بسم الله الرحمن الرحيم

BioChemistry | Lecture #8

Carbohydrates Pt.3

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- We know from the previous lecture that any bond that involves the chiral carbon (the anomeric carbon) is called “glycosidic bond”.
- This bond bind other molecules to its oxygen, for example, it can bind to another:

  - Sugar
  - Alcohol (it produces Acetyl)
  - Nitrogen (to get N-acetyl) the bond is (N-glycoside) it produces DNA
  - Sulfur (the bond is Thioglycoside)
  - Carbon (the bond is called C-glycoside)

- So if it binds to another sugar, we can say it’s basis behind producing (disccharides, oligosaccharides, or polysaccharides)

- If it’s a ribose sugar with its anomeric carbon is attached to the nitrogen in the nitrogenous base (N-glycoside bond).

- What does glucose amine means? And how does it differ from N-glycoside?

- glucose amine is a glucose with amino group but it is not attached to the anomeric carbon, but for N-glycoside, anomoric carbon must involve in the bond.

How to describe Disaccharides ?

- Why do we need this description in the first place?
  Because glucose is everywhere, in di,oligo and poly saccharides (it's the backbone of carbohydrates)

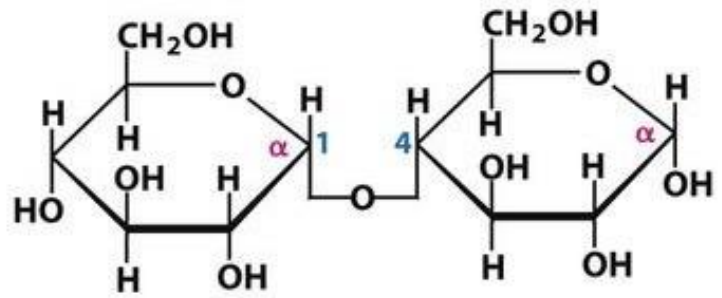
- We describe them by: 1/ what are the monosaccharides that constitute this disaccharide. 2/ the configuration of bonding between them, "is it alpha or beta". 3/the number of carbons that involve that bond "which carbon is linked to which" to know which carbon is involved in the glycoside bond.
  If we have only 1 anomeric carbon, this disaccharide can get oxidized, but if both anomeric carbons are engaged in the bond, there's no oxidation (which means it's not reducing.)

Disaccharides

- Maltose is produced during the germination of seeds and fermentation
- – Formed from the hydrolysis of starch

Look its structure, you

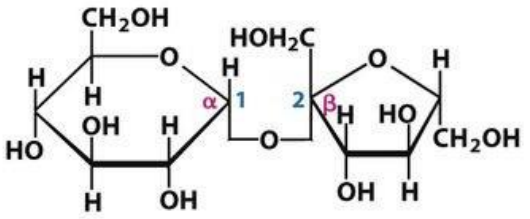
Should be able to recognize the cyclic structure of glucose



Maltose
(α-D-Glucopyranosyl-(1→ 4)-α-D-glucopyranose

- Sucrose is refined from sugarcane, tastes sweet, and is readily available

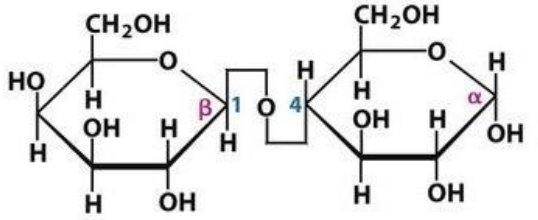
· In the case of sucrose, the first ring is glucose and the second one is fructose (it's obvious because it's a five-membered ring). Carbon number 1 from the glucose is down so it's in the alpha orientation and it's engaging with carbon number 2 from the next ring, it's not reducing here because both of the anomeric carbons are engaged.



Sucrose
(α-D-Glucopyranosyl-(1→ 2)-β-D-fructofuranose

- Lactose is found in milk and milk products

· The structure/ the first one is 6 membered ring, carbon number 2 down, so it might be glucose, but carbon number 4 is upward so it is galactose followed by carbon number 4 down, carbon number 2 down unlike carbon number 6 so it is glucose & alpha onfiguration because the hydroxyl group is projecting upward matching carbon number 6. (it's reducing because the anomeric carbon is free.



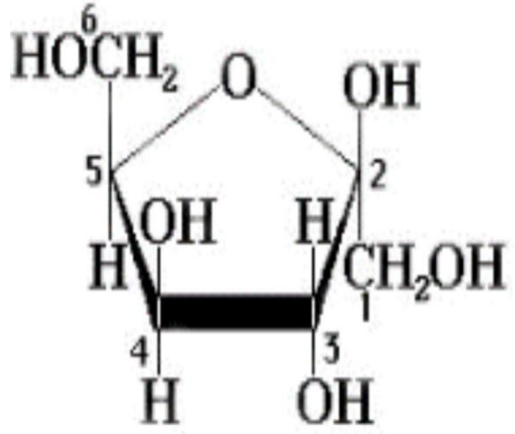
Lactose
(β-D-Galactopyranosyl-(1→ 4)-α-D-glucopyranose

·Remember
there are only two five-membered rings which are fructose and ribose, and the difference between them is how many carbons are outside of the ring.

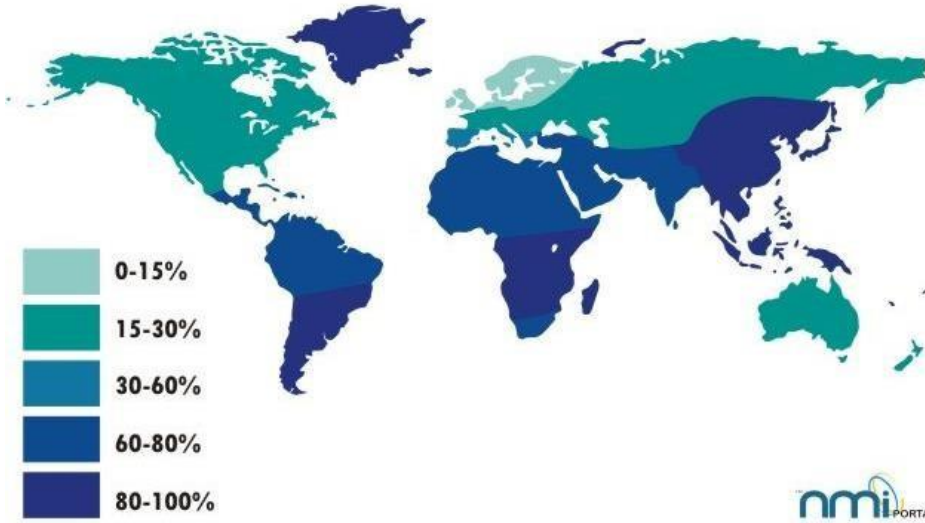
· what is the challenge in understanding the structure of fructose?

It is 5-membered the numbers will not be provided on the exam so you should be able to recognize the structure of fructose) :

The confusing part about the structure of fructose is that there are two carbon atoms outside the ring, which makes it tricky to determine carbon number 1 and carbon number 6. Carbon number 5 always has only a hydrogen attached to it, because its hydroxyl group is the one that attacked the carbonyl group to form the ring.On the other hand, carbon number 2 has a hydroxyl group, and that's how we can correctly number the carbon atoms.

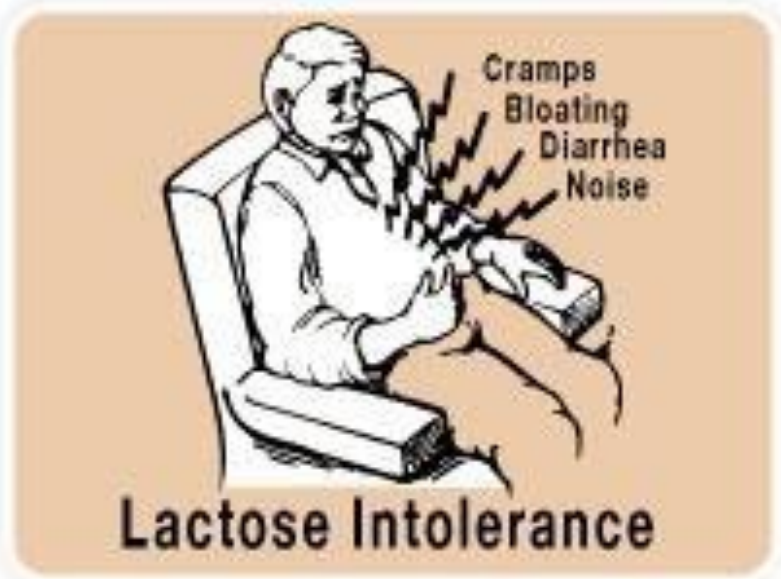


Lactose intolerance

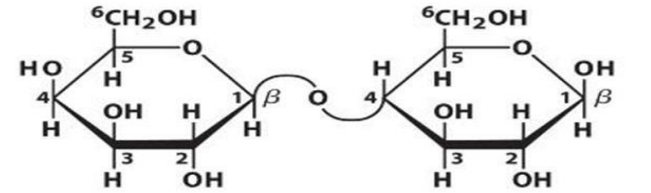


Digestible/ able to be broken down

・So can lactose be hydrolized? Yes it can for every human, and it's done by an enzyme "lactase" which is being produced in the intestines, the lactose will get broken down into glucose and galactose which will be absorbed into cells to get broken down to provide you with energy.



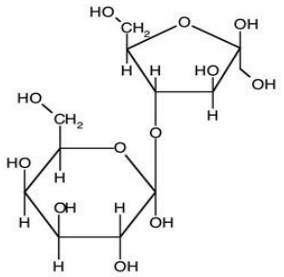
- It is a condition caused by defective lactase
- lactose remains in the intestines & draws excess water
- Bacteria ferment lactose to produce CO_2 and methane
- Symptoms: bloating, cramps, flatulence, and diarrhea



·What will happen if you stopped drinking milk?

