College of Medicine

Medical Chemistry

Lecture No. 4

carbohydrate

First stage

Prof. Dr. Talat T.K.

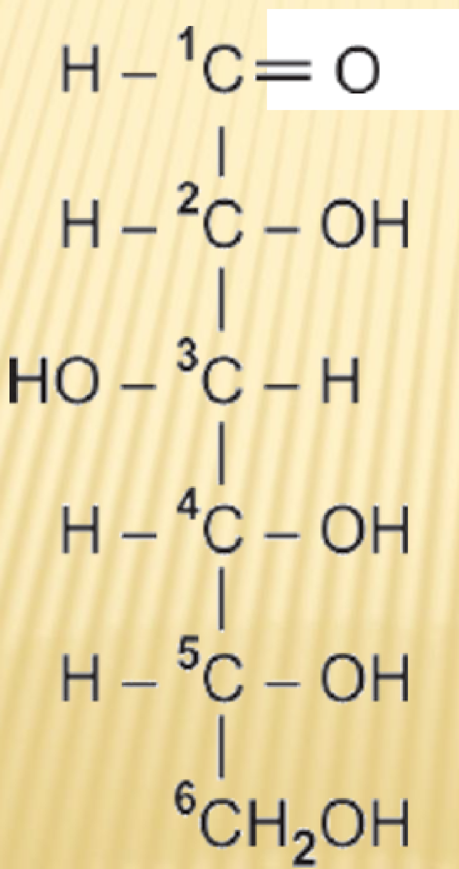
Introduction

Carbohydrates

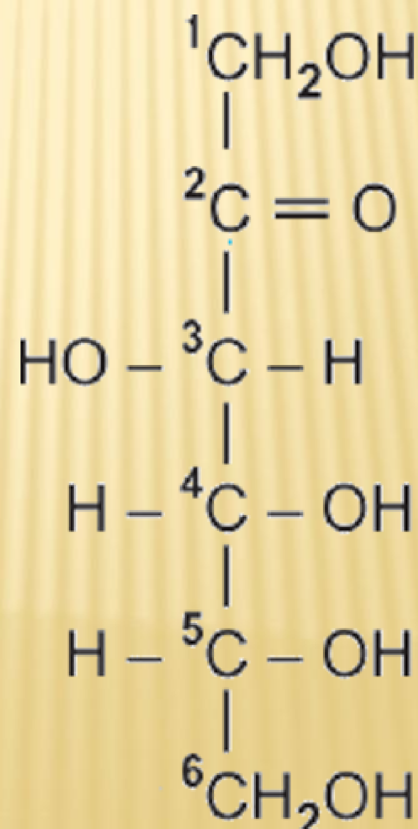
polyhydroxy aldehydes or ketones, or substances

$C_n(H_2O)_n$

GLUCOSE



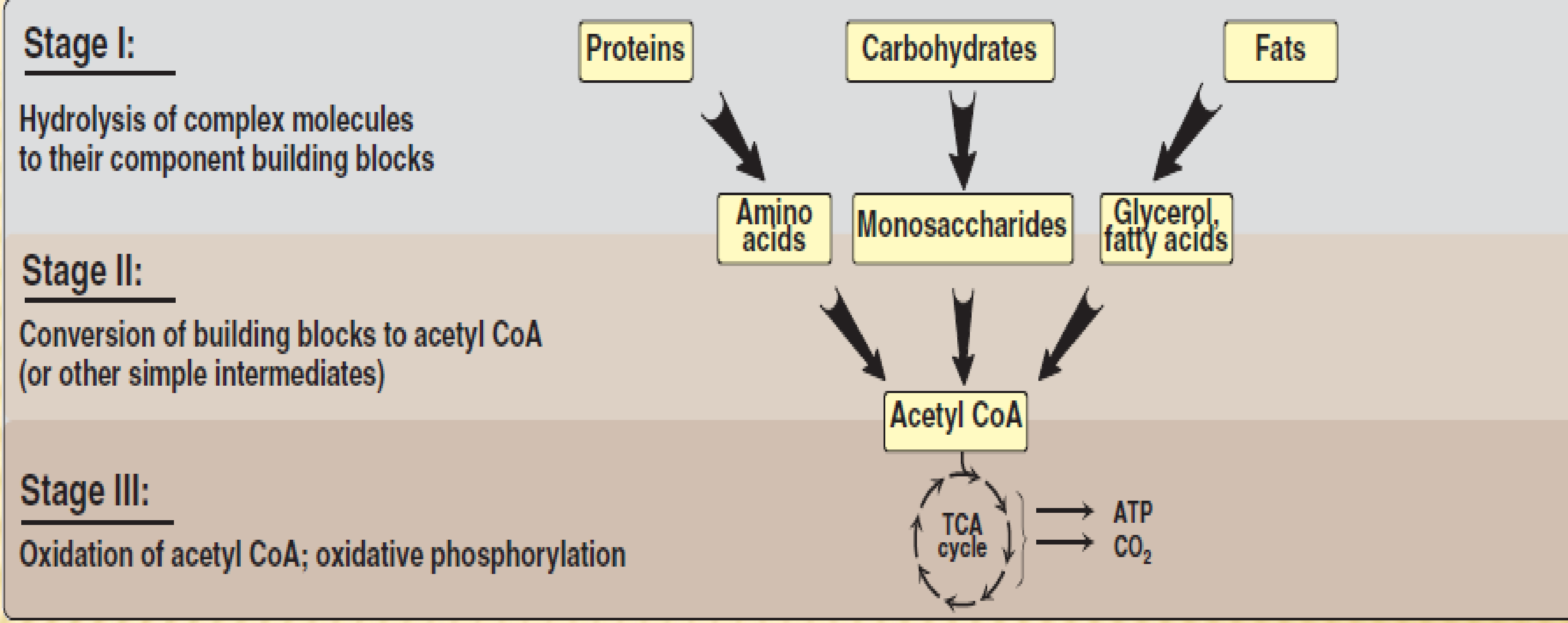
FRUCTOSE

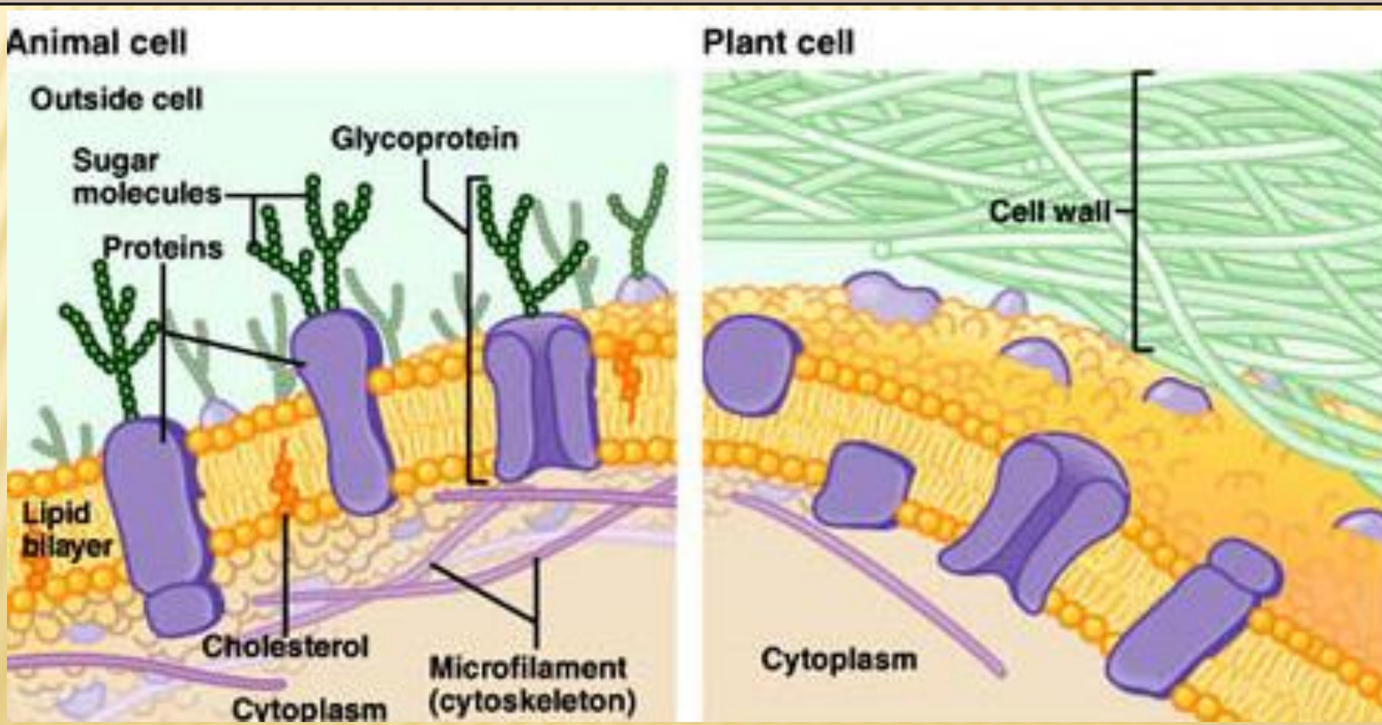


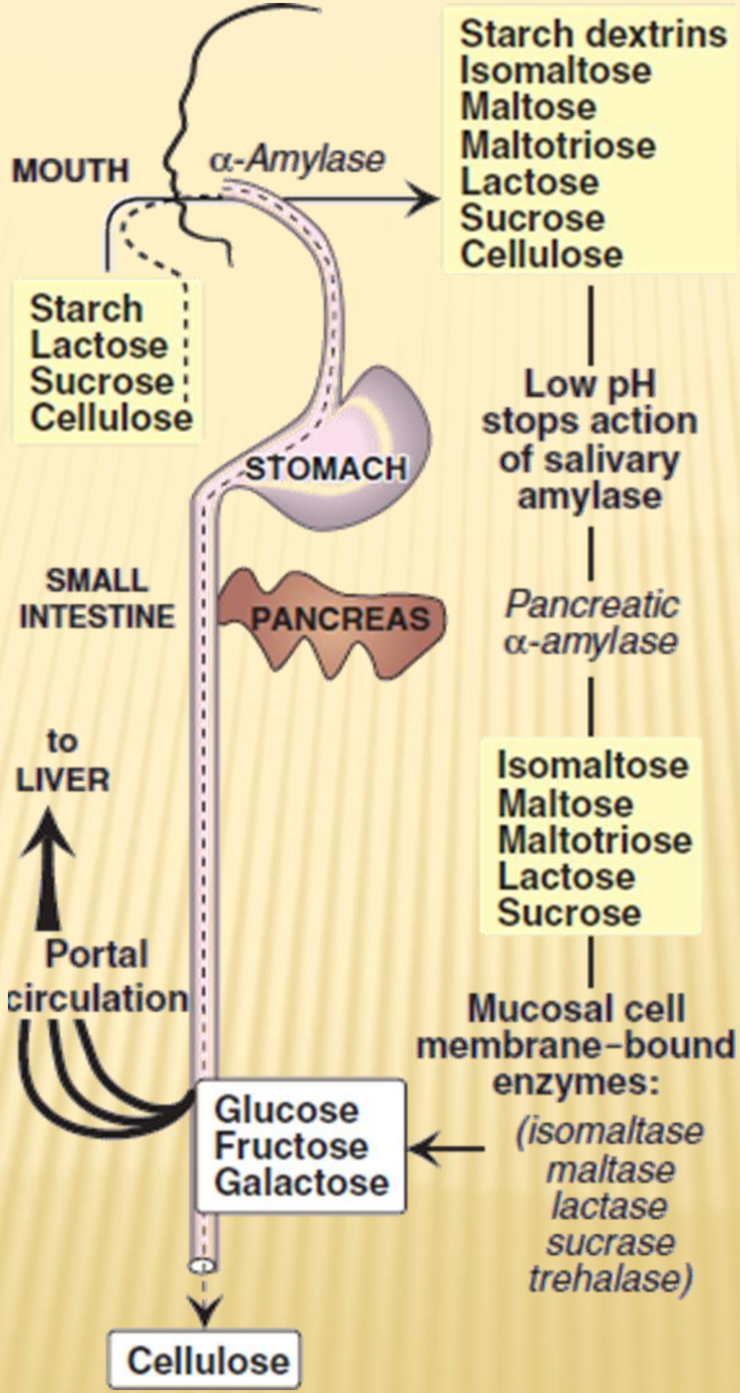
Function of carbohydrate

Carbohydrate functions as Primary Source of Energy (major source of energy for the cell)
Carbohydrate is Major structural component of plant cell
Carbohydrate functions as storage food
Carbohydrate functions as Anticoagulant
Carbohydrate functions as Hormone
Carbohydrate functions as structural framework of RNA and DNA
Carbohydrates provide raw material for industry

the chemistry of these substances usually involves only two functional groups- (carbonyl groops)ketone or aldehyde and alcohol hydroxyl groups.


Stage I:
Hydrolysis of complex molecules to their component building blocks
Proteins
Carbohydrates
Fats
Amino acids
Monosaccharides
Glycerol, fatty acids
Stage II:
Conversion of building blocks to acetyl CoA (or other simple intermediates)
Acetyl CoA
Stage III:
Oxidation of acetyl CoA; oxidative phosphorylation
TCA cycle
ATP
CO_2

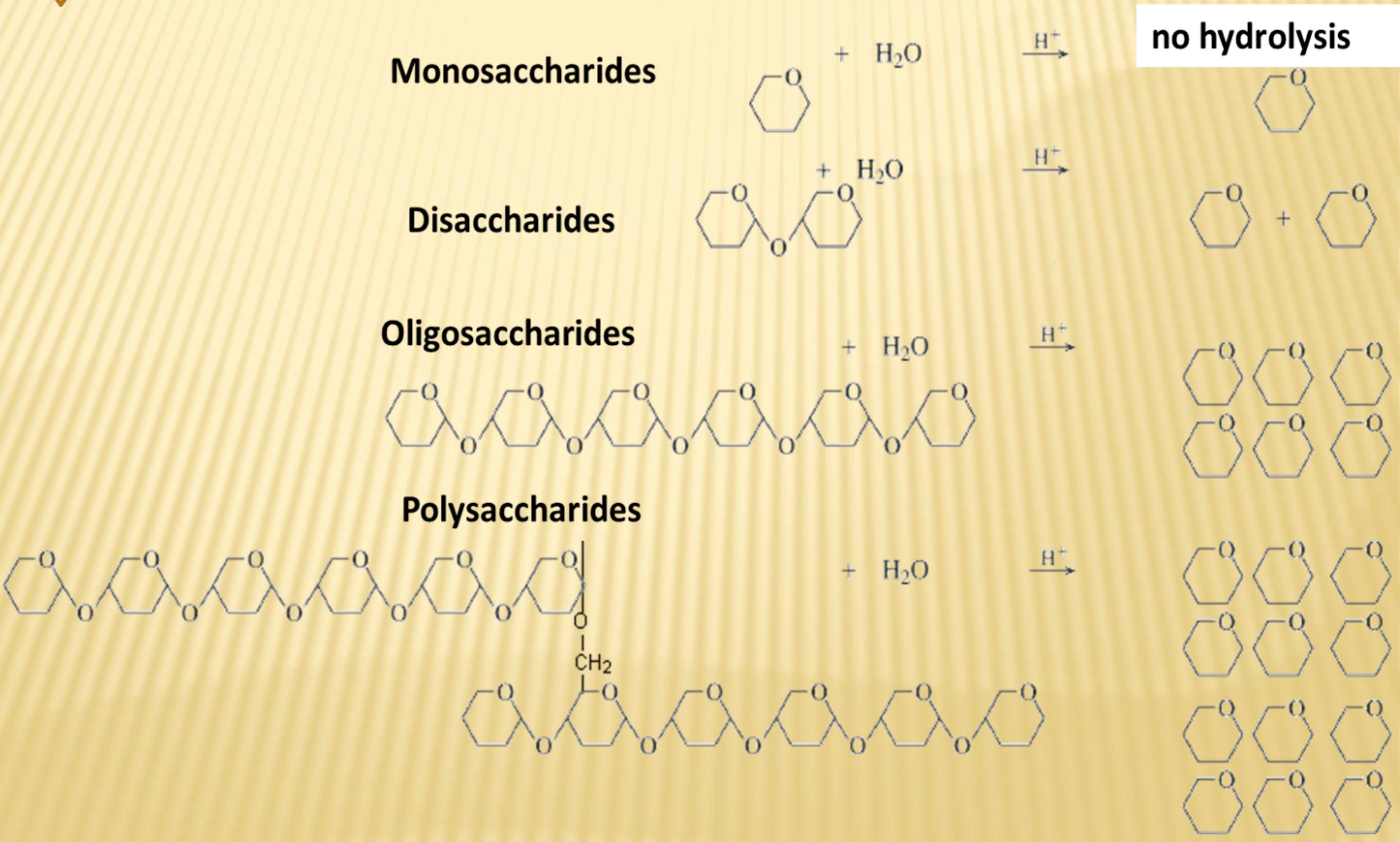

Animal cell
Outside cell
Glycoprotein
Sugar molecules
Proteins
Lipid bilayer
Cholesterol
Microfilament (cytoskeleton)
Cytoplasm
Plant cell
Cell wall
Cytoplasm



