Carbohydrates

Summer 2023

What are they?

- Carbohydrates are polyhydroxy aldehydes or ketones.
- Saccharide is another name for a carbohydrate

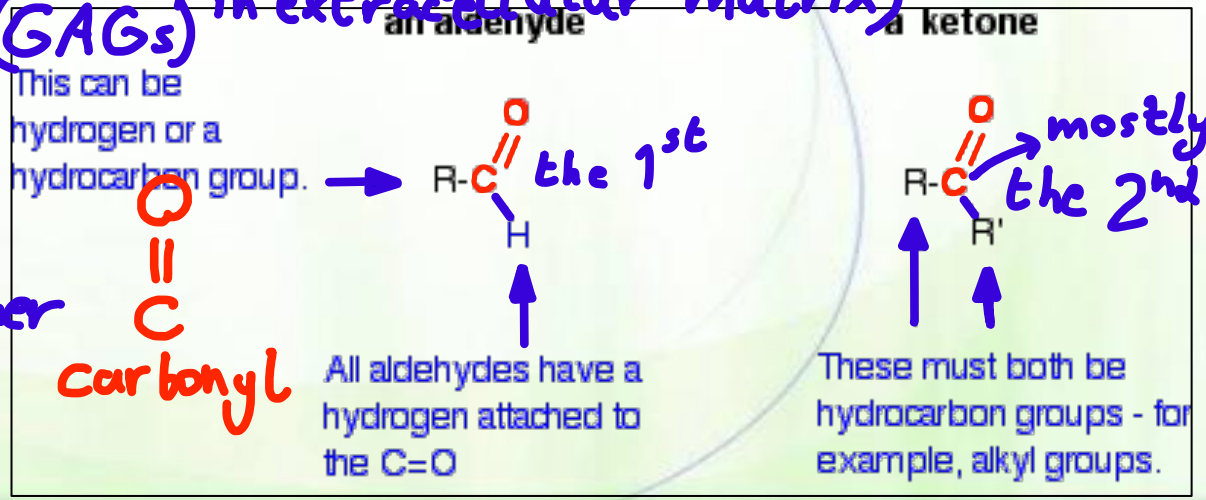
OH متعدد — aldose sugar — ketose sugar

at least in the 2nd carbon (In carbohydrates it's in the 2nd carbon)

- Functions:
  - Source of energy (glycogen and starch)
  - Structure (cellulose and chitin) (in plants, in insects) (support)
  - Building blocks (glycosaminoglycans) (GAGs) (building blocks for molecules in extracellular matrix)
  - Cellular recognition (glycoproteins)

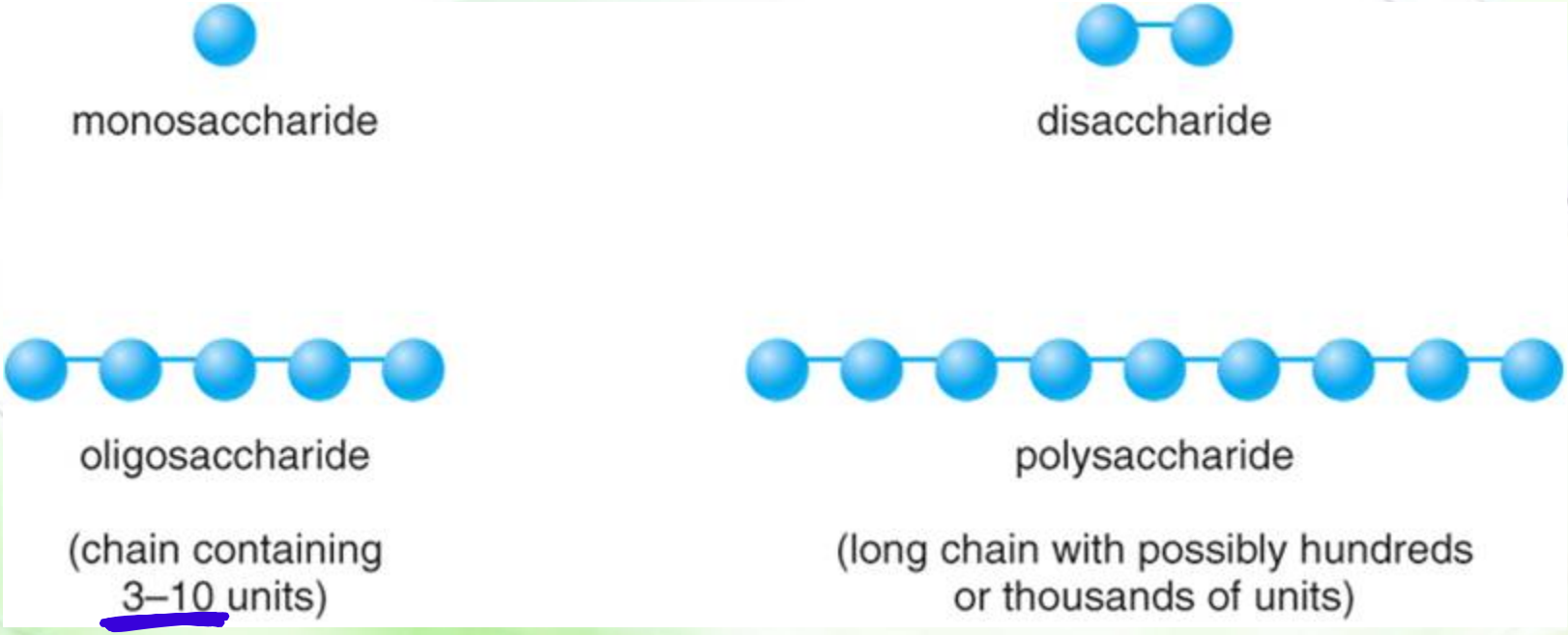
↳ membrane proteins has sugar outside the cell to recognize the cell from another

Like blood group (A, B, AB, O) they differ in sugar in the surface of RBCs



Classification I

- By the number of sugars that constitute the molecule
  - Monosaccharides, Disaccharides, Oligosaccharides, Polysaccharides

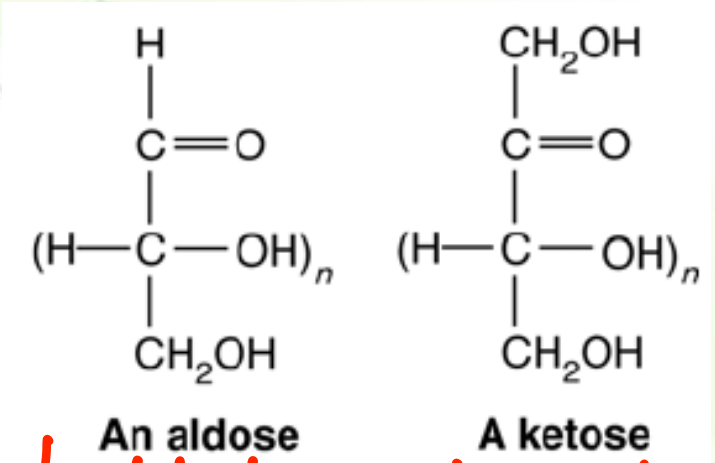


Carbohydrates – natural forms

- Most carbohydrates are found naturally in bound form rather than as simple sugars.
  - Polysaccharides (starch, cellulose, inulin, gums), glycogen
    storage of sugar in plant
    in human
  - Glycoproteins and proteoglycans (hormones, blood group substances, antibodies) (outside the cell to recognizing or identify the cells)
  - Glycolipids (cerebrosides, gangliosides)
  - Glycosides The molecule that contain sugar bond to each others like disaccharides, polysaccharides
  - Mucopolysaccharides (hyaluronic acid) (GAGs)
  - Nucleic acids (DNA, RNA)

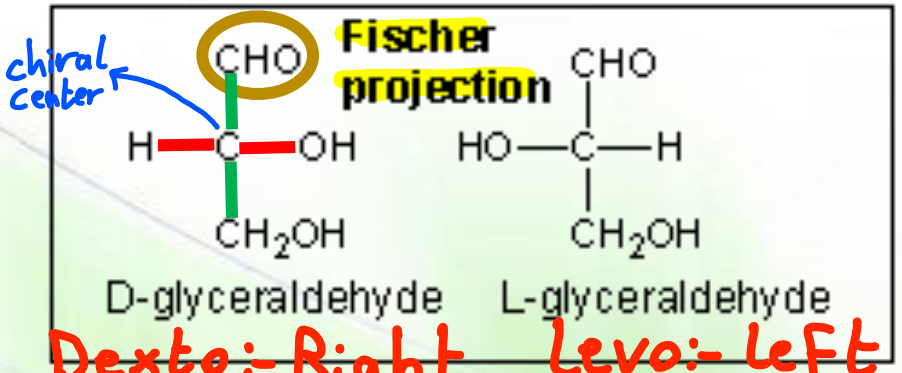
Monosaccharides

- Basic chemical formula: $(CH_2O)n$
- They contain two or more hydroxyl groups.

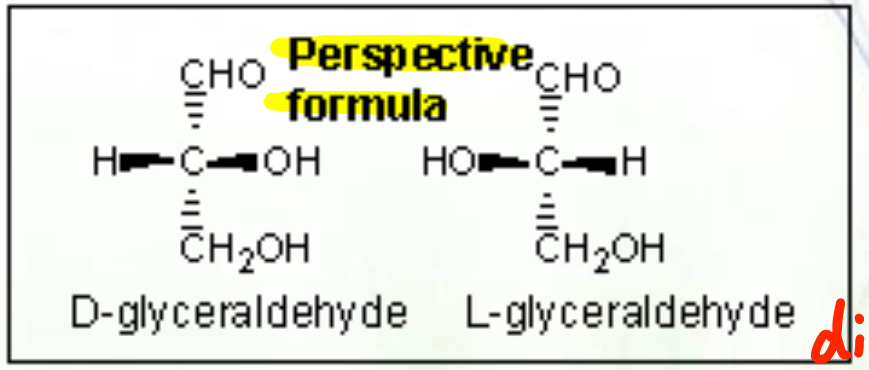


* The simplest aldehyde sugar has 3 carbons atoms because it should have at least 2OH group

Fisher projections or perspective structural formulas.



Dexto:- Right levo:- left



CH2OH
C=O
CH2OH
dihydroxy acetone
*The simplest ketone sugar

— Forward | Backward

Top (C1): Most highly oxidized C

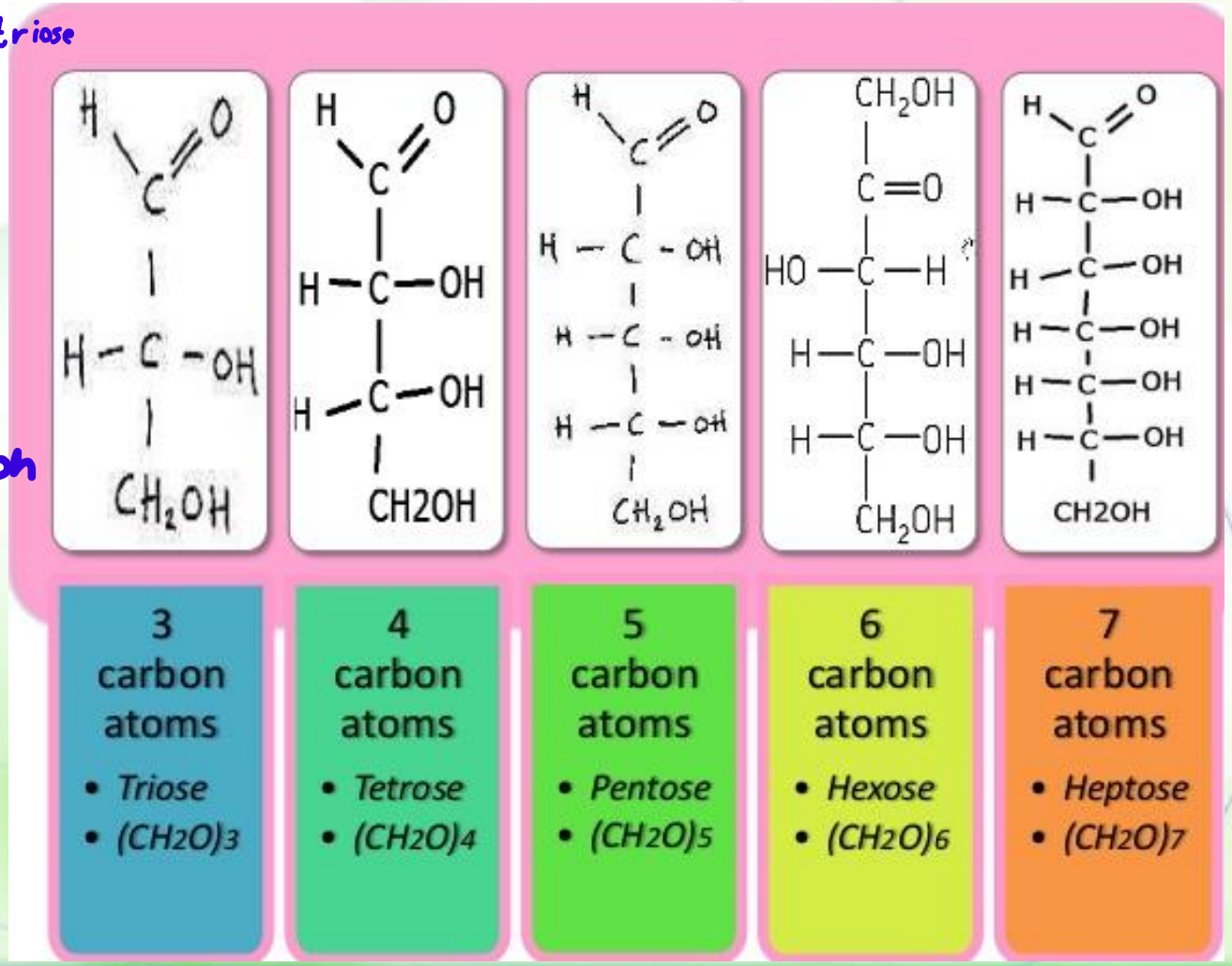
D, L:- For orientation

Classification 2

- By the number of carbon atoms they contain.

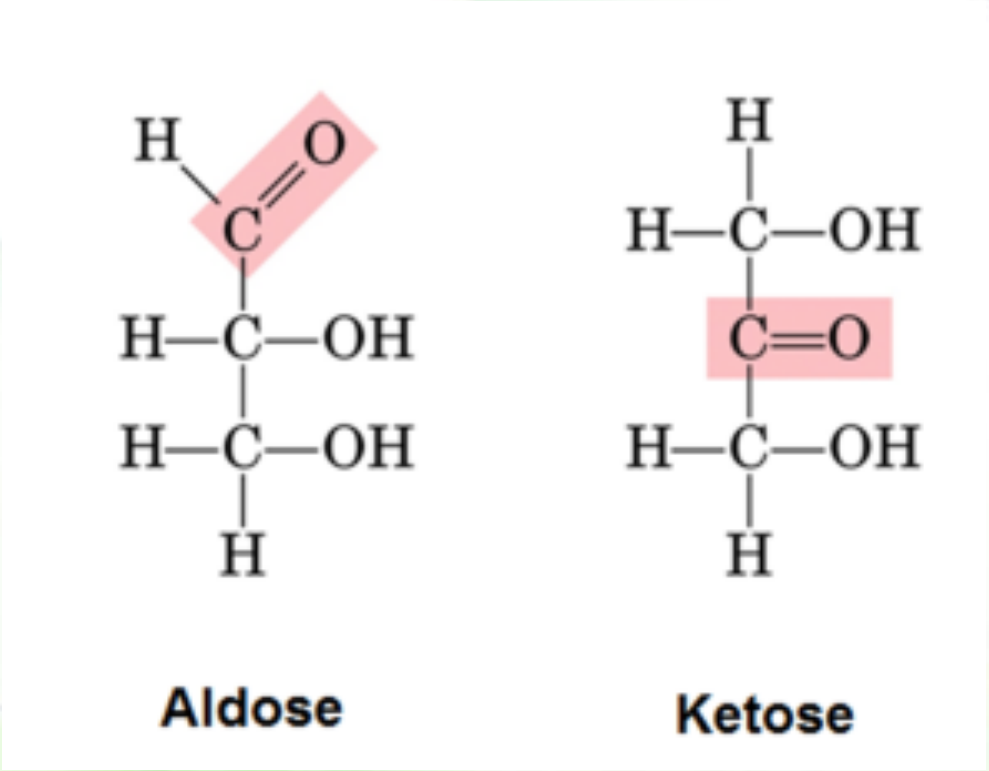
		aldehyde	ketone
Triose	3C	aldotriose	ketotriose
Tetrose	4C	aldotetrose	
Pentose	5C	aldopentose	
Hexose	6C	aldohexose	
Heptose	7C	aldoheptose	
...			

*The most abundant sugars have 5 or 6 carbon atoms



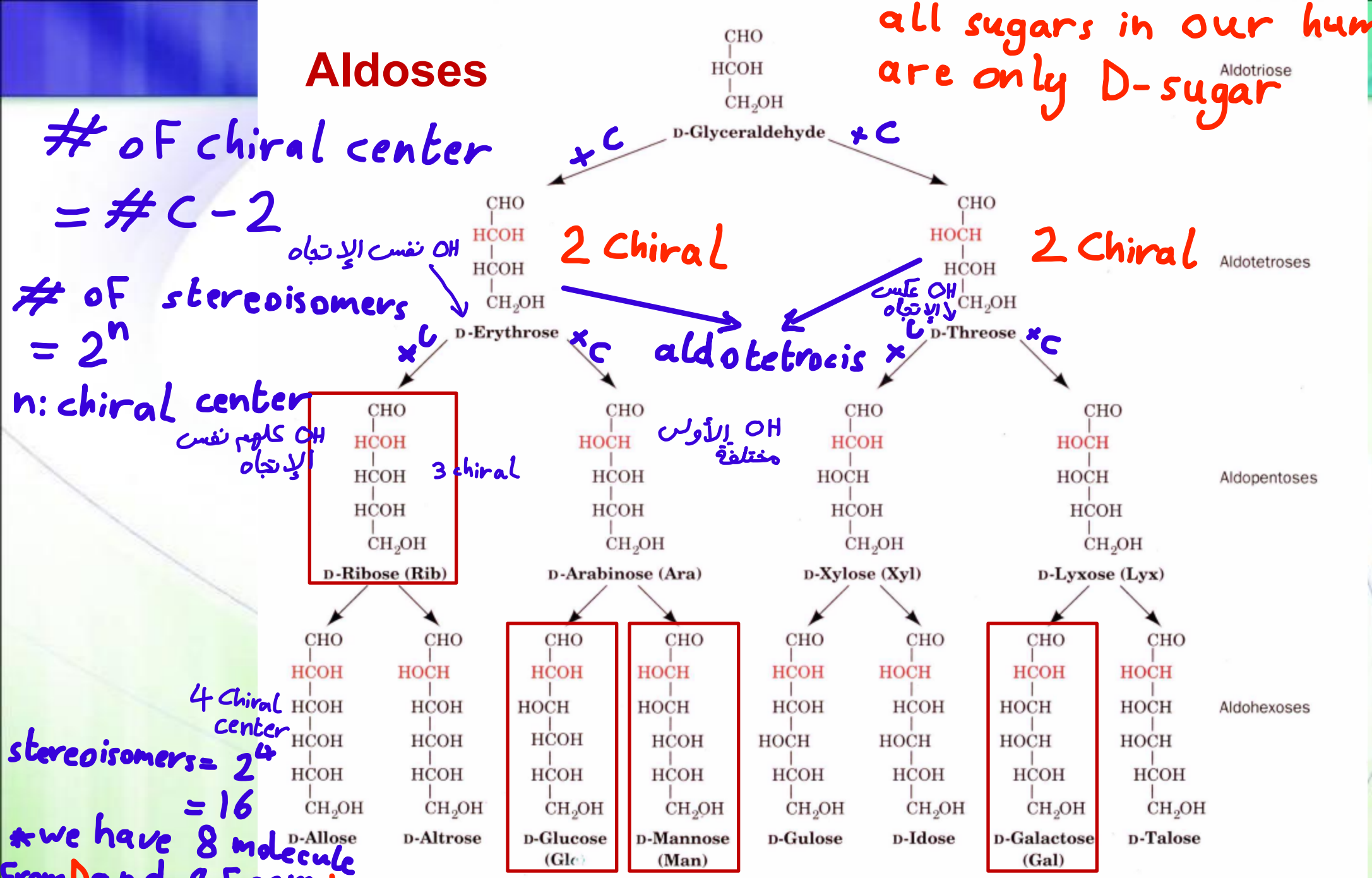
Classification III

- By the functional group



Aldoses

all sugars in our human body are only D-sugar



# of chiral center = # C - 2

# of stereoisomers = 2^n

n: chiral center

4 chiral center

stereoisomers = 2^4 = 16

*we have 8 molecule From D and 8 From L

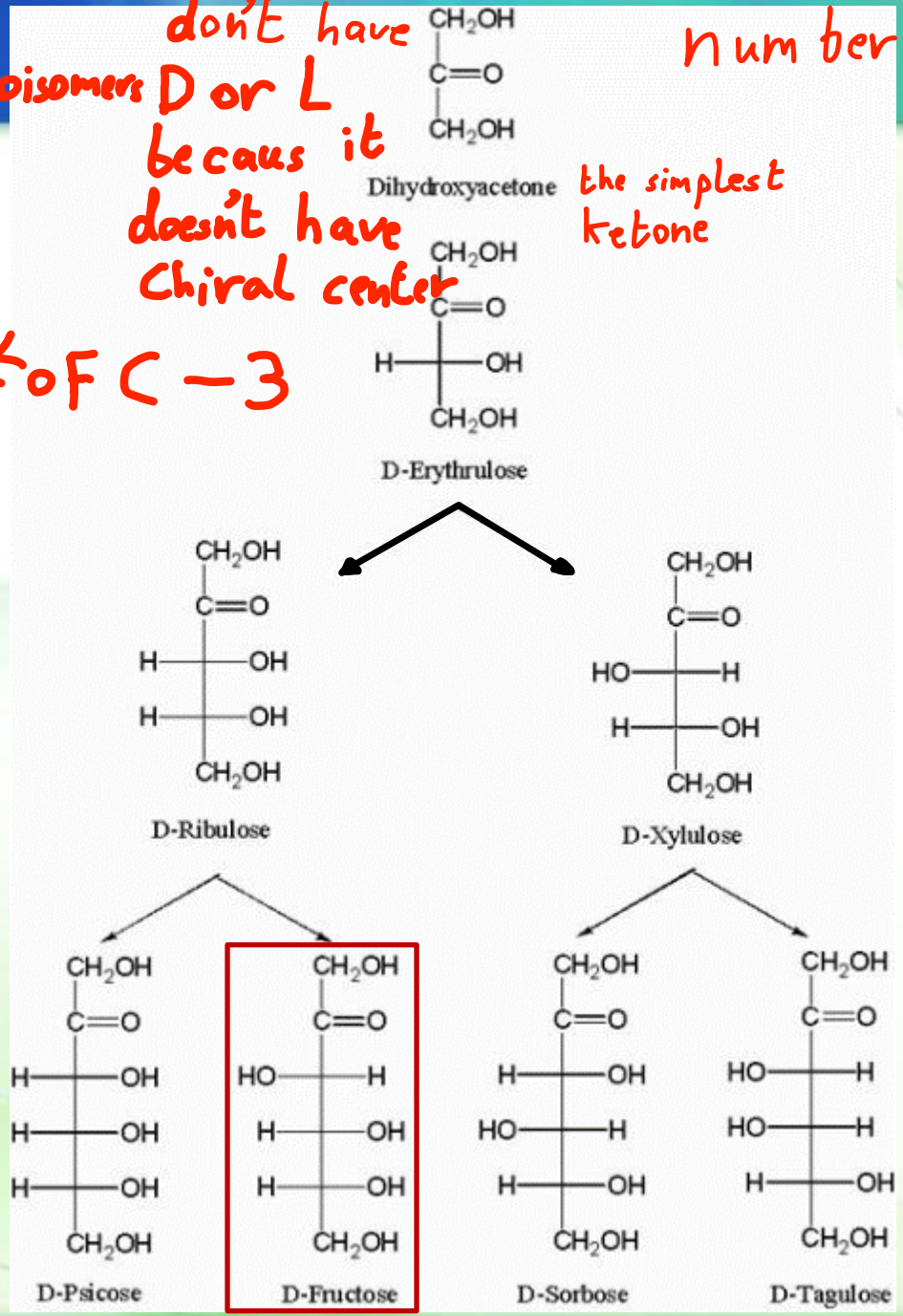
Ketoses

* no stereoisomers D or L because it don't have Chiral center

number of stereoisomers = 2^n

n:- number of chiral center

# of Chiral center = # of C − 3

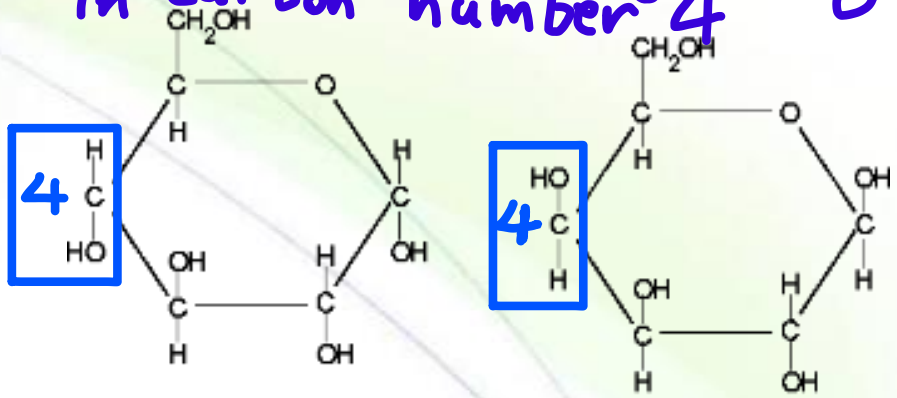


Common Monosaccharides

Glucose and Galactose are similar in every thing except in carbon number 4

لما نفحص تركيز السكر في الدم بنحسب تركيز Glucose فقط

- Glucose: متوسط
  - Mild sweet flavor
  - Known as blood sugar
  - Essential energy source
  - Found in every disaccharide and polysaccharide
- Galactose: (not sweet)
  - Hardly tastes sweet & rarely found naturally as a single sugar
- Fructose:
  - Sweetest sugar, found in fruits and honey
  - Added to soft drinks, cereals, desserts



