Carbohydrates

Biochemistry team

Objectives

To understand:

- 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

Carbohydrates

1) **The most abundant organic molecules in nature**
The empiric formula is $(CH_2O)n$, **"hydrates of carbon"**
2) provide important part of energy in diet
3) Act as the storage form of energy in the body
4) are structural component of

1~ Hydrates of carbon = water + carbon (H2O-C)n

2~ Carbohydrates main function : (Provide + Store) Energy

OVERVIEW CONT'D

Many diseases associated with disorders of carbohydrate metabolism including:

Diabetes mellitus → Means : not started from the childhood.

Galactosemia → Means : high, so it's high concentration of galactose in the blood.

Glycogen storage diseases

Lactose intolerance

CLASSIFICATION

carbohydrates

- **Polysaccharides** (more than 10)
- **Oligosaccharides** (3-10 molecules)
- **Disaccharides** (2 molecules)
- **Monosaccharides** (1 molecule)

Could be either :

Homo : the same monosaccharide repeated

Or :

Hetro : formed from different monosaccharaides

e.g. :

homodisaccharide (2 glucose monomers bonded together)

Hetrodisaccharide (1 glucose molecule bonded to 1 ferctose)

Monosaccharides

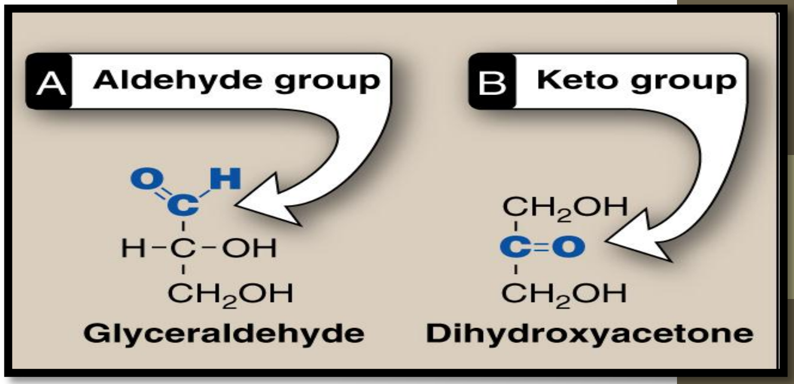
Further classified based on:
تصنف تبعاً لـ :

1. 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

2. Functional sugar group:

- **Aldehyde group - aldoses**
- **Keto group - ketoses**



Monosaccharides

Functional sugar group →

According to :

No. of carbon atoms ↓

	Aldose	Ketose
Triose	Glyceraldehyde	Dihydroxyacetone
Pentose	Ribose	Ribulose
Hexose	Glucose	Fructose

Isomerism

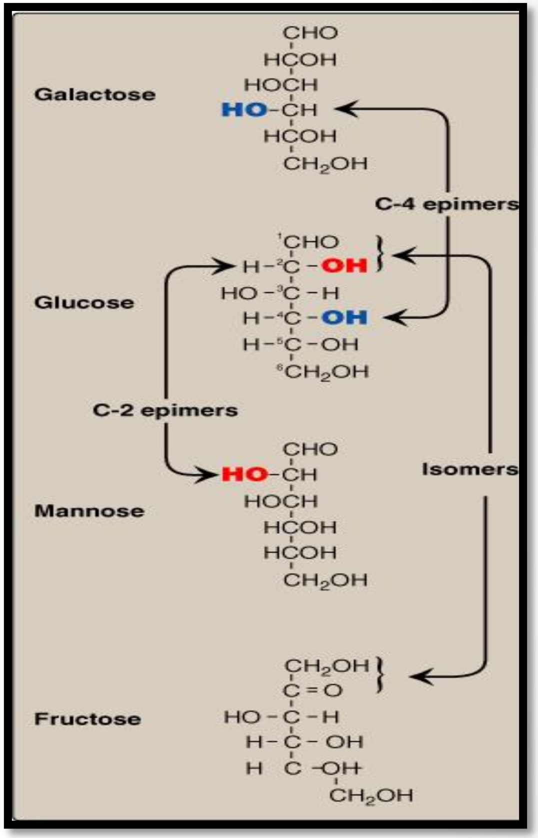
Isomers are molecules having the same chemical formula but different structure formula.

