

Sonic

Biochemistry → Carl Neuberg (1903)

Definition

It is a branch of science which deals with chemical basis of life in plants and animals, like enzymes, hormones, carbohydrates, amino-acids, fats, proteins, DNA, RNA etc.

Importance

- 1) In Medicine
- 2) In Nursing
- 3) In Agriculture
- 4) In Pharmacy
- 5) In Plants

1. In Medicine

→ Physiology :- About biochemical changes and physiological alteration

→ Pathology :- Based on symptoms - clue about biochemical change & disorder.

→ Nutrition deficiency :- Multivitamins & Mineral supplement - role of vitamin

→ Hormonal deficiency :- disorder, hormonal imbalance, physician can understand.

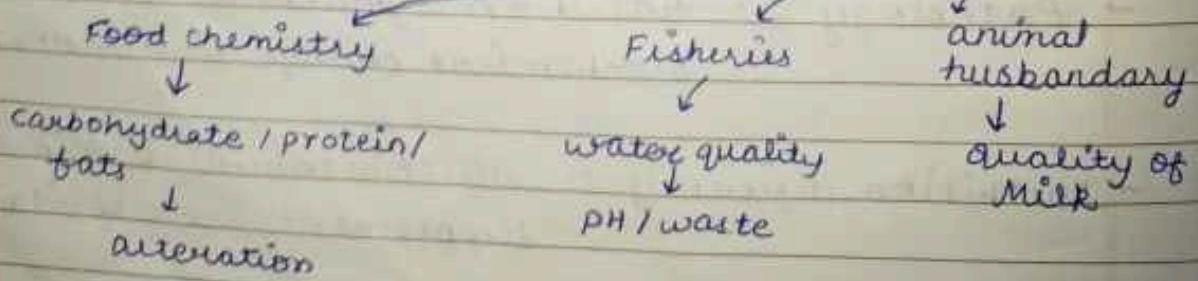
2) In Nursing

- Kidney function test :- chemotherapy treatment helps to understand extent of excretion of drugs/metabolites, change in pH/color.
- Blood Test :- In diabetes - analytical test for blood glucose level, appearance of ketone bodies.
- Liver function test :- disease/damage to liver & effect of medication on liver.
- Serum cholesterol test :- Blood cholesterol / lipoprotein prone ness to cardiovascular disease.

3) In Agriculture

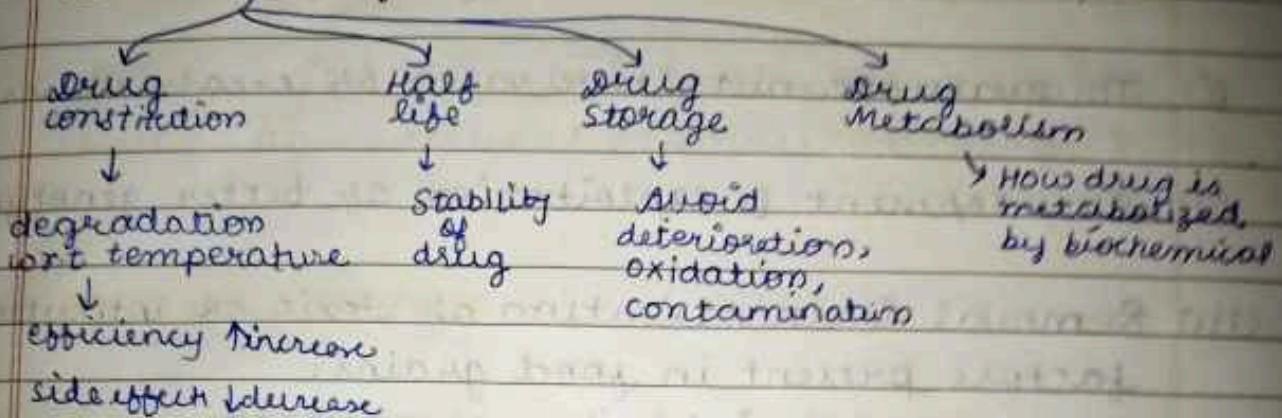
- Imp role in farming, fishery, poultry, sericulture, beekeeping etc.
- Prevent disease - prevention & treatment
- Enhance growth - how to use fertilizers for growth.
- Enhance yield - Hormones(promoters & inhibitors)
- Adulteration - composition alteration

Biochemical test



- Role of nutrient + vitamins, sugars etc

4) In Pharmacy



5) In Plants

- Respiration :- use of oxygen & gives out carbon dioxide.
- Plant's secondary Metabolites :- How gums, tannins, alkaloids, resins, enzymes formed inside the plants.
- Photosynthesis :- use sunlight, CO_2 , H_2O and forms food & oxygen.
- Different sugars :- diff. types of carbohydrates formed in plants. (3-glyceraldehyde, 4-tetrose, 5-pentose, 6-hexose, 7-heptulose (nucleic acid))
- Other function :- Ripening of fruits, seed germination, fats formed in SER.