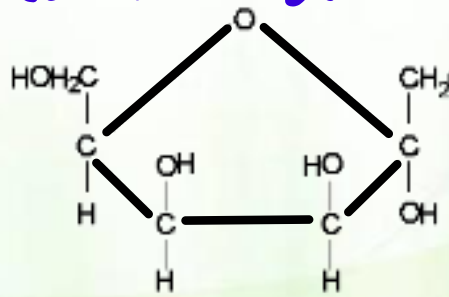
Glucose

Galactose

hexoaldose

Glucose, Galactose and Fructose are present in linear shape, but they don't stay for Long period because it has more Functional groups Like OH, so they react with each other and Form ring structure

* some of OH group will be upward and some downward



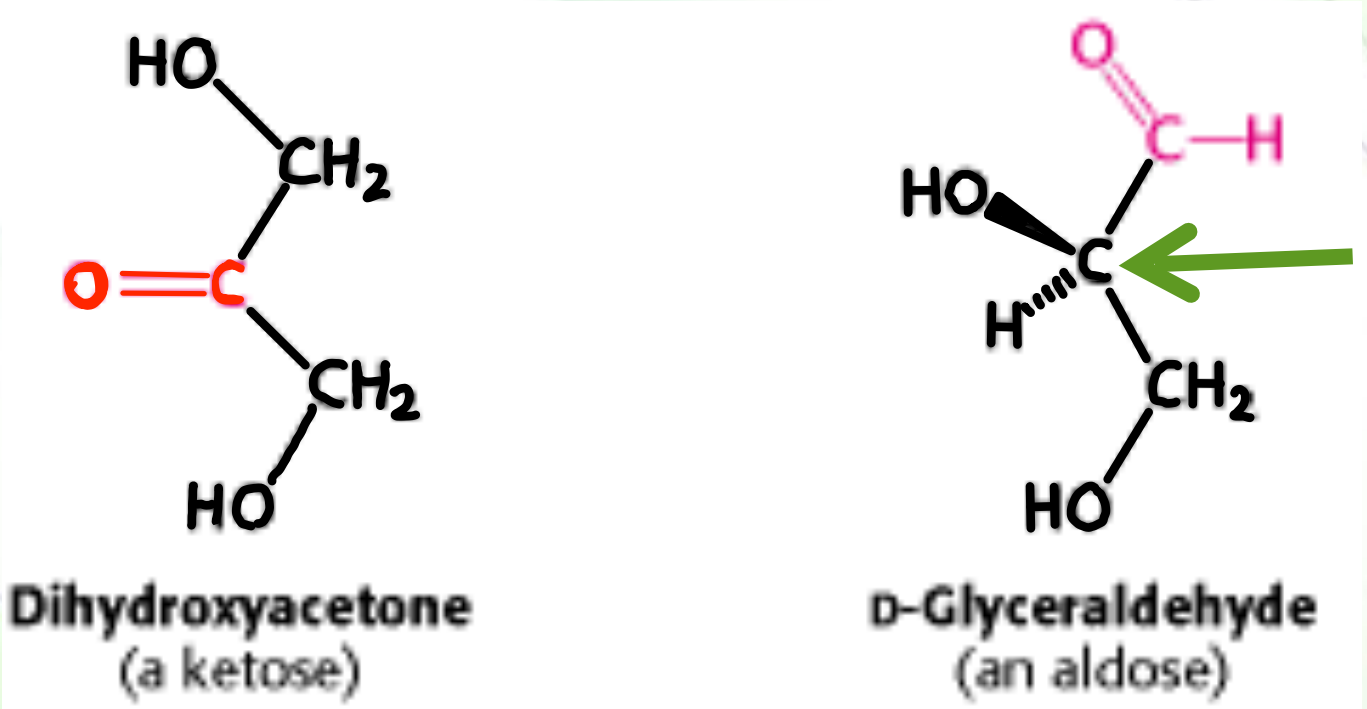
Fructose

hexo ketose

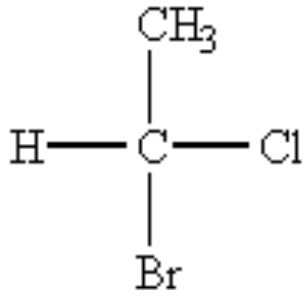
مش مطلوب structure تفاصيل بس لازم Fructose تبع غير متفق عليه

Trioses

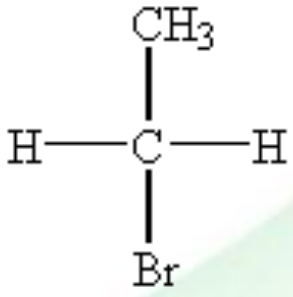
What is a chiral carbon?



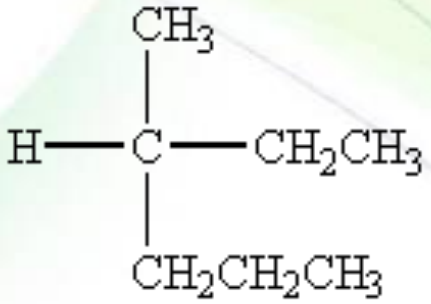
Note what a chiral carbon is...



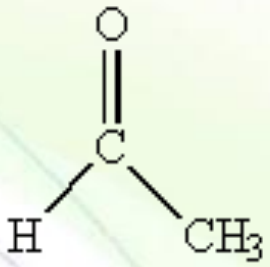
Chiral



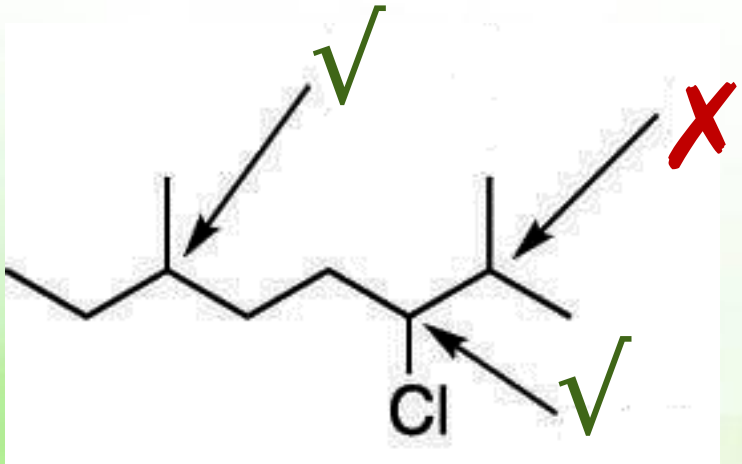
aChiral



chiral



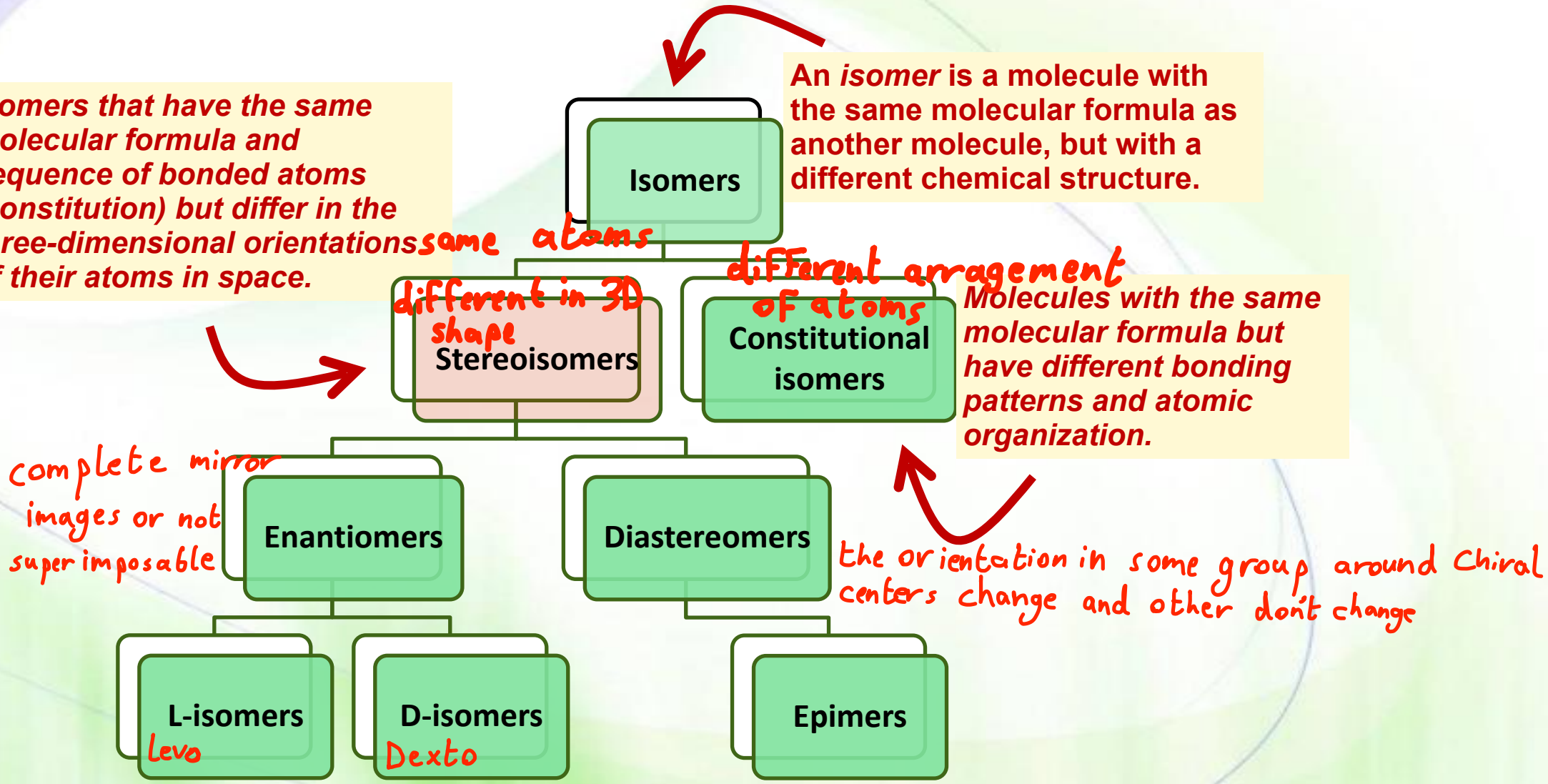
aChiral



Isomerism

An *isomer* is a molecule with the same molecular formula as another molecule, but with a different chemical structure.

Isomers that have the same molecular formula and sequence of bonded atoms (constitution) but differ in the three-dimensional orientations of their atoms in space.



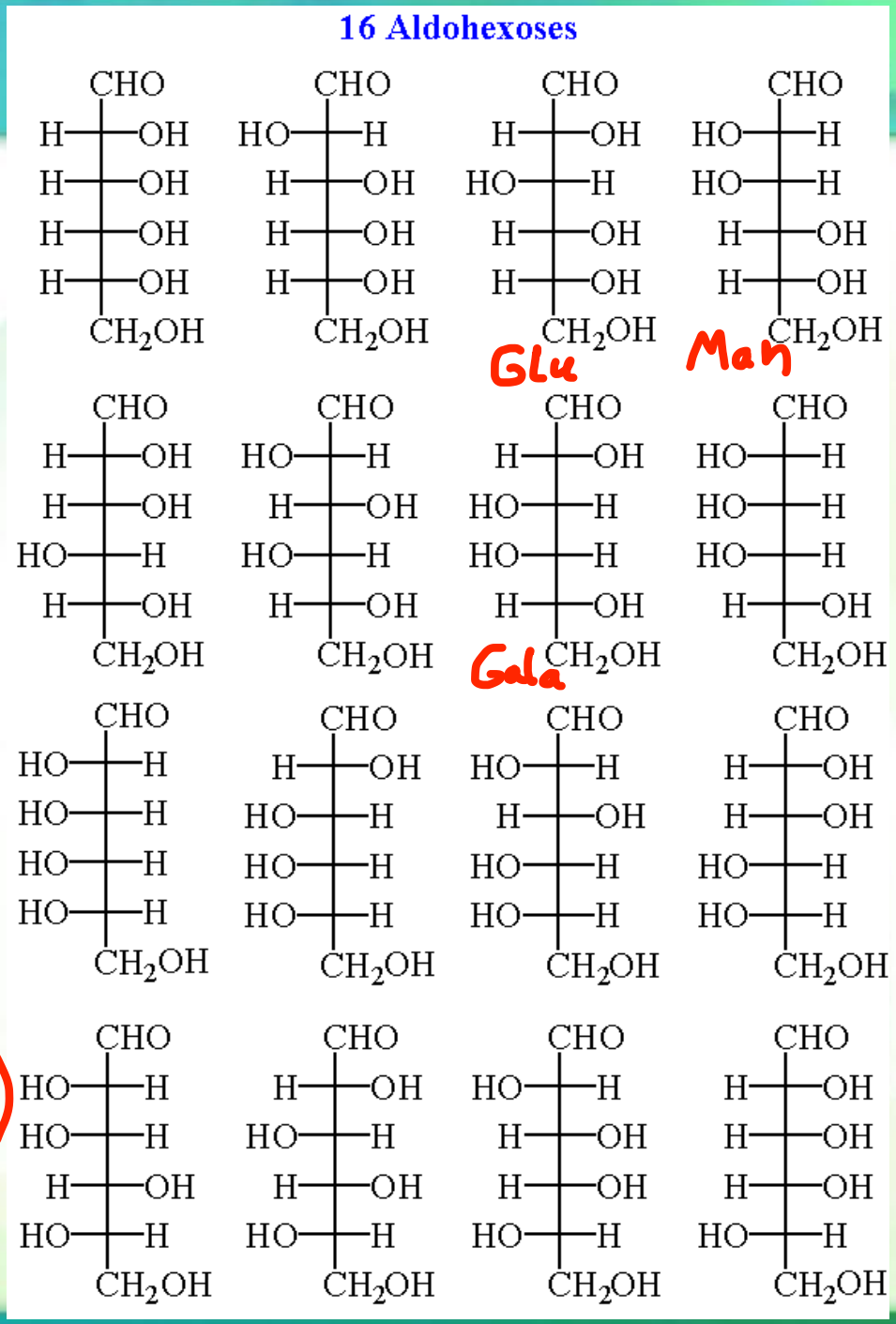
Isomers of glucose

2^n (n is the number of chiral carbons in a sugar molecule)

Search for:

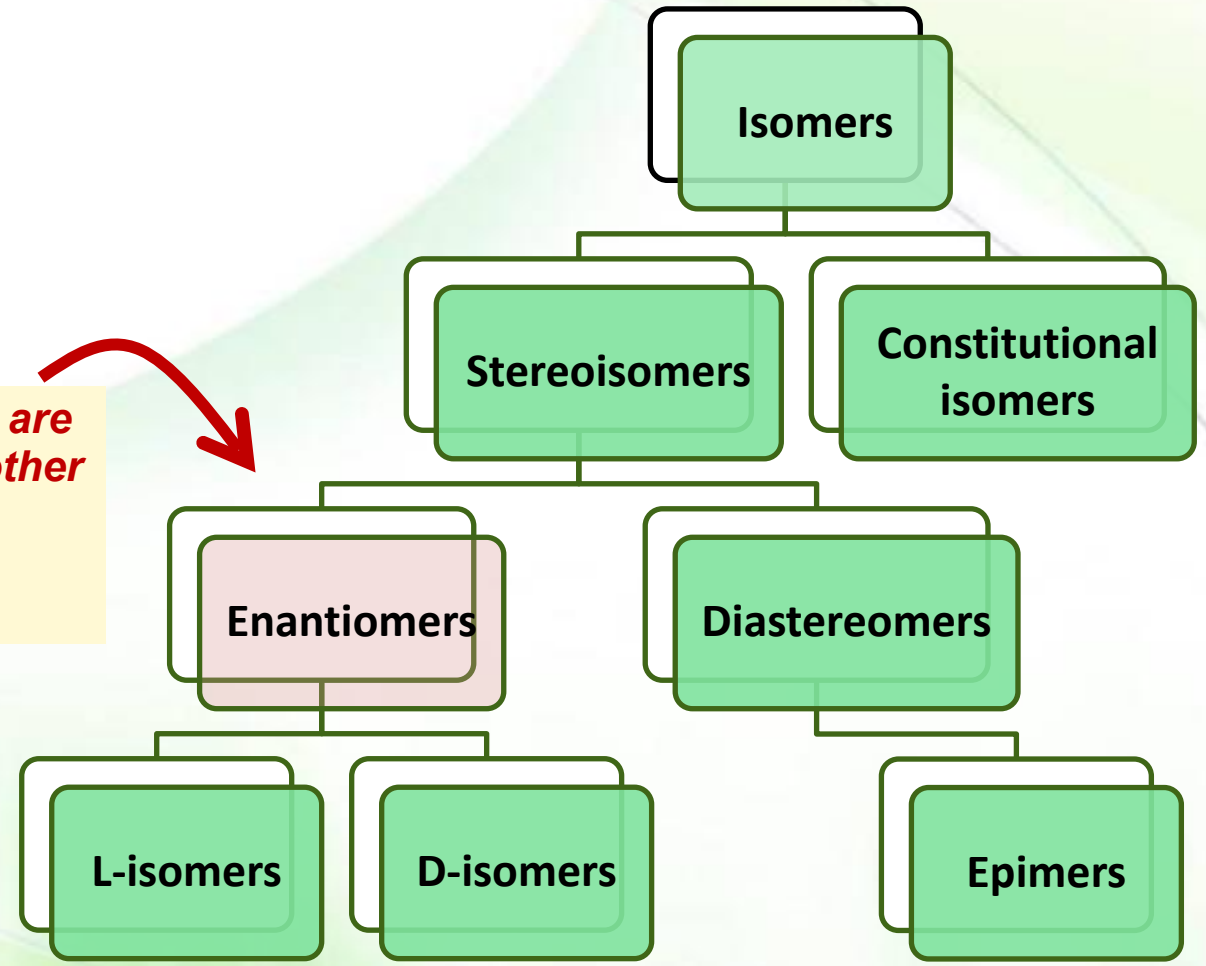
Glucose,
Galactose
Mannose

*The last chiral center always identify (D) and (L)

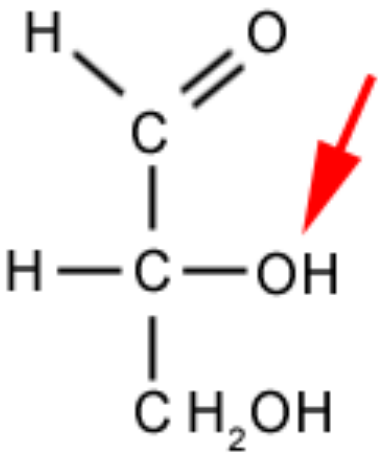


Enantiomers

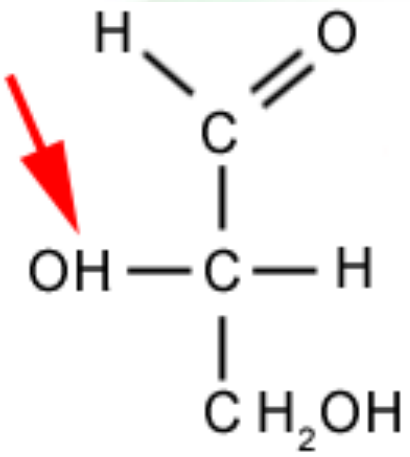
Two stereoisomers that are mirror images of each other and are non-superimposable (not identical)



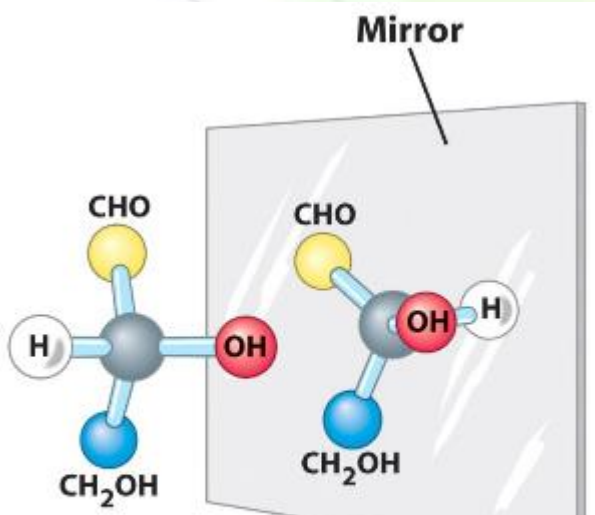
Sugar enantiomers (D- vs. L-)



D-Glyceraldehyde



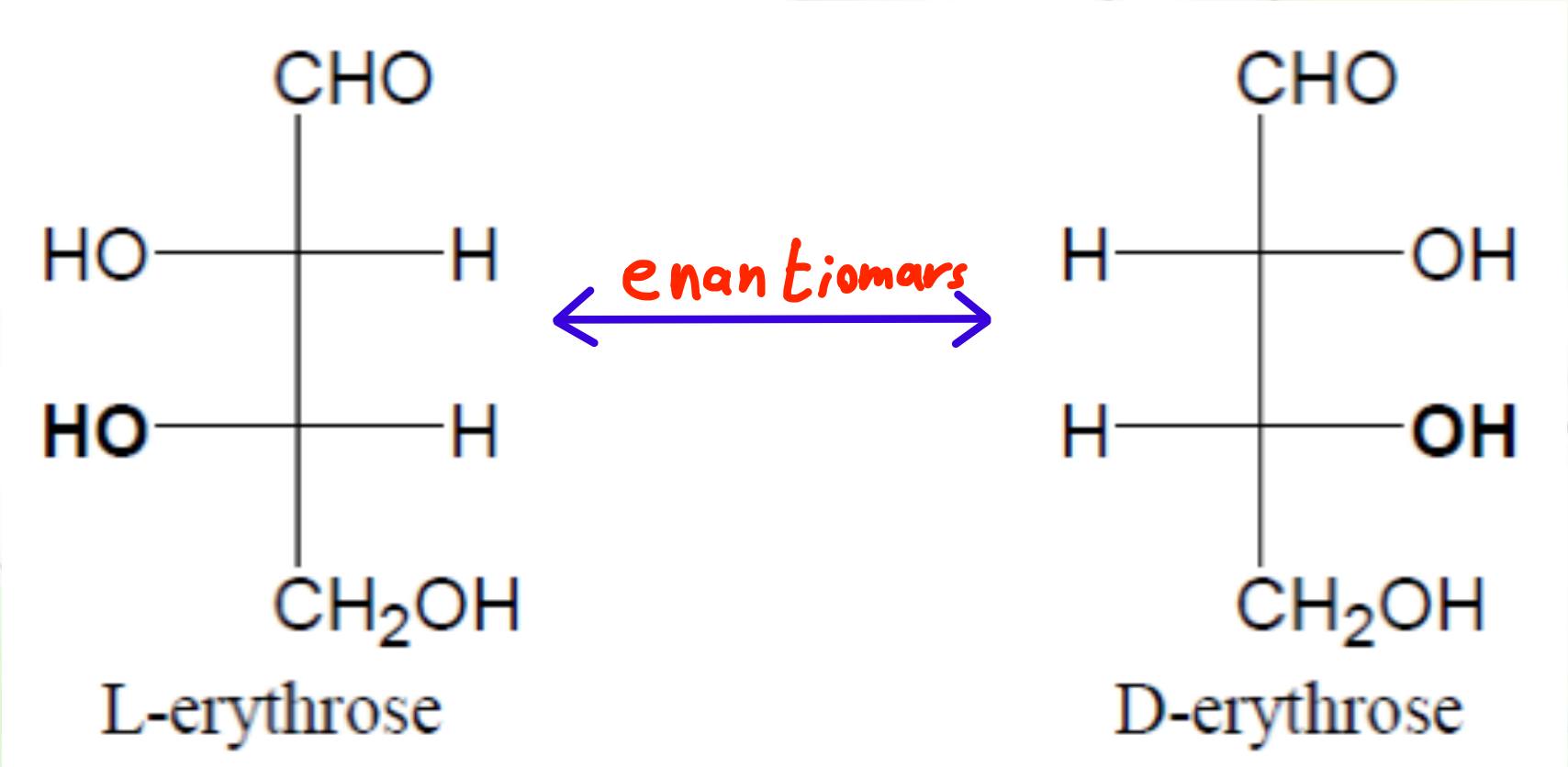
L-Glyceraldehyde



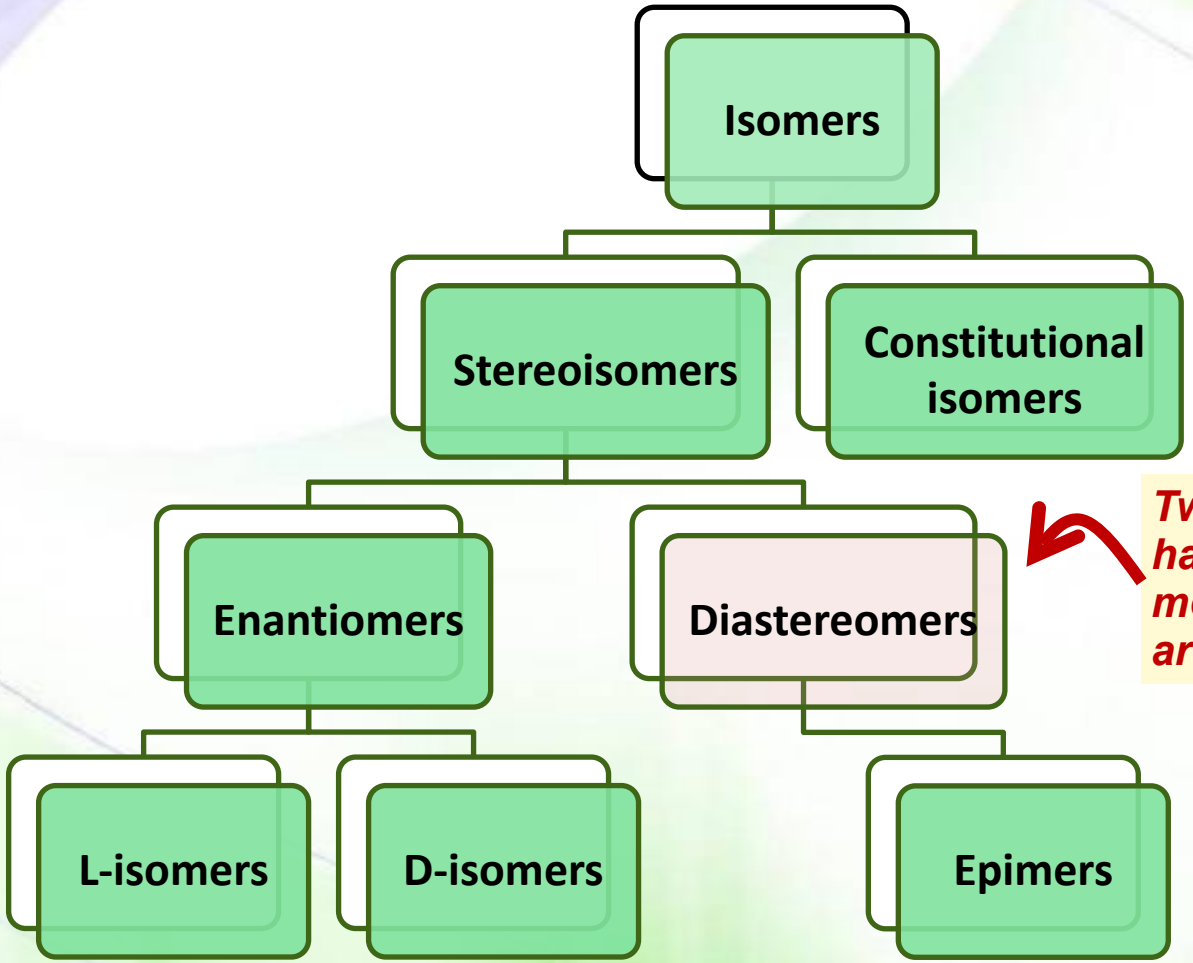
Ball-and-stick models

Which one(s) is a chiral carbon?