Lactase production amounts will get lesser, so if you started drinking milk again your body will not be able to digest it because it doesn't have the Enzyme (or have it in very low am), in this case bacteria will digest it by producing gasses like CO2 which will cause bloating and this is what we call lactose intolerance.

Lactulose Derivative from lactose

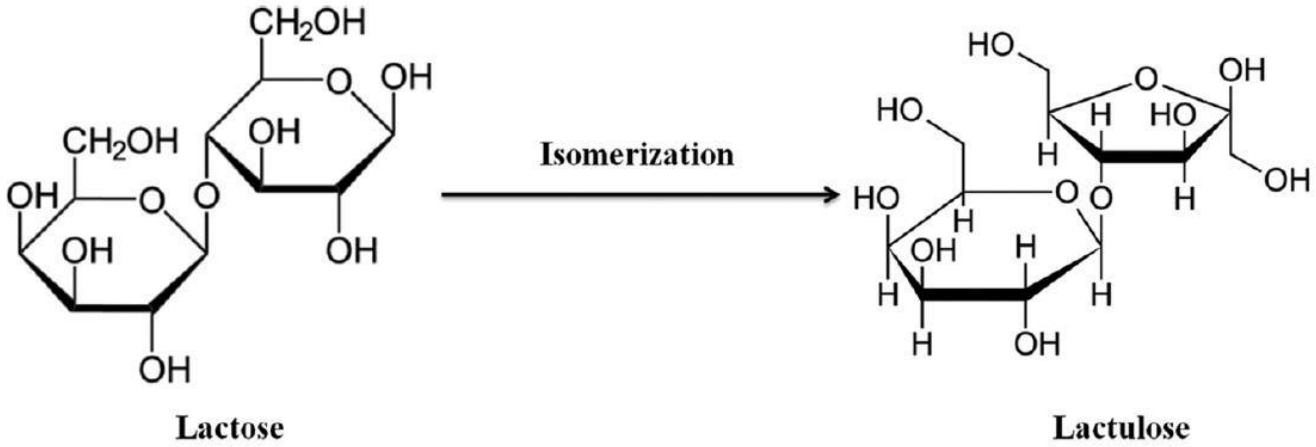


- Synthetic (isomerization)
- In medicine as an osmotic laxative (treatment of constipation)

· how does it differ from lactose?

The glucose part in the lactose became fructose (look at the reaction)

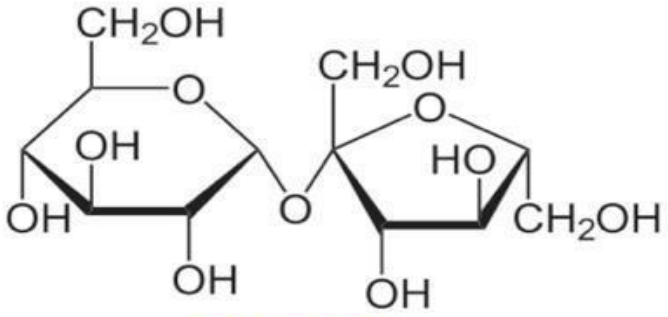
·it's not digestible and it causes diarrhea, it's used to clean up large intestines before operations, and for certain



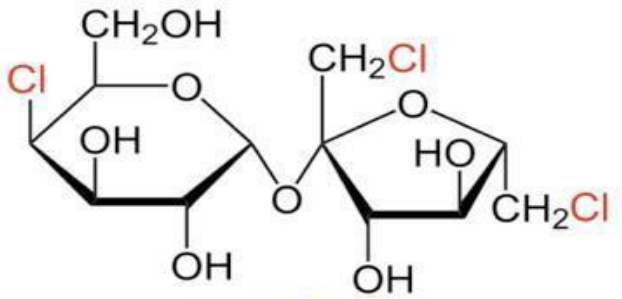
Sucralose (artificial sweetener) Modified sucrose

· Sucrose can be modified by adding certain chloride atoms to its structure creating what we call as "sucralose“

· General thing about sweeteners: there are studies on animals to see the effect on many types and there's no good results, the studies on human are very deficient because there's no long term studies or any control.



sucrose



sucralose

Galactosemia

Normally, bodies convert galactose to glucose in five steps evolving 5 enzymes so if any of these enzymes genetically have deficiency in the body or this process isn't working properly so it will cause increasing in galactose levels in the cells, which means more reduction will happen and more intermediates will be generated like galactitol which is a reduced form of galactose that can be accumulated inside cells and as it is osmotic it will drag water into cells causing swelling and cell damage

Next slide to fully understand

Galactosemia

a disease affecting galactose levels in the blood

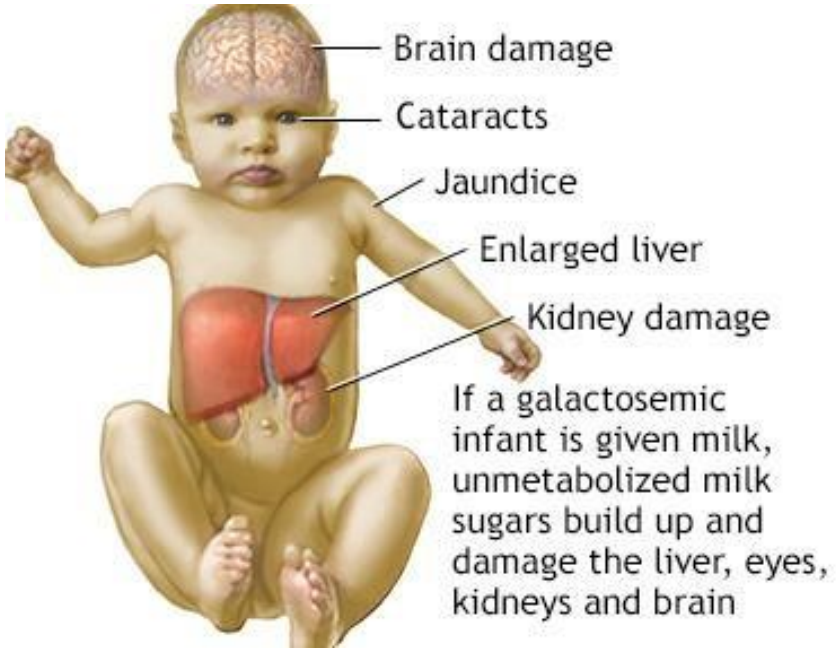
Because of
- Missing a galactose-metabolizing enzyme

galactose levels will increase

And will be
- Converted to the hydroxy-sugar galactitol (cannot escape cells)

Which will accumulate in cells

Causing
- Swelling and cell damage (brain; severe and irreversible retardation)
- Cataract

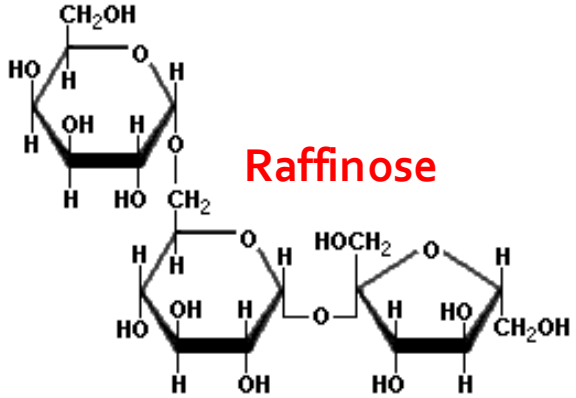


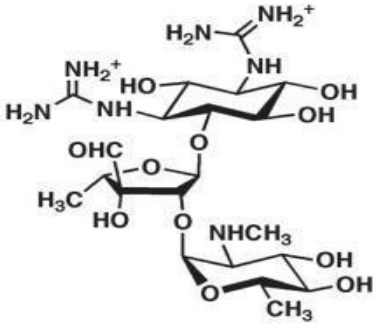
Oligosaccharides

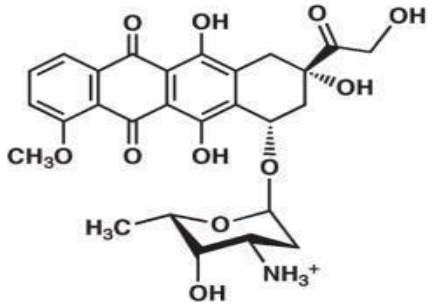
- Raffinose; found in peas and beans

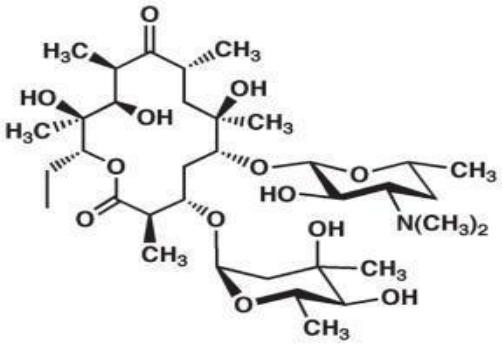
These materials are known for causing bloating in our intestines because they're not hydrolysable, accordingly the bacteria can ferment them producing gases including methane CO2 and H2 gases

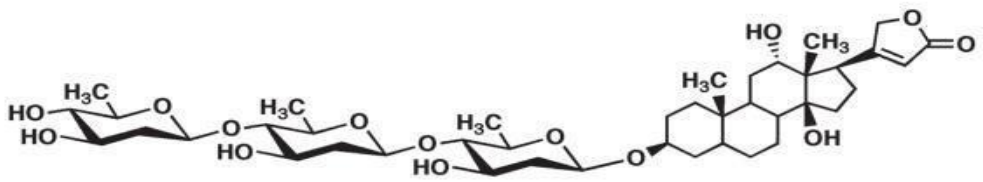
- Composed of galactose, fructose, and glucose



