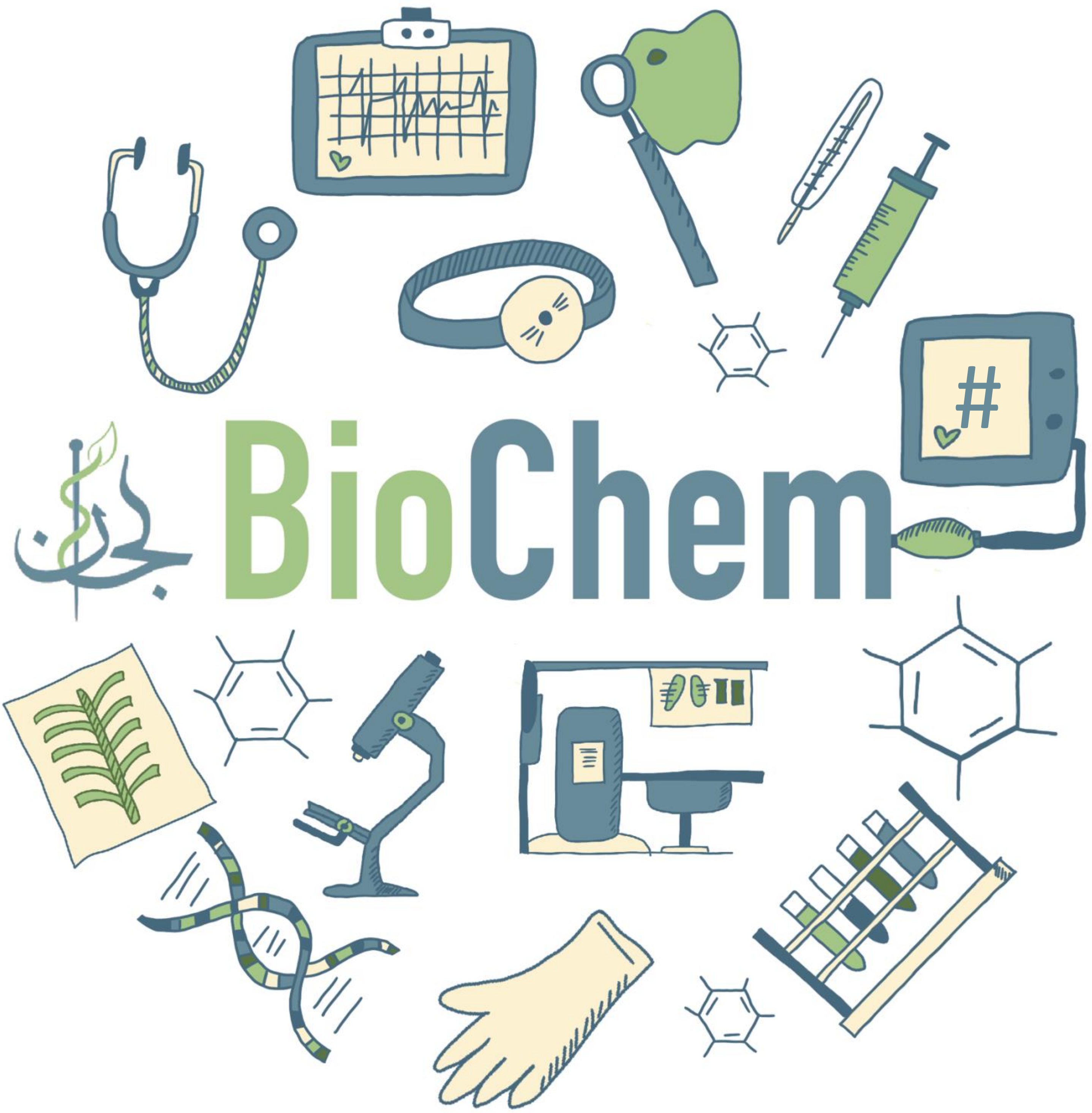


Writer: Ja’far Zaben, Mohammad Darkhabani

Science: Marah Alzoubi

Grammar: Noor Owaimer

Doctor: Dr. Mamoun Ahram

polysaccharides

What are polysaccharides? polysaccharides are polymers made of many (hundreds to thousands) residues of sugar molecules.

Some polysaccharides have repeated (identical) residues and are known as **Homo Polysaccharides**

if they contain different residues, we call them **Hetero Polysaccharides.**

Features of polysaccharides:

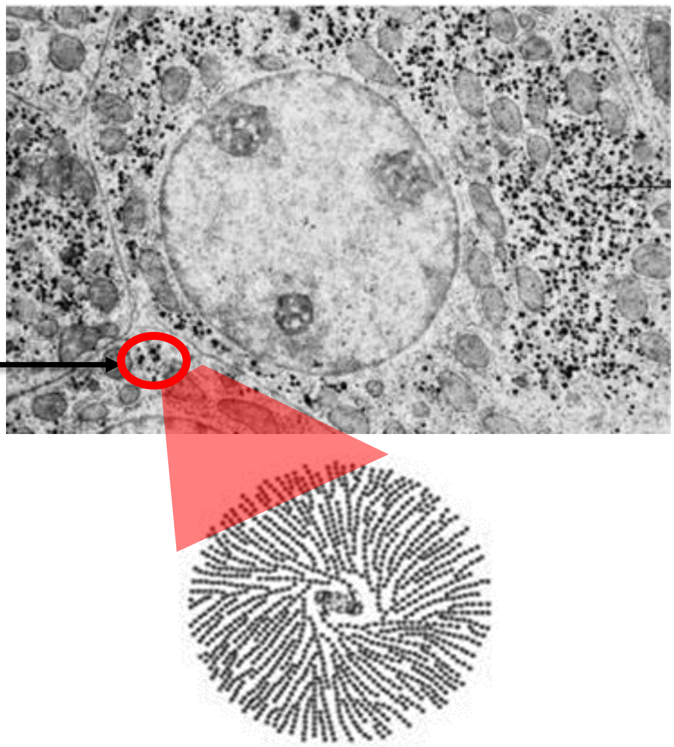
- **Monosaccharides:** residues that make up the polysaccharides.
- **Length** of polysaccharides.
- **Branching:** straight or branched molecule and how extensive (multiple branching) the molecule is.
- We can also look at the function -**purpose-** of the polysaccharides and it is divided into two types:
    1. **Storage:** used for production of energy **(glycogen, starch, dextran).**
    2. **Structural:** make up tough structures such as **(cellulose, pectin, chitin).**

Glycogen:

Is a storage polysaccharide in **animals** and in **humans** as well.
The main storage organ is the **liver**.

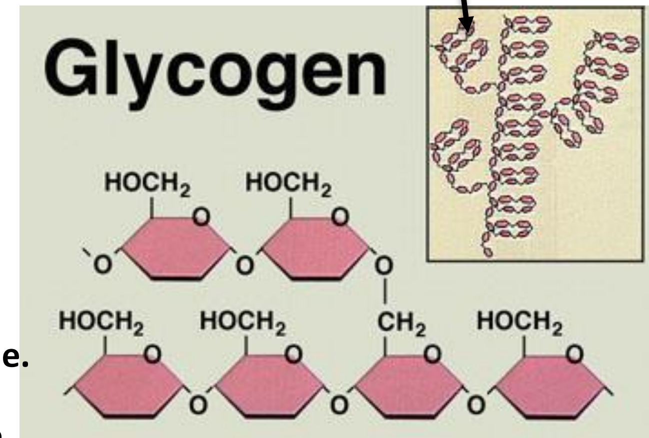
This image is an electronmicroscopic image of a liver cell containing all these black dots which are the glycogen molecules themselves.

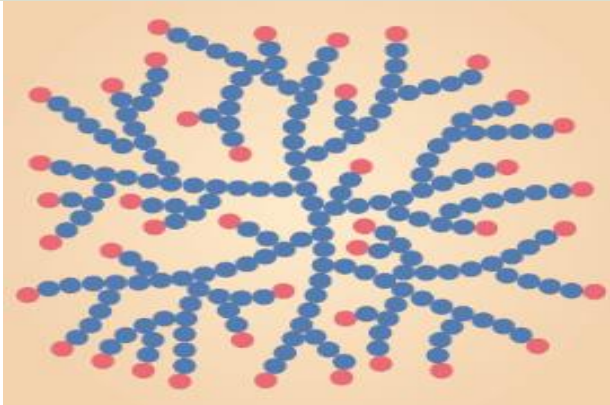
Each black dot (a glycogen molecule) looks like this (zoomed in) and contains a lot of glucose residues.



Black Dot

This is a glycogen molecule and it looks like this

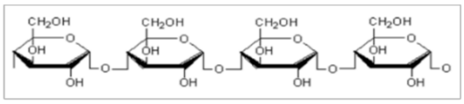




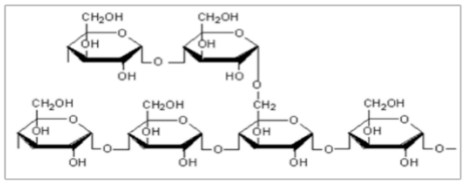
- The building block of the glycogen is glucose residues, so it's a **homopolysaccharide.**
- It is a highly branched molecule as seen.
- The connection (bond) between adjacent residues is α (1-4) Glycosidic bond while the connection between residues that are above each other is an α(1-6) glycosidic bond, this is a branching point between carbon no.1 & carbon no.6

Note: The α (1-6) glycosidic bond only occurs at the branching point.