MOUTH
α-Amylase
Starch dextrins
Isomaltose
Maltose
Maltotriose
Lactose
Sucrose
Cellulose
Starch
Lactose
Sucrose
Cellulose
STOMACH
Low pH stops action of salivary amylase
SMALL INTESTINE
PANCREAS
Pancreatic α-amylase
Isomaltose
Maltose
Maltotriose
Lactose
Sucrose
to LIVER
Portal circulation
Mucosal cell membrane-bound enzymes:
(isomaltase maltase lactase sucrase trehalase)
Glucose
Fructose
Galactose
Cellulose

Classes of Carbohydrates

according to their acid hydrolysis product

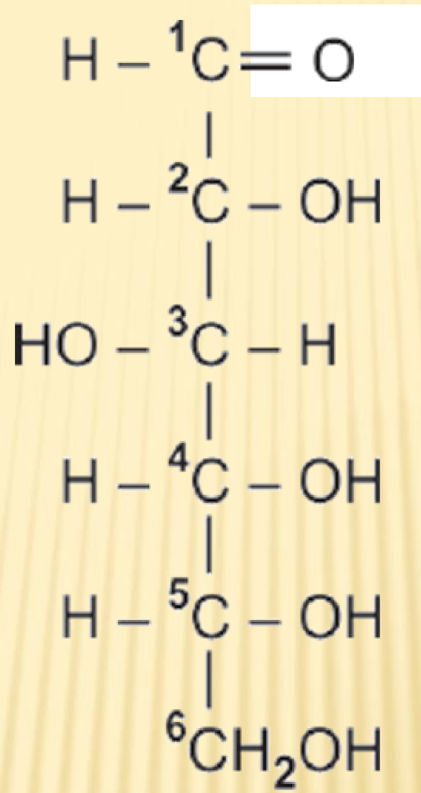


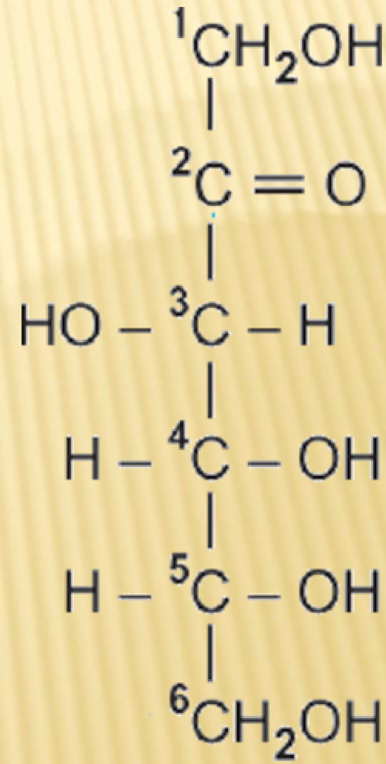
Classes of Carbohydrates

according to

1-the number of carbon atoms present

triose (3 C atoms)
tetrose (4 C atoms)
pentose (5 C atoms)
hexose (6 C atoms)



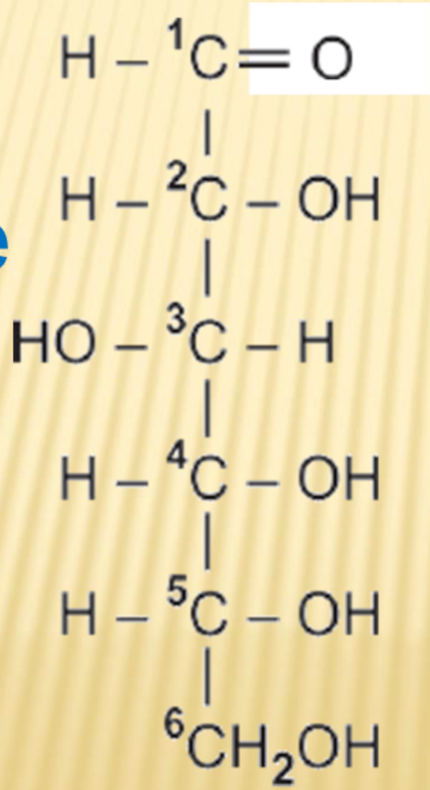


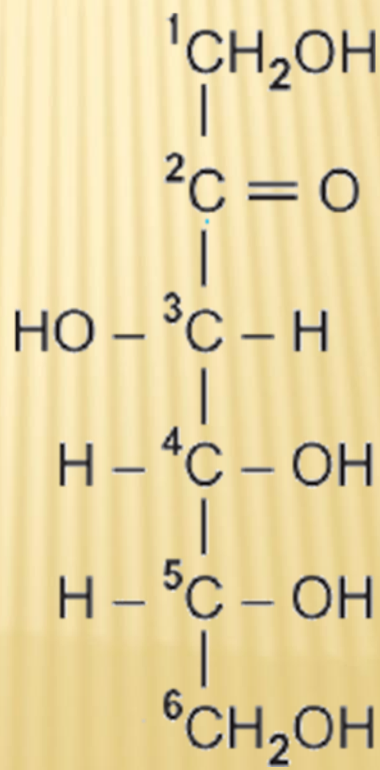
Its contain a indicating the number of carbon atoms in the compound and (the suffix ending –ose indicates that it is a sugar) example n=6
The sugar is hexose

2-type of carbonyl group

When hexose contains ketone group that will be called ketohexose while hexose's aldehyde group that will be called aldohexose

aldohexose



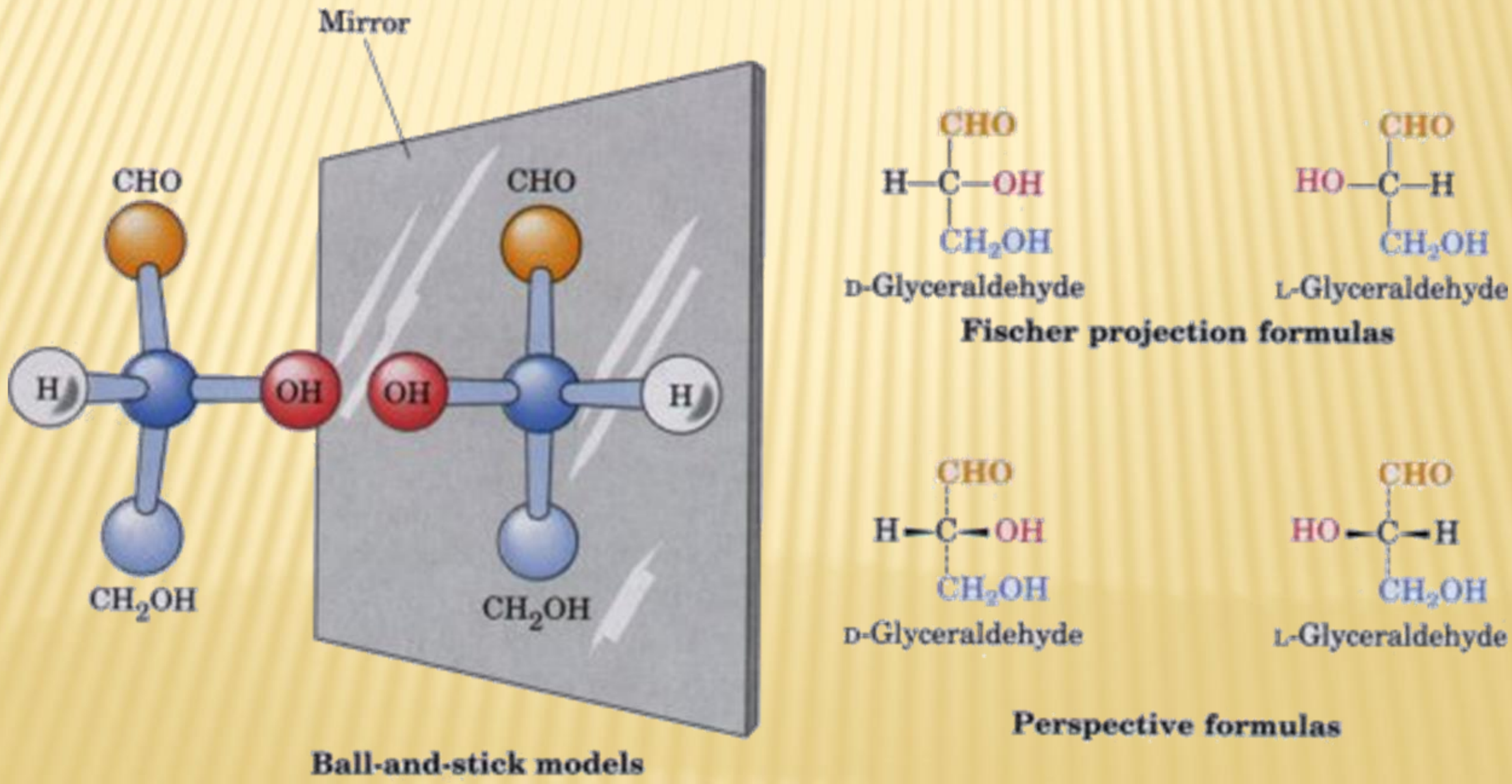


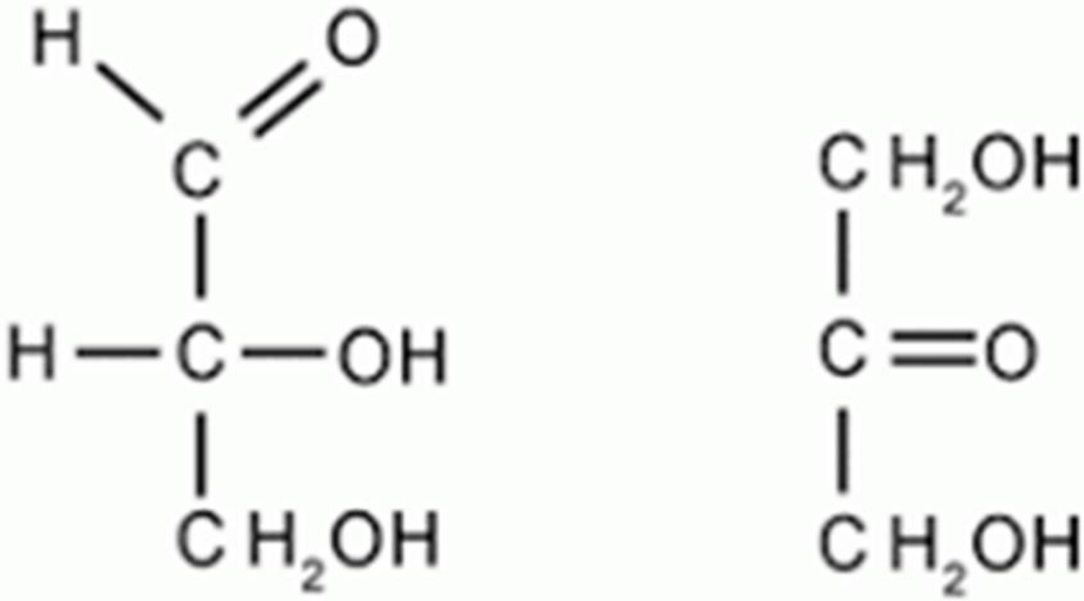
ketohexose

Monosaccharides Have Asymmetric Centers

All the monosaccharides except dihydroxyacetone contain one or more asymmetric (chiral) carbon atoms and thus occur in optically active isomeric forms.

(chiral) carbon atom → bonded to four different groups or atoms

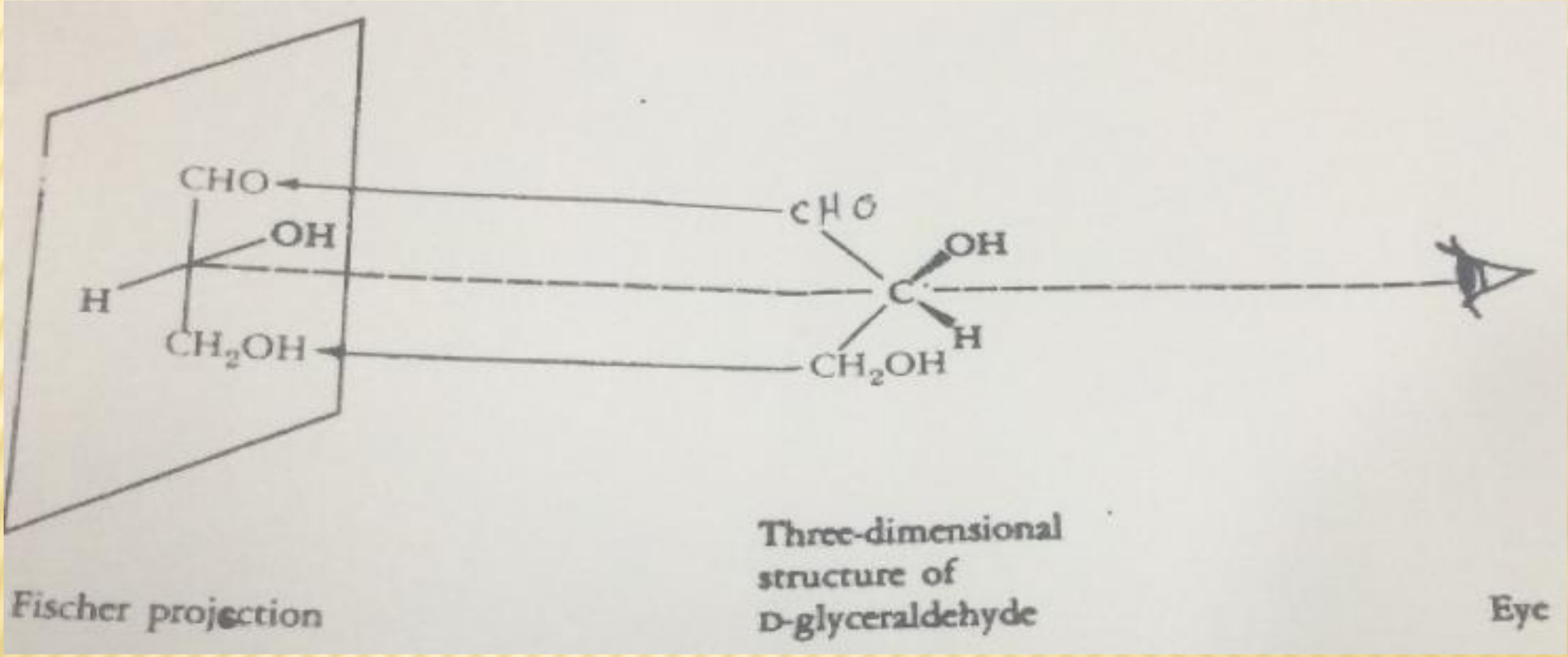




D-Glyceraldehyde Dihydroxyacetone

Fischer projection formula

To represent three-dimensional sugar structures on paper, we often use Fischer projection formula (the projection is written on paper with horizontal and vertical lines as follows

