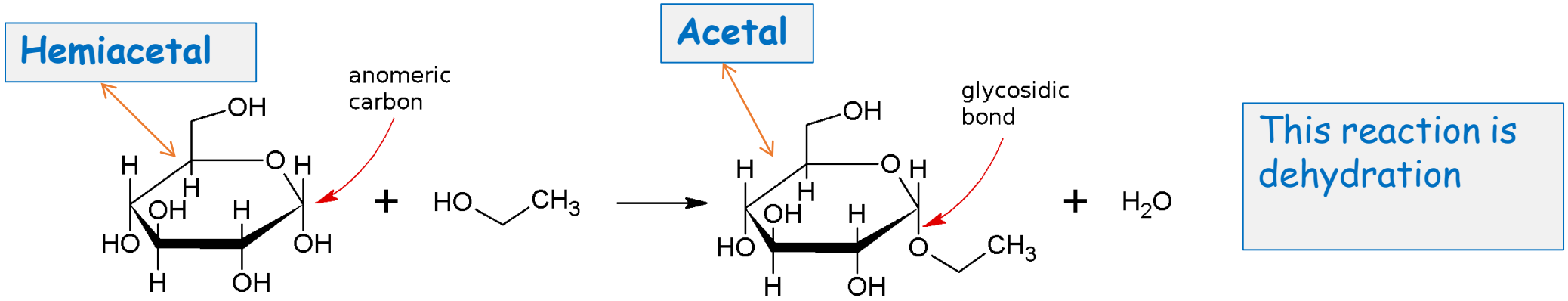
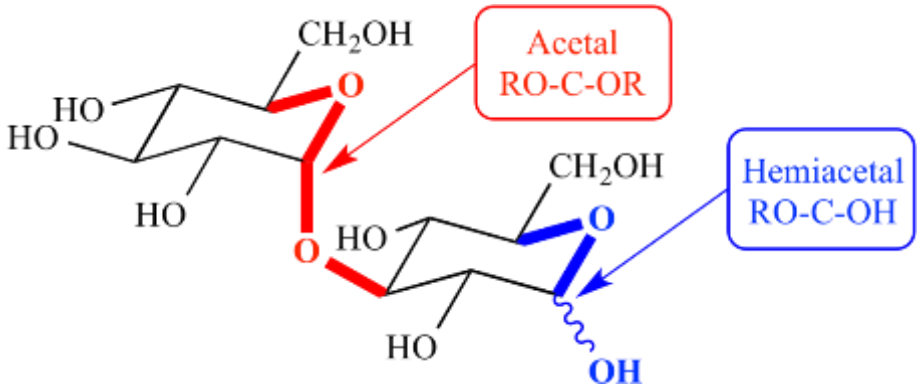
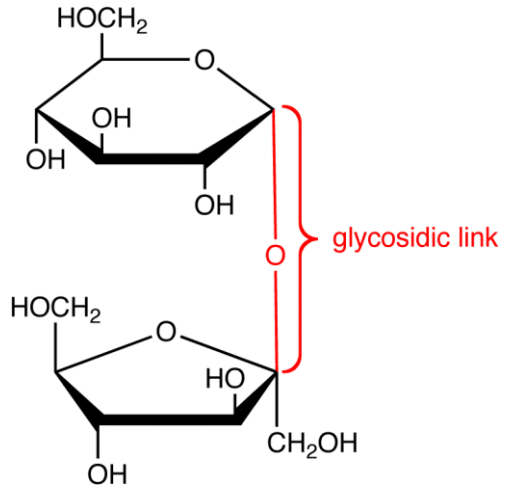
O-glycosides

- What is the reacting functional group? Where does it react? What are the end products? Where are they used?





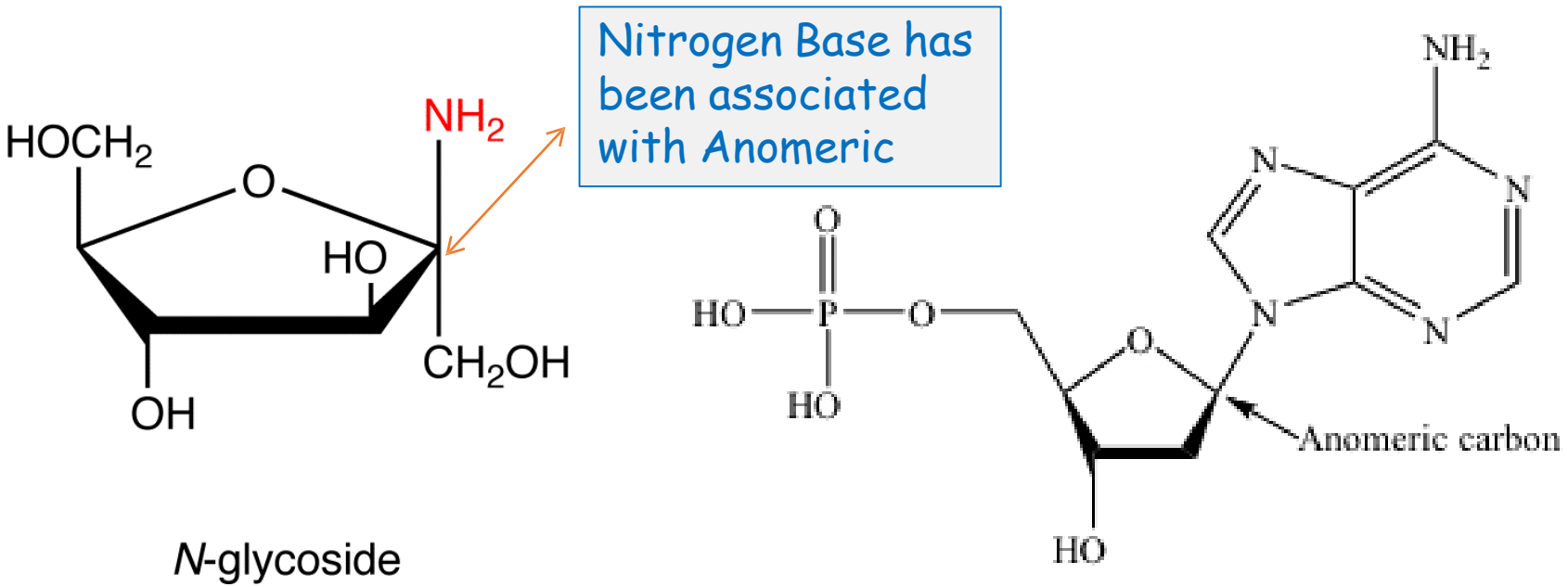


Further explanation regarding the previous slide:

- **O-glycosides**: a reaction between a sugar and an alcohol or sugar and a sugar to form disaccharide or oligosaccharide or polysaccharide
- The first sugar reacts with the second substance (sugar or alcohol) via the anomeric C1, C2, depending on whether it is an aldose or a ketose, The second substance is either alcohol directly or sugar through OH
- When we eat sugars that are more than disaccharides, they are digested, and it involves breaking these bonds to some extent, so they all become monosaccharides, then they enter the absorption process and the body benefits from them. Breaking these bonds requires a water molecule (H2o). This reaction is called hydrolysis

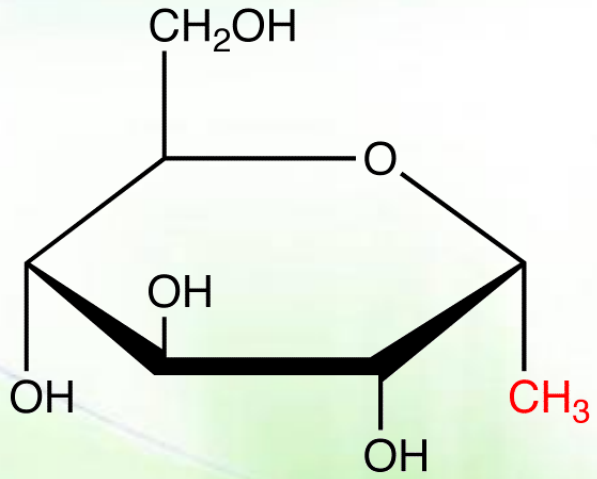
N-glycosides

- What is the reacting functional group? Where does it react? What are the end products? Where are they used?
- Examples: nucleotides (DNA and RNA)

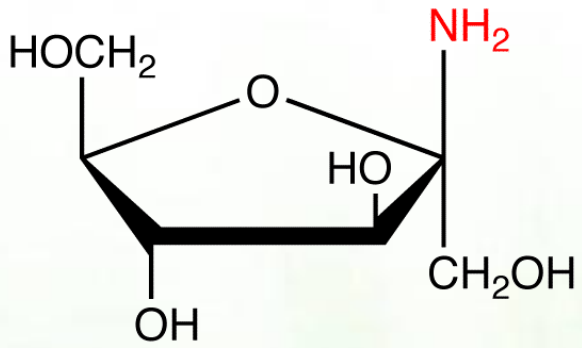


Note

- Glycosides derived from furanoses are called furanosides, and those derived from pyranoses are called pyranosides, regardless if they are N- or O-linkded.



C-glycoside

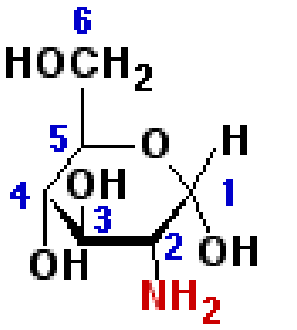


N-glycoside

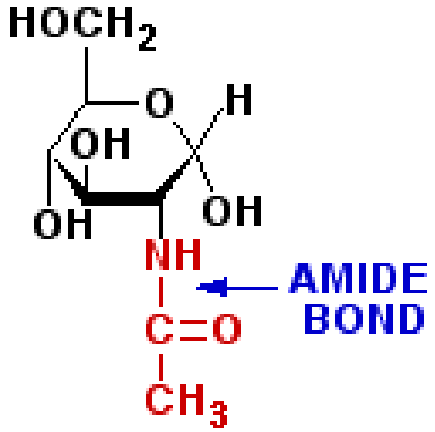
Amino sugars

- What is the reacting functional group? Where does it react? What are the end products? Where are they used?
- Further modification by acetylation

- Amino sugars are generally polar, having non-bonding electrons that increase polarity.
- Oxidation and amination are most common in the sugars that synthesize glycoaminoglycans (GAGs). They are present in the ECM and help the cell respond to environmental stimuli



α-D-2-glucosamine
(GlcN)



N-acetyl-α-D-2-glucosamine
(GlcNAc)

Disaccharides

- What are disaccharide? Oligosaccharides? Hetero- vs. homo-?
- What is the type of reaction?
- What is a residue?
- Synthesizing enzymes are glycosyltransferases
- Do they undergo mutarotation?
- Are products stable?

Distinctions of disaccharides

- The 2 specific sugar monomers involved and their stereoconfigurations (D- or L-)
- The carbons involved in the linkage (C-1, C-2, C-4, or C-6)
- The order of the two monomer units, if different (example: galactose followed by glucose)
- The anomeric configuration of the OH group on carbon 1 of each residue (α or β)

Abundant disaccharides

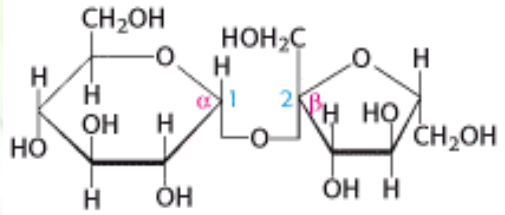
- Configuration
- Designation
- Naming (common vs. systematic)
- Reducing vs. non-reducing

Sucrose: السكروز

The sucrose is produced by linking of glucose and fructose (الجلوكوز والفركتوز) with alpha (1-2) linkage or anomaric (1-2) likage.

