# Biomolecules

## INTRODUCTION

- Living systems are made up of various complex biomolecules like nucleic acids, carbohydrates, proteins, lipids, etc.
- Carbohydrates and proteins are essential constituents of our food.
- In addition, some simple molecules like mineral salts and vitamins also play an important role in the functions of organisms.

## CARBOHYDRATES

- Carbohydrates (hydrates of carbon) are naturally occurring compounds having general formula $C_x(H_2O)_y$, which are constantly produced in nature & participate in many important bio-chemical reactions.

**Ex.** Glucose $C_6H_{12}O_6$ $C_6(H_2O)_6$
Fructose $C_6H_{12}O_6$ $C_6(H_2O)_6$
Cellulose and Starch $(C_6H_{10}O_5)_n$

- Sucrose (Cane sugar) – $C_{12}H_{22}O_{11}$, and Maltose (Malt Sugar) $C_{12}(H_2O)_{11}$
- But some compounds which have formula according to $C_x(H_2O)_y$ are not known as carbohydrate

**Ex.** $CH_2O$ Formaldehyde
$C_2(H_2O)_2$ Acetic acid
$C_3(H_2O)_3$ Lactic acid

- There are many compounds, which shows chemical behaviour of carbohydrate but do not confirm the general formula $C_x(H_2O)_y$ such as –
  $C_5H_{10}O_4$ (2-deoxyribose)
  $C_6H_{12}O_5$ (Rahmnose)
- Carbohydrates, the energy source of living beings, are the most abundant organic compound around us.
- In metabolic process in the living beings, glucose is usually oxidized into carbon dioxide and water to provide energy to the cell for their functioning.

### Definitions

Chemically, the carbohydrates may be defined as optically active polyhydroxy aldehydes or ketones or the compounds which produce such units on hydrolysis.

### Concept Ladder

Saccharin is not carbohydrate but is 500 times sweeter than sucrose.

### Previous Year's Questions

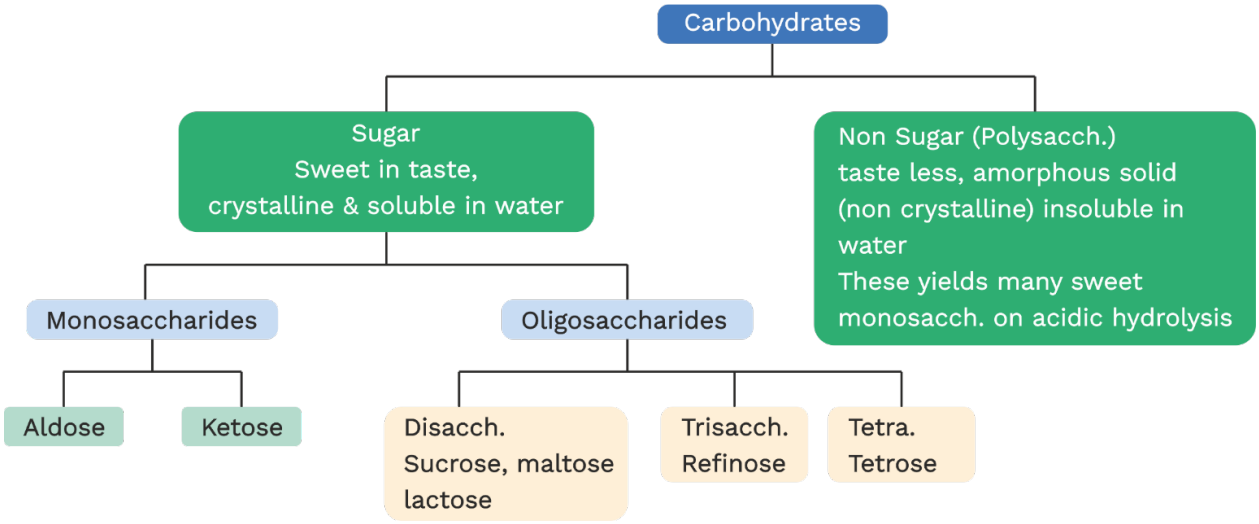
Whcih of the following is the sweetest sugar?

**[AIPMT]**

(1) Fructose (2) Glucose
(3) Sucrose (4) Maltose

## Classification of Carbohydrates

Carbohydrates are classified on the basis of their behaviour on hydrolysis.




## Monosaccharides (simple sugars)

- These are the sugars which cannot be hydrolysed into smaller molecules. General formula is $C_nH_{2n}O_n$.
- About twenty monosaccharides are known to exist in nature. Some examples are fructose, glucose, ribose, etc.
- If –CHO group is present in monosaccharide, then it is known as aldose.
- If $-\overset{\overset{O}{\|}}{C}-$ group is present in monosaccharide, then it is known as ketose.

**Concept Ladder**

Glucose — grape sugar or dextrose.
Fructose — fruit sugar.
Lactose — milk sugar.

| Carbon atoms | General term | Aldehyde | Ketone |
|---|---|---|---|
| 3 | Triose | Aldotriose | Ketotriose |
| 4 | Tetrose | Aldotetrose | Ketotetrose |
| 5 | Pentose | Aldopentose | Ketopentose |
| 6 | Hexose | Aldohexose | Ketohexose |
| 7 | Heptose | Aldoheptose | Ketoheptose |

### Oligosaccharides

- These are the sugars which yields 2-10 monosaccharides units on hydrolysis.
- When two monosaccharide units obtained
- On hydrolysis of a disaccharide, they may be the same or different.

For example,

$$\text{Sucrose} \xrightarrow{\text{Hydrolysis}} \text{Glucose} + \text{Fructose}$$

**(a) Disaccharides :** Two monosaccharide unit on hydrolysis (may or may not be same).

**Ex.** Sucrose, Maltose

**(b)Trisaccharides :** Three monosaccharide unit on hydrolysis.

### Polysaccharides

- These are the non-sugars which yield a large no of monosaccharide units on hydrolysis.
- Polysaccharides are the carbohydrates which on hydrolysis yields a large number of monosaccharide units.
- Polysaccharides are not sweet in taste, hence they are also called non-sugars.
- General formula – $(C_6H_{10}O_5)_n$.

**Ex.** Starch, Cellulose, Glycogen etc.

### Reducing and Non-Reducing Sugars

- Those sugars or carbohydrates which reduce Fehling's solution and Tollens reagent are referred to as reducing sugars.
- All monosaccharides whether aldose or ketose are reducing sugars.
- In disaccharides, when the reducing groups of monosaccharides, that is, aldehydic or ketonic groups, are bonded, then these are referred to as non reducing sugars. e.g., sucrose.

### GLUCOSE

- Glucose occurs in both free and combined forms in nature.
- It is present in honey and sweet fruits.

**Concept Ladder**

A group of polysaccharides which are not so widely used in nature is pentosans $(C_5H_8O_4)_n$ Monosaccharides.

**Rack your Brain**

What is invert sugar and why is it so named?

**Previous Year's Questions**

Which one given below is a non-reducing sugar?

**[NEET(I)-2016]**

(1) Glucose (2) Sucrose
(3) Maltose (4) Lactose

- Also, glucose is present in large amounts in ripe grapes, so it is known as grapes sugar.
- Glucose is the unit of starch, cellulose and glycogens.

### Preparation of Glucose

#### (1) From Sucrose (Cane sugar)

- Fructose and glucose are obtained in equal amounts when sucrose is boiled with dil. HCl or $H_2SO_4$ in alcoholic solution.

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{H^+} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Fructose}}{C_6H_{12}O_6}$$

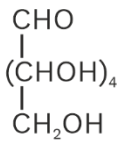
#### (2) From Starch

- Glucose is obtained commercially by the hydrolysis of starch by boiling it at 393 K with dil. $H_2SO_4$.

$$\underset{\text{Starch or cellulose}}{(C_6H_{10}O_5)_n} + nH_2O \xrightarrow[393\ K;\ 2–3\ atm]{H^+} \underset{\text{Glucose}}{nC_6H_{12}O_6}$$

### Structure of Glucose

- Glucose is aldohexose and is also called dextrose.
- Glucose is a monomer of many of the larger carbohydrates, namely cellulose, starch.
- It is considered to be present in large amounts as an organic compound on earth.
- $C_6H_{12}O_6$ is its molecular formula.



Glucose

### Reactions of Glucose

#### (1) Oxidation

- Dicarboxylic acid, saccharic acid can be yielded by oxidizing both glucose as well as gluconic acid with nitric acid.
- This indicates the presence of a primary alcoholic (–OH) group in glucose.

**Rack your Brain**

Fructose contain a keto group but still it reduces Tollens' reagent. Why?

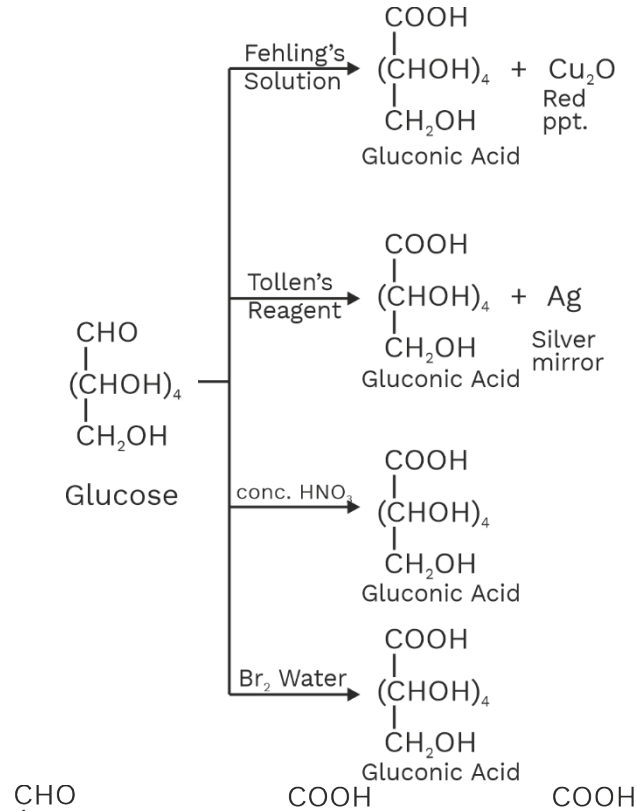
**Concept Ladder**

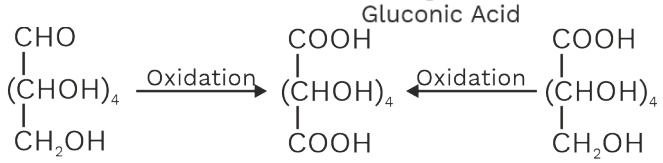
The carbonyl group of aldoses and ketoses can be reduced by the usual carbonyl-group reducing agents (eg., $NaBH_4$). The product of the reduction is a polyalcohol, known as an alditiol.

**Previous Year's Questions**

Sucrose on hydrolysis gives **[NEET-2020]**

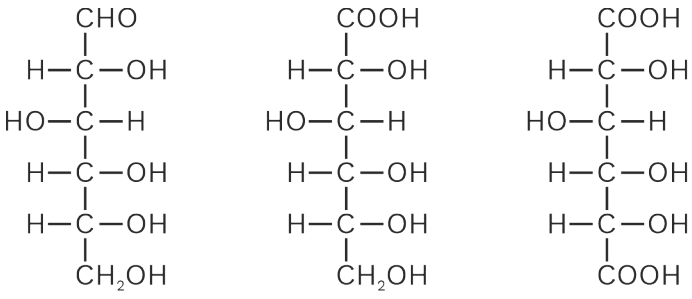
(1) β-D-glucose + α-D-fructose
(2) α-D-glucose + β-D-glucose
(3) α-D-glucose + β-D-fructose
(4) α-D-fructose + β-D-fructose




Glucose | Saccharic acid | Gluconic acid

- Fisher gave the exact spatial arrangement of different — OH groups. Structure I represent the spatial arrangement, and structures II and III represent gluconic acids.



I | II | III

**Previous Year's Questions**

Fructose reduces Tollens' reagent due to

**[AIPMT-2010]**

(1) Asymmetric carbons
(2) Primary alcoholic group
(3) Secondary alcoholic group
(4) Enolisation of fructose followed by conversion to aldehyde by base.

**Rack your Brain**

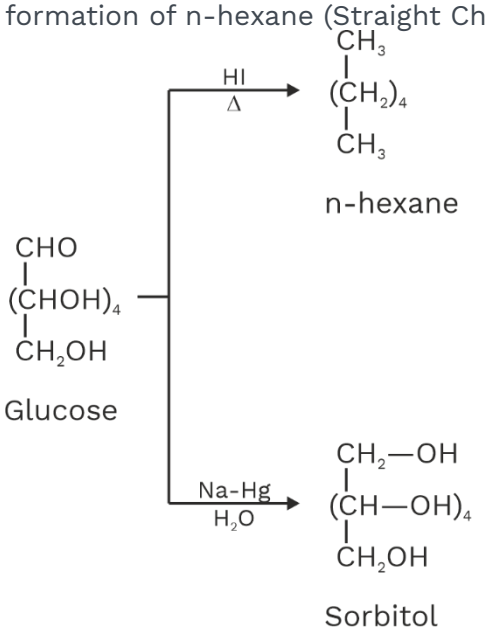
A monosaccharide has a molecular weight of 150. Also itwas not optically active. What is the structure of monosaccharide?