<u>Starch</u>:

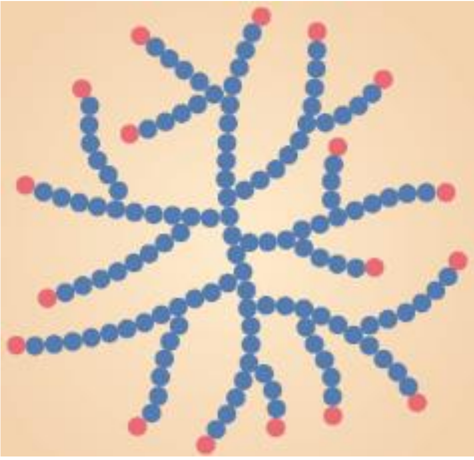


Amylose Structure



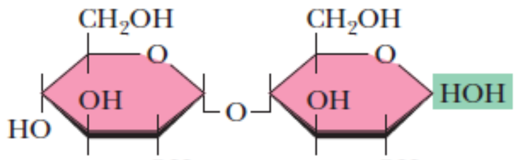
Amylopection Structure

- The storage molecule in **plants** is starch.
- Starch is made of **glucose** monomers (like glycogen), so, it's also a **homopolysaccharide**.
- It exists in two forms: -
  1. <u>**amylose**</u> (10-20%) → mainly a straight molecule (not branched) having α (1-4) glycosidic bond.
  2. <u>**amylopectin**</u> (80-90% "majority") → it is branched but less extensive than glycogen, it has a bonding pattern similar to glycogen (α (1-4) glycosidic linkage), its branching point is also between anomeric carbon 1 & 6 α (1-6) glycosidic bond.



This is an illustration of how starch (**amylopectin** to be exact) looks like.

When **amylopectin** or **amylose** are degraded (broken down) they are degraded into simpler molecules including the disaccharide **maltose** (which is made of two glucose monomers).



Maltose (glucose-α-1,4-glucose)

Glycogen VS. Amylopectin:

- Both are made of the same monomer and both are branched.
- Both are storage molecules meaning that both are mainly used as energy sources.
- Glycogen exists in animals while amylopectin in plants.
- Glycogen is more highly branched.
  -Branch points occur about every 10 residues in glycogen, and about every 25 residues in amylopectin.
- Why is branching important?
  -It makes it more water-soluble and does not crystallize: -
  ✓ Amylopectin which exists in plants (given that plant cells have a lot of water), so there is no need for extensive branching like glycogen, which exists in animals (whose cells don't have a lot of water) and has extensive branching to compensate for the low amounts of water and to be more water soluble.

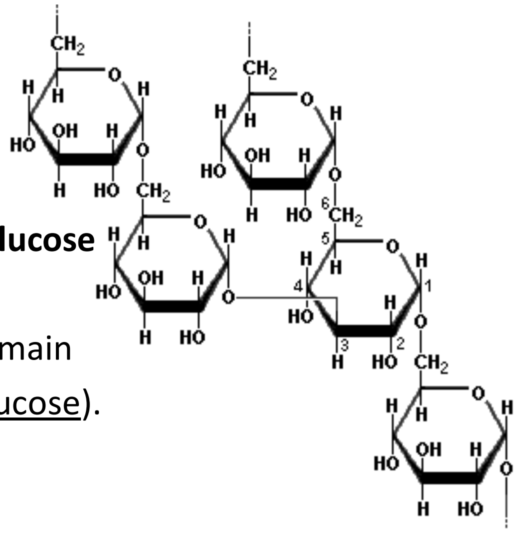
Rule:
More branched
=more water soluble

-Easy access to glucose residues.

> **Rule:**
> More branched = easier access of enzymes to glucose

✓ Glycogen is more branched to make it easier for enzymes to access glucose residues, more glucose residues can be released from glycogen to generate more energy (which is needed in animal cells more).

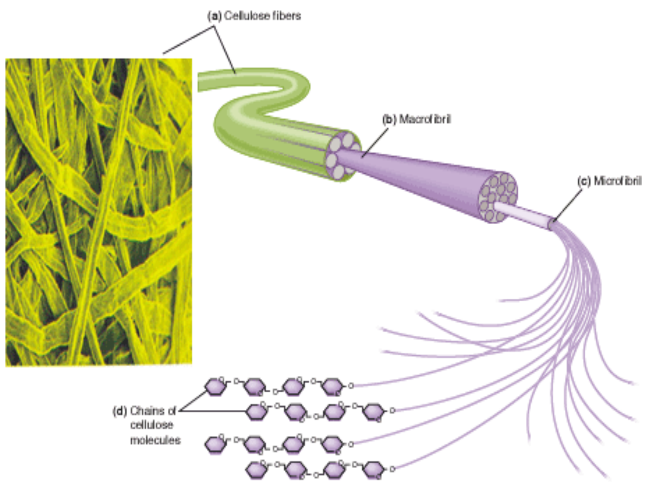
Dextran:



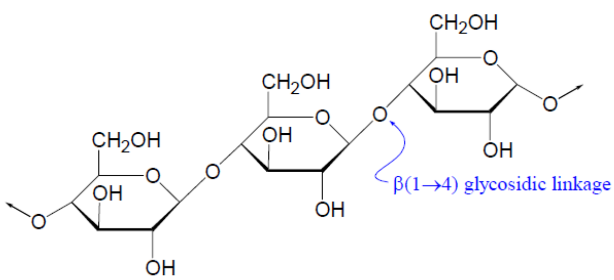
- A **storage** polysaccharide
- Found in **yeast** and **bacteria**.
- It is a **homopolysaccharide** mainly made of **glucose**
- Also, a highly branched molecule.
- It differs in having the glycosidic bond of the main chain as α (1-6) glycosidic bond (<u>α-(1-6)-D-glucose</u>).
- It has a variety of branching points: -
  -Branches: 1-2, 1-3, or 1-4