We can name the linkage by looking at the the anaromic carbon of the first monosaccharide to see if it alpha or beta .

It is non-reducing sugar.



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

Lactose: اللاكتوز

It's a beta (1-4) linkage.
And it's reducing suger because anomaric
Carbon of glucose is free.

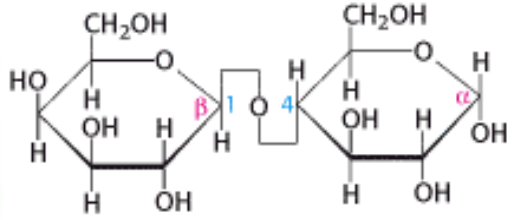
▶ each monosaccharide or disaccharide is reducing except sucrose.

Maltose: ريعشلا ركس

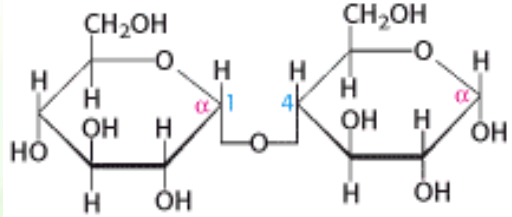
It's an alpha (1-4) linkage.

Maltose found in any Beans capable of fermentation.

Maltose is reducing sugar because anomaric carbon of second glucose is free.



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

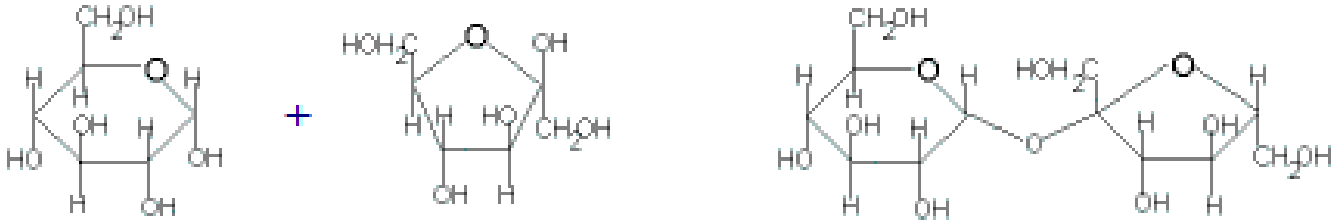
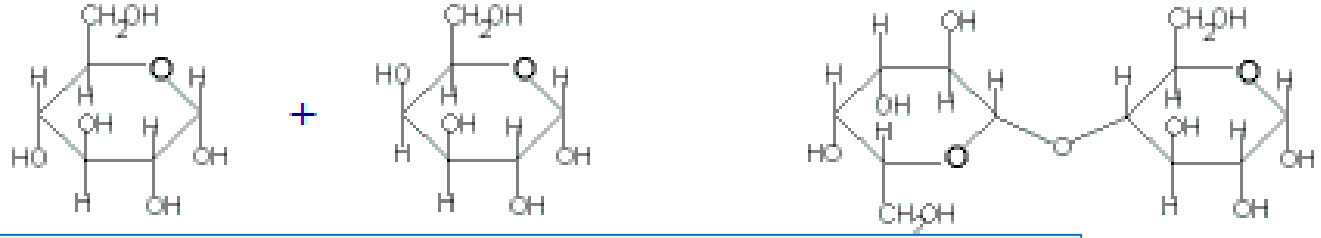
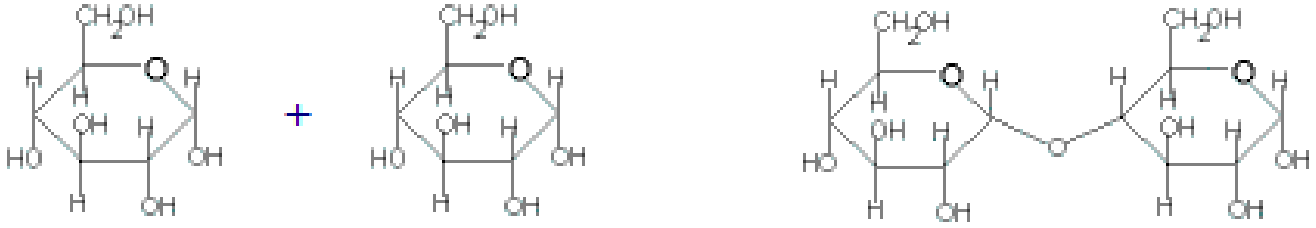


Maltose
(α-D-Glucopyranosyl-(1→4)-α-D-glucopyranose

*sucrose has intermediate sweet taste higher than glucose and lower than fructose.

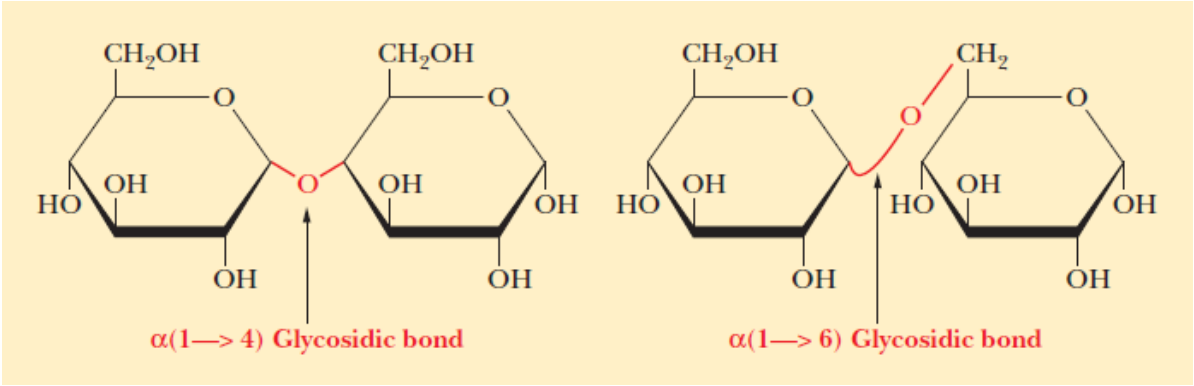
In an expirement we put one gram of sucrose in a cup of water, and half gram of fructose and half gram of glucose in another cup of water ,the sweetness of the second cup was higher than the first one that's because fructose is higher than sucrose in sweetness and the reaction of glucose and fructose produced new substance with different features.

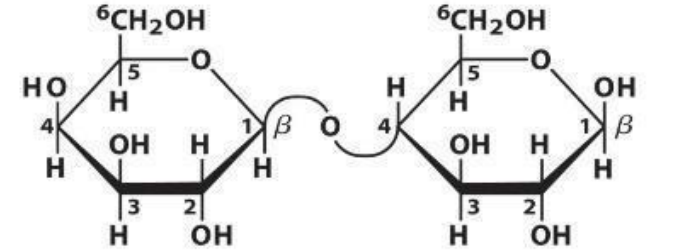
All monosacchrides are oxidized espicially tye anomaric carbon.

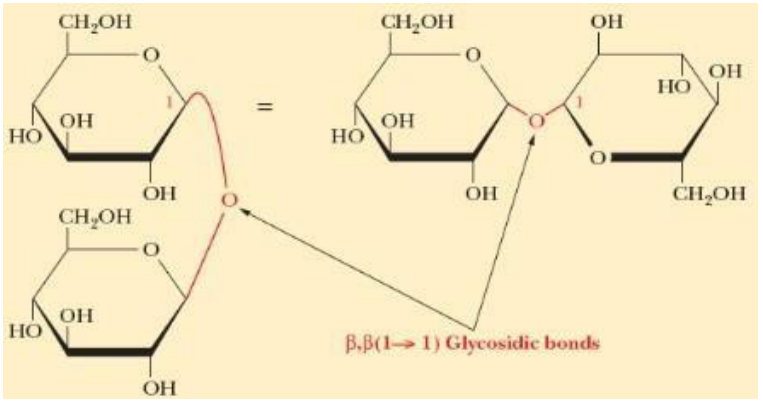
Name	Formula	Formed from	Structure
sucrose	$C_{12}H_{22}O_{11}$	glucose + fructose	---> sucrose + H_2O 
lactose	$C_{12}H_{22}O_{11}$	glucose + galactose	---> lactose + H_2O 
maltose	$C_{12}H_{22}O_{11}$	glucose + glucose	---> maltose + H_2O 

Different forms of disaccharides

The changes of bond depends on the reseduce .
As example,there is an enzyme in the intestine called lactase ,it breaks the glycosidic bond in the lactose, sucrase breaks the glycosidic bond of the sucrose and so on .







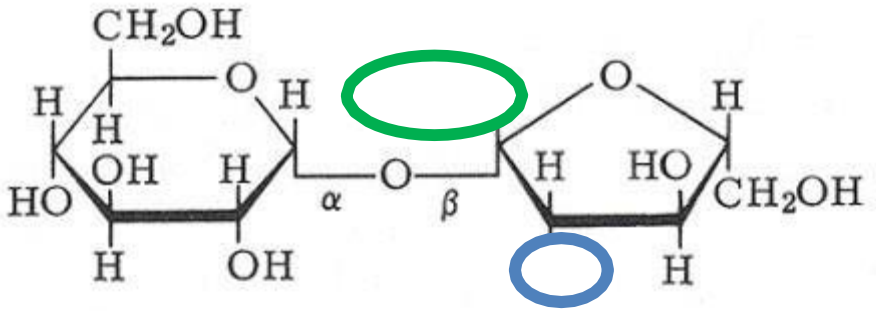
A disaccharide of β-D-glucose.

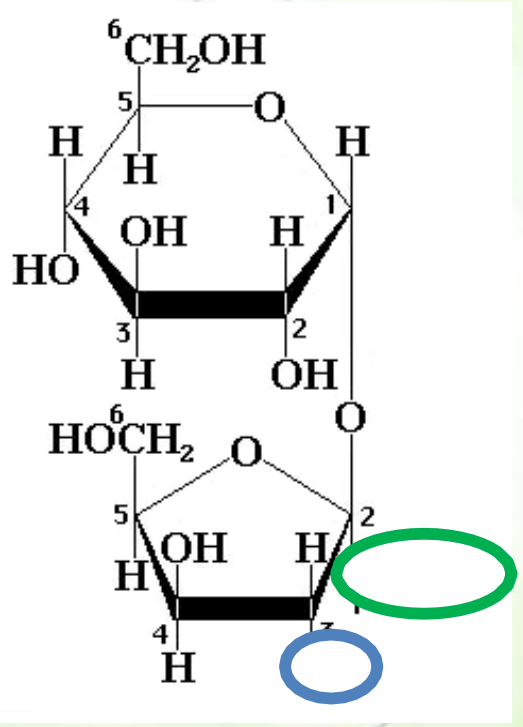
Every sugar has a specific hydolizing enzyme, an example:cellulose ,which is a polysaccharide has a beta(1-4) linkage can not be hydrolized in the human body, because it has not any specific enzyme ,as well as human body has the lactase ,which break the same glycosidic bond.