**Concept Ladder**

The change in specific rotation of an opticaly active compound in solution with time to an equilibrium alue is called mutarotation.

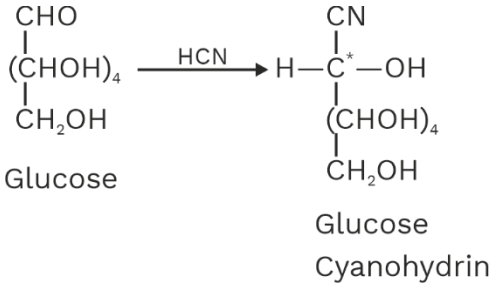
### (2) Reduction

- On prolonged heating with HI, there is formation of n-hexane (Straight Chain).



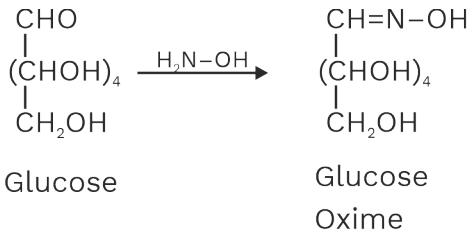

### (3) Cyanohydrin Formation

- It gives cyanohydrin when added a molecule of hydrogen cyanide.




### (4) Oxime Formation

- To form an oxime glucose is reacts with hydroxylamine.




**Concept Ladder**

Glucose in aqueous solutin is reduced with sodium amalgam to hexahydric alcohol sorbitol.

**Rack your Brain**

What is the product formed on oxidation of glucose with mild oxidizing agent such as $Br_2$ water?

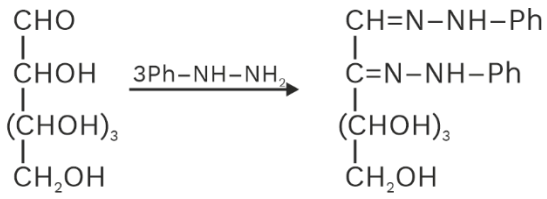
**Previous Year's Questions**

Glucose molecule reacts with X number of molecules of phenyl hydrazine to yield osazone. the value of X is

**[AIPMT]**

(1) two (2) one
(3) four (4) three

### (5) Reaction with phenylhydrazine (formation of osazone)

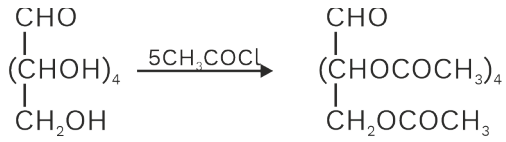



Glucose

Glucosazone

### (6) Acetylation

- Glucose pentaacetate is formed by Acetylation of glucose with acetic anhydride; this also confirms the presence of five –OH groups.
- Five –OH groups should be attached to different carbon atoms.




Glucose

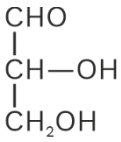
Glucose Pentaacetate

### Stereochemistry of Carbohydrates

### D & L Sugars

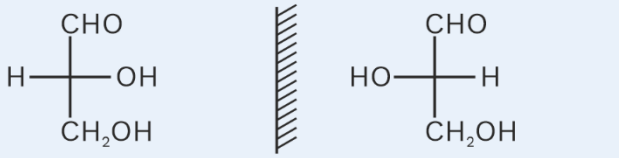
**Aldotriose (Smallest carbohydrate)**

**Ex.**




Glyceraldehyde

**Fischer projection**




D-Glyceraldehyde (+) L-Glyceraldehyde (–)

**Rack your Brain**

What is the product formed when glucose react with excess amount of phenyl hydrazine?

**Concept Ladder**

Glucose pentaacetate cannot be converted into the open chain form because its anomeric hydroxyl group (i.e. $C_1$–OH) is acetylated and hence does not form the oxime.

**Definition**

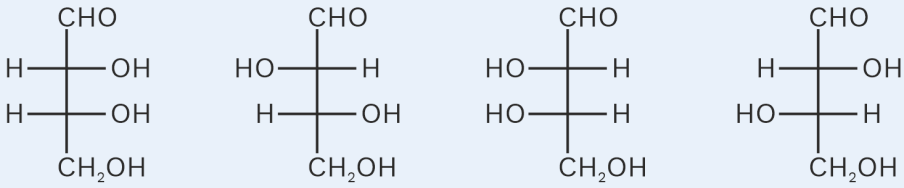
The series of aldoses or ketoses in which the configuration of the penultimate C-atom (C-next to $CH_2$-OH group) is described as D-sugars if -OH is towards RHS & L-sugars if it is towards LHS.

## Aldotetros

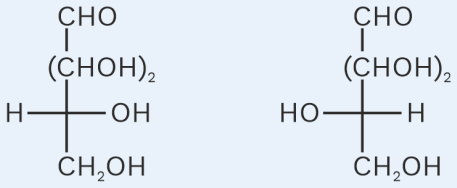
### Types of Aldotetrose

(i) Erythrose
(ii) Threoese

**C–4**

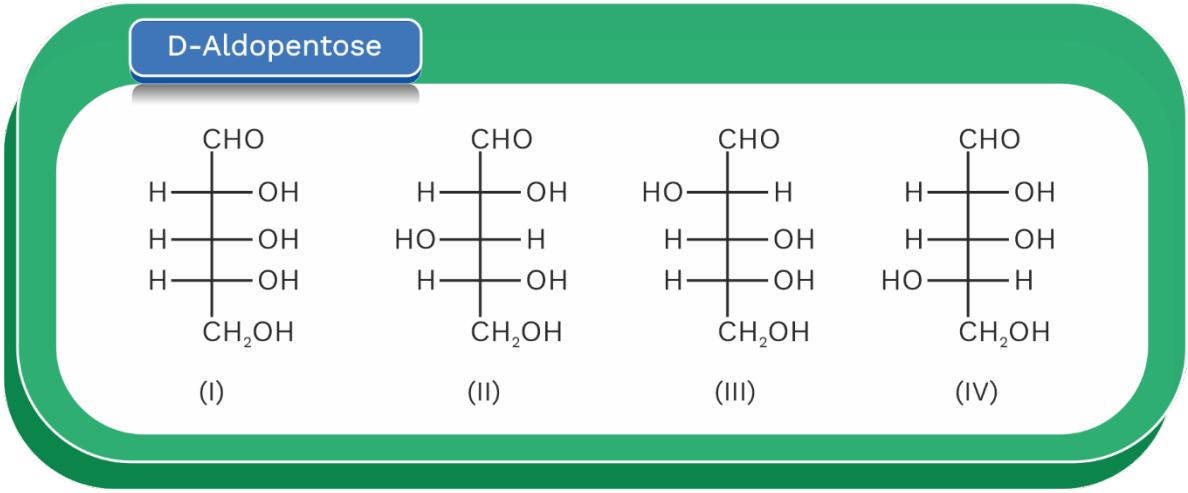



**C–5**



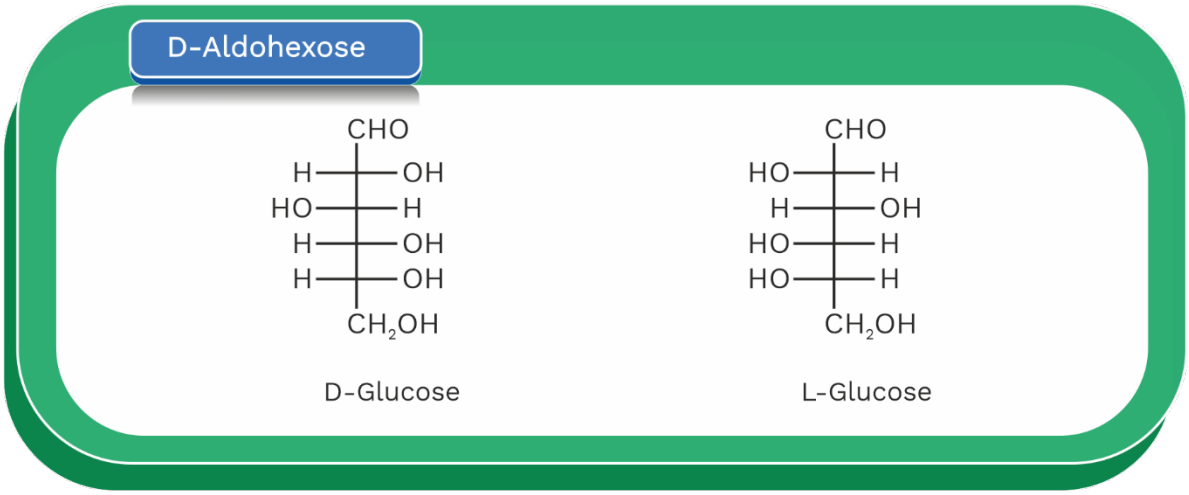

No. of C* = 3 (in Aldopentose)
No. of optical isomers $2^3 = 8$
No. of D Sugars = 4
no. of L-Sugars = 4

### D-Aldopentose




All Isomeric D-Sugars are diastereomers.

**Aldohexose**




No. of C* = 4
No. of stereoisomers = $2^4$ = 16
No. of D-sugars = 8
No. of L-sugars = 8

### Cyclic Structure of Glucose

The structure of glucose explained most of its properties but the following reactions and facts could not be explained by this structure.

- The pentaacetate of glucose does not react with hydroxylamine it is indicated by the absence of free —CHO group indicates.
- a and b are the names of two different crystalline forms of glucose.

### α-D(+) Glucose

The a-form of glucose (m.p. 419 K) is obtained by crystallisation from concentrated solution of glucose at 303 K.

### β-D(+) Glucose

The b-form (m.p. 423 K) is obtained by crystallisation from hot and saturated aqueous solution at 371 K.

**Concept Ladder**

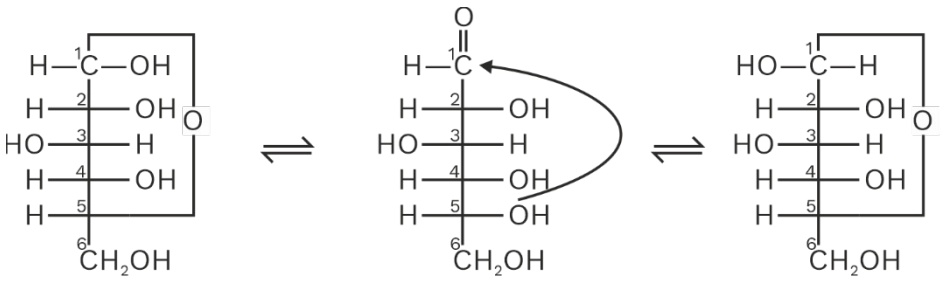
The two cyclic hemiacetal forms of glucose differ only in the configuration of the hydroxyl group at C1, called anomeric carbon. Such isomers, i.e., α-form and β-form, are called anomers.

**Previous Year's Questions**

α-D-glucose and β-D-glucose are

**[AIPMT]**

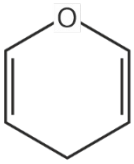
(1) Epimers (2) Anomers
(3) Enantiomers (4) Diastereomers



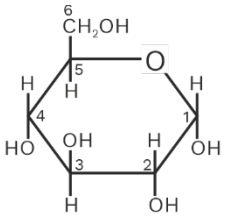
α-D(+)-Glucose β-D(+)-Glucose

### Howarth Structure

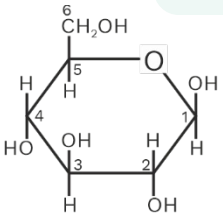
- Pyranose structure is a six-membered cyclic structure of glucose (α– or β–), in analogy with pyran.
- Pyran is a cyclic organic compound with five carbon atoms and one oxygen atom in the ring.
- The Haworth structures given below are the cyclic structure of glucose.



Pyran



α-D(+)-Glucose



β-D(+)-Glucose

### FRUCTOSE

- Fructose is an important ketohexose. It also has the molecular formula $C_6H_{12}O_6$.
- It is obtained by the hydrolysis of disaccharide.

**Ex :** Sucrose $\xrightarrow{\text{Hydrolysis}}$ Glucose + Fructose

- It is a natural monosaccharide found in vegetables, fruits and honey.

### Structure of Fructose

- Based on its reactions, it was found that in the case of glucose contained at carbon number atom two, a ketonic functional group is present and six carbons in a straight chain.

**Previous Year's Questions**

Which one of the following does not exhibit the phenomenon of mutarotation?

