CYTOLOGY

Premed 2018 - JU

◉ Sheet ○ Slides

Number

2

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In the previous lecture we have considered the non-covalent interactions that are classified into:

- van der waals
- ionic interactions
- hydrophobic interactions
- hydrogen interactions

Hydrogen interactions

- Hydrogen interactions are a special type of **ionic interactions**
- They are of the strongest non-covalent interactions

Remember: (hydrogen is not a highly electronegative atom i.e. it does not have a high ability to attract the electrons. Therefore, mostly it would have a partial positive charge when it is bonded to a high electronegative atom such like oxygen, nitrogen, etc).

So, how does the hydrogen bond form ?

As the name implies, hydrogen is involved for sure

NOW, if hydrogen is bonded to such high electronegative atoms in a molecule, it gets a partial positive charge and if there is a highly electronegative atom in ANOTHER molecule that's charged with a partial negative charge, then the partial negative charge(in the 2nd molecule is attracted to the partial positive charge on hydrogen in the 1st molecule) resulting in the hydrogen bond

--→ *And that's why it's considered a special type of ionic interactions(attraction of charges)*

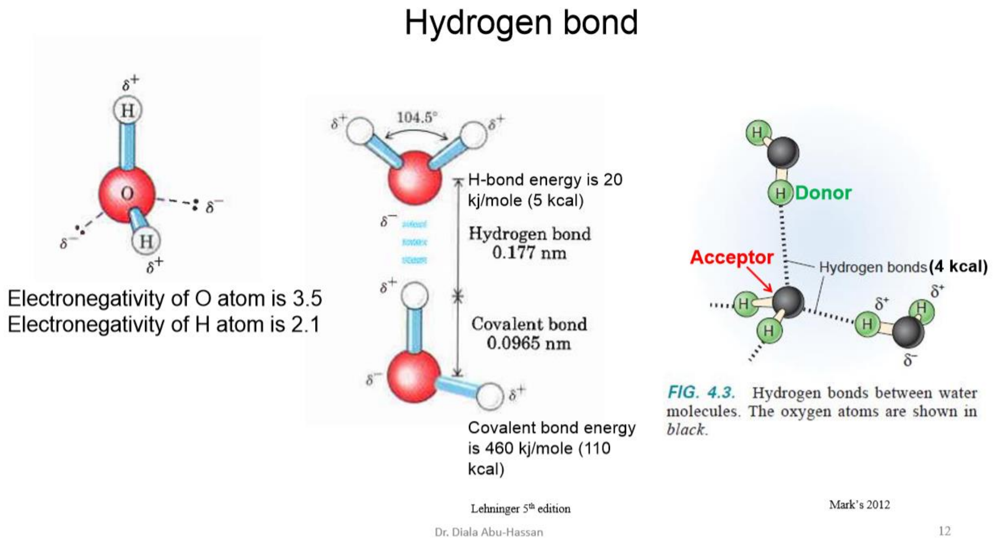
The hydrogen that contributes to the formation of hydrogen bond =hydrogen bond **DONOR**.

The other atom =hydrogen bond **ACCEPTOR** .

So, to form a hydrogen bond you need a donor and an acceptor

i.e. two accepters without a donor cannot form a hydrogen bond.

➡as shown in the figure:



In the water molecule,

- There are two donors – two hydrogen atoms connected to a highly electronegative atom-
- One acceptor-oxygen-
  (so it has a high ability to form a large number hydrogen bonds)
- The length of the hydrogen bond is 0.177 nm .
- The length of the covalent bond(OH) is 0.0965 nm .
  Which is shorter?
  -covalent .
  So, which is stronger?
  -covalent .

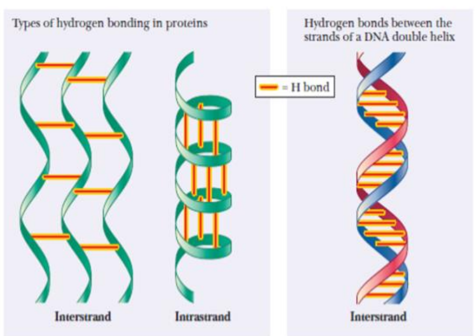
Shortest bond=strongest bond

/covalent bonds are stronger than non-covalent interactions generally/

Generally, What's the importance of non-covalent interactions ,particularly hydrogen bonds?

