

Bio-Molecules

## BIO-MOLECULES

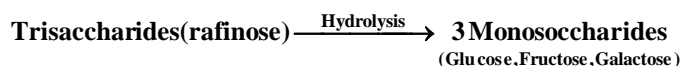
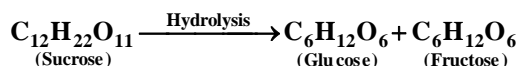
### C1A CARBOHYDRATES:

Carbohydrates have formula  $C_x(H_2O)_y$ . These can be **OPTICALLY ACTIVE POLYHYDROXY ALDEHYDES OR KETONES**. Carbohydrates are also known as **Saccharides**. They are used in Food, cloth and for shelter.

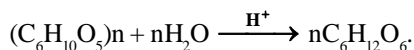
### C1B CLASSIFICATION:

- (i) **MONOSACCHARIDES** : Cannot be hydrolysed further to simpler compounds.  
e.g. : Glucose, Fructose, Galactose.
- (ii) **OLIGOSACCHARIDES** : Carbohydrates which yield few (2-10) of monosaccharides on hydrolysis.

e.g. : **Diasaccharide**  $\xrightarrow{\text{Hydrolysis}}$  **2 Monosaccharides**



- \* Monosaccharides and Oligosaccharides are sweet sugar, crystalline solid and soluble in water.
- (iii) **POLYSACCHARIDES** : High molecular mass carbohydrates which yield many molecules of monosaccharides on hydrolysis. e.g. : **Starch & Cellulose**, both having general formula  $(C_6H_{10}O_5)_n$



- \* They are insoluble in water, they are amorphous solid and tasteless.
- \* These are **NON SUGARS**.

### REDUCING AND NON-REDUCING SUGAR:

- (i) Carbohydrates with  $-CHO$  and  $-\overset{\overset{O}{||}}{C}-$  groups reducible by FEHLING'S solution and TOLLEN'S solution are Reducing sugars  $\Rightarrow$  All Monosaccharides.  
Aldehyde                      Ketone
- (ii) Disaccharides  $\begin{cases} \rightarrow \text{Maltose, Lactose (Reducing)} \\ \rightarrow \text{Sucrose (Non-Reducing)} \end{cases}$

- \* If reducing group in monosaccharides bonded i.e. Aldehyde & Ketone group, then they are non-reducing.

### Practice Problems :

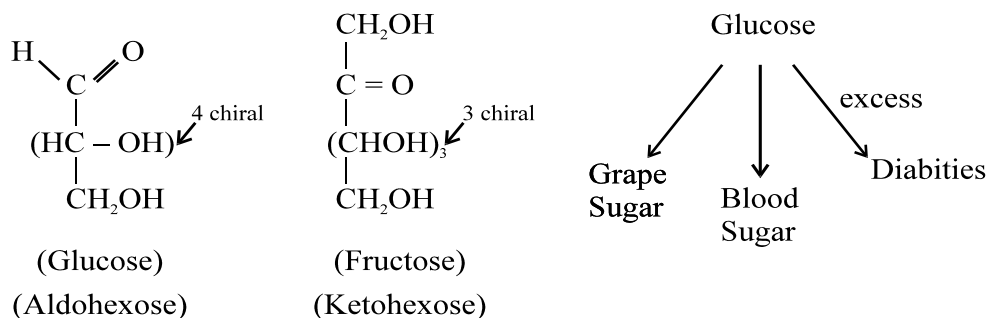
#### 1. What are reducing sugars ?

[Answers : (1) Carbohydrates which react with Fehling's solution to give a red ppt. of  $Cu_2O$  or with Tollen's reagent to give metallic Ag are called reducing sugars. All monosaccharides (both aldoses and ketoses) and disaccharides except sucrose and reducing sugars. Thus, D-(+)-glucose, D-(+)-galactose, D-(-)-fructose, D-(+)-maltose and D-(+)-lactose are all reducing sugars. Monosaccharides containing keto group also reduce Fehling solution because they exist as equilibrium mixture of aldehydic and keto forms. Sucrose is not reducing because the link between glucose and fructose is through aldehydic group]

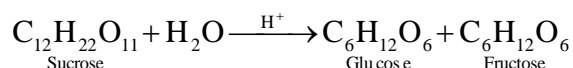
### C2 MONOSACCHARIDES :

All carbohydrates are either mono-saccharides or get converted to mono-saccharide on hydrolysis. Glucose and Fructose are specific examples of aldohexose & ketohexose respectively.

e.g. : Glucose and Fructose  $\longrightarrow$  Fruit Sugar.