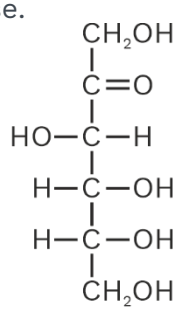
**[AIPMT]**

(1) (+)-Sucrose (2) (+)-Lactose
(3) (+)-Maltose (4) (-)-Fructose

**Concept Ladder**

All the monosaccharides, whether aldoses and ketoses, in their hemiacetal and hemiketal forms behave as reducing carbohydrates.

It is a laevorotatory compound and belongs to D-series. It is appropriately written as D-(–)-fructose.



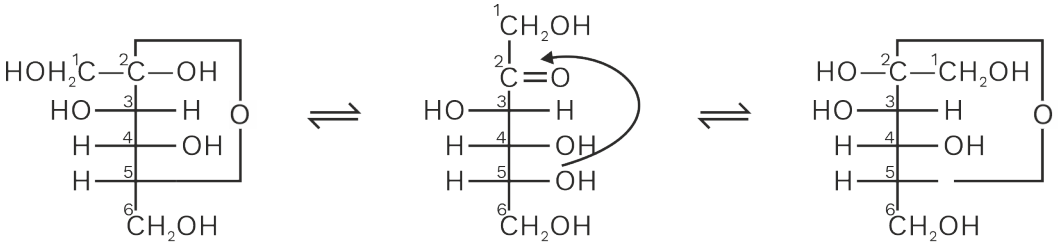
D(–)-Fructose

**Concept Ladder**

D-fructose exists in two stereoisomeric forms, i.e., α-D-fructopyranose and β-D-fructopyranose.

### Cyclic Structure of Fructose

- This structure is obtained by the addition of —OH at $C_5$ to the ketonic group, which produce two cyclic forms.

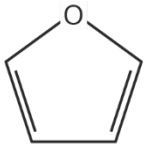


α-D(–)-Fructofuranose

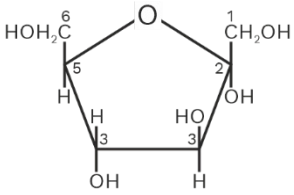
β-D(–)-Fructofuranose

### Howarth Structure

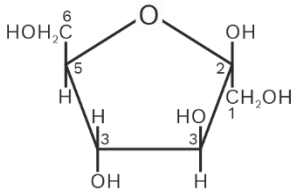
- The ring has an analogy to the compound furan and is a five-membered ring. It is a five-membered cyclic compound with one O and four C atoms.



Furan



α-D(–)-Fructofuranose



β-D(–)-Fructofuranose

**Comparison of Glucose and Fructose**

| S.NO. | Property | Glucose | Fructose |
|---|---|---|---|
| 1 | Molecular formula | $C_6H_{12}O_6$ | $C_6H_{12}O_6$ |
| 2 | Nature | Polyhydroxy aldehyde | Polyhydroxy ketone |
| 3 | Melting point | 146°C | 102°C |
| 4 | Optical nature | Dextro rotatory | Levo rotatory |
| 5 | Molisch test | Violet colour | Violet colour |
| 6 | Tollen's reagent | Silver mirror | Silver mirro |
| 7 | Fehling's solution | Red ppt | Red ppt |
| 8 | Phenyl hydrazine | Forms osazone | Forms osazone |
| 9 | Oxidation by conc. $HNO_3$ | Saccharic acid | Mixture of glycolic acid, Tartaric acid and Trihydroxy Gluteric acid |

## DISACCHARIDES

- By the loss of a water molecule, an oxide linkage is formed, which joins two monosaccharides.
- These two monosaccharides are held together by glycosidic linkage (oxide linkage) through oxygen atom.

**Rack your Brain**

Are all disaccharides sugars?

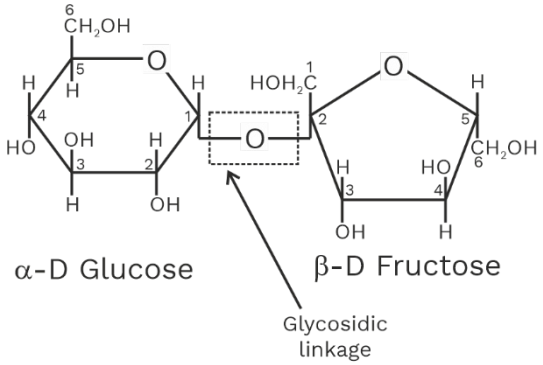
- The reducing groups (aldehydic or ketonic) of monosaccharides are bonded in disaccharides. Therefore these are non-reducing sugars, e.g., sucrose.
- Whereas sugars in which these reducing groups are free, which are called reducing sugars, for example, lactose and maltose.

### (1) Sucrose

- On hydrolysis of sucrose, the equimolar mixture of D(+) glucose and D(-) fructose are formed.

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{H^+} \underset{\text{D(+)-Glucose}}{C_6H_{12}O_6} + \underset{\text{D(−)-Fructose}}{C_6H_{12}O_6}$$

- By a glycosidic linkage between C1 of α-D-glucose and C2 of β-D-fructose, these two monosaccharides can be held together.
- Sucrose is a non-reducing sugar as the reducing groups of glucose and fructose is involved in the formation of a glycosidic bond.




**Sucrose**

- It is dextrorotatory, but after hydrolysis, it gives laevorotatory fructose and dextrorotatory glucose.
- Since the dextrorotation of glucose (+ 52.5°) is less than laevorotation of fructose (–92.4°), hence the mixture is laevorotatory
- Invert sugar is the product formed when there is change in the sign of rotation, from dextro (+) to laevo (–) after the process of hydrolysis of sucrose.

**Concept Ladder**

Sucrose is an naturally occurring sugar found in various amounts in plants like fruits and also produced commercially from sugar cane and sugar beets.

**Previous Year's Questions**

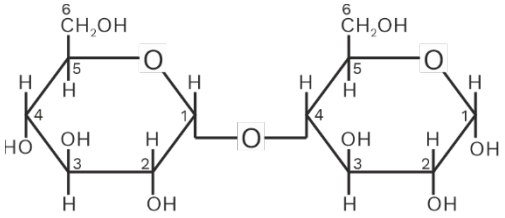
Which one of the following sets of monosaccharides forms sucrose?

**[AIPMT-2012]**

(1) α-D-galactopyranose and α-D-glucopyranose
(2) α-D-glucopyranose and β-D-fructofuranose
(3) β-D-glucopyranose and α-D-fructofuranose
(4) α-D-glucopyranose and β-D-fructofuranose

### (2) Maltose

- It maltose C1 of one glucose (I) is linked to C4 of another glucose unit (II) of two α-D-glucose units.
- In solution, C1 of second glucose produce a free aldehyde group, and it is a reducing sugar as it has reducing properties.

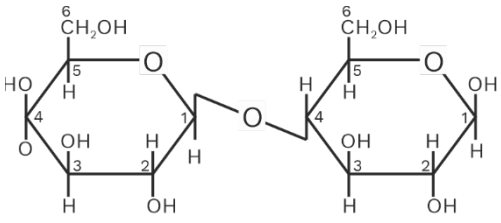


α-D Glucose α-D Glucose

**Maltose**

### (3) Lactose

- Lactose is found in milk so it commonly known as milk sugar.
- It is composed of β-D-galactose and β-D-glucose.
- It has a linkage between C1 of galactose and C4 of glucose. It is considered as reducing sugar as free aldehyde group may be produced at C1 of glucose unit.



β-D Galactose β-D Glucose

**Lactose**

**Concept Ladder**

Maltose can be broken down to glucose by the maltase enzyme, which catalyses the hydrolysis of the glycosidic bond.

**Rack your Brain**

Is maltose sweeter than glucose?

**Concept Ladder**

Unabsorbed lactose passing through the intestinal tract with little lactase causes colic (severe pain in the stomach and bowels) diarrhoea and other interstinal problems. This is called lactose intolerance. This happens in older people.

## POLYSACCHARIDES

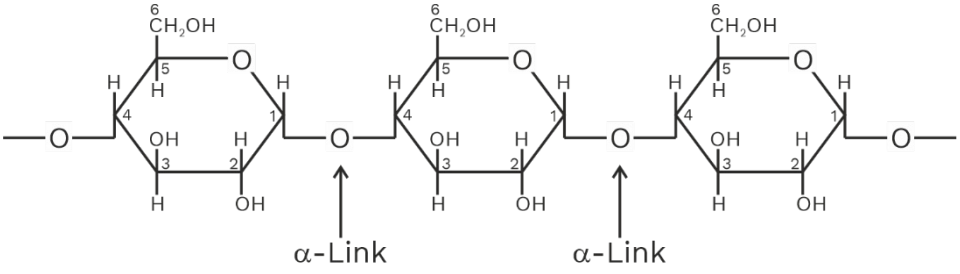
- When a large number of monosaccharide units linked together by glycosidic linkages, polysaccharides are formed. They generally act as the food storage or structural materials.

### (1) Starch

- It is the main storage polysaccharide of plants.
- High content of starch is found in some vegetables, roots, tubers and cereals hence, it is the most important dietary source for human beings.
- It is a polymer of alpha- glucose and consists of two components—Amylopectin and Amylose.

**Amylose**

- Amylose constitutes about 15-20% of starch and is water soluble component.
- Amylose is formed chemically formed by 200-1000 α-D-(+)-glucose units held together by C1–C4 glycosidic linkage, forming long unbranched chain.




**Amylose**

**Amylopectin**

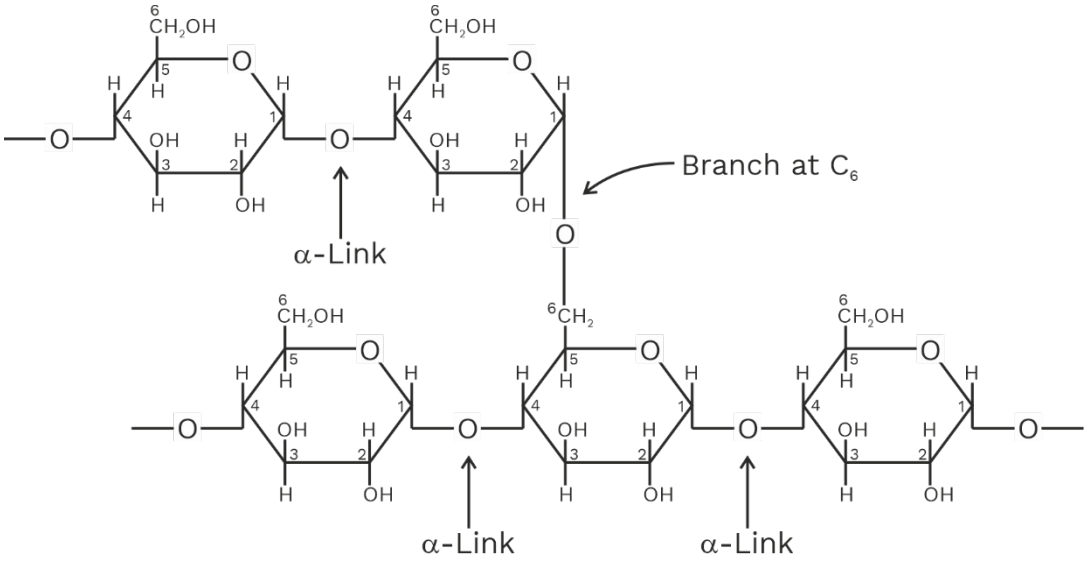
- Amylopectin is constitutes about 80- 85% of starch and is not soluble in water.
- In it, a chain is formed by C1–C4 glycosidic linkage, while branching occurs by C1–C6 glycosidic linkage. It is formed by the branched-chain polymer of α-D-glucose units.

**Concept Ladder**

Starch is a non-reducing saccharide. it neither reduces Tollens' reagent (or Fehling's solution) nor forms an osazone.

**Rack your Brain**

What is the inclusion complex?




**Amylopectin**

### (2) Cellulose

- Cellulose is present mostly in plants and is the most abundant organic substance in the whole plant kingdom. It is found mostly in the cell wall of plant cells.
- It is composed only of α-D-glucose units and is a straight chain polysaccharide , which are linked together by the glycosidic linkage between C1 of one glucose unit and C4 of the next glucose unit.