D- and L-Forms

Aldo-keto

α- and β-anomers

Epimers



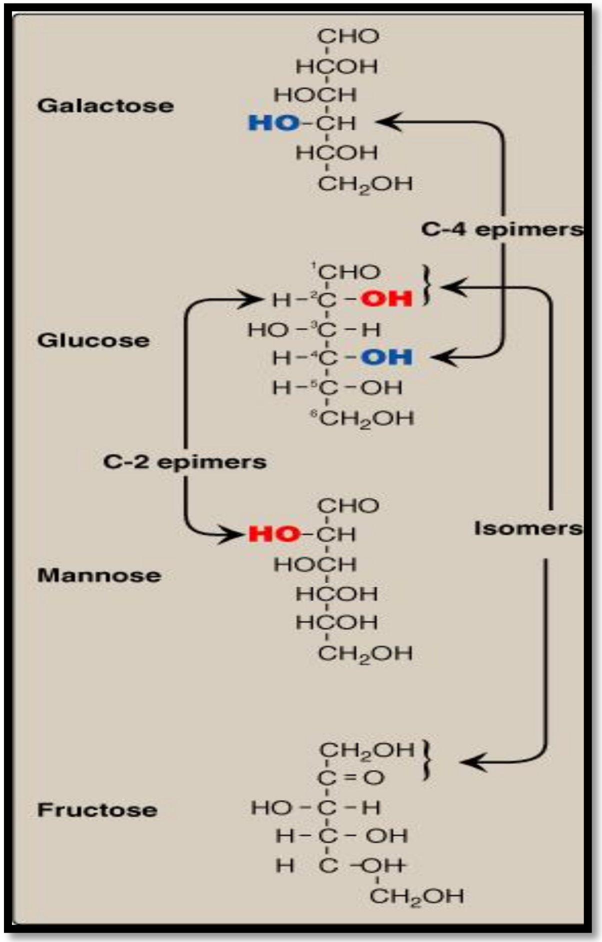
1) Aldo-Keto Isomers

Example:

Glucose (Aldose)

and

Fructose (Ketose)



Two sugar molecules that have the same chemical formula, but different types of functional groups (one has the keto group and the other has the aldehyde group).

2) Epimers

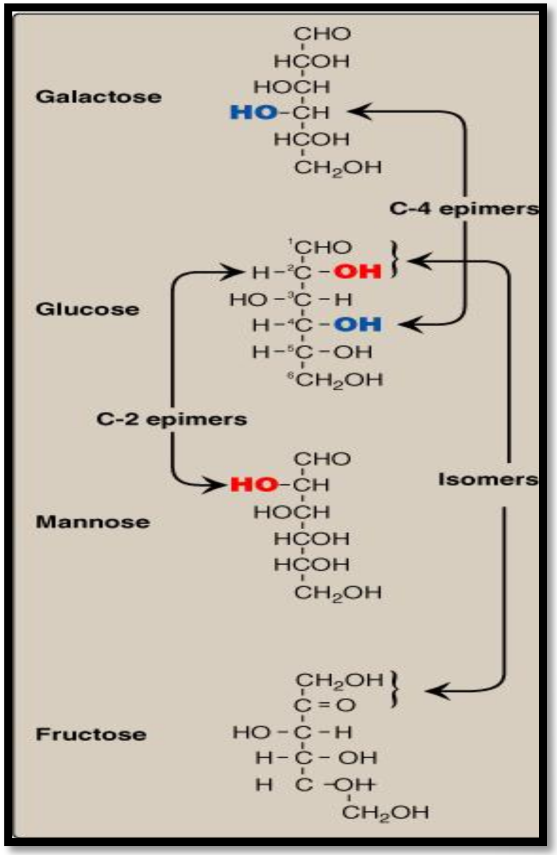
CHO dimers that differ in configuration around only one specific carbon atom

-Glucose and galactose, C4

-Glucose and Mannose, C2

* Galactose and mannose are not epimers.

Another dif :
The same structure molecules except for OH & H arrangement around one carbon.
How to find Epimers?
1) Number the carbon atoms starting from the nearer end of the functional group (usually carbonyl group).
2) Detect the carbons of the same number but on two different molecules, and see if they have different configurations (must be one carbon only).