D و L بتحدد مين آخر chiral



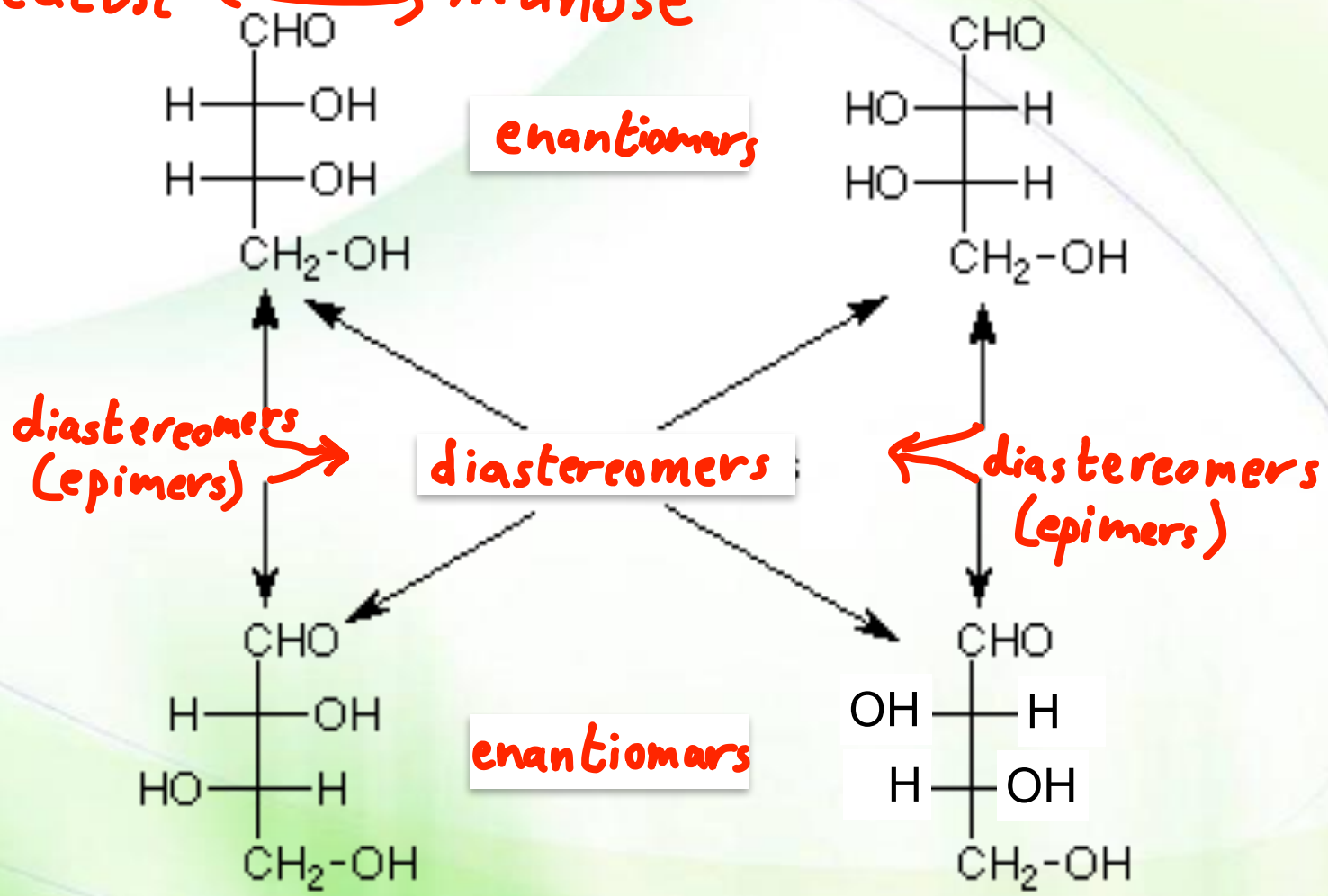
Isomerism



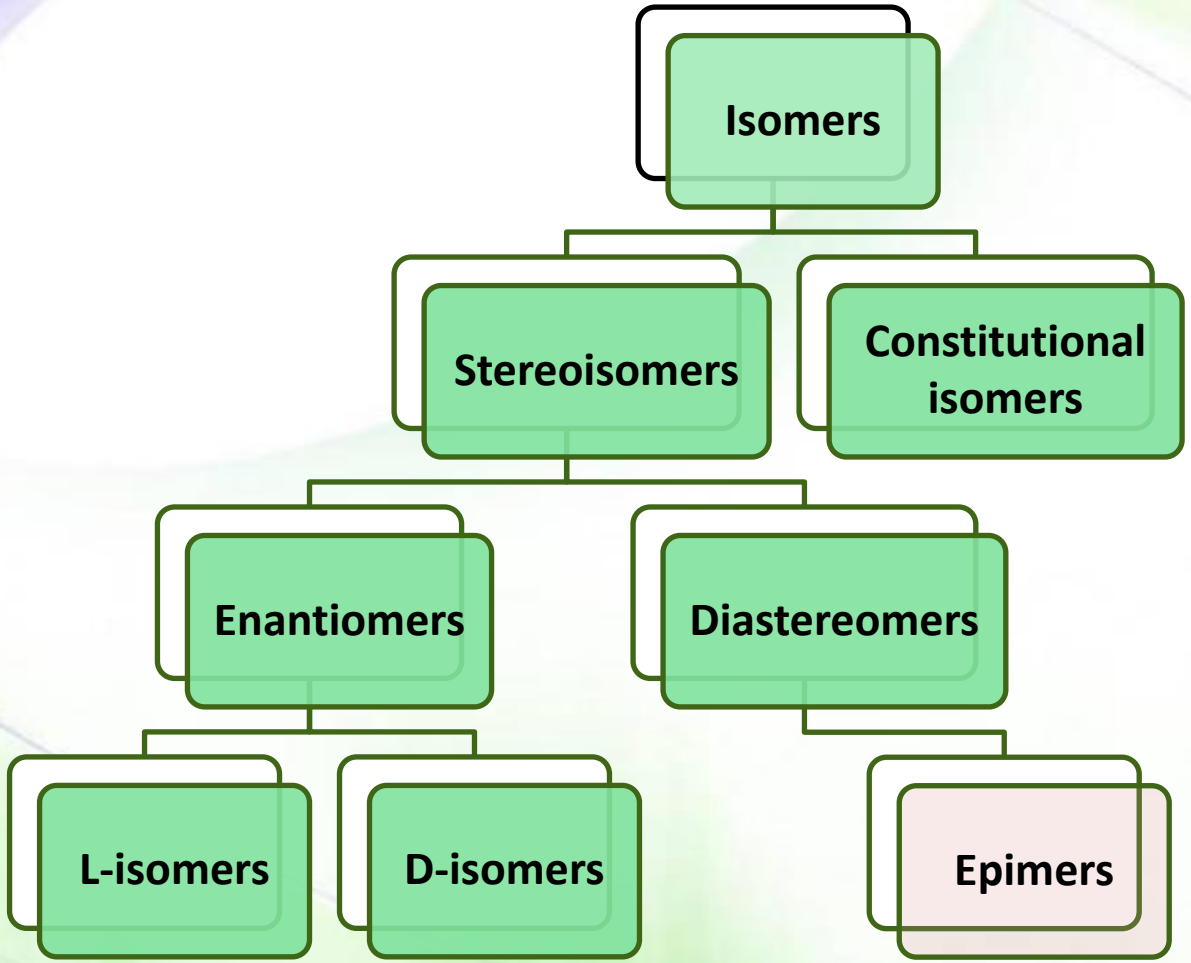
Two or more stereoisomers of a compound having different configurations at one or more (but not all) of the chiral carbons and are not mirror images of each other.

Stereoisomers, but non-mirror images and non-superimposable, then…*diastereomers*

Glalactos ⟷ dias Glucose ⟷ dias manose



Isomerism

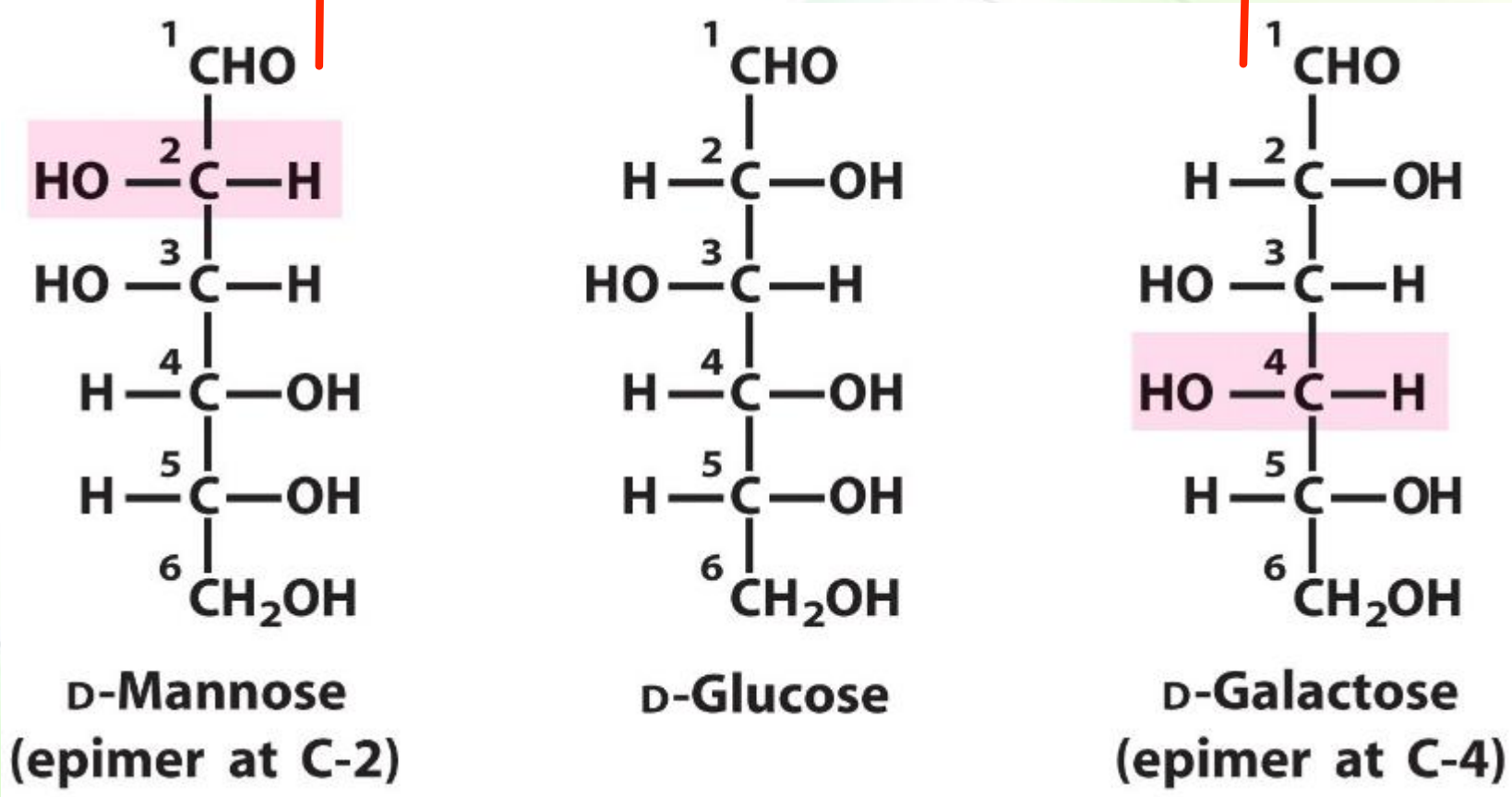


Epimer refers to one of a pair of stereoisomers whereby two isomers differ in configuration at only one chiral carbons.

Diastereomers with different orientation of one chiral carbonm

then... *epimers*

diastereomers



Is L-glucose an epimer with D-mannose and D-galactose? No

Acetal/ketal vs. hemiacetal/hemiketal

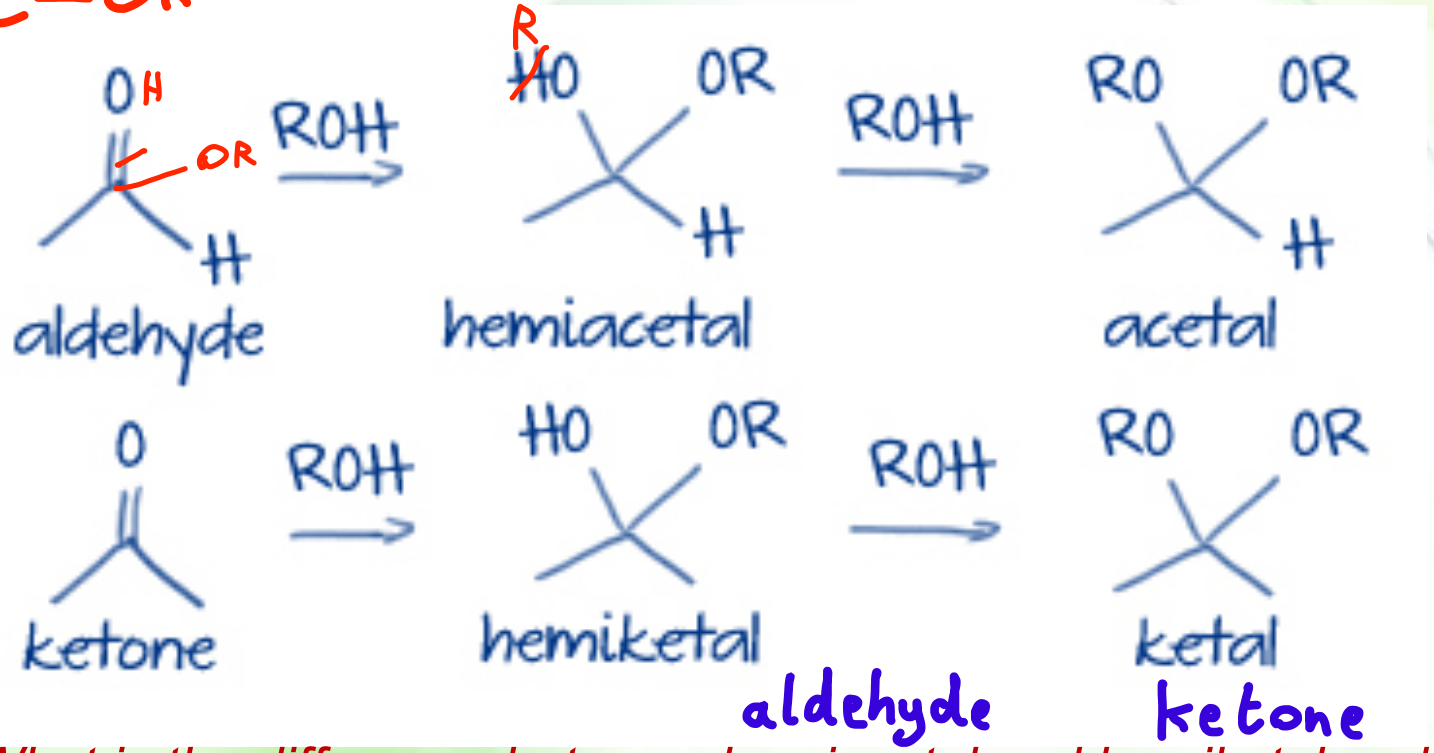
HO—C—OR

aldehyde ketone

Hemiacetal and hemiketal: ether and alcohol on same carbon

Acetal and ketal: two ethers on same carbon

RO—C—OR



aldehyde ketone

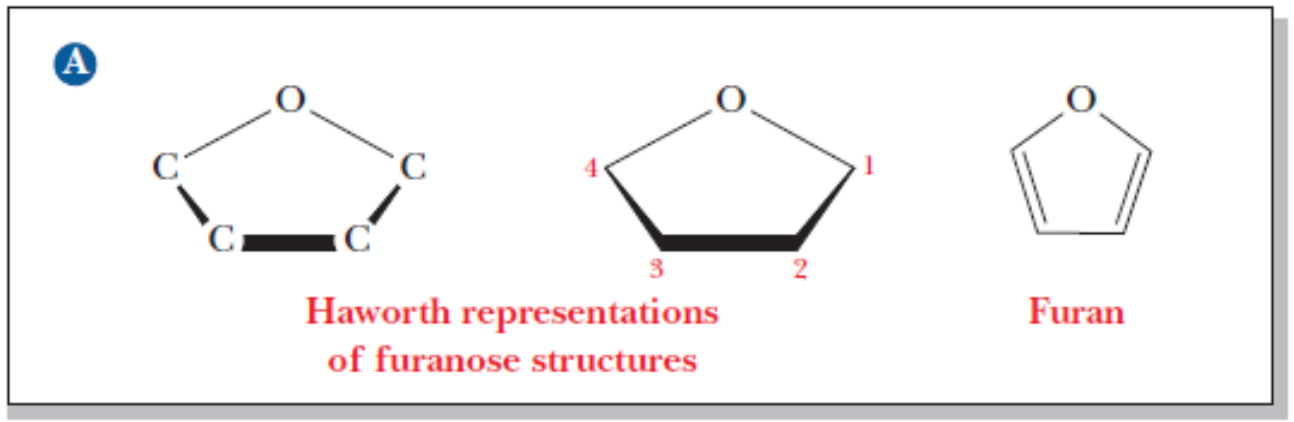
What is the difference between hemiacetal and hemiketal and the difference between acetal and ketal?

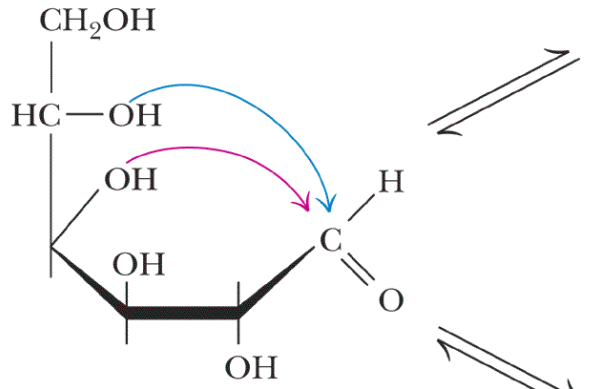
aldehyde ketone

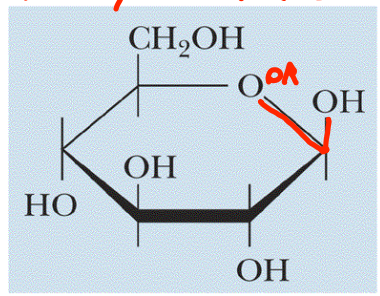
Formation of a ring structure

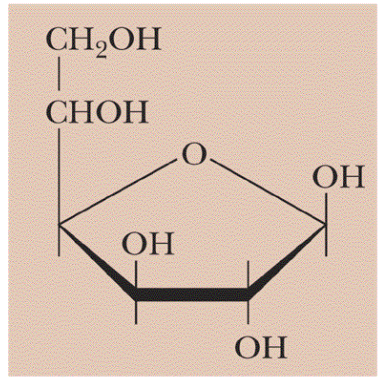
ribose = riboFuranose

hemiketal/hemi acetal









GlucoPyranose

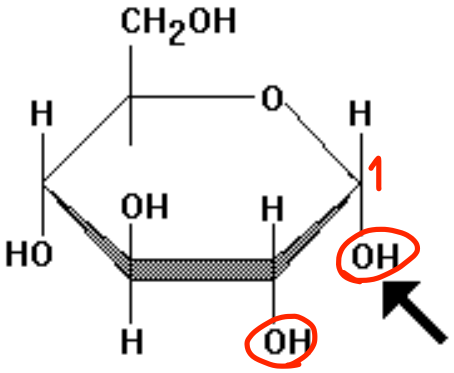
GalactoPyranose

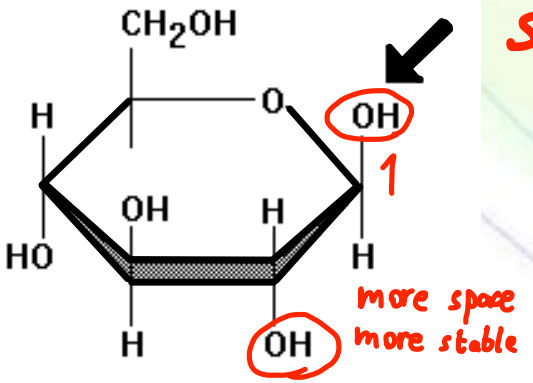
Anomers (states between which the molecule can alternate)

alpha:- downward

beta:- upward

the orientation of OH is spontanesly occur in one reaction the two anomer Formed





more space more stable

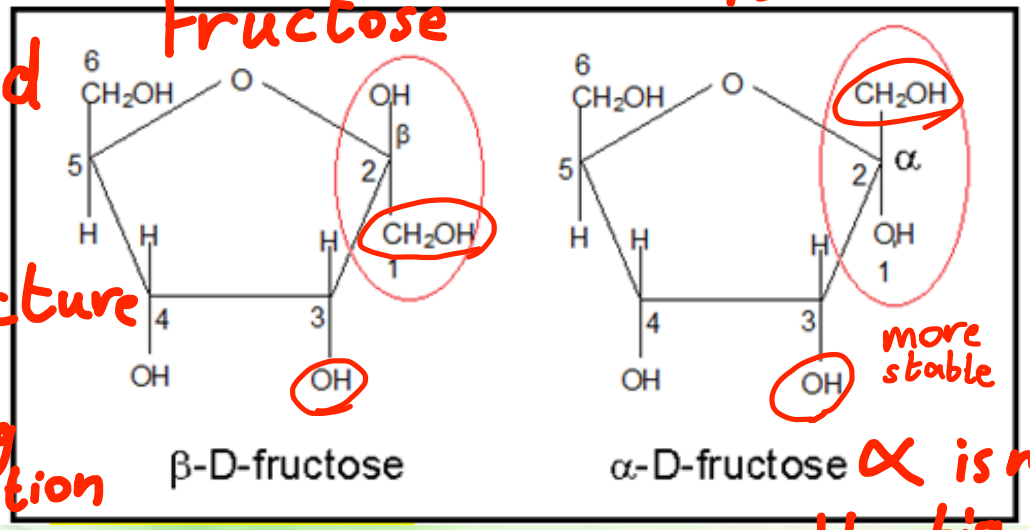
beta is more stable than alpha because the big group far from OH

*In linear structure any right OH group will be down in ring structure, and any left OH group will be up in ring structure

*most of time it's stays in a ring structure

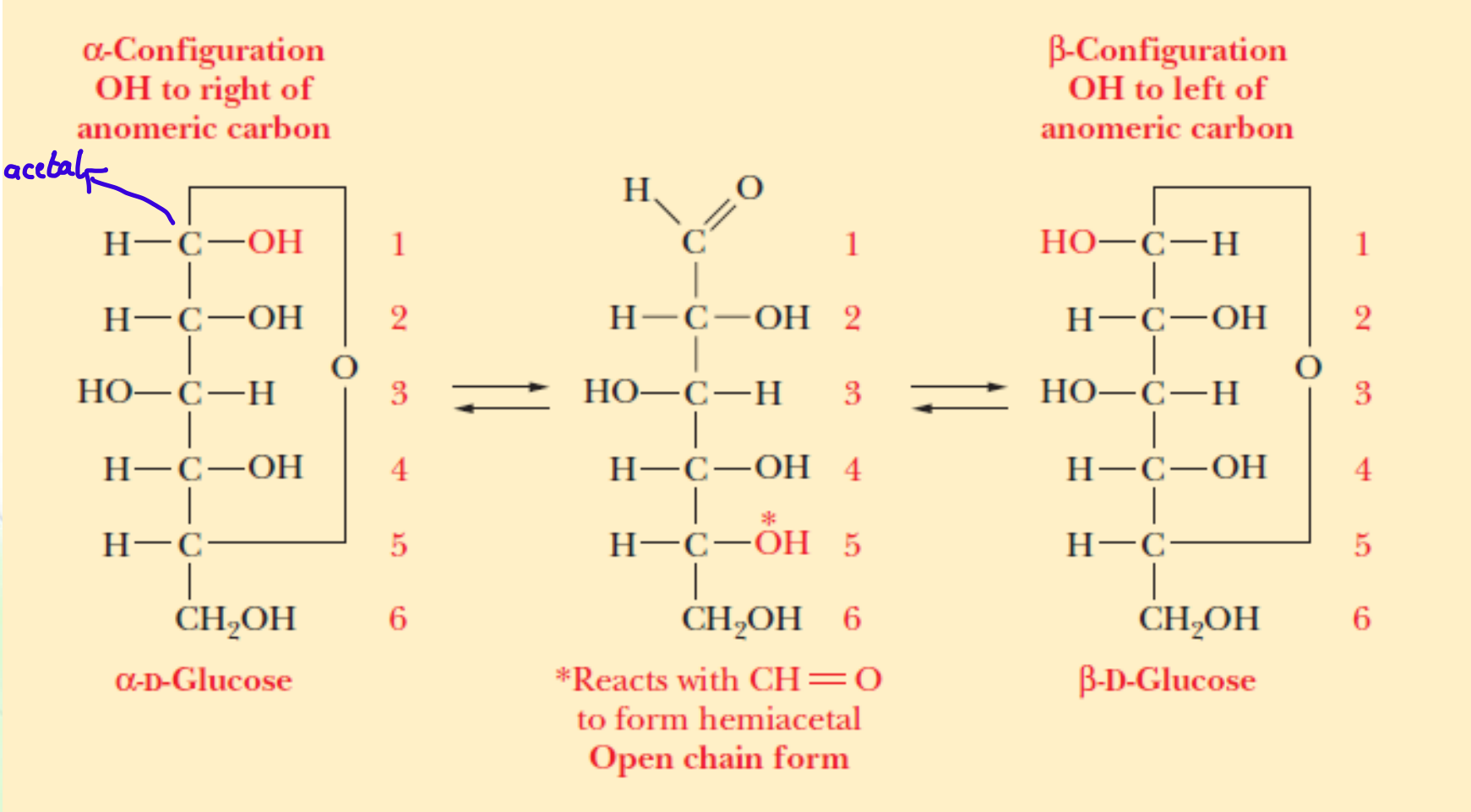
*In the reactions the ring will open and do the reaction and return to ring structure