Sucrose

Notice: The doctor doesn't mention this information

Sucrose is the common table sugar its components are 1) alpha glucose (the hydroxyl group of the anomeric carbon is directed downwards opposite in direction to the last carbon) & 2) fructose (the hydroxyl group is directed upwards in the same direction as the last carbon) in the isolated form . The connection happens on carbon no.1 of glucose & carbon no. 2 of fructose which are both anomeric carbons (this sugar is the only disaccharide that is a non-reducing sugar , because both of the anomeric carbon of two monosaccharides connected to each other , and as we know that the anomeric carbon determine the reducing feature of sugar {Hetero-disaccharide}.





Lactulose

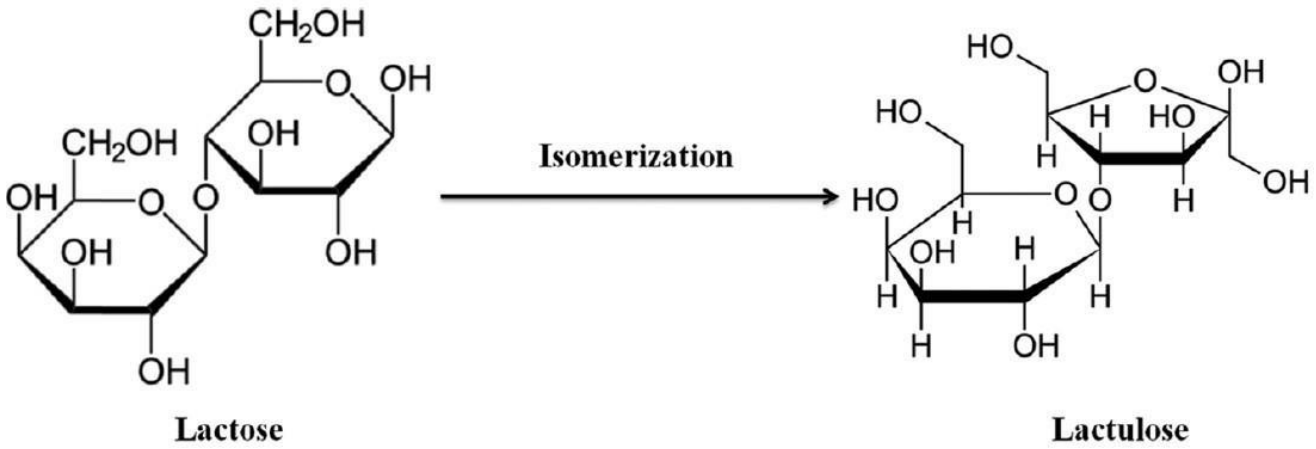
- It is formed by the isomerization of lactose either chemically or enzyr
- What is it made of?
- It has health benefits:
  - It is used in treating constipation by increasing water absorption in the colon.
  - It promotes the growth of health-promoting gut bacteria.
  - It increases the production of small-chain fatty acids and the removal of toxic ammonia.
  - It modulates the immune system.

- Lactose :type of aldose
- Lactulose :type of ketose

&& When we do Isomerization process to Lactose we get Lactulose and The bond still between carbon (1) and carbon (4) because they are an isomer

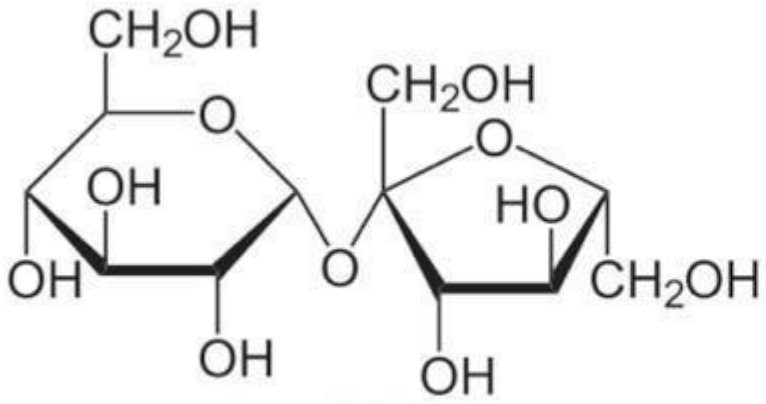
#The absorption process happen just for the monosaccharide in our body so our body (hydrolysis the polysaccharide and the disaccharide to monosaccharides)

#Lactulose: An isomer of Lactose

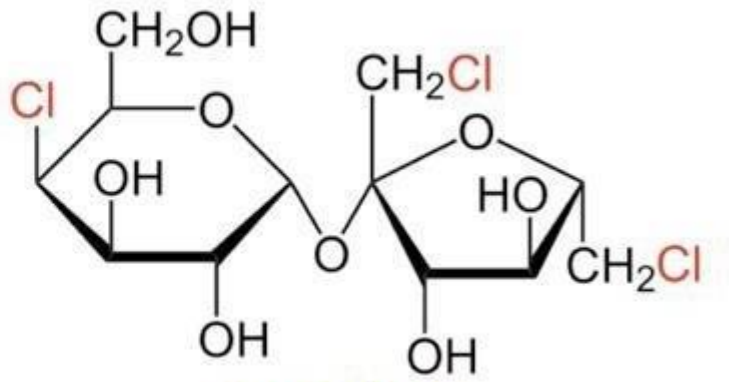


When we eat something that we can't digest it (convert it to monosaccharide) That will cause increasing of the osmotic pressure in the stomach so the H_2O molecules enter to make dilution process so the secretions of the stomach become less rigidity so that will solve the constipation problem

Sucralose (artificial sweetener)



sucrose



sucralose

News > WebMD Health News

Sucralose Damages DNA, Linked to Leaky Gut: Study

Lisa O'Mary
June 01, 2023

Sucralose, a Common Artificial Sweetener, May Increase Cancer Risk

WebMD

- sucrose becomes modified into sucralose, it is considered an artificial sweetener (splenda) , used mostly in diets , there are some reports talking about how harmful these sweeteners are for animals.
- In the old reports they thought that sucralose doesn't affect in human but in new reports discover that sucralose effect in human

Sucralose ,which is marketed under the trade name Splenda, differs from sucrose in two ways. The first difference is that three of the hydroxyl groups have been replaced with three chlorine atoms. The second is that the configuration at carbon atom 4 of the six-membered pyranose ring of glucose has been inverted, producing a galactose derivative. The three hydroxyl groups that have been replaced by chlorine atoms are those bonded to carbon atoms 1 and 6 of the fructose moiety and to carbon atom 4 of the galactose moiety

Milk problems

- Lactose Intolerance: A deficiency of the enzyme lactase in the intestinal villi allows lactase of intestinal bacteria to digest it producing hydrogen gas, carbon dioxide, and organic acids and leading to digestive problems (bloating and diarrhea).
- Galactosemia: Missing a galactose-metabolizing enzyme can result in galactosemia where nonmetabolized galactose accumulates within cells and is converted to the hydroxy-sugar galactitol, which cannot escape cells. Water is drawn into cells and the swelling causes cell damage, particularly in the brain, resulting in severe and irreversible retardation. It also causes cataract.

#Cataract(نيعلا تسدع ماتعا) :A cataract is a cloudy area in the lens of your eye (the clear part of the eye that helps to focus light).

#The milk has many components ; such as carbs , fatty acids ,amino acids and proteins and for sure lactose (the main sugar of milk)

#during the early stages of life (babies) we have a high activity of lactase (this enzyme helps to digest lactose, a sugar found in milk and several other dairy products) because in this period of time the human being is completely depended on milk until 6 years old child (the number and activity of this enzyme decreased)

due to the decreasing of the lactase activity , 50% population suffer from that problem which makes them hate taking milk ; it may cause :

1)diarrheal (low number of lactase --> a lot of non-digest lactose (as a disaccharides) will stay in intestine --> high osmotic pressure --> moving the water toward the intestine --> make diarrheal)

2) The lactose can be used by bacterial flora to produce side product gases like CO2 and CH4

- it isn't necessary for adult to drink milk continuously for the reason (to take its benefits) instead we can take Ca+2 from other Dairy products also we can take vit D from the sun .
- Milk allergy is not considered a complication of taking lactose.
- the adult's teeth can be strengthened by **fluoride** not Ca+2

 # Galactosemia is a genetic disease this happened by galactose a monosaccharide so it can be digested and enter the cells but the cells didn't use it ; there's a deficient enzyme in the degradative (metabolic) pathway of galactose l then the galactose builds up inside the cell ; so the cell drive another pathway which is convert the galactose into alcohol by reduction (galactose → galactitol) , now we have another problem that the galactose has transferases but galactitol hasn't so the galactitol builds up inside the cell --> building up osmotic pressure inside the cells = attracts H2O to the cells --> swelling --> cells explosion -->dies

The direct damage in nerves because it isn't regenerate that make Retardation

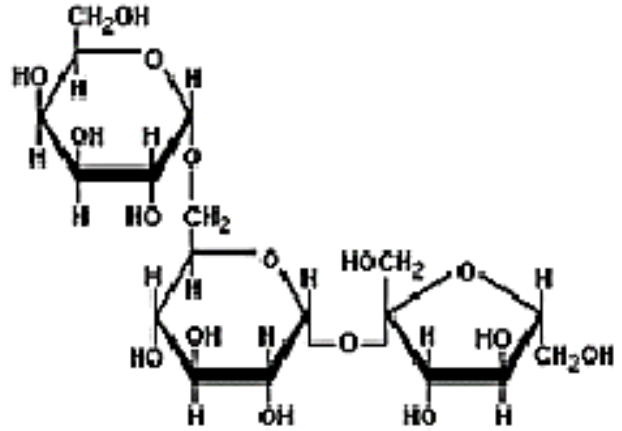
Raffinose

- What are oligosaccharides?
- Example: raffinose
- It is found in beans and vegetables like ca
  brussels, sprouts, broccoli, and asparagus

The bond (1,2) between fructose and glucose can be broken but the bond between galactose and glucose can't be broken and it will stay in the intestine--> more water attraction --> this makes bacterial flora to work and produce CO2,CH4

"You want that double-order of our world-famous baked beans for here... or, we sincerely hope... to go?"

Humans lack the alpha-galactosidase enzyme that is needed to break down raffinose, but intestinal bacteria can ferment it into hydrogen, methane, and other gases.



Raffinose : trisaccharide consist of galactose + glucose + fructose

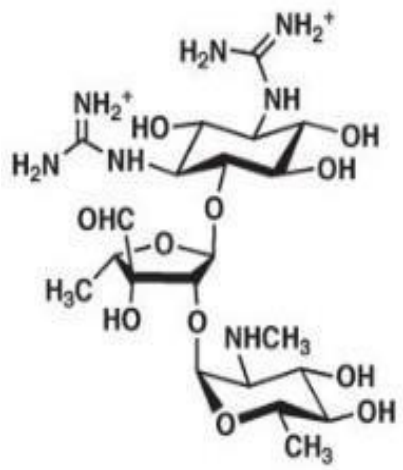
Homework

Recognize the monosaccharides that make up raffinose.