**Previous Year's Questions**

Cellulose is polymer of **[AIPMT]**

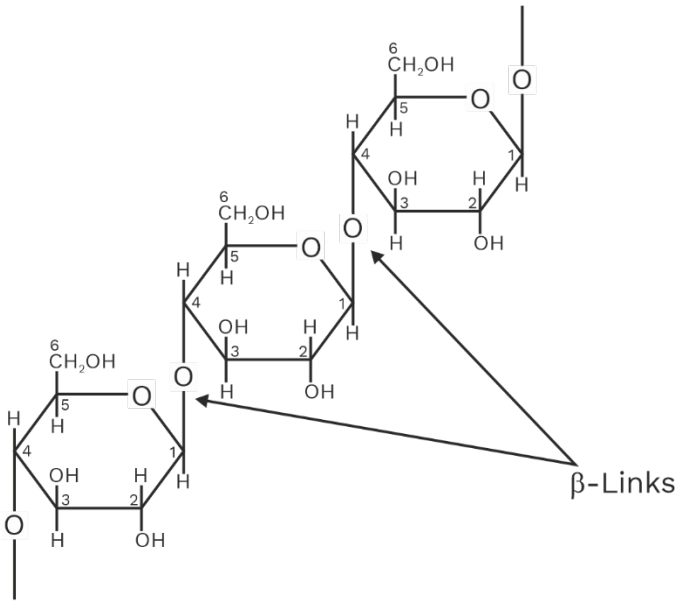
(1) Glucose (2) Fructose
(3) Ribose (4) Sucrose

**Q1** What are disaccharides? Give one example.

**Sol.** Disaccharides on hydrolysis give two molecules of the same or different monosaccharides. For example, sucrose, maltose, lactose, etc.

**Q2** Which of the two components of starch is water soluble?

**Sol.** Amylose is water soluble but amylopectin is water insoluble.




**Cellulose**

### (3) Glycogen

- In animal body glycogen is stored in the form of carbohydrates.
- Its structure is similar to amylopectin that's why it is also known as animal starch and is rather more highly branched.
- It is present in brain, muscles and liver. Enzymes break the glycogen down to glucose whenever body wants glucose.

**Concept Ladder**

Excess glucose gets stored in the liver as glycogen or, with the help of insulin, converted into fatty acids, circulated to other parts of the body and stored as fat in adipose tissue.

**Rack your Brain**

Why is glucose stored as glycogen ?

**Q3** What is Molisch test? Explain.

**Sol.** All carbohydrates, i.e., monosaccharides, oligosaccharides and polysaccharides are characterised by Molisch test. A 1% alcoholic solution of $\alpha$-naphthol is called Molisch reagent. When Molisch reagent is added to an aqueous solution or suspension in water of a carbohydrate followed by conc. $H_2SO_4$ along the sides of the test tube, a violet ring is formed at the junction of the two layers.

- Glycogen is also found in fungi and yeast.

| Carbohydrates | Type | Reducing/ Non Reducing | Units | Linkage |
|---|---|---|---|---|
| Glucose | Monosaccharide | Reducing | Glucose | — |
| Fructose | Monosaccharide | Reducing | Fructose | — |
| Sucrose | Disaccharide | Non Reducing | a-D-Glucose and b-D-Fructose | C1 of Glucose and C2 of Fructose |
| Maltose | Disaccharide | Reducing | Both are a-D-Glucose | a-1, 4' glycosidic linkage |
| Lactose | Disaccharide | Reducing | b-D-Glucose and b-D-Galactose | a-1, 4' glycosidic linkage |
| Starch | Polysaccharide | Non Reducing | Amylose + Amylopectin | a-1, 4' and a-1, 6' glycosidic linkage |
| Cellulose | Polysaccharide | Non Reducing | b-D-Glucose | b-1, 4' glycosidic linkage |
| Glycogen | Polysaccharide | Non Reducing | Amylopectin | a-1, 4' and a-1, 6' glycosidic linkage |

### Importance of Carbohydrates

- In life of both plants and animals they are essential as they form a large portion of our food.
- In ayurvedic of medicine, honey has been

used for a long time as an instant source of energy.

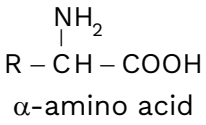
- Starch and glycogen form of these areused as storage molecules in plants and animals respectively.
- Cell wall of plants and bacteria is made from cellulose.
- They provide various raw materials for many important industries like paper, textiles, lacquers and breweries.

**PROTEINS**

- Brezeliues introduced the term protein which means first (Proteios = first).
- They are the most abundant biomolecules of the living system. Chief sources of proteins are cheese, milk, pulses, peanuts, etc.
- They form the fundamental basis of structure and functions of life. They are present in every part of the body.
- They are also required for maintenance and growth of body.
- It is derived from Greek word, "proteins" which means primary or of prime importance.
- All proteins are polymers of α-amino acids.

**Amino Acids**

- Amino acids are carboxylic acids having an $-NH_2$ group. When the $-NH_2$ group is at α-position these are called α-amino acids.



α-amino acid

- Amino acids can be categorized as α, β, γ, δ and so on, it depends on the relative position of amino group with respect to carboxyl group. Only α-amino acids are obtained on hydrolysis of proteins. They also can contain

**Concept Ladder**

Cellulose is commonly used in foods and bakery formulations as a source of dietary fiber or to improve their texture. It is also used as a bulking agent in low-calorie and gluten-free baked products.

**Rack your Brain**

What is the monomer unit of protein?

**Previous Year's Questions**

Which of the following is a basic amino acid?

**[NEET-2020]**

(1) Serine (2) Alanine
(3) Tyrosine (4) Lysine

other functional groups.

- The property of the compond or its source are reflected by their trivial names.
- Glycine is so-called as it has a sweet taste, and tyrosine (in Greek, tyros means cheese) was first obtained from cheese.
- Amino acids are generally represented by a 3 letter symbol, sometimes 1 letter symbol is also used.

### Classification of Amino Acids

- On the basis of relative no. of carboxyl and amino groups in their molecule, they are classified as acidic, basic or neutral.

(1) **Neutral :** Equal number of carboxyl and amino groups makes it neutral

(2) **Basic :** More number of amino than carboxyl groups makes it basic

(3) **Acidic :** More carboxyl groups as compared to amino groups makes it acidic.

### Non-essential Amino Acids

- Non-esseitial amino acids are defined as the type of amino acids, which can be synthesised in the body.

### Essential Amino Acids

- Essential amino acids are defined as the type of amino acids, which cannot be synthesized in the body and must be obtained by the diet.
- Their deficiency causes Kwashiorkor, a disease.

  Examples of essential amino acids include, valine, lucine, isolucine, lysine, threonil, phenyl alanine methionyl, tryptophan, histidine and arginine.

**Rack your Brain**

Lack of essential amino acids in the diet leads to the disease called?

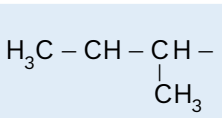
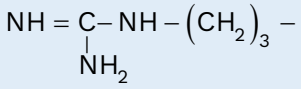
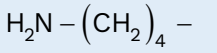
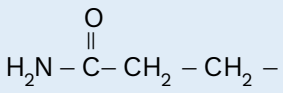
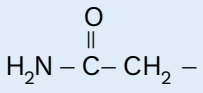
**Concept Ladder**

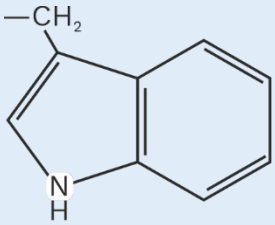
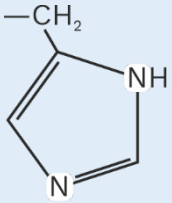
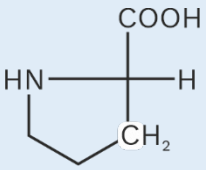
Nonessential amino acids support tissue growth and repair, immune funciton, red blood cell formation, and hormone synthesis.

**Previous Year's Questions**

The non-essential amino acid among the following is **[NEET-2019]**

(1) Lysine (2) Valine
(3) Leucine (4) Alanine

| S.No. | Name of the Amino Acids | Characteristic feature of side chain. R | Three letter symbol | One letter of code |
|---|---|---|---|---|
| 1 | Glycine | H | Gly | G |
| 2 | Alanine | —$CH_3$ | Ala | A |
| 3 | Valine* | $(H_3C)_2CH$— | Val | V |
| 4 | Leucine* | $(H_3C)_3CH—CH_2$— | Leu | L |
| 5 | Isoleucine* |  | Ile | I |
| 6 | Arginine* |  | Arg | R |
| 7 | Lysine* |  | Lys | K |
| 8 | Glutamic acid | HOOC—$CH_2$—$CH_2$— | Glu | E |
| 9 | Aspartic acid | HOOC—$CH_2$— | AsP | D |
| 10 | Glutamine |  | Glu | Q |
| 11 | Asparagine |  | Asn | N |
| 12 | Threonine* | $H_3C$—CHOH— | Thr | T |
| 13 | Serine | HO—$CH_2$— | Ser | S |

| S.No. | Name of the Amino Acids | Characteristic feature of side chain. R | Three letter symbol | One letter of code |
|---|---|---|---|---|
| 14 | Cysteine | $HS—CH_2—$ | Cys | C |
| 15 | Methionine* | $H_3C—S—CH_2—CH_2—$ | Met | M |
| 16 | Phenylalanine* | $C_6H_5—CH_2—$ | Phe | F |
| 17 | Tyrosine | $(p)HO—C_6H_5—CH_2$ | Tyr | Y |
| 18 | Tryptophan* |  | Trp | W |
| 19 | Histidine* |  | His | h |
| 20 | Proline |  | Pro | P |

*Essential amino acids

### Charactertic Features of Amino Acids

- Amino acids are generally colourless, crystalline solids.
- These are water-soluble and have high melting point.
- These are behave like salts rather than simple amines or carboxylic acids. This behaviour is

**Previous Year's Questions**

Which of the following comopund can form a zwitter ion?

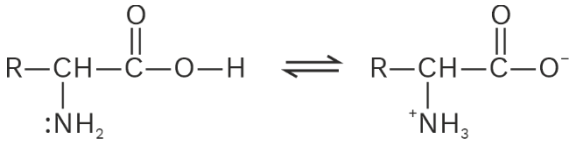
**[NEET-2018]**

(1) Aniline (2) Acetanilide
(3) Benzoic acid
(4) Glycine

due to the presence of both basic (amino group) and acidic (carboxyl group) groups in the same molecule.

**Zwitter Ion**

- In aqueous solution, amino group can accept a proton and the carboxyl group can lose a proton, which give rise to a dipolar ion termed as zwitter ion.



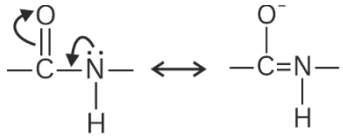
(Zwitter ion)

- Zwitter ion contains both positive and negative charges but is neutral in nature.
- As α-carbon atom is asymmetric; therefore, all other naturally occurring α-amino acids are optically active, except glycine. These exist both in 'D' and 'L' forms. L-configuration is the most naturally occurring amino acid. L-Amino acids are represented by writing the $-NH_2$ group on the left-hand side.

**Peptide bond or Peptide Linkage**

Peptides are those amides which are formed due to condensation between $2NH_2$ group and–COOH group of two different amino acids.

- The –CO–NH– bond is called peptide linkage or bond. The >C=O group of an amide is $sp^2$ hybridised with coplanar structure.



- To eliminate water molecule and form peptide bond —CONH—, the combination of the amino group of one molecule with the carboxylic group of other, there is a reaction between two molecules of similar or different

**Rack your Brain**

Glycine exists as a zwitter ion but o- and p-aminobenzoic acids not exists. Why?

**Concept Ladder**

pH at which there is no net migration of the amino acid under the influence of an applied electric field is called isoelectric point.

**Previous Year's Questions**

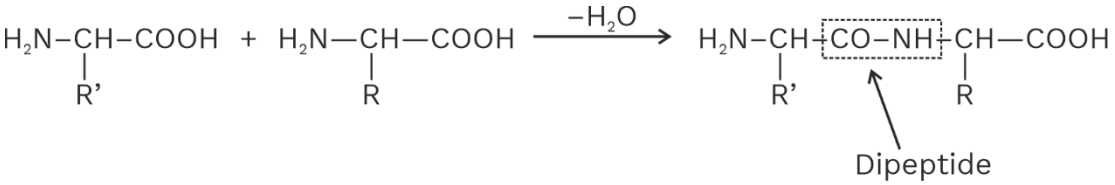
In a protein molecule various amino acid are linked together by **[AIPMT-2012]**

(1) Peptide bond
(2) Dative bond
(3) α-glycosidic bond
(4) β-glycosidic bond

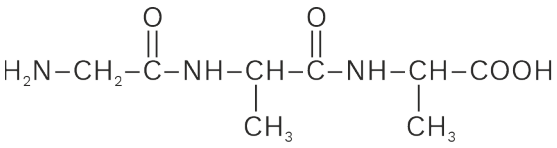
amiono acids The product of the reaction is made up of two amino acids; hence it is termed dipeptide.

For example,

when carboxyl group of glycine combines with the amino group of alanine we get a dipeptide, glycylalanine.




- An amino acid unit having a free $NH_2$ group is known as N-terminal amino acid while an amino acid with a free –COOH group is known as C-terminal amino acid.
- N-terminal amino acid residue in a protein is determined by Sanger (1-fluoro-2, 4-dinitrobenzne) or DNP (2, 4-dinitrophenyl) method.
- C-terminal amino acid residue in a protein is determined by hydrazinolysis.
- When writing the structure of peptides, the N terminal end is taken on left hand side while, C-terminal end is at right hand side.