Fructose



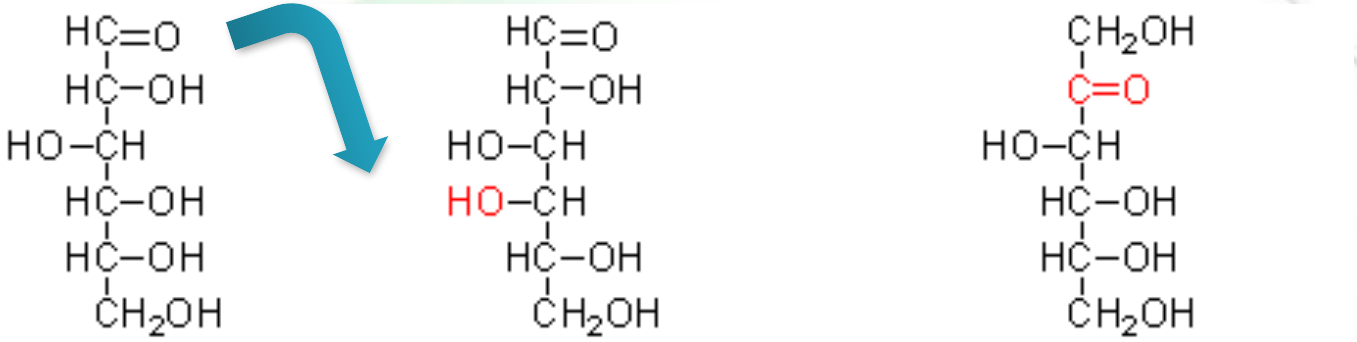
α is more stable because the big group far from OH

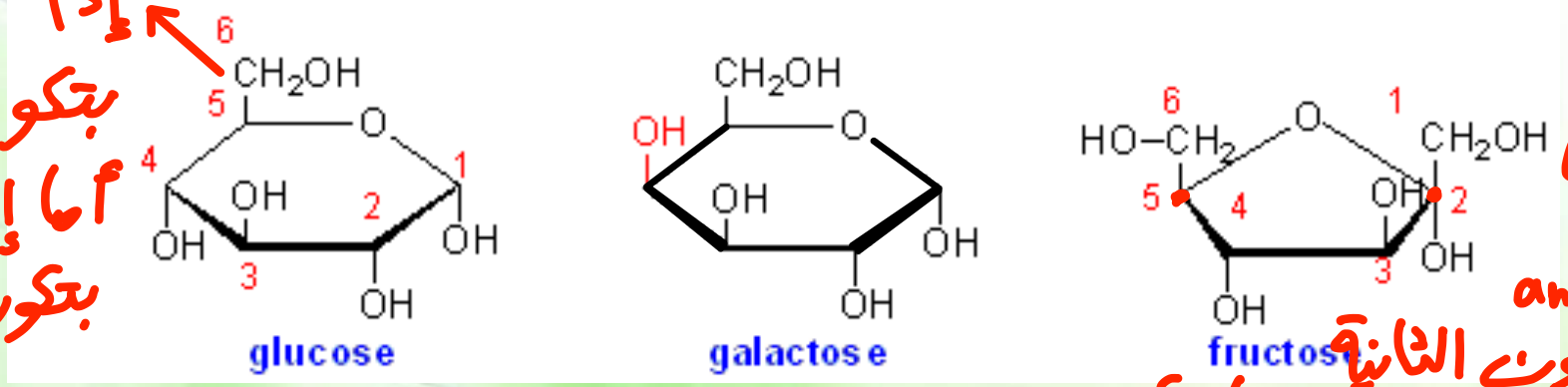
Anomers as Fischer projection



Chain to ring

Left-up, right-down





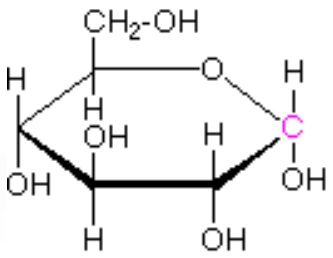
إذا كانت لفوق
بتكون D
أما إذا كانت لتحت
بتكون L

اللي عليها
في OH
anomeric
بقدر أميز ذرة الكربون الثانية
من خلال CH_2OH و OH المرتبطين فيها عكس

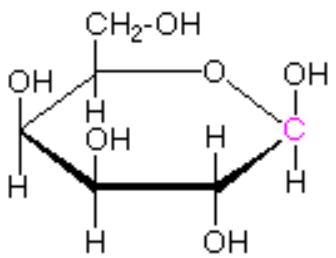
Cyclic aldohexoses

الذرة الخامسة فيها بس CH_2OH

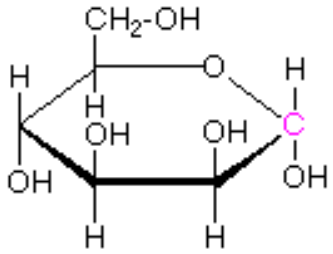
Examples of Some Pyranose Forms of Hexoses



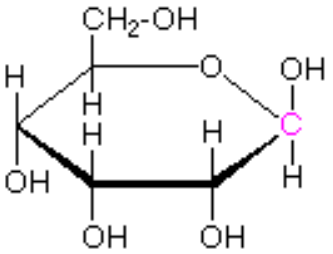
α-D-glucopyranose



β-D-galactopyranose

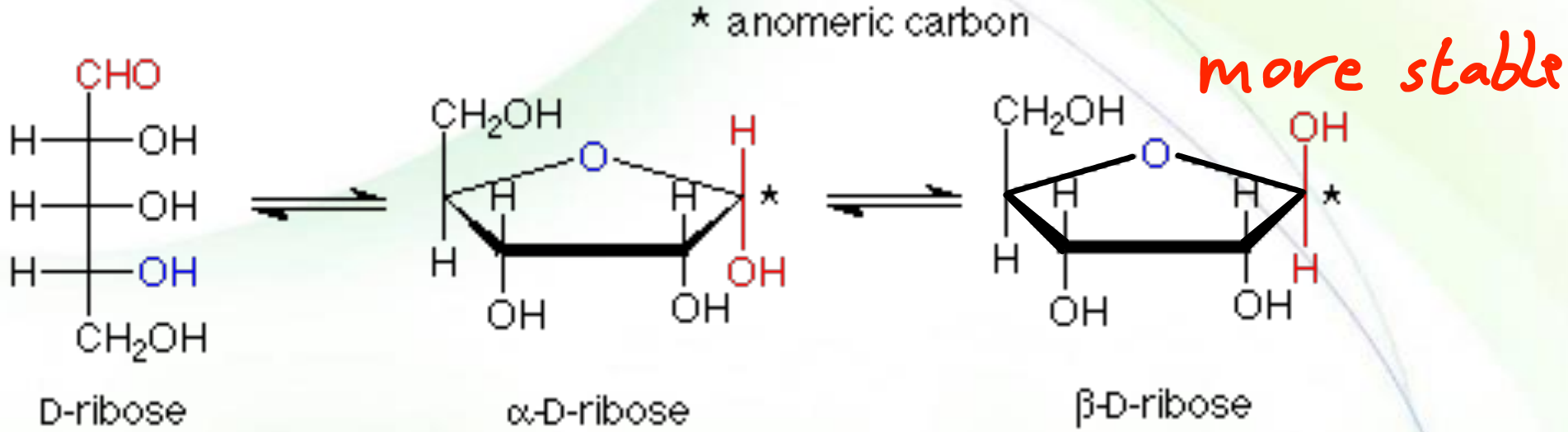


α-D-mannopyranose



β-D-allopyranose

Cyclic ribofuranose



Modified sugars

Sugar acids (oxidation)

- Where is it oxidized? What does it form?

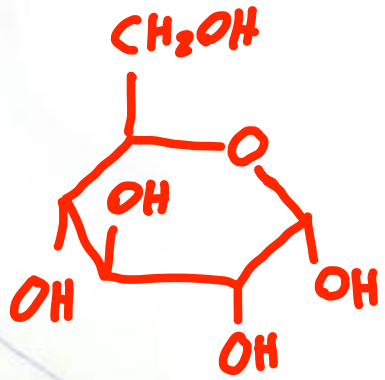
aldehyde $\xrightarrow{\text{oxidation}}$ carboxylic acid

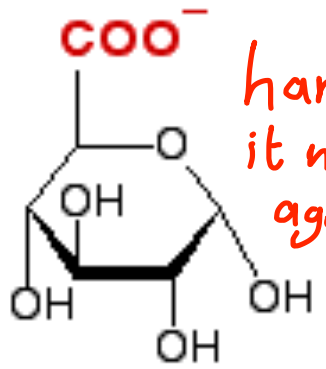
alcohol $1^{\circ} \xrightarrow{\text{oxidation}}$ aldehyde

alcohol $2^{\circ} \xrightarrow{\text{oxidation}}$ ketone

alcohol $3^{\circ} \xrightarrow{\text{oxidation}}$ ✗

* In sugar OH and aldehyde oxidized



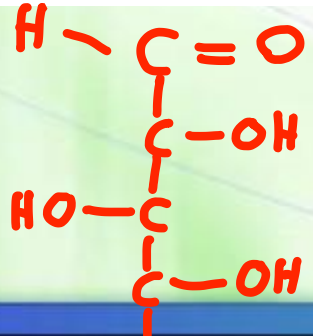


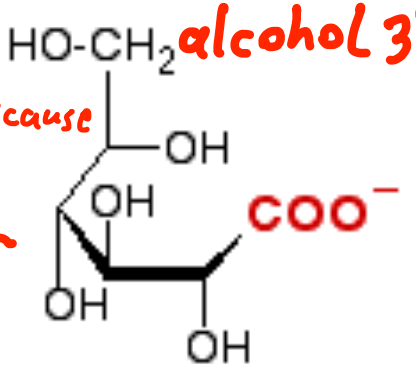
harder oxidation because it needs strong oxidizing agent (two steps)

α-D-glucuronate

(D-glucuronic acid, **GlcUA**)

from **oxidation of glucose C6 OH**

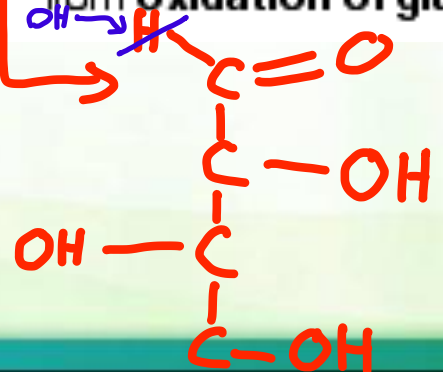




D-gluconate

(D-gluconic acid, **GlcA**)

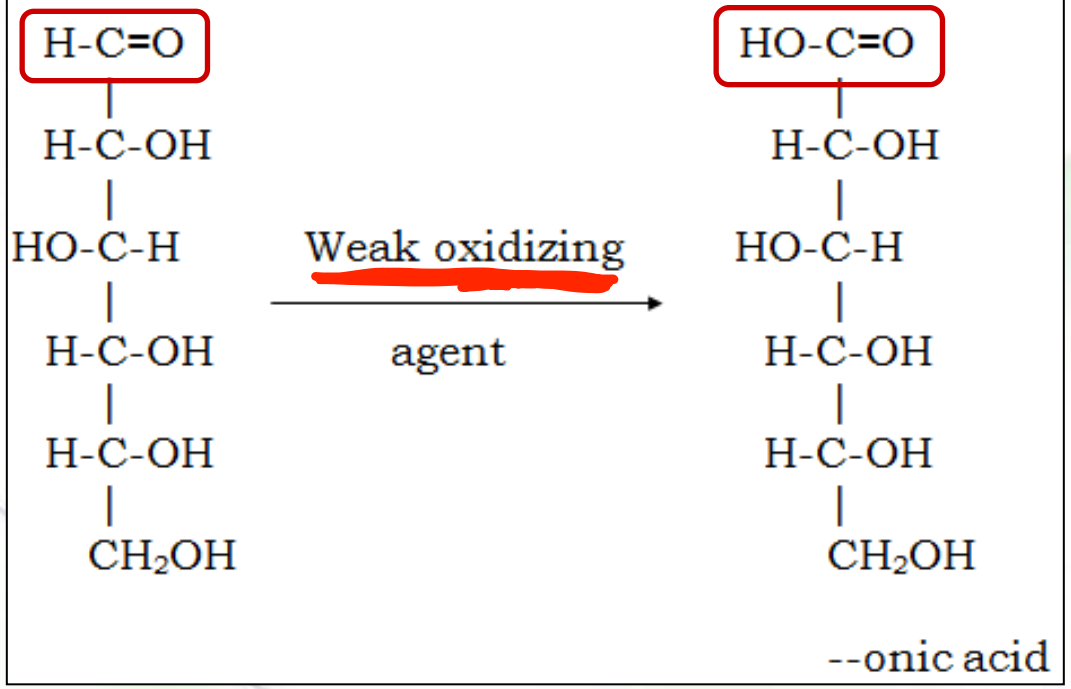
from **oxidation of glucose C1 aldehyde)**

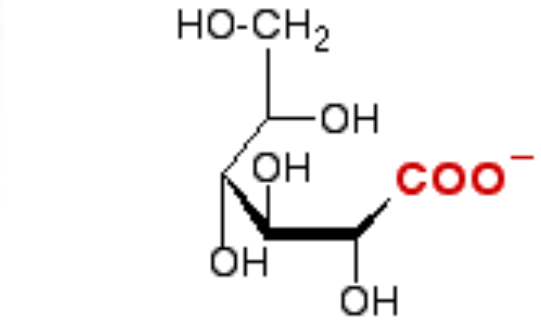


easier to Form because it need weak oxidizing agent (one step)

Example 1:

a. Weak oxidizing agent

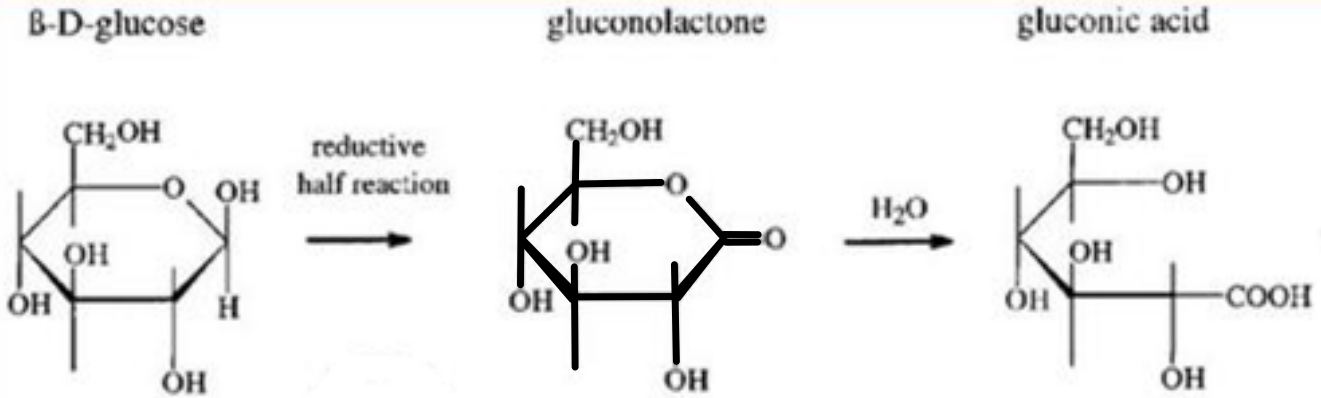




D-gluconate

(D-gluconic acid, **GlcA**)

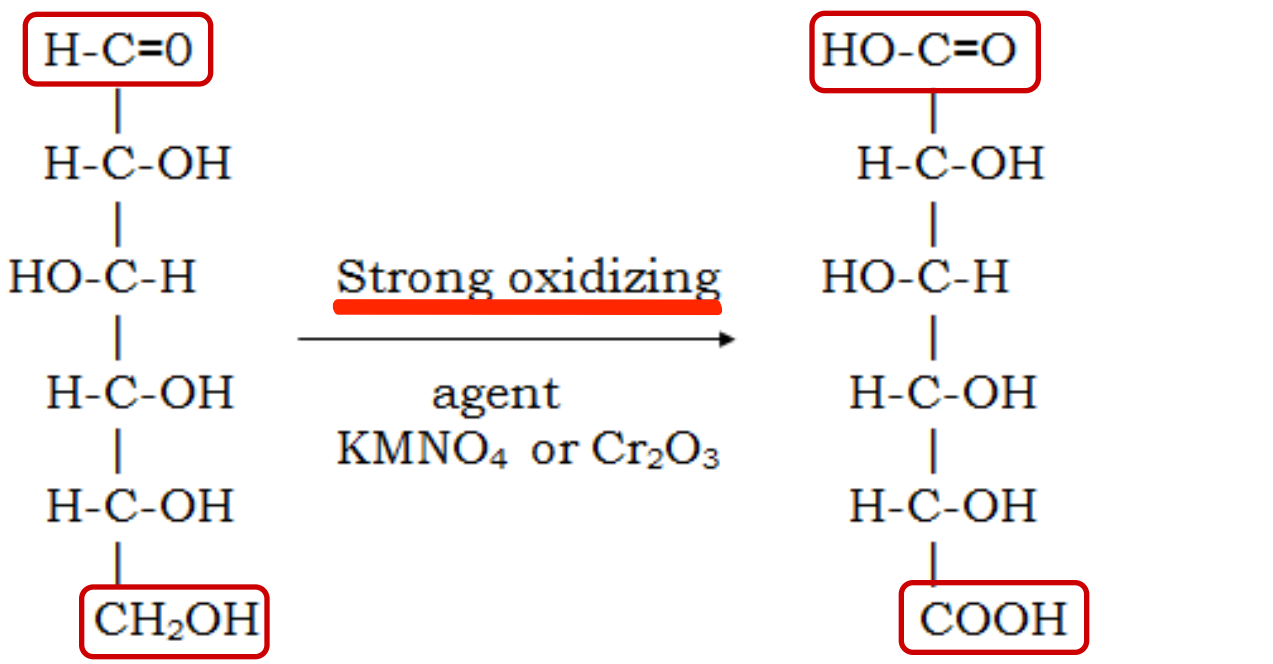
from **oxidation of glucose C1 aldehyde)**



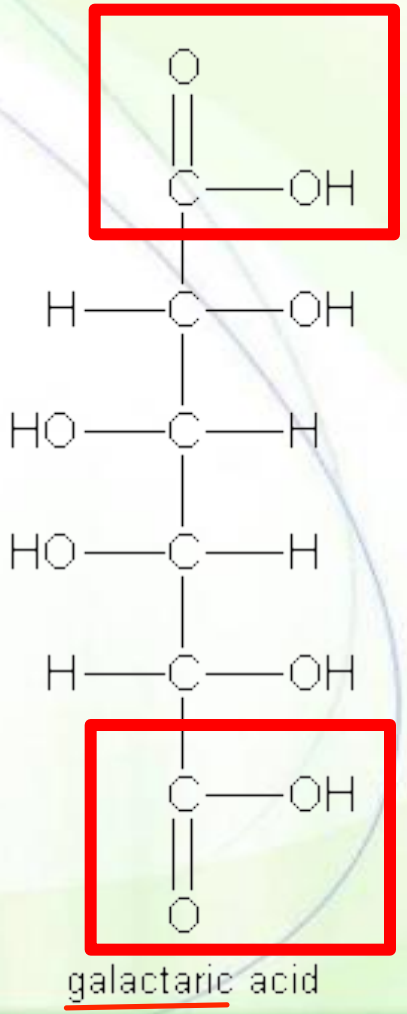
Example 2

b. Strong oxidizing agents

1st, 6th carbon



-aric acid
A dicarboxylic acid

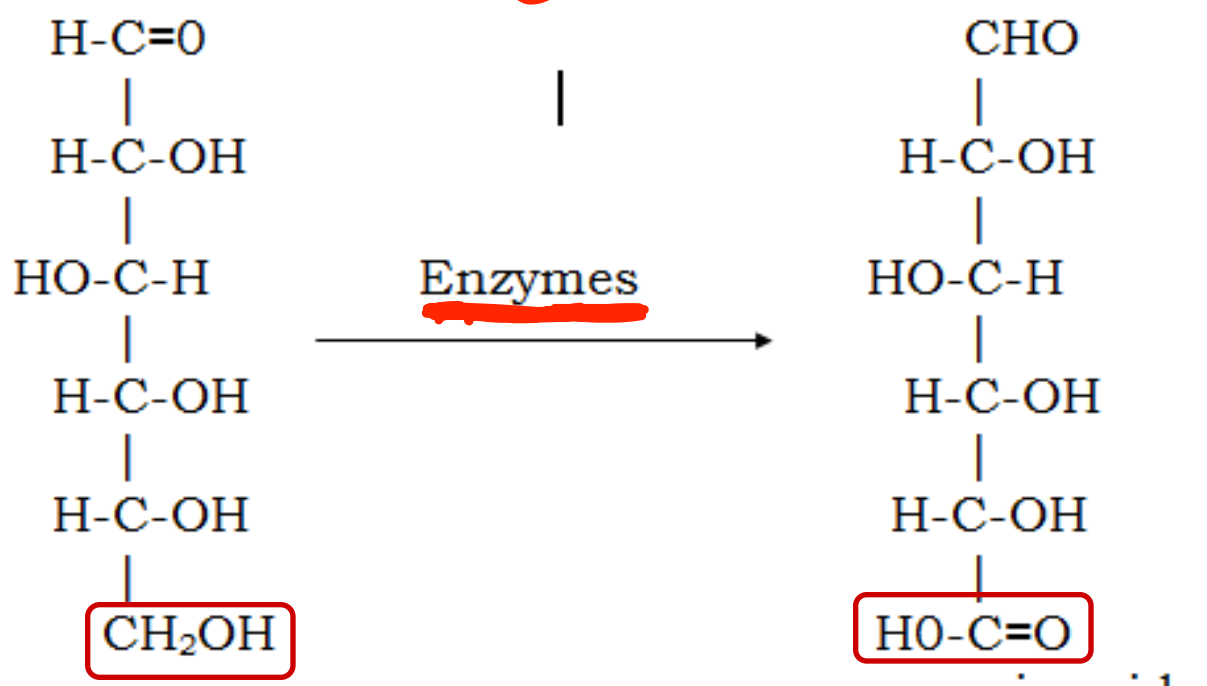


galactaric acid

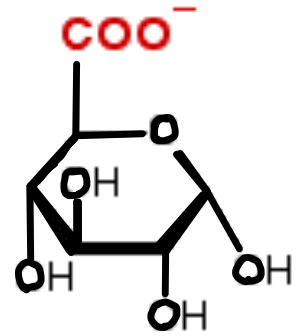
Example 3

c. Oxidation of primary alcohol end in biological systems

6th C



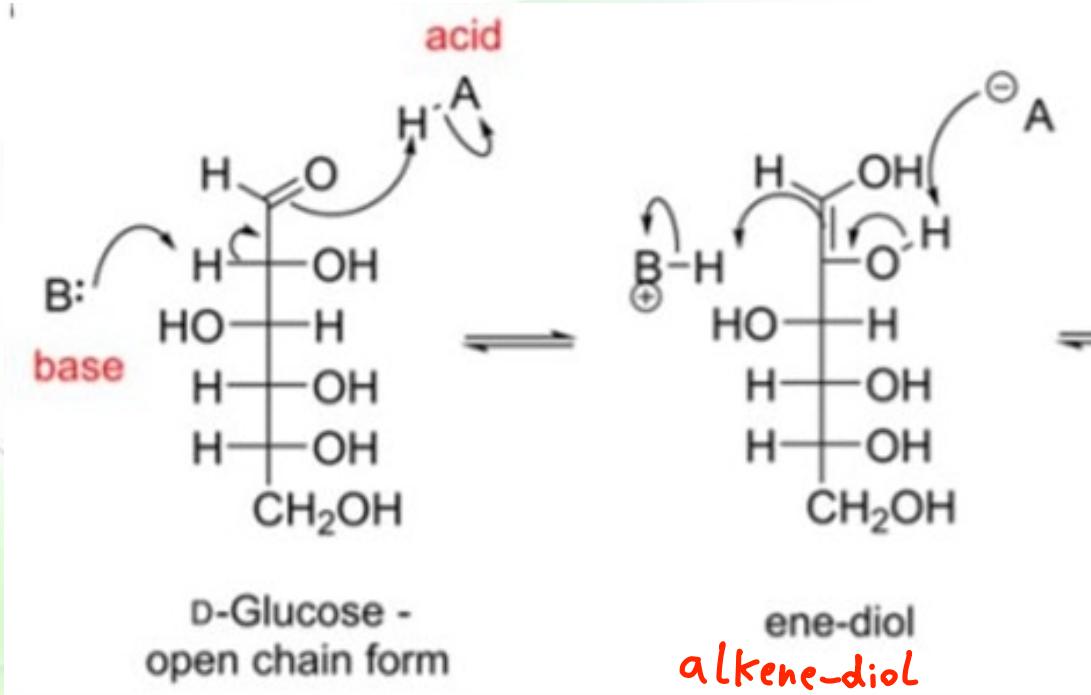
-uronic acids



α-D-glucuronate
(D-glucuronic acid, **GlcUA**)
from **oxidation of glucose C6 OH**

Note

- Oxidation of ketoses to carboxylic acids does not occur, but they can be oxidized because of formation of enediol form.