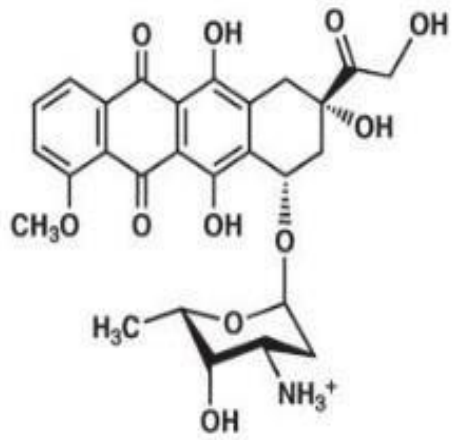
What is the monosaccharide that is attached to *what* disaccharide?

Oligosaccharides as drugs

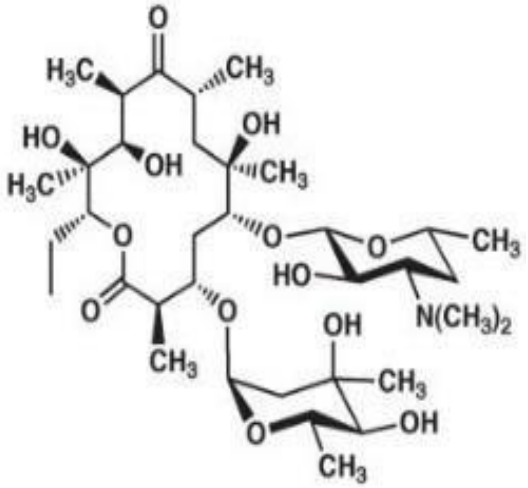
- Streptomycin and erythromycin (antibiotics)
- Doxorubicin (cancer chemothera
- Digoxin (cardiovascular disease)



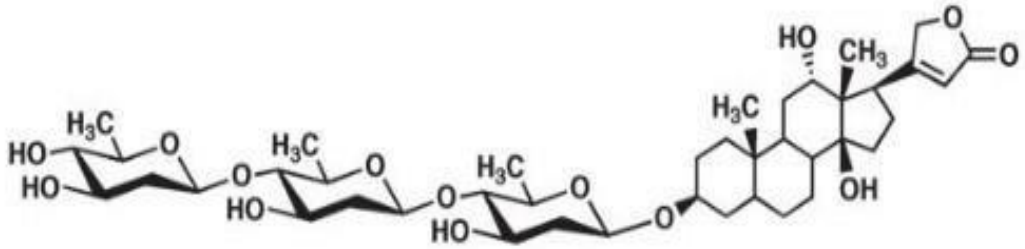
Streptomycin



Doxorubicin



Erythromycin A



Digoxin

Many medicines have sugars in their structure (but it can't be 100% sugar)

Polysaccharides

Very huge molecule maybe consist of thousands of carbons

- What are polysaccharides?
- Homopolysaccharide (homoglycan) vs. heteropolysaccharides
- Features of polysaccharid

If their made of the same monomer we consider it homo-polysaccharides, if their made from more than one type of monosaccharides we consider it hetero-polysaccharides.

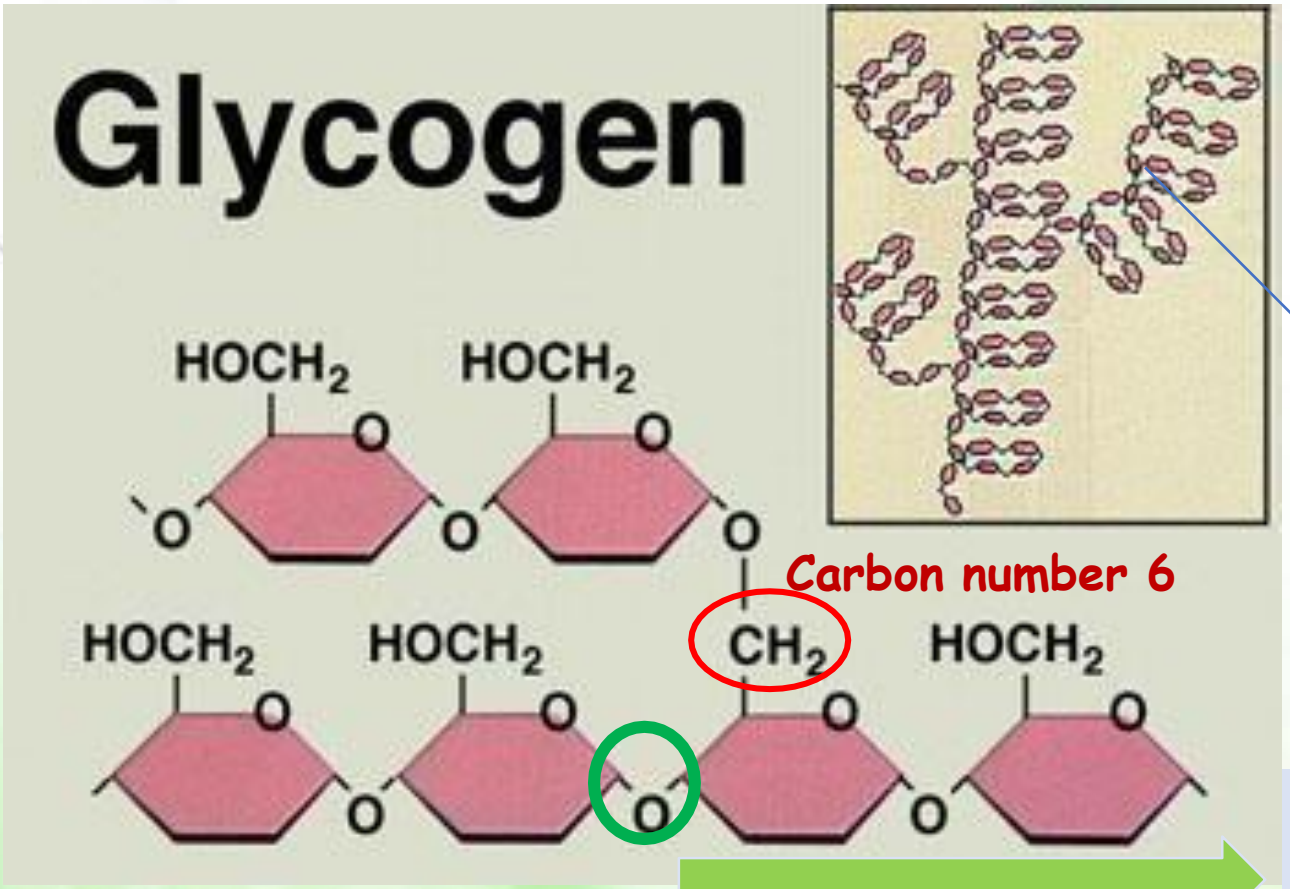
  - Monosaccharides
  - Length
  - Branching
  - Purpose:
    - Storage (glycogen, starch, dextran)
    - Structural (cellulose, pectin, chitin)

Glycogen

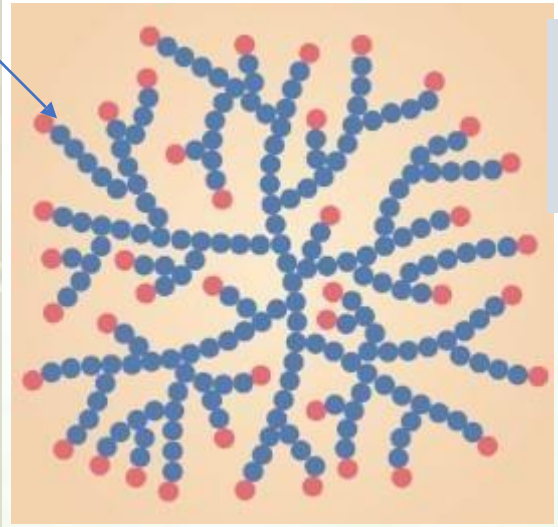
Glycogen (animal starch) : the storage of sugar in all animal cells

عبير ردصم مسجلاف كيلى

Glycogen granules



Carbon number 6



Non reducing sugar (non-reducing ends)

Alpha 1-4 linkages happen along the main chain & branched chain

- the main store of glycogen is Liver and Muscles, since these tissues are very vital and need a large amount of energy.
- Because carbon number one is taken for the bond with the previous residue, all the ends of glycogen end with carbon number four.

#The best way to make branches is on the carbon number 6 because of the low steric strain between the sugar that make it

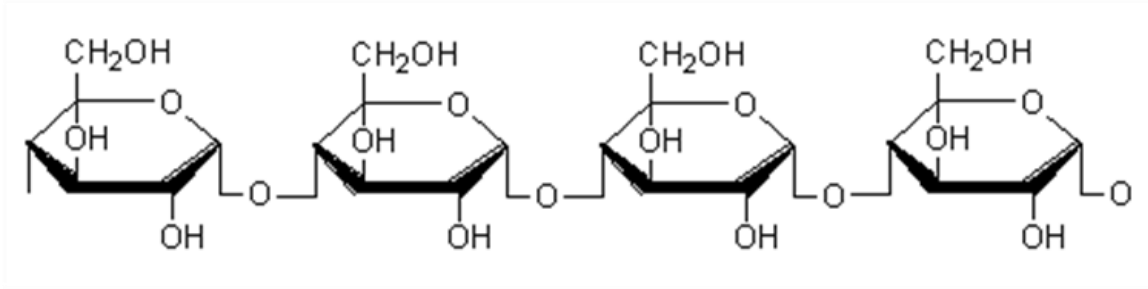
This type of polysaccharide is branched, it has so many layers of branching that happen very often (every 10-13 glucose residues there would be a branching point.

Branching occurs on carbon no.6 (which is outside the cycle)Because carbon(1,4) are in interaction .

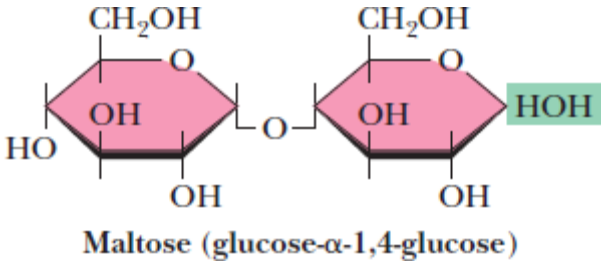
Starch

It is a homosacchride

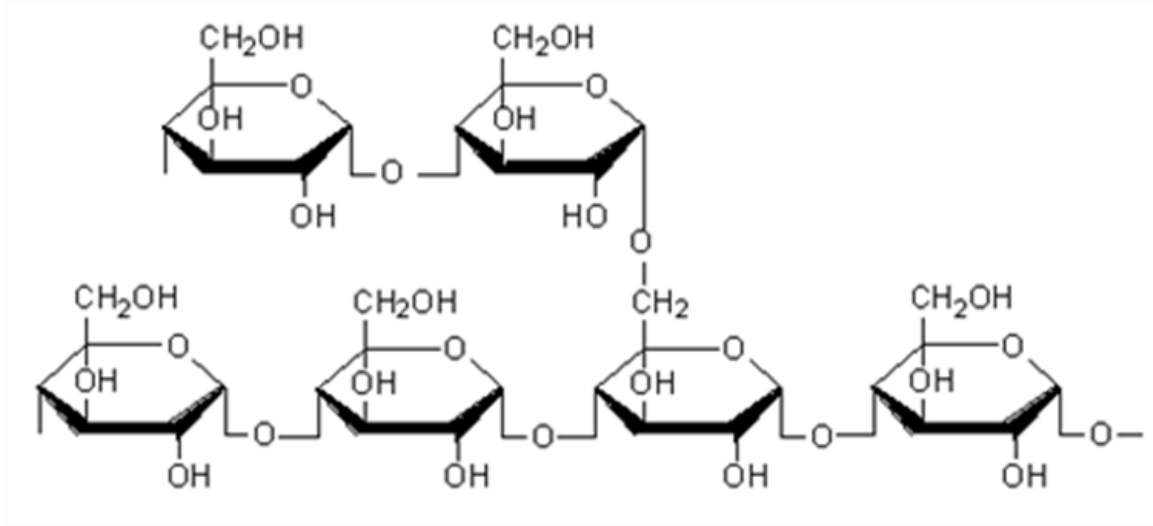
- Which organisms?
- Forms:
  - amylose (10-20%)
  - amylopectin (80-90%)