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 the **asymmetric carbon farthest from the carbonyl carbon**

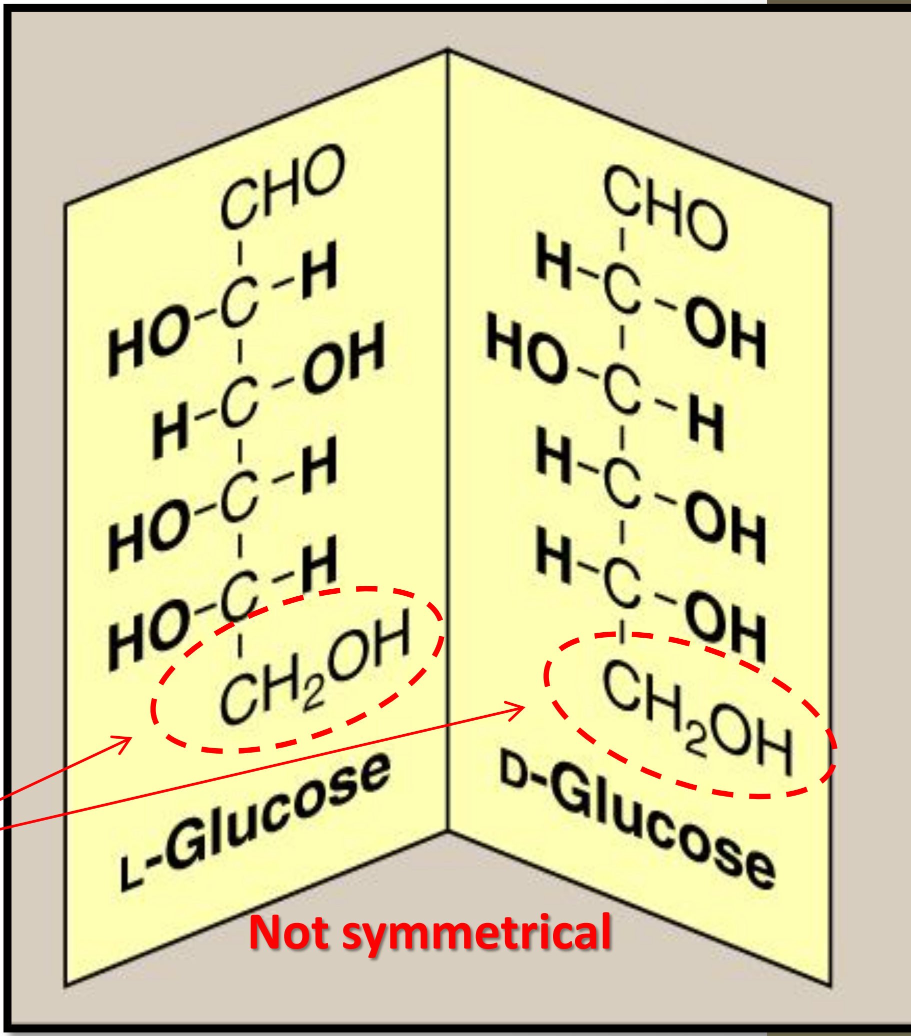
*Majority of sugars in humans are **D-sugars**

How to find Enantiomers?

1) Look for asymmetrical carbon (must be attached to 4 different groups)

2) If you find more than 1 asymmetrical carbon, choose the furthest one from the carbonyl group.

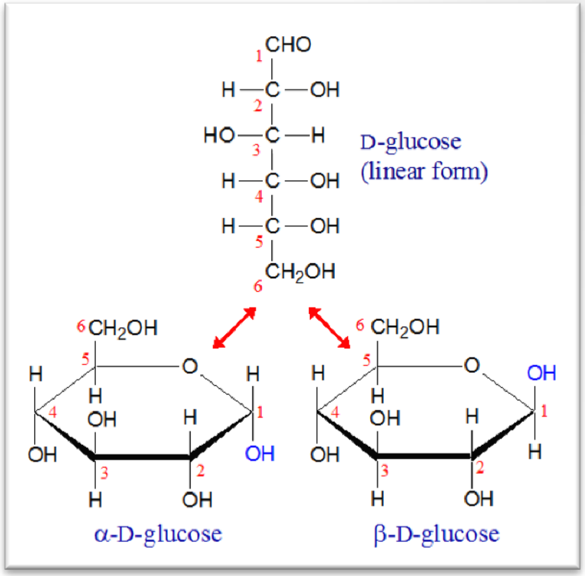
3) If the –OH group is on the right (D) and if it is on the left (L).



4) α- and β-Forms

Cyclization of Monosaccharides

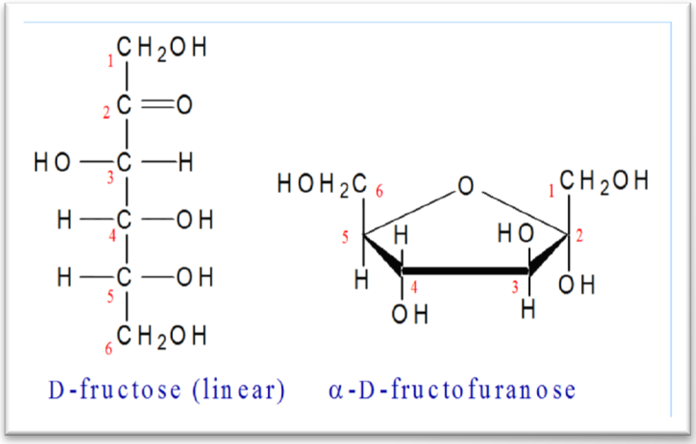
- Monosaccharaides with 5 or more carbon are predominantly found in the ring form.



- The aldehyde & ketone group reacts with the –OH group on the same sugar.

Either α or β, depending on the OH attached to the main carboxylic group.

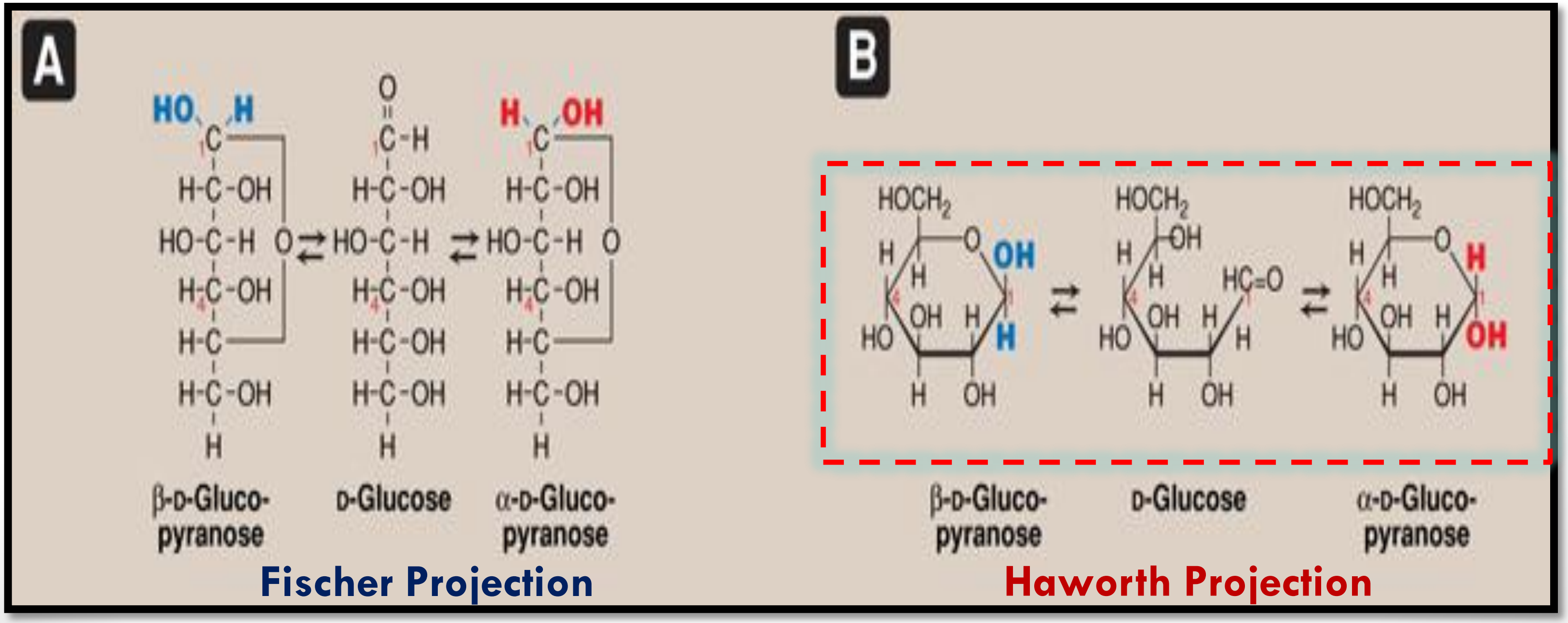
- Cyclization creates an anomeric carbon (former carbonyl carbon) generating α & β configuration.