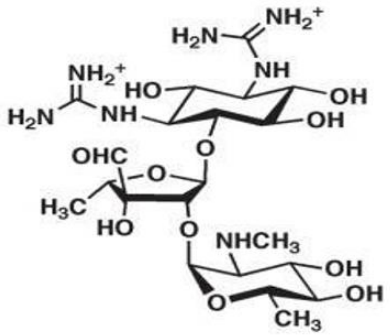

Streptomycin


Doxorubicin


Erythromycin A

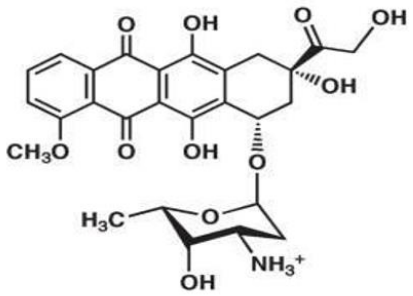

Digoxin

Oligosaccharides



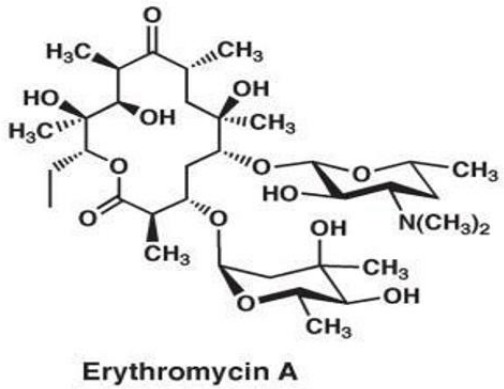
Streptomycin

Some of the materials that are commercially applied in pharmaceuticals as an antibiotic and has 2 monosaccharides



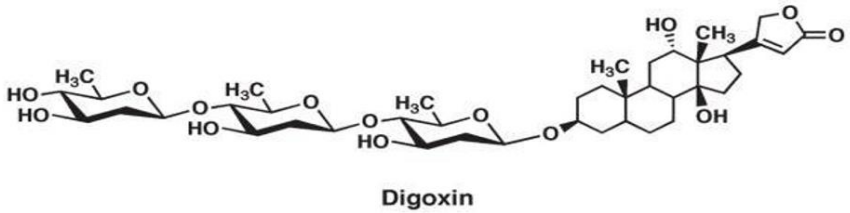
Doxorubicin

It is a highly used anti-cancer drug for breast cancer and has 1 monosaccharide



Erythromycin A

Another antibiotic with 2 monosaccharides in its structure



Digoxin

A drug which is used in cases of heart failure with 3 monosaccharides attached to the structure

Polysaccharides

Firstly remember that Every di oligo poly saccharide should have glucose

So how can we describe polysaccharides?

A) consists of glucose only (homopolysacharide) or glucose with other monosaccharides (heteropolysacharide)
B) Being branched or not
C) Types of the glycosidic linkage (α and β)
D) Its length
E) The numbers of carbons involved in the bond
F) Creatures or the organisms that this polysaccharide exists in

Polysaccharides

It is a polymer (a basic unit that is being repeated more and more and more…) that can be classified according to their function
We care about the structure and how it is related to the function -> if we change the structure the function will be changed as well

- Homopolysaccharide vs. Heteropolysaccharide

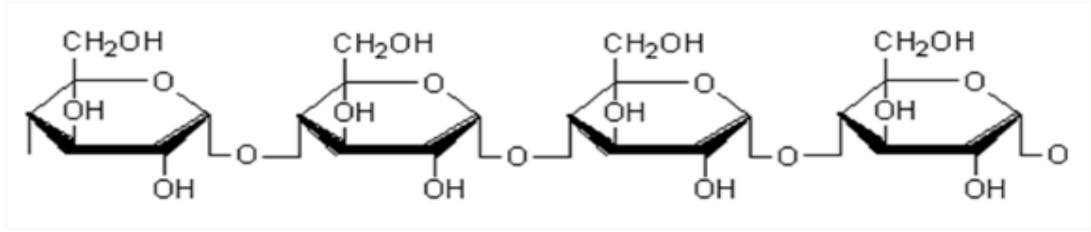
glucose only being repeated (homopolysacharide) or glucose with other monosaccharides being repeated (heteropolysacharide)

- Cellulose & chitin: β-glycosidic linkages
- Starch, glycogen, and dextran: α-glycosidic linkages

Polysaccharides are classified according to their function to two main groups: storage (that use alpha glycosidic linkages that are accessible for the enzymes so it can be hydrolysed) and structure support (that use beta linkages which is much more rigid and not hydrolysable and accordingly it's used for support)

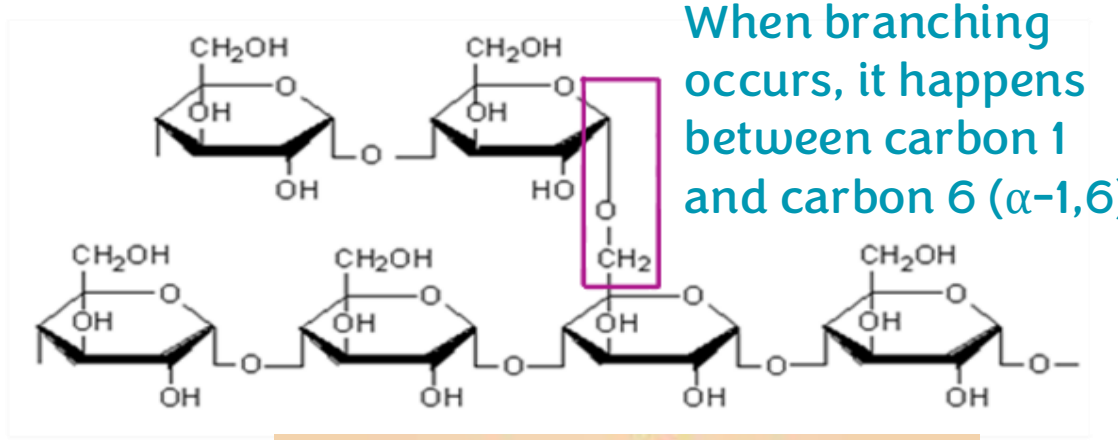
Starch homopolysacharide

- Which organisms? Plants
- Forms:
  - amylose (10-20%) Linear
  - amylopectin (80-90%) Branched
    - every 25 residues



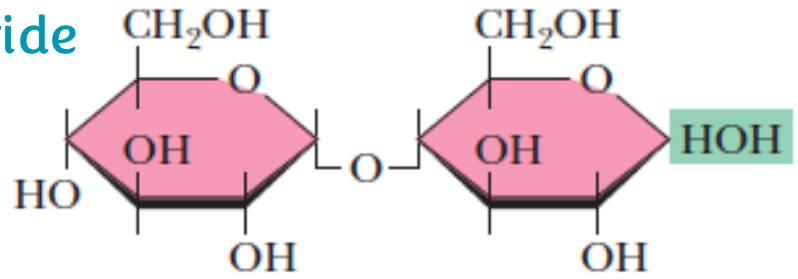
Amylose Structure

When branching occurs, it happens between carbon 1 and carbon 6 (α-1,6)

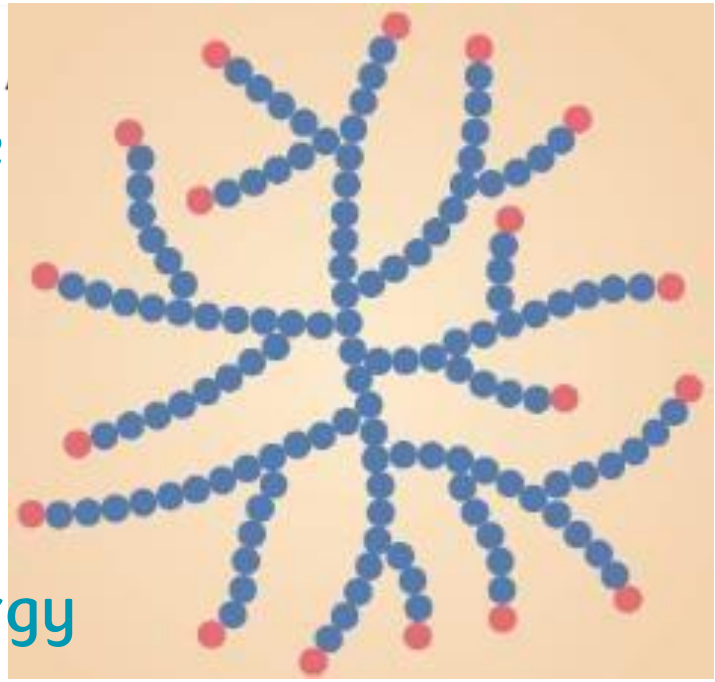


Residue is the basic unit inside the structure which are the monosaccharides

branching occurs out of this linear molecule



Maltose (glucose-α-1,4-glucose)