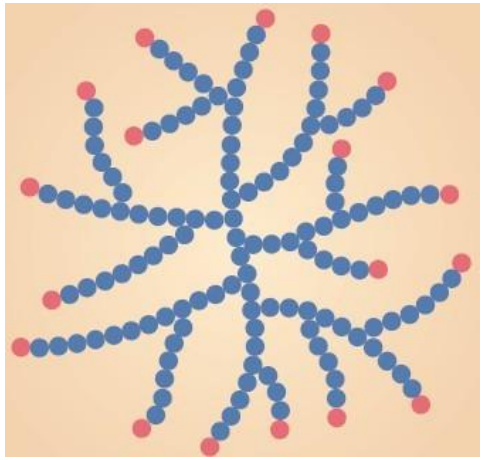
Amylose Structure



Maltose (glucose-α-1,4-glucose)



Amylopection Structure



•Starch is a plant polysaccharide, so the source of it is plant cells, we don't synthesize them in our cells however we can obtain them from food, and there are different sources of starch like rice and corn.

- It is composed of two different forms of molecules :
- Amylopectin (major component)
- Amylose (minor component)

•Amylose is made of long chains of glucose connected by alpha 1-4 linkages Amylose doesn't have branches.

- Mean while amylopectin has branches every 25 residues
  The similarities: both made glucose with alpha (1,4)
  The differences: Amylose helix shape without branching, but amylopectin branches on carbon 6 with alpha (1,6) linkage and it's not reducing
  When it enters the body , it will exposed to fragmentation and becomes maltose and it will break by maltase in more than one place, such as the oral cavity and pancreas to become an monosaccharide and ready to absorption

Glycogen vs. amylopectin

If we have more branched it will increase the surface area and increasing the solubility

- Both are made from the same monomer (glucose) and both are branched.

Amylopectin can be digested when obtained through our diet

- Glycogen exists in animals and 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.
  - Easy access to glucose residues.

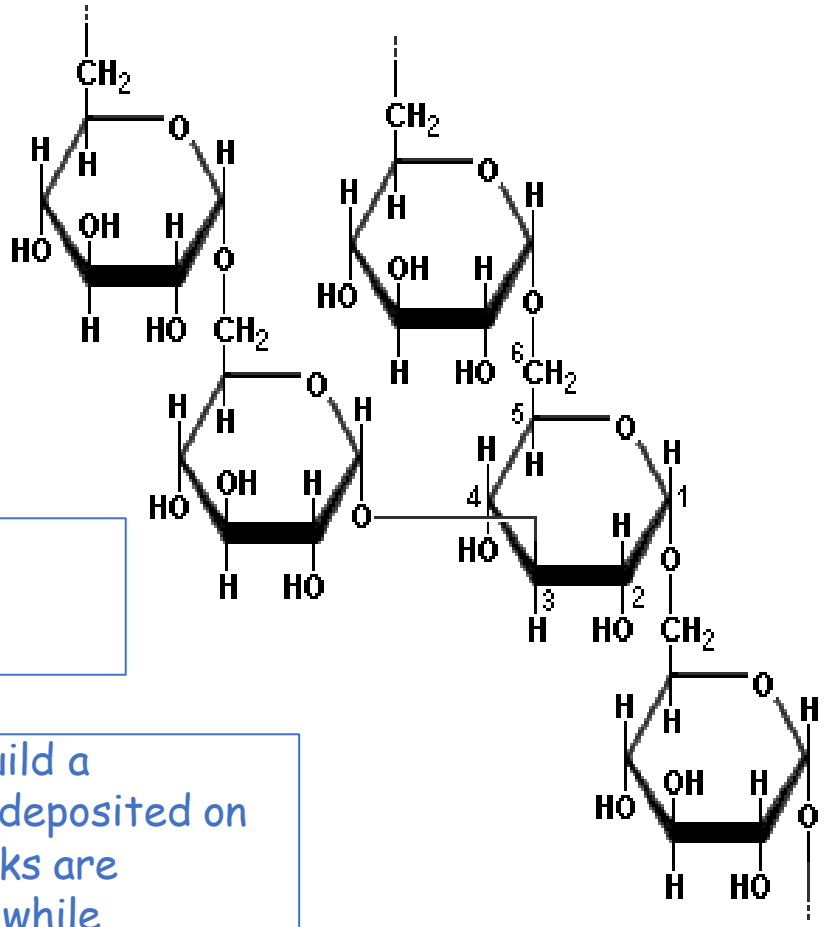
Both have the same types of bonds
They have different sources: Glycogen is synthesized by animals, Amylopectin is synthesized by plants.

Branching provides more free ends, so there will be more sites that enzymes can attack and break glycogen down, and this will increase the efficiency of breaking down this molecule.

Dextran

Important in oral cavity

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

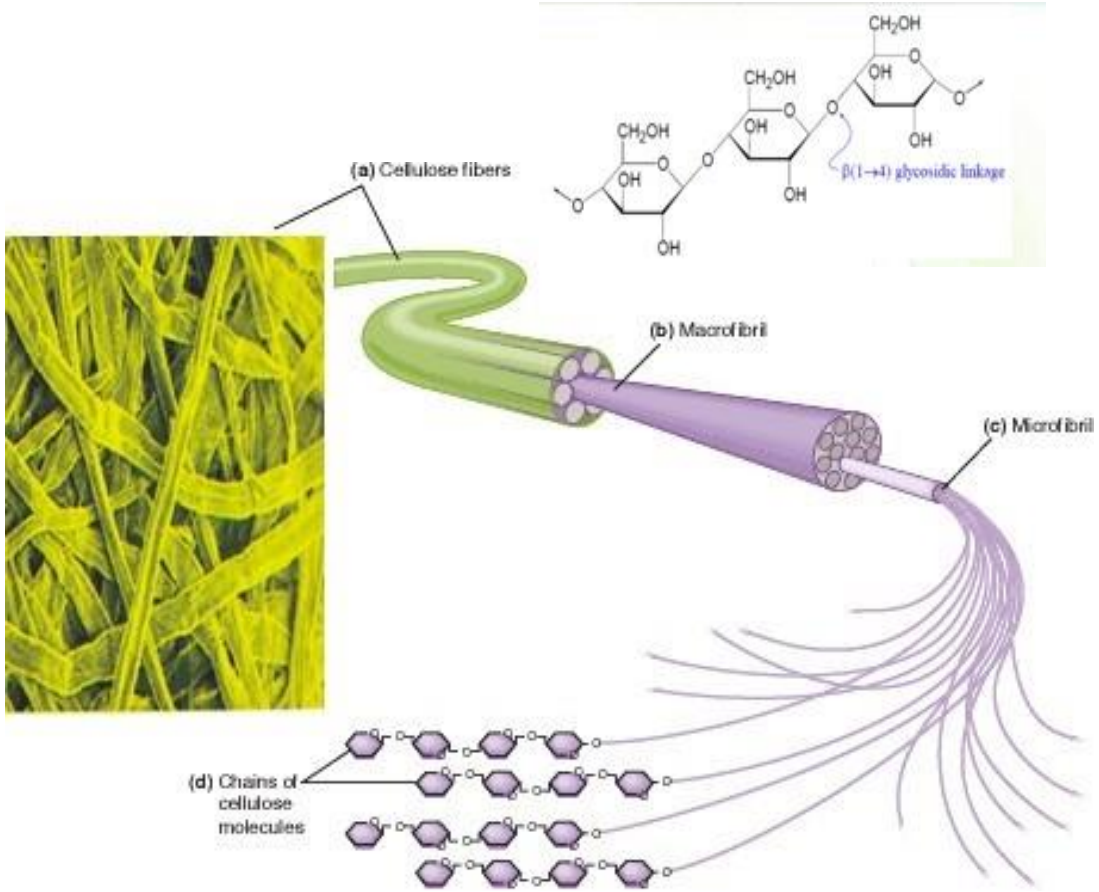


Because of the possibility of these different branches a complicated & highly branched polysaccharides are formed

Bacteria in the mouth produce dextran and build a complicated molecular network, that could be deposited on the surface of teeth. These molecular networks are inhabited by bacteria, that linger there for a while, producing acids and helping to encourage the destruction and damage leading to tooth decay and caries. That's why its important to maintain oral health

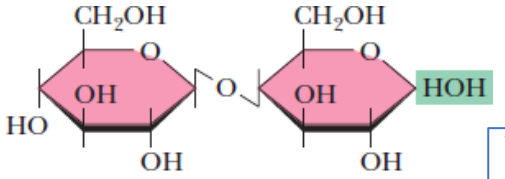
Cellulos

Provides structural support especially In the stalks, leaves and even fruits of different plants.
Linkage is beta 1-4 glycosidic linkage.
Our bodies can't break down cellulose or any molecule that has a beta
linkage. (we don't have cellulase)
Cellulose has no branching and parallel chains hydrogen bond which gives it rigidity.



Cellulose and diet

- Since cellulose is hydrophilic it will attract and aggregate water molecules in intestines which reduces constipation.
  Cellulose is also a bulky molecule, it increases in size so you feel more full.



Cellobiose (glucose-β-1,4-glucose)

This is the disaccharide building block of cellulose,

It has a string-like shape so we can compact it and form a non- covalent interactions so it's becoming stronger

What the Dr said about the previous slide:

- We can found it in plants
- Our body can't digest it,but some animals can like cows
- Because it's polar so can make hydrogen bonds with water that will increase the osmotic pressure,so it's gives a feeling of fullness
- Also it's can make a network that can catch the cholesterol snd some toxins

Chiti

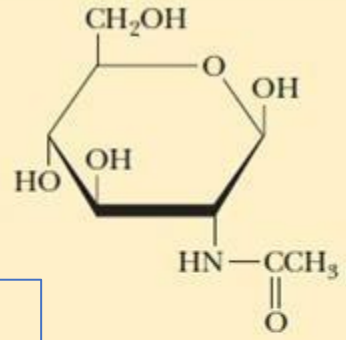
Its structural and homo saccharide

- What is the precursor? N-acytelglucoseamine
- Where does it exist? exoskeleton of insects

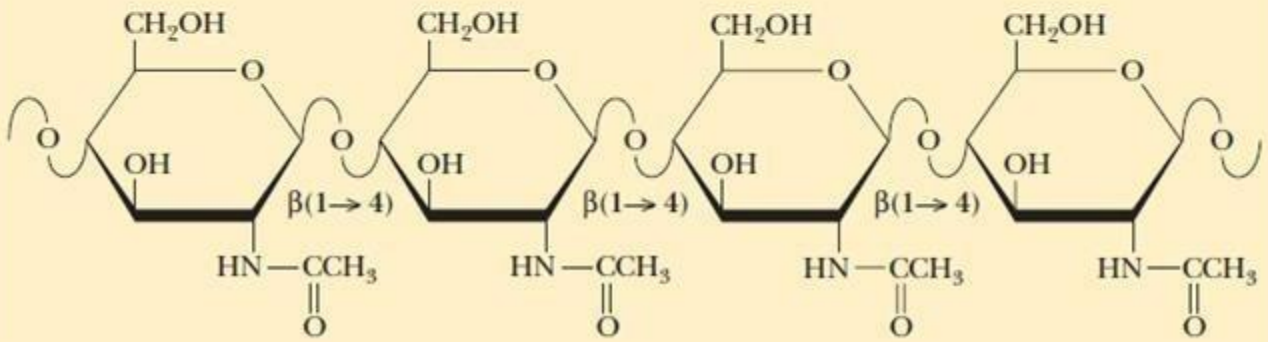
Exoskeleton

That covers some sea animals and insects

It's too modified suger



N-Acetyl-β-D-glucosamine



1-4 beta linkage.
Structural polysaccharide.