Cellulose:

- Cellulose is a structural polysaccharide.
- Cellulose is also a homopolysaccharide, mainly made of glucose residues.
- The difference between cellulose and glycogen or starch is that in cellulose the glycosidic linkage is in the beta configuration [β (1-4) glycosidic linkage] which is more rigid and cannot bend thus cannot be branched forming a straight chain (unlike alpha α).



> **<u>Further explanation:</u>** looking back at amylopectin and the glycogen molecules, they are highly branched and that is because their alpha subunit can be bent.

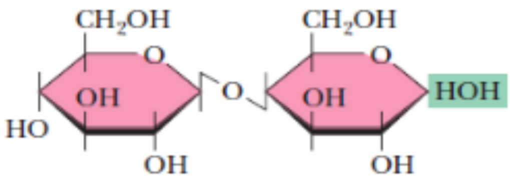


- So to compensate (تعويض) for no branching in cellulose, the chains that line up on top of each other form extensive **hydrogen bonding**, creating a really strong structure and adding to the strength of the already rigid beta linkages, making this structural molecule strong enough to create the stem of plants.

Hint from us:

Alpha→ can be bent → branching can occur

Beta → no bending → no branching



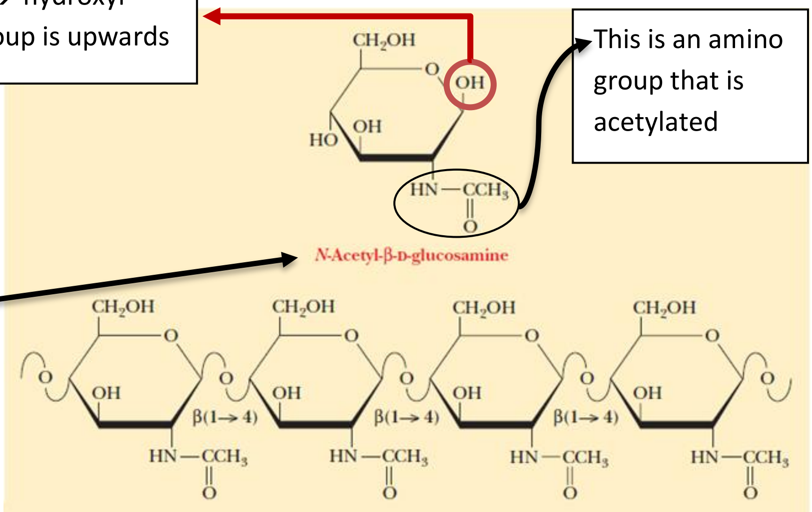
Cellobiose (glucose-β-1,4-glucose)

TAKE A BREAK & COME BACK STRONGER LIKE CELLULOSE

Chitin:

β → hydroxyl group is upwards

This is an amino group that is acetylated

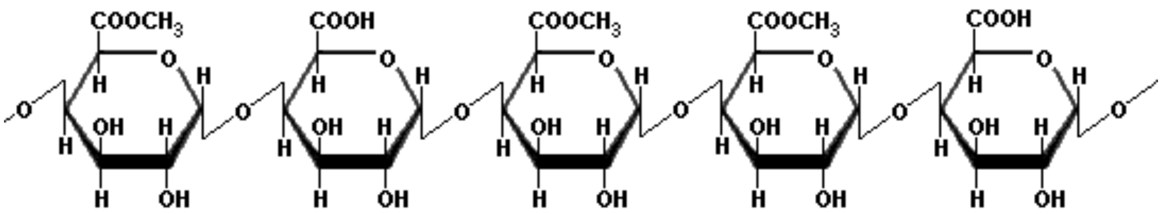


- Chitin is a structural polysaccharide in the exoskeleton of insects
- It is a homopolysaccharide that is made of [N-Acetyl-β-D-glucosamine] as its monomer.
- The glycosidic bond is also in the beta configuration [β (1-4)], so it cannot be bent and there is no branching, thus it's a straight molecule).
- The presence of acetyl group makes the h-bonding more extensive between the molecules creating an overall rigid molecule for the exoskeleton of the insects (like cockroaches that create خشخة sound when stepped on).

Remember we talked about this molecule in the first part of the carbs lectures.

Pectin:

- It is another polysaccharide that exists in plant cells along with cellulose.
- Its is made up of galacturonic acid.



-About this figure: Notice the hydroxyl group of carbon no.2 which is below the ring, carbon no.3 is above the ring, carbon no.4 is above the ring, thus this molecule is actually galactose and is modified, making it galacturonic acid.