G–A–A

Glycine–Alanine–Alanine

- A tripeptide contains 3 amino acids linked by 2 peptide linkages, therefore it can be form if a 3rd amino acid combines to a dipeptide.
- When 4, 5 or 6 amino acids are linked, the respective products are termed as tetrapeptide, pentapeptide or hexapeptide.

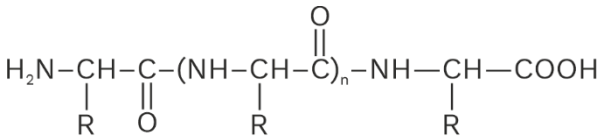
**Rack your Brain**

What is the peptide bond?

**Concept Ladder**

An alkaline solution of a protein or a polypeptide when treated with a few drops of 1% $CuSO_4$ solution, produces a violet colouration. The colour is due to the formation of a coordination complex of $Cu^{2+}$ with >C=O and -NH groups.

When the no. of such amino acids is more than 10, then the products are known as polypeptides.



Polypeptide

- Protein is defined as a polypeptide with more than 100 amino acid residues, having molecular mass higher than 10,000 u.

### Classification of Proteins

They can be classified into 2 types on the basis of their molecular shape.

#### (1) Fibrous Proteins

- When the polypeptide chains are held together by H and $S_2$ bonds and run parallel, then fibre – like structure is formed.
- Proteins are generally insoluble in water and are quite stable against a moderate change in temperature and pH value.

**Ex :** keratin (present in hair, wool, silk) and myosin (present in muscles), etc.

#### (2) Globular Proteins

- In such proteins, the polypeptide intramolecular chains get folded to give a spheroidal shape due to intramolecular hydrogen bonding, van der Waals forces, dipolar interaction and disulphide bridging. These are usually soluble in water and change with a change in temperature and pH.

**Ex :** Insulin, ,albumins, Enzyme, haemoglobin and antibodies.

**Previous Year's Questions**

In a protein molecule various amino acids are linked together by **[AIPMT]**

(1) peptide bond
(2) dative bond
(3) $\alpha$-glycosiddic bond
(4) $\beta$-glycosidic bond

**Rack your Brain**

What is snake venom made of?

**Concept Ladder**

Polypeptides are amphoteric in character because of the presence of terminal ammonium and carboxylate ions as well as the ionized side chains of amino acid residues.

### Hydrolysis of Proteins

Proteins can be hydrolysed and on the basis of hydrolysis they are of following types.

**(1) Simple Proteins :** On hydrolysis they give only a-amino acids

**Ex :**Albumins, globulins etc.

**(2) Conjugated Proteins :** These are having a Non-protein Prosthetic group and on it's bases they are of following types.

**(a) Nucleo protein :** Here Prosthetic group. is nucleic acid. e.g., Nuclein

(**b) Glycoprotein :** Here Prosthetic group is any carbohydrate. e.g., Mycin

**(c) Chromo protein :** Here Prosthetic group is any pigment having metals like Fe, Cu, etc.

**Ex :** Haemoglobin, Chlorophyll.

**(3) Derived Protein :** They are achieved by the partial hydrolysis of simple conjugated proteins.

**Ex :** Proteoses, Peptones.

### Structure of Proteins

Amino acids are joined together by an amide linkage called peptide bond. Proteins are long polymers of amino acids linked by peptide bonds (polypeptides)

#### (1) Primary Structure

- Frederic Sanger gave Primary structure of Insulin for the first time.
- Proteins may have one or more than one polypeptide chains.
- Amino acids of each polypeptide in a protein are joined to each other in a specific sequence and this sequence is termed as primary structure of that protein.

#### (2) Secondary Structure

- By intramolecular H-bonding between the carboxyl and amino groups there is regular folding of the backbone of the polypeptide chain which arises secondary structure.

**Previous Year's Questions**

Which is the correct statement?

**[AIPMT]**

(1) Starch is a polymer of a-glucose

(2) Amylose is a compoonent of cellulose

(3) Proteins are comopsed of only one type of amino acid

(4) In cyclic structure of fructose, there are four carbons and one oxygen atom.

**Rack your Brain**

What is the disease caused by defective heamoglobin molecule in which one of the glutamic acid molecule is replaced by valine?

**Previous Year's Questions**

The helical structure of protein is stabilised by

**[AIPMT]**

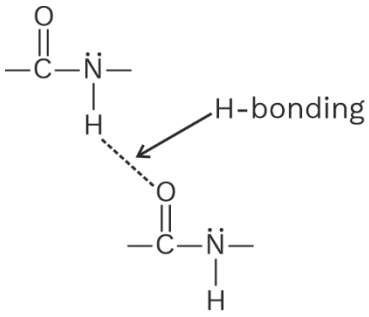
(1) Dipeptide bonds

(2) Hydrogen bonds

(3) Ether bonds

(4) Peptide bonds

- Secondary structures are found to present in two different types of structures viz. α-helix and β-pleated sheet structure.
- By intramolecular H-bonding between —CO— and —NH— groups of the peptide bond there is regular folding of the backbone of the polypeptide chain which aries α-helix and β-pleated sheet structures.




**(a) α-Helix Structure**

- α-Helix is one of the most common ways in which a polypeptide chain forms all possible hydrogen bonds by twisting into a right handed screw (helix) with the –NH group of each amino acid residue hydrogen bonded to the >C=O of an adjacent turn of the helix.
- Stabilization of an α-helical configuration by hydrogen bonding.

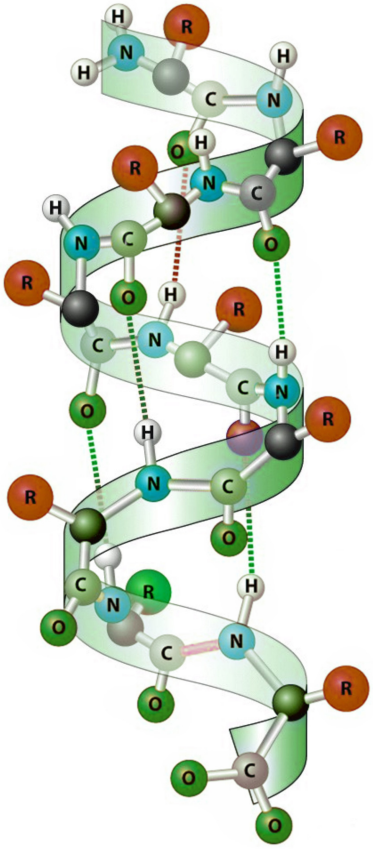
**Ex :** α-keratin in skin, nails, myosin in muscles, fibroin in silk. α-Helix is called 3.6 helix as each turn of helix has 3.6 amino acids and a 13-membered ring.

**(b) β-pleated sheet structure**

- In β-pleated sheet structure all peptide chains are stretched out to nearly maximum extension and then laid side by side which are held together by intermolecular hydrogen bonds.

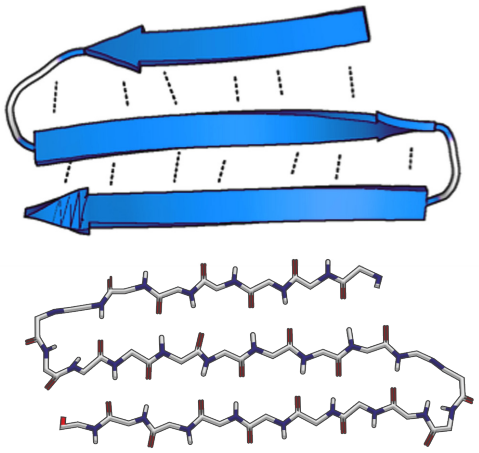
**Rack your Brain**

Which types of bonds are responsible for the stability of α-helix?



- When the size of the groups (Alkyl Group) is moderate, the polypeptide chains contract a little to give a β-pleated sheet structure to protein molecule, as in silk protein fibroin.
- β-pleated sheet structure are parallel and Anti parallel type.
- In parallel form all polypeptide chain run in the same direction while in Anti parallel form, the alternate Polypeptide chain run in same direction.

**Ex :** Parallel conformation — Keratin in hair
Anti–Parallel Conformation — Silk Protein fibroin



β-Pleated sheet structure of proteins

### (3) Tertiary Structure

- The tertiary structure of proteins represents the folding of the polypeptide chains or folding of the secondary structure of proteins.
- Tertiary and secondary structures of proteins are stabilise by the forces of H-bonds, disulphide linkages, van der Waals and electrostatic forces of attraction.
- It gives rise to 2 major molecular shapes that is fibrous and globular.

### (4) Quaternary Structure

- Some of the proteins are composed of more than one polypeptide chains referred to as sub-units.
- When these subunits have spatial arrangement with respect to each other then they are termed as quaternary structure.

**Ex:** Haemoglobin is an aggregate of four sub-units, two identical α-chains (having 141 Amino acid residues and two identical β-chains (having 146 Amino acid residues).

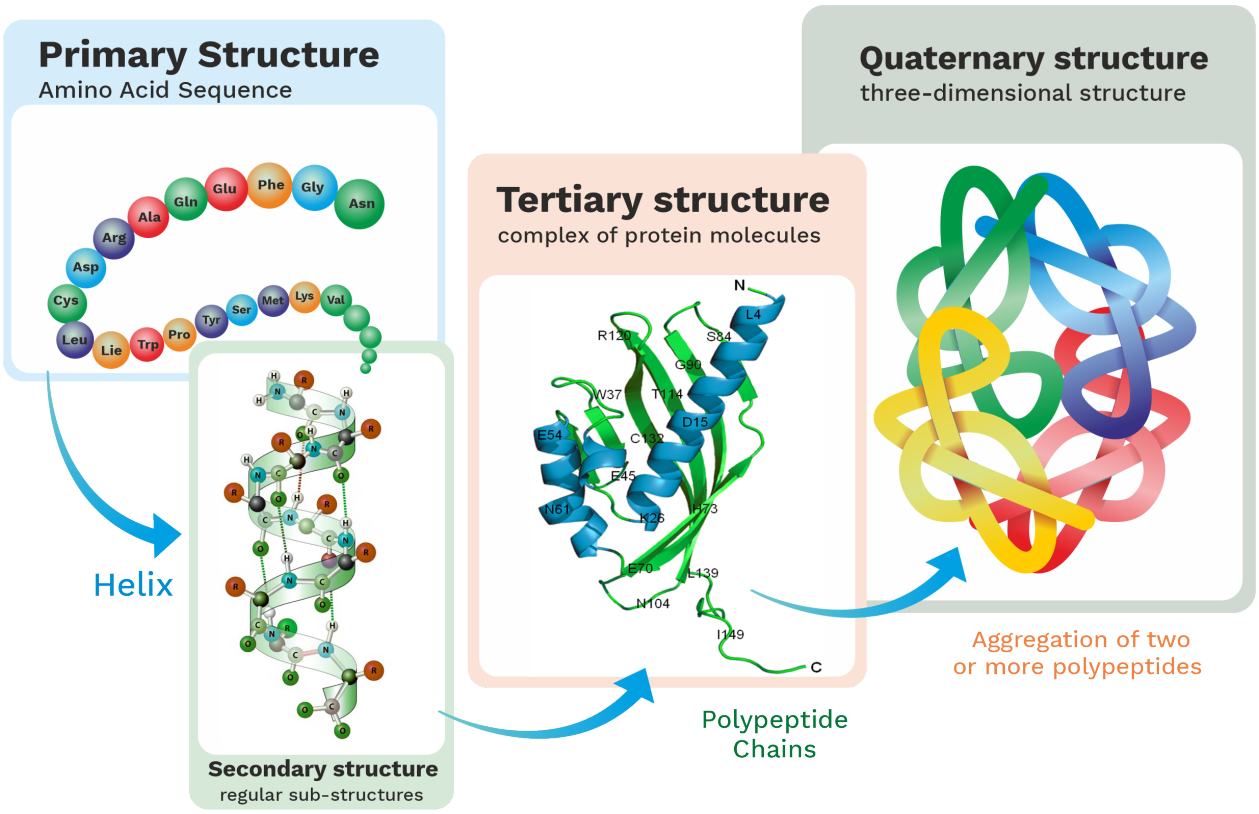
**Concept Ladder**

The tertiary structure is the three-dimensional structure of globular proteins. It arises due to the folding and superimposition of various secondary structural elements.

**Previous Year's Questions**

Hemoglobin is **[AIPMT]**

(1) A vitamin
(2) A carbohydrate
(3) An Enzyme
(4) A globular protein




**Denaturation of Proteins**

- Disruption of the native conformation of a protein will cause the protein to loose its biological activity. This is called denaturation.
- Various changes in the surroundings of a protein such as pH, temperature, presence of salts or certain chemical agents can disrupt the complex three-dimensional structure (conformation) of the proteins.
- Due to physical and chemical changes, the H-bonds are disturbed.