It's a hetrosacchride

Pecti

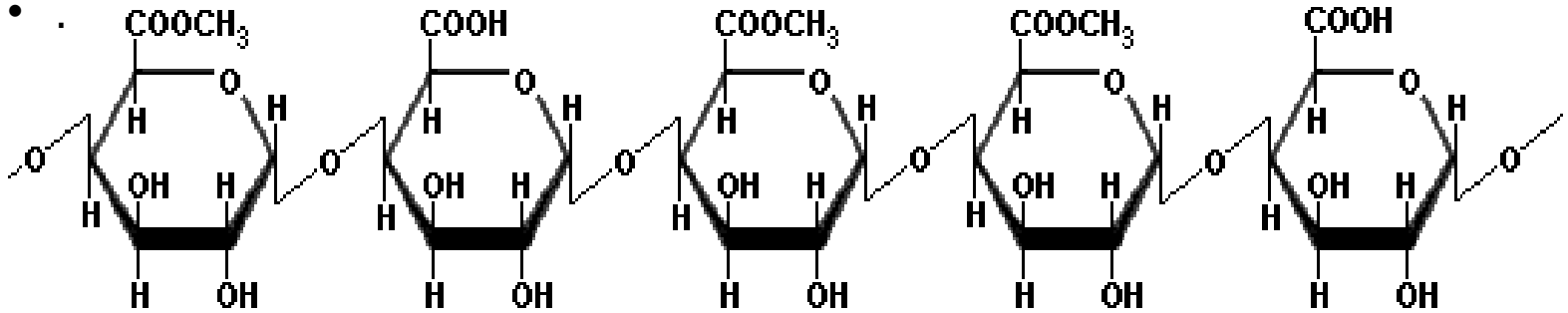
It's found in bacteria and plants cell

n

- What is the precursor? Modified galactose. Modifications include oxidation and esterification.
- Where does it exist? Used as a gelling agent in vegetarian jelly, as an alternative to the gelling agent extracted from animals called gelatin.

Ester coming from glucuronate

Galacturonate



Don't focus on the structure and modification of the monomers

Are polysaccharides reducing?

- 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.

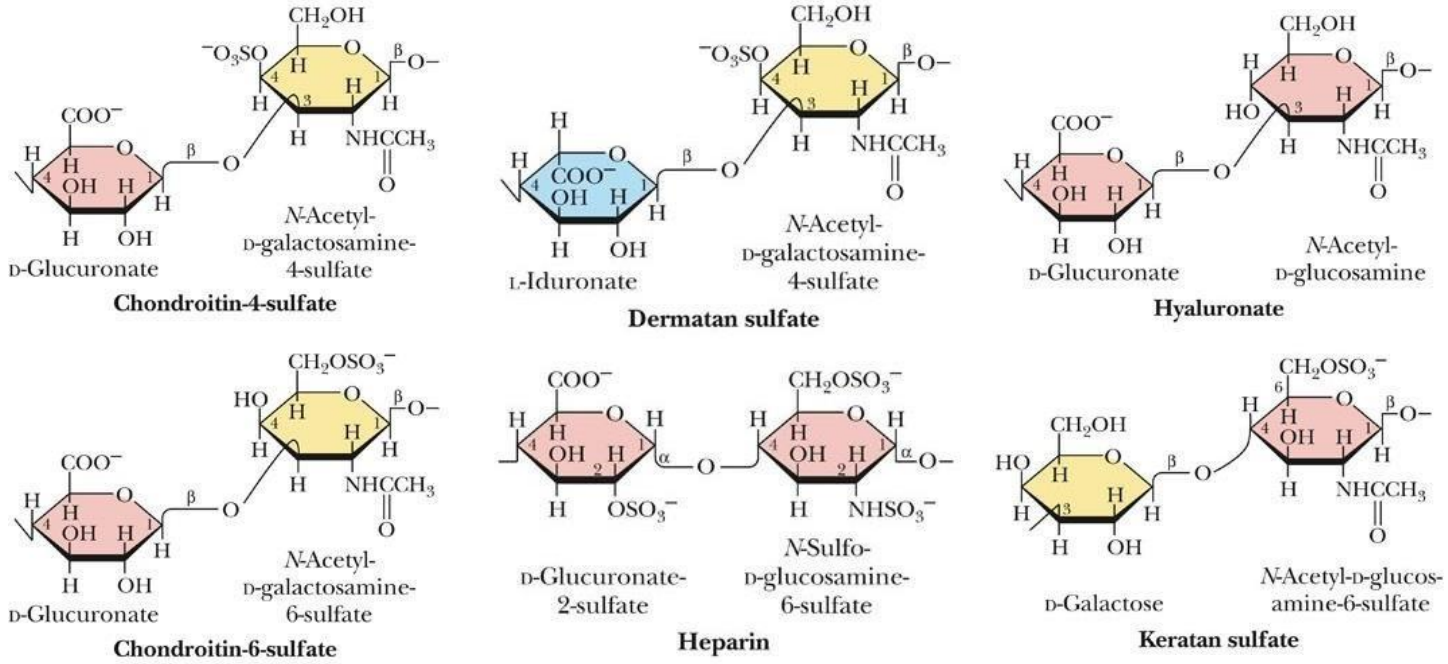
Glycosaminoglyca ns

(GAG's)

- What are they? Where are they located?

It's made in our body and it's hetrosacchride

- 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



You have to know only the names of these structure

What the Dr said about the previous slide:

- GAGs are composed of repeating units of disaccharides.
- At least one of them is an amino sugar (glucosamine or galactosamine)
- Also one of them (not necessarily the other one) has a negative charge, it can be sulfated or carboxylated.
- Such a molecule is highly polar and negatively charged which makes it a very viscous structure (aggregates a lot of water molecules). That's why GAGs can be found in places in our body that require shock absorbement.

It's in the ECM (extra cellular matrix) and it's dynamic cuz it's react with the surroundings environment

Note: more branches more resistant

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

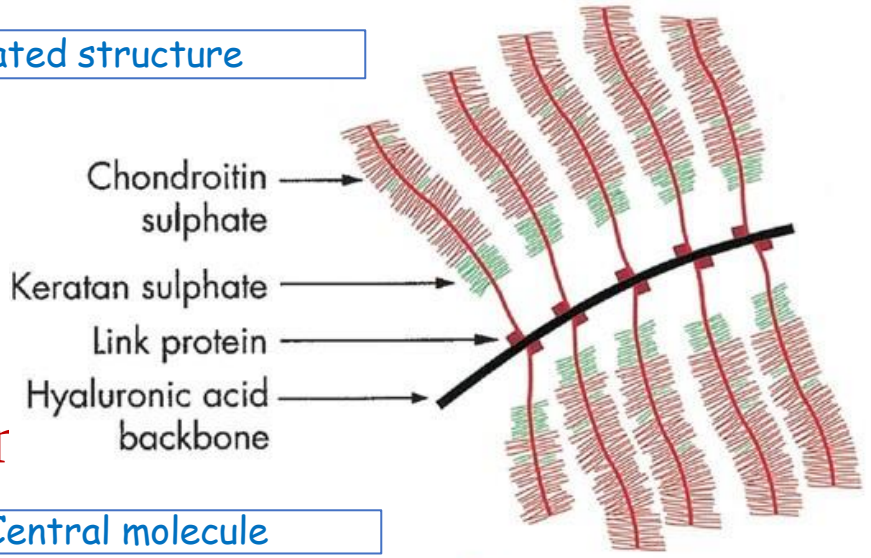
Proteoglycans

The main molecule is sugar with a small amount of protein added to it.

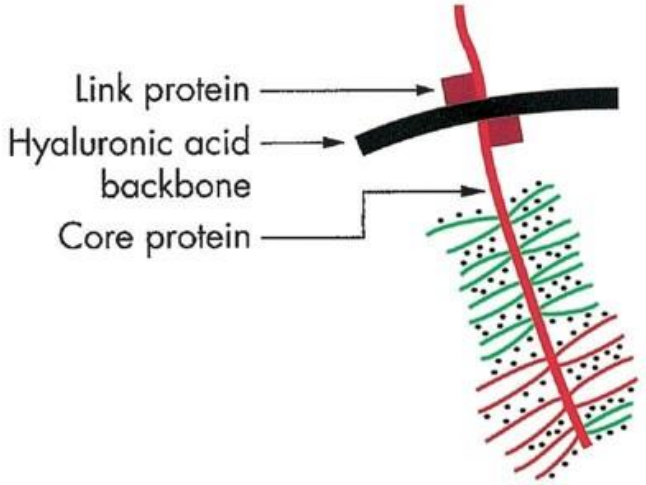
- Lubricants
-
-
- Structural components in cor tissue
- Mediate adhesion of cells to extracellular matrix
- Bind factors that stimulate cell proliferation

Helps in cell-cell communication
The sugar is the major component & the protein is the minor component

A complicated structure

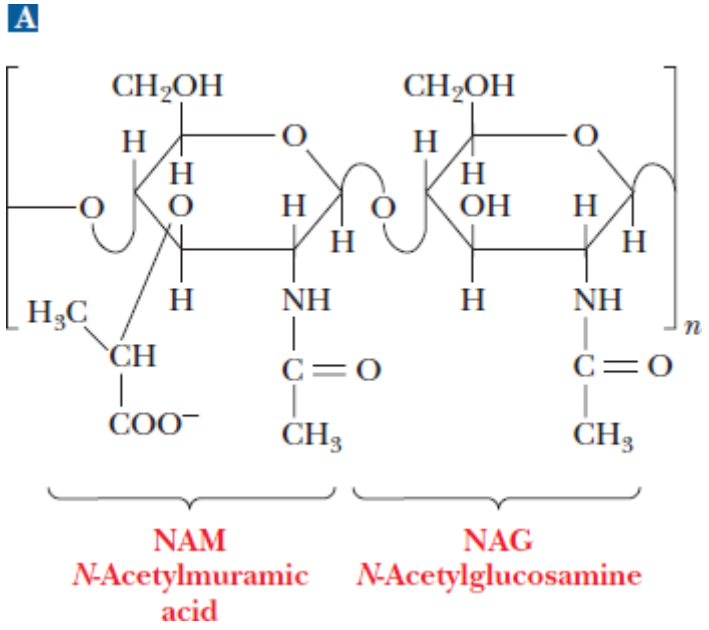


Central molecule

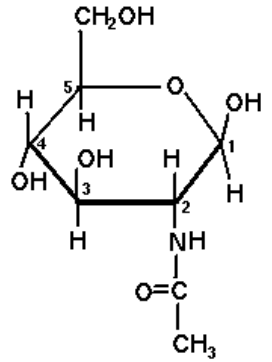


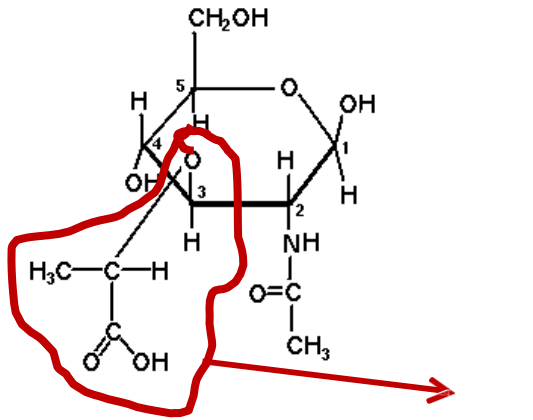
Bacterial cell wall

The hetero-polysaccharide that composes the bacterial wall is composed of repeating units of NAM and NAG.