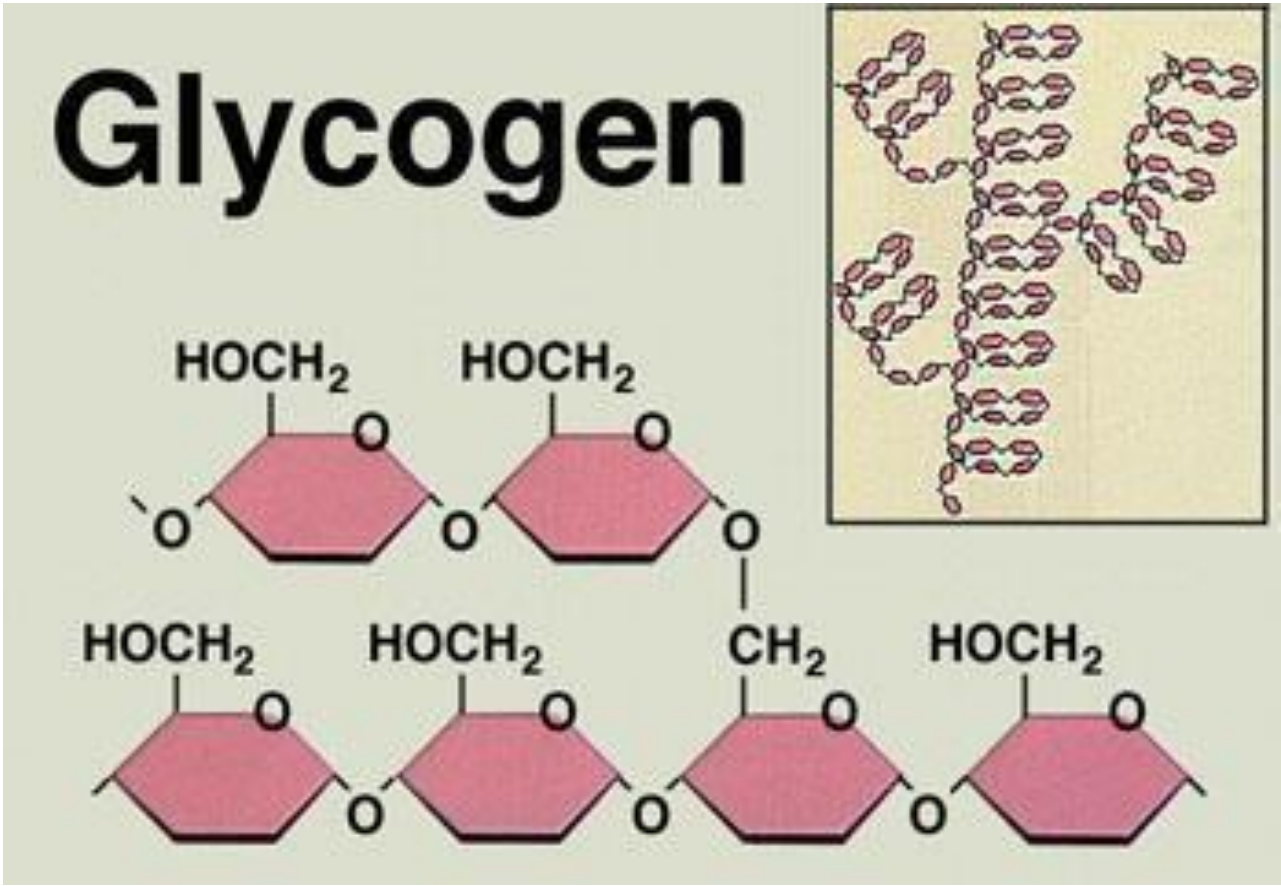


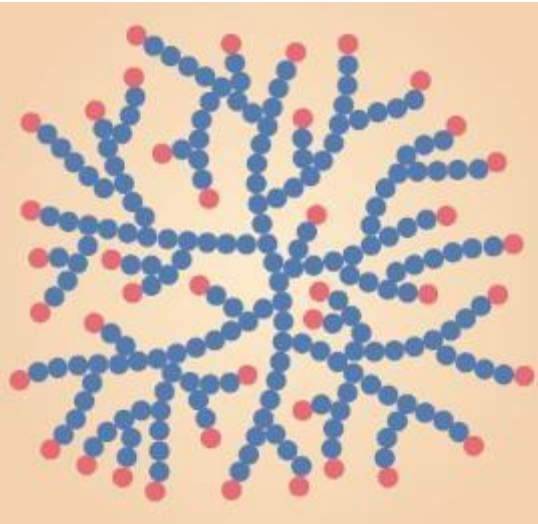
Type of linkage is alpha because starch is for storing energy

Glycogen

Similar to amylopectin but because it's in animals so it's much more branched -> more places for enzymes to act on -> more hydrolysis -> faster glucose release

- More highly branched
- Every 10 residues
- More water-soluble
- Easy enzyme access to glucose residues

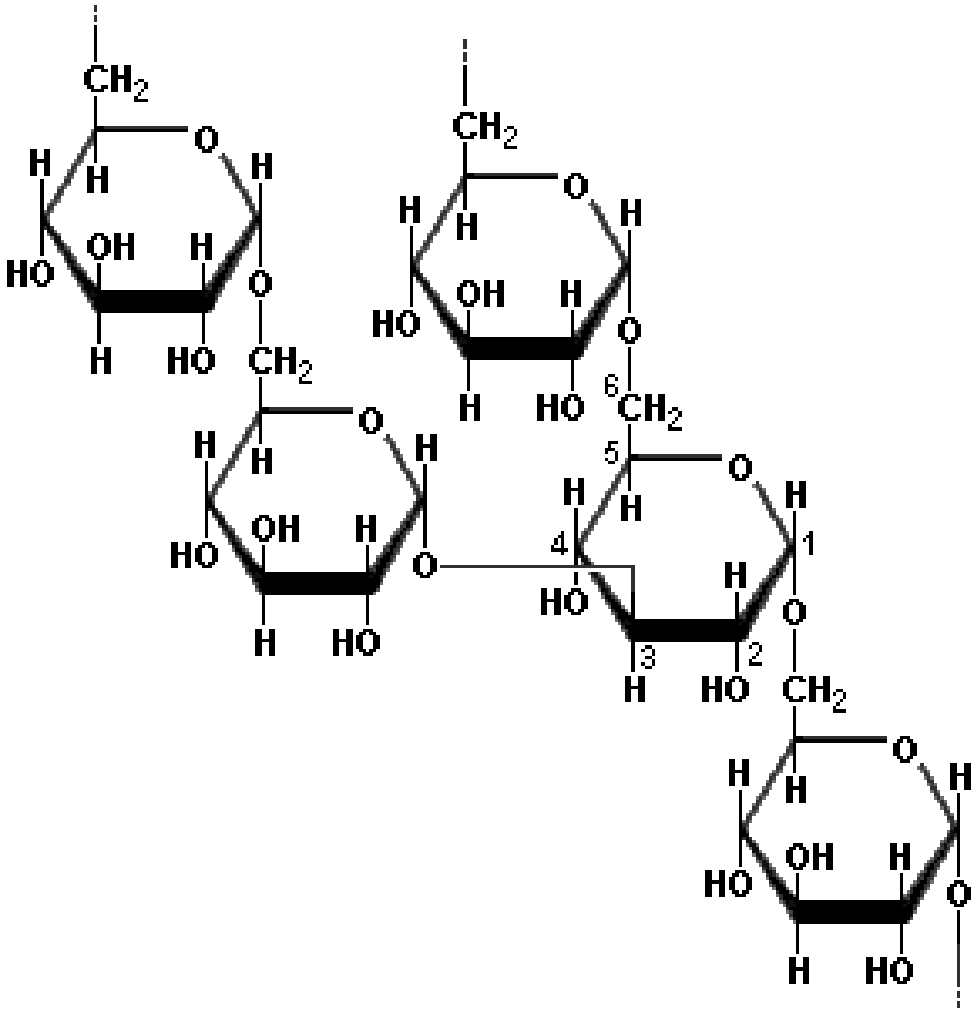




homopolysacharide

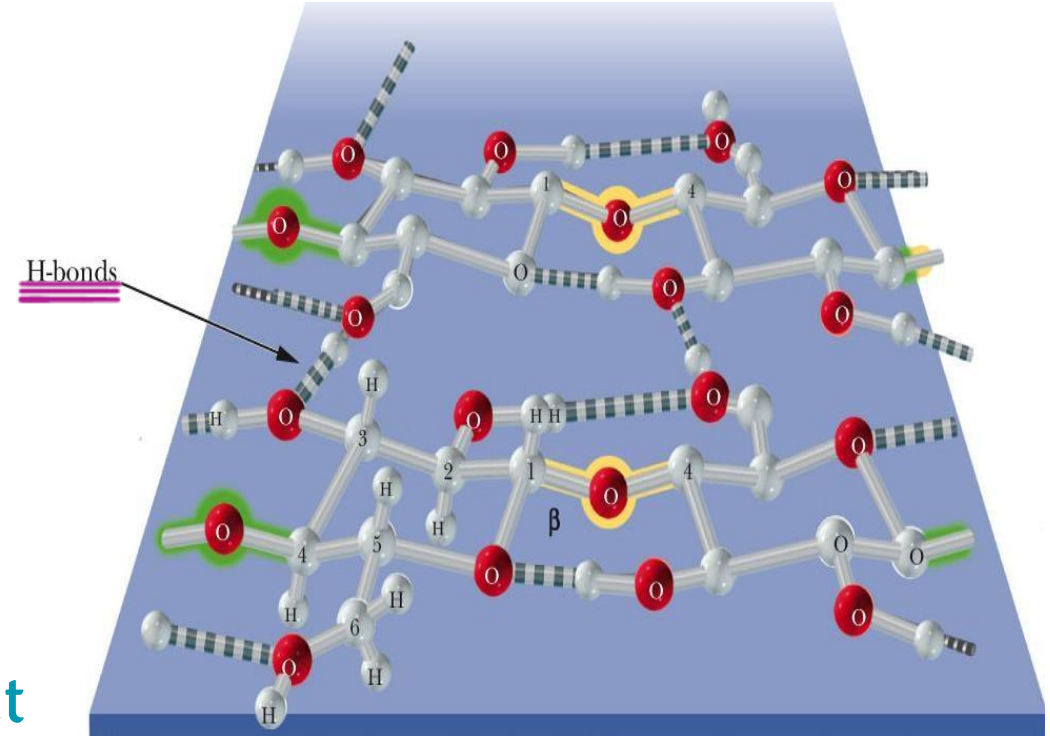
Dextran homopolysacharide

- A storage polysaccharide
- Yeast and bacteria
- α-(1-6)-D-glucose with branched chains
- Branches: 1-2, 1-3, or 1-4