* Rearrangement of of the electrons and conversion of a ketose to aldose, then it oxidized so all of sugar are oxidized

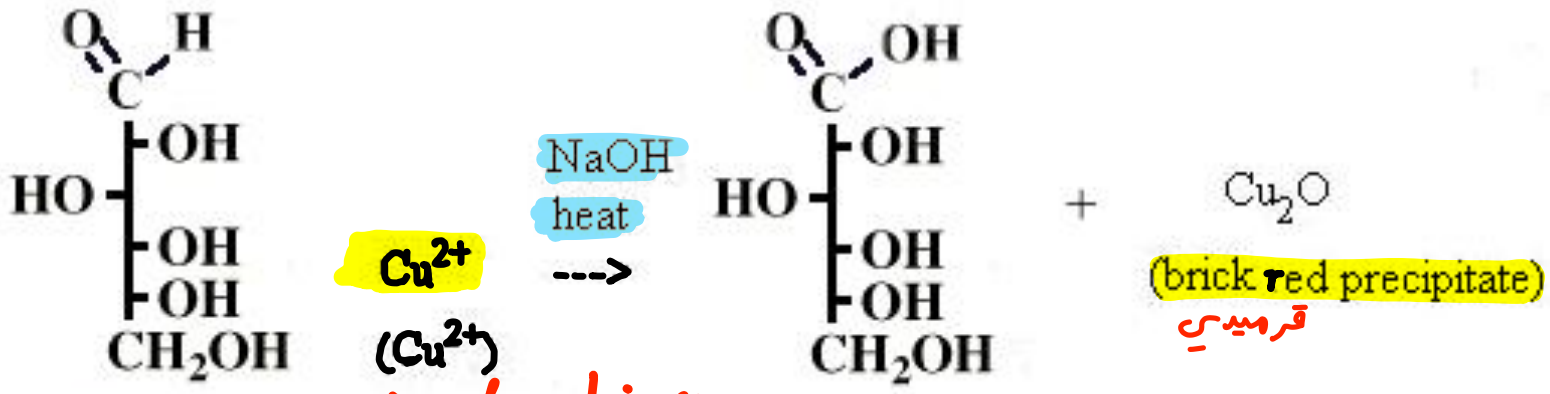
For example:-

Fructose (ketose) it has carbonyl group in carbon number 2, the double bond transfer from the

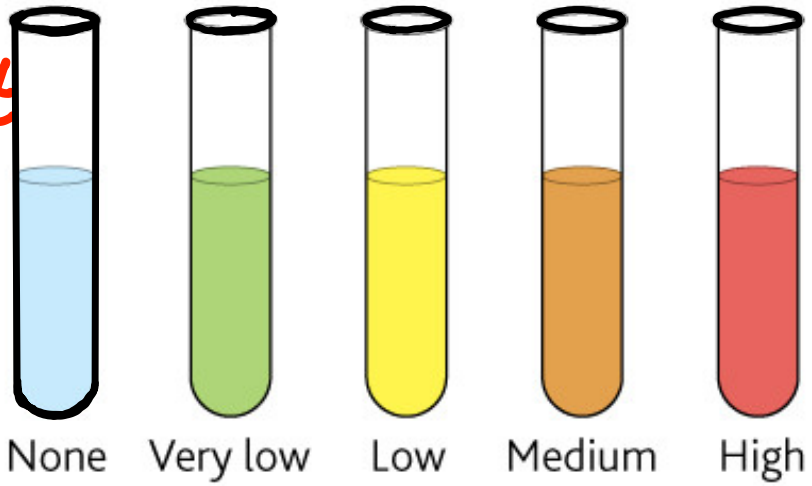
Benedict's test

2nd carbon to the 1st carbon

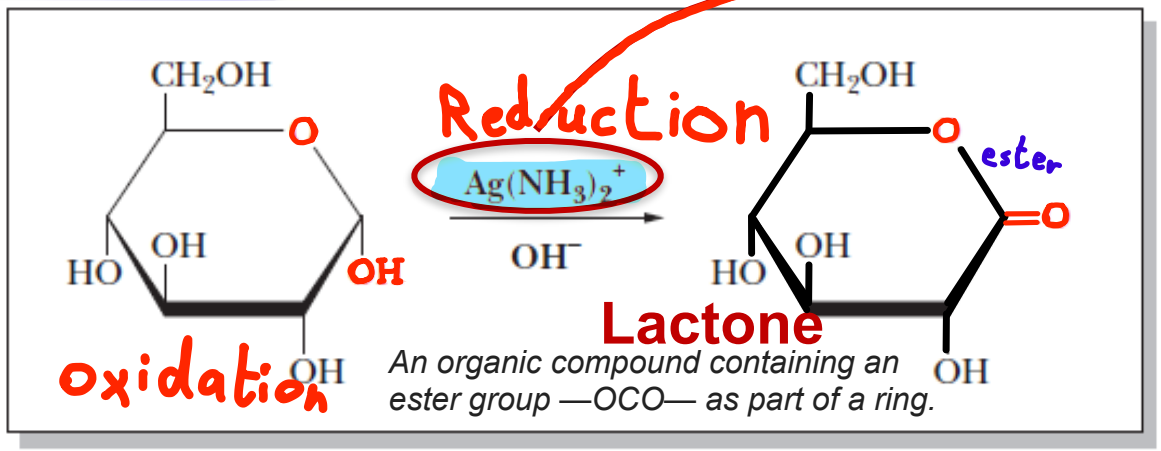
Test to distinguish between aldehyde and ketone



* The ketone doesn't oxidized , but ketose oxidized

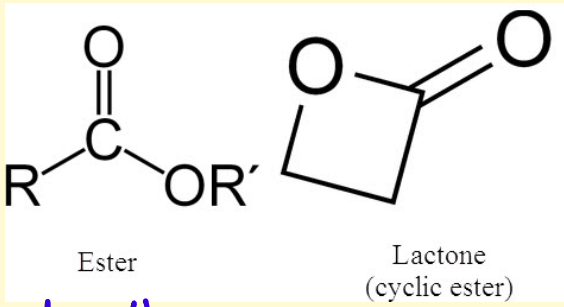


Oxidation of cyclic sugars (lactone)



Tollen's test

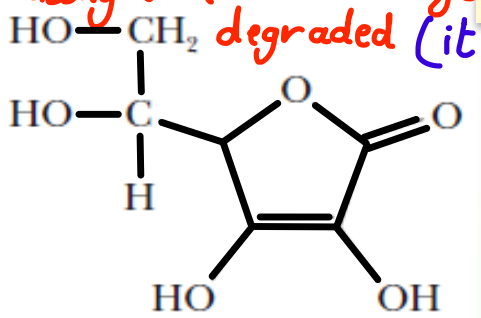
Lactones are cyclic esters of organic



A more recent method for the detection of glucose, but not other reducing sugars, is based on the use of the enzyme glucose oxidase.

* vitamin C is only present in Fresh Food and vegetables, IF it stay For along time vitamin C get degraded (it oxidized)

- **Vitamin C (ascorbic acid) is an unsaturated lactone.**
- **Air oxidation of ascorbic acid, followed by hydrolysis of the ester bond, leads to loss of activity as a vitamin.**
- **A lack of fresh food can cause vitamin C deficiencies, which, in turn, can lead to scurvy.** (problem in manufactor of collagen)



Ascorbic acid (Vitamin C)

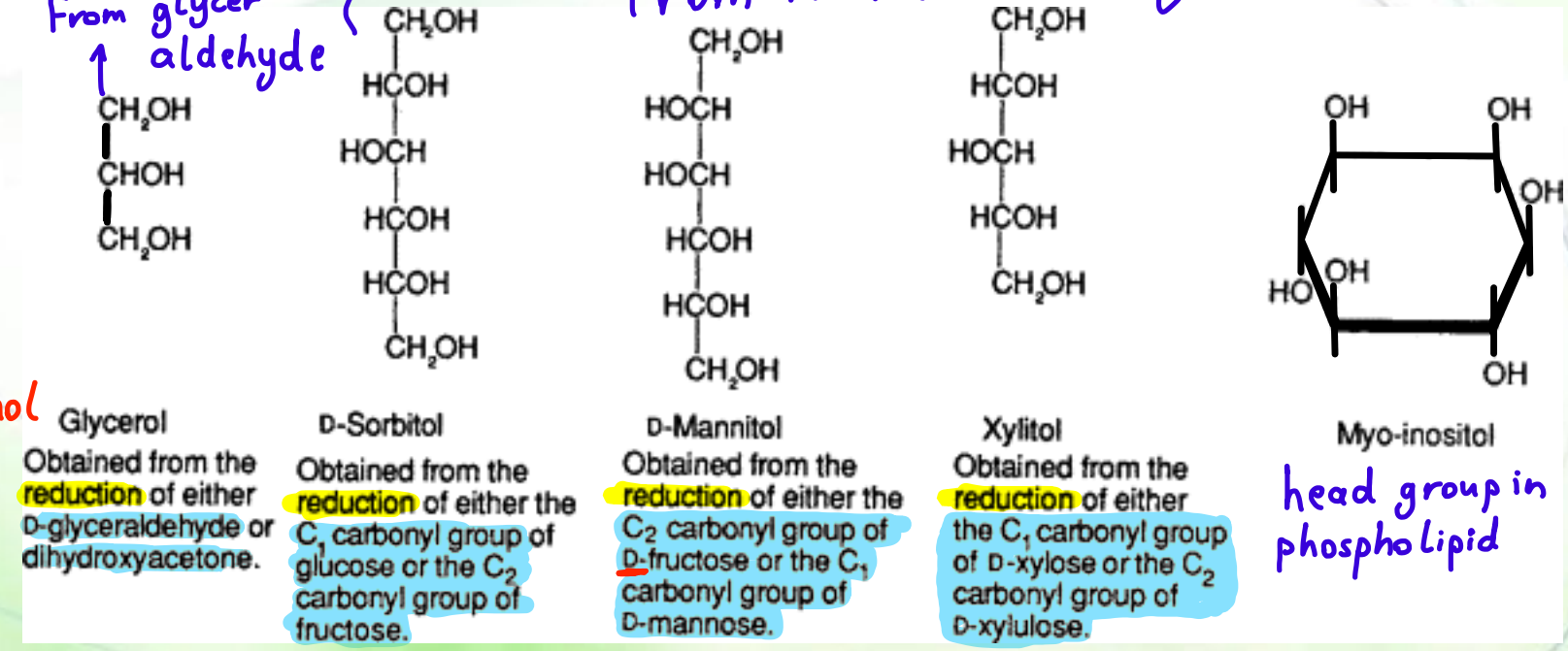
For immune system

* The most abundant protein in human body is collagen, it's Found in bone, basement membrane, cartilage,----

Sugar alcohols (reduction)

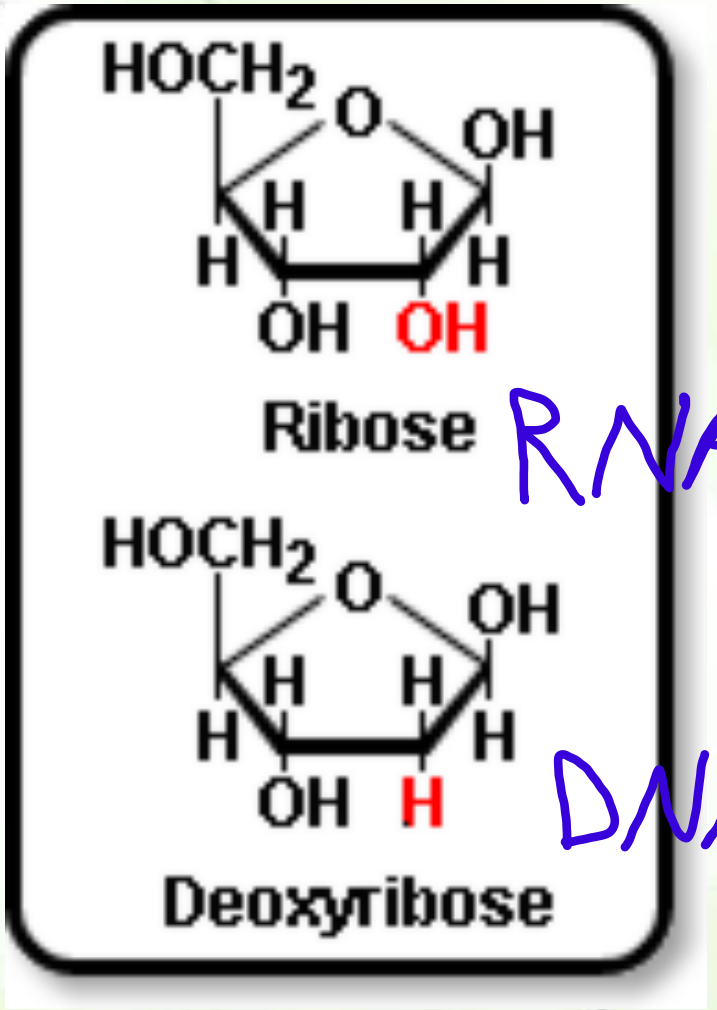
Gala → Galactitol

- What does it form? sorbose → sorbitol, mannose → mannitol, xylulose → xylitol
- Examples include sorbitol, mannitol, and xylitol, which are used to sweeten food products



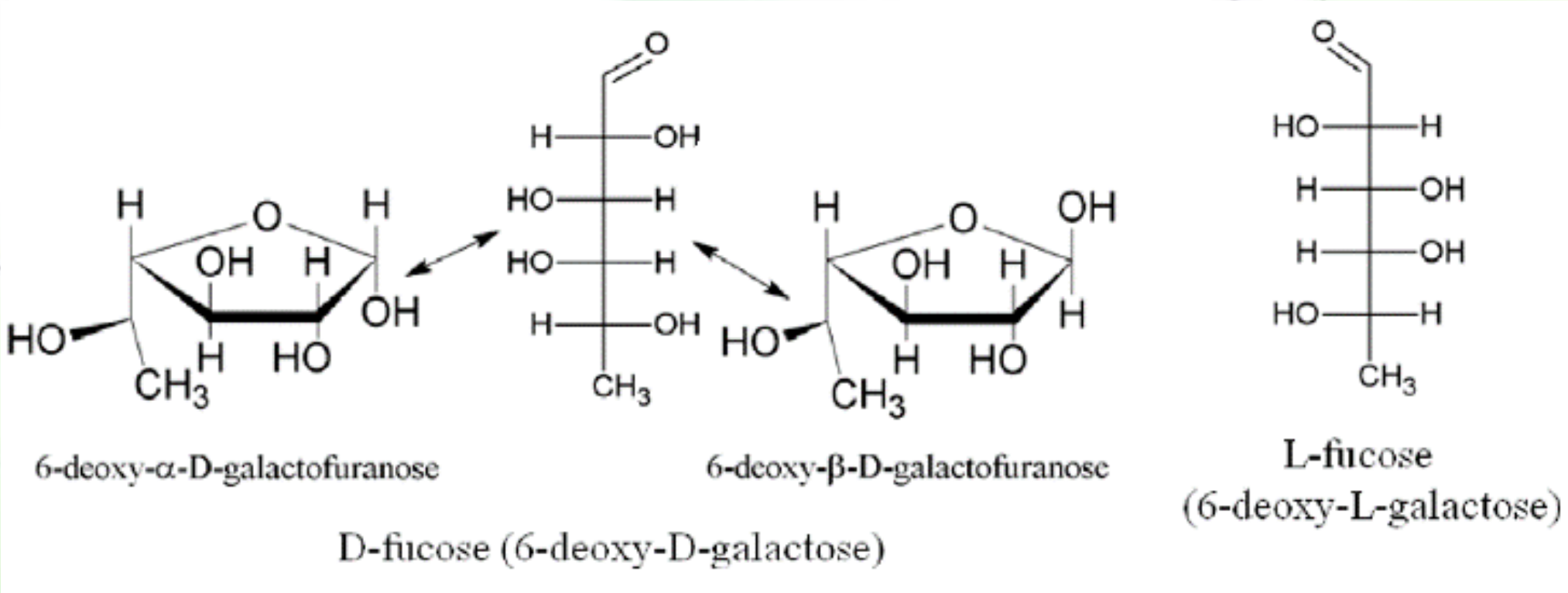
Deoxy sugars (reduced sugars)

- One or more hydroxyl groups are replaced by hydrogens.
- An example is 2-deoxyribose, which is a constituent of DNA.



Another one

- L-fucose (L-6-deoxygalactose)
  - found in the carbohydrate portions of some glycoproteins



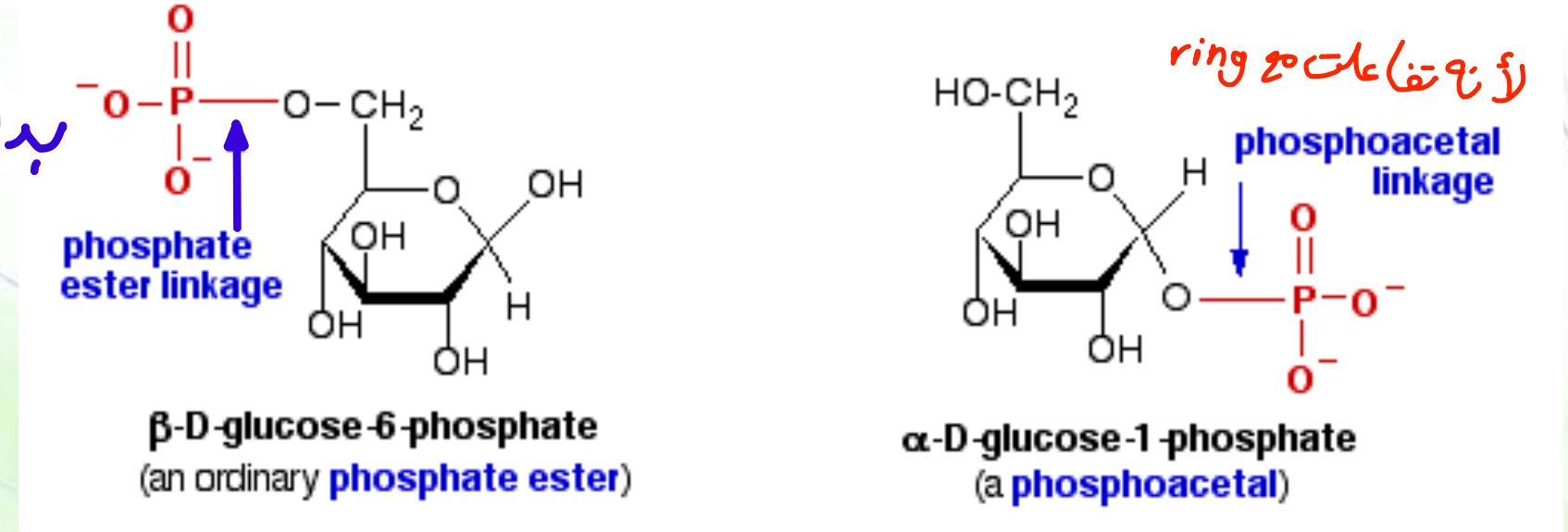
Sugar esters (esterification)

$R-\overset{O}{\overset{\|}{C}}-OR$ Form From carboxylic acid + alcohol

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

phosphoesterification:- Formation of ester bi bond with phosphate rather than C (P"-OR)

بدل C حطينا P

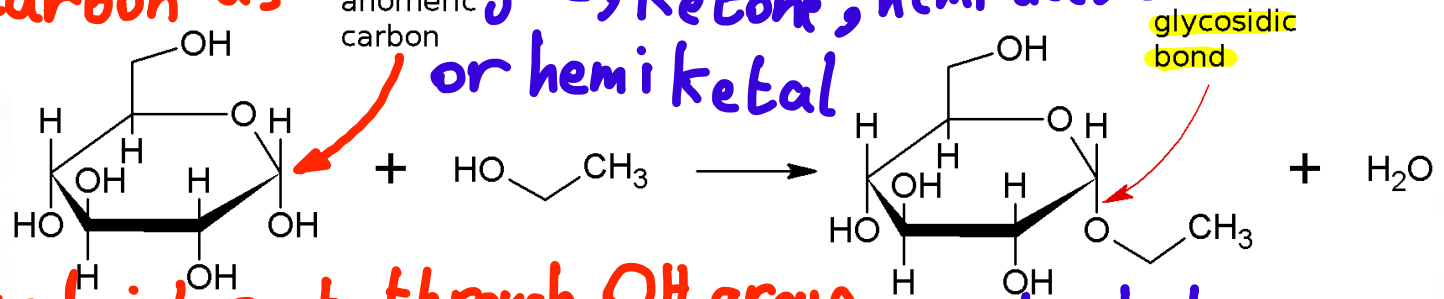


O-Glycosides

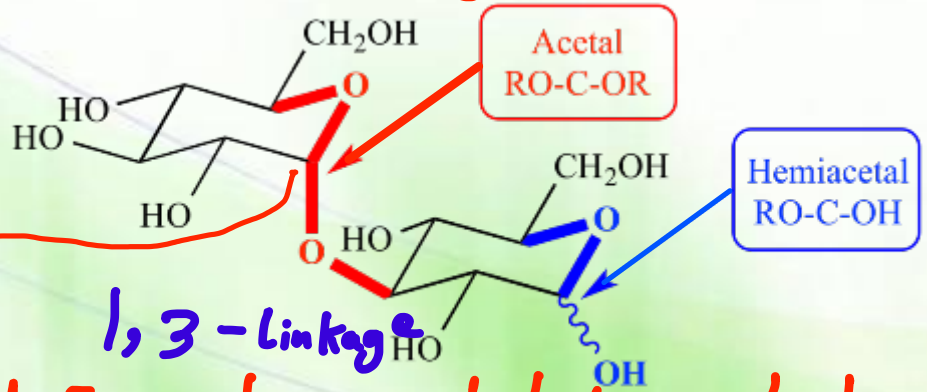
any molecule that include react of sugar with another suger like di, oligo and poly saccharides

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

* The First sugar interact through anomeric carbon as aldehyde, ketone, hemi acetal or hemi ketal

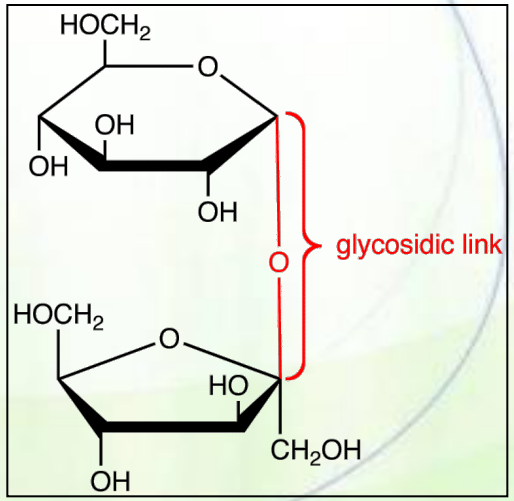


* The secound interact through OH group as alcohol



1, 3 - linkage

changed From hemiacetal to acetal

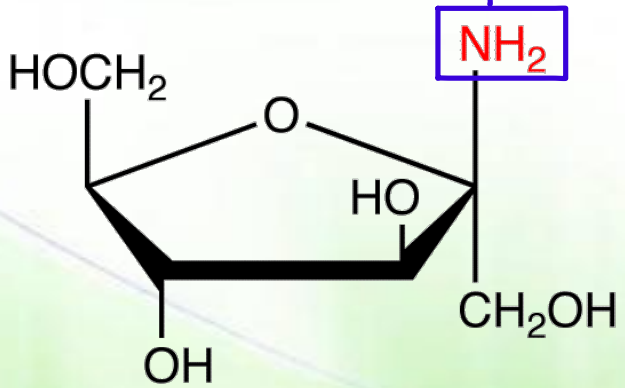


N-glycosides

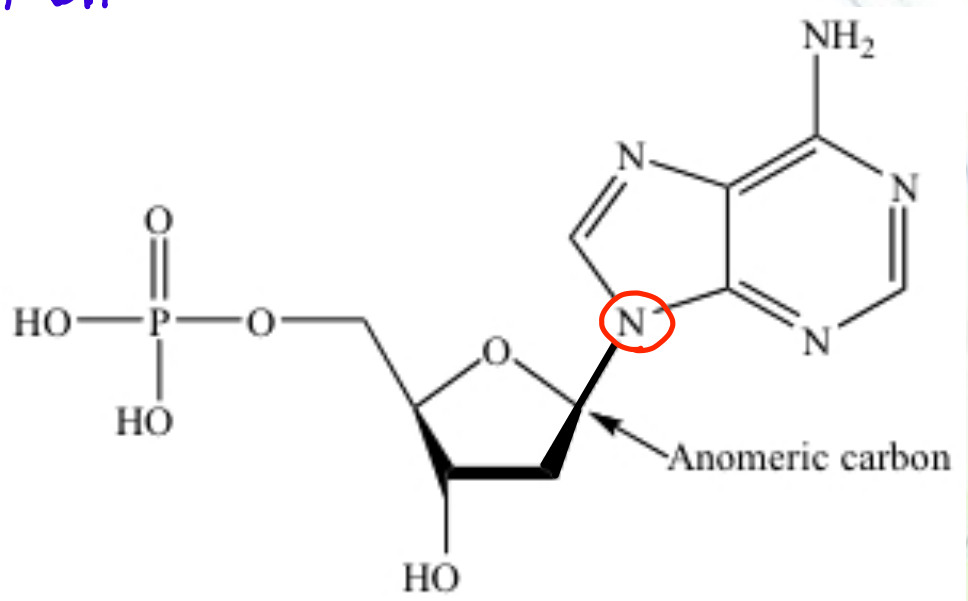
* The connection between this molecule through the N sugar and sugar مش شرط يكون بين *

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

Instead of OH



N-glycoside

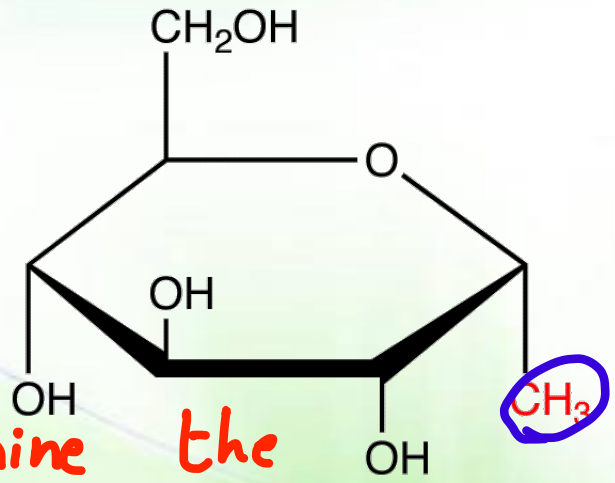


Nucleotids

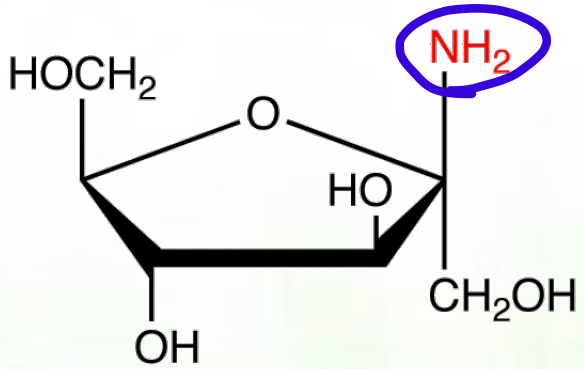
Note

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

* Other type of glycoside is C-glycoside



C-glycoside



N-glycoside

* We can determine the glycoside through the point of connection Like C_9N_2O

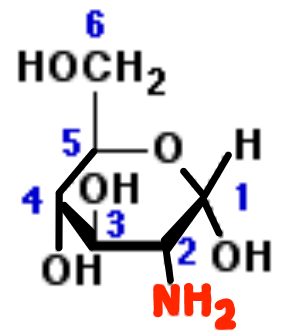
Amino sugars

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

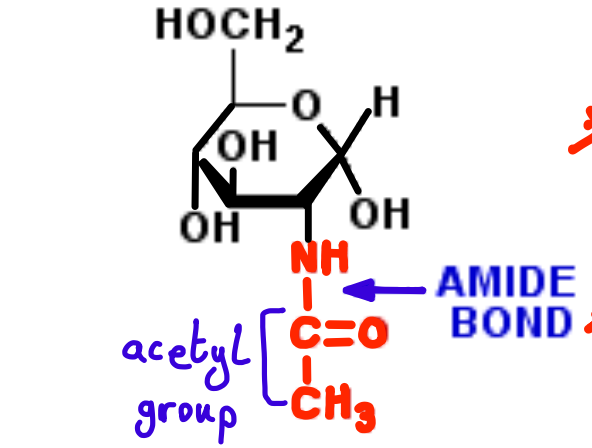
On carbon number 2

* The purpose of this modification is Formation of more polar sugar

*We increase the polarity to use it is different places and Functions mostly in ECM specificly as a GAGs