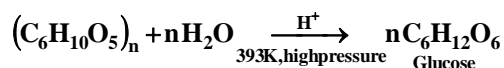
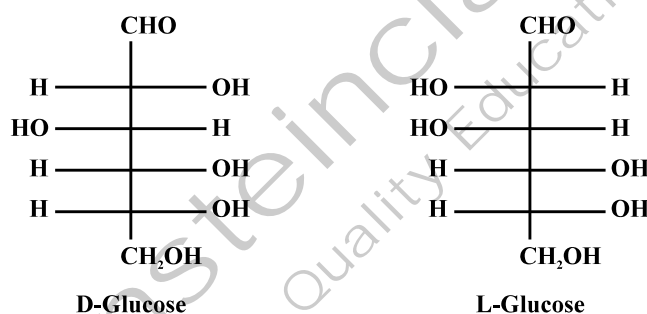
**Preparation of Glucose :**

- From Sucrose (cane sugar)



Fructose reduces Fehling's & Tollen's reagent in alk. medium though it does not contain -CHO group

- From Starch

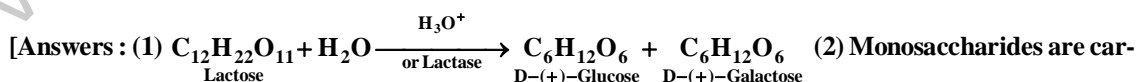
**Structure of D-Glucose & L-Glucose**

Stereochemistry of all sugar has been determined by relating it to that of D- or L-Glyceraldehyde

**Practice Problems :**

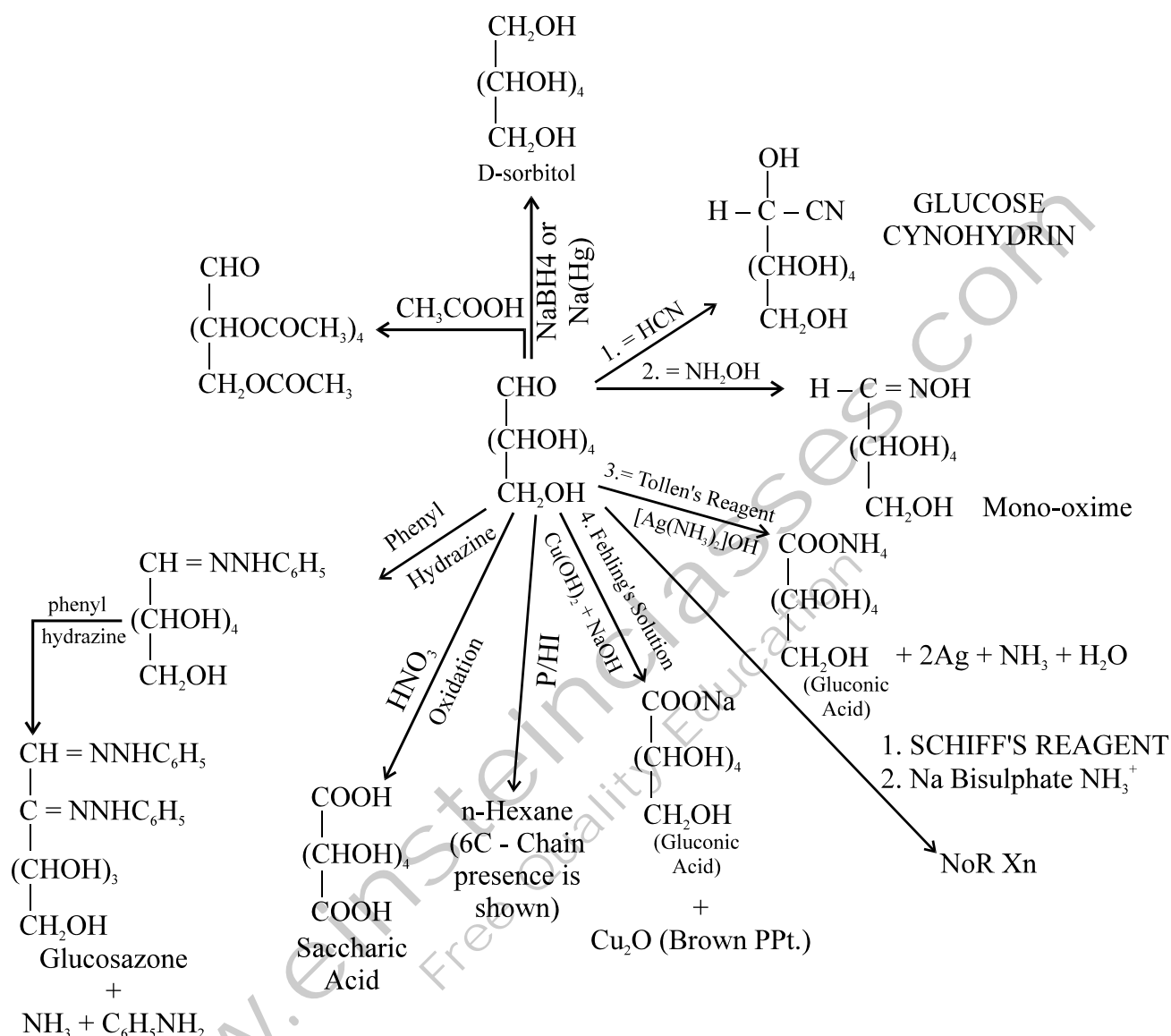
- What are the expected products of hydrolysis of lactose ?
- What are monosaccharides ?
- Write two main functions of carbohydrates in plants.
- Classify the following into monosaccharides and disaccharides.