1. *They hold the structure of very large molecules such as DNA and Proteins –they contribute to the final 3D shape of a protein-*

Noncovalent Interactions



Examples:

- ***collagen***

actually, it's the most abundant protein in the body, and is found in hair and skin. Also, it has more than one type as it is found in bones and many other tissues.

Its fibril form is composed of 3 helices winded around each other
-What holds these together? HYDROGEN BONDS.
*As a protein it has a structural role so its main function is to give **support** in bone..skin ,etc.*

- ***DNA molecule:***

The Double helix : two strands are held together by the base pairing between (C and G), (A and T), the base pairing is hydrogen bonds!
i.e. the whole strands are held together by the hydrogen bonds which leads to the final structural and functional shape of DNA .

- ***Water***

The hydrogen bond contributes to the Physical properties of water, such as:

- Adhesion
- Melting and boiling point :if you compare the structure of a water molecule to other molecules, relatively its high .
- Cohesion/Surface tension
- Expansion when frozen
- Its specific heat (or heat capacity) is higher than other liquids .

Remember: specific heat is the amount of energy needed to increase the temperature of 1 gram of water molecules(or substance) about
1 degree

-and this is important, as you move to a cold place for example, you don't have a large change in the temperature of your body due to the high specific heat of water inside it

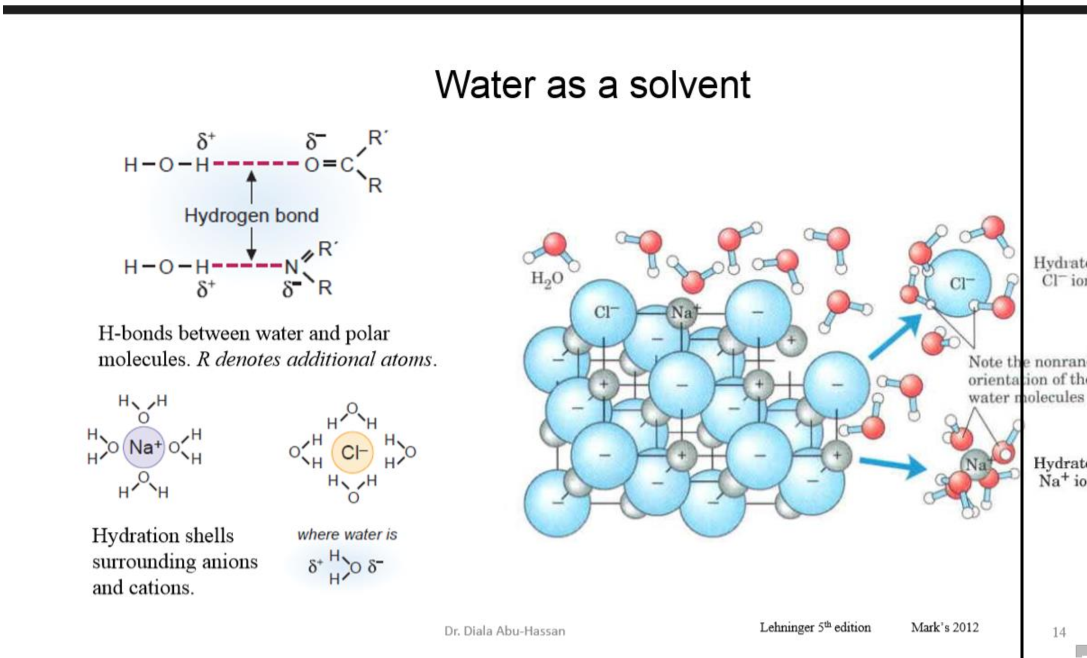
- It acts as a solvent for many solutes .

Solving : physical process in which molecules of solute enter between the inter molecular spaces of the water molecules and bind with them via the hydrogen bonds.

Eg: solving salt (NACL) in water

As shown in the figure aside:

Water molecules start to interfere ions (Na+ and Cl-) until they reach to the point that each ion is surrounded with water molecules forming **THE HYDRATION SHELL** which is composed of the ion(in the middle) surrounded by water molecules .