α-D-2-glucosamine
(GlcN)



N-acetyl-α-D-2-glucosamine
(GlcNAc)

* COOH more polar than OH
* NH_2 more polar than OH because it's Form alot of hydrogen bonds

*once they are polar they attract more H_2O, so they gel structure

they have a function in shock absorbtion

Disaccharides

reaction of sugar with another (O-glycosidic Linkage)

- 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?

different Type

same type

* The types of disaccharides is determined by the type of monomeres or residues, if they in similar type or different, which one the First, the bond between them and between which atoms

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)

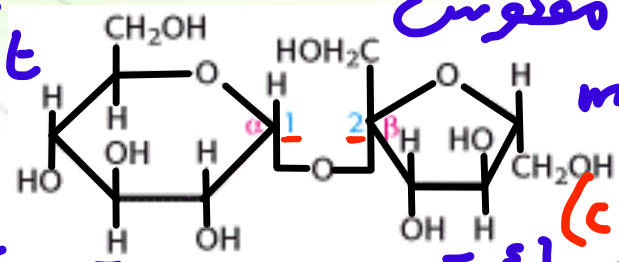
Abundant disaccharides

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

sucrose → less sweet

Fructose + Glucose → more sweet

Less sweet



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

سكروس

more sweet

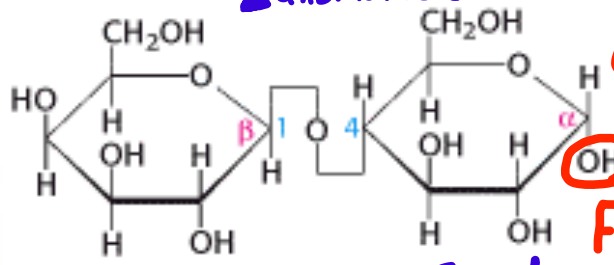
(can't oxidized)

من قصب السكر والشمندر

مائدة

(non-reducing)

anomaric (1→2) or α-(1→2)



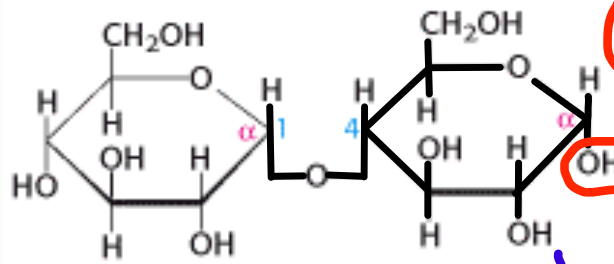
Lactose
(β-D-Galactopyranosyl-(1→4)-α-D-glucopyranose

(can oxidized)

(reducing)

Free

حليب



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

(can oxidized)

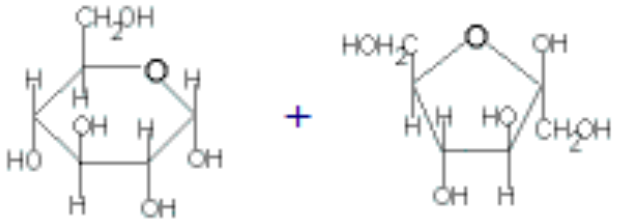
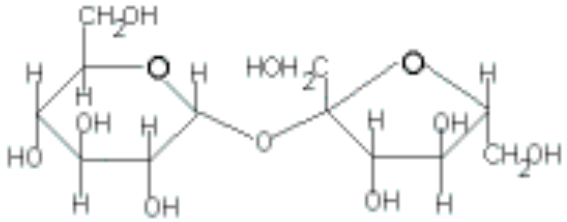
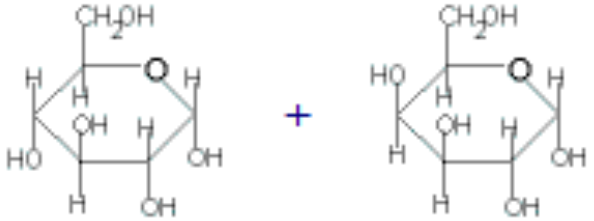
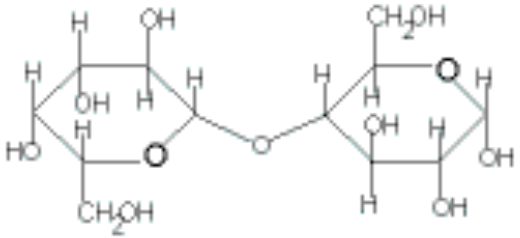
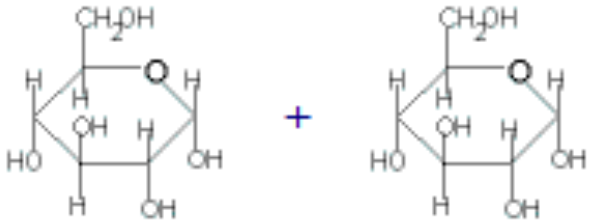
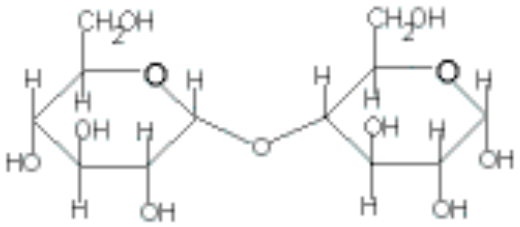
(reducing)

شعير

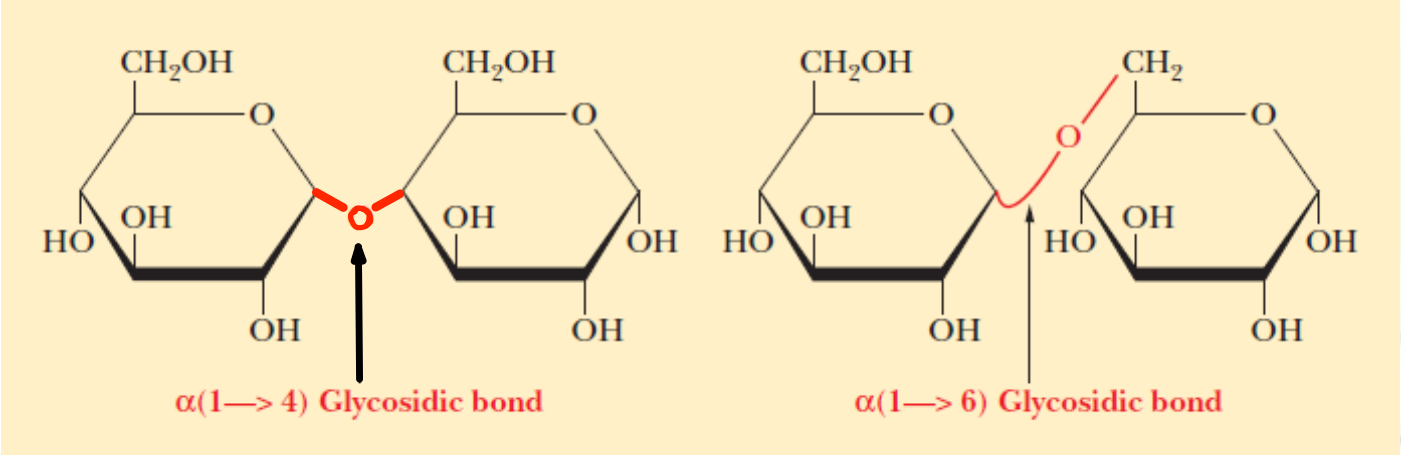
* ose :- sugar
* sucrose is moderate sweet between glucose and Fructose
* The sugar can be oxidized easly through there anomaric carbon

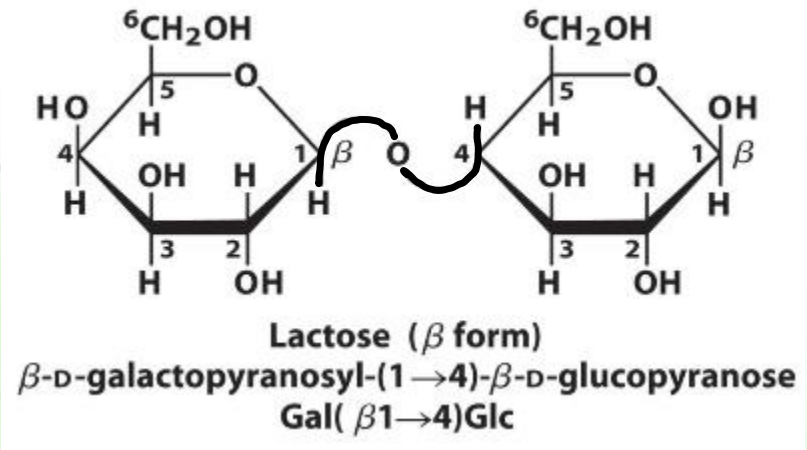
* The sucrose, maltose, lactose bonds can be digested by digestion system by lactase For lactose, maltase For maltose and sucrase For sucrose in small intestine to Form mono saccharides because the human body can't absorb disaccharides, but it can absorb monosaccharides

* Formation oF disaccharides is dehydration reaction

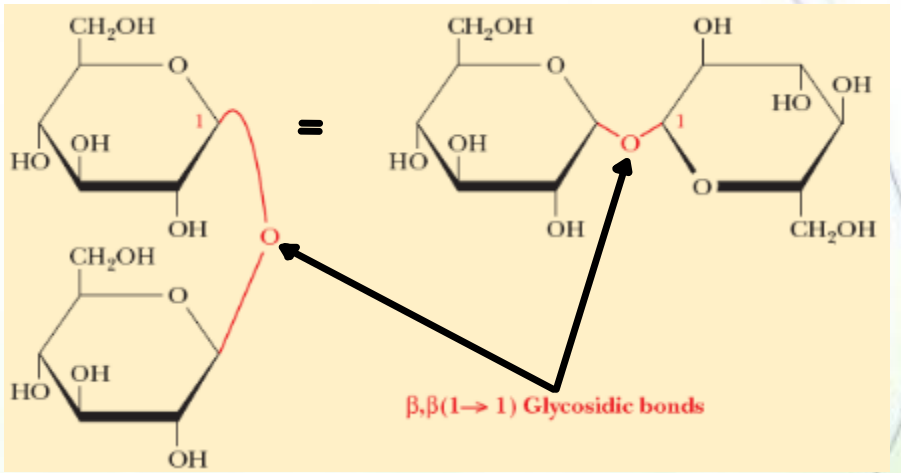
Name	Formula	Formed from	Structure
		glucose + fructose	---> sucrose + H_2O
sucrose	$C_{12}H_{22}O_{11}$		
		glucose + galactose	---> lactose + H_2O
lactose	$C_{12}H_{22}O_{11}$		
		glucose + glucose	---> maltose + H_2O
maltose	$C_{12}H_{22}O_{11}$		

Different forms of disaccharides



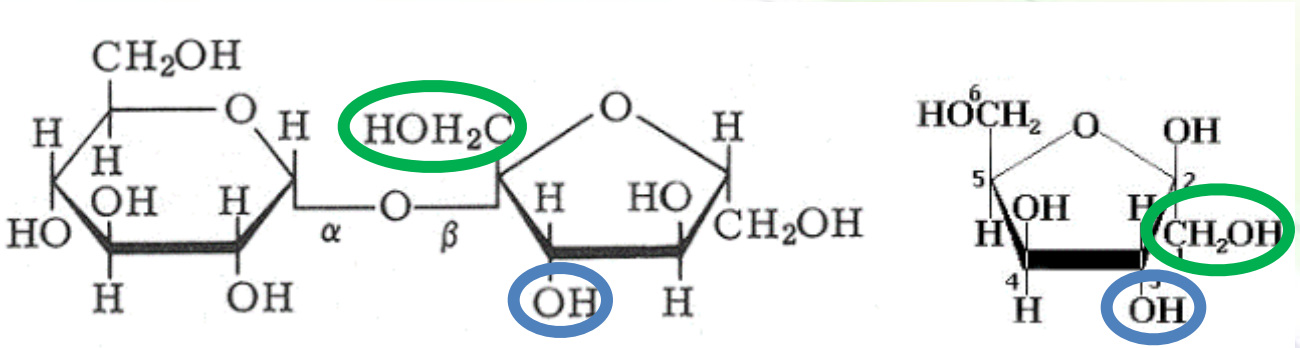


Lactose (β form)
β-D-galactopyranosyl-(1→4)-β-D-glucopyranose
Gal(β1→4)Glc

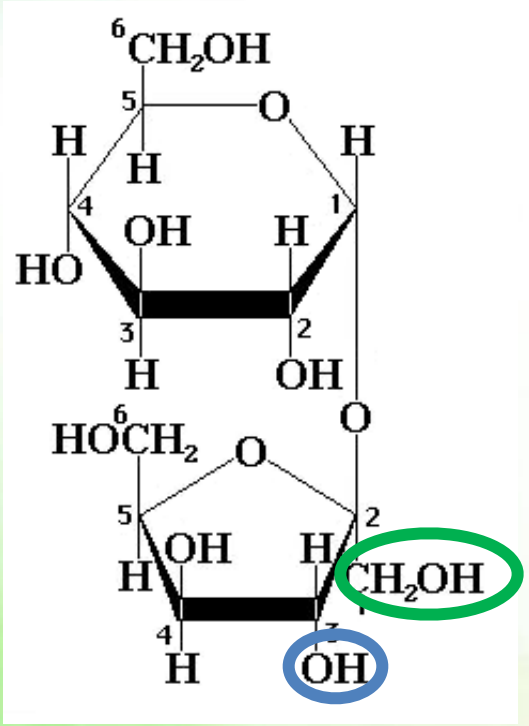


A disaccharide of β-D-glucose.

Sucrose


CH2OH
O
H
HOH2C
HO
OH
α
β
CH2OH
OH

HOCH2
OH
CH2OH
OH

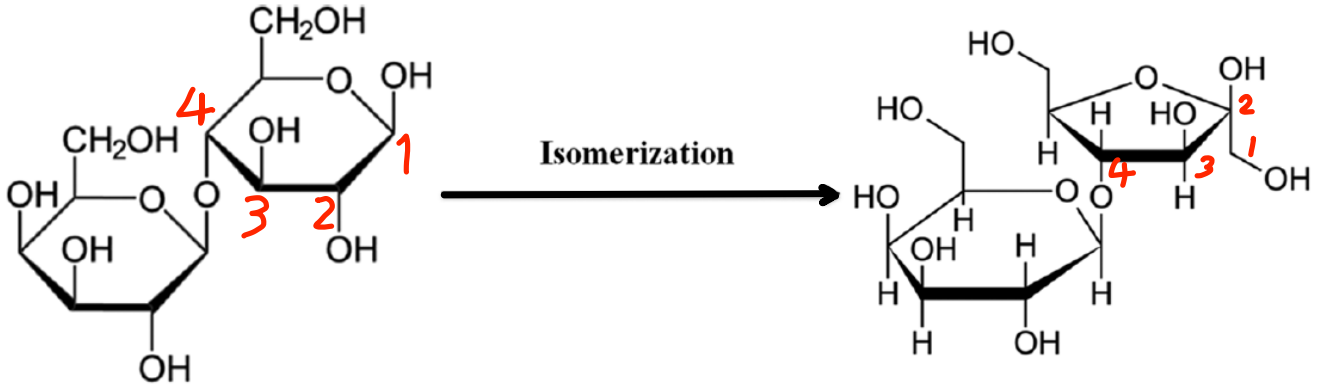

CH2OH
HO
OH
HOCH2
CH2OH
OH

Lactulose (artificial)

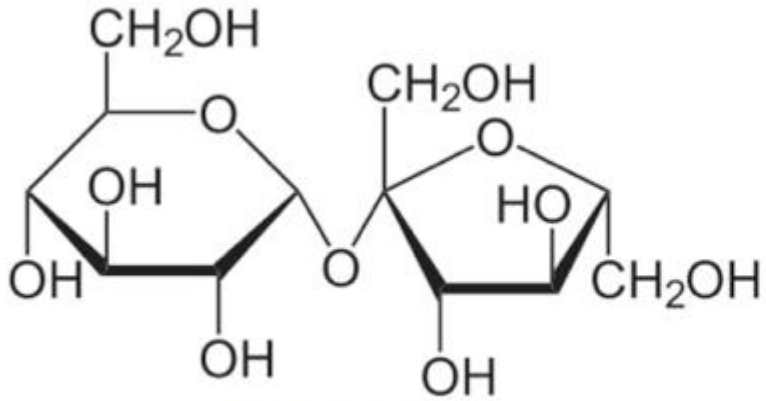
* It's an isomer For glucose

- It is formed by the isomerization of lactose either chemically or enzymatically.
- What is it made of?
- It has health benefits: إمساك
  - 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.

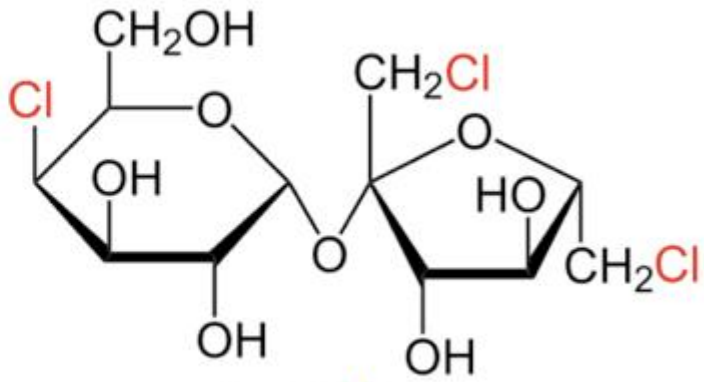
* Lactase Enzyme can't digest it, so it stay in small intestine as a disaccharide that it effect in osmosis prussure that is increase, so the water move out from intestine



Sucralose (artificial sweetener)



sucrose



sucralose

بتطلع لبرا

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

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.

* The milk contain Lactose that is disaccharide, so it is digested by lactase that is an intestinal enzyme.
The enzyme activity is redused by ages, so lactose will stay in intestine like lactulose, so the osmotic prussure increase that cause diarrhea
* normal Flora which is bacteria use lactose and break it and the by produt of these metabolic pathways produse product Like CO_2, methane

* When galactose enter to human body and absorbed the body can't use it and it's in high amount it will transform to polyalcohol, so it accumulate in human body and it

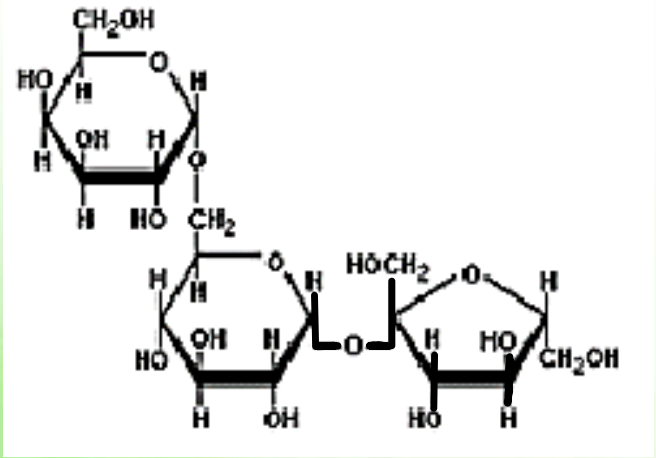
can't exit that increase osmotic prussure, attracted more H_2O make the cells swelling and explosure

* The most effected cell is neurons cell and lens of eyes

Raffinose

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

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.

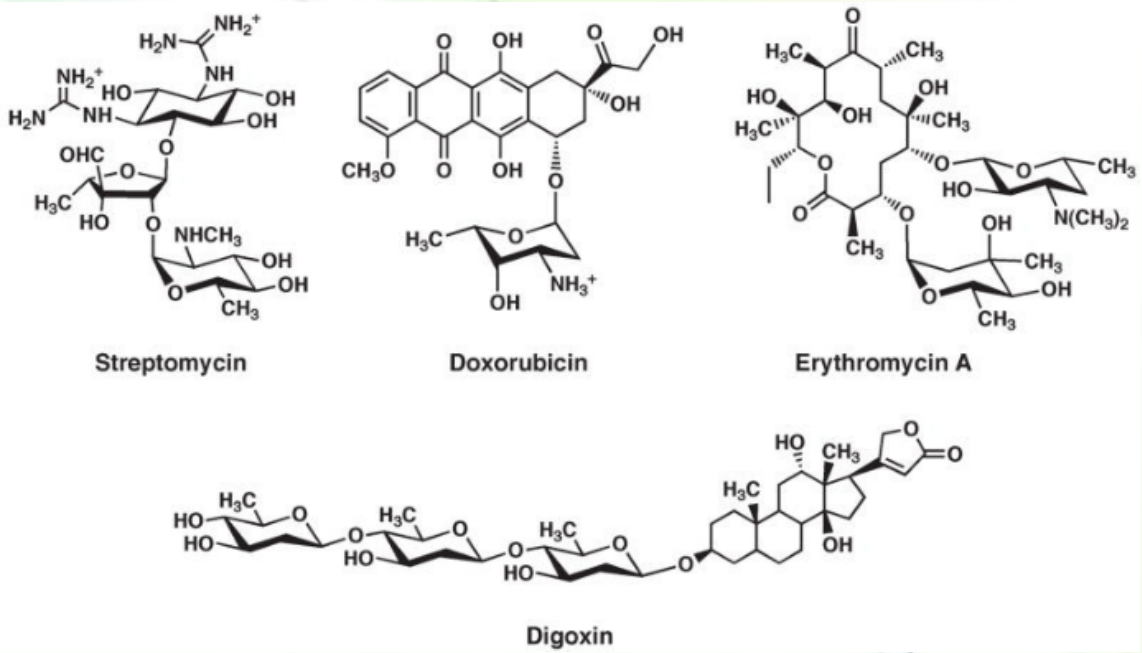


Homework

1. Recognize the monosaccharides that make up raffinose.
2. What is the monosaccharide that is attached to *what* disaccharide?

Oligosaccharides as drugs

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



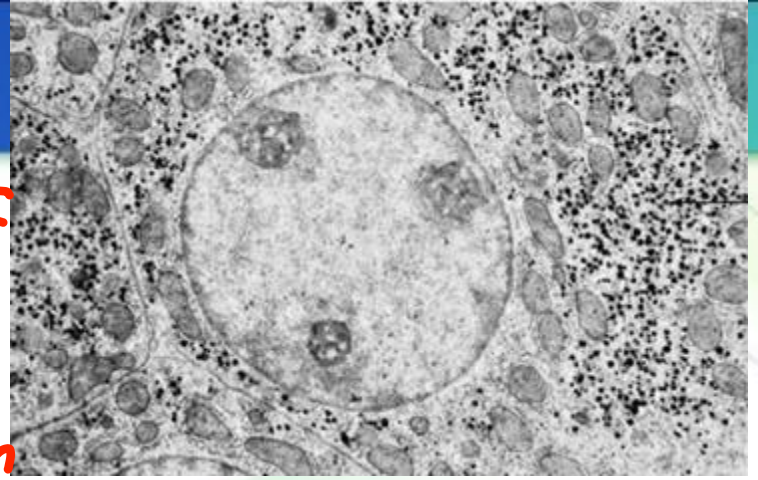
Polysaccharides

*ahunderds, thousands and millions of residues
*they can be formed by same residues or different residues

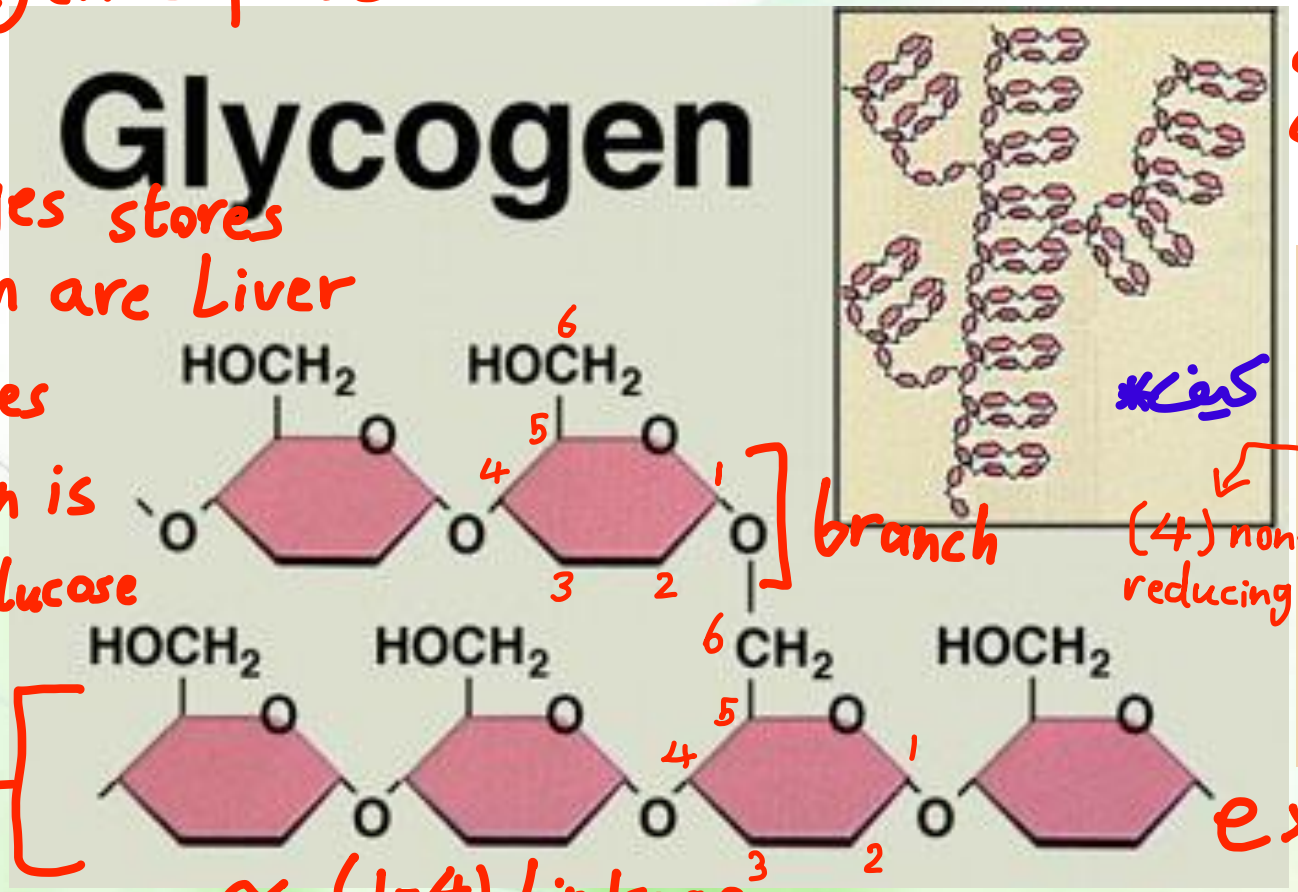
- What are polysaccharides?
- Homopolysaccharide (homoglycan) vs. heteropolysaccharides
  same residues different residues
- Features of polysaccharides:
  - Monosaccharides
  - Length
  - Branching
  - Purpose:
    - Storage (glycogen, starch, dextran)
    - Structural (cellulose, pectin, chitin)