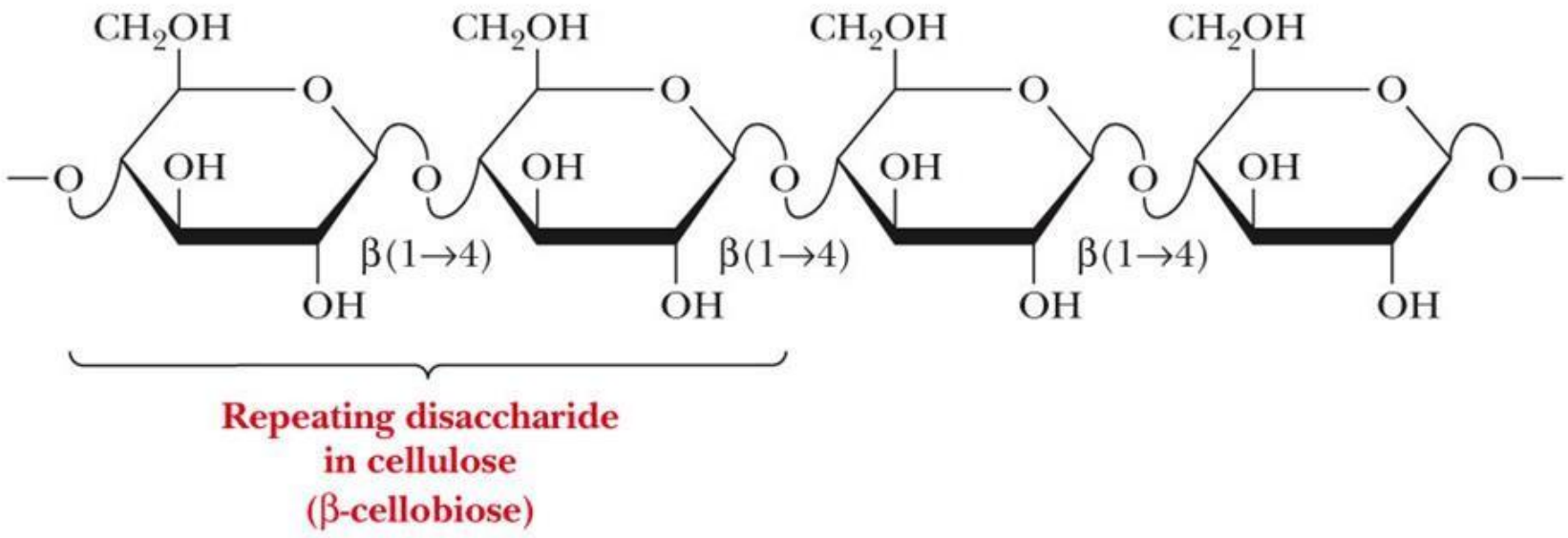


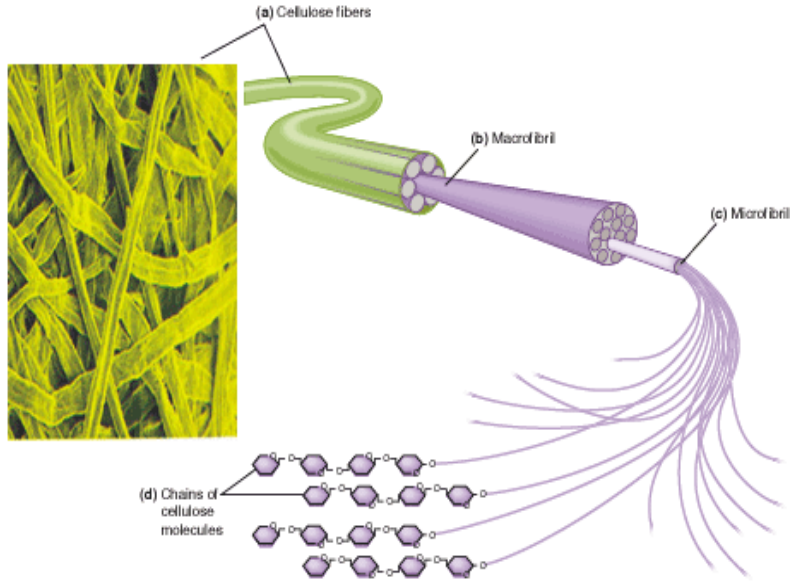
Cellulose homopolysacharide

- Plants, linear, ~3000 unit, Per molecule
- β- 1,4-glycosidic bonds,
  Cellulases



Humans cannot digest cellulose but some animals can, they benefit from the glucose in it



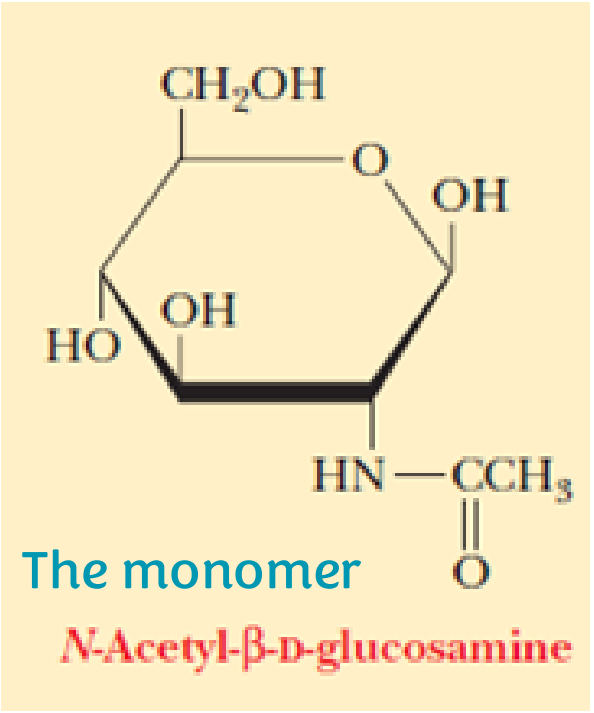


Chitin

Hard polysaccharide

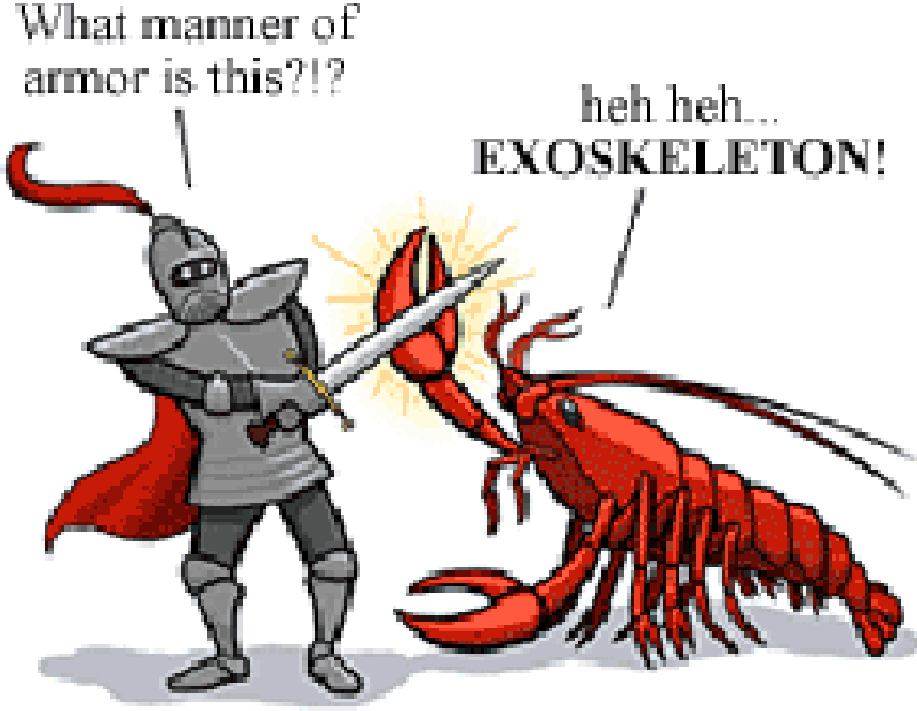
- What is the precursor?
- Where does it exist?