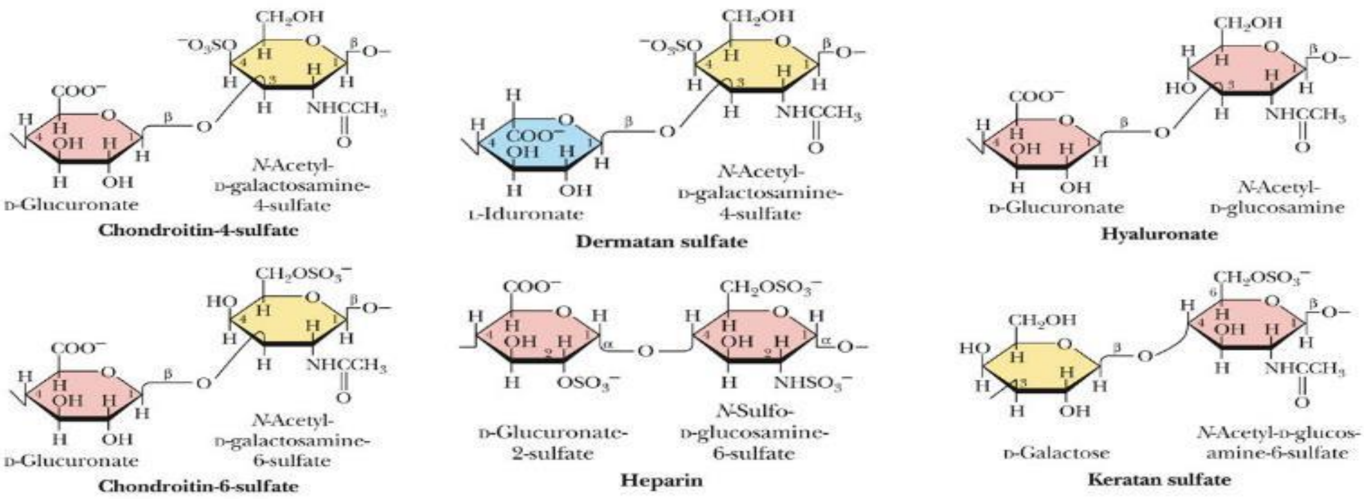
- The bonding is α (1-4) glycosidic bond.
- Pectin can be used in the food industry.

Are polysaccharides reducing?

- Polysaccharide are not reducing sugars, even though there are some free anomeric carbons, but they are not enough to make the overall molecule a reducing sugar.
- A sample that contains only a few molecules of a large polysaccharide, each molecule with a single reducing end, might well produce a negative test because there are not enough reducing ends to detect.

Glycosaminoglycans (GAGs)

- Sometimes we can have modified monosaccharides, for example they can be modified into sugar acids, sugar alcohols, converted into amino groups or we can have the addition of a sulfate group.
- These modified monosaccharides (sugar that contain amino group) are main components of large molecules known as **Glycosaminoglycans** which are made of repetitive disaccharides (made from the modified monosaccharides we talked about above).



- All of these GAGs are negatively charged, and they exist extracellularly in the connective tissue.

-The table below shows some examples of GAGs, no need to memorize the structures or components of them, just know the names and their characteristics mentioned above.

- For example, Heparin is an anti-coagulant (prevents coagulation -clotting- of blood), it has an amino group and these two disaccharides are repeated over and over again.

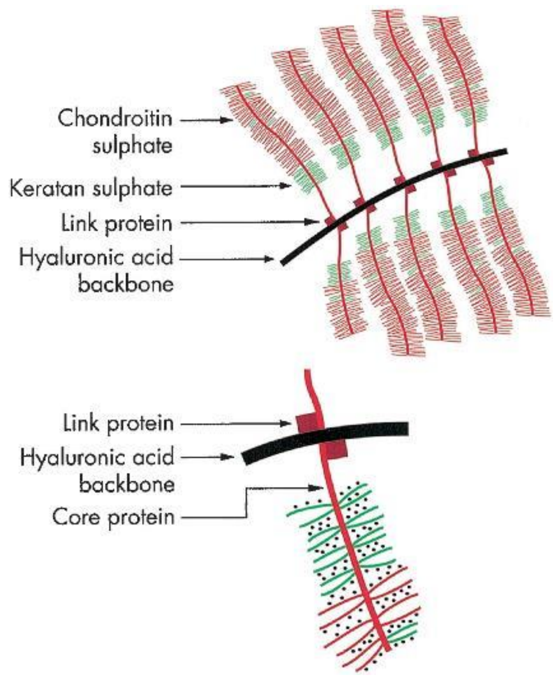
Localization and function of GAG:

GAG	Localization	Comments
Hyaluronate	synovial fluid, **vitreous humor, ECM of loose connective tissue**	**the lubricant fluid , shock absorbing** As many as 25,000 disaccharide units
Chondroitin sulfate	**cartilage**, bone, heart valves	**most abundant GAG**
Heparan sulfate	basement membranes, components of cell surfaces	contains higher acetylated glucosamine than heparin
Heparin	component of intracellular granules of mast cells lining the arteries of the lungs, liver and skin	**A natural anticoagulant**
Dermatan sulfate	skin, blood vessels, heart valves	
Keratan sulfate	cornea, bone, cartilage aggregated with chondroitin sulfates	Only one not having uronic acid