Ribose, 2-deoxyribose, maltose, galactose, fructose and lactose.



bohydrates which cannot be hydrolysed to smaller molecules. Their general formula is  $(\text{CH}_2\text{O})_n$ , where  $n = 3 - 7$ . Those which contain an aldehyde group (-CHO) are called aldoses and those which contain a keto ( $\text{C} = \text{O}$ ) group are called Ketoses (3) (i) The polysaccharide cellulose acts as the chief structural material of the plant cell walls. (ii) The polysaccharide starch is the major reserve food material in the plants. It is stored in seeds and acts as the reserve food material for the tiny plant till it is capable of making its own food by photosynthesis (4) Monosaccharides : Ribose, 2-deoxyribose, galactose and fructose. Disaccharides : Maltose and lactose]

## C3A PROPERTIES OF GLUCOSE:

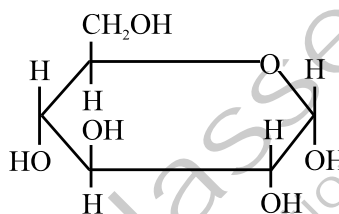
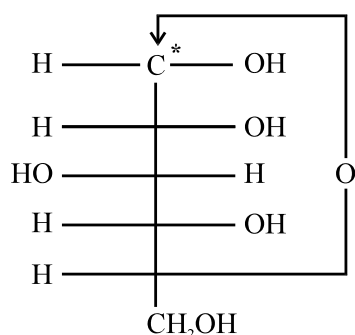
**Practice Problems :**

- Glucose and sucrose are soluble in water but cyclohexane or benzene (simple six membered ring compounds) are insoluble in water. Explain.
- How do you explain the absence of aldehyde group in the pentaacetate of D-glucose ?
- What happens when D-glucose is treated with the following reagents ?  
 (i) HI      (ii) Bromine water      (iii) HNO<sub>3</sub>
- Enumerate the reactions of D-glucose which cannot be explained by its open chain structure.

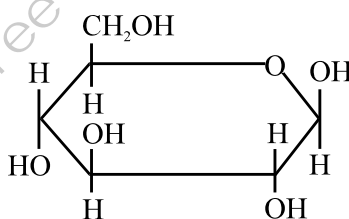
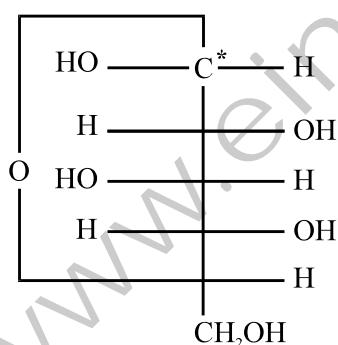
[Answers : (1) Glucose containing five and sucrose containing eight –OH groups form H-bonds with water. Due to this extensive intermolecular H-bonding, glucose and sucrose are soluble in water in spite of the fact that molecular masses (180 g mol<sup>-1</sup> and 342 g mol<sup>-1</sup>, respectively) are high. In contrast, benzene (molecular mass = 78 g mol<sup>-1</sup>) and cyclohexane (molecular mass = 84 g mol<sup>-1</sup>) have

low molecular mass. Even then they are insoluble in water. It is because these compounds do not contain –OH groups and hence do not form H-bonds with water (2) when glucose is treated with acetic anhydride, the OH group at C-1, along with the four other OH groups at C-2, C-3, C-4 and C-6 form a pentaacetate. Pentaacetate of glucose does not contain a free OH group at C-1. Therefore it cannot get hydrolysed in aqueous solution to produce the open chain aldehydic form and hence it does not react with  $\text{NH}_2\text{OH}$  to form glucose oxime (4) Reactions of glucose which cannot be explained by open chain structure are : (i) Despite having the aldehydic group, glucose does not give 2, 4 Dinitrophenylhydrazine (2, 4-DNP) test and Schiff's test. It also does not form hydrogensulphite addition compound with  $\text{NaHSO}_3$ , (ii) The pentaacetate of glucose does not react with hydroxylamine showing the absence of aldehydic group. (iii) Glucose exists in two different forms  $\alpha$ -glucose and  $\beta$ -glucose.  $\alpha$ -glucose has melting point 419 K while  $\beta$ -glucose has melting point 423 K.  $\alpha$ -form of glucose is obtained by crystallisation from concentrated solution of glucose at 303 K while and  $\beta$ -form is obtained by crystallisation from hot and saturated aqueous solution at 371 K.]

### C3B CYCLIC STRUCTURE OF GLUCOSE:



$\alpha$  - (D) Glucose



$\beta$  - (D) Glucose

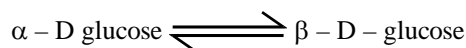
#### Annomers

due to difference in configuration at c-1 \* carbon

### MUTOROTATION:

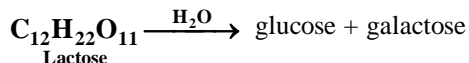
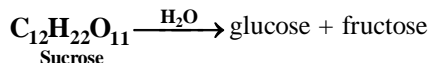
When 2 forms  $\alpha_D$  glucose are dissolved in  $\text{H}_2\text{O}$  and allowed to stand in water, then specific rotation changes slowly to  $+52.5^\circ$ .

This spt. change in specific rotation of an optically active glucose when dissolved in water is Mutarotation. Also shown by Fructose.

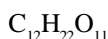


**C4 DISACCHARIDES :**

disaccharides  $\xrightarrow{H_2O}$  2 moles of monosaccharides (same or either different)



maltose  $\xrightarrow{H_2O}$  glucose + glucose



The disaccharides may be reducing or non-reducing depending upon position of linkages

↓  
This linkage is  
**GLYCOSIDIC LINKAGE**

between 2 monosaccharides units.

- (i) If the glycoside linkage involves the carbonyl functional group of both monosaccharides units, the resulting disaccharides is non-reducing e.g. Sucrose.
- (ii) If one of carbonyl functional group of any monosacchride units is free, then resulting disaccharide would be reducing e.g. Maltose & Lactose.