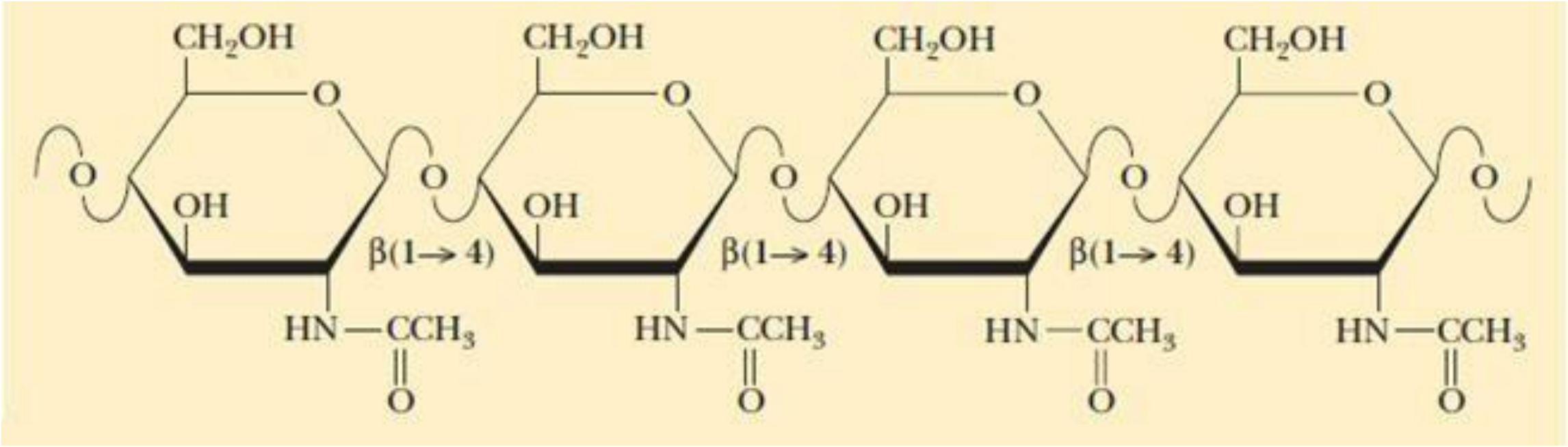
Constitutes the exoskeleton of insects



The monomer

N-Acetyl-β-D-glucosamine

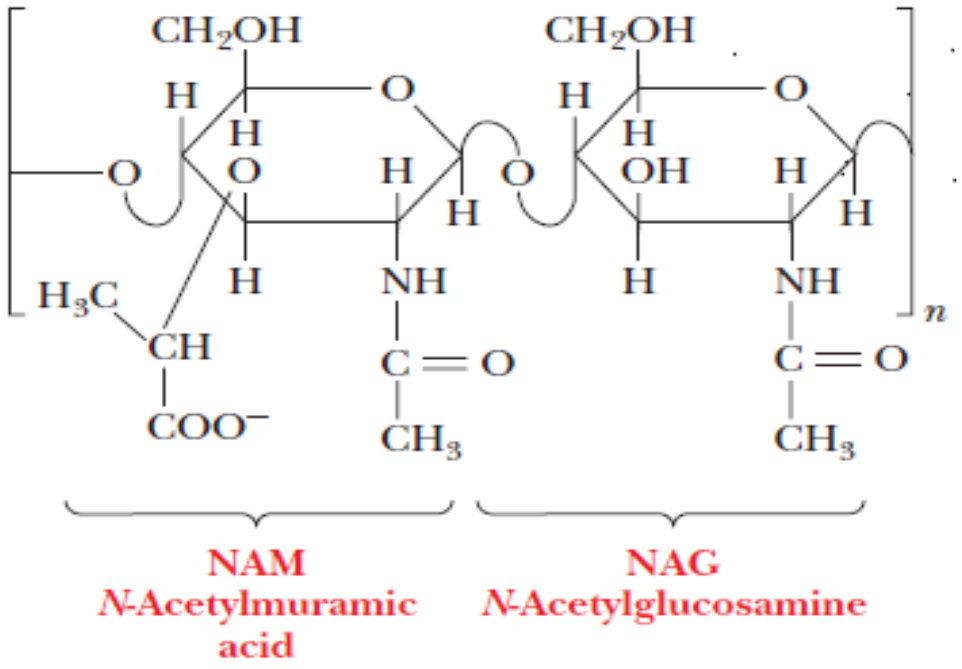




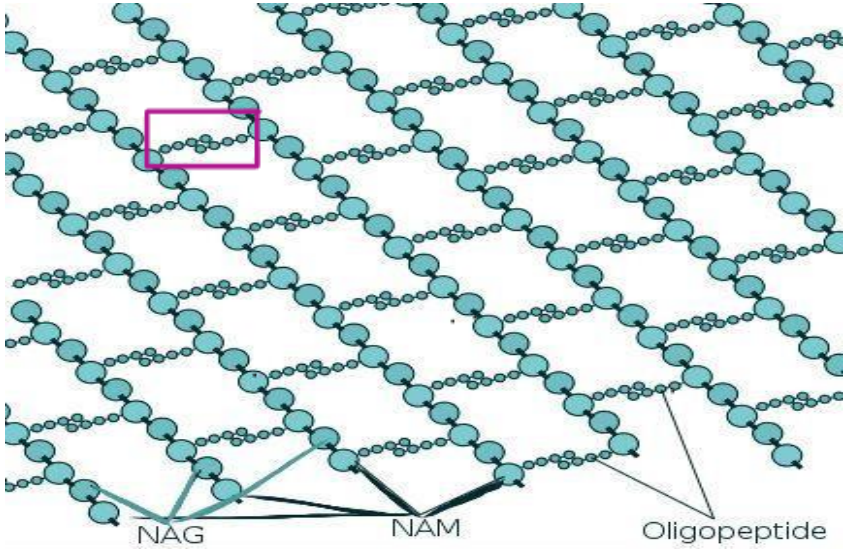
Bacterial cell wall

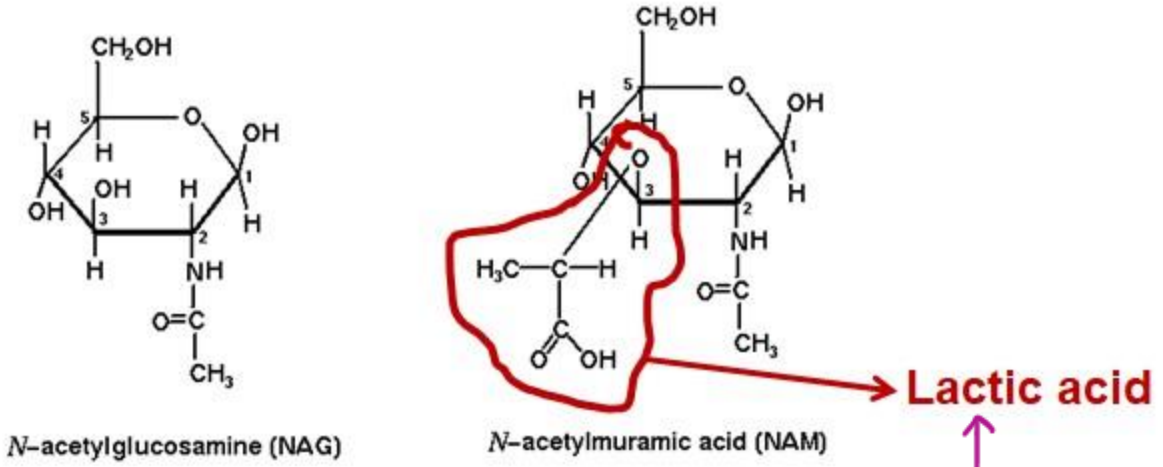
It's a repeating disaccharide layed to each other by cross linking of different types amino acids producing this sheet like structure

A



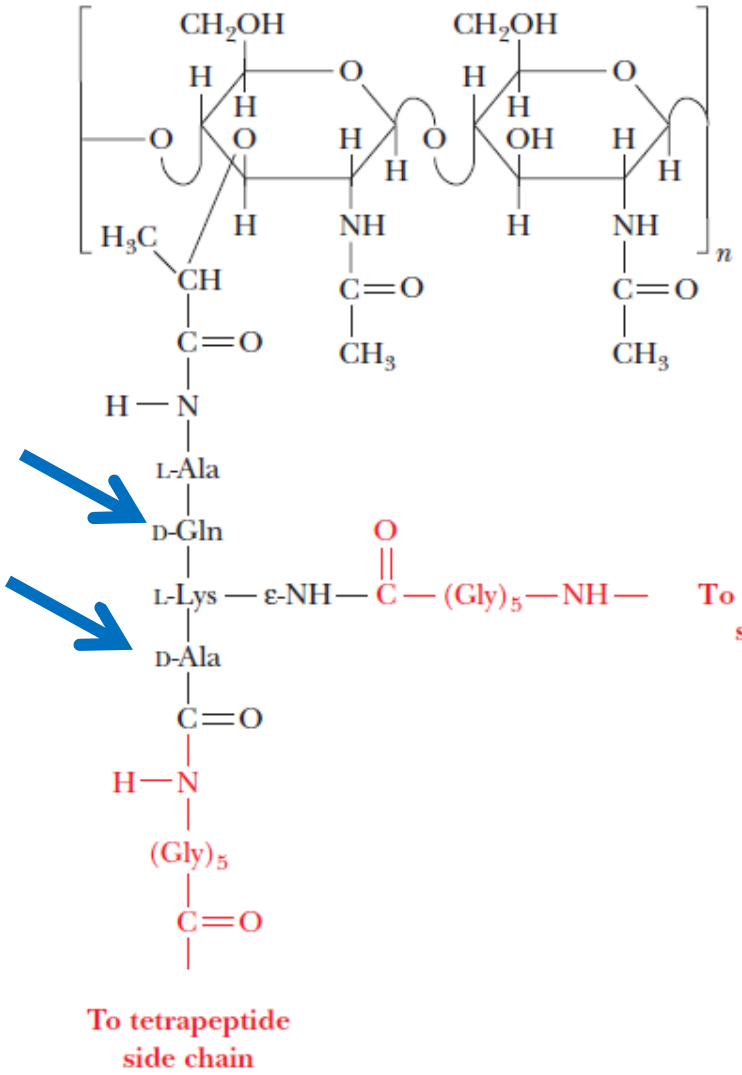
These 4 amino acid are attached to the other 4 through the N-acetylmuramic acid this is why you need the carboxylic group to connect them with each other which results in the strength of the bacterial cell wall