*They differ in type of linkage (α, β), the atoms that are connected (1-4, 1-6), branches or not (linear or branches chain) and the Function (storage or structural molecule have mechanical Function)

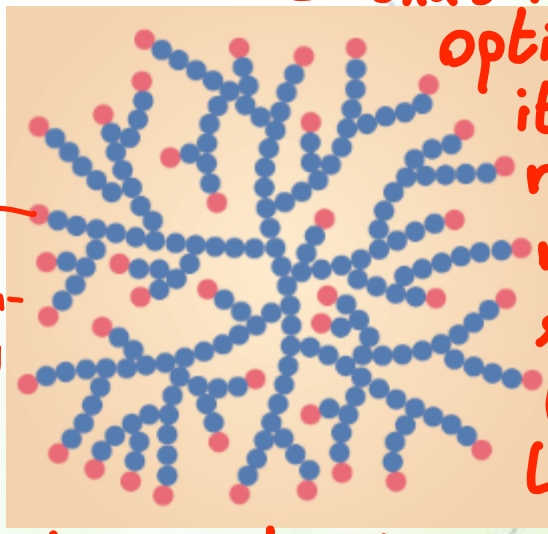
Glycogen



* A storage Form of sugar in animal cells
* Glycogen is present in all cells
* The larges stores of glycogen are Liver and mucsles
* Glycogen is made by glucose



* carbon number 1 can be connected to the main chain through carbon number 6 that is the best option because it's outside the ring, so we have more space, but in the branch the Linkage is (1→4)



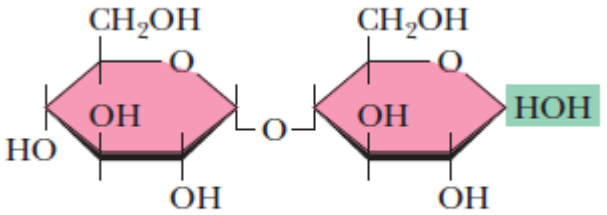
extensivly branched

* The importance of branching is increase the area that increase the breakage

Starch

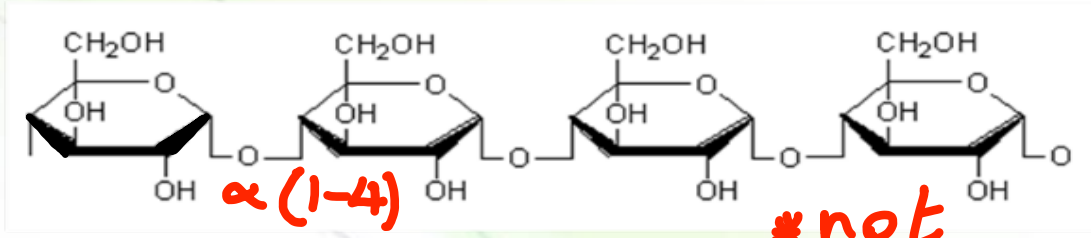
* Starch is presents in plants

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

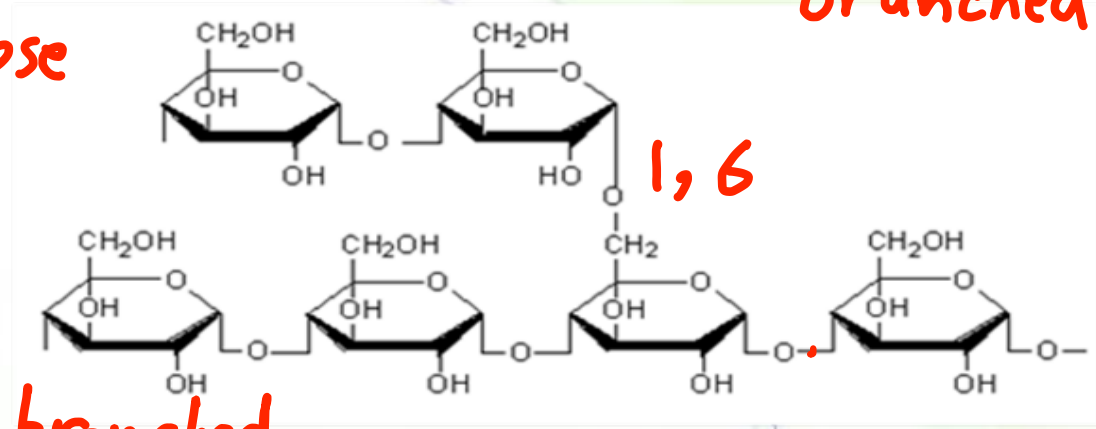


Maltose (glucose-α-1,4-glucose)

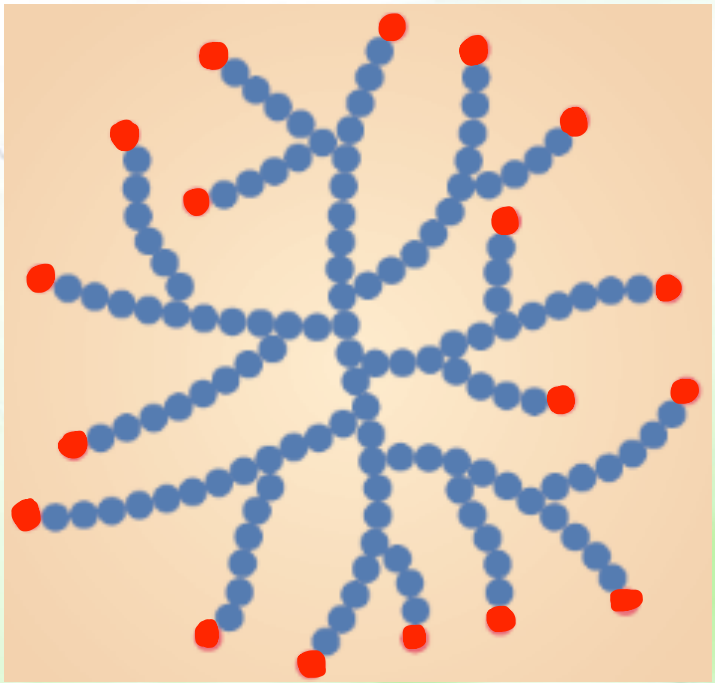
monomers of glucose



Amylose Structure * not branched



Amylopection Structure



(not reducing) * branched

(can't be oxidized)

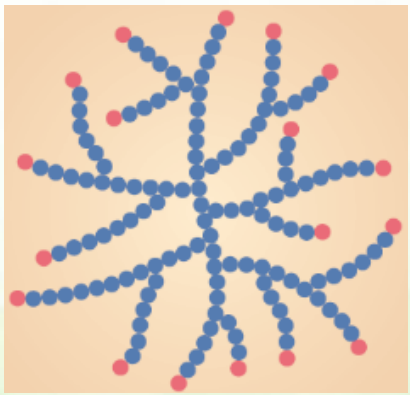
amylase make frgmentation

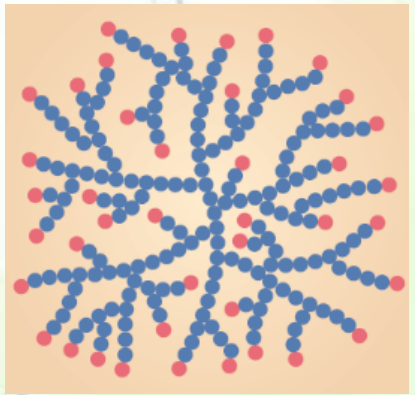
Glycogen vs. amylopectin

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

Glycogen is more extinsive branching than amylopectin

more branch more solubility

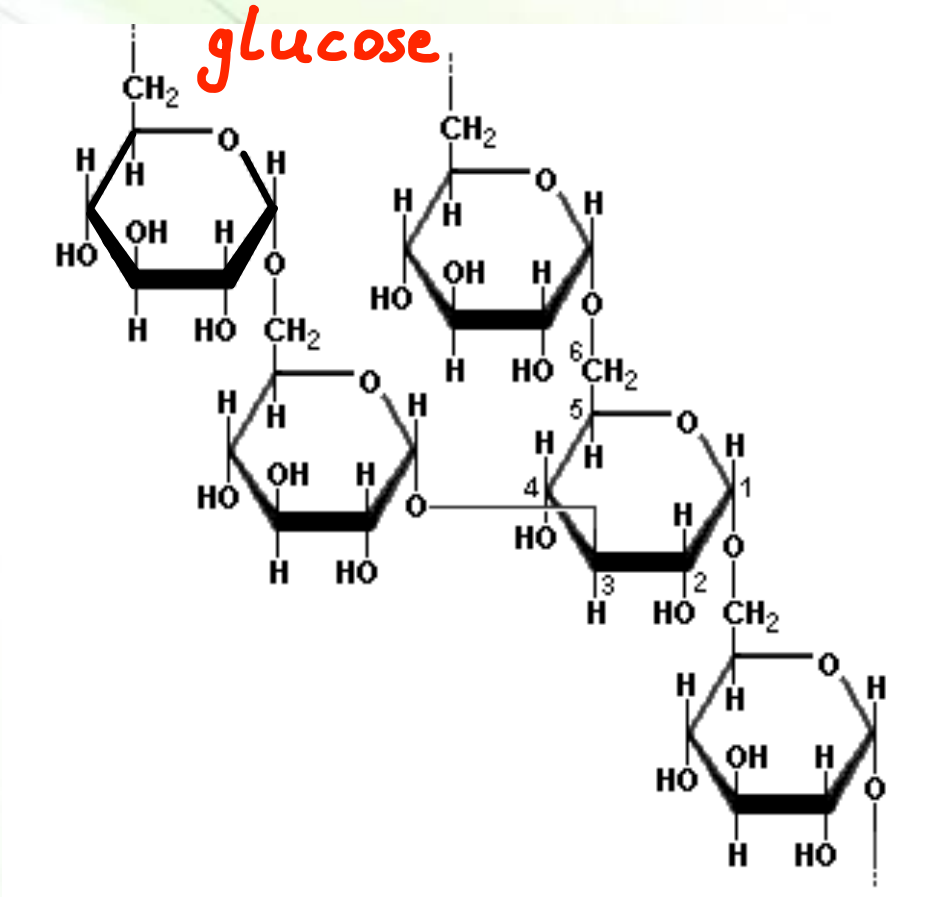




Dextran

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

* It is homopoly saccharide

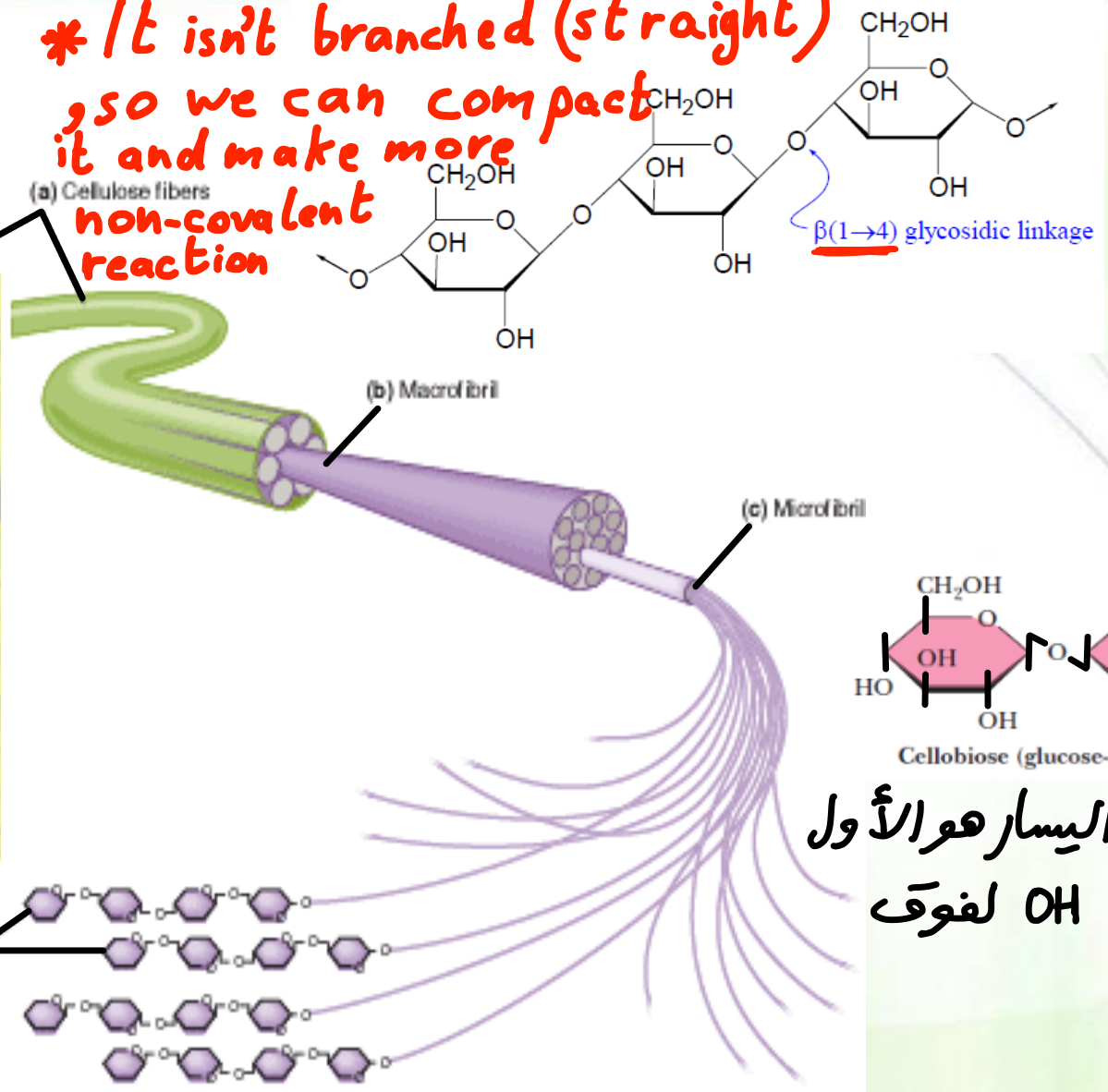


Cellulose

* In plants
* all of stalk tree are cellulose
* It's a structural polysaccharide
* human body can't digest cellulose molecule becaue we don't have an enzyme that digest B(1-4) bond
* The enzyme can be Found in intestine of herbivore

حيوانات آكلة للأعشاب

* It isn't branched (straight) ,so we can compact it and make more non-covalent reaction

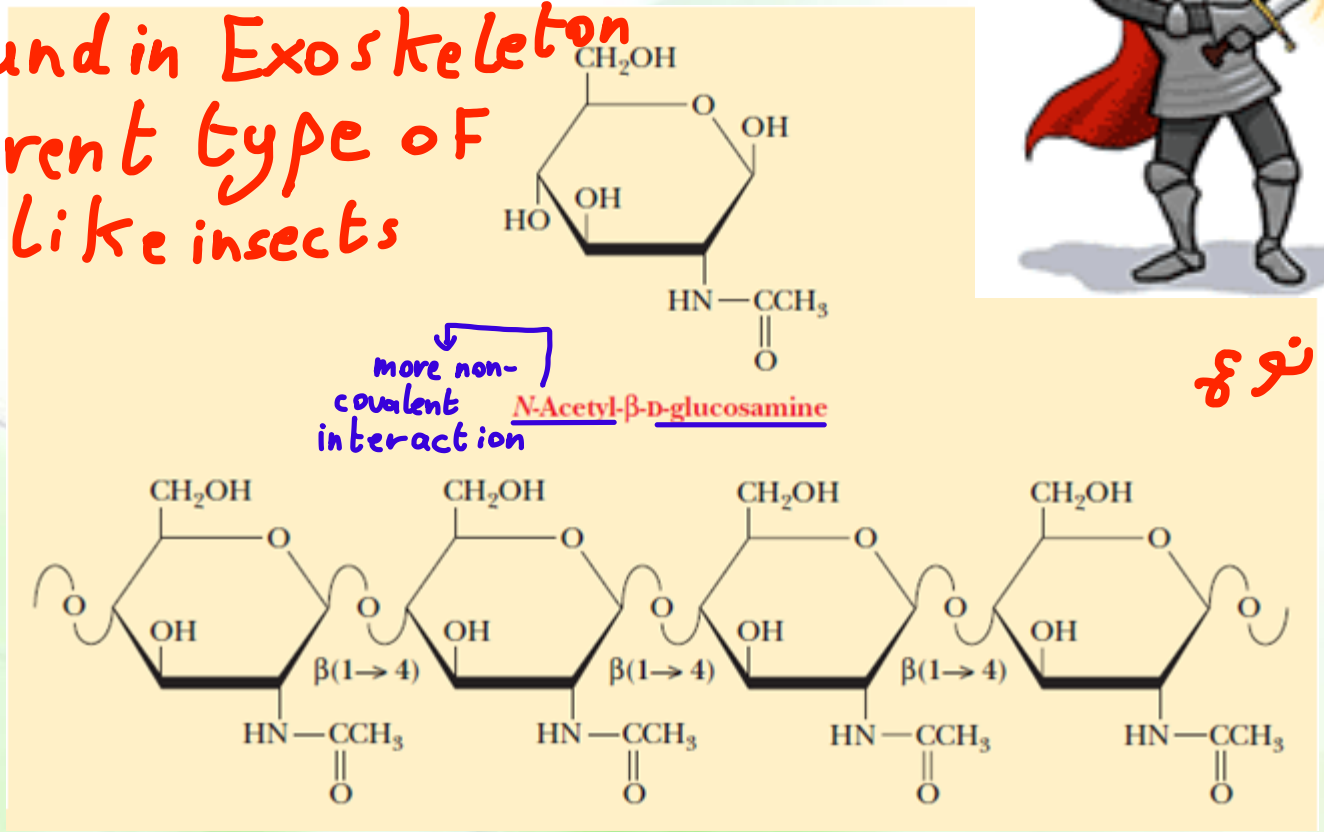


إلي على اليسار هو الأول لأن OH لفوق B

Chitin

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

* Structural polysaccharide
* It is Found in Exoskeleton of different type of animals like insects

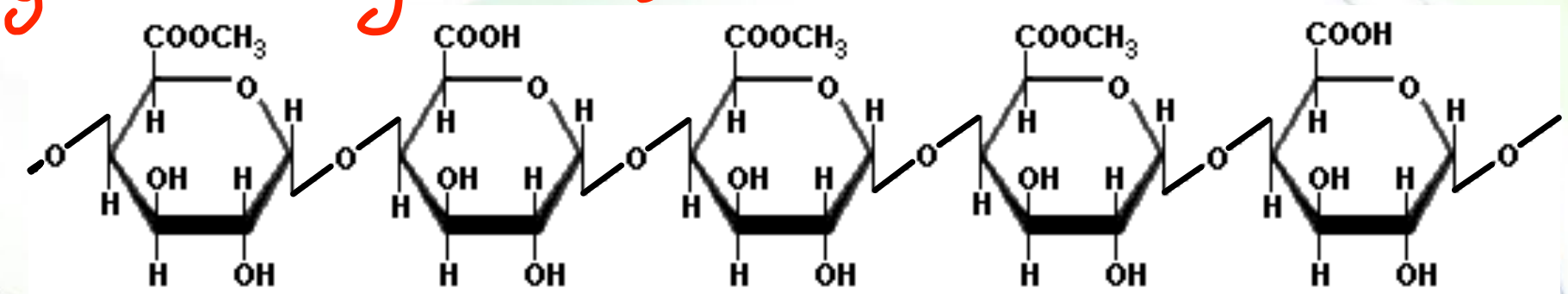


مش مهم أعرف نوع الرابطة

Pectin

- What is the precursor? monomere oF modified sugar (heteropoly saccharides)
- Where does it exist? In plants and bacteria
  Gylatin in animals

methyl galacurnate galacurnate



مادة محفزة لتكوين الحالة الهلامية

* pectin is gelling agent

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.

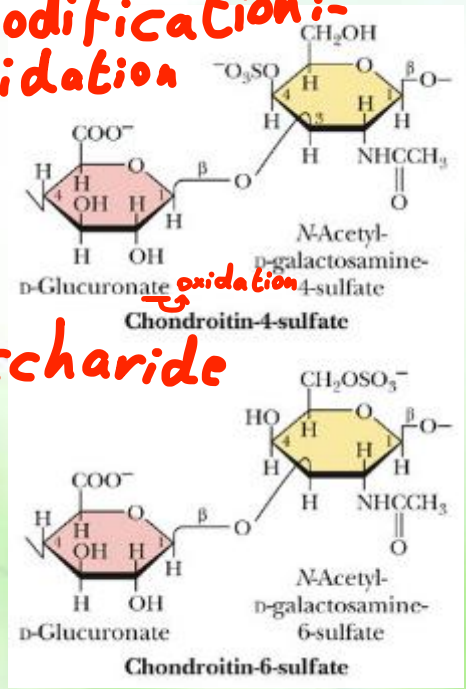
* Most of interactions are occured in anomaric carbon with another thing most of ends is a normal carbon (not anomaric carbon) ,so they are non-reducing because they don't have reducing residues

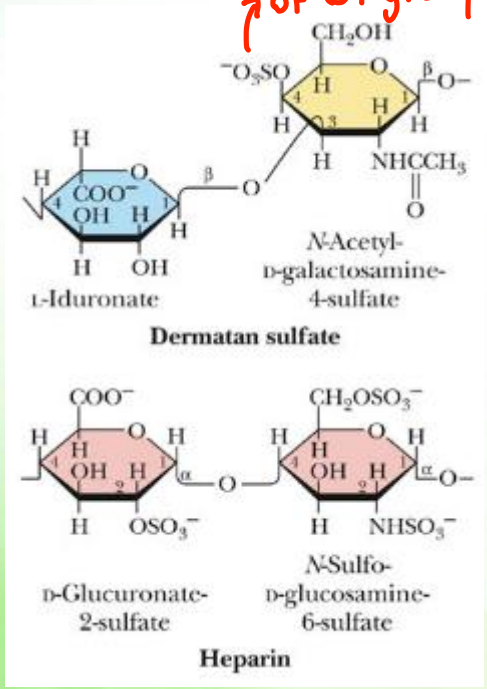
Glycosaminoglycans (not reducing)

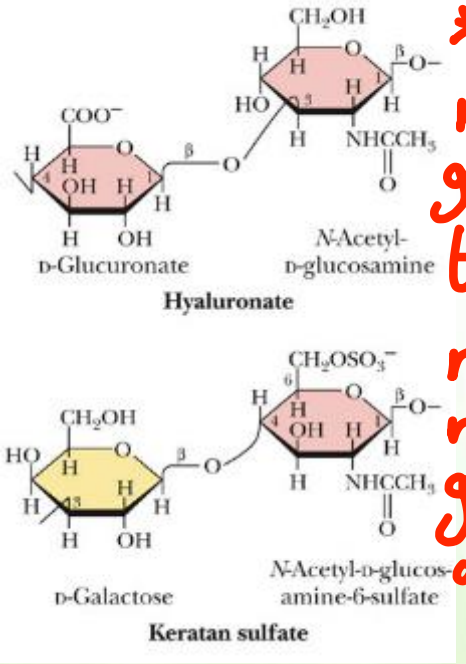
- What are they? Where are they located? In ECM
- Derivatives of an amino sugar, either glucosamine or galactosamine
- At least one of the sugars in the repeating unit has a negatively charged carboxylate or sulfate group

* We have 3 modification:-
1-sulfation 2-oxidation
3-amination
* They are heteropolysaccharide

sulfated ↑ of OH group



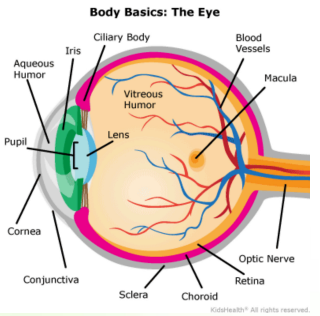




* They are of modified glucose and galactose to increase the polarity of residues to attract more H_2O, so it become gel like structure they act as shock absorber

Localization and function of GAG

GAG	Localization	Comments
Hyaluronate	gel materials Fill eyes ball 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	بخفف لزوجة الدم component of intracellular granules of mast cells lining the arteries of the lungs, liver and skin	تخثر **A natural anticoagulant**
Dermatan sulfate	Dermis (skin) skin, blood vessels, heart valves	
Keratan sulfate	cornea, bone, cartilage aggregated with chondroitin sulfates	Only one not having uronic acid