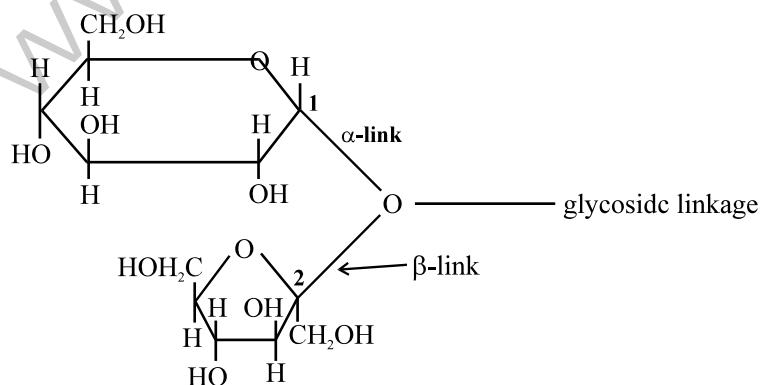
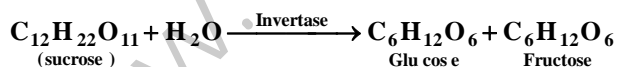
**SUCROSE :** (Sugarcane, beet root) → property → colourless, water soluble and sweet substance.



Dextrorotatory but after hydrolysis gives dextrorotatory glucose + leavo fructose. (mixture is Laevorotary. (partial reacmisation)) as leavo rotation is more than dextrotation of glucose.

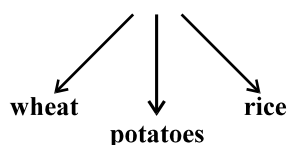
⇒ Change in rotation ⇒ INVERSION

Mixture is INVERT SUGAR.

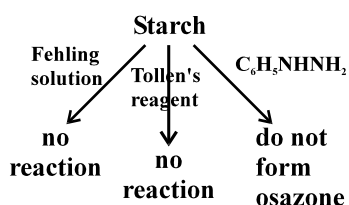
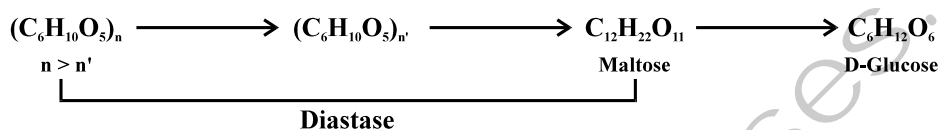


+  $\longrightarrow$  given to optically active compound which rotates plane of polarized light clockwise or left

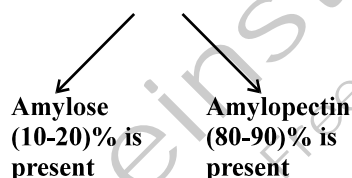
Polysaccharide  $\rightarrow$  Starch  $\rightarrow$  occur in all plants



- (i) Starch occur in form of granules, which vary in size and shape depending on their plant source
- (ii) Starch is amorphous powder, insoluble in cold water
- (iii) Starch solution gives blue colour in water disappear on heating
- (iv) On hydrolysis it break down to molecules of variable size completely



- (v) It indicates the presence of glucosidic linkage
- (vi) Starch is a mixture of two polysaccharide



#### Amylose

- (i) water soluble & give blue colour with  $\text{I}_2$
- (ii) having  $\alpha$ -D-Glucose units joined together linkage involving  $\text{C}_1$  and  $\text{C}_4$  of another glucose
- (iii) It can have 100-3000 D-Glucose

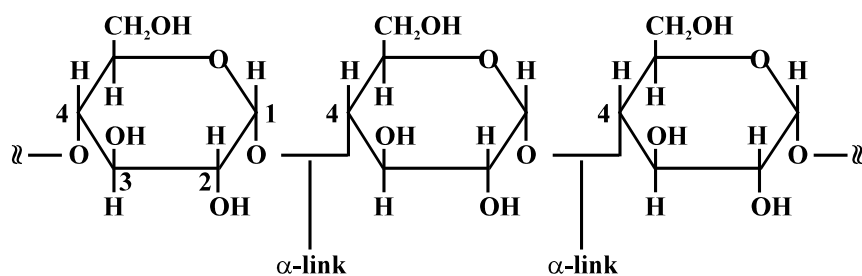
#### Amylopectin

Branched chain polysaccharide insoluble in water, which does not give blue colour with  $\text{I}_2$ .