→ Importance of Biochemistry in agriculture

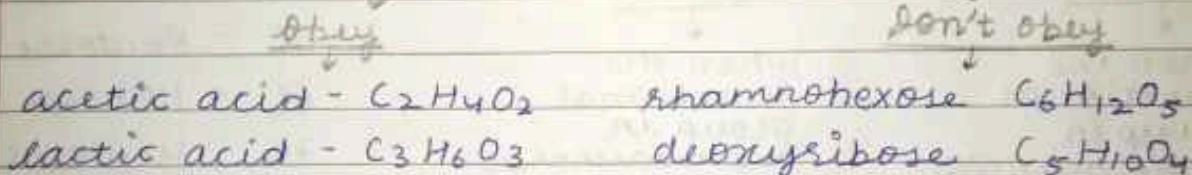
- (i) To evaluate nutritive value of cereal/pulses.
- (ii) Development & exploitation of better genotype.
- (iii) Removal & inactivation of toxic or antinutritional factors present in food grains.
e.g. Trypsin inhibitor of soybean.
- (iv) Food preservation & processing technology & post-Harvest physiology of fruit/crops/ vegetables and their nutritional quality.
- (v) Use of non-conventional sources of protein
e.g. Single cell protein, fish protein etc.
- (vi) Developments in the field of inter-mediatory metabolism i.e. synthesis/degradation of constituents of living tissues.
- (vii) Composition of certain soils and their deficiencies.
- (viii) Plants uptake / utilization of nutrients.
- (ix) Application of fertilizers & pesticides
- (x) Formulation of animal feeds
- (xi) Disease/Pest/ Drought resistance

(xii) Formulation of balanced diet.

(xiii) Production of alternative fuel source using agricultural biomass.

Carbohydrates

- Carbohydrates may be defined as polyhydroxy aldehydes or ketones or compounds which produce them on hydrolysis.
- Hydrates of carbon $(C_6H_{12}O_6)_n$



Functions

- Most abundant dietary source of energy (4 cal/g)
- Precursor for many organic compounds (fats, amino acid).
- Structure of cell membrane (glycoprotein, glycolipid)
cellular function - growth, adhesion, fertilisation
- Structural comp. of organism fibre (cellulose) - Plants
chitin - exoskeleton of insects
- Storage form of energy (glycogen) immediate
energy demand

Classification

- 1) Monosaccharides
 - 2) Oligosaccharides
 - 3) Polysaccharides
- } Sugars

sweet
cystalline
soluble in water

Classification of Monosaccharides

Based on functional group

Aldose

When the functional group in monosaccharide is $(-\text{CHO})$ or aldehyde

e.g. glucose

glycereraldehyde

Ketose

When the functional group in monosaccharide is $(-\text{CO})$ or keto

e.g. fructose

dihydroxyacetone

Based on number of carbon atoms

3C - Trioses

4C - Tetroses

5C - Pentoses

6C - Hexoses

7C - Heptoses

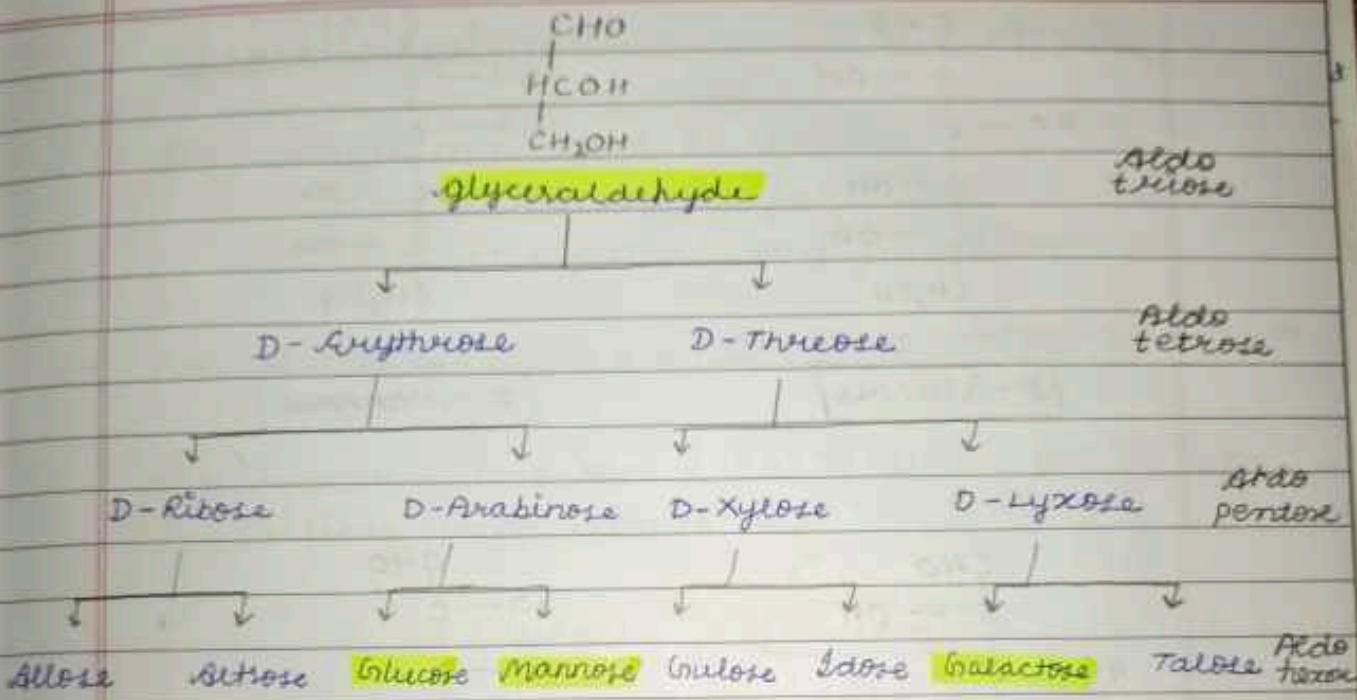
Glucose : Aldohexose

Fructose : Ketohexose

$(\text{C}_3\text{H}_6\text{O}_3)$	Triose
$(\text{C}_4\text{H}_8\text{O}_4)$	Tetrose
$(\text{C}_5\text{H}_{10}\text{O}_5)$	Pentose
$(\text{C}_6\text{H}_{12}\text{O}_6)$	Hexose
$(\text{C}_7\text{H}_{14}\text{O}_7)$	Heptose

Aldose	Glyceraldehyde
	Erythrose
	Ribose
	Glucose
	Glucoseptose

Ketose	Dihydroxyacetone
	Erythrulose
	Ribulose
	Fruuctose
	Sedoheptulose

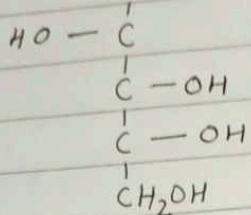
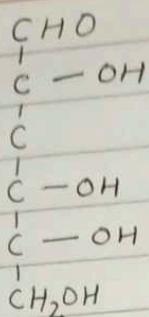


dihydroxyacetone - keto triose

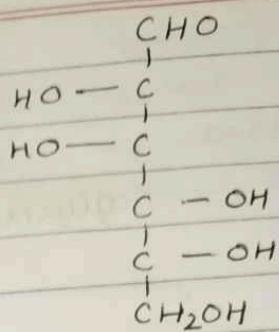
D-erythulose - keto tetrose

D-Xylulose , D-ribulose - keto pentose

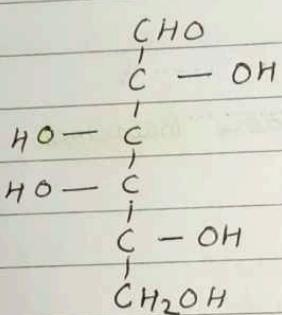
D-Tagatose , D-psicose
D-Sorbose , D-fructose]- keto hexose



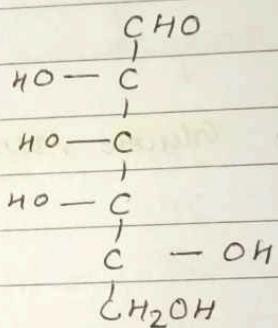
[D-Glucose]



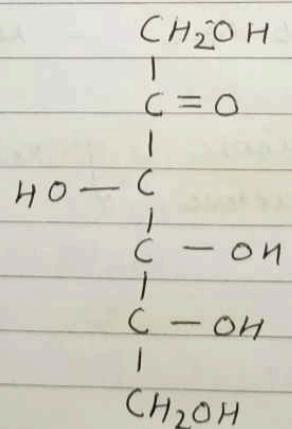
[D-Mannose]



[D-Galactose]



[D-Talose]



[D-Fructose]

Stereoisomerism

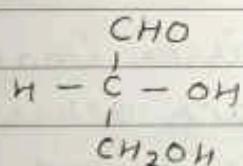
- The compounds that have -
 - same structural formulae
 - different spatial configuration
- Possible no. of isomer = 2^n , no. of asymmetric carbon

for example i. Glucose → has 4 asymmetric carbon

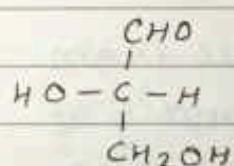
$$\text{so possible no. of isomer} = 2^4 \\ = 16$$

Glucose. = 16 isomers

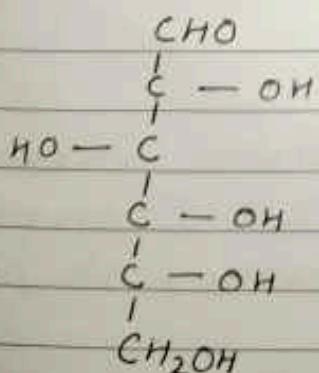
- Reference carbohydrate = Glyceraldehyde
(triose)
 - 1 asymmetric carbon
 - so $2^1 = 2$ stereoisomers (D & L)



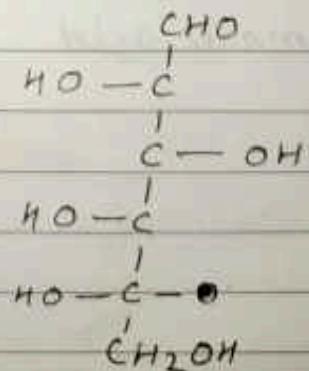
D-Glyceraldehyde



L-Glyceraldehyde



D-Glucose



L-Glucose

Isomerism

→ Different compounds with same molecular formula

↓
**Structural
isomers**

- same molecular formula
- different structures
 - chain
 - position
 - functional group

↓
**Stereo
isomers**

- same molecular formula
- same structure, different spatial configuration

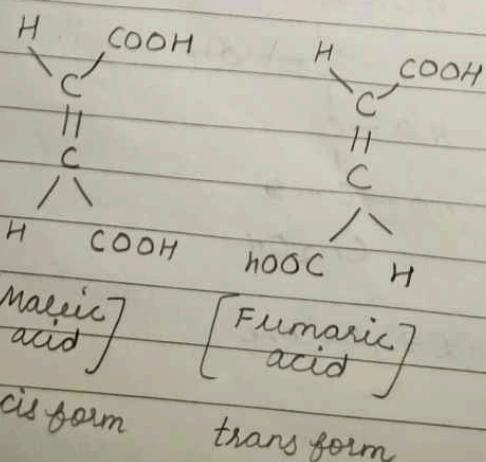
↙
**Geometrical
stereoisomers
(cis-trans)**

Isomer arise from peculiar geometry of compounds having $C=C$.

e.g. Maleic acid & fumaric acid

↘
**optical
stereoisomers
(enantiomers)**

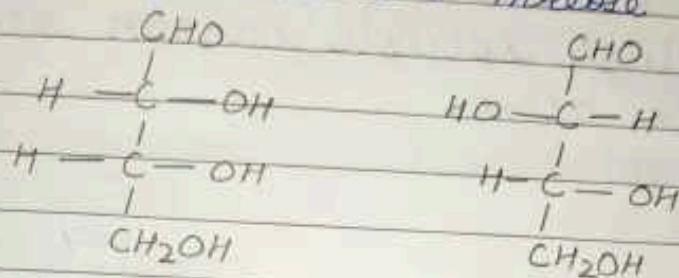
- Mirror images of each other
- designated as D- & L-sugar.



Diastereomers

- The stereoisomers which are not mirror images of one another.

e.g.: - D-erythrose & D-threose



{D-erythrose}

{D-threose}

Optical activity

- characteristic feature of compounds with asymmetric carbon atom.
- When a beam of polarised light passes through a solution of optical isomer



Rotation of
polarized light

Right

Left

Dextrorotatory (+)

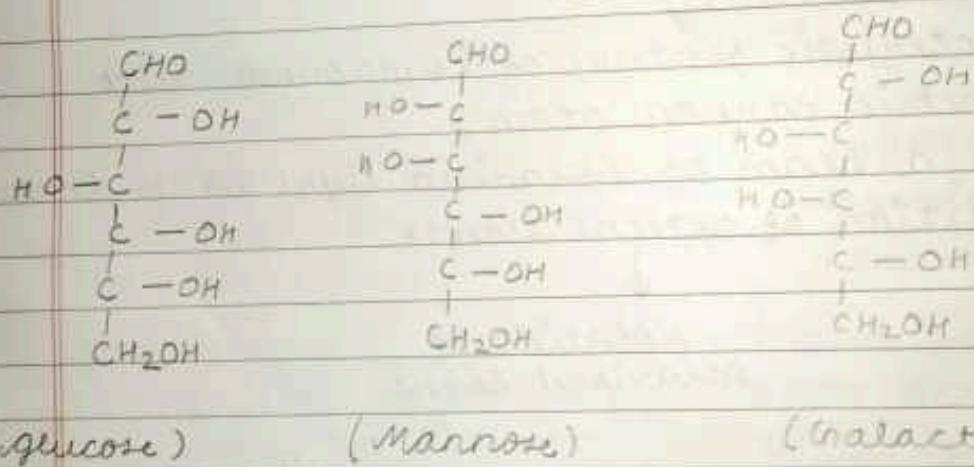
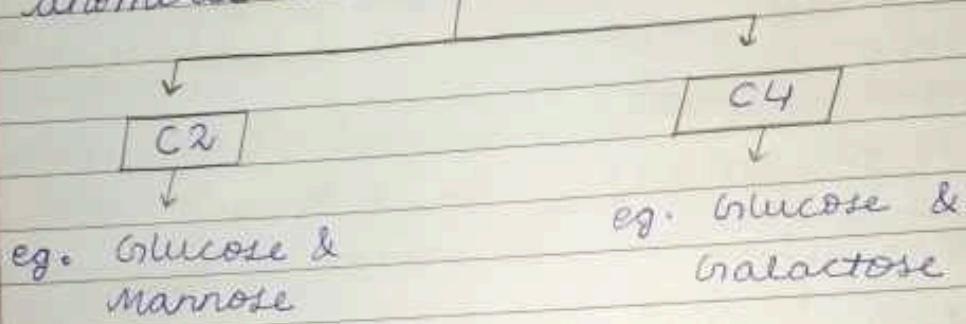
Levorotatory (-)

Lacemic mixture or (DL mixture)

- When D & L-isomers are present in equal concentration.
- Does not exhibit any optical activity.

Isomers

- When two monosaccharides differ from each other in their configuration around a singlet single specific carbon other than anomeric atom.

Mutarotation

- The change in the specific optical rotation representing the interconversion of the α & β forms of D-glucose to an equilibrium mixture.
- All reducing sugars (except few ketoses) undergo mutarotation.

α -D-glucose \rightleftharpoons

(+112.2°)

• freshly prepared glucose.

Equiv^m mixture
(+52.7°)

β -D-glucose
(+18.7°)

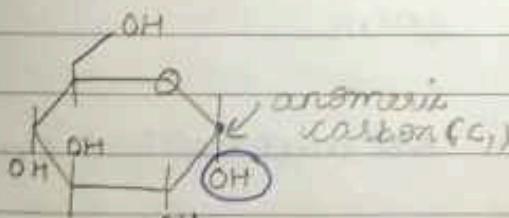
• In presence of alkali.

- Equim^m mixture contains
- 63% β -anomer
 - 36% α -anomer
 - 1% open chain form

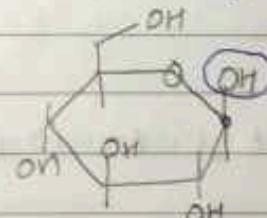
In aqueous solution, β -form is more predominant due to its stable conformation

→ Anomeric forms

- Sugars with an open-chain structure have a reactive carbon atom called anomeric carbon (C_1)
- The α -anomer has the hydroxy (-OH) group attached to the anomeric carbon positioned below the plane of ring.
- The β -anomer has the hydroxyl (-OH) group positioned above the plane of ring.



(α -glucose)



(β -glucose)

→ Dynamic equilibrium

- In solⁿ, the sugar molecules exist in a dynamic equ^m between the α - & β -forms.
- The conversion occurs through an open-chain structure.

→ Factors affecting mutarotation

- The extent of mutarotation is influenced by factors such as temperature, concentration & pH.
- High temperatures & higher concentration generally accelerate the mutarotation process.
- The pH of the solution can also affect the rate of mutarotation.

Difference between reducing & non-reducing sugars

Reducing sugar

1. Free aldehyde (C_1) and free ketone at C_2 .
2. Hemiacetal and Hemiketals. They are acetal & ketal form.
3. Exhibit mutarotation
4. Do form osazones with phenylhydrazine.
5. Form oximes with hydroxylamine.
6. Eg - Glucose, Fructose, Lactose, Maltose

Non-Reducing sugar

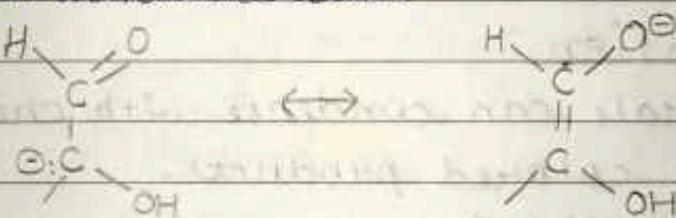
1. Not free but instead utilized in bond formation.
2. No mutarotation
3. No osazones.
4. No oximes formation
5. Eg sucrose, glycogen, insulin

Reactions of Monosaccharides

1. Tautomerization / enolization
2. Oxidation
3. Reduction
4. Dehydration
5. Osazone formation

1) Tautomerization

- The process of shifting a hydrogen atom from one carbon atom to another to produce ene-diols is called tautomerization.
- sugar having anomeric carbon undergo this process in alkaline solⁿ.



2) Oxidation

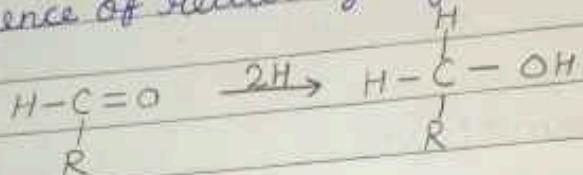
- Depending on the oxidizing agent used, terminal aldehyde (ketone) or terminal alcohol or both the groups may be oxidised.
e.g. glucose

→ Oxidⁿ of aldehyde group \rightarrow gluconic acid formation
 $(\text{CHO} \rightarrow \text{COOH})$

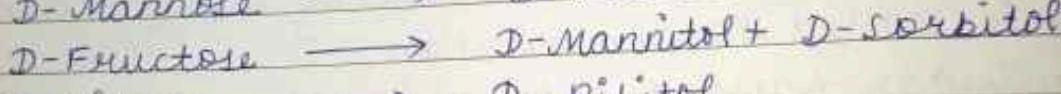
→ Oxidⁿ of terminal alcohol group \rightarrow glucuronic acid formation
 $(\text{CH}_2\text{OH} \rightarrow \text{COOH})$

3) Reduction

→ Aldehyde / keto group of monosaccharide is reduced to form corresponding alcohol, in presence of reducing agent - sodium amalgam.



→ Examples :-



4) Dehydration

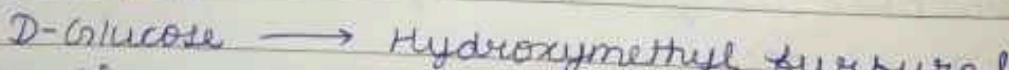
→ Furfurals can condense with phenolic compounds to form colored products.

• Basis of Molisch test.

→ Oligosaccharides $\xrightarrow{\text{Hydrolysed}}$ Monosaccharides
Polysaccharides \downarrow

dehydration

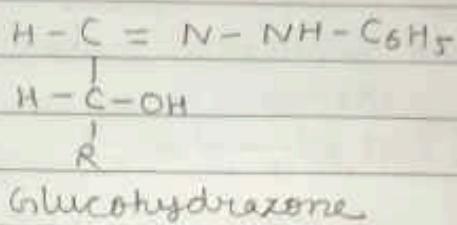
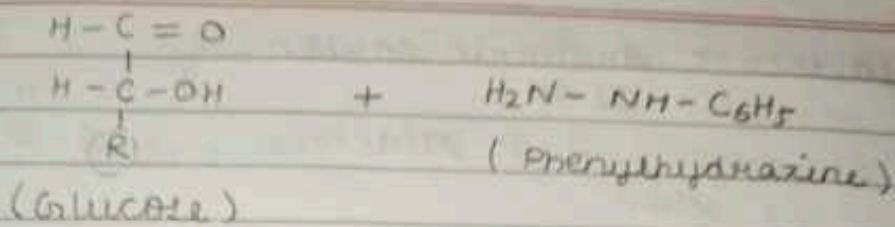
→ Example



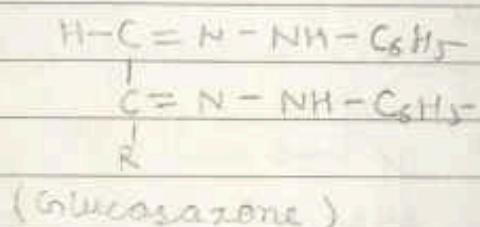
5) Oxazone formation

→ Phenylhydrazine in acetic acid, when boiled with reducing sugars to form oxazones.

→ Chemical reaction →

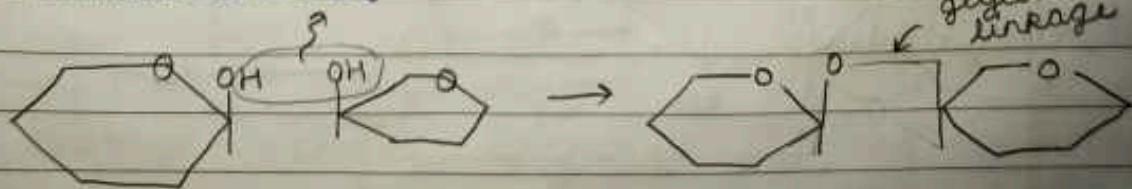


(Phenylhydrazine)

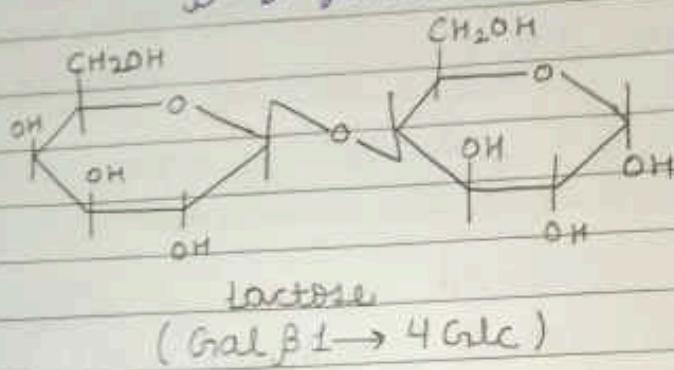


Oligosaccharides

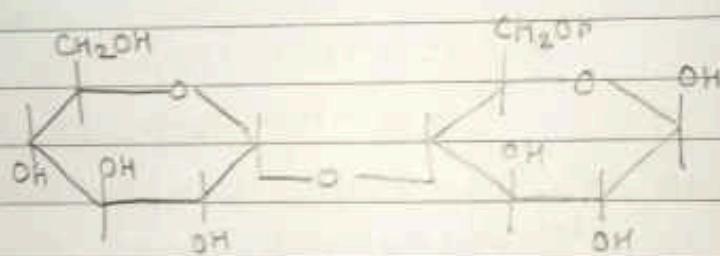
- Monosaccharide condense through glycosidic linkage to form oligosaccharide.
- Glycosidic bond is covalent bond
- Hydroxyl group on anomeric carbon (reacts) of second monosaccharide → Disaccharide



1) Lactose \rightarrow Anomeric carbon
 C1 of
 β -D-galactose & C4 of
 α -D-glucose



2) Maltose \rightarrow C1 of two α -D-glucose
 &
 C4

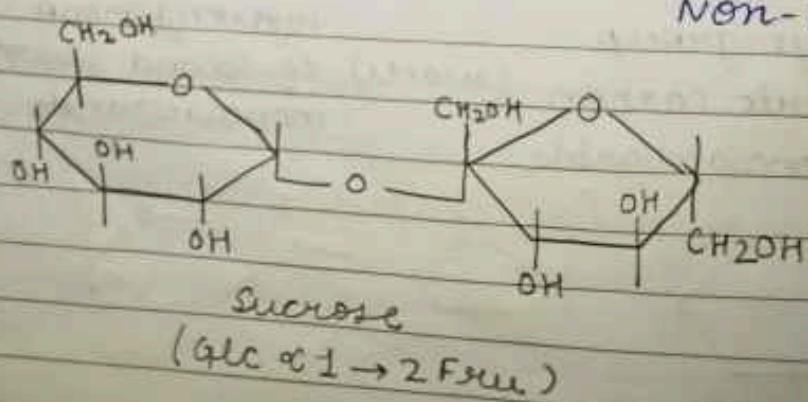


Maltose

\rightarrow Lactose, Maltose: one anomeric carbon has been used in bond, leaving second free hence called reducing sugars.

3) Sucrose \rightarrow C1 of α -D-glucose & C2 of β -D-fructose

- lacks free reducing group - Hence Non-Reducing



Sugar Alcohols

1. Sorbitol
2. Mannitol & Erythritol
3. Inositol

- 1) Sorbitol →
 - Natural, also made commercially
 - fruits - cherries
 - used - diabetic soft drink, jams, chocolates
 - 60% as sweet as sucrose
- 2) Mannitol →
 - derived from mannose Glucosamine
 - Food manufacture
 - Mannitol is extracted commercially from a seaweed.
- 3) Inositol →
 - cyclic alcohol
 - 6 hydroxyl radicals
 - allied to glucose
 - present in cereals.

Polysaccharides

→ Many monosaccharide units condense to form polysaccharide through glycosidic linkage.

Classification on the basis of :-

Function		Nature		Repeating units	
structural	storage	Linear	Branched	Homo Polysacc.	Hetero polysacchar
Cellulose	Glycogen	Cellulose	Starch	Starch	
Chitin	Starch	Chitin	Glycogen	Glycogen	
Pectin	Inulin	Oamylose	Amylopectin	Creatin	Hemicellulose
Hemicellulose				Inulin	Pectin

Important Polysaccharides

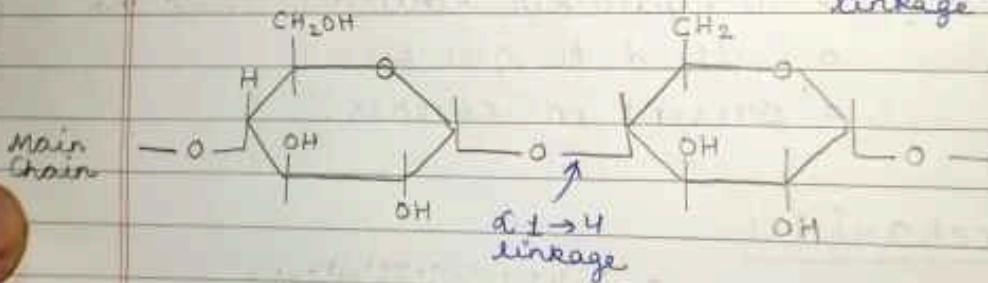
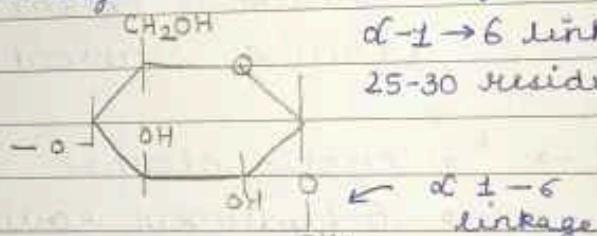
1. Starch
2. Glycogen
3. Dextran
4. Cellulose
5. Chitin

1) Starch

→ In plants - insoluble starch granules
 → Each molecule - amylose & amylopectin

unbranched polymer
 of glucose joined in
 $\alpha 1 \rightarrow 4$ linkage

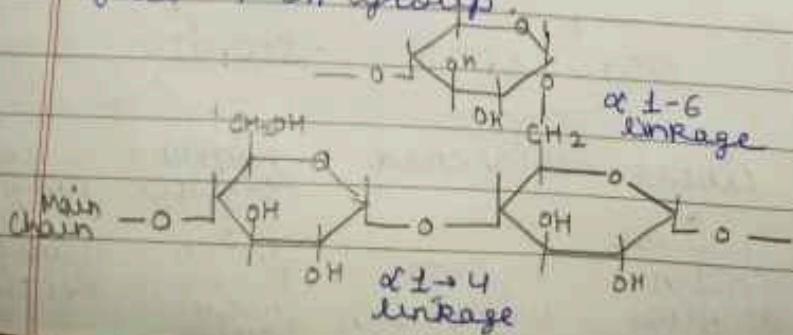
branched glucose
 residues at $1 \rightarrow 4$
 linkage, also additional
 $\alpha 1 \rightarrow 6$ linkage at every
 25-30 residues.



2) Glycogen

→ glucose unit linked $\alpha 1 \rightarrow 4$ glycosidic bond &
 for every 10 units $\alpha 1 \rightarrow 6$ linkage.

→ Glycogen chain terminates in non-reducing end with
 free 4'-OH group.

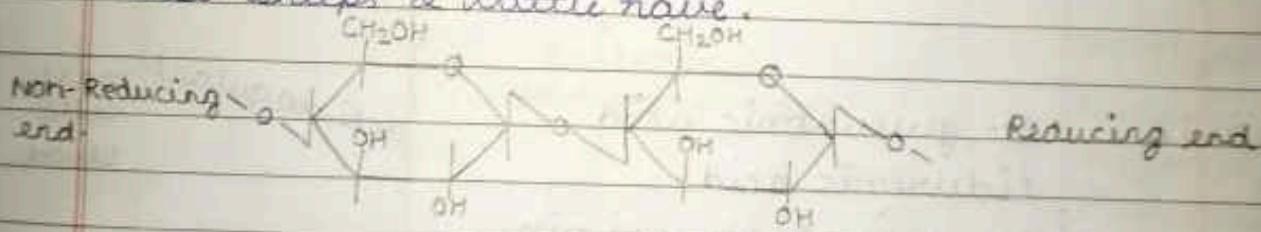


3) Dextran

- glucose polymer is mainly linked $\alpha 1 \rightarrow 6$ bonds but also few $\alpha 1 \rightarrow 2$ bonds.
- $\alpha 1 \rightarrow 3$ }
 $\alpha 1 \rightarrow 4$ } for bacteria/yeast species as source
- used as plasma expanders
- derived compounds used as -- anti-coagulants for blood.

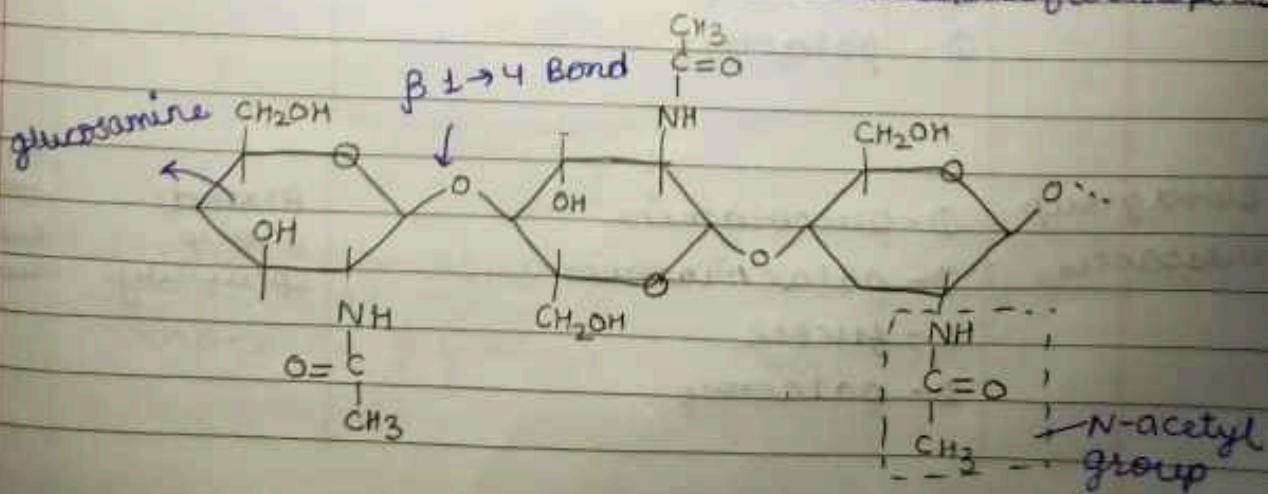
4) Cellulose

- unbranched polysaccharide of glucose $\beta 1 \rightarrow 4$ bonds
- Arranged as straight fibrils
- wood: also contain lignin
- Non-ruminants (mammals) - lack enzyme to break
- Several spp of bacteria & molds have this enzyme.
Also sheep & cattle have.



5) Chitin

- Repeating unit (NAG, NAM)
- N-acetyl- β -D-muramic acid
N-acetyl-D-glucosamine
- 2-deoxy-2-acetamide-D-glucose
- Also called animal cellulose - outer skeleton of arthropoda



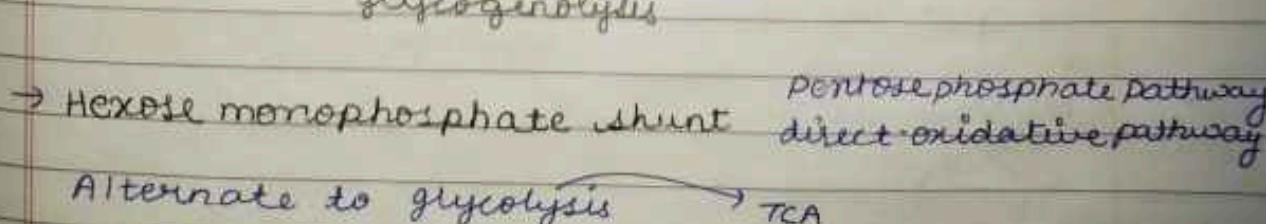
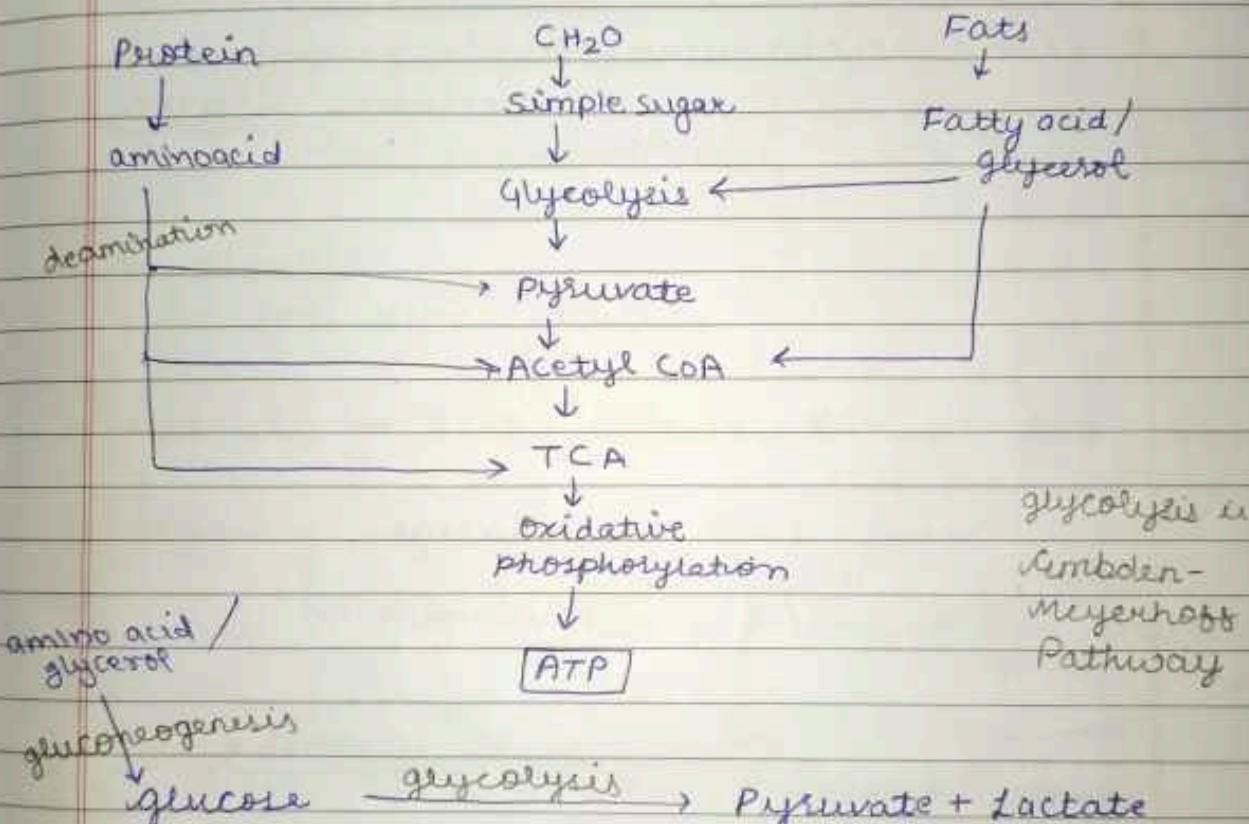
Heteropolysaccharides (or Heteroglycans)

- contain two or more different monosaccharide units.
- Have complex nature

Heteropolysaccharide	component sugars	Function	Distribution
Hyaluronic acid	D-glucuronic acid and N-acetyl-D-glucosamine	lubricant, shock absorber, water binding	connective tissue, skin
chondroitin -4-sulphate	D-glucuronic acid N-acetyl-D-galactosamine -4-O-sulfate	calcium accumulation, cartilage & bone formation	cartilage
Heparin	D-glucuronic acid Liduronic acid N-sulfo-D-glucosamine	anti-coagulant	mast cells, blood
Gamma globulin	N-acetyl-hexosamine D-mannose D-galactose	anti-body	Blood
Blood group substances	D-glucosamine D-galactosamine L-fucose D-galactose	BLOOD group specificity	cell surfaces, especially red blood cells.

Carbohydrate Metabolism

- Metabolism - Sum total of all enzymatic reactions in orderly & regulated way.
- Anabolism (reductive)
- Catabolism (oxidative)



→ Metabolism includes

1. Glycolysis
2. TCA cycle
3. Glyoxylate cycle
4. Electron Transport Chain

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