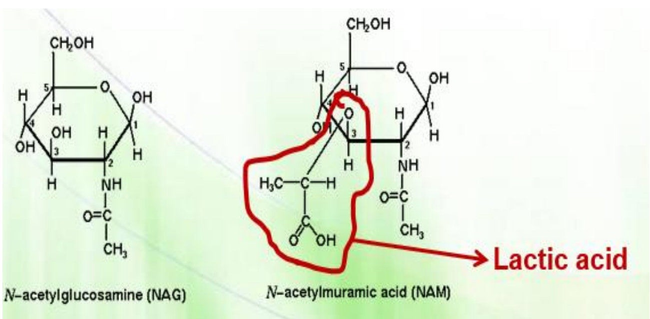
Notes on the table:

- Chondroitin sulfate is a highly negatively charged molecule, it is present in cartilage (ex: knee) in order to reduce friction between bones, let's say you jumped in the air, when landing this cartilage present in your knee will be compressed, after a while, the leg relaxes, how? The negative charges present in chondroitin sulfate would repel each other causing the cartilage to inflate back up into its original shape.

Proteoglycans:

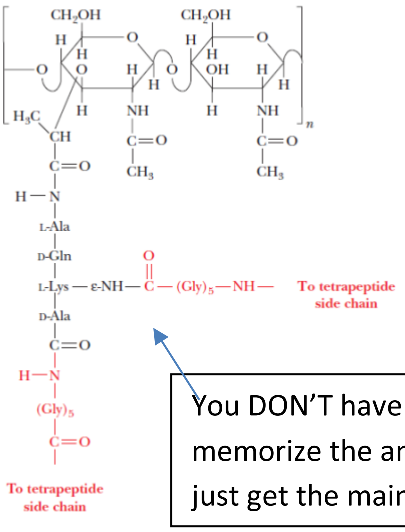


- They are majorly composed of GAGs associated with some proteins or peptides.
- They can function as lubricants.
- They are structural components in connective tissue (They are present in the extracellular matrix).
- Mediate adhesion of cells to the extracellular matrix, so they can be used by cells to transmit signals (تذكرو الهستو يا قطاعات☺)
- Bind factors that stimulate cell proliferation → they are a storage place for hormones, ligands, and other small molecules which can be released slowly when needed in cells.
  - ➢ An example of peptidoglycans (proteoglycans) are molecules that exist in the **bacterial cell wall** which is mainly made of proteoglycans, and the sugary part is made of 2 main sugars:

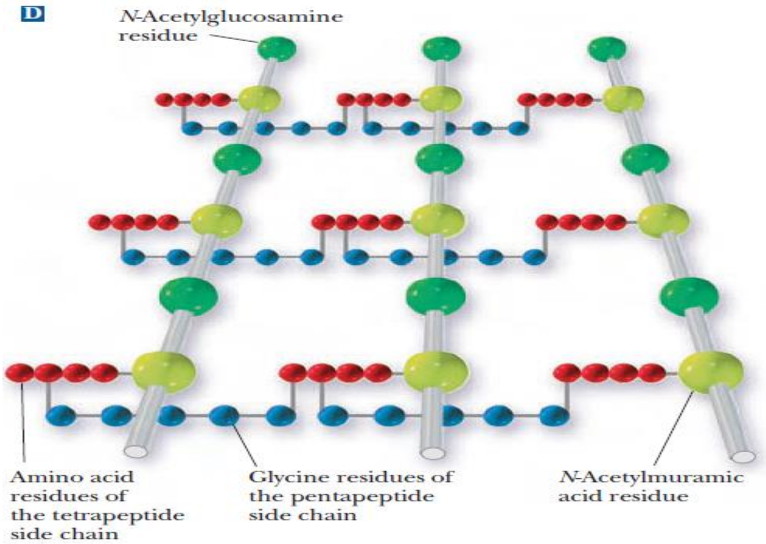


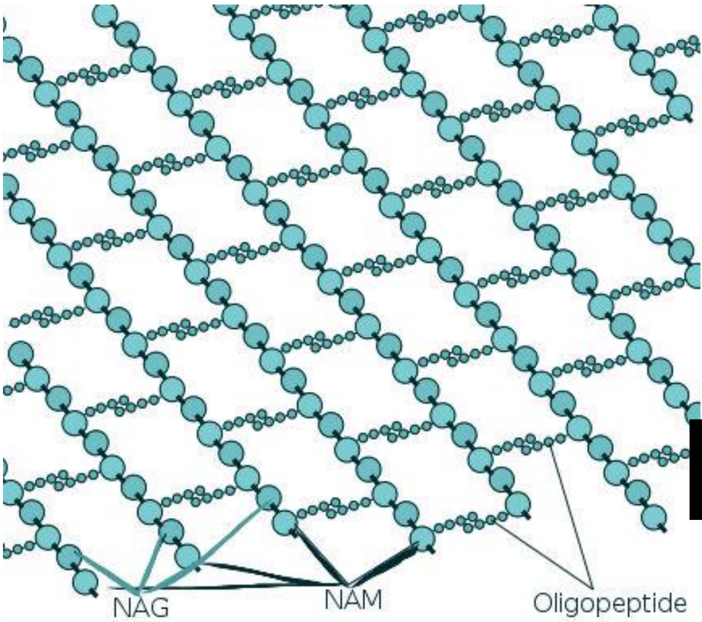
-It is made of these two sugars (disaccharide) as repeating units.

- ➢ NAG is simple, it has an amino group associated with an acetyl group.
- ➢ NAM is more complex, having the amino group associated with an acetyl group and it also contains lactic acid.



You DON'T have to memorize the amino acids, just get the main idea.

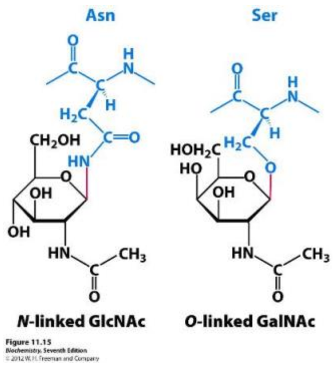




So they are lined as such and connecting them are some amino acids that can connect to each other making a tough cell wall

Glycoproteins:

- Majority of structure is protein with some sugars (opposite of proteoglycans)
- These sugars can be attached to amino acids of proteins via two linkages: -
  - \- The *N*-glycosidic linkage is through the amide group of asparagine (Asn, N).
  - The *O*-glycosidic linkage is through the hydroxyl group of serine (Ser, S), threonine (Thr, T) or hydroxylysine (hLys) --> (which is a modified amino acid).

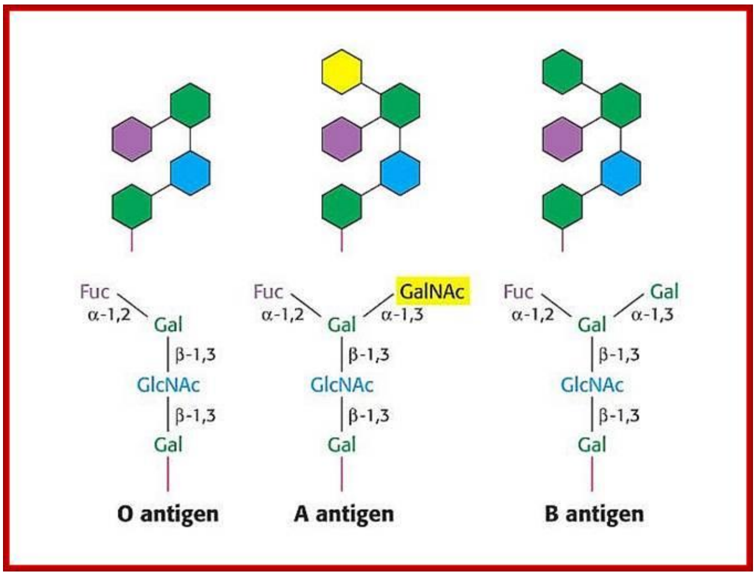


These sugars that decorate proteins are important for a number of reasons:

- Protein folding → to get protein into its final structure.
- Protein targeting → like we learned in cytology, ex: lysosomal proteins must have mannose associated with them to be targeted to lysosomes.
- Prolonging protein half-life → ex: glycosylated protein = 20 days not glycosylated protein = 30 minutes only!
- Cell-cell communication → remember that these proteins exist on the cell surface.
- Signaling → we can also have the sugary part inside cells (**inositol**).
- Soluble proteins as well as membrane proteins → sugars make the protein more soluble.

Blood typing and glycoproteins:

- Modification of proteins in the cell surface of RBCs is important for blood typing.
- We have 4 different blood types (A, B, O, AB).
- The difference between these blood types is actually the sugars that are associated with the proteins of these RBCs (N-acetyl galactosamine for A, Galactose for B, none for O).

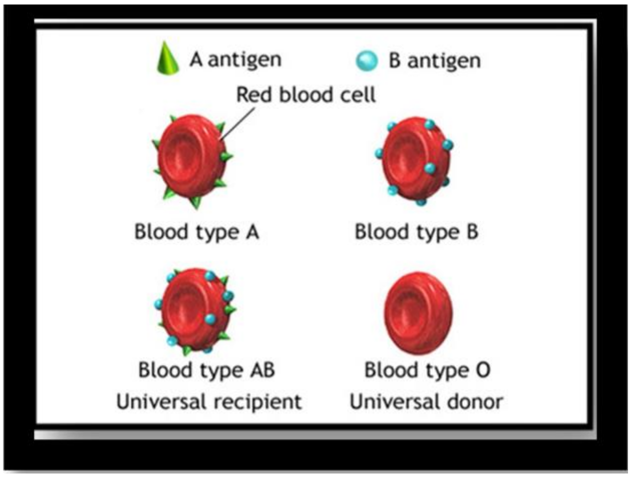


Since O-antigen doesn't have any additional sugars, a person with O blood type can donate blood to anyone.