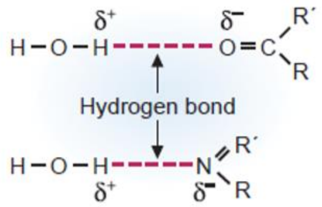


- NOTE that the water molecules direct themselves in a clever way, how?

Look at Na+, water directs its oxygen atom(which has a partial negative charge) towards it, whereas it directs the positive charge of the hydrogen towards the negative charge of Cl-.

Notes:

- **Not** only ionic compounds are dissolved in water, for example RCOR(ketone) as shown in the fig aside .



H-bonds between water and polar molecules. *R denotes additional atoms.*

  - Is it a hydrogen bond donor, acceptor or both?

It's an acceptor.

  - Does It form a hydrogen bond with molecules of the same group (ketones)??

No, as said, an acceptor with an acceptor does not form a hydrogen bond.

That's why the boiling and melting point of acetone –in this example-is very low!

Because there are not many hydrophobic interactions to be broken

- Just to keep in mind how its boiling point is very low. Remember for example that Acetone is used in removing the nail paint and it volatilize very fast ^^

-For solvation to be formed it needs to form a hydrogen bonds with water, where hydrogens of water as donor and the molecule (ketone) as an acceptor.

Well, does **any** hydrogen atom form a hydrogen bond, what do you think?

Actually not all hydrogen atoms form hydrogen bonds. For example, hydrogen attached to carbon, doesn't have a partial positive charge so it can't form a hydrogen bond ☺

Properties of Noncovalent Interactions

1. Reversible

2. Relatively weak. 1-30 kj/mole vs. 350 kj/mole in C–C bond

3. Molecules interact and bind specifically.

What are the general properties of all non-covalent interactions ?

Noncovalent Interactions

-Noncovalent forces significantly contribute to the structure, stability, and functional competence of macromolecules in living cells.

- Can be either attractive or repulsive.

-Involve interactions both within the biomolecule and between it and the water of the surrounding environment.

between it and the water of the surrounding environment.

<u>*Let's discuss more:*</u>

1) Reversible : they form and break all the time because molecules are moving.

(Remember, the main factors that affect the formation of non covalent interactions are **DISTANCE AND OREINTATION** .

i.e. if they move away from each other or are in an improper orientation , bond is broken .

2) They are relatively weak: specifically if we compare them to covalent bonds .

3) They interact and bind specifically: we have certain conditions, +Ve charge with –Ve charge are attracted, -ve and -ve repulse each other, hydrogen bond has specific conditions to form and so on .

- ***Non-covalent interactions rely on the number of bonds rather than the strength of each single bond***, for them to contribute to the structure of DNA and proteins, we need a large number of bonds .

Covalent vs Noncovalent bonds

Table 2.3
Some Bond Energies

	Type of Bond	Energy (kJ mol^{-1})	Energy (kcal mol^{-1})
Covalent Bonds (Strong)	O—H	460	110
	H—H	416	100
	C—H	413	105
Noncovalent Bonds (Weaker)	Hydrogen bond	20	5
	Ion–dipole interaction	20	5
	Hydrophobic interaction	4–12	1–3
	Van der Waals interactions	4	1

*Note that two units of energy are used throughout this text. The kilocalorie (kcal) is a commonly used unit in the biochemical literature. The kilojoule (kJ) is an SI unit and will come into wider use as time goes on. The kcal is the same as the "Calorie" reported on food labels.

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Campbell 6th edition

If you compare -in terms of strength- covalent and non-covalent bonds you will see that covalent bonds are stronger for sure ^^

Carbohydrates

What are carbohydrates ? ❖

Poly hydroxy aldehydes or ketones naturally occurring compounds -organic molecule.

- *Poly:* many .

-*Hydroxy* : contains hydroxyl groups .

-*Aldehydes* : contains carbonyl group (COOH) at carbon number one .

-*Ketones* : contains carbonyl group (COOH) at carbon- at least- number two .

-*ose* : means this is a sugar .

-*Ketose* : ketone sugar .

-*Aldose* : aldehyde sugar .