**Ex :**(i) On boiling an egg the albumin get coagulated.

(ii) During formation of cheese from milk, the globular protein lactalbumin becomes fibrous.

**Previous Year's Questions**

Which structure(s) of proteins remain(s) intact during denaturation process?

**[NEET-2019]**

(1) Both secondary and tertiary structure

(2) Primary structure only

(3) Secondary structure only

(4) Tertiary structure only

### Detection of Protein

**(1) Millon's test:** Aqueous solution of protein (except tyrosine) gives a white precipitate with millon's reagent (Mercurous nitrate and mercuric nitrate in HNO2 ).

**(2) Xantho protein test:** Here, protein having tyrosine and phenyl alanine amino acids give a yellow colour when tested with conc. HNO3

**(3) Nin-hydrin test:** Protein on boiling with dilute aqueous solution of nin-hydrin (2, 4-dihydroxy indane-1, 3-dione) gives blue violet colouration.

**(4) Biuret test:** Alkaline solution of proteins gives violet colouration with 1% copper sulphate solution due to formation of a complex between $Cu^{2+}$ and the peptide linkage.

### LIPIDS

- Lipids are generally not soluble in water
- Lipids are simple fatty acids. Carboxyl group attached to an R group form fatty acids, it can be ethyl ($-C_2H_5$), or methyl ($-CH_3$) or higher number of $-CH_2$ groups (1 carbon to 19 carbons).

**Ex :** (i) palmitic acid has 16 carbons including carboxyl carbon.
(ii) Arachidonic acid contains twenty carbon atoms which includes the carboxyl carbon.

- Fatty acids contains saturated (without double bond) or unsaturated groups(with one or more than one C=C double bonds).
- Glycerol is another simple lipid which is trihydroxy propane.
- Both glycerol and fatty acids makes many lipids. Fatty acids are found esterified with glycerol, therefore they can be monoglycerides, diglycerides and triglycerides.
- Oils have lower M.P. (e.g., gingelly oil) and hence remain as oil in winters. These are also called oils and fats based on melting point.

**Concept Ladder**

The most widely used method for determining the N-terminal amino acid residue in a protein or a polypeptide molecule is called the DNP-method or Sanger's method.

**Rack your Brain**

What is difference between lipid and fat?

**Previous Year's Questions**

The cell membranes are mainly composed of

**[AIPMT]**

(1) Fats
(2) Proteins
(3) Phospholipids
(4) Carbohydrates

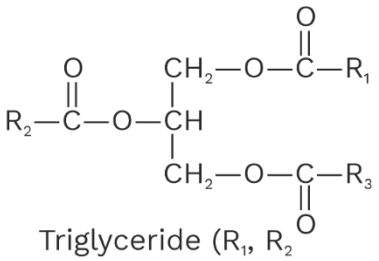
- Phospholipids are some lipids containing phosphorous and a phosphorylated organic compound in them. Lecithin is one example. They are found in cell membrane.
- Some tissues especially the neural tissues have lipids with more complex structures.

$CH_3—(CH_2)_{14}—COOH$

Fatty acid
(Palmitic acid)

$CH_2—OH$
$CH_2—OH$
$CH_2—OH$

Glycerol



Triglyceride ($R_1$, $R_2$ and $R_3$ are fatty acids)

## ENZYMES

- The biological catalysts which can increase the rate of biochemical reactions even under mild conditions of temperature and pH of living organisms are termed as enzymes.
- Enzymes are chemically similar to globular proteins.
- They are very specific for each reaction and for every substrate.
- They are usually named after the compound or group of compounds upon which they work.

**Ex :** The enzyme that catalyses hydrolysis of maltose into glucose is named as maltase

$$\underset{\text{Maltose}}{C_{12}H_{22}O_{11}} \xrightarrow{\text{Maltase}} 2\ \underset{\text{Glucose}}{C_6H_{12}O_6}$$

- After the reaction enzymes are also mentioned, where they are used.

**Ex :** Oxidoreductase enzymes are the enzymes which can catalyse the oxidation of one substrate and simultaneously reduce another substrate.

- They are very specific in their action on substrates and each enzyme catalyses only a specific type of reaction.

### Concept Ladder

Iodine number is no. of grams of $I_2$ that combines with 100 g of fat or oil. It is used to measure extent of unsaturation in oil or fat.

### Previous Year's Questions

Enzymes are made up of **[AIPMT]**

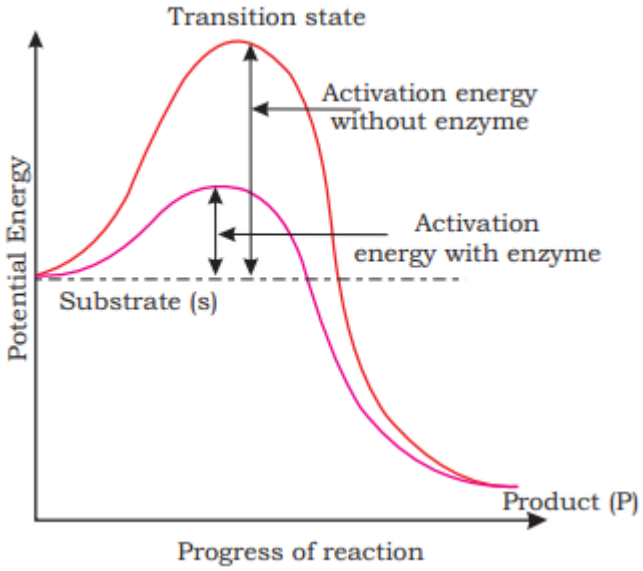
(1) Edible proteins
(2) Proteins with specific structure
(3) Nitrogen containing carbohydrates
(4) Carbohydrates

- They are active at moderate temperature (310 K), neutral pH (7) and 1 atmospheric pressure.
- The action of enzymes are inhibited by various organic and inorganic molecules called inhibitors.
- The activity of enzymes can be increased by metal ions and smaller organic molecules called coenzymes or cofactors. For example, inorganic ions, $Mg^{2+}$, $Mn^{2+}$, $Fe^{2+}$, $Co^{2+}$, $Cu^{2+}$ , organic molecules like vitamins (thiamine, riboflavin).

### Mechanism of Enzyme Action

- For the progress in reaction enzymes are needed only in small quantities.
- Enzymes function by lowering the energy of activation of a particular reaction.

**Ex :** For sucrose the activation energy for acid hydrolysis is 6.22 kJ $mol^{-1}$, whereas when it is hydrolysed by the enzyme its activation energy is only of 2.15 kJ $mol^{-1}$.




**Concept Ladder**

Protein co-factor complex is called holoenzyme while the inactive protein part is apoenzyme.
Holoenzyme ⇌Apoenzyme + cofactor

**Rack your Brain**

which is cause of albinism?

**Concept Ladder**

Enzyme streptokinase is used to dissolve blood clot in coronary artery (which is cause of heart attack).

**Lock and Key Hypothesis**

- A number of cavities are present on the surface of enzymes. These cavities have specific shapes and groups like $-NH_2$ $-COOH$, $-OH$ etc.
- These are active centres on enzyme surfaces.
- Here 'key' (reagent or substrate) fits in the 'lock', that is, the active site of catalyst to give an intermediate complex, which changes into product and the enzyme catalyst is released.

$$E + S \rightleftharpoons E - S \xrightarrow{R} \underset{\text{Activated complex}}{E + P}$$

**Rack your Brain**

Urea's enzyme can catalyse hydrolysis of urea but not of n-methyl urea. Why?

| S.No. | Enzyme | Enzymatic Reaction |
|---|---|---|
| (i) | Invertase or sucrose | Sucrose $\rightarrow$ Glucose + Fructose |
| (ii) | Maltase | Maltose $\rightarrow$ Glucose + Glucose |
| (iii) | Lactose | Lactose $\rightarrow$ Glucose + Galactose |
| (iv) | a-Amylase | Starch $\rightarrow$ n × Glucose |
| (v) | Pepsin | Proteins $\rightarrow$ a-Amino acids |
| (vi) | Trypsin | Proteins $\rightarrow$ a-Amino acids |
| (vii) | Nucleases | DNA or RNA $\rightarrow$ Nucleotides |
| (viii) | DNA polymerase | Deoxynucleotide triphosphates $\rightarrow$ DNA |
| (ix) | RNA polymerase | Ribonucleotide triphosphates $\rightarrow$ RNA |

## VITAMINS

- They are the organic compounds which are required in small amounts in our diet but their deficiency causes specific diseases.
- Plants can synthesise almost all of vitamins but most of the vitamins cannot be synthesised in our body.
- Some of vitamins produce by bacteria of the gut.
- Vitamins are categorised by alphabets A, B, C, D, etc. Some of them are further termed as sub-groups e.g. $B_1$, $B_2$, $B_6$, $B_{12}$, etc.

**Definition**

organic compounds required in the diet in small amounts to perform specific biological functions for normal maintenance of optimum growth and health of the organism.

### Classification of Vitamins

- On the basis of their solubility in $H_2O$ or fat they are classified into two groups.

### (i) Fat Soluble Vitamins

- Vitamins which are soluble in oils and fats but not soluble in water are to be considered in this group.
- They are vitamins A, D, E and K. These can be stored in adipose (fat storing) tissues and liver

### (ii) Water Soluble Vitamins

- Vitamins which are soluble in water but insoluble in fat or oils.
- Vitamin B & vitamin C are soluble in water so they can grouped together.

**Rack your Brain**

Which vitamin is not found in plants?

**Previous Year's Questions**

Which of the following is not a fat soluble vitamin?
**[AIPMT-2011]**
(1) Vitamin B complex
(2) Vitamin D
(3) Vitamin E
(4) Vitamin A

**Q4** Deficiency of which vitamin causes
(i) Pernicious anaemia (ii) convulsions

**Sol.** (i) Pernicious anaemia is caused by deficiency of vitamin $B_{12}$.
(ii) Convulsion sare caused by deficiency of vitamin $B_6$.

| S.No. | Name of Vitamins | Sources | Deficiency diseases |
|---|---|---|---|
| (i) | Vitamin A | Carrots, fish liver oil, butter and milk | Xerophthalmia, night blindness |
| (ii) | Vitamin $B_1$ (Thiamine) | Milk, green vegetables, cereals and yeast | Beri beri (loss of appetite, retarded growth) |
| (iii) | Vitamin $B_2$ (Riboflavin) | Egg white, milk, liver, kidney | Digestive disorders, cheilosis (fissuring at corners of mouth and lips) and burning sensation of the skin. |
| (iv) | Vitamin $B_6$ (Pyridoxine) | Milk, cereals, egg yolk and grams, yeast | Convulsions |
| (v) | Vitamin $B_{12}$ | Fish, meat, egg and curd | Pernicious anaemia (RBC deficient in haemoglobin) |
| (vi) | Vitamin C (Ascorbic acid) | Amla, Citrus fruits and green leafy vegetables | Scurvy (bleeding gums) |
| (vii) | Vitamin D | Exposure to sunlight, fish and egg yolk | Osteo- malacia (joint pain in adults and soft bones) and rickets (bone deformities in children) |
| (viii) | Vitamin E | Vegetable oils like sunflower oil ,wheat germ oil,etc. | Increased fragility of RBCs and muscular weakness |
| (ix) | Vitamin K | Vegetable oils like sunflower oil, etc. | Increased blood clotting time |

## NUCLEIC ACIDS

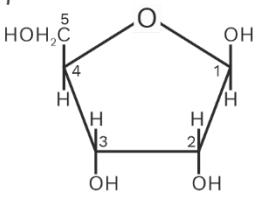
- For each and every species, every generation resembles its ancestors in many ways.
- For this transmission of inherent characters nucleus of a living cell is responsible, which is also termed as heredity.
- Chromosomes are particles made up of proteins and another type of biomolecules called nucleic acids and present in the nucleus of the cell is responsible for heredity.
- Deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) are two types of nucleic acids. They are also called polynucleotides as they are long chain polymers of nucleotide.
- Nucleic acids contain the elements nitrogen, carbon, oxygen, phosphorus and hydrogen.

### Chemical Composition of Nucleic Acids

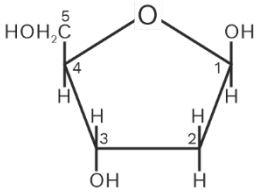
- The Complete hydrolysis of DNA (or RNA) yields a pentose sugar, phosphoric acid and nitrogen containing heterocyclic compounds (called bases).

### Pentose Sugar

- In DNA molecules, the sugar moiety is β-D-2-deoxyribose whereas in RNA molecule, it is β-D-ribose.




β-D-ribose




β-D-2-deoxyribose

### Bases

- The bases that occur in nucleic acids are derivatives of pyrimidine and purine.