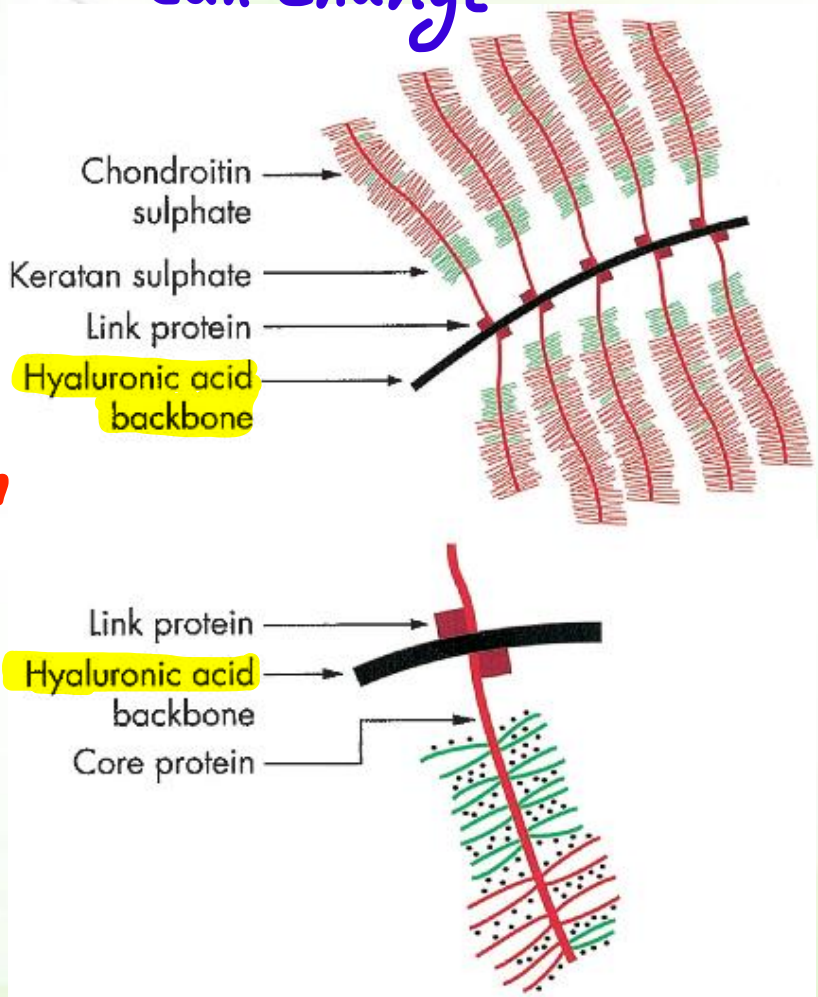


Proteoglycans

minor major

* They are dynamic, so they can change

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

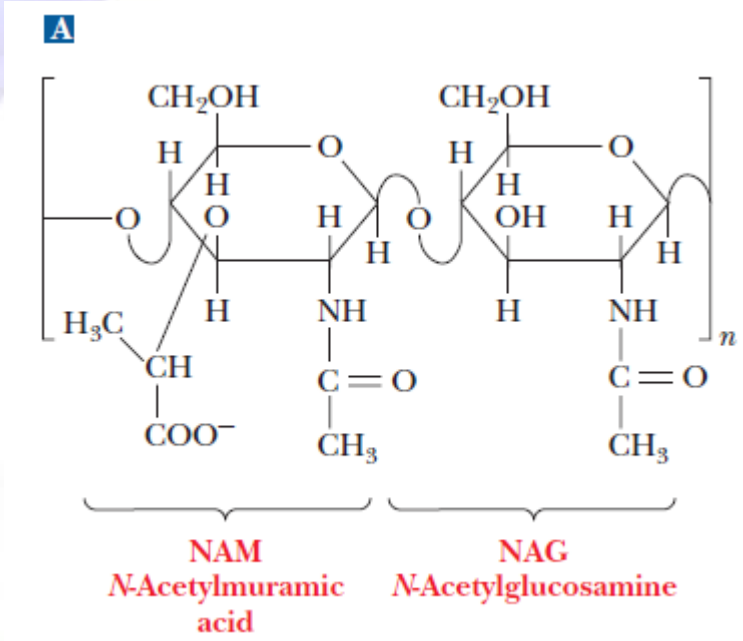


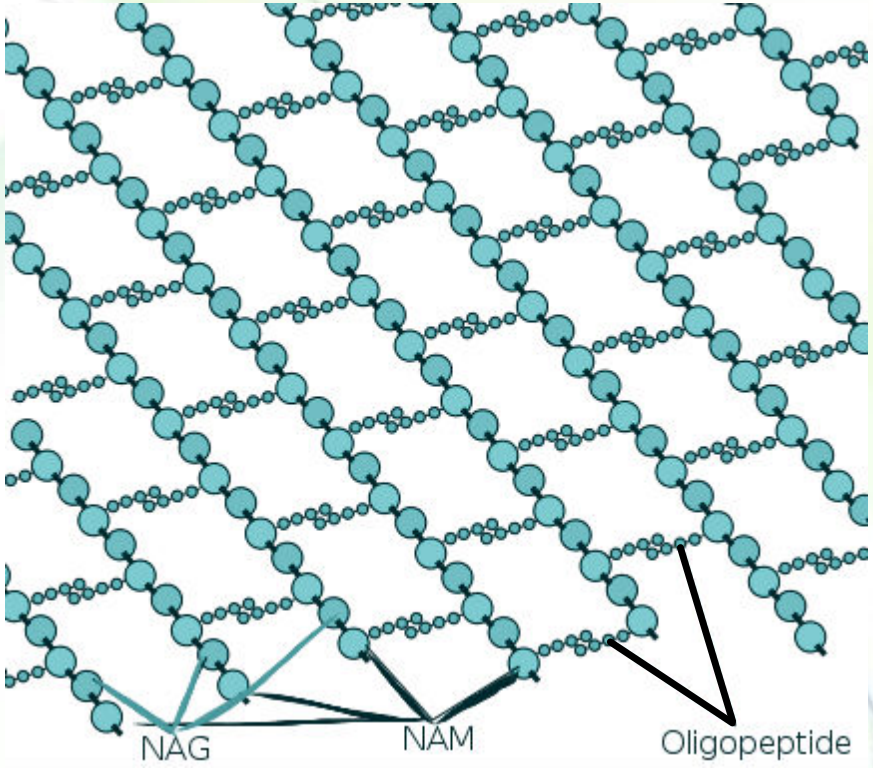
Proteoglycan is opposite of Glycoprotein

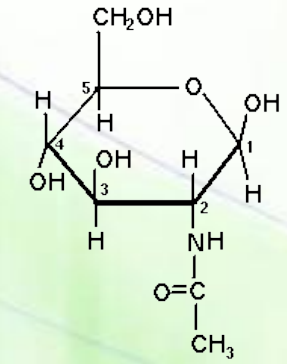
minor major minor major

زي إسماعيل العارضة العائلة هي الأكبر

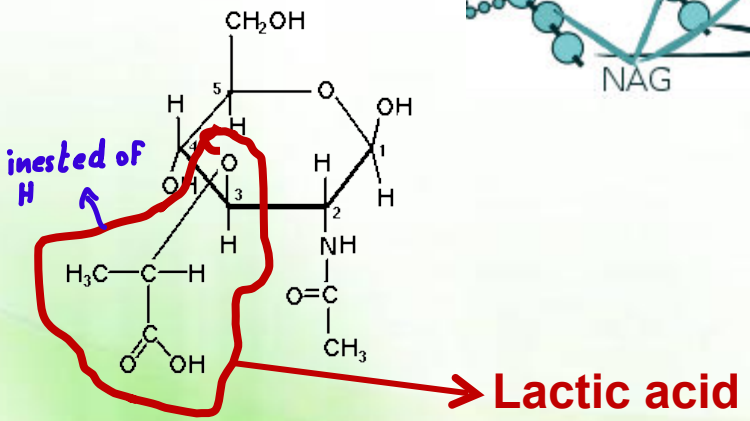
Bacterial cell wall





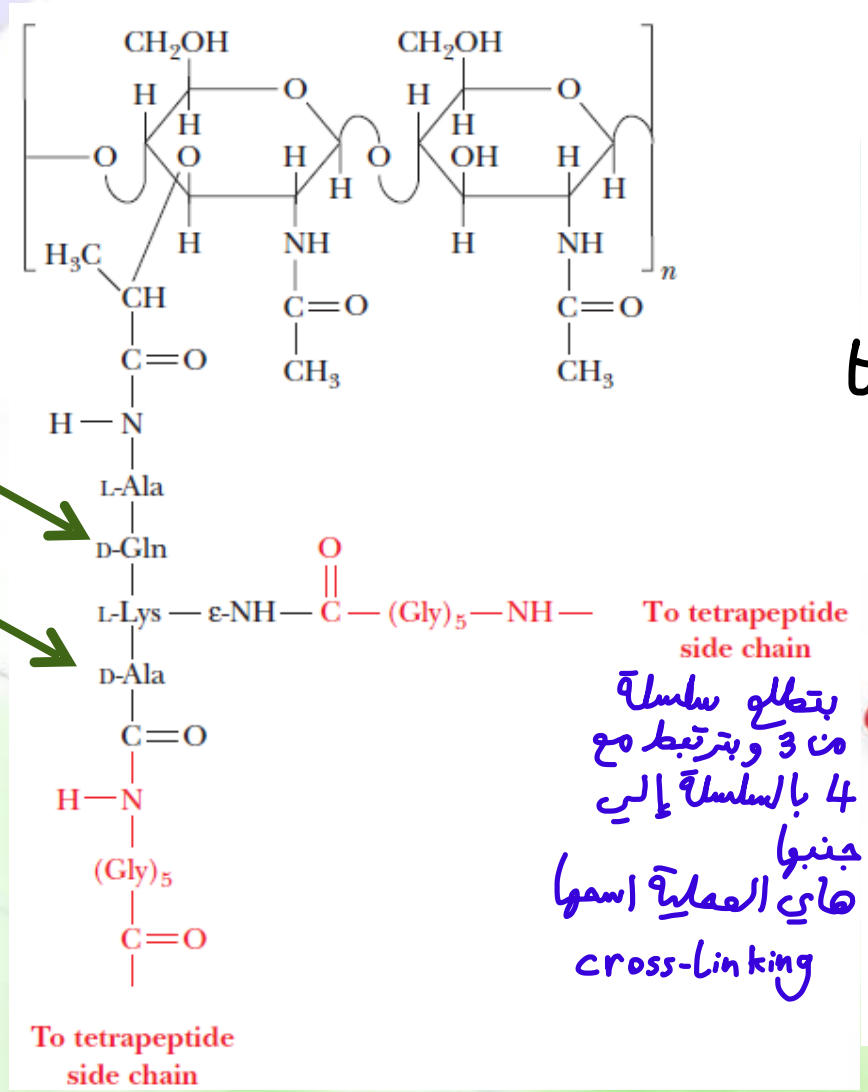


N–acetylglucosamine (NAG)

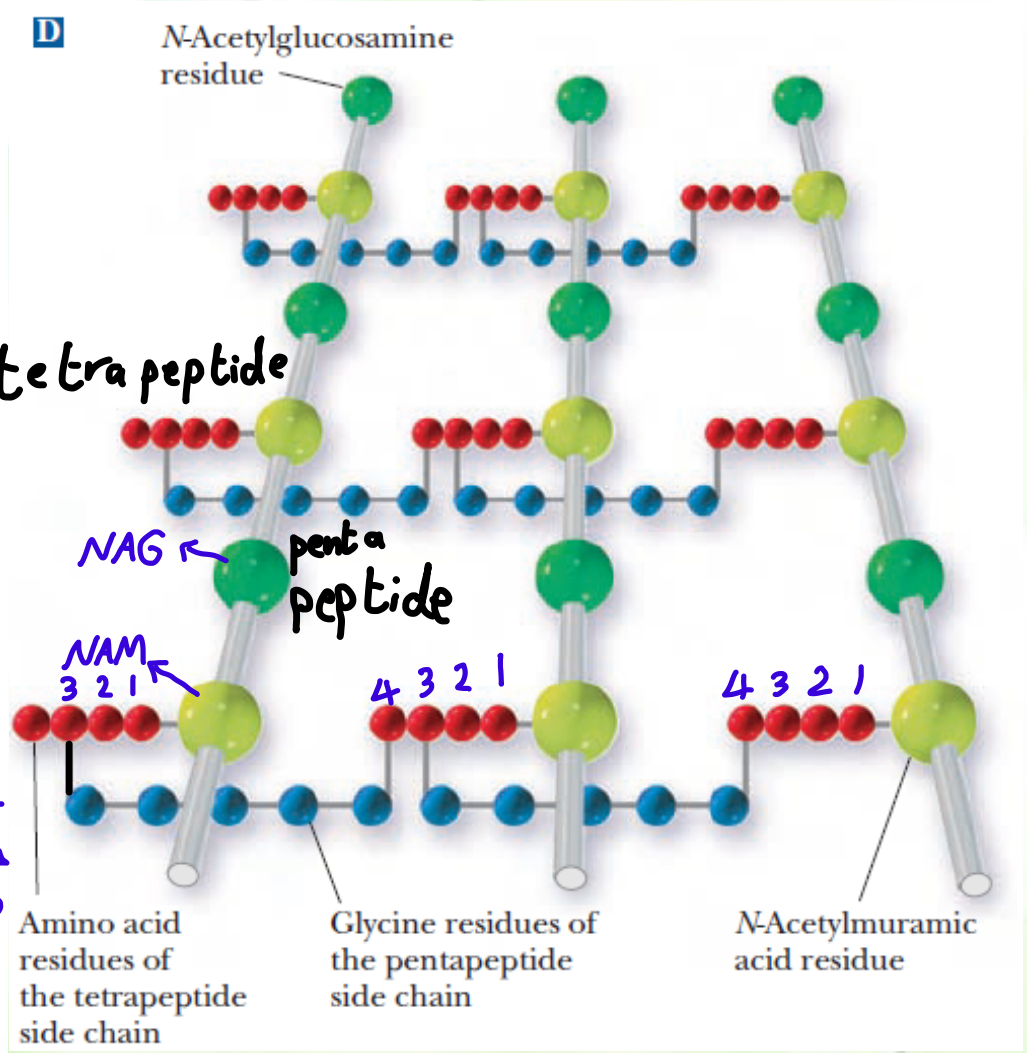


N–acetylmuramic acid (NAM)

Peptidoglycan



بتطلع سلسلة من 3 وبترتبط مع 4 بالسلسلة إلي جنبها هاي العملية اسمها cross-linking



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 group of serine (Ser, S), threonine (Thr, T) or hydroxylysine (hLys)

بحفظهم عند amino acids

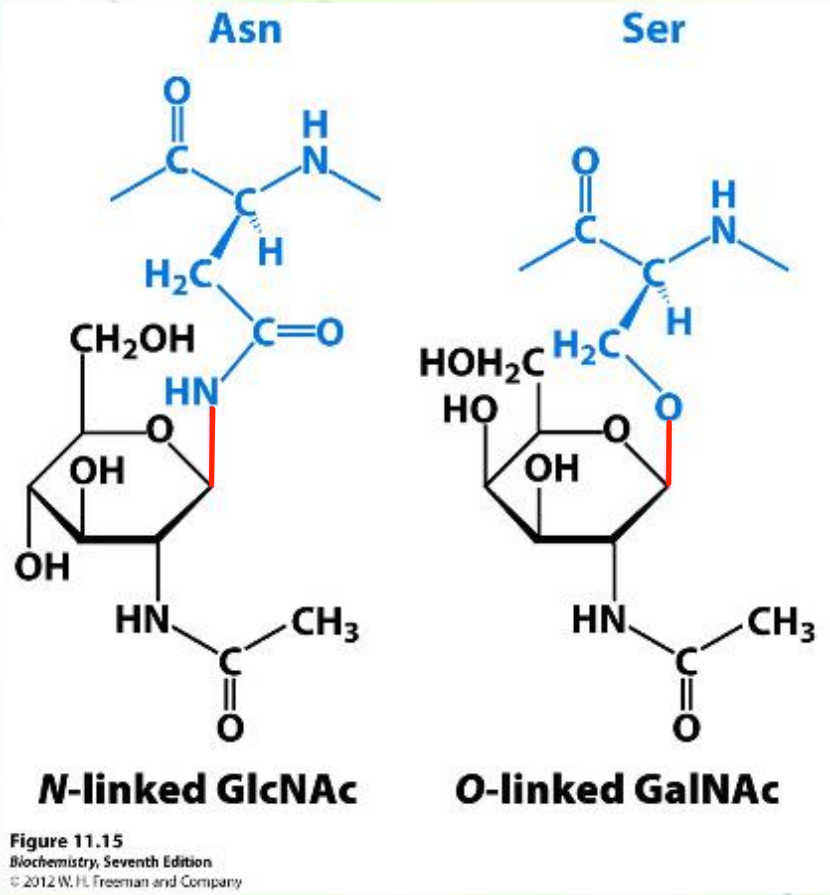


Figure 11.15
Biochemistry, Seventh Edition

Significance of protein-linked sugars

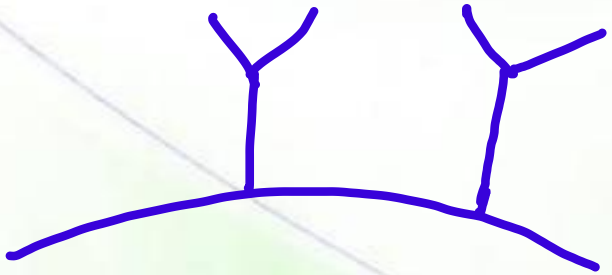
- Soluble proteins as well as membrane proteins
- Purpose:
  - Protein folding
  - Protein targeting
  - prolonging protein half-life
  - Cell-cell communication
  - Signaling

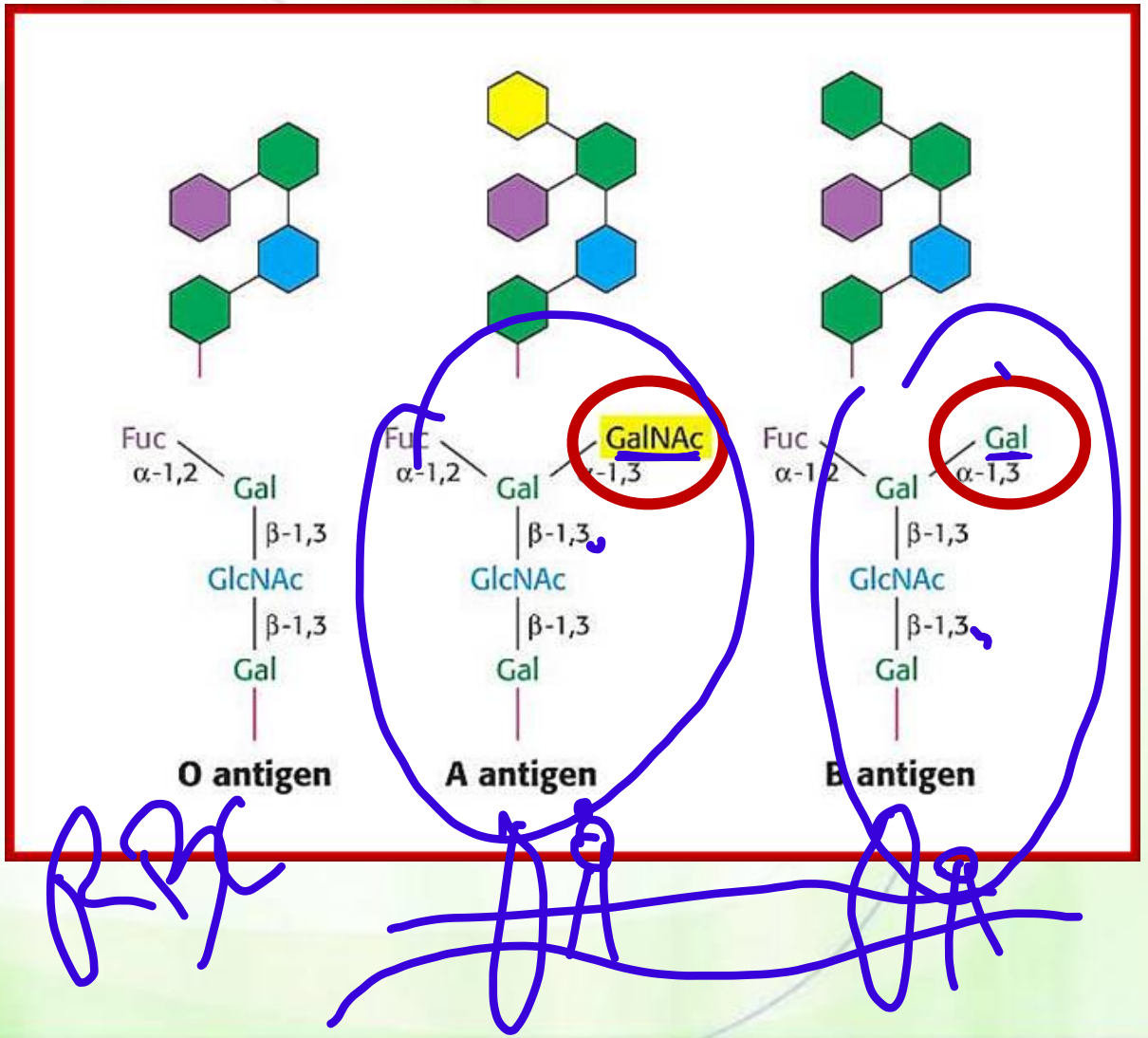
sugar helps protein to Form 3D shape

protein are made in ER, then to golgi apparatus to be modified, Finally targeting to cell membrane, mitocondria, nucleus, ER or lysosome by sugars

Blood typing and glycoproteins

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

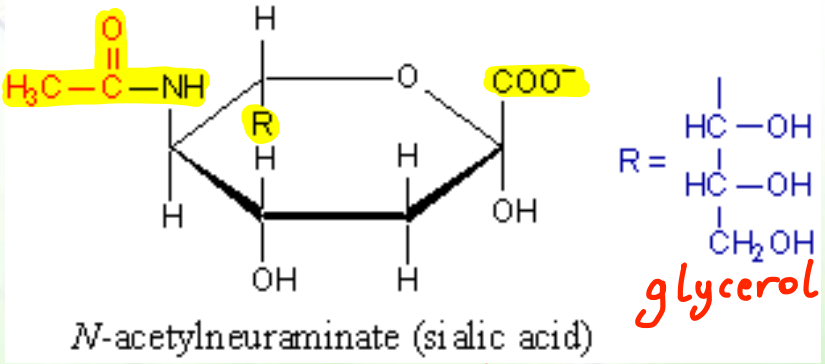




Sialic acid

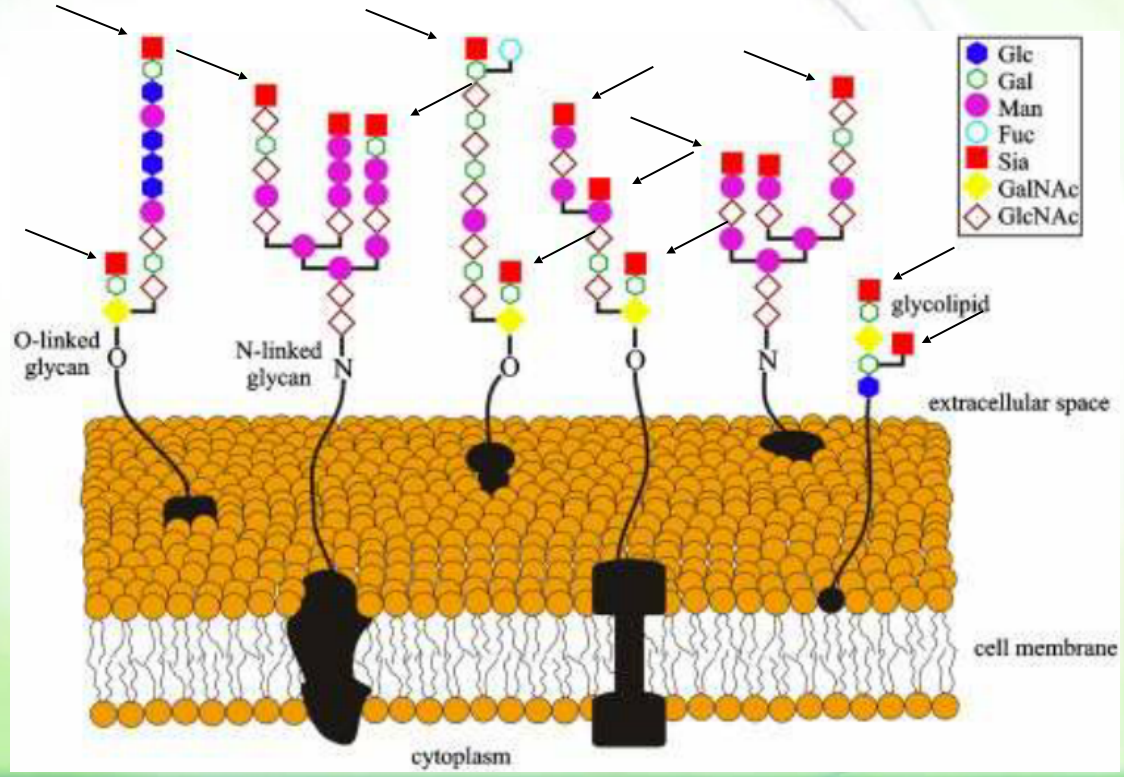
* Present in glycolipid

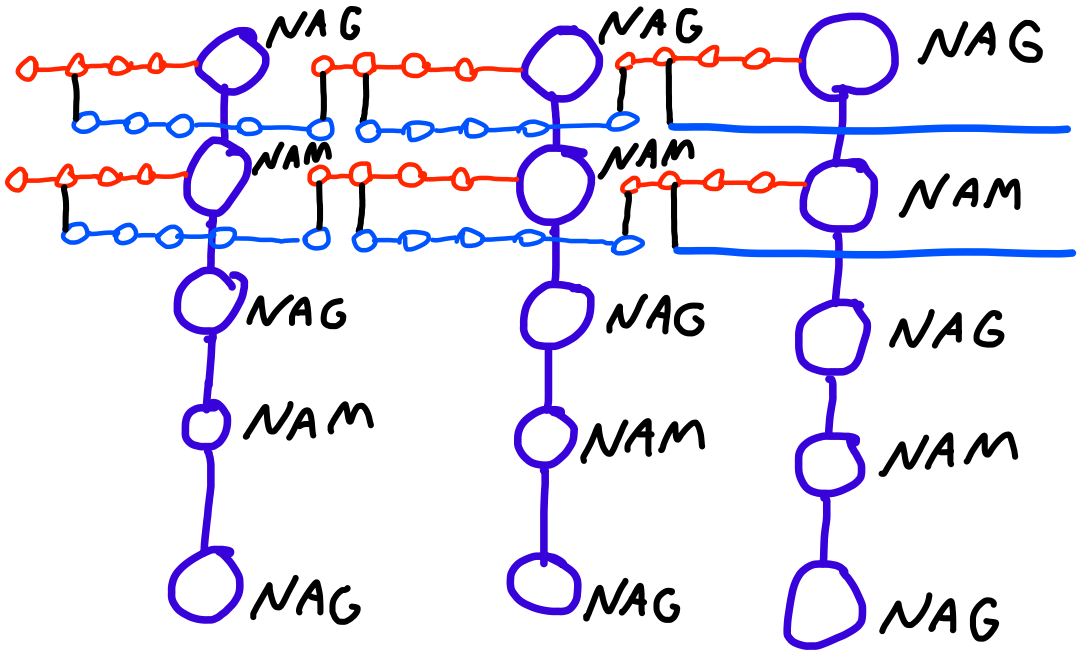
- N-acetylneuraminate
- Precursor: the amino sugar, neuraminic acid
- Location: a terminal residue of oligosaccharide chains of glycoproteins and glycolipids.



N-acetylneuraminate (sialic acid)

modified galactose

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