*** How many carbon are present in the smallest aldehyde sugar or ketone sugar?**

Three

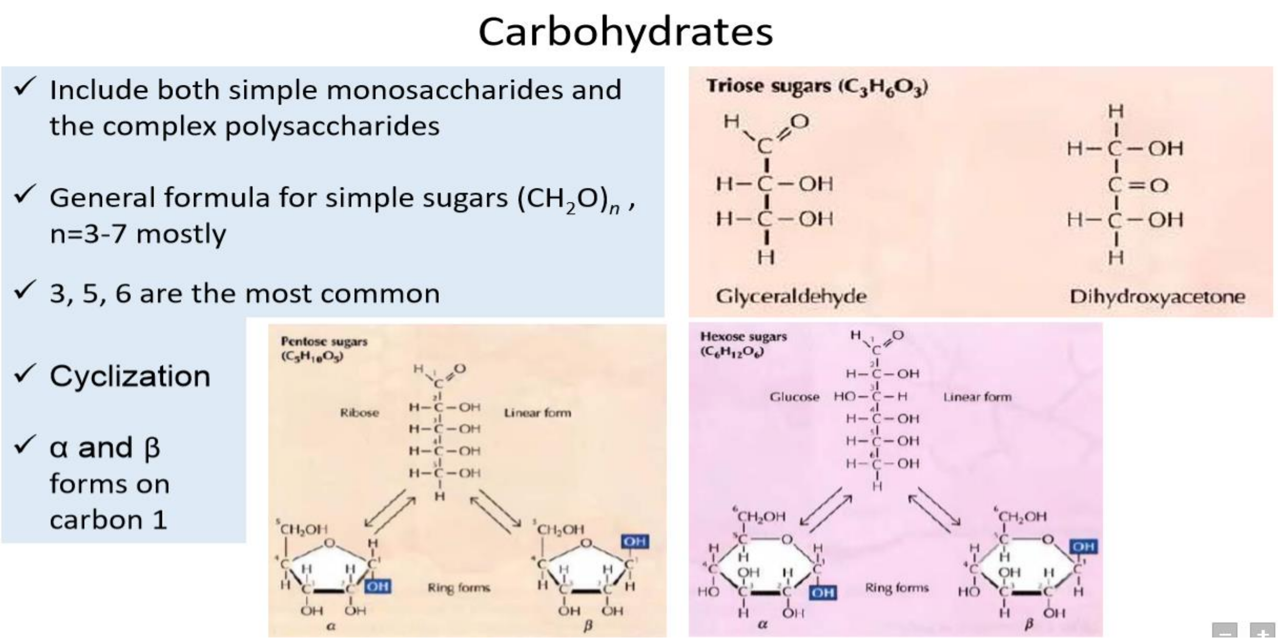
Ok, why

Let's think about an aldehyde with two carbons, one of them will have the carbonyl group and the 2nd will have the hydroxyl group .

The simplest ketose sugar is : dihydroxyacetone

But remember! Sugars must contain a carbonyl group and MORE than one hydroxyl group in its structure.

The simplest aldose sugar is : glyceraldehyde



as shown in the figure above:

Carbohydrates are classified according to their structure:

1) linear form .

2) cyclized form (Rings) .

Note: Ribose sugar contains 5 carbons (pentose)," pent" refers to 5 and "ose" to sugar, it is an aldose because of the presence f carbonyl group on carbon number 1

Mostly this sugar (pentose) interact to form rings(carbon number 1 with hydroxyl group of carbon 4 -before the last carbon- in aldehydes), if it is a ketose then carbon 2 with 4

note: Linear form is occasionally present

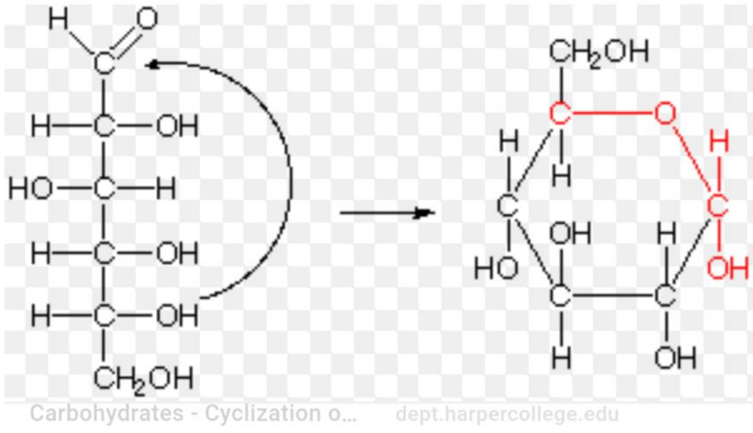
the OH groups which are in the linear form on the right side of carbons they will be downwards whereas the OH groups which are on the left side as in glucose on 3C will be upwards

Right-→ down the ring

Left -→ above the ring

Keep in mind that alpha or beta form depends on the anomeric carbon- C number 1

The smallest sugar that can form a ring has 4 carbons .



Where does Hydrogen of the OH group on the anomeric carbon come from ?

--→ because of this interaction we need to break one of its bonds (double bonds) on COOH , for the oxygen it needs another bond to be saturated so that It binds to a Hydrogen and this creates a hydroxyl group on carbon number one.

**Will this OH group be upward or downward ?*

it has the two orientations, it can be either upward (β) or downward (α) .

- each sugar molecule is present in all forms alpha , beta and **linear** and there is equilibrium between those form and it converts from one form to another .

Note: moving from (α) to (β) or vice versa we need to pass through the linear form .

look at the structures again, suppose that I give you 100% time and we want to divide it between alpha, beta and linear, how will you divide it ?

Actually linear is the least stable due to the functional groups it has
BETA is about 64%
ALPHA is about 36%
Why??
Beta is more stable, as it has its OH group is directed UPWARDS, and the one next to it is directed downwards, so I REDUCED the REPULSION between them (much more than alpha)

***most of the time beta sugars are more stable BUT you should pay attention to carbon number 4 or 3 – depending on its type.. aldehyde or ketone- and see the direction of the OH group on it, if it is downwards then beta sugars are more stable, if its upwards then alpha sugars are more stable*.**

DNA molecule has one form of sugar –which is beta deoxyribose-

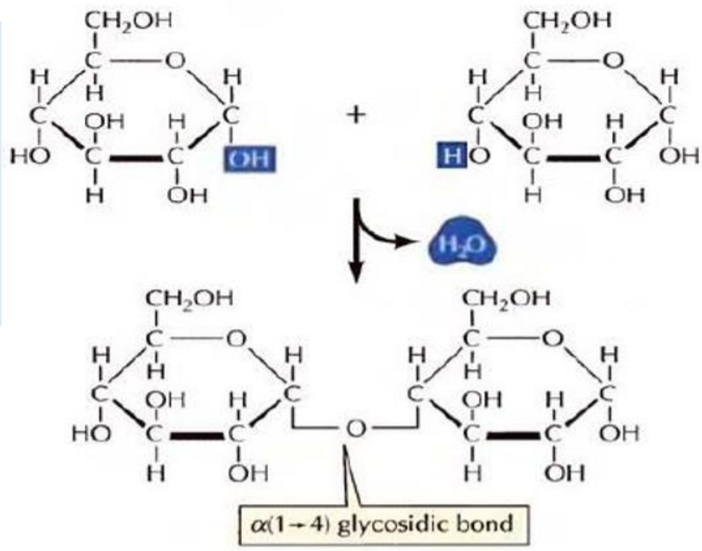
Here, it makes a difference
Whether you choose alpha or beta
Because DNA is a very large molecule
And the stereochemistry plays a role here.

On the other hand, if I have a glucose molecule and I want to metabolize it (extract energy), it doesn't matter whether its alpha or beta.

Disaccharides

✓ **Connecting monosaccharides:**

- The OH group on anomeric carbon of the 1st molecule is going to interact With OH group of the other carbon(usually not the anomeric one) .



Interaction happens between first molecule as a hemiacetal .
Hemiacetal: it's a molecule that has an (OH) group and (OR) group on the same carbon [look at the figure aside before the reaction occurs, the anomeric carbon -1st carbon]

- Interacting to alcohol (OH group of carbon 4 in the 2nd molecule)
- Hemiacetal + alcohol = acetal

Heme means half, hemiacetal because it has one (OR) group and after the reaction is finished it is an acetal as it has 2 (OR) groups ☺

✓ Dehydration reaction

✓ 2 residues=disaccharide

✓ A few residues=oligosaccharide

✓ Hundreds or thousands residues=polysaccharide

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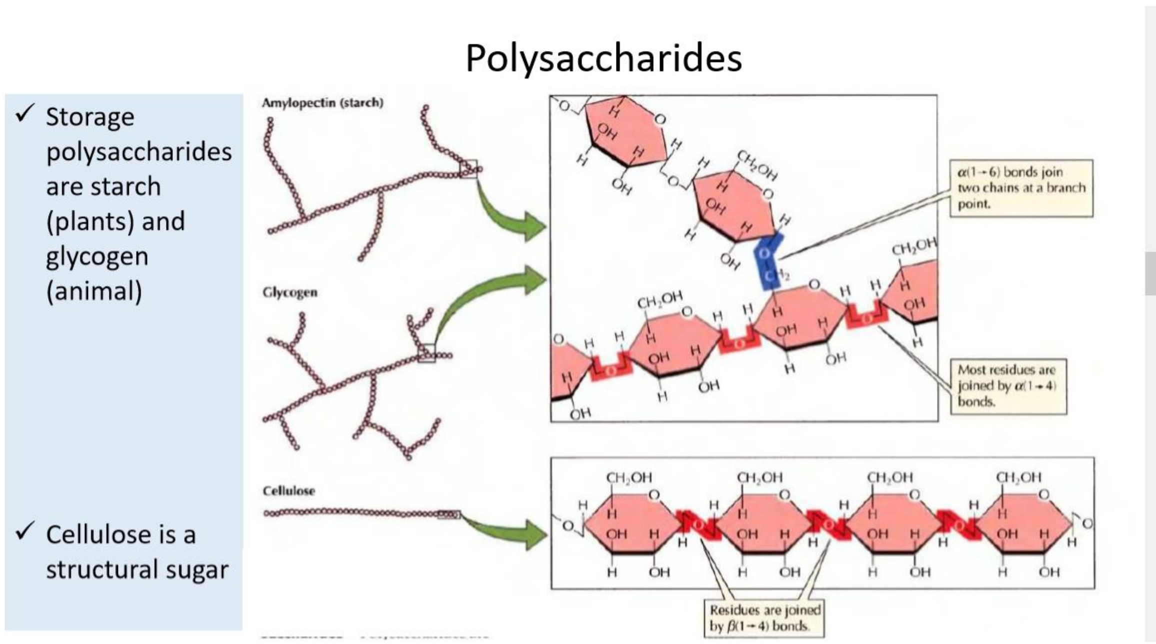
*Just in case you get confused about alpha and beta and which one is digested, think about it in this way, as I mentioned before if you want to metabolize glucose for example in order to get energy, it makes no difference whether its alpha or beta, the point is that the ENZYME which recognize α(1-4) glycosidic linkage does NOT recognize beta ones, and that's why cellulose is not digested in our bodies for example(due to the absence of the enzyme cellulase) .



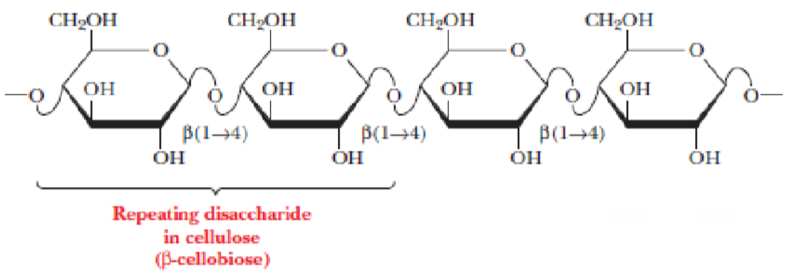
-Notice the shape of linkage in alpha(it looks like ٧) but in beta it looks like (N letter) .

Structural polysaccharides

Cellulose:

- Its made up of β glucose and connected with β(1-4) glycosidic linkage .
- Cellulose fibers are found in fruits, vegetables and trees .
- It is a structural polysaccharide .
- Linear, does not have branches
  (which makes the whole surface area open for hydrogen bonding-→ mechanical strength) .

Cellulose



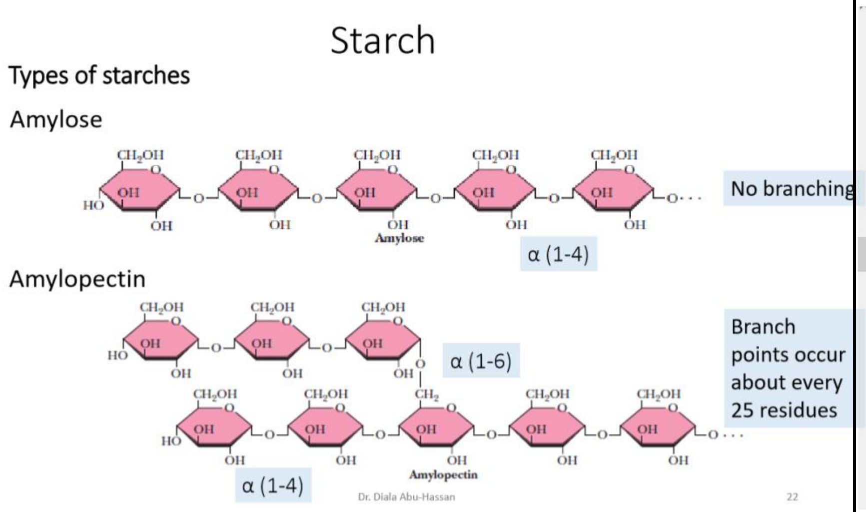
- Animals lack cellulases enzymes that hydrolyze cellulose to glucose.
- Cellulases are found in the bacteria that inhabit the digestive tracts of insects and grazing animals, such as cattle and horses.

Storage polysaccharides

1)Starch :

a) Amylopectin

- It's a component of starch(storage polysaccharide in plants).
- It can be digested as it has alpha one four linkage .
- Branched .
- Major.

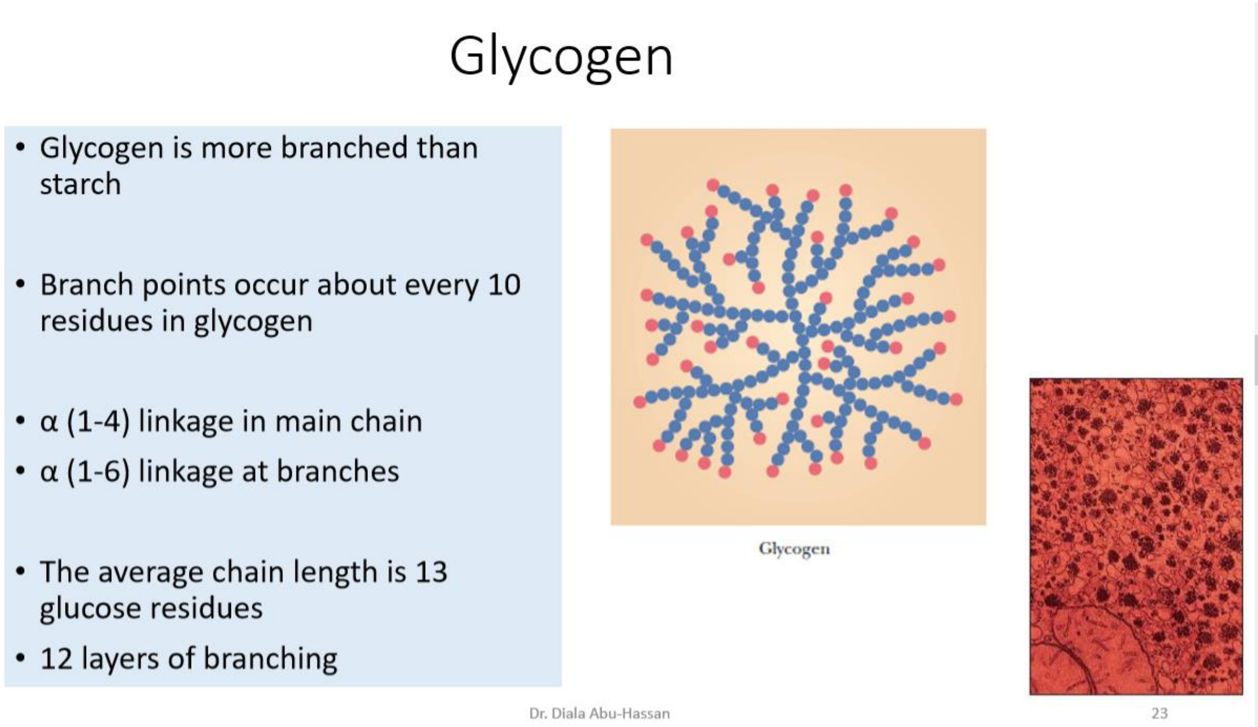


b) Amylose

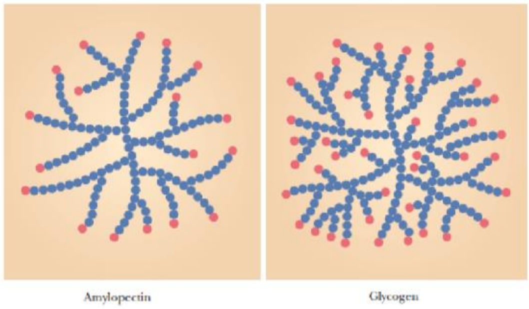
- unbranched
- 20% of starch (minor) .
- Linear molecule that forms a helix .

2)Glycogen

- Glucose as a monomer with α(1-4) glycosidic linkage .
- Much more branching with a layers of it .
- Storage polysaccharide in human body and animal cells .
- Stored in liver and muscles .



Amylopectin versus glycogen



- Branching
- Source

What is the importance(roles) of carbohydrates?

Roles of Carbohydrates

Major energy sources

Starting material for the **synthesis of other cell constituents**

Major **nutrients** of the cells

Oligosaccharides play a key role in **cell–cell interactions, adhesion, immune recognition, protein targeting and protein folding.**

Polysaccharides are essential **structural components** of several classes of organisms such as cellulose (a major component of grass and trees)

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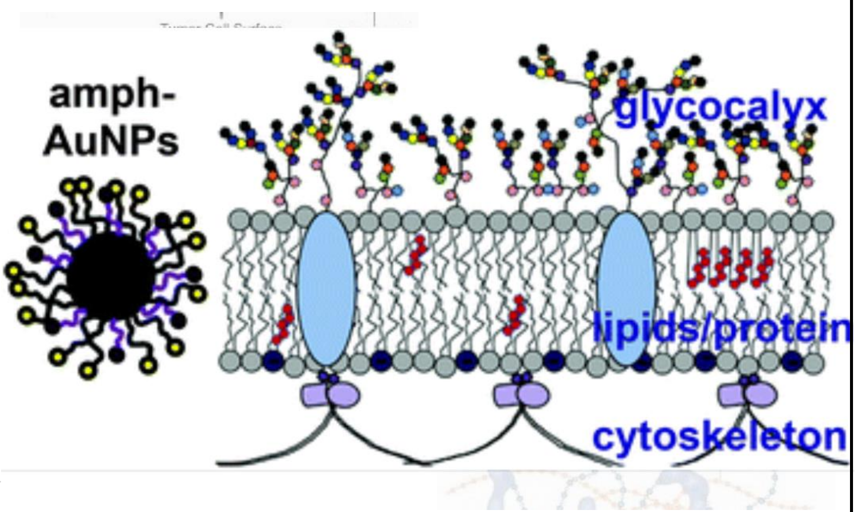
Let's end this sheet with some examples☺ :

1) structural proteins : for example, Glycocalyx around membranes that have a structural role acting as a layer around the whole cell that protect .



2) cell-cell recognition :

The difference between blood groups in humans body **is** the sugars that come out of the red blood cells.

3) Immune recognition

About immune recognition: when we get infection by bacteria or virus, the immune system recognize it as an antigen through sugars that are on cells surface.

4) protein targeting:

After synthesizing proteins and modifying them, they are packaged and sent to its final destination, so how does it know that it should go to plasma membrane and not mitochondria for example? By **labeling** ,and one type of labeling (tagging) is by using sugars .

5) protein folding:

Forming a 3D shape is contributed by sugars if it is a **glycoprotein**.

Additional notes

- The first thing that your body start to digest to get the energy is sugar .
- The glycogen storage in your body is enough to supply you with energy for about 12 hours if you are fasting and then we start to take our energy from other sources .
- Why is it recommended to eat fibers(cellulose) if you want to lose weight or you have constipation?
  It activate the muscles and increases the contraction .
- Furthermore, it acts as a meshwork that catches toxins, cancerogenic materials, extra cholesterol and others.

(لَوْ أنّ النّاسَ كُلّما اسْتَصْعَبُوا أمْرًا تَرَكُوه، مَا قَامَ للنّاسِ دُنيا ولا دِين)

عُمر بن عبد العزيز-