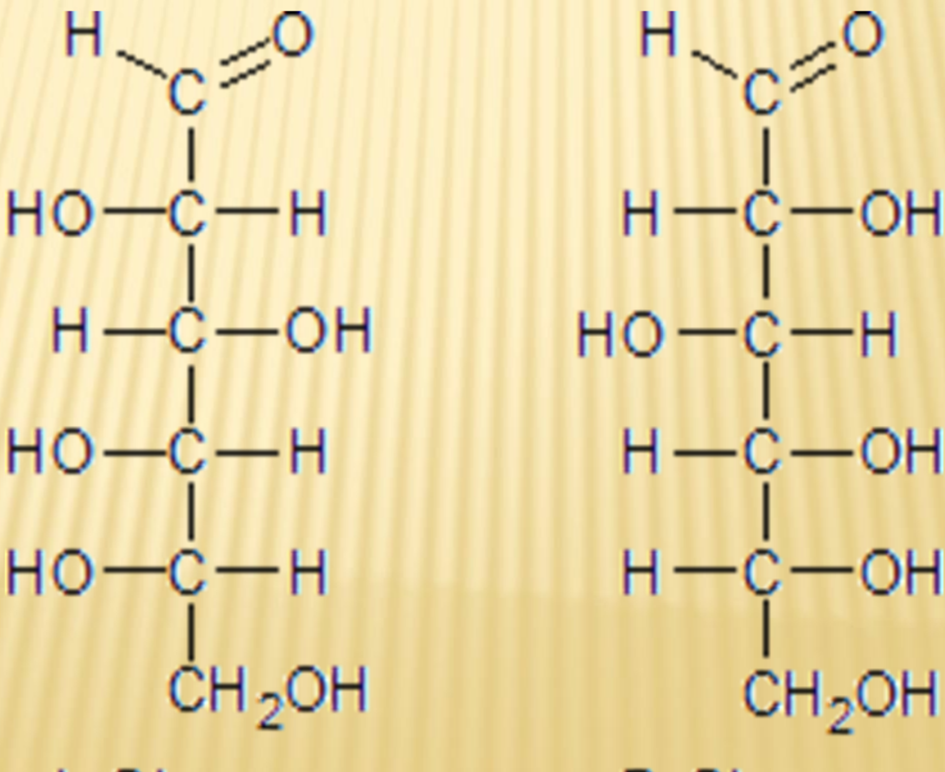


The vertical line ————> groups or atoms which projects away from the viewer

the horizontal line ————> groups or atoms which projects toward the viewer

In Fischer projection formula

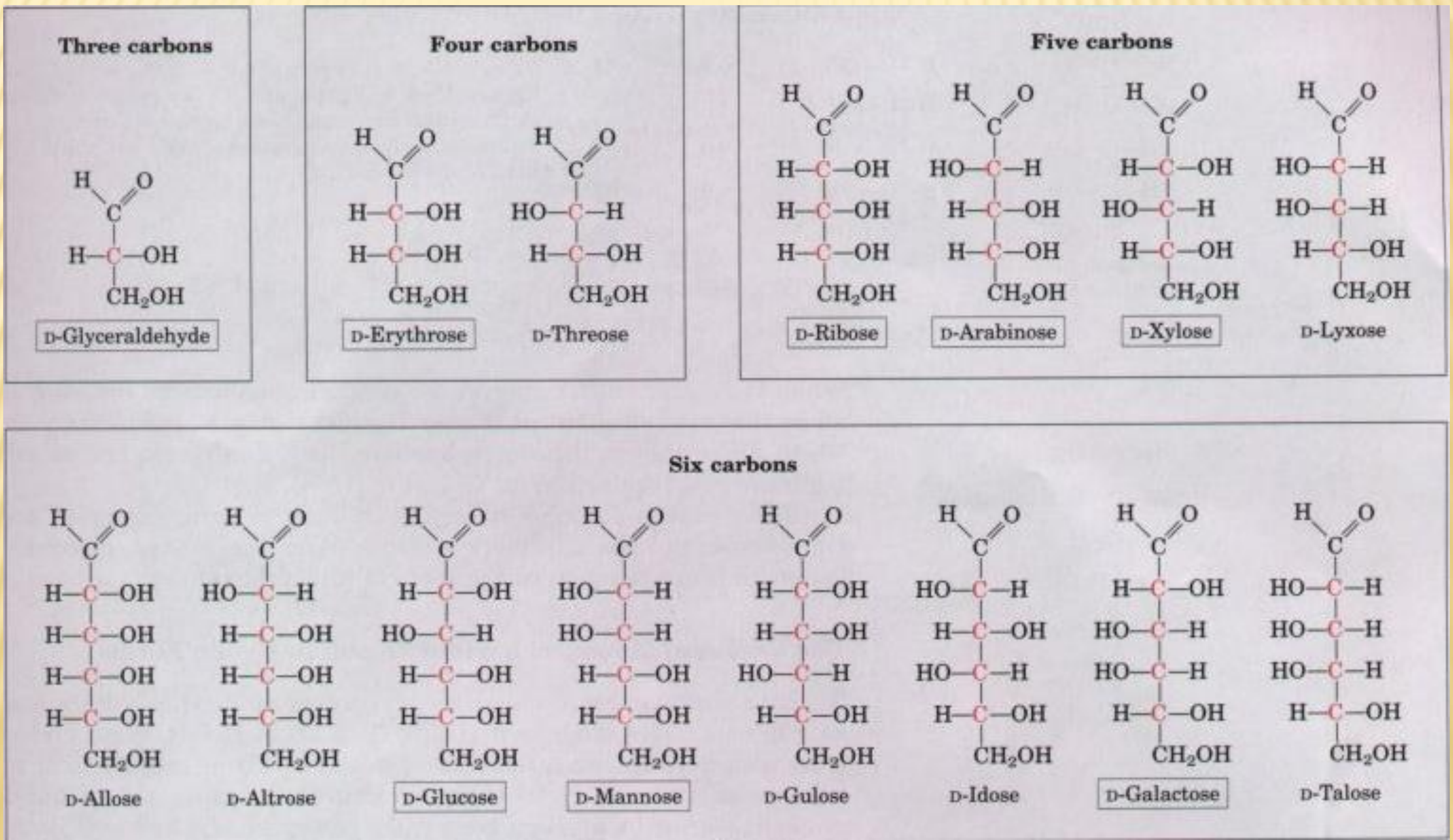
When the hydroxyl group on the reference carbon(chiral carbon farthest from the carbonyl group) is on the right in the projection formula, the sugar is the D isomer, when the left, it is the L isomer.



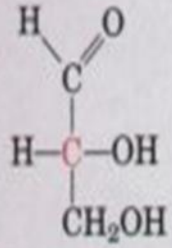
L-Glucose D-Glucose

In stereoisomerism, the isomerism have the same molecular formula and the same structural formula but differ from each other in structural arrangement.

Number of stereoisomer = 2^n **(n = number of chiral centers)**

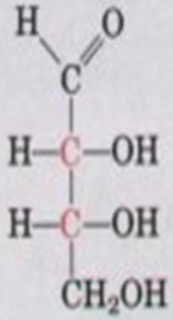


Three carbons

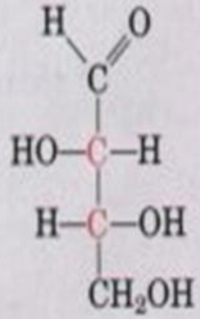


D-Glyceraldehyde

Four carbons

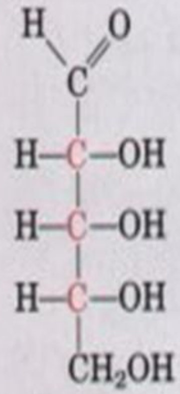


D-Erythrose

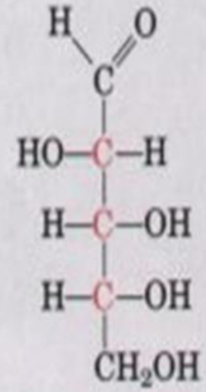


D-Threose

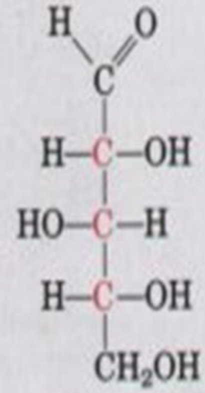
Five carbons



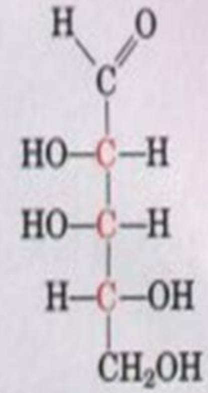
D-Ribose



D-Arabinose

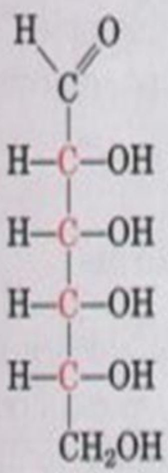


D-Xylose

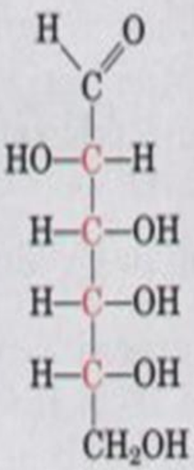


D-Lyxose

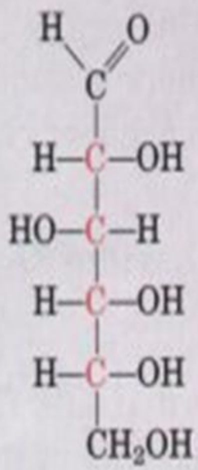
Six carbons



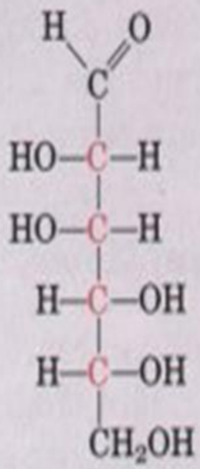
D-Allose



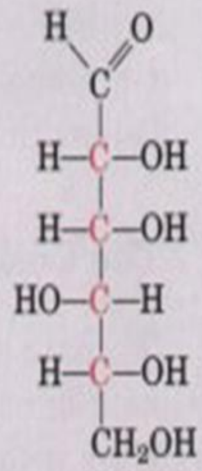
D-Altrose



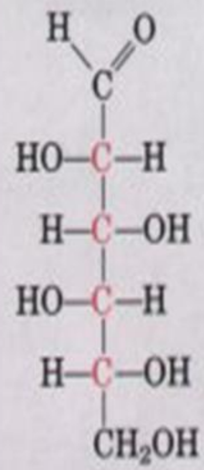
D-Glucose



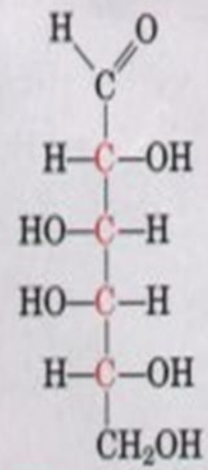
D-Mannose



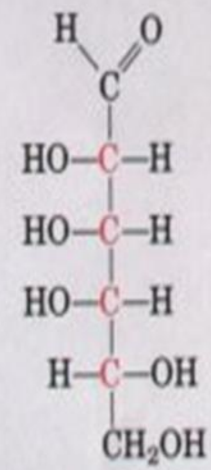
D-Gulose



D-Idose



D-Galactose



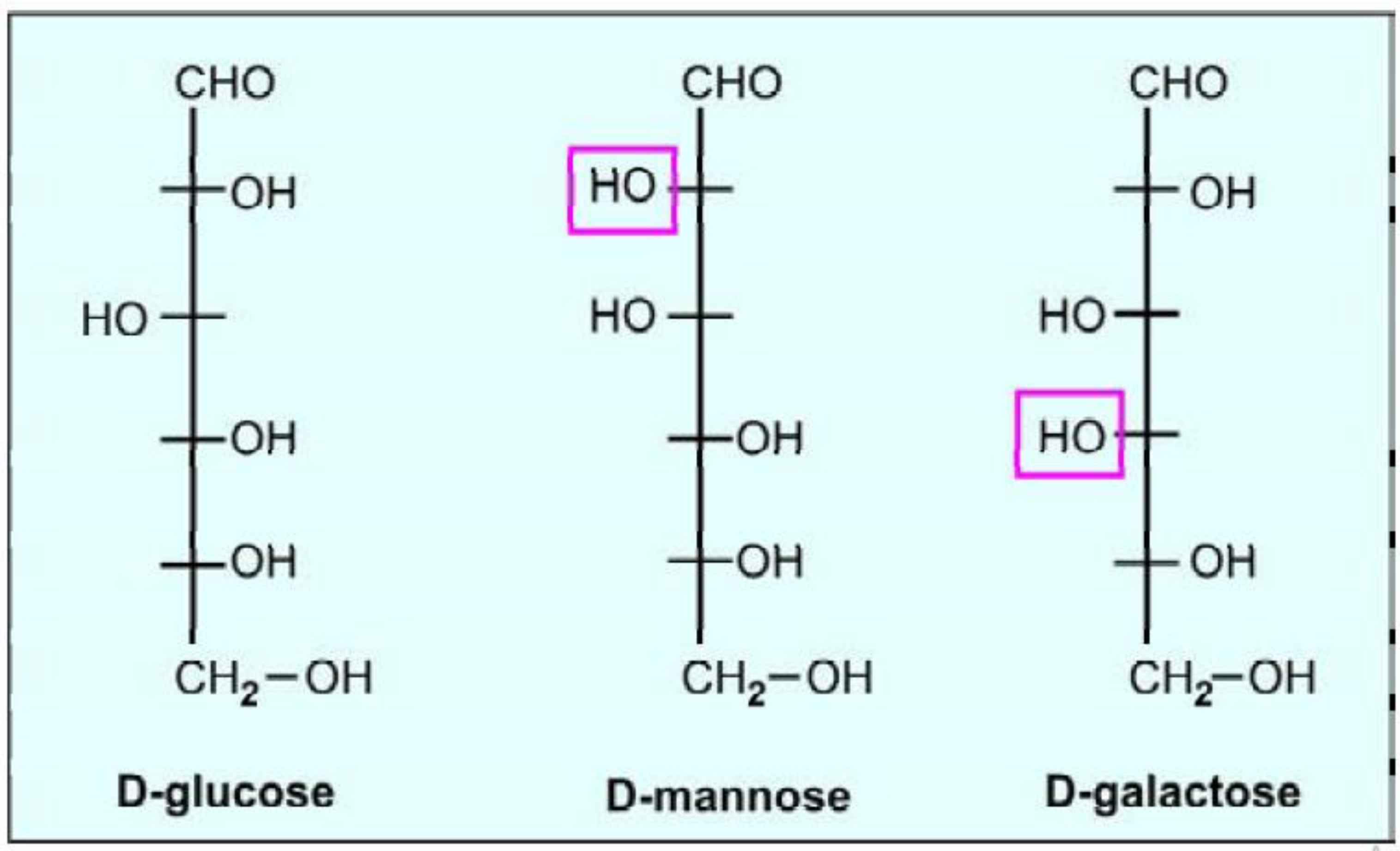
D-Talose

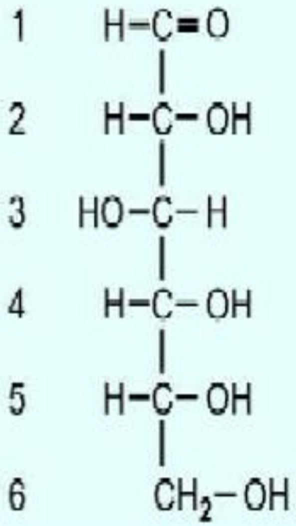
Epimerism of Aldoses

i. When sugars are different from one another, *only in configuration with regard to a single carbon atom* (other than the reference carbon atom), they are called epimers.

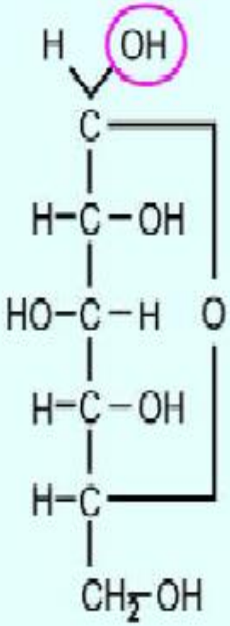
ii. For example, glucose and mannose are an epimeric pair which differ only with respect to C2

iii. Similarly, galactose is the 4th epimer of glucose

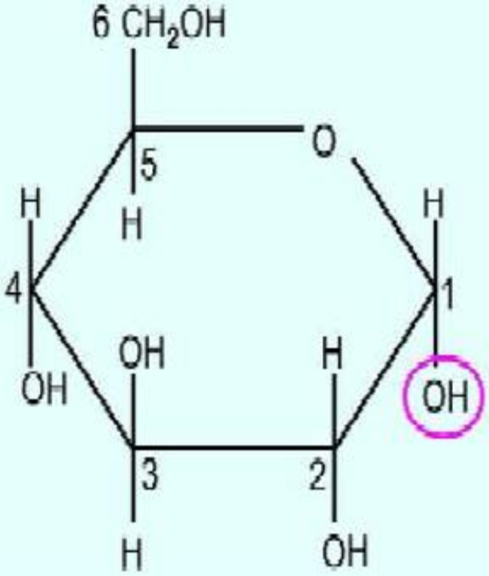




D-glucose, open chain projection formula

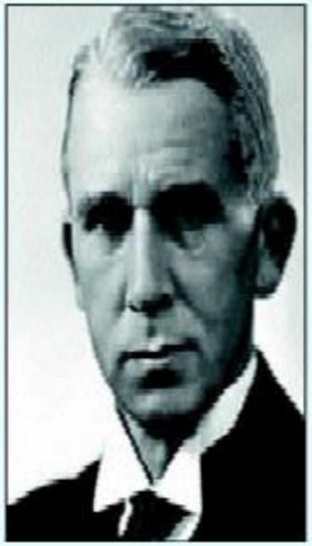


α-D-glucose, closed ring structure, Fischer formula



α-D-gluco pyranose, Haworth formula

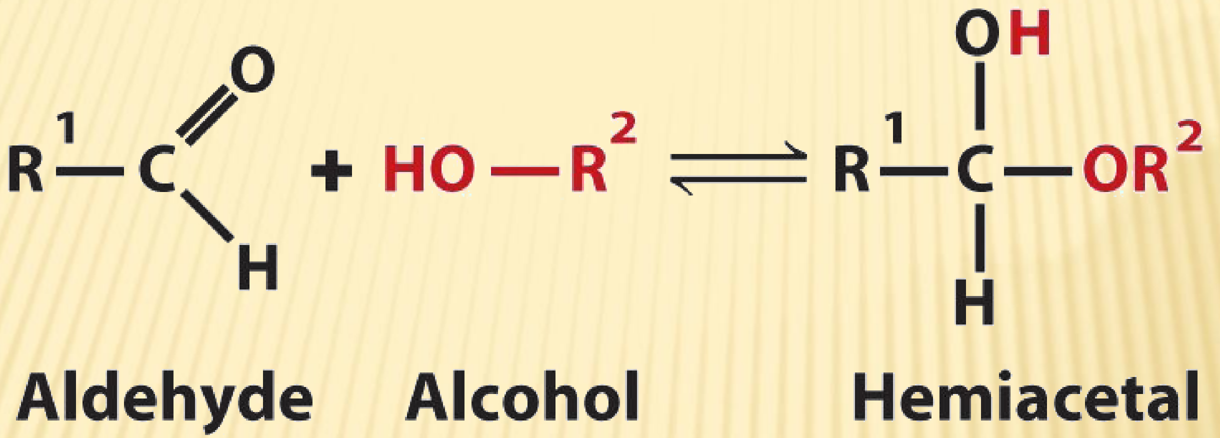
Emil Fischer
NP 1902
1852-1919

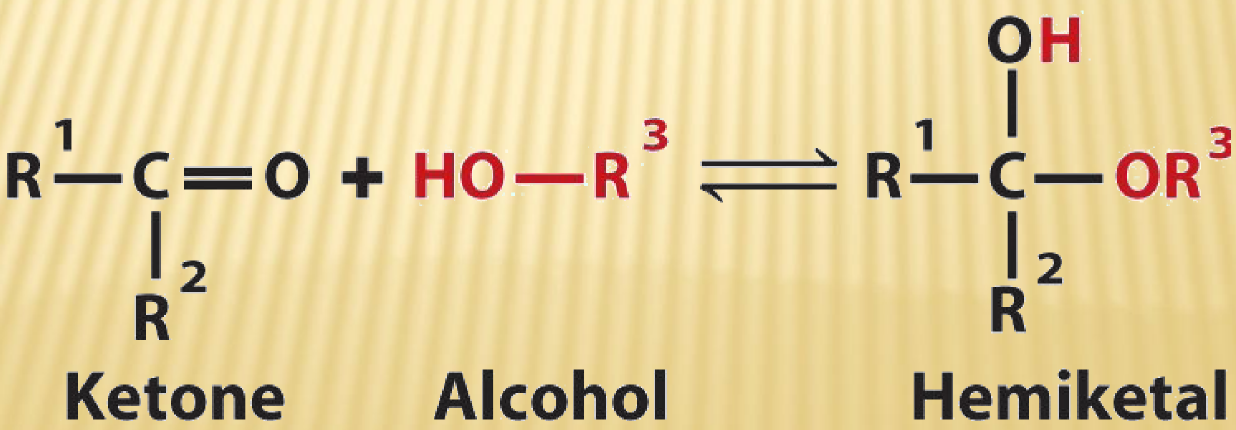


Walter Haworth
NP 1937
1883-1950

Activate Win
Go to Settings to

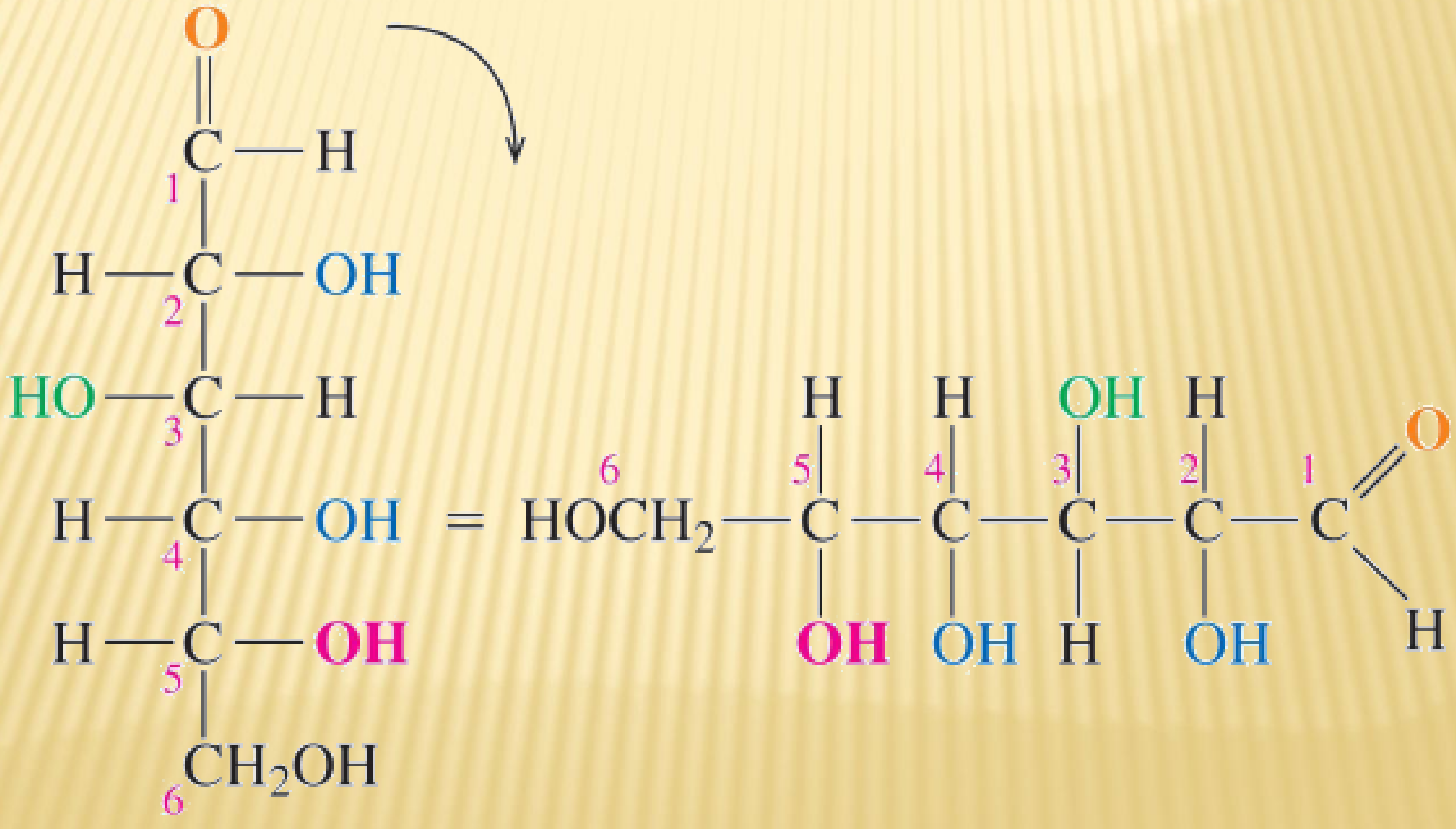
aldehydes or ketones will react with an alcohol to form hemiacetals or hemiketals





Haworth Structures of Monosaccharides

Step 1 Number the carbon chain and turn clockwise to form a linear open chain

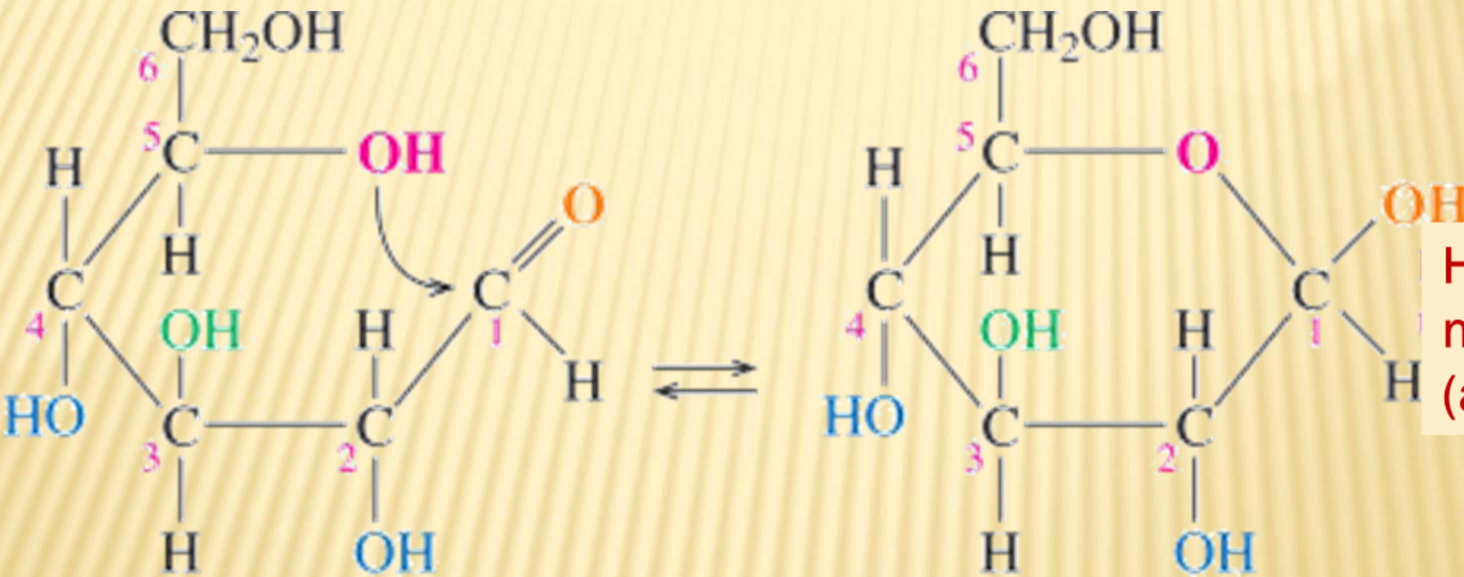


D-Glucose (open chain)

Haworth Structures of Monosaccharides

Step 2.

- Bond the carbon 5 –O– to carbon 1.
- Place the carbon 6 group above the ring.



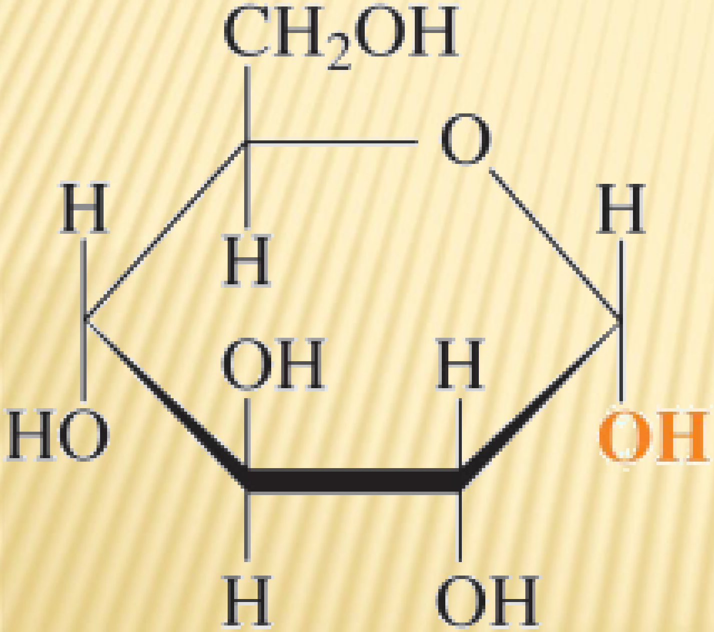
Hydroxyl group on new chiral carbon (anomeric carbon)

Carbon -5 oxygen bonds to carbonyl

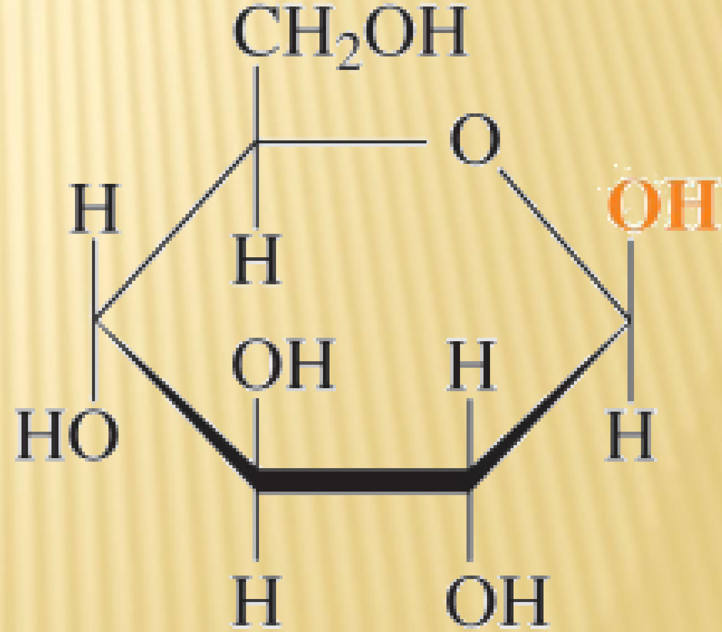
Cyclic Structure

Haworth Structures of Monosaccharides

Step3: when the new –OH on anomeric carbon 1 down is called as the α isomer while above for the β isomer



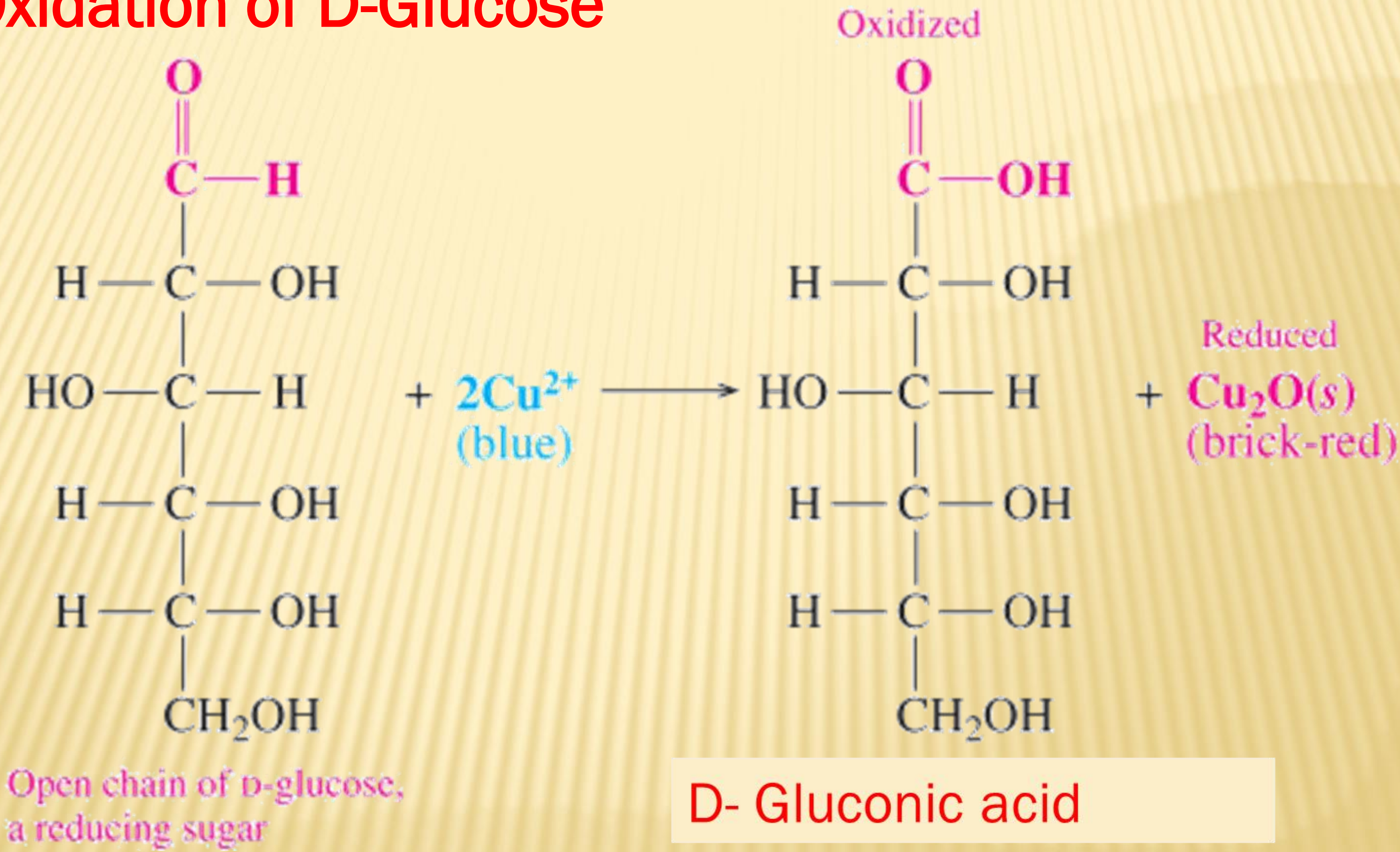
α-D- Glucose



β-D- Glucose

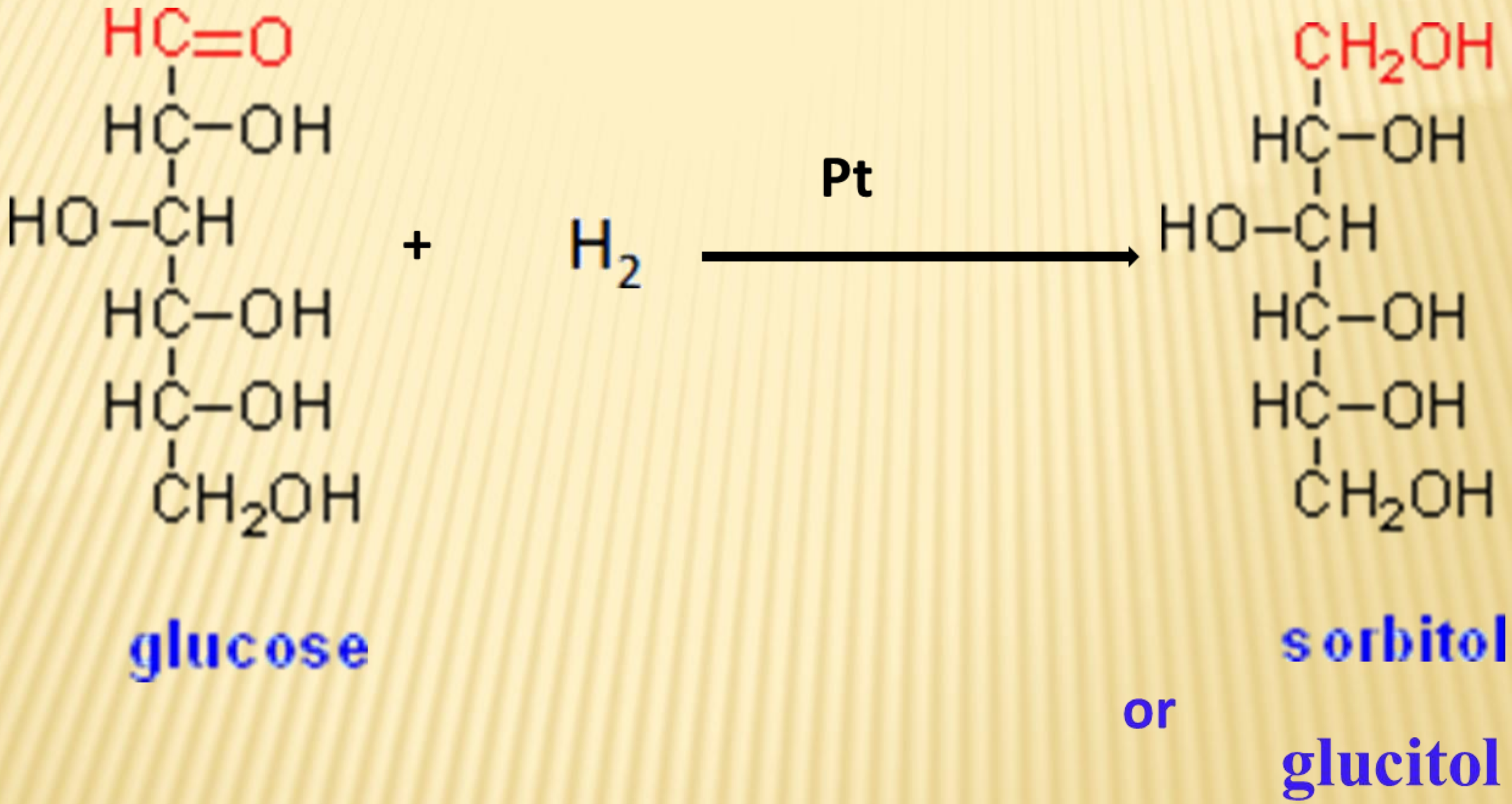
REACTION

Oxidation of D-Glucose



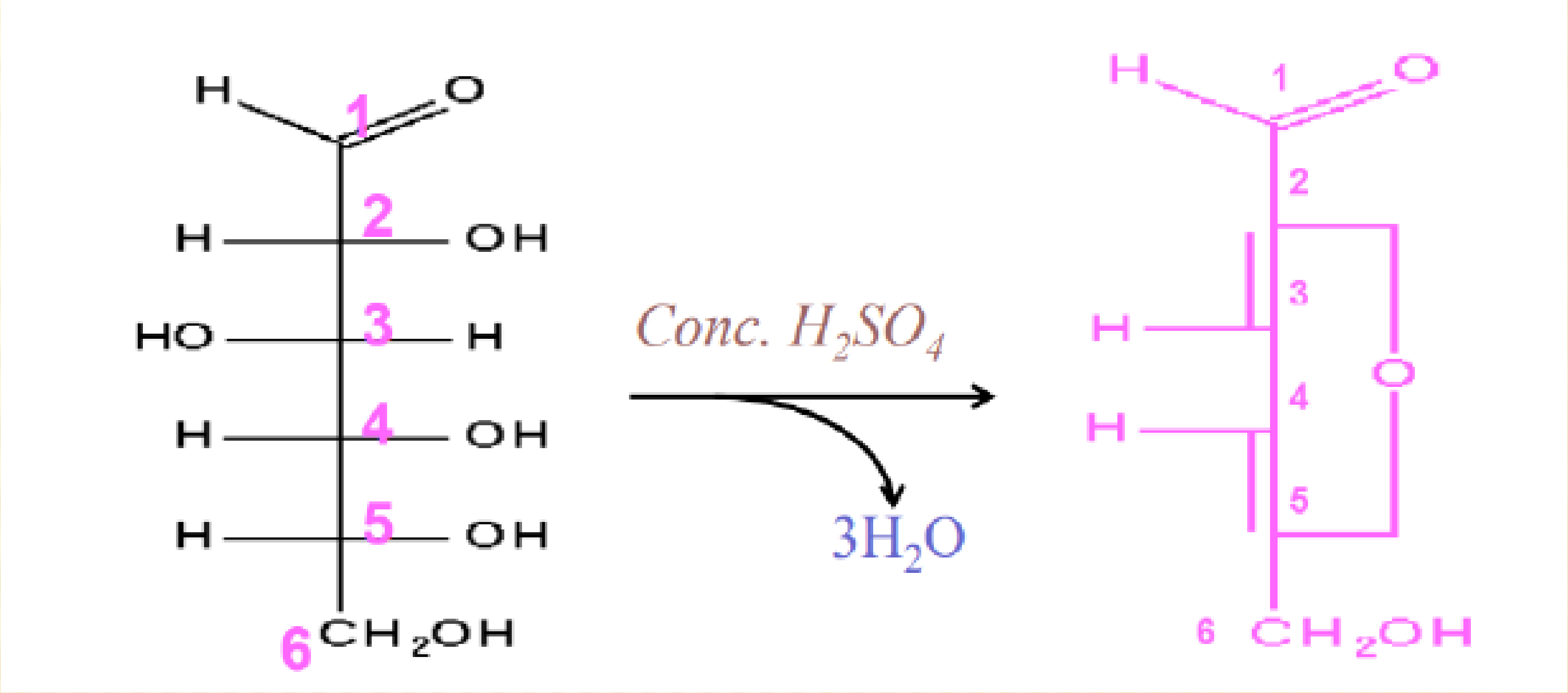
D- Gluconic acid

Reduction of Monosaccharides

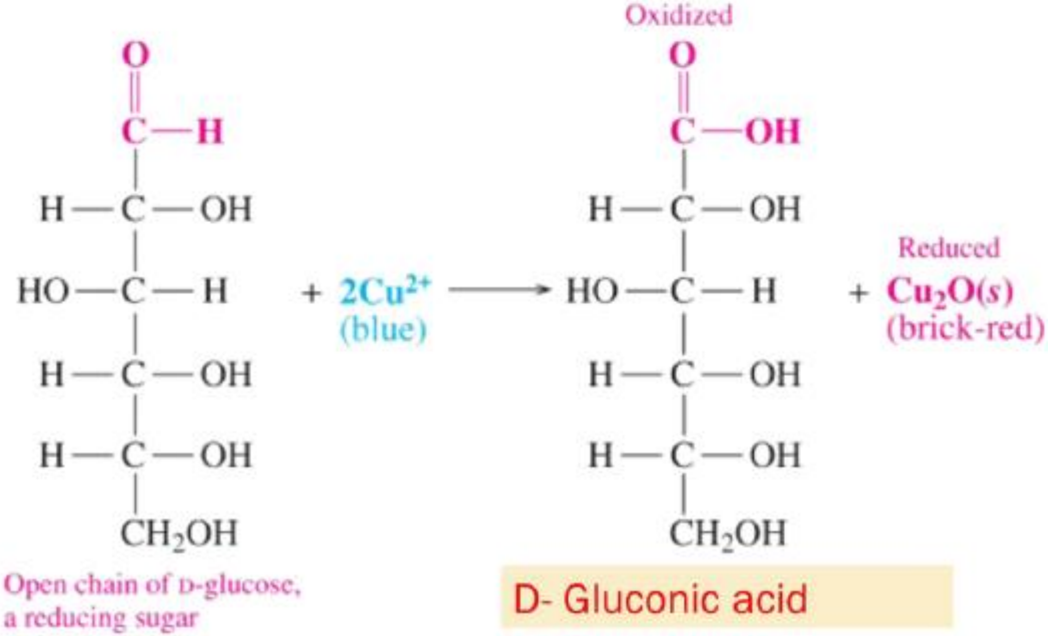


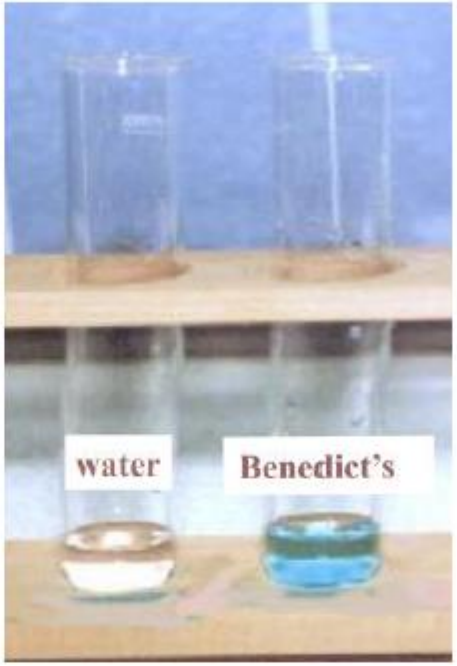
Disaccharide

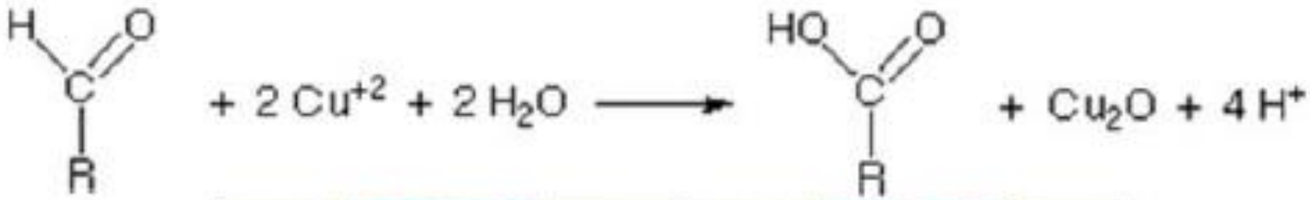
Monosaccharides		Disaccharide
glucose + glucose	$\longrightarrow$	maltose + H_2O
glucose + galactose	$\longrightarrow$	lactose + H_2O
glucose + fructose	$\longrightarrow$	sucrose + H_2O

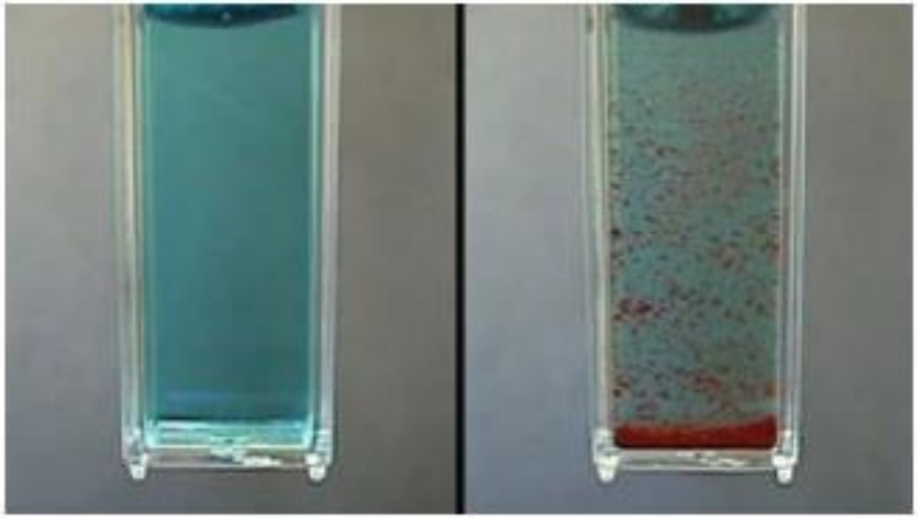


H
O
1
2
H
OH
3
HO
H
4
H
OH
5
H
OH
6
CH2OH
Conc. H2SO4
3H2O
H
1
O
2
3
H
O
4
H
5
6
CH2OH

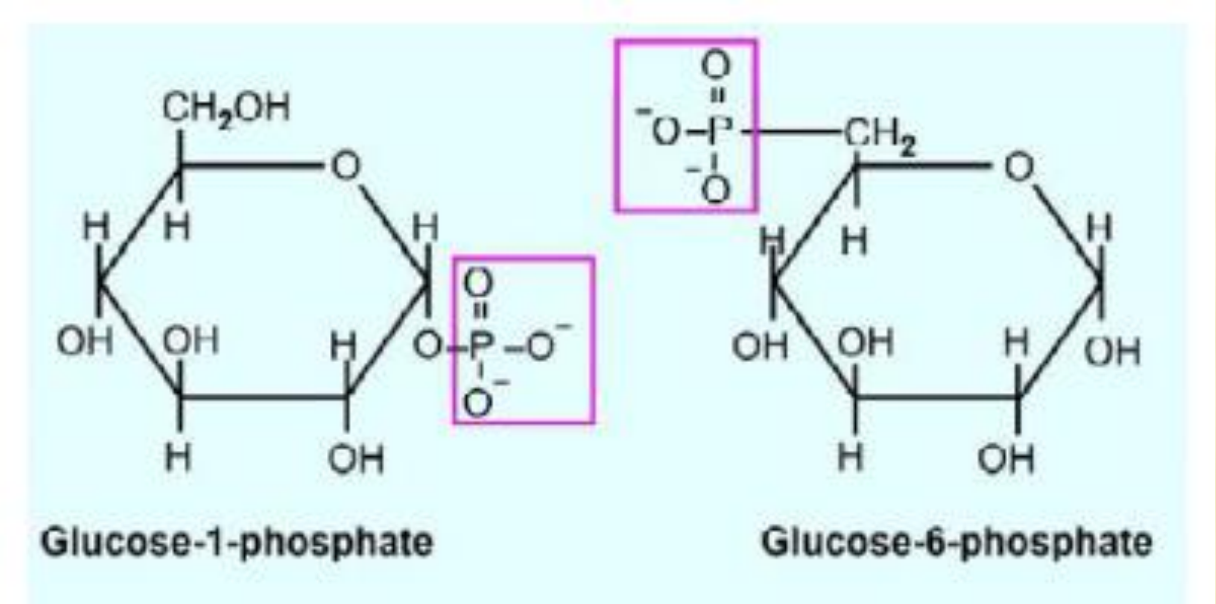

Oxidized
Reduced
+ 2Cu2+
(blue)
+ Cu2O(s)
(brick-red)
Open chain of D-glucose,
a reducing sugar
D- Gluconic acid


water
Benedict's

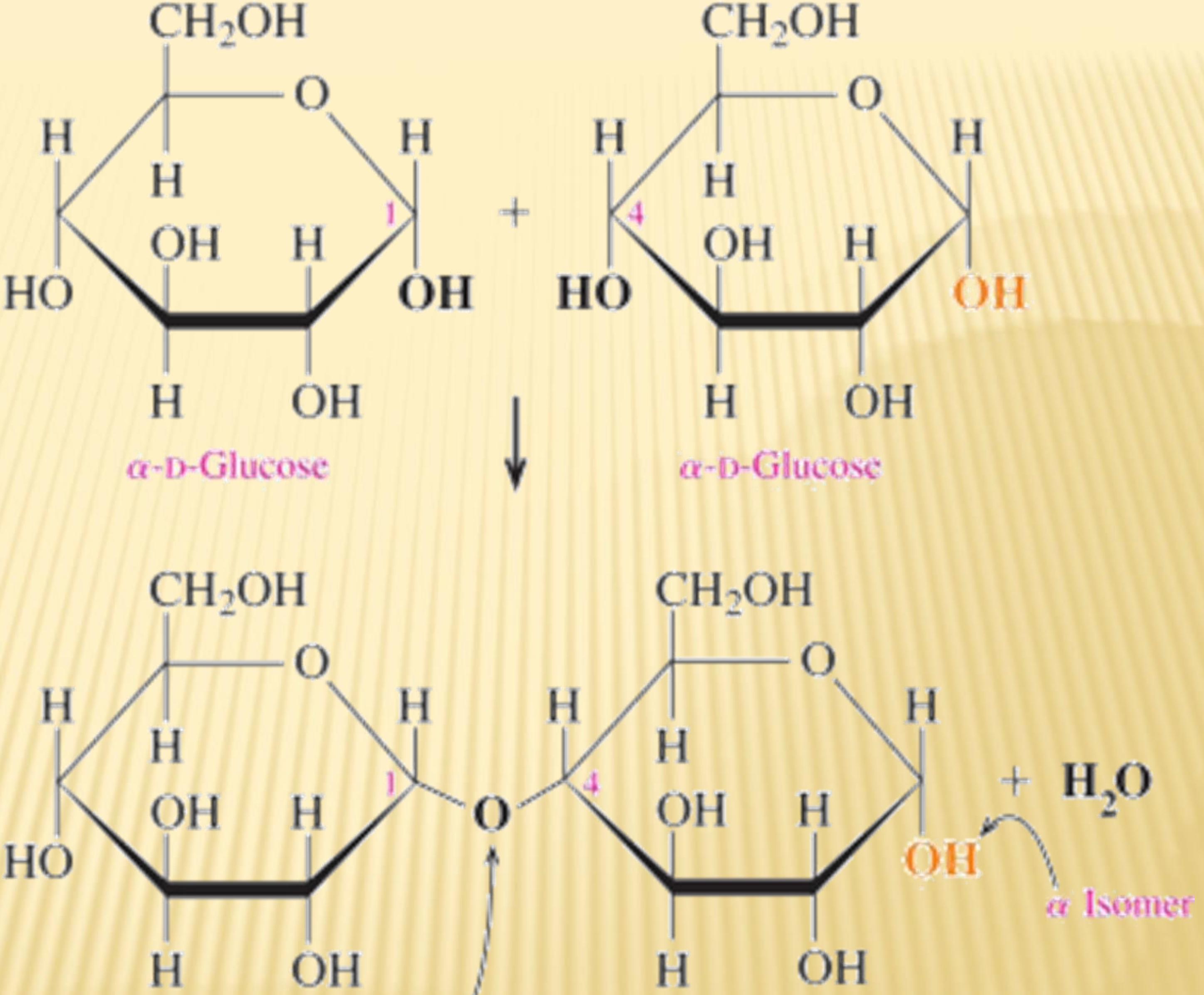




Red scum at bottom


CH2OH
O
H
H
H
O
OH
OH
H
O-P-O-
O-
H
OH
-O-P-CH2
-O
O
H
H
H
OH
OH
H
OH
H
OH
Glucose-1-phosphate
Glucose-6-phosphate