NAG is modified by adding lactic acid to form NAM.


N–acetylglucosamine (NAG)

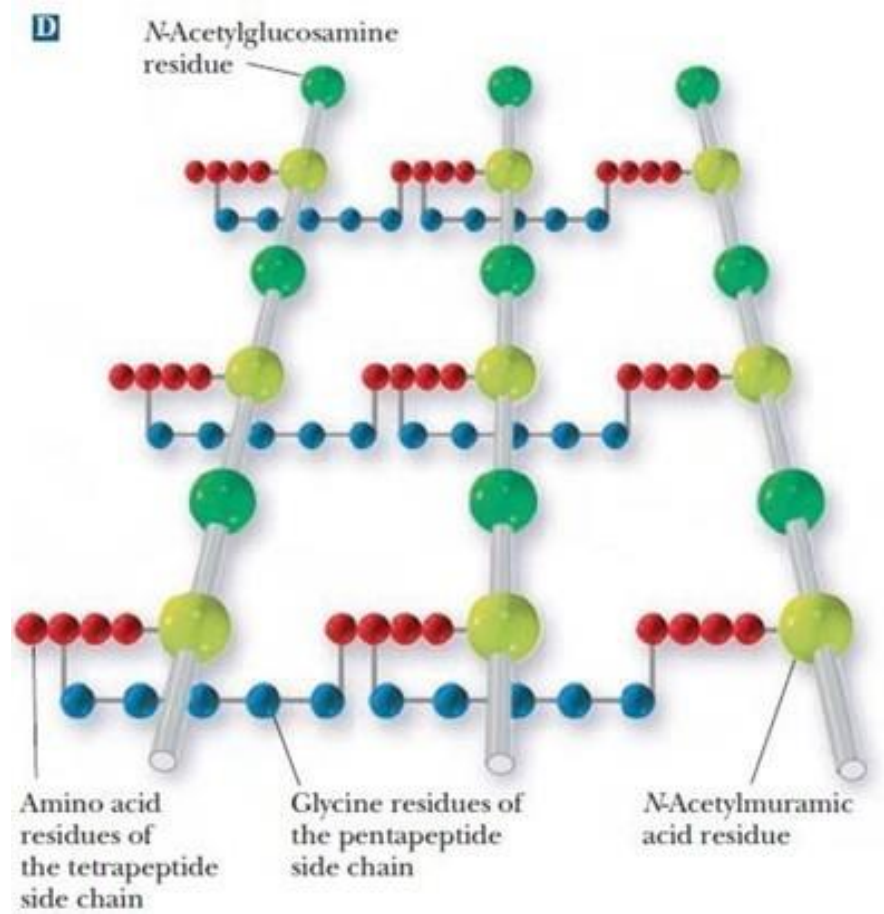

N–acetylmuramic acid (NAM)

Lactic acid

As you can see repeating units of NAG and NAM are arranged parallel to each other with peptide chains cross linking them. This is why they are called peptidoglycans.

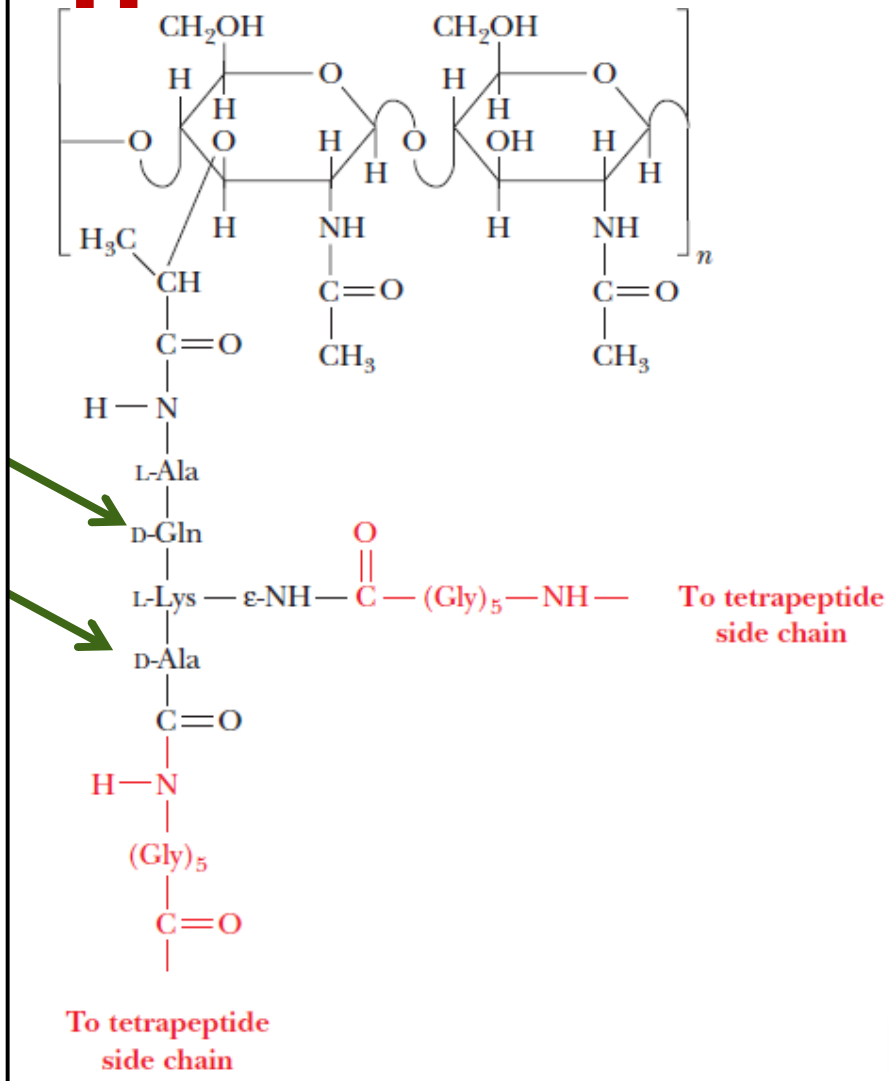
Green and yellow balls represent the disaccharides repeating units. The red and blue balls are amino acids.

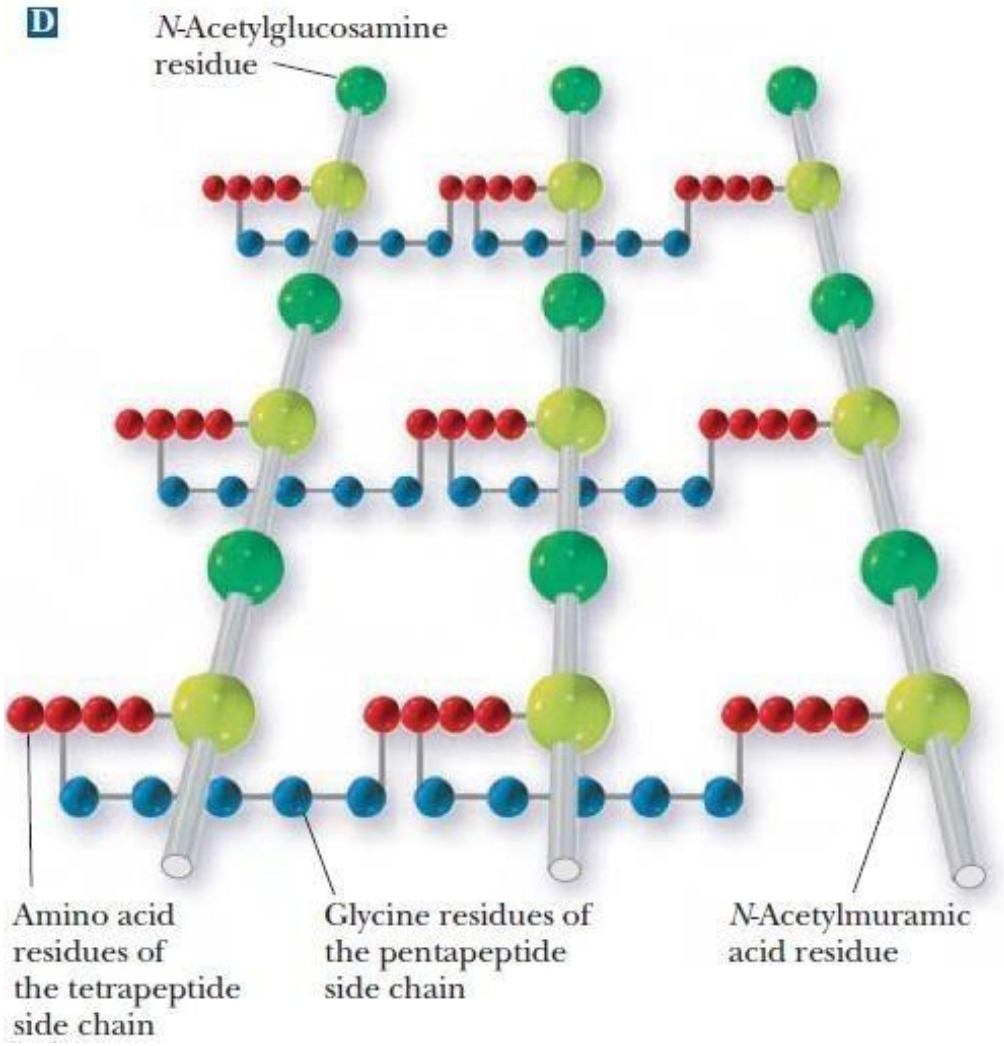
This arrangement is what gives the bacterial cell wall its rigidity,.



Peptidoglycan

The 4 red balls are (Ala,Gln,Lys,Ala). the last two (Lys and Ala) are connected to Gly (blue balls) to bind the polysaccharide chains together.





