CHE-MM: XII

14. BIOMOLECULES

Biomolecules: Chemical compounds found in living organisms. Responsible for their growth, maintenance and their ability to reproduce.

e.g: Carbohydrates, proteins, nucleic acids, lipids, vitamins etc.

CARBOHYDRATES / *Saccharides*

- **Old definition**: These are the hydrates of carbon - $C_x(H_2O)_y$.
- **Modern definition**: They are **polyhydroxy aldehydes** or **ketones** or substance which produces such units on hydrolysis.

Classification of carbohydrates

➔ ***Based on their behaviour on hydrolysis:***

- **Monosaccharides**: These are carbohydrates which cannot be hydrolysed into simpler units of polyhydroxyaldehydes or ketones.
  E.g.: Glucose, fructose, galactose, ribose etc.
- **Oligosaccharides**: These are carbohydrates which give 2-10 monosaccharide units on hydrolysis.
  They are further classified as disaccharides, trisaccharides, tetrasaccharides etc.
  E.g.: Sucrose, maltose, lactose etc.
- **Polysaccharides**: These are carbohydrates which give a large number of monosaccharide units on hydrolysis.
  E.g.: starch, cellulose, glycogen, gums etc.

➔ ***Based on their reducing character:***

Based on this, carbohydrates are of two types –

- Reducing sugar - Carbohydrates which contain free aldehydic or ketonic groups
  e.g.: All monosaccharides, disaccharides like maltose and lactose
- Non-reducing sugar- Carbohydrates which do not contain free aldehydic or ketonic group
  e.g.: Sucrose, all polysaccharides

➔ ***Based on their physical properties:***

- **Sugars:** Carbohydrates which are sweet in taste, crystalline and water soluble.
- **Non-sugars:** Carbohydrates which have no sweet taste, not crystalline and water insoluble. eg: all polysaccharides

I. Monosaccharides

Classification:-

➔ ***Based on the functional group***:

- **Aldose**: Monosaccharide containing an aldehyde (-CHO) group
- **Ketose:** Monosaccharide containing a keto (> C = O) group.

➔ ***Based on the no. of carbon atoms***:

- Aldose or ketose containing 3 carbon atoms are called triose, 4 carbon atoms are called tetrose etc.

1. Glucose / dextrose

Glucose is an aldohexose. Its molecular formula is $C_6H_{12}O_6$.

Preparation

- *From sucrose (Cane sugar):* Sucrose boiled with dil. HCl or H_2SO_4 in alcoholic solution, glucose and fructose are obtained in equal amounts.

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{H^+} C_6H_{12}O_6 + C_6H_{12}O_6$$

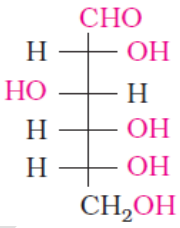
- *From starch:* Commercially glucose is obtained by hydrolysis of starch by boiling it with dil. H_2SO_4 at 393 K under pressure.

$$(C_6H_{10}O_5)_n + nH_2O \xrightarrow{H^+} nC_6H_{12}O_6$$

Experiments on elucidating the structure

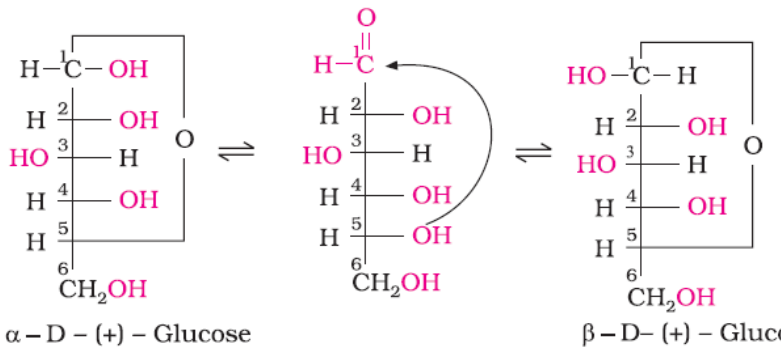
Glucose react with	Product	Inference
HI	n-Hexane	All the 6 carbon atoms are linked in a straight chain
HCN	Cyanohydrin	Presence of carbonyl group
NH_2OH	Oxime	
Bromine water (Br_2/H_2O)	Gluconic acid	Carbonyl group is aldehyde
Acetic anhydride	Glucose pentaacetate	Presence of 5 –OH group
Conc. HNO_3	Saccaric acid	One of the –OH group is primary.

- Based on the above information, Fischer (1891) proposed an open chain structure for glucose as follows:



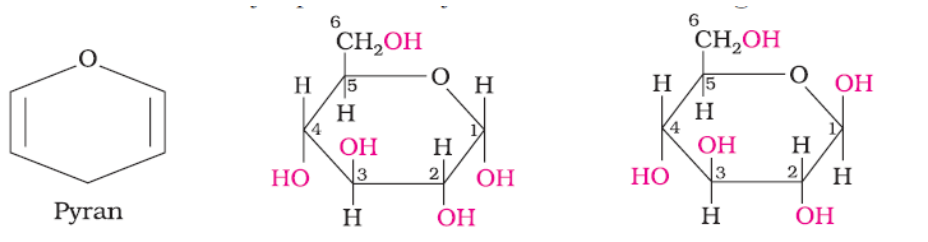
D- Glucose (Open chain structure)

- But this open chain structure cannot explain the following observations:
  1. Glucose does not react with 2,4-Dinitrophenyl hydrazine, Schiff's reagent and with $NaHSO_3$.
  2. The pentaacetate of glucose does not react with hydroxylamine indicating the absence of free —CHO group.
  3. The existence of two different crystalline forms of glucose (α and β form).
- In order to explain the above, it was proposed that one of the –OH groups may add to the –CHO group and form a cyclic hemi-acetal structure. The –OH at C_5 is involved in ring formation. (1, 5 – oxide ring).



Thus the two cyclic forms exist in equilibrium with the open chain structure. The two cyclic hemi-acetal forms of glucose differ only in the configuration at first carbon (anomeric carbon). So they are called ***anomers***. *They are stereo isomers which differ only in the configuration at the first carbon*.

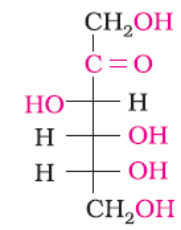
- The six membered cyclic structure of glucose is called Pyranose structure. The anomeric forms of glucose can be represented as follows:



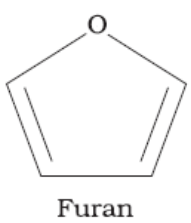
2. Fructose

- Fructose is an important ketohexose also with molecular formula $C_6H_{12}O_6$.

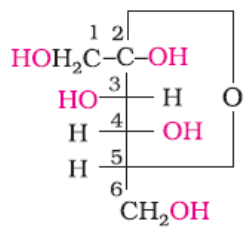
Structure



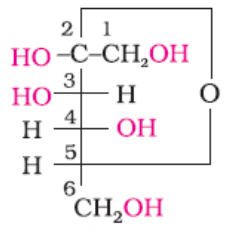
D – (–) – Fructose



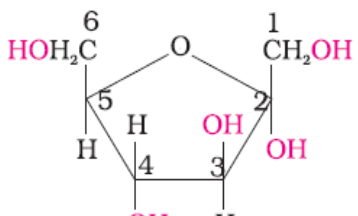
Furan



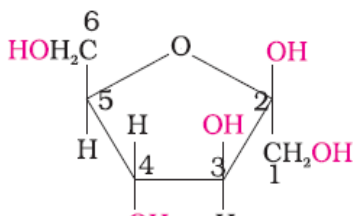
α – D – (–) – Fructofuranose



β – D – (–) – Fructofuranose



α – D – (–) – Fructofuranose



β – D – (–) – Fructofuranose

II. Disaccharides

➔ ***Glycosidic linkage***

It is the bond formed when individual monosaccharides are linked between 2 carbon through oxygen atom (C-O-C) by dehydration.

No.	Sugar	Reducing character	Monosaccharides	Glycosidic linkage b/w
1.	Sucrose	Non-reducing	α-D glucose + β-D-fructose	C_1 of α-glucose and C_2 of β-fructose (C_1 – C_2)
2.	Maltose	Reducing sugar	α-D glucose + α-D-glucose	C_1 of one α-glucose and C_4 of another α-glucose (C_1 – C_4)
3.	Lactose	Reducing sugar	β-D-glucose + β-D-galactose	C_1 of galactose and C_4 of glucose

? ***Hydrolysis of cane sugar is also called inversion of sugar***

➔ Cane sugar is sucrose, which on hydrolysis gives an equimolar mixture of D(+)glucose and D(-)fructose.

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + H_2O \longrightarrow \underset{\substack{\text{D(+)Glucose}\\(+52.50)}}{C_6H_{12}O_6} + \underset{\substack{\text{D(-)Fructose}\\(-92.40)}}{C_6H_{12}O_6}$$

Sucrose is dextro rotatory but after hydrolysis gives dextro rotatory glucose and laevo rotatory fructose. Since the laevo rotation of fructose (-92.40) is more than dextro rotation of glucose (+52.50), the mixture is laevo rotatory. So the process is called *inversion of cane sugar* and the product formed is called ***invert sugar***.

III. Polysaccharides

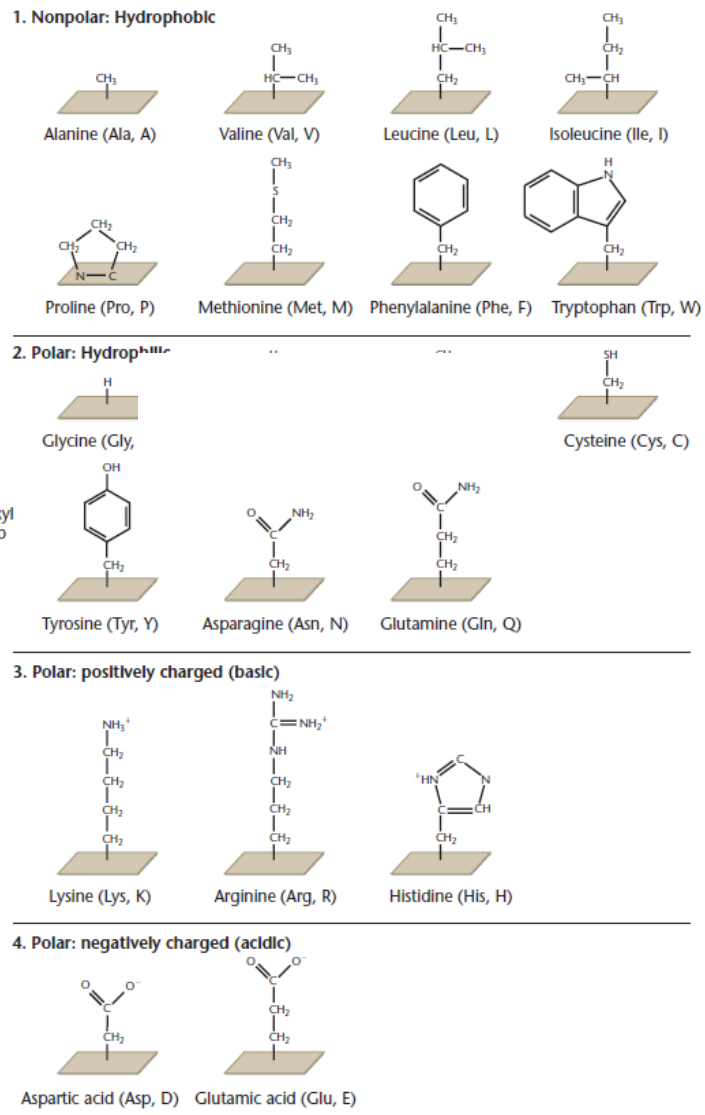
No.	Sugar	Reducing character	Mono-saccharides	Glycosidic linkage b/w
1.	Starch	Non-reducing	α-D-glucose	It contains two components – 1. **Amylose** is a linear polymer of α-D-glucose (C_1-C_4) 2. **Amylopectin** is a branched chain polymer of α-D-glucose (C_1-C_4& C_1-C_6)
2.	Cellulose	Non-reducing	β-D-glucose	C_1 of one glucose and C_4 of another glucose
3.	Glycogen	Non-reducing	α-D-glucose	Similar to amylopectin

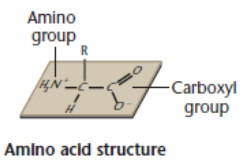
Importance of Carbohydrates

a. As storage molecules as starch in plants and glycogen in animals.
b. Cell wall of bacteria and plants is made up of cellulose.
c. Used as raw materials for industries like textiles, paper, lacquers and breweries.
d. Carbohydrate in the form of wood is used for making furniture etc.

PROTEINS

- They are heteropolymers of amino acids linked by peptide bonds.
- Amino acids contain amino (-NH_2), and carboxyl (-COOH) as functional group. Depending upon the relative position of the –NH_2 group *w.r.t* –COOH group, the amino acids are classified as α, β, γ, δ and so on.
- There are 20 α-amino acids used for protein synthesis. Their chemical structure and designation are -





Classification of Amino acids-

a. Based on the availability, amino acids are 2 types:

- **Essential amino acids** (should get through diet)- Lysine, leucine, isoleucine, methionine, phenylalanine, tryptophan, arginine, histidine, threonine and valine include in this type.
- **Non-essential amino acids** (body can synthesize)- Alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, proline, serine and tyrosine.

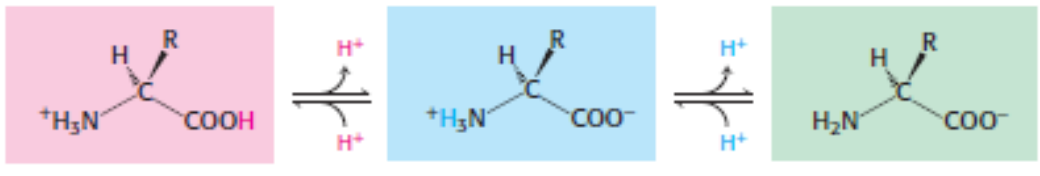
b. Based on the no. of amino & carboxyl group, amino acids are

- Acidic- Contain 1 amino group and 2 carboxyl group. They are **aspartic acid** and **glutamic acid**.
- Basic - Contain 2 amino group and 1 carboxyl group. They are **lysine, arginine** and **histidine.**
- Neutral -Contain 1 amino group and 1 carboxyl group. (others)

c. Some amino acids are **aromatic** (have a benzene ring in the variable group) – They are tyrosine, phenyl alanine, and tryptophan.

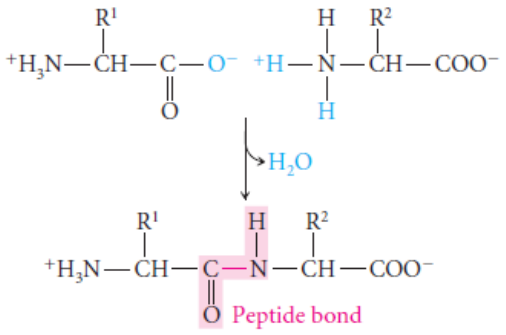
➢ The structure of amino acids changes in solutions of diff. pH, because they have ionizable –NH_2 & –COOH groups.

The stage with both NH_3^+ ions & COO^- ions is termed as ***zwitter ionic*** (***zwitter^{Ger}: both,*** act as both anion & cation).



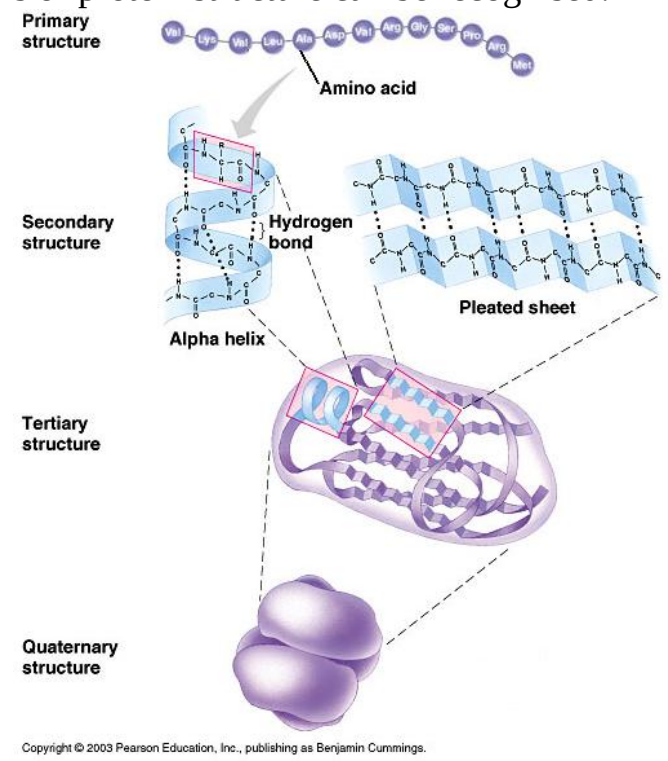
Structure of proteins-

- ***Peptide bond*** is formed when –COOH group of one amino acid reacts with $–NH_2$ group of next amino acid by releasing a molecule of water (dehydration).



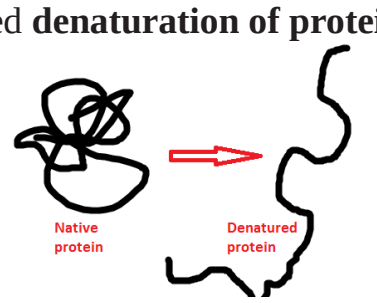
Levels of protein structure:

4 levels of protein structure can be recognised:



1. **1^0 structure:** It describes the sequence of amino acids, i.e. the positional information in a protein.
2. **2^0structure:** The shape in which a long polypeptide can exist**.**
   2 types:-
   (i) **α- helix:** A protein thread is folded in the form of a helix. This structure is maintained by H-bonds which are formed between –NH group of one amino acid and –CO group 4 amino acids away. It has only right handed helices.
   (ii)**β-pleated sheet:** In this, the polypeptide chain lie side by side in a zig-zag manner with alternate R groups on the same side situated at fixed distance apart.
3. **3^0structure:** Long protein chain is folded extensively upon itself. It is maintained by ionic bond, H-bond, S=S bond as well as van der Waals and electrostatic forces of attraction. It gives rise to two major molecular shapes viz. fibrous and globular.
   (a) Fibrous proteins- Rod– like structure formed when the α-helixes run parallel and are held together by H and disulphide bonds. Such proteins are generally insoluble in water.
   e.g.: keratin (present in hair, wool, silk) and myosin (present in muscles), etc.
   (b) Globular proteins- Spherical shape structure formed when the chains of polypeptides coil. These are usually soluble in water.
   e.g.: Insulin and albumins.
4. **4^0structure:** Some proteins are an assembly of more than one polypeptide or subunits. The separate subunits are held by hydrophobic interactions and H and ionic bonds.
   E.g. Hb has 4 subunits (2 α and 2 β subunits)

- The **2^0** or **3^0structure of proteins** gets disturbed on change of pH or temperature and they are not able to perform their functions. This is called **denaturation of proteins**.



e.g.: The coagulation of egg white on boiling, curdling of milk.

ENZYMES

- Enzymes are ***biological catalysts*** which influence biochemical reactions.

VITAMINES

- ✓ **Vitamins** are accessory food factors required in the diet.
- ✓ They are classified as -
  (i) Fat soluble (A, D, E and K)
  - They are stored in liver and adipose (fat storing) tissues.

  (ii)Water soluble (B group and C).
  - Water soluble vitamins must be supplied regularly in diet because they are readily excreted in urine and cannot be stored (except vitamin B_{12}) in our body.
- ✓ Deficiency of vitamins leads to many diseases.

Sl. No.	Name of Vitamins	Sources	Deficiency diseases
1.	Vitamin A	Fish liver oil, carrots, butter and milk	Xerophthalmia (hardening of cornea of eye) Night blindness
2.	Vitamin B_1 (Thiamine)	Yeast, milk, green vegetables and cereals	Beri beri (loss of appetite, retarded growth)
3.	Vitamin B_2 (Riboflavin)	Milk, eggwhite, liver, kidney	Cheilosis (fissuring at corners of mouth and lips), digestive disorders and burning sensation of the skin.
4.	Vitamin B_6 (Pyridoxine)	Yeast, milk, egg yolk, cereals and grams	Convulsions
5.	Vitamin B_{12}	Meat, fish, egg and curd	Pernicious anaemia (RBC deficient in haemoglobin)
6.	Vitamin C (Ascorbic acid)	Citrus fruits, amla and green leafy vegetables	Scurvy (bleeding gums)
7.	Vitamin D	Exposure to sunlight, fish and egg yolk	Rickets (bone deformities in children) and osteomalacia (soft bones and joint pain in adults)
8.	Vitamin E	Vegetable oils like wheat germ oil, sunflower oil, etc.	Increased fragility of RBCs and muscular weakness
9.	Vitamin K	Green leafy vegetables	Increased blood clotting time

NUCLEIC ACIDS /Polynucleotide

- Nucleic acids are responsible for the transfer of characters from parents to offsprings.
- There are 2 types of nucleic acids —**DNA** and **RNA**.
- Nucleic acids are **heteropolymer** of nucleotides.
  A nucleotide consists of -

1. **A nitrogen bases,** 2 types-
   - ➢ **Purines:** It includes *Adenine (A)* and *Guanine (G)*
   - ➢ **Pyramidines:** It includes *Thymine (T*-in DNA*), Cytosine (C) & Uracil (U* -in RNA*)*
2. **A pentose sugar (**β-D-2-deoxyribose in DNA or β-D-ribose in RNA**)**
3. **A phosphate group**.

Nitrogen base → Nucleoside → Nucleotide
+Sugar + phosphate

2^0 structure of DNA (Watson - Crick Model)

- DNA exists as a **double helix**. The 2 **polynucleotide strands** are arranged antiparallely.
- The backbone of DNA is formed by the ***sugar-phosphate-sugar chain***. ***Nitrogen base pairs*** form the steps of DNA.
- A phosphate molecule links the **3'-carbon** atom of one sugar of one nucleotide to the **5'-carbon** of the sugar of the succeeding nucleotide.
- There is an ***ester bond*** between PO_4^{3-} and –OH group of sugar**.** As there is one such ester bond on either side, it is called ***phosphodiester bond.***
  The nitrogen bases are projected more or less perpendicular to this backbone but face inside.
- A pairs with T **(A=T)** by 2 hydrogen bonds.
  G pairs with C **(G≡C)** by 3 hydrogen bonds.