found in the ring form.

- The aldehyde or ketone group reacts with the –OH grp on the same sugar

- Cyclization creates an ***anomeric carbon*** (former carbonyl carbon) generating the a and β configurations.



NOTE:

- in the case of Glucose, the carbonyl carbon reacts with C5 and makes a ring.
- The hydroxyl group can go up or down so that is the formation of isomers (anomers)

Mutarotation:

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

Definetions that might help you:

***Anomeric carbon:** The carbon at which anomers rotate.

***Anomer:** stereoisomers of a sugar which differ only in how they are configured around anomeric carbon.

***Stereoisomers :** are isomeric molecules that have the same molecular formula and sequence of bonded atoms but differ in the three-dimensional orientations of their atoms in space.

Reducing sugar

A REDUCING SUGAR :

is any sugar that is capable of acting as a reducing agent because it has a free aldehyde group or a free ketone group … in other words when 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 .

- They 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 .

A positive result is indicative of an underlying pathology, because sugars are not normally percent in urine

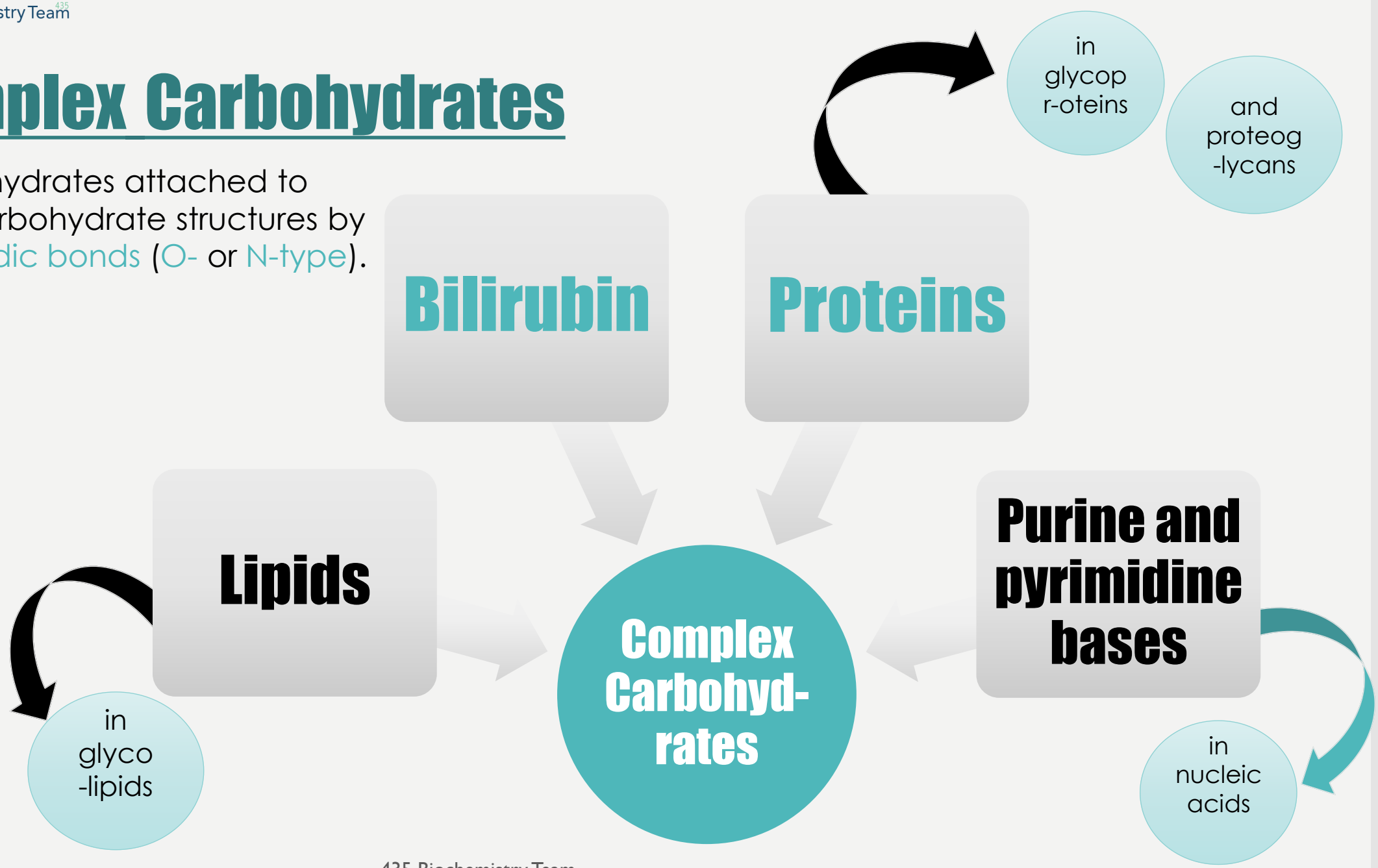
EXAMPLES:

- monosaccharides.
- Lactose.
- Maltose.

Sucrose is non-reducing, Why?
Sucrose is the combination of cyclic structures of Glucose and Fructose and therefore does not have a free aldehyde or ketone group.

Complex Carbohydrates

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



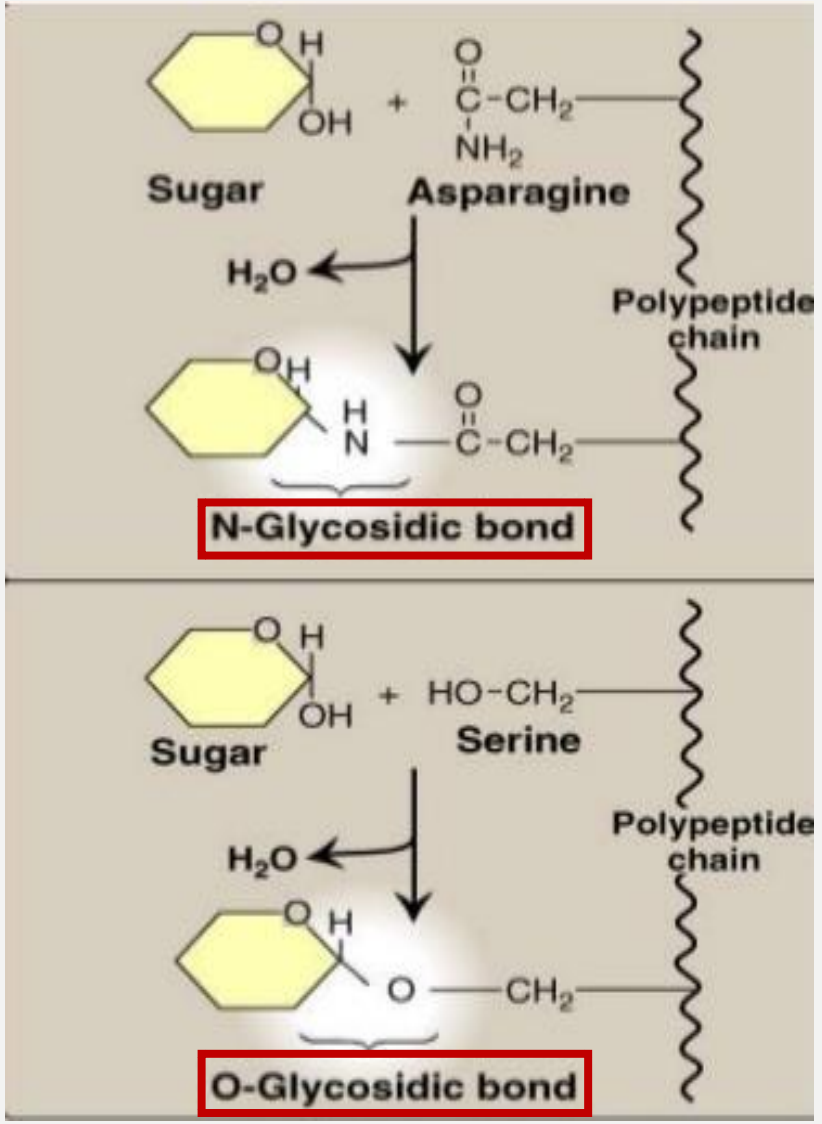
Glycosidic Bonds

-It is a type of covalent bond that joins a carbohydrate (sugar) molecule to another group (ممكن يكون شوقر وممكن يكون شي ثاني مثل الكوميليكس شوقرز).

- N-Glycosidic bond
- O-Glycosidic bond

If the group on noncarbohydrated molecule to which sugar attaches is

- NH_2
- OH



NOTE:

- All sugar-sugar glycosidic bond is: O-Glycosidic bond>

Glycosaminoglycans (GAGs)

* are large complexes of negatively charged heteropolysaccharide chains
  - Result of negatively:
    they "slip" past each other and this produces the "slippery" consistency of mucous secretions and synovial fluid
* are linear polymers of repeating disaccharide units
  - [acidic sugar-amino sugar]n
    - The amino sugar (usually sulfated) is either
      D-glucosamine or D-galactosamine
    - The acidic sugar is either
      D-glucuronic acid or L-iduronic acid
* are strongly negatively-charged: carboxyl groups of acidic sugars and
  Sulfate groups
* GAGs are associated with a small amount of protein forming → proteoglycans
* GAGs bind with a large amounts of water → producing the gel-like matrix that forms the extracellular matrix

mucopolysaccharides

mucopolysaccharides

-the original naming of these compounds

- The viscous, lubricating properties of mucous secretions also result from GAGs

GAGs' solution:

When it compressed: → the water is "squeezed out", then it will be (smaller volume)

When the compression is released: → the GAGs spring back to their original, them it will be (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

Members of GAGs: (examples)

- Chondroitin sulfates: Most abundant GAG
- Keratan sulfates: Most heterogeneous GAGs
- Hyaluronic acid: Compared to other GAGs, it is unsulfated and not covalently attached to protein
- Heparin: Unlike other GAGs that are extracellular, heparin is intracellular and serves as an anticoagulant

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Summary

Carbohydrates: hydrates of carbon $(CH_2O)n$

* Abundant. * Energy storage. * Structural component of cell membrane
* The bond is O-glycosidic bond.

Carbohydrates metabolism disorder

- Diabetes mellitus
- Galactosemia
- Glycogen storage disease
- Lactose intolerance

classification

monosaccharide

It is simple sugars
It is further classified based on:
* No. of carbon atoms
Triose, tetrose, pentose..etc
* Functional sugar group
Aldoses, ketoses

disaccharide

Joining of two monosaccharides
* Maltose(α -1,4) = glucose + glucose
* Sucrose (α -1,2) = glucose + fructose
* Lactose (β -1,4) = glucose + galactose

oligosaccharide

Joining of (3-10) monosaccharides

polysaccharide

>10 monosaccharides
* Homopolysaccharides
- Branched:
glycogen, starch
- Unbranched:
cellulose
* Heteropolysaccharides
glycosaminoglycans (GAGs)

Monosaccharide Isomerism

Aldo-ketose	glucose and fructose ribose and ribulose glyceraldehyde and dihydroxyacetone
Epimers	glucose and galactose C4 glucose and mannose C2
D- and L- forms	(Mirror image) D-glucose L-glucose * based on the position of –OH grp on the asymmetric C farthest from the carbonyl C
α- and β- anomers	α-D-glucose β-D-glucose α- OH تحت / β- OH فوق

Reducing sugar: Free O on the anomeric C of a sugar

All monosaccharides

Maltose

Lactose

* Sucrose is non-reducing sugar

Complex carbohydrate:

Carbohydrate and non-carbohydrate attached by glycosidic bond (O- or N-)

* Purine and pyrimidine bases.
* Bilirubin. * Glycolipids.
* Glycoproteins and proteoglycans.

Glycosaminoglycans (GAGs):

Negatively charged heteropolysaccharides (acidic sugar –amino sugar)n

* Slippery consistency of mucous secretion and synovial fluids.
* Like a sponge..This property contributes to the resilience of synovial fluids and the vitreous humor of the eye.

Examples:

1- chondroitin sulfates 2- keratan sulfates

3- hyaluronic acid 4- heparin

Videos

- ✓ Carbohydrates
- ✓ Monosaccharaides
- ✓ Video of disaccharide + polysaccharide
- ✓ Isomers
- ✓ Carbohydrates - cyclic
- ✓ structures and anomers

Boys Team:

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- محمد الصهيل .
- خالد النعيم .
- إبراهيم الشايع.
- محمد الدغيثر.

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- بدور جليدان.
- علا النهير.
- أفنان المالكي.
- أمجاد الدهيش.
- دلال الحزيمي.
- فاطمه الدين.
- جواهر الحربي.
- جوهره المالكي.
- خوله العريني.
- لجين السواط.
- منيال باوزير.
- نوره القحطاني.
- رزان السبتي .
- رهف العباد .
- وضحى العتيبي.
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