Glycoproteins

- The carbohydrates of glycoproteins are linked to the protein component through either *O*-glycosidic or *N*-glycosidic bonds
  - The *N*-glycosidic linkage is through the amide group of asparagine (Asn, N)
  - The *O*-glycosidic linkage is to the hydroxyl of serine (Ser, S), threonine (Thr, T) or hydroxylysine (hLys)

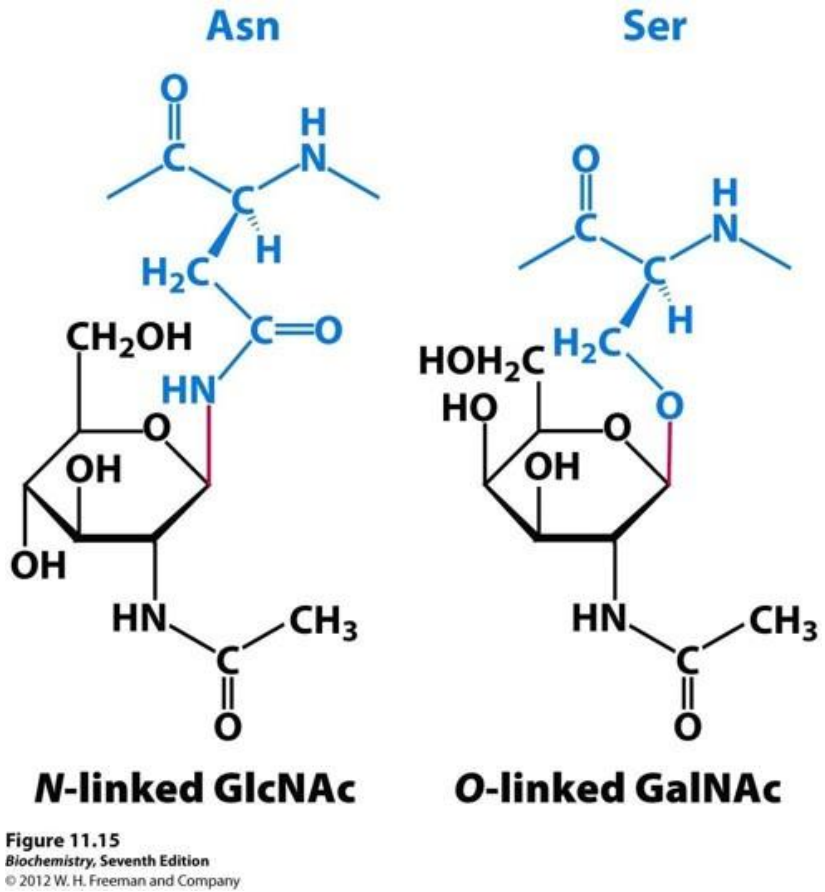


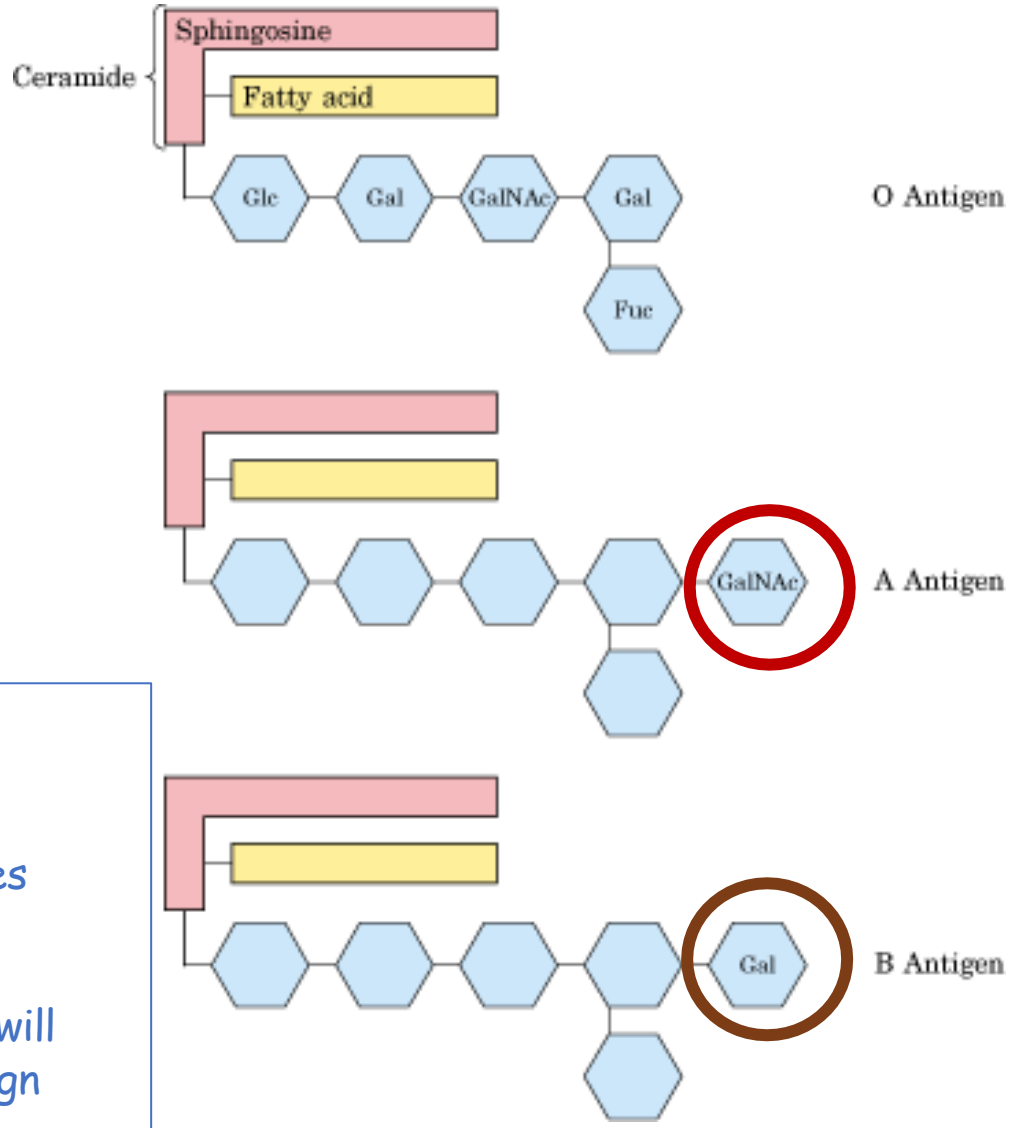
Figure 11.15
Biochemistry, Seventh Edition

Significance of protein-linked sugars

- Soluble proteins as well as membrane proteins
- Purpose:
  - Protein folding: the sugar component facilitates the process of getting the correct 3D shape of a protein.
  - Protein targeting to cellular compartments.
  - prolonging protein half-life
  - Cell-cell communication
  - Signaling: signaling means transferring information from outside the cell to the inside.

Blood typing

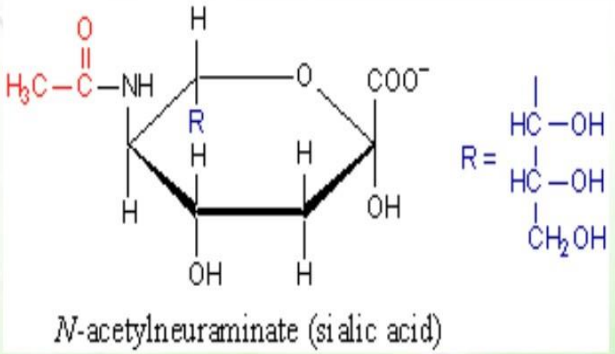
- Three different structures:
  - A, B, and O
- The difference:
  - *N*-acetylgalactosamine (for A)
  - Galactose (for B)
  - None (for O)



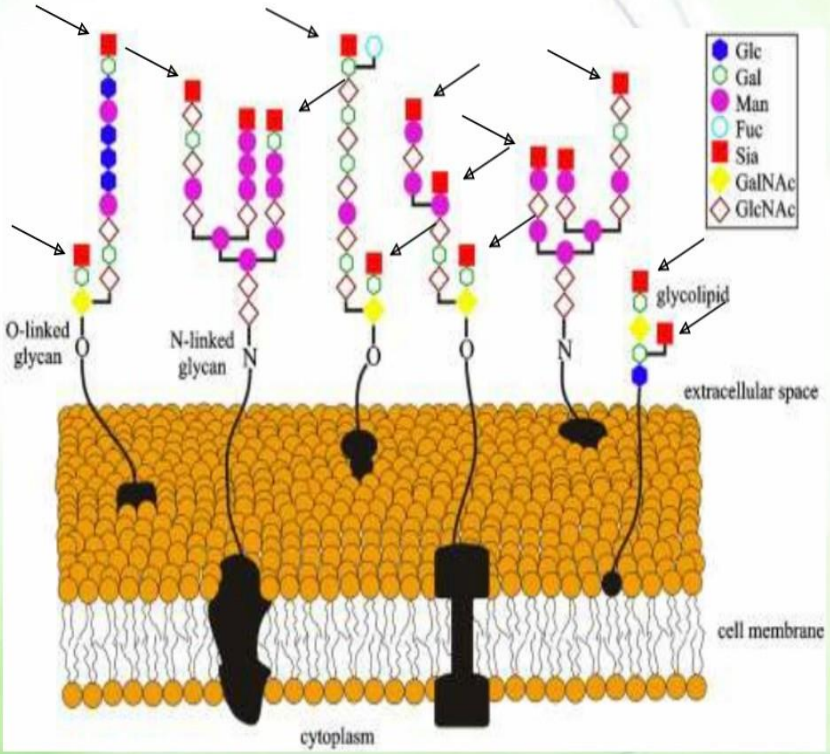
The reason why a person with blood type O can donate blood to a person with any other blood type Is because the O antigen doesn't have any additional monosaccharides that can be identified as foreign.
but if someone of blood type A donates to someone with type O, the recipient's body will recognize N-acytylgalactoseamine as foreign and hemolysis will occur.

Sialic acid

- N-acetylneuraminate
- Precursor: the amino sugar, neuraminic acid
- Location: a terminal residue of oligosaccharide chains of glycoproteins and glycolipids.



N-acetylneuraminate (sialic acid)



Past Paper questions

1) The residues of the following disaccharide are connected by a beta linkage:

A) Sucrose

B) Maltose

C) Pectin

D) Lactose

E) Raffinose

Answer: D

2) The storage form of sugars in animal cells is:

A) Glycogen

B) Pectin

C) Chitin

D) Amylose

E) Cellulose

Answer: A

3)The hetero-polysaccharides with sulfated sugars, amino sugars and/or oxidized sugars that are mainly derived of glucose and galactose and are found in extracellular matrix are:

A) Pectin

B) Glycosaminoglycans

C) Chitin

D) Dextran

E) Cellulose

Answer: B

4)In the congenital disease galactosemia, high concentrations of galactose and galactitolaccumulate in the blood. On the basis of their names, you would expect which one ofthe following statement to be correct ?

A. galactitol is an aldehyde formed from the keto sugar galactose

B. galactitol is the oxidized form of galactose

C. galactitol is the sugar alcohol of galactose

D. both galactitol and galactose are sugars

E. both galactose and galactitol would give a positive reducing sugar test

Answer: C

5)A patient was diagnosed with a deficiency of the lysosomal enzyme alpha-galactosidase.The name of the deficient enzyme suggest that it hydrolyzes a glycosidic bond, which bestdescribes the bond that can't be broken ?

A. multiple hydrogen bonds between two sugar molecules

B. Between the anomeric carbon of a sugar and an OH (or N) of another molecule

C. Between two anomeric carbons in polysaccharides

D. Internal bond formation between the anomeric carbon of a monosaccharide andits own fifth carbon hydroxyl group.

E. Between the carbon containing the aldol or keto group and the α-carbon of the sugar.

Answer: B