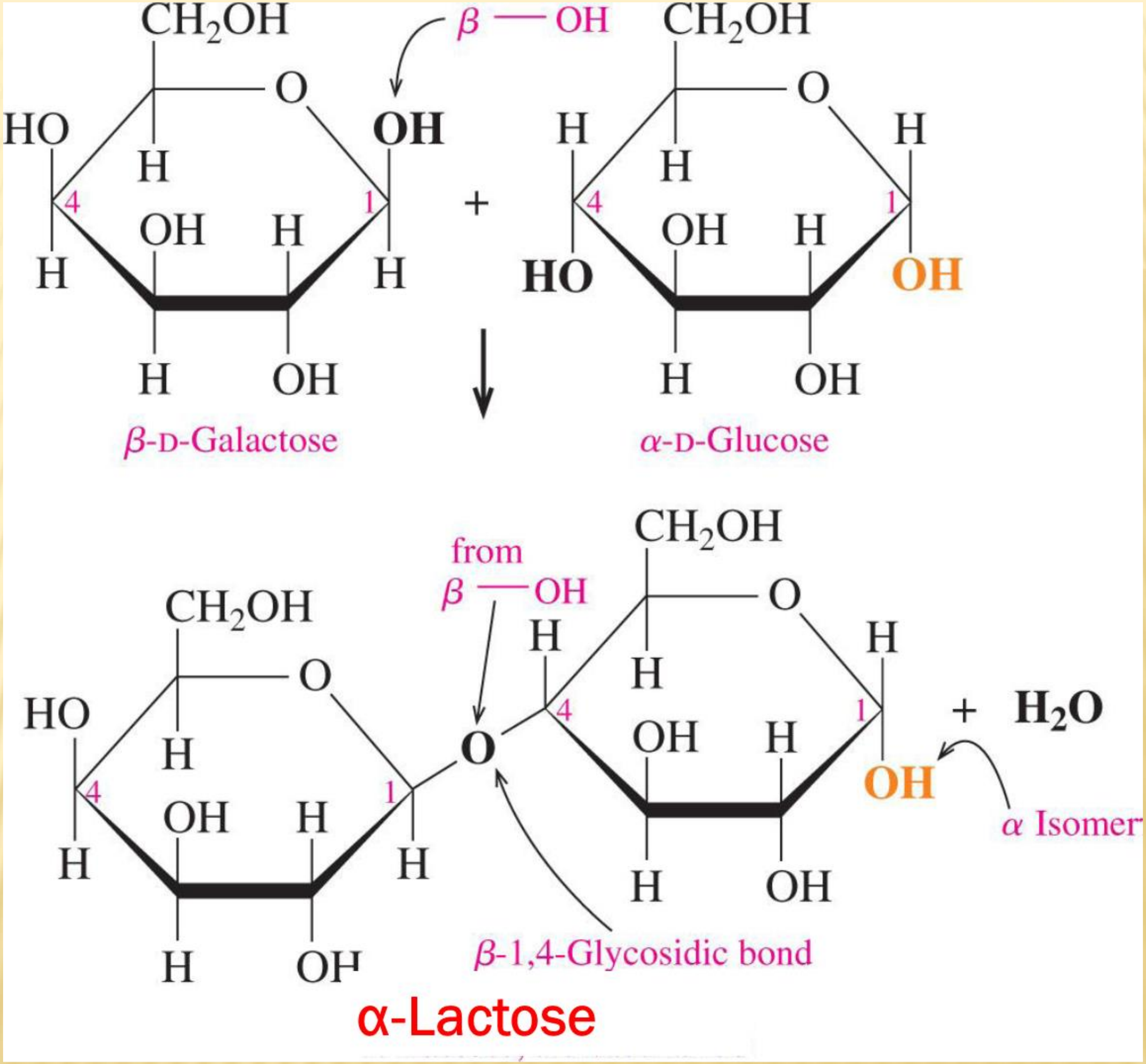
Maltose



α (1→4) glycosidic linkage

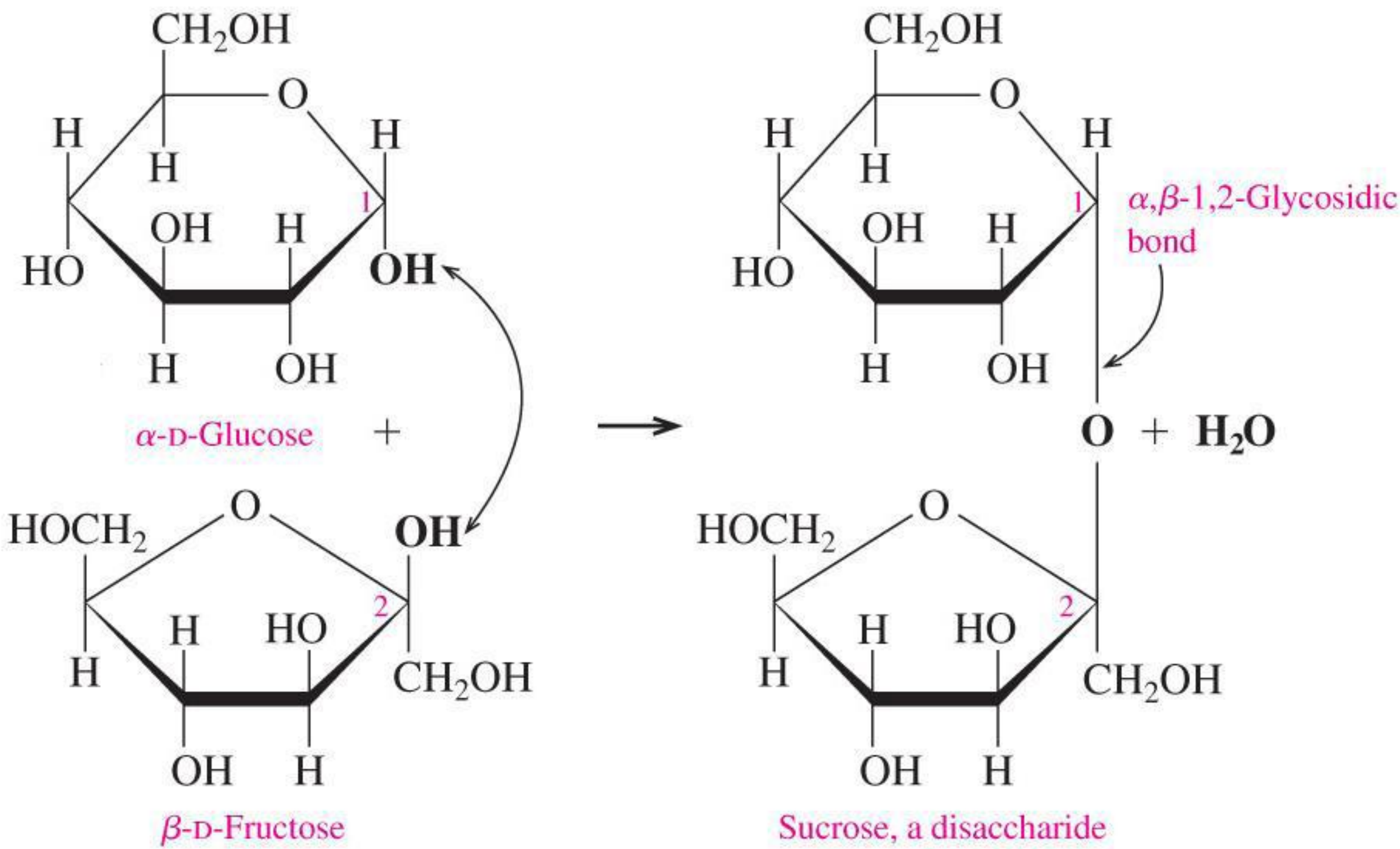
α- Maltose

Lactose



CH2OH
β — OH
O
HO
OH
H
4
1
OH
H
H
H
H
OH
+
CH2OH
O
H
H
H
4
1
OH
H
HO
OH
H
OH
β-D-Galactose
α-D-Glucose
from
β — OH
CH2OH
O
H
H
H
4
1
OH
H
OH
+ H2O
α Isomer
H
OH
CH2OH
O
HO
H
4
1
OH
H
H
H
O
H
OH
β-1,4-Glycosidic bond
α-Lactose

Sucrose


CH2OH
O
H
H
H
1
OH
H
HO
OH
H
OH
α-D-Glucose
+
HOCH2
O
OH
2
H
HO
H
CH2OH
OH
H
β-D-Fructose
α,β-1,2-Glycosidic
bond
O + H2O
Sucrose, a disaccharide

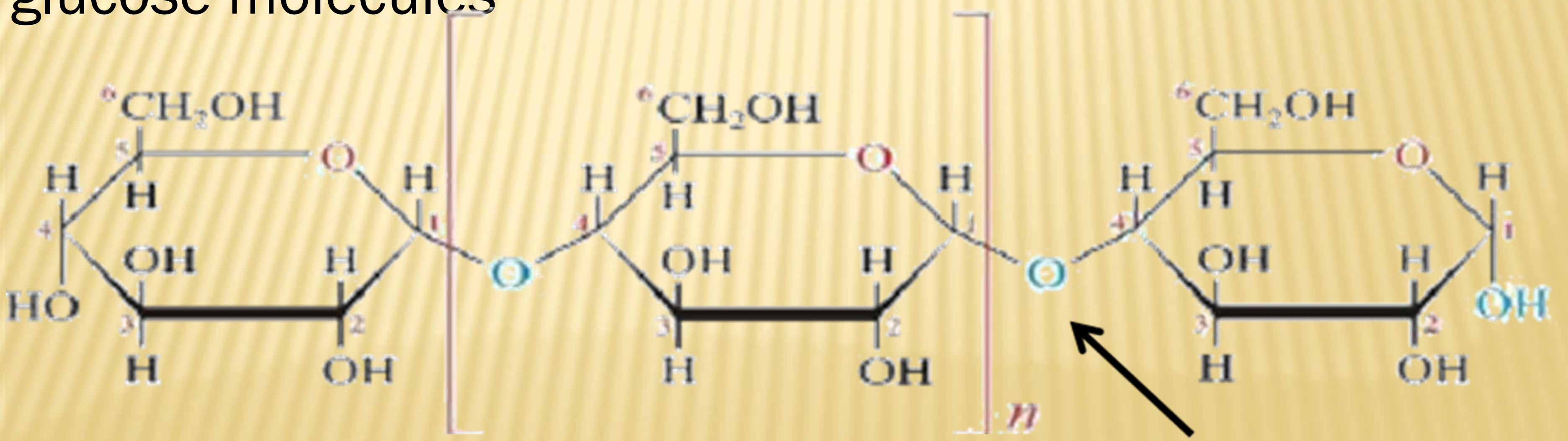
Polysaccharides: They contain more than ten molecules of monosaccharide units.

They are further classified into **homopolysaccharides** and **heteropolysaccharides**.

- *Homopolysaccharides*: They are polymer of same monosaccharide units. Some examples for homopolysaccharides

1-Starch: It is a mixture of two polysaccharides Amylose and amylopectin.

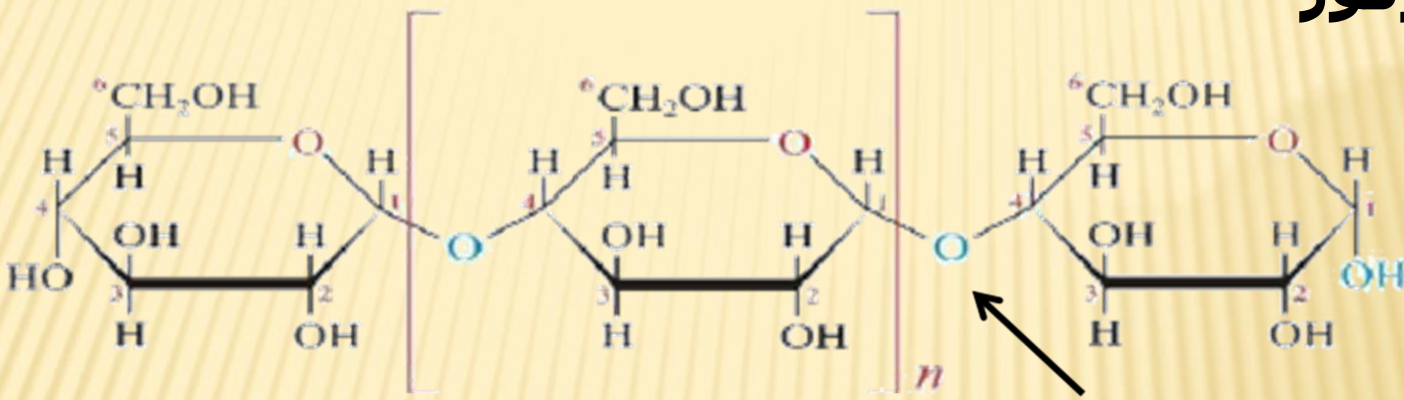
Amylose → straight-chain polysaccharide made of *α*-D-glucose molecules



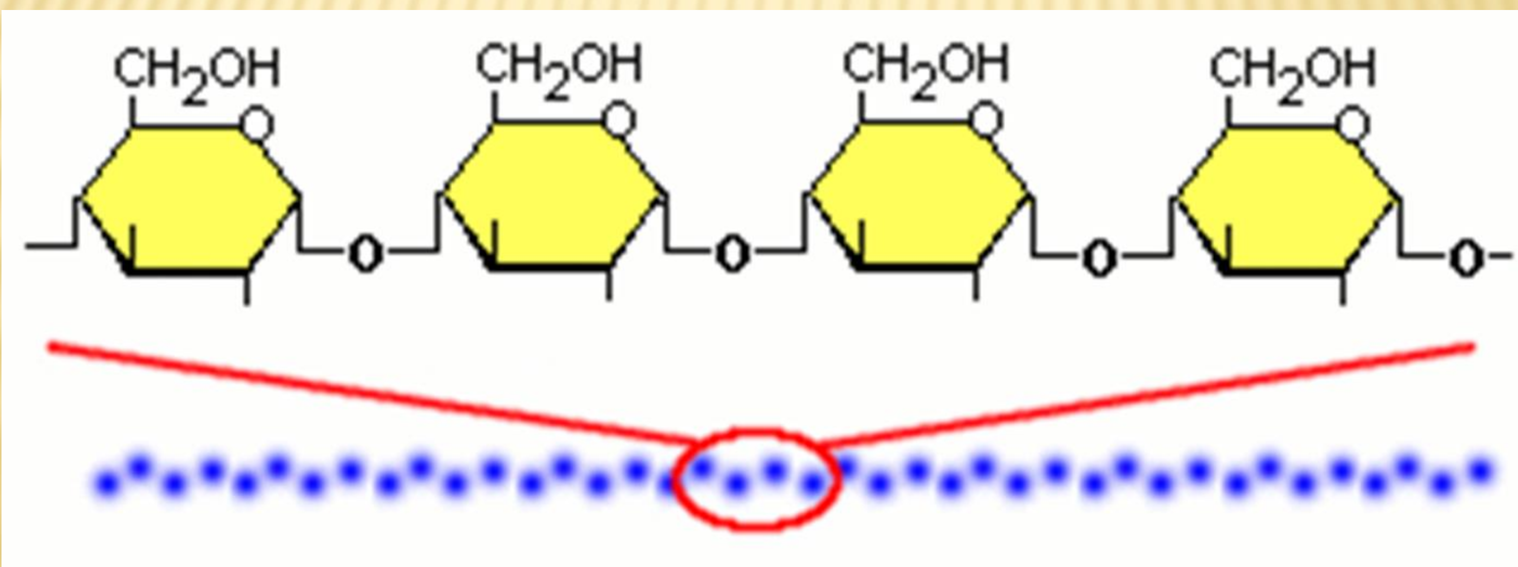
α (1→4) glycosidic linkage

Amylose → straight-chain polysaccharide made of α-D-glucose molecules

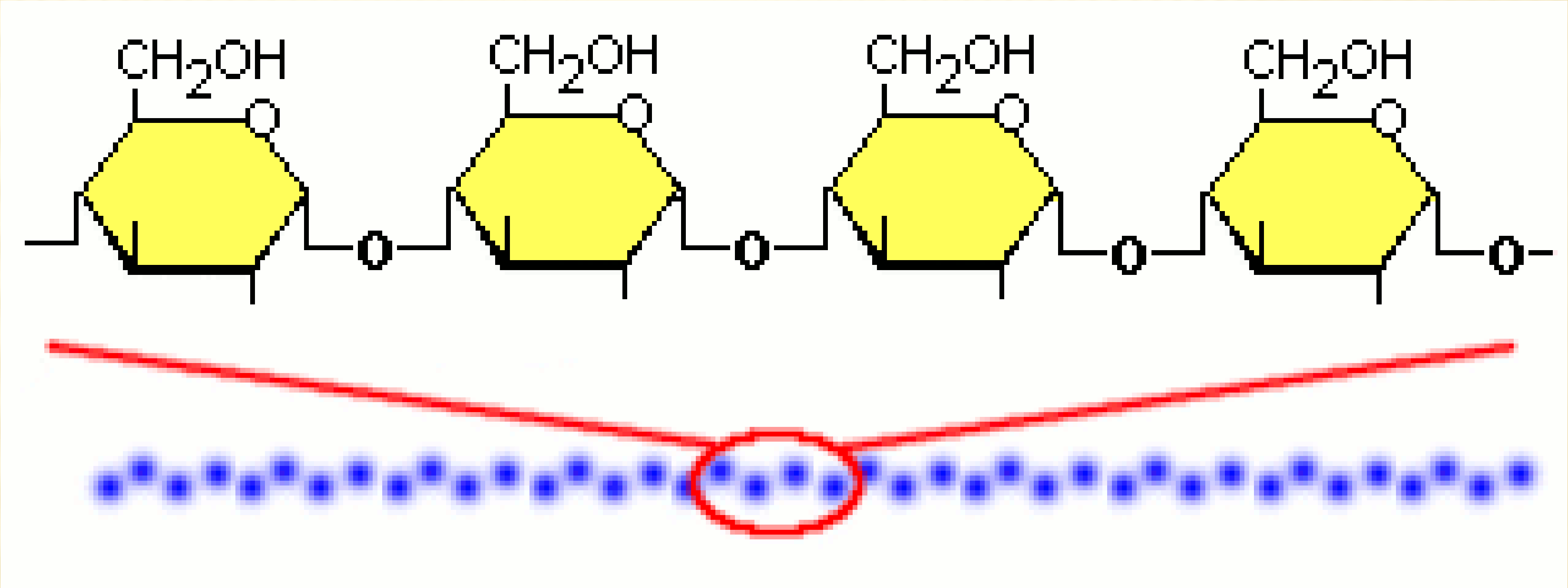
أميلوز : عديد السكاريد مستقيمة السلسلة مصنوع من جزيئات
α-D-الجلوكوز



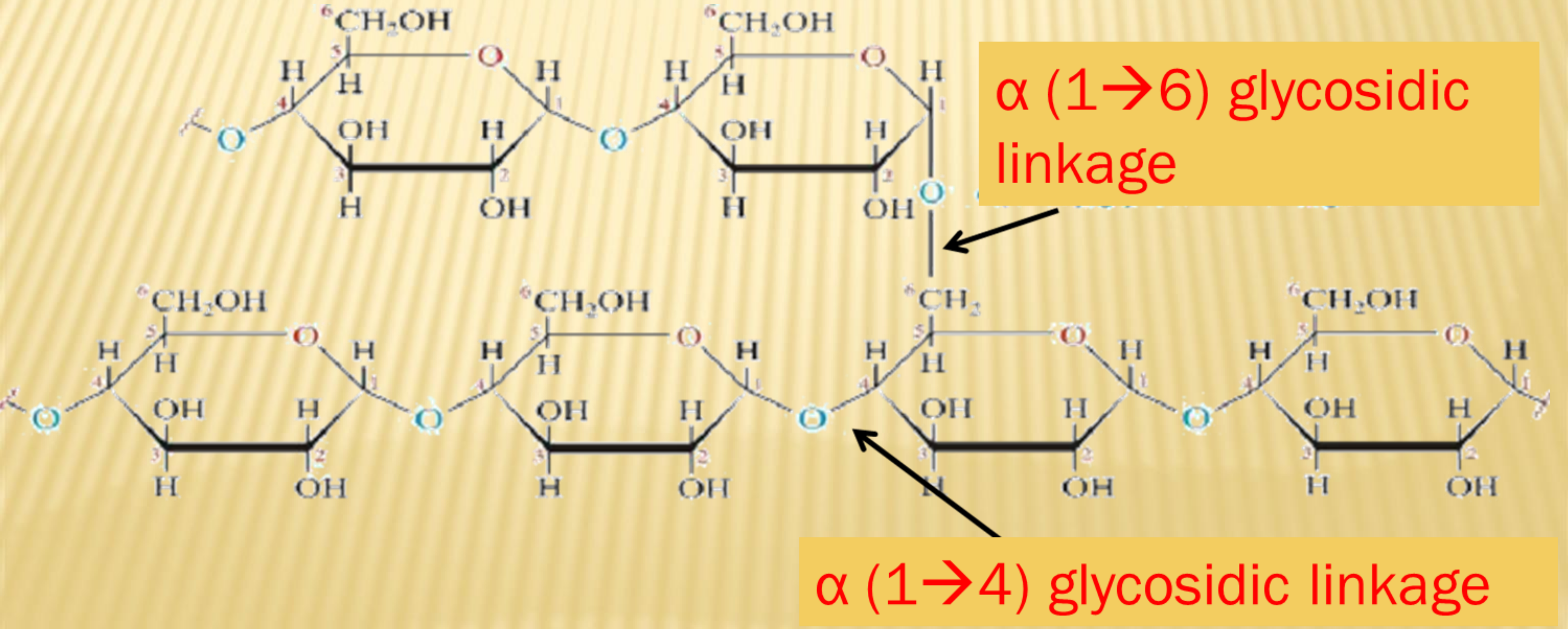
α (1→4) glycosidic linkage



Amylose

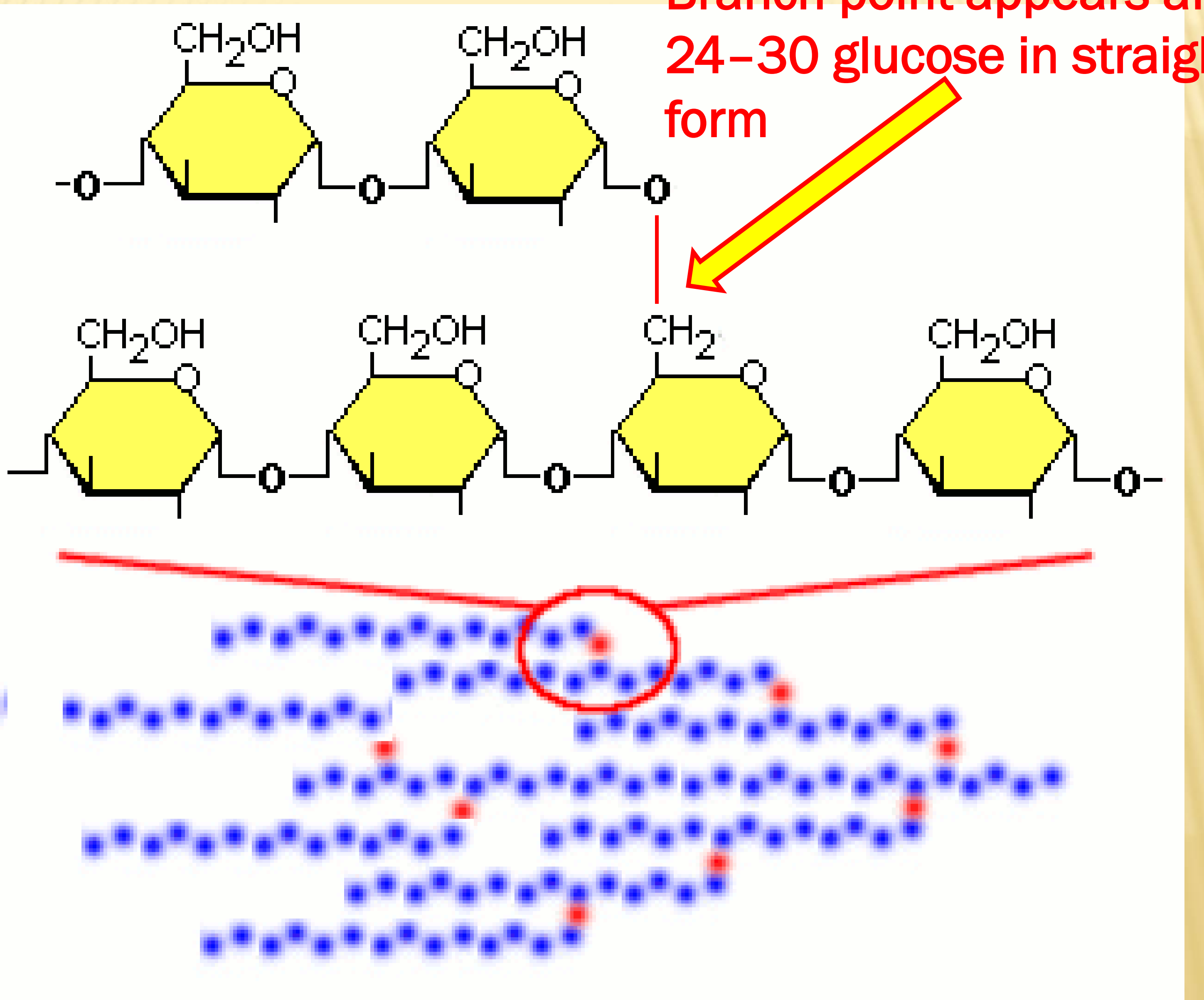


Amylopectin →polymer of *α*-D-glucose molecules that contain **main chain** (**straight chain**) and **the branched-chain** of polysaccharide that linked by α-1,4-glycosidic bonds and *α*-1,6 -glycosidic bonds between the glucose units



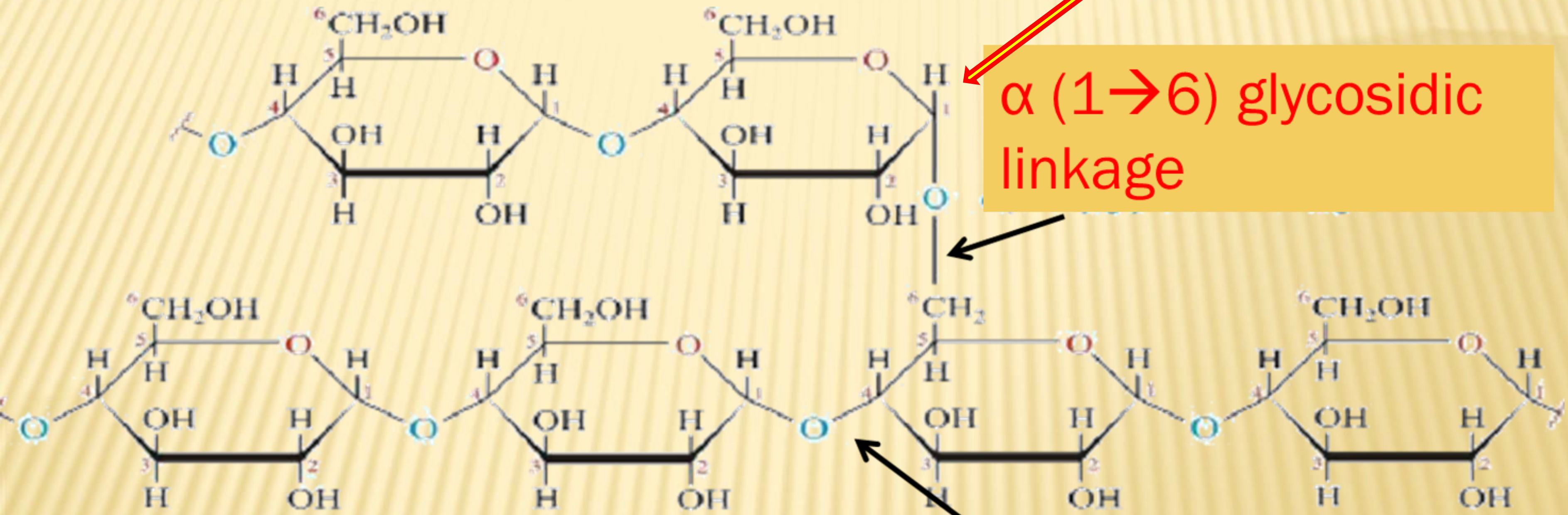
Amylopectin

Branch point appears after every 24–30 glucose in straight chain form



2-Glycogen, or animal starch

Branch point appears after every 10–15 glucose in straight chain form

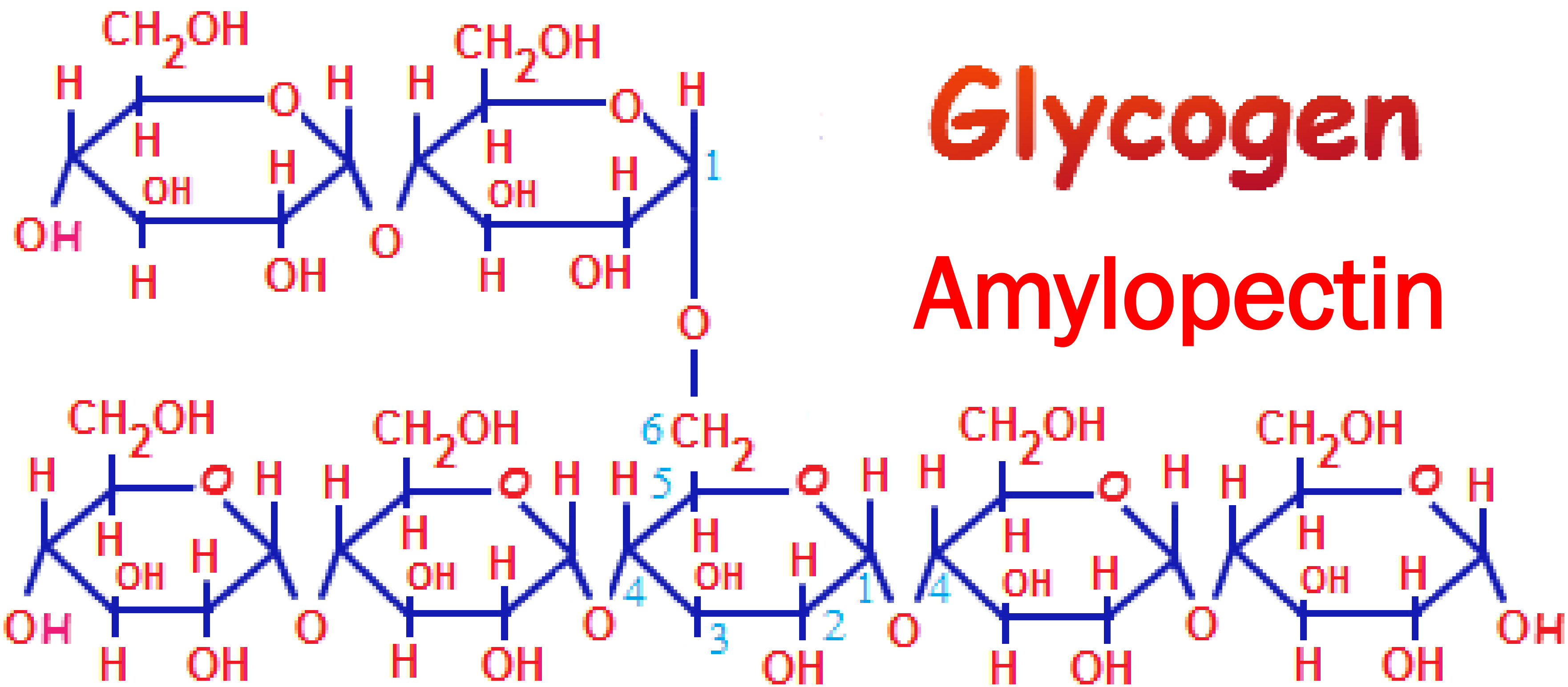


α (1→6) glycosidic linkage

α (1→4) glycosidic linkage

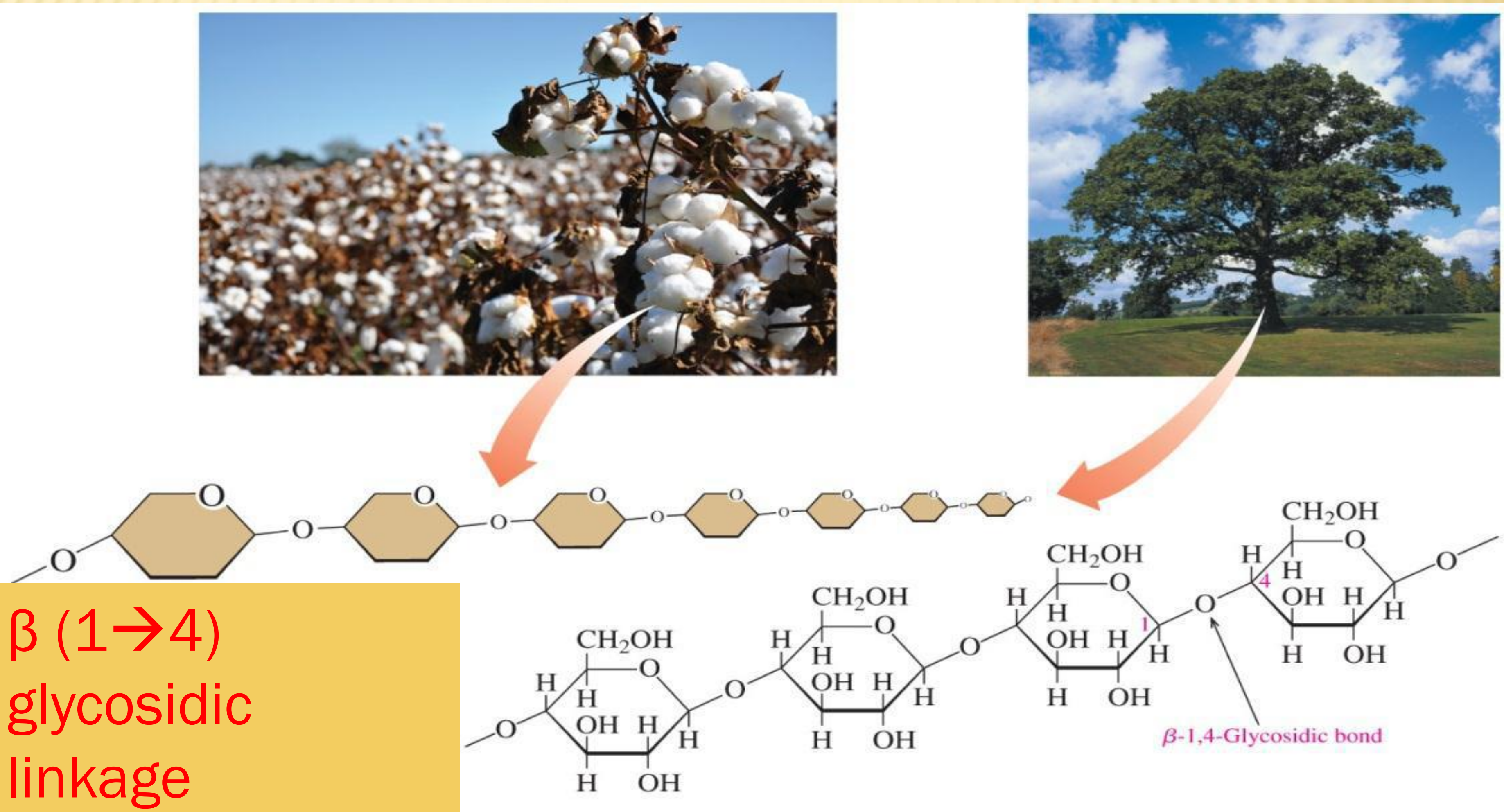
Glycogen

Amylopectin



3-Cellulose

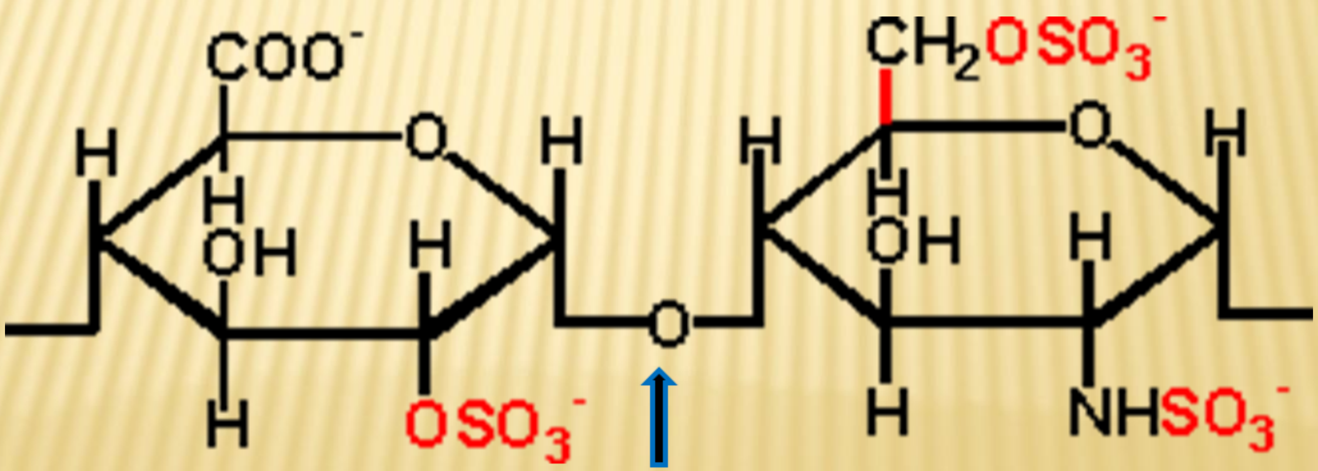
Cellulose, the major structural unit of wood, is a polysaccharide of glucose units in unbranched chains, and has β-1,4-glycosidic bonds



β (1→4) glycosidic linkage

•**Heteropolysaccharides**: They are polymer of different monosaccharide units or their derivatives , for example Heparin

Heparin: is linear polysaccharide consisting of 1→4 linked uronic acid and glucosamine residues that has highly sulfated and a clinically used anticoagulant



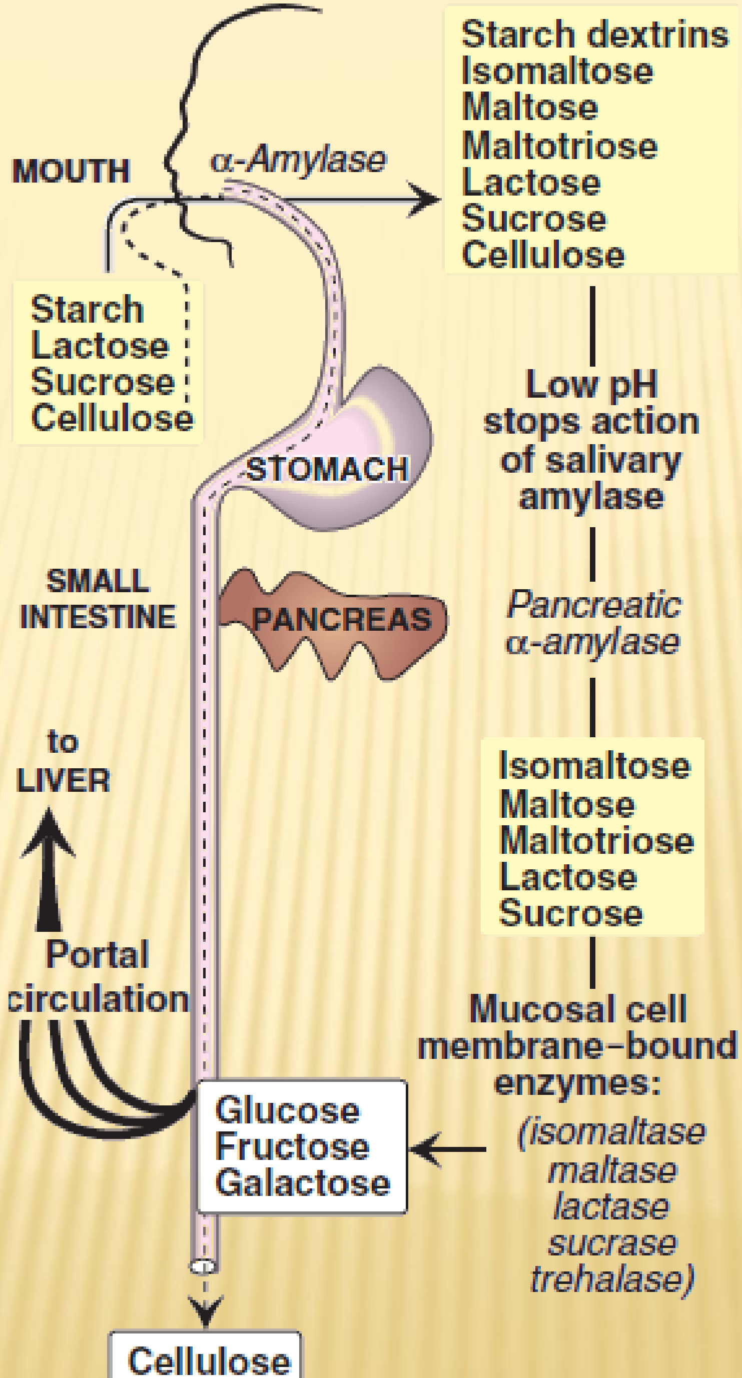
1→4

Uronic acid

Glucosamine

Differences between amylose and amylopectin

Properties	*Amylose*	*Amylopectin*
Amount present in starch	15–20%	80–85%
Structure	Unbranched, linear	Highly branched. Branch point appears after every 24–30 glucose in straight chain form
Molecular weight	60 kDa	500 kDa
Linkage	250–300 glucose residues are joined by a 1-4 glycoside link	Mainly formed by a 1–4 linkages between glucose residues. Branch point occurs by forming a 1–6 glycosidic linkage
Reaction with iodine solution	Blue color forms because the iodine molecules are trapped inside the helical structure. Color disappears upon heating. Reappears upon cooling	Reddish violet color

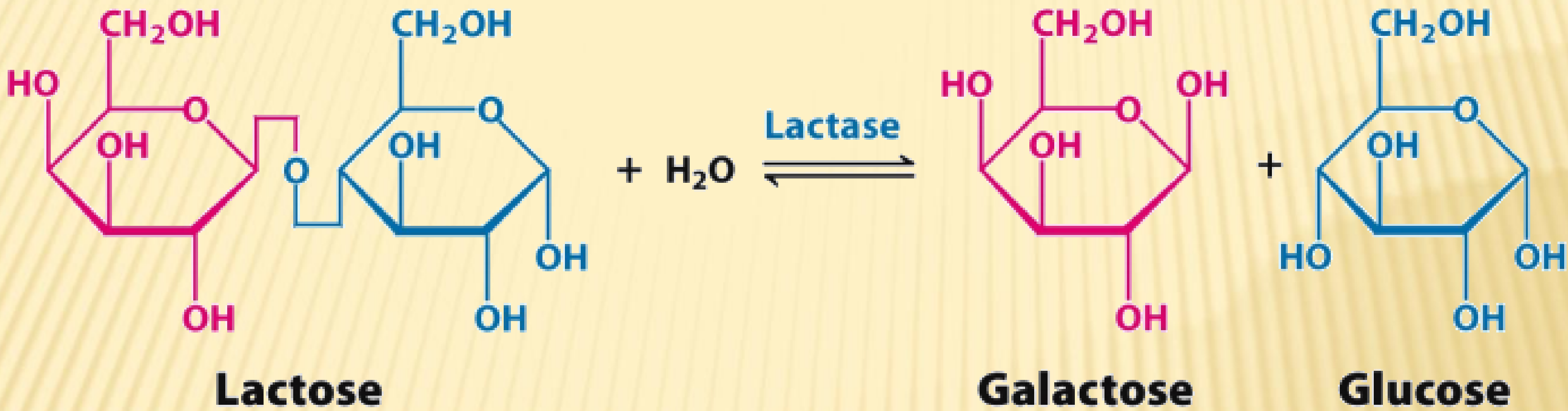


MOUTH
α-Amylase
Starch dextrins
Isomaltose
Maltose
Maltotriose
Lactose
Sucrose
Cellulose
Starch
Lactose
Sucrose
Cellulose
STOMACH
Low pH stops action of salivary amylase
SMALL INTESTINE
PANCREAS
Pancreatic α-amylase
Isomaltose
Maltose
Maltotriose
Lactose
Sucrose
to LIVER
Portal circulation
Mucosal cell membrane-bound enzymes:
(isomaltase maltase lactase sucrase trehalase)
Glucose
Fructose
Galactose
Cellulose

Enzymes of gastrointestinal tract

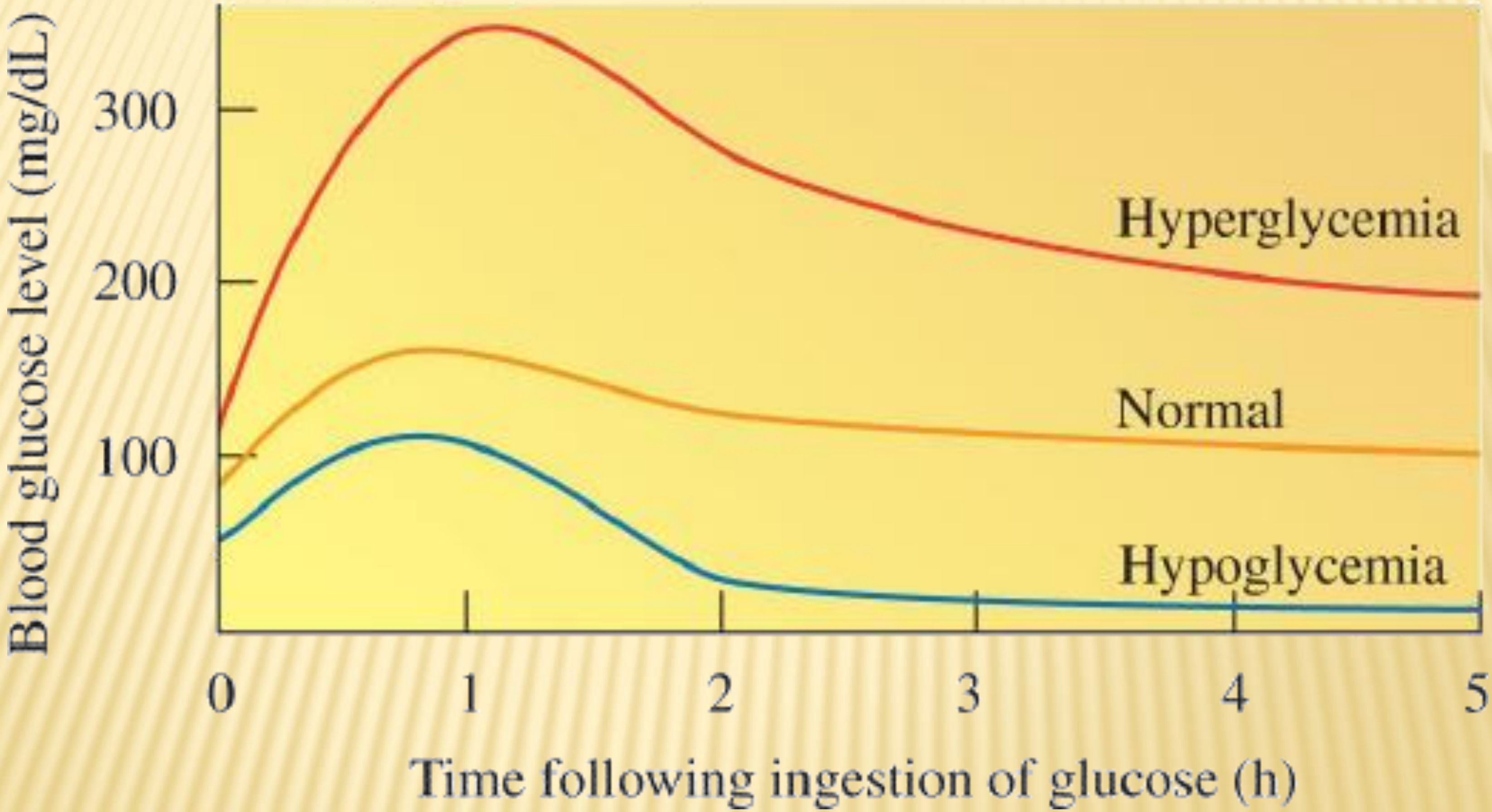
Gastric juice	*Pancreatic juice*	*Intestinal*
Pepsinogen (inactive form of the enzyme pepsin, which is secreted by chief cells of stomach)	Trypsinogen (inactive form of trypsin)	Aminopeptidase
HCl (secreted by parietal cells)	Chymotrypsinogen (inactive form of chymotrypsin)	Dipeptidase
Intrinsic factor (parietal cells)	Procarboxypeptidase (inactive form of carboxypeptidase)	Nucleotidase
Mucin (mucous cells)	Amylase	Maltase
	Lipase	Sucrase
	Ribonuclease	Lactase
		Isomaltase

Degradation of disaccharides



Maltose + H_2O $\xrightarrow{\text{maltase}}$ glucose + glucose

Sucrose + H_2O $\xrightarrow{\text{sucrase}}$ glucose + fructose


Blood glucose level (mg/dL)
300
200
100
Hyperglycemia
Normal
Hypoglycemia
0
1
2
3
4
5
Time following ingestion of glucose (h)

Clinical significant of Glucose

Glucose metabolism is defective in two very common metabolic diseases, obesity and diabetes