**Concept Ladder**

Nucleic acids play an essential role in transmission of the hereditary characteristics and in the biosynthesis of proteins.

**Rack your Brain**

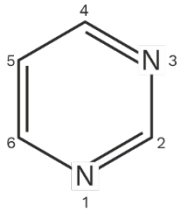
What are the main function of DNA and RNA in organisms?

**Previous Year's Questions**

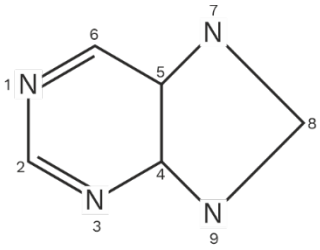
Deficiency of vitamin $B_1$ causes the disease

**[AIPMT-2012]**

(1) Convulsions (2) Beri-Beri
(3) Cheilosis (4) Sterility

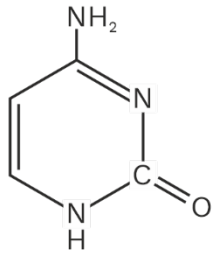


Pyrimidine

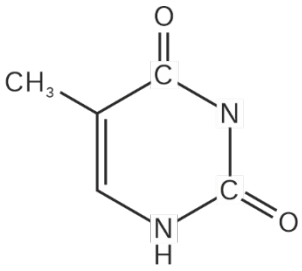


Purine

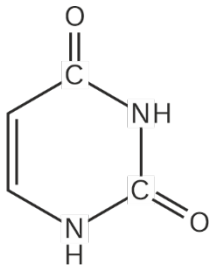
- Pyrimidine bases are uracil, thymine and cytosine.



Cytosine (C)

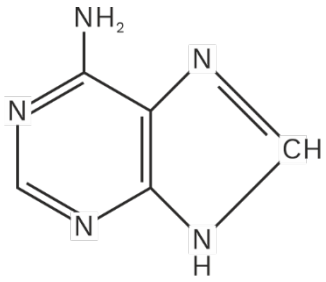


Thymine (T)

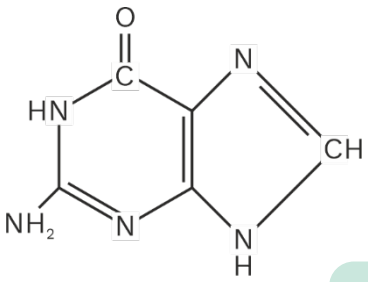


Uracil (U)

- The purine bases found in nucleic acids are adenine and guanine.



Adenine (A)



Guanine (G)

- DNA contains 4 bases viz. adenine (A), guanine (G), cytosine (C) and thymine (T).
- RNA also contains 4 bases, the first 3 bases (adenine (A), guanine (G), cytosine (C)) are same as in DNA but the fourth one is uracil (U).

**Previous Year's Questions**

In DNA, the linkages between different nitrogenous bases are **[NEET-2013]**

(1) Phosphate linkage
(2) H-bonding
(3) Glycosidic linkage
(4) Peptide linkage

## Chargaff Rule

- In 1955 Erwin Chargaff given the Chargaff Rule. The rule states that 'For any given species in DNA, the ratio of adenine to thymine is equal to the ratio of cytosine to guanine. The ratio is termed as Chargaff's ratio.
- This rule was important for solving the structure of DNA.
- Chargaff's rule, [A] + [G] = [C] + [T]
- DNA from any species of any organism should have a 1:1 stoichiometric ratio of purine and pyrimidine bases.

**Rack your Brain**

What is the chargaff rule and why it is important?

## Structure of Nucleic Acids

### Nucleoside

- Nucleoside is a unit formed by the attachment of a base to 1 position of sugar.
  Sugar + Base = Nucleoside
- In nucleosides, for distinguish between bases from it, the sugar carbons are numbered as 1, 2, 3 etc.

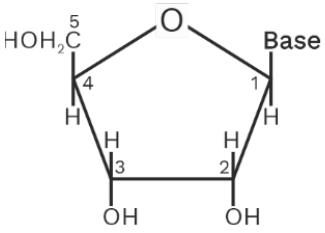
**Previous Year's Questions**

in DNA, the linkages between different nitrogenous bases are **[NEET-2013]**

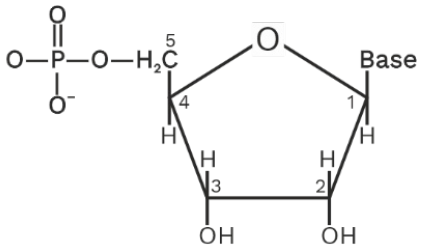
(1) phosphate linkage
(2) H-bonding
(3) glycosidic linkage
(4) peptide linkage

### Nucleotide

- A nucleotide unit formed by the attachment of a base 1 position of sugar and attachment of phosphoric acid with 5 position of sugar.
  Sugar + Base + Phosphoric acid = Nucleotide

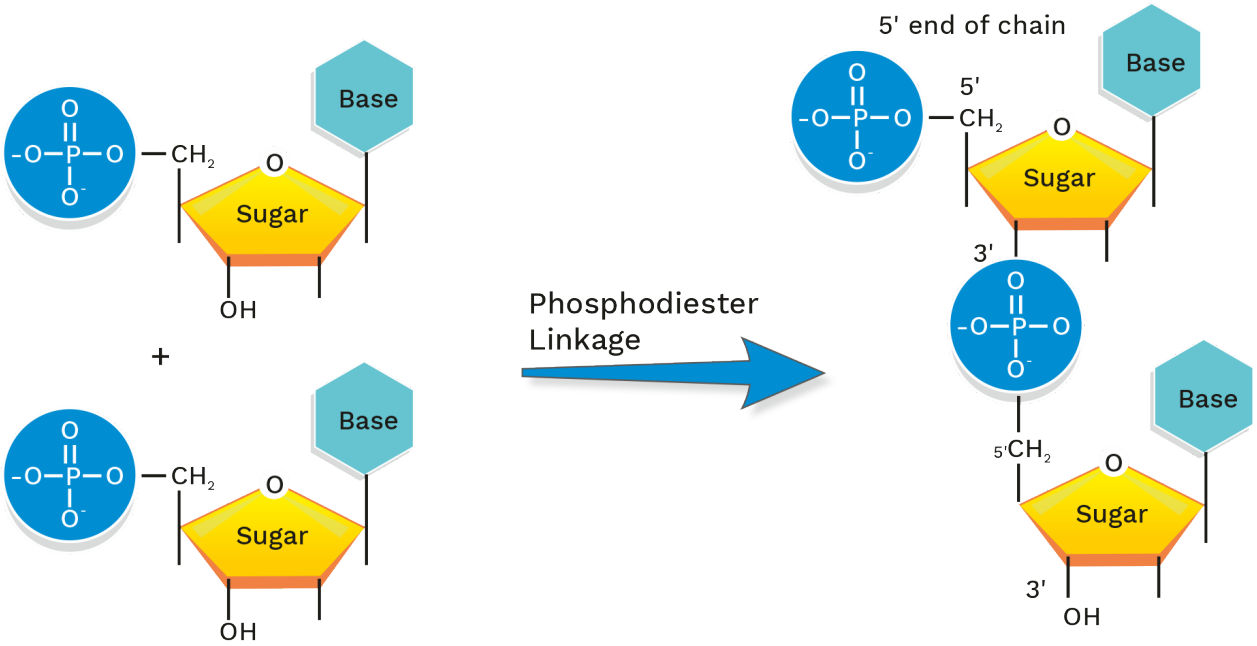



Nucleoside

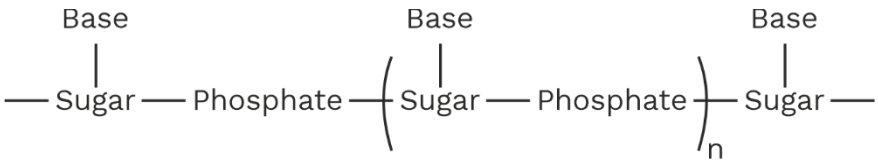



Nucleotide

- By phosphodiester linkage between 5 and 3 carbon atoms of the pentose sugar, nucleotides are joined together. The formation of a typical dinucleotide.




- A simplified version f nucleic acid chain is as shown below.




**Double strand helix structure for DNA**

- The sequence of bases along the DNA or RNA chain shows primary structures of these and it controls the specific properties of nucleic acids.
- An RNA molecule is usually a single chain of ribose containing nucleotides.
- DNA consists of 2 long strands of polynucleotides coiled around each other in the form of a double helix (Watson and Crick model) ladder like structure joint together by hydrogen bonding.
- Here, hydrogen bonding is in between the nitrogenous base molecules of the nucleotide monomer. Adenine with thymine forms two

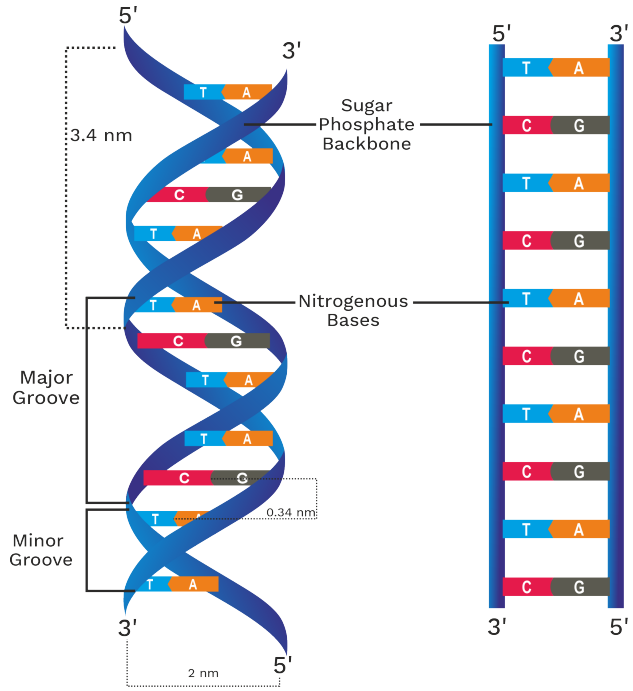
**Previous Year's Questions**

Which of the following is correct about H-bonding in nucleotide? **[AIPMT]**

(1) A-T, G-C (2) A-G, T-C
(3) G-T, A-C (4) A-A, T-T

hydrogen bonds while guanine forms three hydrogen bonds with cytosine.

- Thymine combines only with deoxyribose sugar while uracil combines with only ribose sugar.




## Ribonucleic Acid (RNA)

- RNA single stranded helics is present which sometimes foldsback on itself.
- Its molecules are of 3 types and all three of them performs different functions.
- They are named as ribosomal RNA (r-RNA), messenger RNA (m-RNA), and transfer RNA (t-RNA).

### Central Dogma

- Central Dogma was first proposed in 1958 by Francis Crick, discoverer of the structure of DNA.
- Transcription, Translation and Replication are the 3 main processes used by all cells

**Rack your Brain**

What type of linkage holds together the monomers of DNA?

**Concept Ladder**

Mutation is sudden change in base sequence of DNA due to radiations or chemicals.

**Previous Year's Questions**

The central dogma of molecular genetics states that the genetic information flows from

**[NEET-2016]**

(1) Amino acids → Proteins → DNA

(2) DNA → Carbohydrates → Proteins

(3) DNA → RNA → Proteins

(4) DNA → RNA → Carbohydrates

for maitaining their genetic information and also for converting the genetic information encoded in DNA into gene products, which are either proteins or RNA, depending on the gene.

**Definition**

A sequence of bases on DNA is also unique for a person and information regarding this is called DNA fingerprinting.

### Difference Between DNA and RNA

| S.No. | Deoxyribonucleic Acid (DNA) | Ribonucleic Acid (RNA) |
|---|---|---|
| (i) | DNA occurs n the nucleus of the cell. | RNA occurs in the cytoplasm of the cell. |
| (ii) | The sugar present in DNA is D-(–)-2-deoxyribose. | The sugar present in RNA is D-(–)-ribose. |
| (iii) | DNA contains cytosine and thymine as pyrimidine bases and guanine and adenine as purine bases. | RNA contains cytosine and uracil as pyrimidine bases and guanine and adenine as purine bases. |
| (iv) | DNA has double-standard a-helix structure. | RNA has single standard a-helix structure. |
| (v) | DNA undergoes replication. | RNA usually does undergo replication. |
| (vi) | DNA controls the transmission of hereditary effects. | RNA controls the synthesis of proteins. |

### DNA Fingerprinting

- For cracking the genetic code Dr. Khorana, Marshall Nirenberg and Robert Holley won the Nobel Prize for Medicine and Physiology in 1968.

- DNA fingerprinting cannot be altered by any known treatment and is same for every cell.
- It is now used :

(i) For determining paternity of an individual
(ii) in forensic laboratories for identification of criminals.
(iii) for identifying racial groups to rewrite biological evolution.
(iv) for identifying the dead bodies in any accident by comparing the DNA's of parents or children.