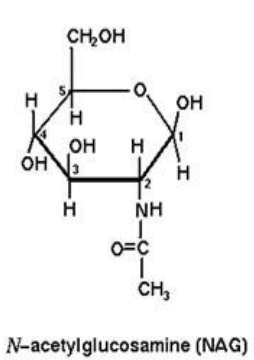


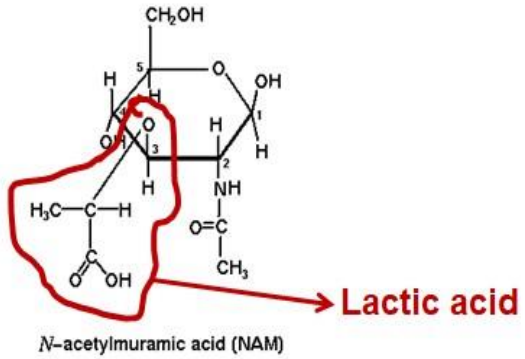


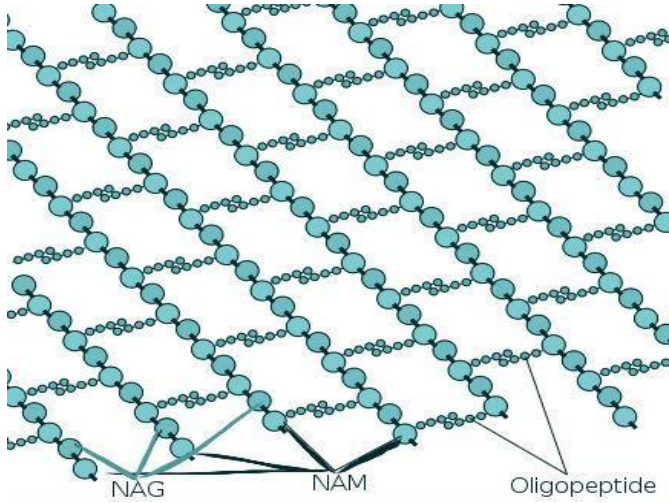
The difference between them

Bacterial cell wall





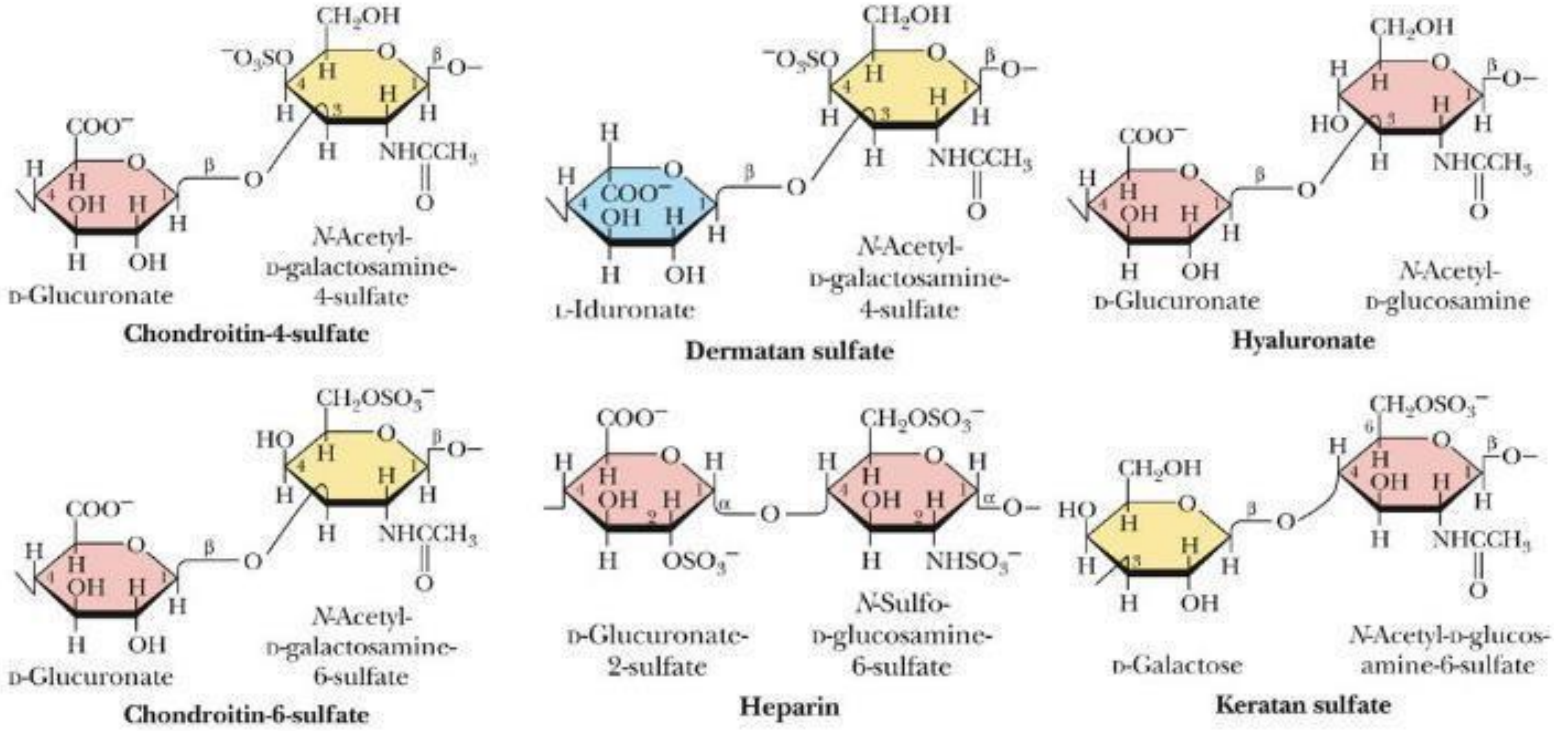




Glycosaminoglycans

- What are they? Where are they located?
- Derivatives of an amino sugar, either glucosamine or galactosamine
- At least one of the sugars in the repeating unit has a negatively charged carboxylate or sulfate group -> increases the solubility -> viscosity -> higher lubrication (in eyes and joints)

We don't need to memorise the structures but we need to know the names of them



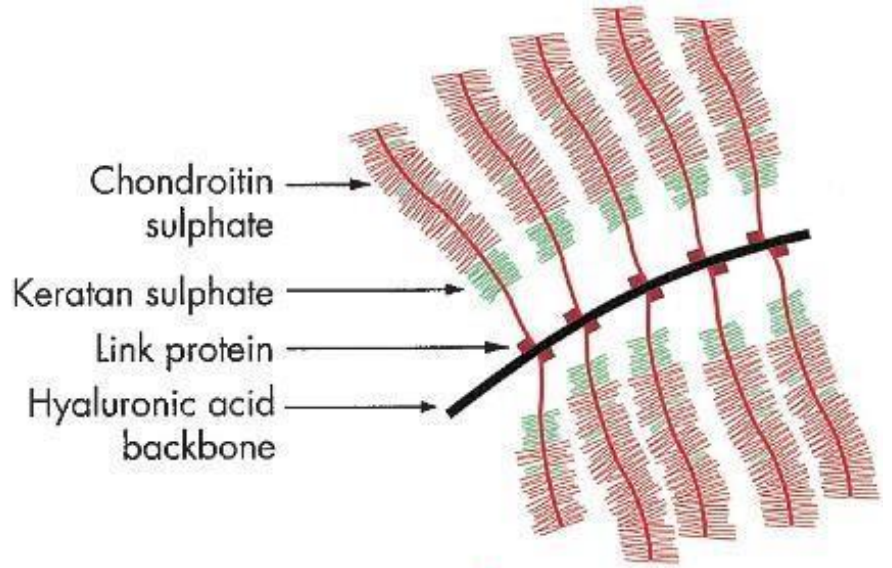
Localization and function of GAG

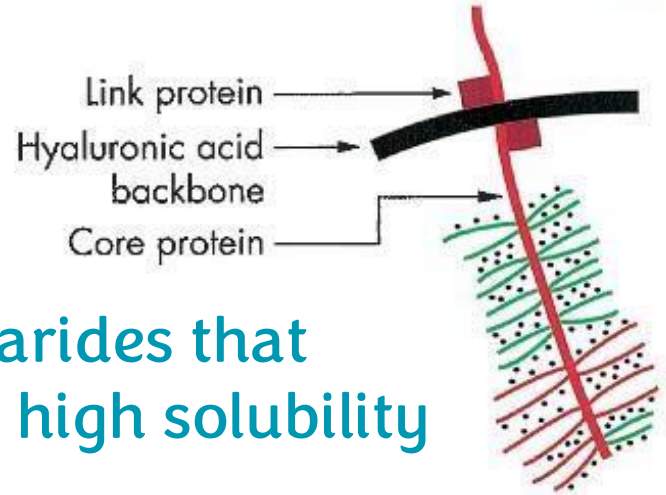
GAG	Localization	Comments
Hyaluronate	synovial fluid, **vitreous humor,** **ECM of loose connective tissue**	**the lubricant fluid , shock absorbing** As many as 25,000 disaccharide units
Chondroitin sulfate	**cartilage**, bone, heart valves	**most abundant GAG**
Heparan sulfate	basement membranes, components 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

Proteoglycans

The main component are the glycans

- Lubricants
- Structural components in connective tissue
- Mediate adhesion of cells to the extracellular matrix
- Bind factors that stimulate cell proliferation