Mutarotation

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

كل من حلقتي α و β أثناء الذوبان قابلة للتتفكك و التحول إلى سلسلة مفتوحة و العكس صحيح (أي أن العملية رجعية ، فالسلسلة المفتوحة قد تعود مكونة إحدى الحلقتين إما α أو β) .



Disaccharides

two <u>mono</u>saccharaides joined by a bond called **O-glycosidic** bond

Examples of Disaccharides:

1) Maltose
(α-1, 4)
glucose + glucose

Carbon number **one** of the first molecule (type **α**) with carbon number **4** of the second molecule (No α OR β because it's not C1) , joined by an oxygen atom

2) Sucrose
(α-1,2)
glucose + fructose

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

Glycosidic Bonds

Sugar units form glycosidic bonds between other sugar units or other molecules.

Type:

1) **N-Glycosidic:** the 2 molecules are likned by a Nitrogen atom.

2) **O-Glycosidic:** the 2 molecules are joined by Oxygen atom.

Polysaccharides

Heteropolysaccharides

long chain of the different sugar units
e.g. glycosaminoglycans or
(GAGs)

Homopolysaccharides

long chain of the SAME sugar units
e.g. 1000s of glucose molecules.

UNBRANCHED

Cellulose

↓

β-glycosidic polymer

BRANCHED

Glycogen & starch

↓

α-glycosidic polymer

Complex carbohydrates

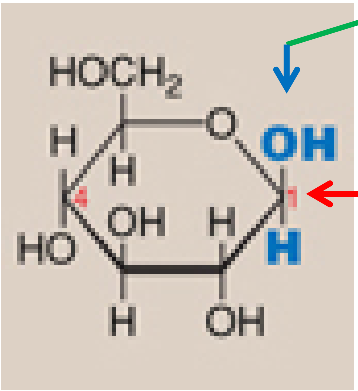
Carbohydrates + non-carbohydrate joined by glycosidic bonds (O- or N-type)

Found in

- **Lipids** → **in glycolipids**
- **Proteins**
  - **glycoproteins**: proteins are MORE than carbohydrates
  - **proteoglycans**: proteins are LESS than carbohydrates
- **Bilirubin**
- **Purine & pyrimidine bases** → **in nucleic acids**

Purine & Pyrimidine are the nitrogen bases: A, C, T and G

Reducing sugar



If the Oxygen on the anomeric carbon of a sugar was free (not attached to any other molecules) the sugar can act as a **reducing agent**.

Examples of reducing sugars

- All Monosaccharaides
- Maltose
- Lactose

Why isn't **Sucrose** a reducing sugar?

Sucrose consists of glucose + fructose. These two monomers are attached to each other by the oxygen atom (the one that should be free).

The importance of reducing sugar

Reducing sugars reduce **chromogenic** agents to give a colored precipitate

↓

like Benedict's reagent or Fehling's solution

Urine is tested for the presence of reducing sugars using these colorimetric tests

Glycosaminoglycans (GAGs)

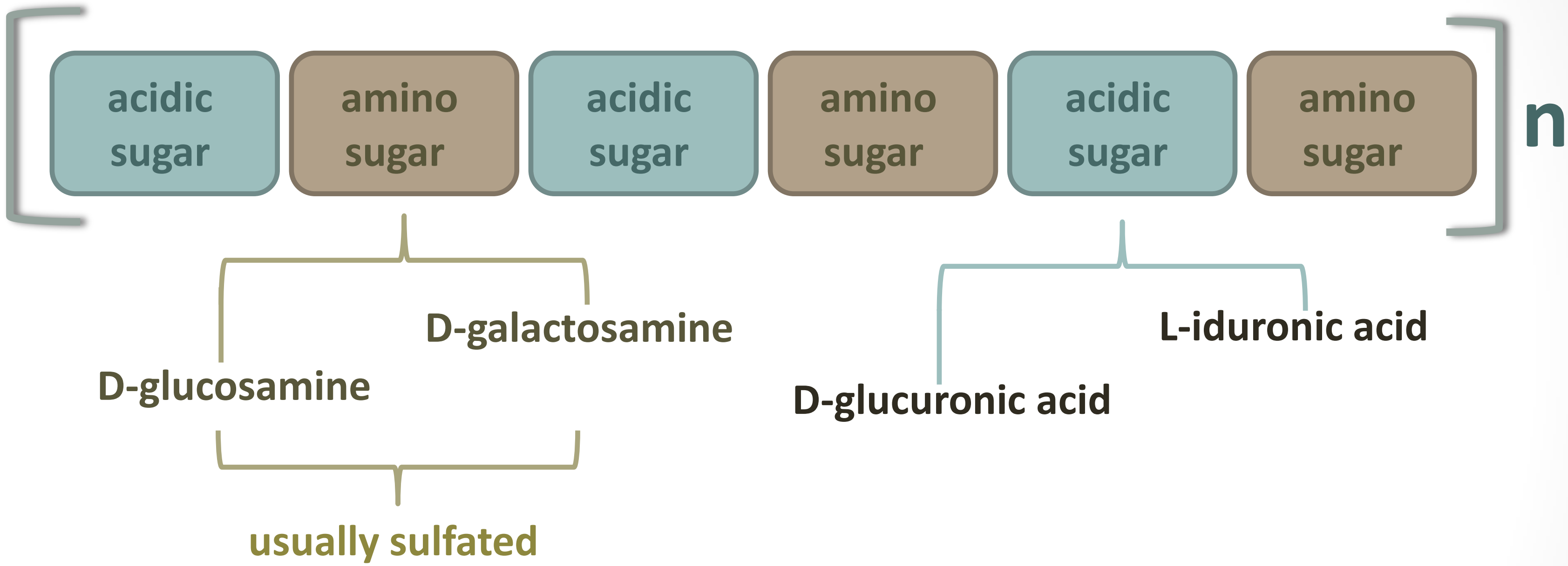
As previously seen, GAGs are a kind of (Heteropolysaccharides)

GAGs characteristics:

- **negatively** charged chains.
- are associated with a small amount of protein.
  - → They form **proteoglycans**, which consist of over 95% carbohydrates.
- bind with large amounts of water.
  - → producing the gel-like matrix that forms body's ground substance.
- the original naming of these compounds was mucopolysaccharides
  - → Because they result in the viscous, lubricating properties of mucous secretions.

GAGs structure

GAGs are linear polymers of **repeating disaccharide** units



So now we can say that GAGs are strongly negatively-charged because of:

- carboxyl groups of acidic sugars
- Sulfate 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 of their negative charges

This property contributes to the **resilience of synovial fluid and the vitreous humor of the eye**

جزيئات هذا المركب ذات الشحنة السالبة أكثر نفوراً من بعضها البعض، مما يكسب المركب صفة سائلة أقرب للمخاطية ، و حجم أكبر نتيجة تباعد (تنافر) الجزيئات. عند تعرض المركب الذائب في الماء لضغط عال ، يتخلص من جزيئات الماء المتداخلة بين جزيئاته، هذا الضغط يُجبر جزيئات المركب من الاقتراب من بعضها رغما عن تشابه شحنتها، و عند زوال هذا الضغط يعود المركب لحالته الطبيعية نتيجة التنافر الحاصل بين الجزيئات.

Members of GAGs

Examples of GAGs are:

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

that means that they are the most varied.

GONGRATS!!!

You are officially done with the carbohydrates lecture!
You have learned a lot of new information and gained a not-bad knowledge :p
Please scroll back to the objectives and make sure you covered them all

Whey are you still reading this?
Go have a snack or something