While someone with an A or B antigen cannot donate to other blood types due to them having a specific sugar.

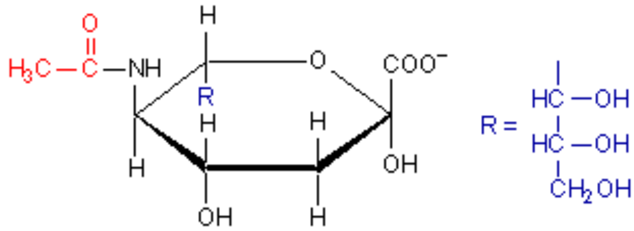
Finally, someone with AB type cannot donate to anyone, but can be a recipient of all.

(No addition) (Both A & B have additional sugar)



Sialic Acid (*N*-acetylneuraminate):

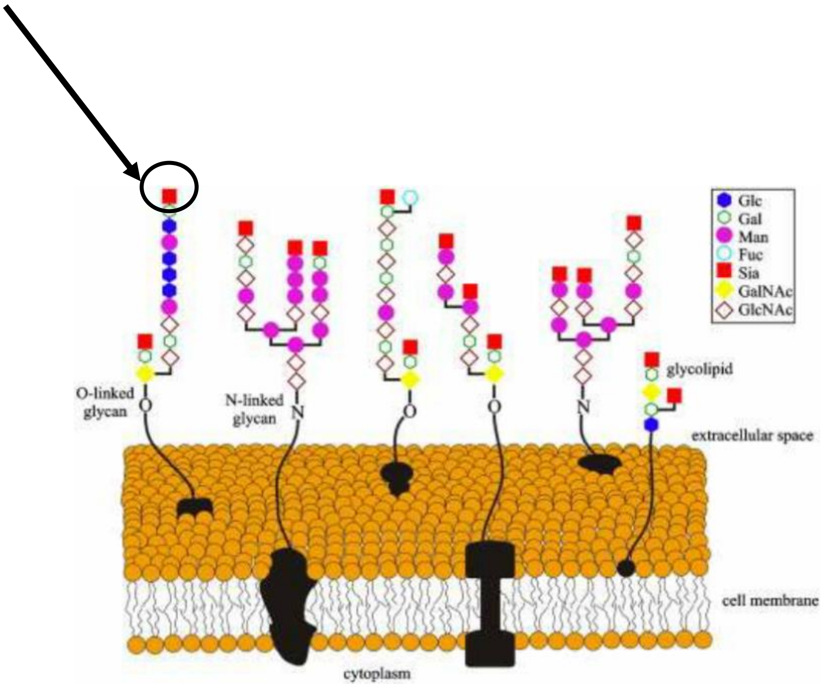
- It is an amino sugar having an acetyl group associated to it, while it is itself a modified sugar acid, also, its precursor happens to be the amino sugar: neuraminic acid.
- It is a negatively charged sugar acid that exists as the final sugar in the sequence of sugars attached to proteins or lipids.



N-acetylneuraminate (sialic acid)

Don't memorize the structure

- Location: a terminal residue of oligosaccharide chains of glycoproteins and glycolipids.



SHORT QUIZ

Amylopectin and cellulose are compared.

1) Both these polysaccharides

A) have extended linear shapes.
b) function as structural components.
c) contain α-glycosidic bonds.
d) contain 1,4-glycosidic bonds

2) Which property is shared by these polysaccharides?

a) Both are composed entirely of D-glucose.
b) Both are heteropolysaccharides.
c) Both contain negatively charged groups.
d) Both are branched structures.

3) Which product could be formed from the breakdown of these polysaccharides?

a) Cellulose could be broken down into sucrose.
b) Cellulose could be broken down into chitin.
c) Amylopectin could be broken down into maltose.
d) Amylopectin could be broken down into glucosamine.

4) Which characteristic distinguishes amylopectin and glycogen?

a) They have different types of glycosidic bonds.
b) They have different degrees of branching.
c) Only amylopectin can form hydrogen bonds.
d) Only glycogen has a coiled shape

Amylose and cellulose are compared.

5) Which property is shared by these two polysaccharides

a) Both function mainly in energy storage.
b) Both have coiled shapes.
c) Both are homopolysaccharides.
d) Both have the same molecular weight

6) Which property differs between these two polysaccharides?

a) the monosaccharide components
b) the orientation of the glycosidic bonds
c) the degree of branching
d) the carbons linked by the glycosidic bonds

7) When comparing amylose to glycogen,

a) only amylose contains hydrogen bonds.
b) only glycogen contains a reducing end.
c) only amylose contains 1,4 glycosidic bonds.
d) only glycogen contains 1,6 glycosidic bonds.

8) If you have a polysaccharide that contains in its structure 30 monosaccharide, how many water molecule/s you should add to make a complete hydrolysis of this molecule?

a) 1
b) 15
c) 30
d) 29

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
D	A	C	B	C	B	D	D

FIN