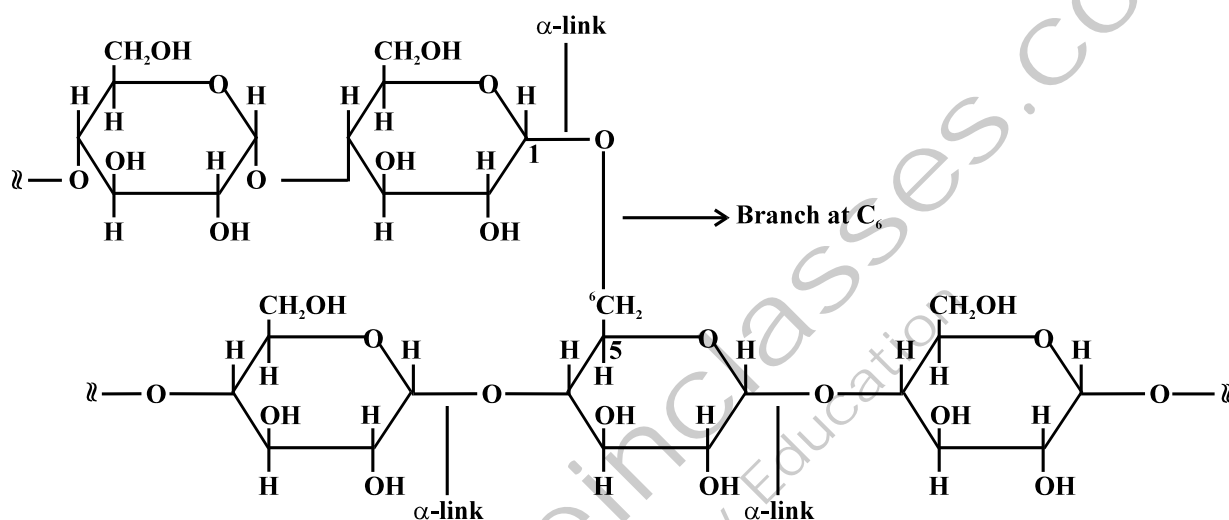
It is composed of 25-30  $\alpha$ -D-glucose units by  $\alpha$ -Glucosidic joined by  $\alpha$ -D-glycosidic linkage between C-1 of one glucose unit and  $\text{C}_4$  of next glucose unit (similar to amylose)

However these chains are connected with each other by 1,6-linkages.

Starch is major food material. It is hydrolysed by enzyme amylase present in saliva. The end product is glucose which is essential nutrient.



Amylose

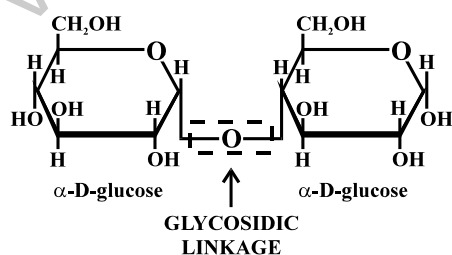


Amylopectin

**Practice Problems :**

1. What do you understand by the term glycosidic linkage ?
2. What is glycogen ? How is it different from starch ?
3. What are the hydrolysis product of (i) sucrose and (ii) lactose ?
4. What is the basic structural difference between starch and cellulose ?

[Answers : (1) The oxygen linkage through which two monosaccharides are joined together by the loss of a water molecule to form a molecule of disaccharide is called the glycosidic linkage.

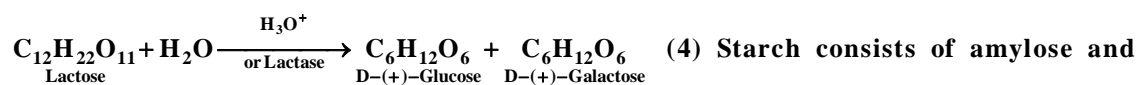
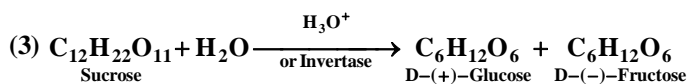


(2) Starch is not a single compound but is a mixture of two

component – a water soluble components called amylose (15-20%) and water insoluble component amylopectin (80-85%). Amylose is a linear polymer of  $\alpha$ -D-glucose. Both glycogen and amylopectin are branched polymer of  $\alpha$ -D-glucose. Glycogen is more highly branched than amylopectin.



Amylopectin chains consists of 20-25 glucose units while glycogen chains consist of 10-14 glucose units

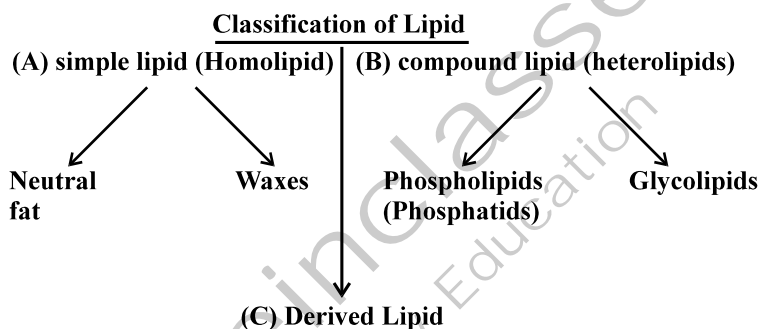


amylopectin. Amylose is a linear polymer of  $\alpha$ -D-glucose while cellulose is a linear polymer of  $\beta$ -D-glucose. In amylose, C-1 of one glucose unit is connected to C-4 of the other through  $\alpha$ -glycosidic linkage as shown under carbohydrates in “Chapter At A Glance”. However, in cellulose, C-1 of one glucose unit is connected to C-4 of the other through  $\beta$ -glycosidic linkage. Amylopectin, on the other hand, has highly branched structure]

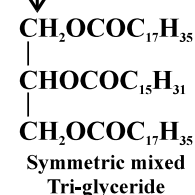
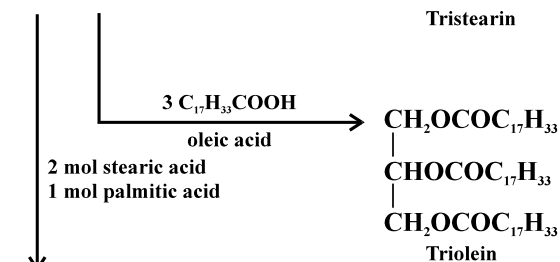
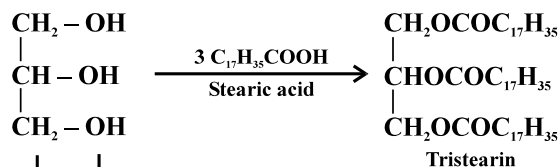
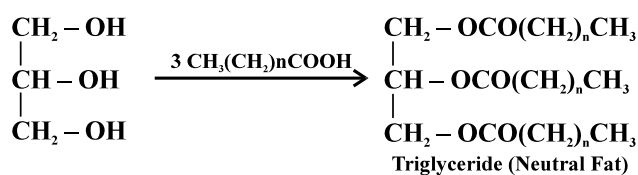
### C5 Lipid :

Lipid are naturally occurring compound related to fatty acids and it include Fats, Oils, Waxes.

In body they serve as source of energy, They are store in adipose tissues. They are lyophobic in nature and soluble in organic solvent. Phospholipid is important constituent of cell membrane



- (A) Simple Lipid : They are triglycerides i.e. esters of glycerol with long chain fatty acids.
- (i) Fatty acids have even numbers of carbons may be saturated or unsaturated.  
Unsaturated/Saturated Fatty Acids
- (ii) The three fatty acid in triglycerides may be same or different.
- (iii) Fats are glycerides of saturated fatty acids e.g. tripalmitin and tristearin.
- (iv) Oils contain unsaturated fatty acids e.g. triolein,  $\alpha$ -oleo- $\beta$ -palmito- $\alpha$ -stearin is an example of mixed triglyceride.



The presence of double bond with less stable cis stereochemistry in unsaturated fatty acid. In oleic acid it is at C-9. In linoleic acid  $\text{C}_{17}\text{H}_{31}\text{COOH}$  at C9 & C12. In linoleic acid  $\text{C}_{17}\text{H}_{29}\text{COOH}$  at C9 & C12. In solid state the molecules of saturated fatty acids fit closely due to zig-zag tetrahedral structure. The cis unsaturated fatty acid chains have a bend at the double bond & do not fit clearly resulting in lowering of melting point of the fat. Application of lipid : Fats are important food reserves of animals and plant cells. Phospholipid are structural component of cell membrane and are also used as detergent to emulsify fat for transport within the body.

#### Proteins :

Proteins are high polymers. They are polyamides which contain C, H, N, O and S. Proteins are derived from  $\alpha$ -amino carboxylic acid monomers. A simple protein may contain hundreds or even thousands of these amino acid units. In living organism, twenty  $\alpha$ -amino acids occur which combine to form different protein molecules.

- (i) **Amino Acid** : A simple  $\alpha$ -amino acid can be represented as  $\text{R} - \overset{\alpha\text{-C-atom}}{\underset{\text{NH}_2}{\text{CH}}} - \text{COOH}$  (carboxy group).
- (amino acid)

Due to the transfer of proton from carboxy to the amino group,  $\alpha$ -amino acids exist as dipolar ions or zwitter ions. Amino acids contain an acidic (carboxyl group) and a basic (amino group) within the same molecule. In aqueous solution, the carboxyl group loses a proton while the amino group accepts it. As a result, a dipolar or zwitter ion is formed. In zwitter ionic form,  $\alpha$ -amino acids show amphoteric behaviour as they react with both acids and bases. In the acidic medium,  $\text{COO}^-$  ion of the zwitter ion accepts a proton

to form the cation (I) while in the basic medium,  $\text{NH}_3^+$  ion loses a proton to form the anion (II).

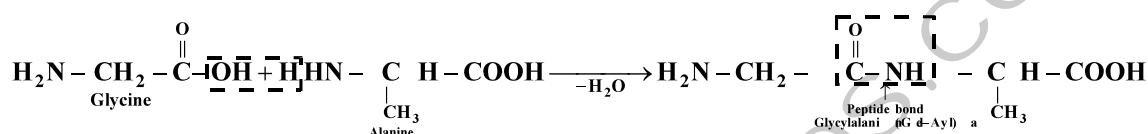
**The amino acids are of two types :**

- (i) Non-essential amino acids
- (ii) Essential amino acids

$\alpha$ -Amino acids which are needed for health and growth of human beings but are not synthesised by the human body are called essential amino acids. For example, valine, leucine, arginine, etc. On the other hand,  $\alpha$ -amino acids which are needed for health and growth of human beings and are synthesised by the human body are called non-essential amino acids. For example, glycine, alanine, glutamine, etc.

**Polypeptide Formation :**

Peptide bond : Proteins are condensation polymers of  $\alpha$ -amino acids in which the same or different  $\alpha$ -amino acids are connected by peptide bonds. Peptide bond is an amide linkage formed between  $-\text{COOH}$  group of one  $\alpha$ -amino acid and  $\text{NH}_2$  group of the other  $\alpha$ -amino acid by loss of a molecule of water. For example :



**Structure of Proteins :** Proteins have three structures :

- (i) Primary structure
- (ii) Secondary structure
  - (a)  $\alpha$ -helix structure
  - (b)  $\beta$ -pleated structure
- (iii) Tertiary structure
  - (a) Fibrous structure
  - (b) Globular structure

**Primary structure :** Proteins may contain one or more polypeptide chains. Each polypeptide chain has a large number of  $\alpha$ -amino acids which are linked to one another in a specific manner. The specific sequence in which the various  $\alpha$ -amino acids present in a protein are linked to one another is called its primary structure.

**Secondary structure :** The fixed conformation which the polypeptide chains assume as a result of hydrogen bonding is called the secondary structure of the proteins. The two types of secondary structures are :  $\alpha$ -helix and  $\beta$ -pleated sheet structure

The  $\alpha$ -helix structure of proteins is stabilised by intramolecular H-bonding between  $\text{C} = \text{O}$  of one amino acid residue and the  $\text{N} - \text{H}$  of the fourth amino acid residue in the chain.

**Tertiary structure :** It implies the three dimensional structure of proteins.

**Globular proteins :** This structure results when the chains of polypeptides coil around to give spherical shape. These proteins are usually soluble in water. Insulin and albumin are the common examples of globular proteins.

**Fibrous proteins :** When the polypeptide chains run parallel and are held together by hydrogen bond and disulphide bond, then fibre-like structure is obtained. Such proteins are called fibre proteins. Fibre proteins are insoluble in water. Some examples of fibrous proteins are keratin and myosin.

**Denaturation of protein :** Each protein in the biological system has a unique three-dimensional structure and has specific biological activity. This is called native form of a protein. When a protein in its native form is subjected to physical changes such as change in temperature, pH etc., hydrogen bonds are broken. Consequently, unfolding of protein molecule occurs and the protein loses its biological activity. This loss of biological activity is called denaturation. During denaturation,  $2^0$  and  $3^0$  structures of proteins are destroyed but  $1^0$  structure remains intact. An example of denaturation of proteins is the coagulation of albumin present in the white of an egg.

**Practice Problems :**

- The melting points and solubility in water of amino acids are generally higher than that of the corresponding halo acids. Explain.
- Where does the water present in the egg go after boiling the egg ?
- Why cannot vitamin C be stored in our body ?
- What products would be formed when a nucleotide from DNA containing thymine is hydrolysed ?
- When RNA is hydrolysed, there is no relationship among the quantities of different bases obtained. What does this fact suggest about the structure of RNA ?
- What are essential and non-essential amino acids ? Give two examples of each type.
- Define the following as related to proteins (i) Peptide linkage (ii) Primary structure (iii) Denaturation.
- What are the common types of secondary structure of proteins ?
- What type of bonding helps in stabilizing the  $\alpha$ -helix structure of proteins ?
- Differentiate between globular and fibrous proteins.
- How do you explain the amphoteric behaviour of amino acids ?
- What is the effect of denaturation on the structure of proteins ?

[Answers : (1) The amino acids exist as zwitter ions,  $\text{H}_3\text{N}^+ - \text{CHR} - \text{COO}^-$ . Thus they acquire salt like structure. Due to this dipolar salt like character they have strong dipole-dipole attractions. Therefore, their melting points are higher than haloacids which do not have salt like character. Again due to salt like character, they interact strongly with  $\text{H}_2\text{O}$ . Polar solutes dissolve in polar solvents. As a result, solubility in water of amino acids is higher than that of the corresponding haloacids. (3) Being water soluble, vitamin C is readily excreted in urine and hence cannot be stored in the body (4) Thymine, 2-deoxy-D-ribose and phosphoric acid (5) This can be explained in terms of single strand structure of RNA. A DNA molecule has two strands in which the four complementary bases pair each other, i.e., cytosine (C) always pairs with guanine (G) while thymine (T) always pairs with adenine (A). Therefore, when a DNA molecule is hydrolysed, the molar amounts of cytosine is always equal to that of guanine and that of adenine is always equal to that of thymine. In RNA, there is no relationship between the quantities of four bases (C, G, A and U) obtained, that is the base-pairing principle is not followed. Therefore, unlike DNA, RNA has a single strand (2) When the egg is boiled, the proteins first undergo denaturation and then coagulation, and the water present in the egg gets absorbed in the coagulated proteins (8) The fixed conformation which the polypeptide chains assume as a result of hydrogen bonding is called the secondary structure of the proteins. The two types of secondary structures are :  $\alpha$ -helix and  $\beta$ -pleated sheet structure (9) The  $\alpha$ -helix structure of proteins is stabilised by intramolecular H-bonding between  $\text{C} = \text{O}$  of one amino acid residue and the  $\text{N} - \text{H}$  of the fourth amino acid residue in the chain (12) During denaturation, secondary and tertiary structures of proteins are destroyed but primary structure remains unchanged. As a result of denaturation, the globular proteins (soluble in  $\text{H}_2\text{O}$ ) are converted into fibrous proteins (insoluble in  $\text{H}_2\text{O}$ ) and their biological activity is lost]

**C6 Enzymes :**

Enzymes are biological catalysts. Each biological system requires a different enzyme. Thus, in contrast to conventional catalysts, enzymes are very specific and efficient in their action. They are required in only small quantity and work at optimum temperature (310 K) and pH (7.4) under one atmospheric pressure. Chemically, they are globular proteins. However, some enzymes are also associated with some non-protein component called the cofactor for their activity.

**Cofactors are of two types :**

- Inorganic ions** such as  $\text{Zn}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Mn}^{2+}$ ,  $\text{Fe}^{2+}$ ,  $\text{Cu}^{2+}$ ,  $\text{Co}^{2+}$ , etc.
- Organic molecules** : These are also of two types :
  - Coenzymes** : These are usually derived from vitamins such as thiamine, riboflavin, etc.
  - Prosthetic group** : These are also derived from vitamins such as biotin but are tightly held to the

protein molecule by covalent bonds. They can be separated only by careful hydrolysis.

**Practice Problems :**

1. **What are enzymes ?**

**C7 Nucleic Acid :**

Nucleic acids are biomolecules which are found in the nuclei of all living cells in form of nucleoproteins or chromosomes (proteins containing nucleic acids as the prosthetic group).

**Nucleic acids are of two types :**

- (i) deoxyribonucleic acid (DNA) and
- (ii) ribonucleic acid (RNA).

**Important functions of nucleic acids :**

- (i) DNA is responsible for transmission of hereditary effects from one generation to another. This is due to the unique property of replication during cell division and two identical DNA strands are transferred to the daughter cells.
- (ii) DNA and RNA are responsible for protein synthesis needed for the growth and maintenance of our body. Actually the proteins are synthesised by various RNA molecules (r-RNA, m-RNA and t-RNA) in the cell but the message for the synthesis of a particular protein is given by DNA molecules.

**DNA :** It occurs in the nucleus of the cell. The two strands in DNA molecule are held together by hydrogen bonds between purine base of one strand and pyrimidine base of the other and vice versa. Because of different sizes and geometries of the bases, the only possible pairing in DNA are G (guanine) and C (cytosine) through three H-bonds, i.e., (C ≡ G) and T (thymine) through two H-bonds (i.e., A = T). Due to this base-pairing principle, the sequence of bases in one strand automatically fixes the sequence of bases in the other strand. Thus, the two strands are complementary and not identical.

**RNA :** It occurs in the cytoplasm of the cell. The sugar present in RNA is D(-)-ribose. It has a **single-stranded**  $\alpha$ -helix structure. In RNA, purine bases are adenine (A) and guanine (G) while pyrimidine bases are cytosine (C) and uracil (U). RNA usually does not undergo replication. It controls the synthesis of proteins.

**Practice Problems :**

1. **What are nucleic acids ? Mention their two important functions.**
2. **What is the difference between a nucleoside and a nucleotide ?**
3. **The two strands in DNA are not identical but are complementary. Explain.**
4. **Write the important structural and functional differences between DNA and RNA.**
5. **What are the different types of RNA found in the cell ?**

[Answers : (2) A nucleoside is formed when 1-position of a pyrimidine (cytosine, thiamine or uracil) or 9-position of a purine (guanine or adenine) base is attached to C-1 of sugar (ribose and deoxyribose) by a  $\beta$ -linkage. Thus, in general, nucleosides may be represented as : Sugar-Base]. A nucleotide contains all the three basic components of nucleic acids, i.e., a phosphoric acid group, a pentose sugar and a nitrogenous base. These are obtained by esterification of C<sub>5</sub>-OH group of the pentose sugar by phosphoric acid (4) DNA : (i) The sugar present in DNA is 2-deoxy-D(-)-ribose. (ii) DNA contains cytosine and thymine as pyrimidine bases. (iii) DNA has double stranded  $\alpha$ -helix structure, their molecular mass may vary from  $6 \times 10^6 - 16 \times 10^6$  u. (iv) DNA has unique property of replication. (v) DNA controls the transmission of hereditary effects. RNA : (i) The sugar present in RNA is D(-) ribose. (ii) RNA contains cytosine and uracil as pyrimidine bases. (iii) RNA has single stranded  $\alpha$ -helix structure, their molecular mass ranging from 20,000 to 40,000 u. (iv) RNA usually does not replicate. (v) RNA controls the synthesis of proteins (5) There are three types of RNAs : (i) Ribosomal RNA (rRNA) (ii) Messenger RNA (mRNA) (iii) Transfer RNA (tRNA)]

**C8 Vitamins :**

They are the chemical substances which are needed in small amounts for the growth and health of human beings. Vitamins cannot be synthesised in the body (except Vitamin D) and hence must be supplied in the food. Their deficiency can cause one or the other disease. Vitamin D may be produced in the skin by the irradiation of sterols present in oils and fats.

**Vitamins are classified into two groups depending upon their solubility :**

- (i) **Water soluble vitamins :** Vitamin B-complex ( $B_1$ ,  $B_2$ ,  $B_5$ , i.e., nicotinic acid,  $B_6$ ,  $B_{12}$ , pantothenic acid and folic acid) and vitamin C.
- (ii) **Fat soluble vitamins :** Vitamins A, D, E and K. They are soluble in liver and adipose (fat storing tissues). However, biotin, i.e., vitamin H is neither soluble in water nor in fat.

**Practice Problems :**

1. **How are vitamins classified ? Name the vitamin responsible for the coagulation of blood ?**
2. **Why are vitamin A and vitamin C essential to us ? Give their important sources.**

[Answers : (2) Vitamin A is essential as its deficiency causes xerophthalmia (hardening of cornea of eye) and night blindness. Sources : Fish liver oil, carrots, butter and milk. Vitamin C is essential as its deficiency causes scurvy (bleeding gums) and pyorrhoea (loosening and bleeding of teeth).