**Biological Functions of Nucleic Acids**

- During cell division a DNA molecule is capable of self-duplication and identical DNA strands are transferred to daughter cells.
- In the cell various RNA molecules can synthesisize proteins but for a particular protein the message for the synthesis is present in DNA.
- DNA is the chemical basis of heredity and can be considered as the reserve of information about genetic.
- Over millions of years DNA is exclusively responsible to maintain the indentification of different species of organisms.

**Concept Ladder**

The process by which a single DNA molecule produces two identical copies of itself is called cell division (mitosis) or replication.

**Previous Year's Questions**

An example of biopolymer is **[AIPMT]**

(1) teflon (2) neoprene
(3) nylon-6, 6 (4) DNA

**The Major Complex Biomolecules of Cells**

| Biomolecule | Building Block | Major Functions |
|---|---|---|
| Protein | Amino acid | Basic structure and function of cell |
| DNA | Deoxyribonucleotide | Hereditary information |
| RNA | Ribonucleotide | Protein synthesis |
| Polysaccharide | Monosaccharide | Storage form of energy |
| Lipids | Fatty acids & glycerol | Storage form of energy for meeting long term demands |

**HORMONES**

- They are the molecules that act as intercellular messengers.
- Hormones are substances or biomolecules manufactured in minute amounts in endocrine or ductless glands.
- They are carried directly into different parts by the blood stream.
- The major hormone secreting glands include the intestinal mucosa pancreas, adrenals, thyroid, pituitary, ovaries and testes.

**Types of Hormones**

**(1) Steroids**

- These type of hormones are produced by adrenal cortex and gonads (testes in males and ovaries in females).

**Ex :** estrogens and androgens.

- For various functions of the body hormones released by the adrenal cortex play very important role.

**(i) Glucocorticoids**

- They control the modulate inflammatory reactions, carbohydrate metabolism and are involved in reactions to stress.

**(ii) Mineralocorticoids**

- They control the level of excretion of salt and water by the kidney.

**(2) Polypeptids —** e.g. insuline and endorphins.

**(3) Amino Acids Derivatives —** epinephrine and norepinephrine.

**Definition**

Hormones are produced by endocrine glands in the body and are poured directly in the blood stream which transports them to the site of action.

**Concept Ladder**

If adrenal cortex does not function properly then one of the results may be Addison's disease characterised by hypoglycemia, weakness and increased susceptibility to stress.

**Previous Year's Questions**

Which of the following hormones is produced under the conditions of stress which stimulate glycogenolysis in the liver of human beings?

**[NEET-2014]**

(1) Thyroxin (2) Insulin
(3) Adrenaline (4) Estradiol

**Functions of Hormones**

- Hormones have several functions in the body.
- In the body they help for maintaining the balance of biological activities.
- The example of this function like insulin keeps the blood glucose level within the narrow limit. When there is rapid rise in blood glucose level in response insulin is released.
- Hormone glucagon tends to increase the glucose level in the blood. Insulin and Glucagon hormones will regulate the glucose level in the blood.
- Growth and sex hormones play role in development and growth.
- Thyroxine formed in thyroid gland is an iodinated derivative of amino acid tyrosine.
- Lethargyness and obesity are the characteristics of hypothyroidism which is due to abnormally low level of thyroxine.
- Hyperthyroidism is caused due to increased level of thyroxine.
- Hypothyroidism and enlargement of the thyroid gland are caused by low level of iodine in the diet.By adding sodium iodide to commercial table salt ("Iodised" salt), it can be controlled.
- Hormones released by gonads are responsible for developing secondary sex characters.
- Testosterone is responsible for developing secondary male characteristics (facial hair, deep voice, general physical constitution) and for males it is the main sex hormone.
- Likewise estradiol is the main female sex hormone. It participates in the control of menstrual cycle and is responsible for development of secondary female characteristics.
- Progesterone is responsible for preparation of uterus for implantation of fertilised egg.

**Rack your Brain**

Which disease is caused by deficiency of insulin?

**Previous Year's Questions**

Which of the following statements is not correct?

**[NEET-2017]**

(1) Ovalbumin is a simple food reserve in egg-white

(2) Blood proteins thrombin and fibrinogen are involved in blood clotting.

(3) Denaturation makes the proteins more active.

(4) Insulin maintains sugar level in the blood of a human body.

| S.No. | Name | Organ of Secretion | Functions |
|---|---|---|---|
| (A) | Sex hormones | | |
| | (a) Androgens (Testosterone) | Testes | Control the development and normal functioning of Androsterone and male sex organs. |
| | (b) Estrogens (Estrone, Estradiol, Estriol) | Ovary | Control the development and normal functioning of female sex organs. |
| | (c) Gestogens (Progesterone) | Corpus luteum | Control the development and maintenance of pregance. |
| (B) | Adrenal cortex hormones or corticoids (Cortisone, Corticosterone, Aldosterone etc.) | Adrenal cortex | Regulate the metabolism of carbohydrates, fats & proteins and; control the balance of water and minerals in the body. |

| Name | Organ of Secretion | Functions |
|---|---|---|
| (i) Adrenaline or Epinephrine | Adrenal medulla | It is an amine compound and was the first hormone to be isolated. Prepares animals and humans for emergency in many ways by raising the pulse rate, blood pressure etc. stimulates the breakdown of liver glycogen into blood glucose and fats into fatty acids during emergency. These properties make adrenaline as one of the most valuable drugs used in medicine. |
| (ii) Thyroxine | Thyroid gland | Controls metabolism of carbohydrates, lipids and proteins. |

**Q5** Glucose or sucrose are soluble in water but cyclohexane and benzene (simple six membered ring compounds) are insoluble in water Explain.

**Sol.** Glucose contains 5 and sucrose contains 8 —OH groups. These —OH groups form H-bonds with water. Due to this H-bonding they are soluble in water. Whereas benzene and cyclohexene are simple molecules and do not contain —OH groups and hence do not form H-bonds and are insoluble in water.

**Q6** What are the expected products of hydrolysis of lactose?

**Sol.** Lactose being a disaccharide gives 2 molecules of monosaccharides i.e., 1 molecule each of D-(+)-glucose and D-(+)-galactose.

$$\underset{\text{Lactose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow[\text{or}]{H_3O^+} \underset{\text{Lactose}}{} \underset{\text{D–(+)–Glucose}}{C_6H_{12}O_6} + \underset{\text{D–(+)–Glactose}}{C_6H_{12}O_6}$$

**Q7** The melting points and solubility in water of a-amino acids are generally higher than those of corresponding halo acids. Explain.

**Sol.** The amino acids exist as zwitter ions. They have strong electrostatic attractions because of dipolar salt like character. Therefore, their M.P. are higher than haloacids which do not have salt like character, they interact strongly with $H_2O$. As a result, solubility of amino acids in water is higher than that of the corresponding haloacids which do not have salt like character.

**Q8** Where does the water present in the egg go after boiling the egg?

**Sol.** Proteins first undergo denaturation and then coagulation, after boiling of egg and coagulated protein absorbs water present in egg, this is probably through hydrogen bonding.

**Q9** Why cannot Vitamin C be stored in our body?

**Sol.** As vitamin C can be soluble in water and therefore it can be excerted in urine, therefore cannot be stored in the body.

**Q10** Which products would be formed when a nucleotide from DNA containing thymine is hydrolysed?

**Sol.** 2-deoxyribose and phosphoric acid along-with thymine are formed when a nucleotide from DNA containing thymine is hydrolsyed.

**Q11** What are monosaccharides?

**Sol.** Monosaccharides are carbohydrates having general formula is $(CH_2O)_n$ Where n = 3 – 7 and cannot be hydrolysed to smaller molecules. These are of following 2 types: The onecontaining an aldehyde group (—CHO) are called aldoses and other one is a keto (C=O) group are called ketones.

**Q12** What are reducing sugars?

**Sol.** Reducing sugars are those which can behave as reducing agents. A reducing group is present in them, which may be aldehydic (-CHO) or ketonic (>C=0) group.

**Q13** Write two main functions of carbohydrates in plants.

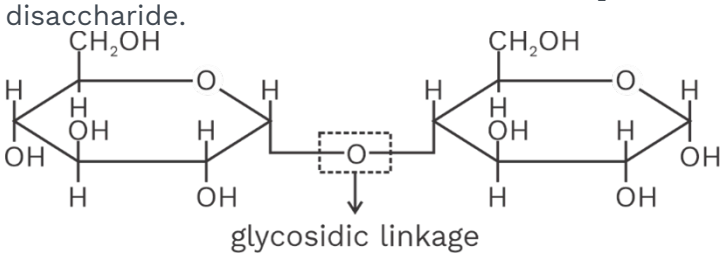
**Sol.** The 2 main functions of carbohydrates in plants are as follows:
(a) Reserve food material: The major reserve food material in the plants is polysaccharide starch. It is stored in seeds and used as the reserve food material for the tiny plant untill they are capable of making their own food by photosynthesis.
(b) Structural material for plant cell walls: The polysaccharide cellulose acts as the chief structural material of the plant cell walls.

**Q14** Classify the following into monosaccharides and disaccharides. Ribose, 2-deoxyribose, maltose, galactose, fructose and lactose.

**Sol.** Monosaccharides: Ribose, 2-deoxyribose, galactose and fructose. Disaccharides: Maltose and lactose.

**Q15** What do you understand by the term glycosidic linkage?

**Sol.** Glycosidic linkage is the oxide linkage through which 2 monosaccharide units are joined together by the loss of a $H_2O$ molecule to form a molecule of disaccharide.




**Q16** What is glycogen? How is it different from starch?

**Sol.** Glycogen is a form of carbohydrates which is stored in animal body. It is also called animal starch and its structure is similar to amylopectin which means that it forms a branched chain polymer consisting $\alpha$-D-glucose units in which the formation of chain is by C1—C4 glycosidic linkage whereas branching occurs by the formation of C1— C6 glycosidic linkage.

**Q17** What are the hydrolysis products of (i) sucrose, and (ii) lactose?

**Sol.** Both sucrose and lactose are disaccharides. Lactose on hydrolysis gives 1 molecule each of galactose and glucose, whereas sucrose on hydrolysis gives 1 molecule each of fructose and glucose.

$$\underset{\text{Sucrose}}{C_{12}O_{22}O_{11}} + H_2O \xrightarrow{H_3O^+} \underset{\text{D–(+)–Glucose}}{C_6H_{12}O_6} + \underset{\text{D–(–)–Fructose}}{C_6H_{12}O_6}$$

$$\underset{\text{Lactose}}{C_{12}O_{22}O_{11}} + H_2O \xrightarrow{H_3O^+} \underset{\text{D–(+)–Glucose}}{C_6H_{12}O_6} + \underset{\text{D–(+)–Galactose}}{C_6H_{12}O_6}$$

## Chapter Summary

**Carbohydrates**

1. All naturally occuring monosaccharides belong to D-series [i.e., in Fischer projections the —OH group at their penultimate carbon atoms is oriented towards right as in D(+) glyceraldehyde].
2. Fructose-sweetest of all natural sugars : Saccharin is not carbohydrate but is 500 times sweeter than sucrose.
3. Glucose is reducing sugar.
4. Glucose-grape sugar or dextrose, fructose is gruit sugar, lactose is milk sugar.

**Proteins and amino acids**

1. Prosthetic group of nucleoprotein is nucleic acid.
2. All enzymes are globular proteins.
3. During denaturation biological activity of proteins is lost but chemical activity remains same.
4. Biuret test and Ninhydrin test is done to detect presence of amino acids and proteins.

**Enzymes**

1. Enzyme sterptokinase is used to dissolve bloot clot in coronary artery (which is cause of heart attack).
2. Pepsin and trypsin enzymes convert proteins into $\alpha$-amino acids.
3. Deficiency of enzyme tyrosinase leads to albinism.

**Nucleic acid**

1. DNA bases are A, G, C, T and RNA bases are A, G, C, U.
2. Complementary base pairing A = T, C = G.
3. Genetic codes are triplets.
4. DNA controls transmission of hereditary characters and RNA controls protein synthesis.

**Lipids**

1. Lecithin and cepthalins are phospholipids.
2. Iodine number is no. of gms of $I_2$ that combines with 100 g of fat or oil. It is used ot measure extent of unsaturation in oil or fat.
3. Lipids are soluble in butter.
4. Drying oils have unsaturated fatty acids e.g. - lineolic acid.

**Hormones**

1. Insuline is peptide hormone. Its deficiency causes diabetes mellitus.
2. Thyroxin hormone has iodine.
3. Adrebnaline is called fight or flight hormone because it prepares animals for emergency situations.

**Vitamins**

1. Vitamin $B_{12}$ has N, P, and Cobalt.
2. Vitamin $B_{12}$ is not found in plants. It is found in animals only, synthesised by micro-organism in liver.