Repeating disaccharides that gives the structure high solubility

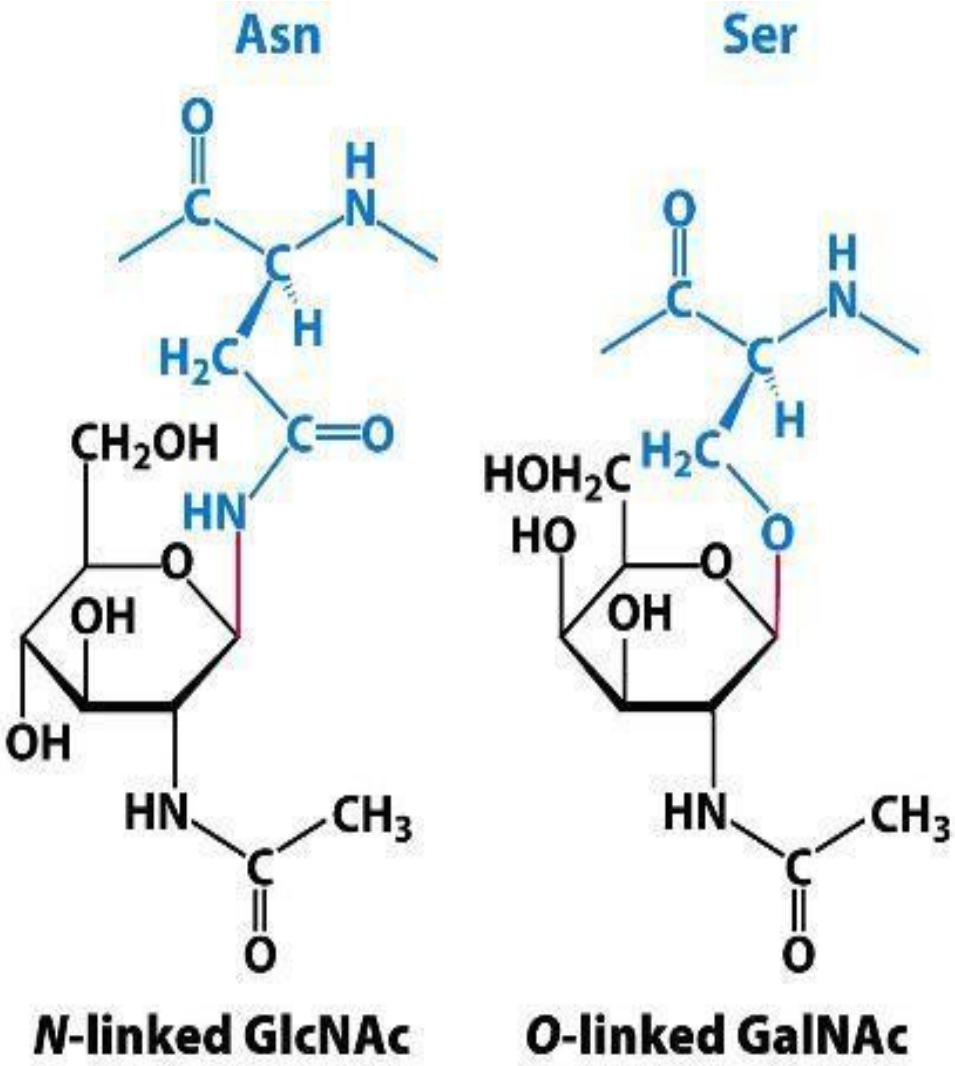
Glycoproteins

The main component are the proteins

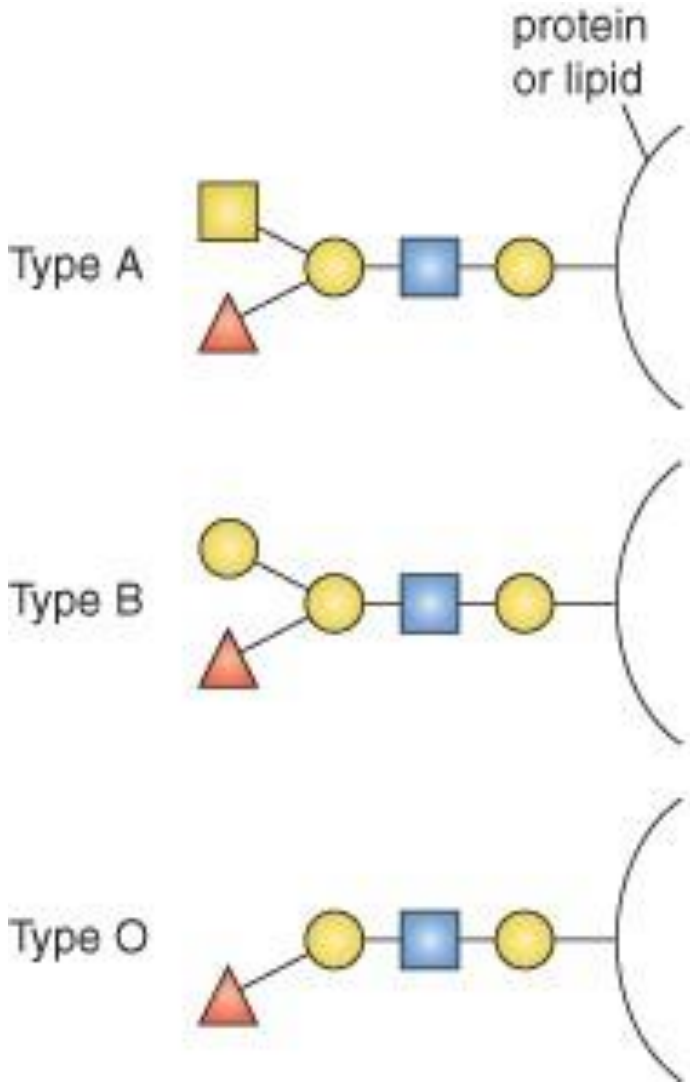
Sugars are not added randomly to proteins

They are either added to the nitrogen of a specific amino acid (N linked glycoprotein) or the oxygen in the side chain (O linked glycoprotein)

- O-glycosidic; hydroxyl group of serine (Ser, S), threonine (Thr, T) or hydroxylysine (hLys)
- N-glycosidic bonds; through the amide group of asparagine (Asn, N)
- Significance:
  - Protein folding
  - Protein targeting
  - Prolonging protein half-life
  - Cell-cell communication
  - Signaling



Blood typing



On the surface or red blood cells we have oligosacharide as a coding that consists of:

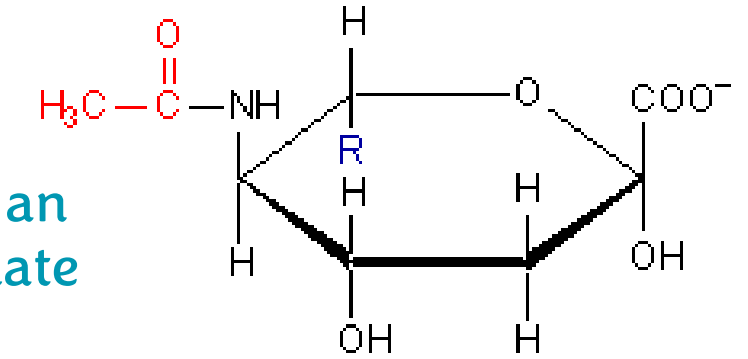
- Galactose
- *N*-Acetylglucosamine
- *N*-Acetylgalactosamine
- Fucose

Reduced galactose

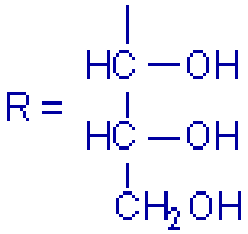
People with AB blood type have both The A and B oligosacharides on their RBCs

Sialic acid

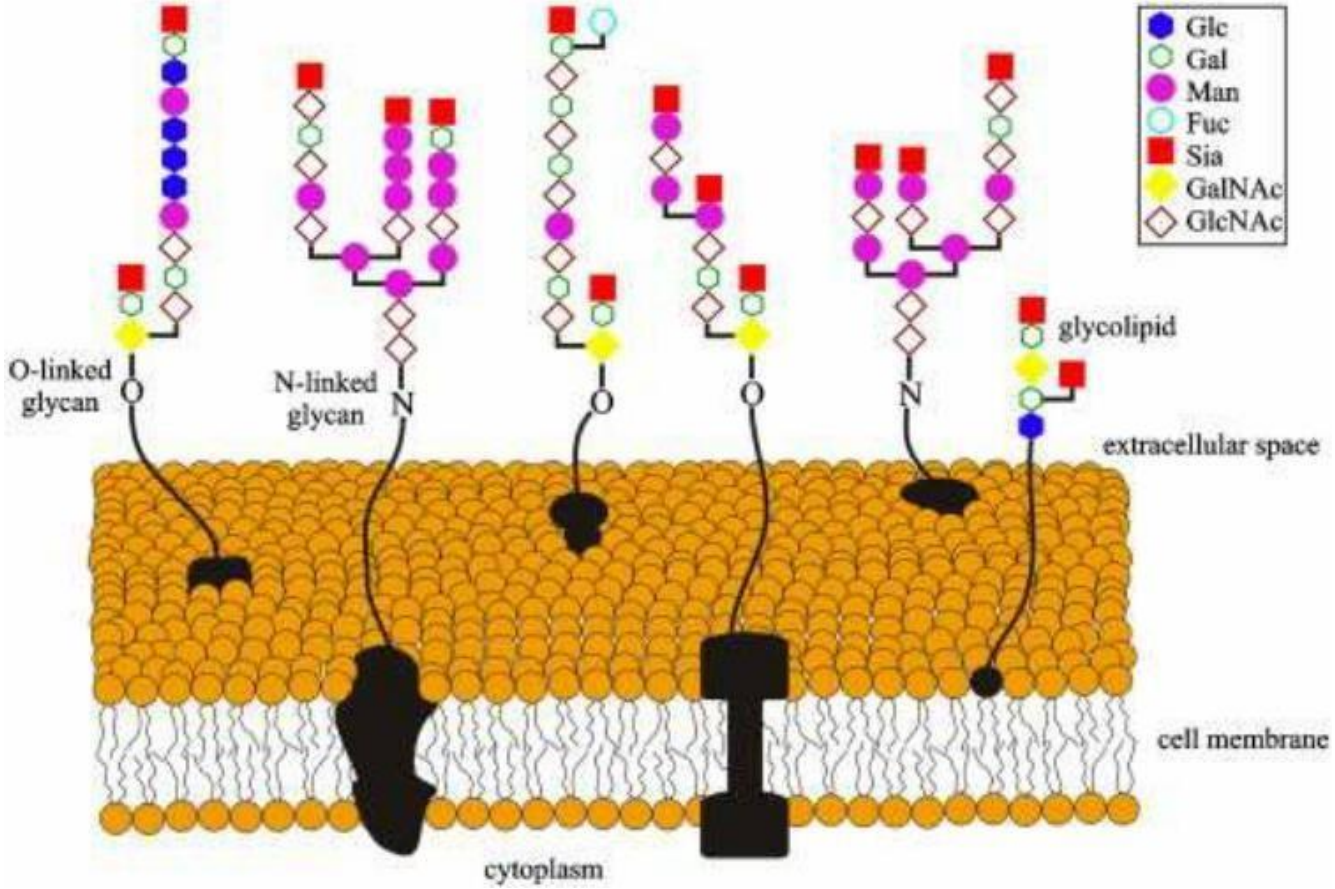
Terminal monosaccharide with an acidic structure with a carboxylate group and an acetyl group



N-acetylneuraminate (sialic acid)



- A terminal residue of oligosaccharide chains of glycoproteins and glycolipids



For any feedback, scan the code or click on it.

Corrections from previous versions:

Versions	Slide # and Place of Error	Before Correction	After Correction
V0 → V1			Many things were edited
V1 → V2			

رسالة من الفريق العلمي: