BIOMOLECULE-I

BIOMOLECULES

All the carbon compounds that we get from living tissue can be called biomolecules i.e. all the organic molecules present in the living organisms are called biomolecules.

CELLULAR POOL

All the organic and inorganic elements and compounds present in living system are called cellular pool.

On the basis of size and solubility, molecules are of 2 types.

1. **Micromolecules**

   Micromolecules are smaller in size, have low molecular weight (up to 1000 Da), simple in structure, solubility is high, found in gas / liquid /solid form and can be organic /inorganic and can pass through cell membrane.

   e.g, water, minerals, amino acids, sugar, lipids and nucleotides.

2. **Macromolecules**

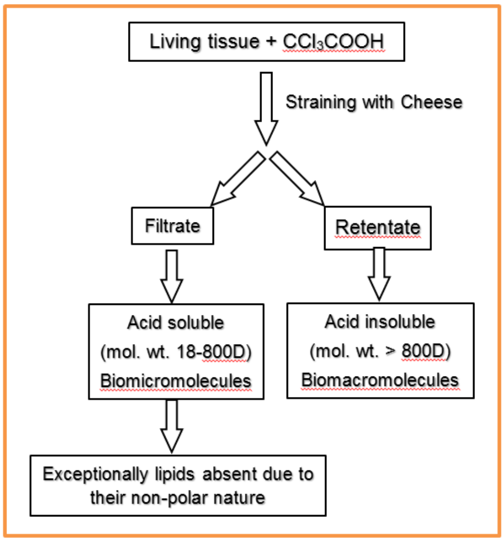
   Macromolecules are larger in size, complex in structure with high molecular weight and low solubility. These are formed by polymerization (condensation involving loss of water) of a large number of micromolecules; found mostly in colloidal form; organic in nature and can not pass through the membrane, therefore, every cell has to produce its own macromolecules, e.g., Proteins, Nucleic acids and Polysaccharides (formed by condensation of amino acids, nucleotides and monosaccharide's respectively).

Resonate the Concept
• Increase in the variety of molecules in a cell causes stability.

How to analyse chemical composition

In order to study the various biomolecules found in living tissues (a vegetable or a piece of liver etc.), grind it in trichloroacetic acid (CCl_3COOH) with the help of pestle and mortar. It is strained through cheese cloth or cotton and we obtain two fractions. The filtrate is called acid soluble pool while the retentate is acid insoluble fraction. Chemicals present in both the fractions are further separated by various analytical techniques and identified.

The acid soluble pool contains chemicals with small molecular mass of 18-800 daltons approximately. They are biomicromolecules. The acid insoluble fraction contains chemicals with molecular mass around 10000 daltons and above, they are biomacromolecules. Biomacromolcules are of large size and high molecular weight, complex molecules that are formed by condensation of bimicromolecules. Biomacromolecules are of three types-proteins, nucleic acids and polysaccharides.



Resonate the Concept
• Lipids have a molecular mass of micromolecules, less than 800 D. They, however, do not appear in the acid soluble pool due to their non-polar nature, so lipids are not true macromolecules. • Except lipids, macromolecules are also called polymers as they are formed by the process of polymerization or union of repeating subunits called monomers.

Primary and Secondary Metabolites

Thousands of organic compounds including amino acids, sugars, *etc* biomolecules act as 'metabolites'.

1. Primary Metabolites

Substances that are required for growth of living organisms. Proteins, carbohydrates, fats, amino acids, nucleic acids are the primary metabolites. They are found in all organisms.

2. Secondary Metabolites

Substances that are not required (waste material) for growth of living organisms. However, many of them are useful to 'human welfare' (e.g., rubber, drugs, spices, scents and pigments). Some secondary metabolites have ecological importance as rotenone is wide spectrum insecticide, so used to control insects.

Some Secondary Metabolites	
Pigments	Carotenoids, Anthocyanins, etc.
Alkaloids	Morphine, Codeine, etc.
Terpenoides	Monoterpenes, Diterpenes etc.
Essential oils	Lemon grass oil, etc.
Toxins	Abrin, Ricin
Lectins	Concanavalin A
Drugs	Vinblastin, curcumin, etc.
Polymeric substances	Rubber, gums, cellulose

Elements	% Amount
Oxygen	62
Carbon	20
Hydrogen	10
Nitrogen	3
Calcium	2.5
Phosphorus	1.14
Chlorine	0.16
Sulphur	0.14
Potassium	0.11
Sodium	0.10
Magnesium	0.07
Iron	0.01
Iodine	0.014

A Comparison of Elements Present in Non-Living and Living Matter		
Element	**% Weight of Earth's Crust**	**% Weight of Human Body**
Hydrogen (H)	0.14	9.5
Carbon (C)	0.03	18.5
Oxygen (O)	46.6	65.0
Nitrogen (N)	Very little	3.3
Sulphur (S)	0.03	0.3
Sodium (Na)	2.8	0.2
Calcium (Ca)	3.6	1.5
Magnesium (Mg)	2.1	0.1
Silicon (S)	27.7	Negligible

Average Composition of Cells		
S. No.	**A. Inorganic Compounds**	**%**
1.	Water	70 – 90%
2.	Ions (Salts, acids, bases, gases)	1%
B. Organic		
1.	Proteins	10 – 15%
2.	Lipids	2%
3.	Carbohydrates	3%
4.	Nucleic acids	5 – 7%

1. Inorganic compounds

Water - Most abundant substance of all living organisms. It forms about 70-90% of the cell. Water is transparent, colourless and odourless. It has high surface tension, high specific heat, high heat of vaporization pH value of water is 7. The density of water is maximum at 4^0C. It freezes at 0^0C and boils at 100^0C. The molecule of water is composed of 2 atoms of hydrogen and one atom of oxygen linked by covalent bonds. Bond angle is 104^0. Water exists in two forms, free water (about 95%) and bound water (about 5%).

Functions of water - Water is an important structural component. It gives an ideal medium for chemical reactions. It is a **universal solvent**. A number of waste products are eliminated in solution form mainly as urine with the help of water. It keeps the surface of tissues and organs moist. In living organism, water gives a medium for distribution or transportation of living matter. Water works as a dispersion phase in the colloidal system of protoplasm. Its high specific heat prevents temperature hazards due to sudden change.

Water content in different organisms and body parts		
1.	Body of jelly fish	99%
2.	Dormant seed	6%
3.	Bone cells	25 – 40%
4.	Skeleton muscles	75%
5.	Embryo	90 – 95%
6.	Dentine of tooth	10%
7.	Enamel of tooth	5%
8.	Brain cell	90%
9.	Nerve cells	80%

Mineral salts: Salts in protoplasm occur in ionised form. They are responsible for conductivity & irritability. Some important minerals and their functions are given in below table.

	Minerals	**Important functions**
1.	Calcium	Important mineral for formation of bones and teeth. Essential for blood clotting, muscle contraction, membrane permeability and nerve impulse conduction.
2.	Phosphorus	Phosphorus is an important component of the phospholipids of biomembranes and of the nucleotides of nucleic acids (DNA and RNA).
3.	Sulphur	It is a component of two amino acids (cysteine & methionine) which participate in polymerization of some structural proteins.
4.	Iron	Combination of iron with porphyrin pigment yields haem which is a component of haemoglobin of RBC and myoglobin of muscle.
5.	Magnesium	Combination of magnesium with prophyrin yields the green pigment, chlorophyll, of plants.
6.	Iodine	It is component of thyroxine hormone of thyroid gland.
7.	Copper	It is component of haemocyanin which serves as respiratory pigment in certain higher invertebrates.
8.	Manganese	It is a cofactor in metallo enzymes.
9.	Cobalt	It is component of vitamin in B_{12}. Its deficiency may cause anaemia.
10.	Sodium, Potassium and Chloride	These ions are mainly responsible for maintenance of osmolarity of cytosol and extracellular fluids.

Acids & bases : They form buffer system & maintain pH of protoplasm (carbonic acid -bicarbonate buffer) Phosphoric acid (H_3PO_4) is found in nucleic acids and hydrochloric acid (HCl) is found in gastric juice.

Gases : There are four major gases in protoplasm, which remain dissolved in its free water. These four gases are $CO_2 > O_2 > N_2 > H_2$ (Solubility order). CO_2 is used in synthesis of urea and dissociation of oxyhaemoglobin. O_2 is used in the oxidation of the substances. H_2 is used for ETS.

2. Organic Compounds

Mainly four organic compounds are found in acid-insoluble pool i.e. proteins, nucleic acids, carbohydrates and lipids. In organic compounds, the main bonds exist between C–C and C–H. Normally, the organic compounds remain suspended or dissolved in the water of the protoplasm.

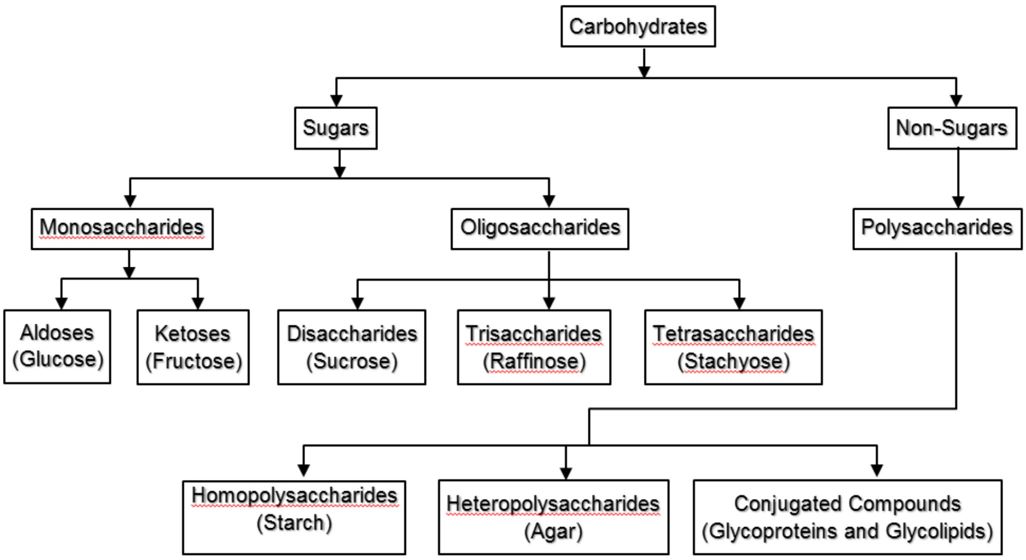
Types of Organic Compounds

There are various types of organic compounds in protoplasm like carbohydrates, amino acids & proteins, lipids, nucleic acid, enzyme and vitamins.

Resonate the Concept

- Hardest material in animal kingdom is enamel.
- Hardest material in plant kingdom is sporopollenin.

CARBOHYDRATES



Carbohydrates are aldehyde or ketone derivatives of polyhydroxy alcohol. These compounds are made up of carbon, hydrogen and oxygen. Ratio of H & O is 2 : 1. A carbohydrate may contain aldehyde or ketone group and is called aldose or ketose, respectively. Certain carbohydrates contain some nitrogen, phosphorous, or sulphur. Carbohydrates are produced by green plants during photosynthesis. About 80 percent of the dry weight of the plant is made up of carbohydrates. Carbohydrates are also called saccharides or sugars.

Resonate the Concept

- Carbohydrate provides 55 - 65% of total energy required.
- **Caloric value** – 4.1 Kcal / gm.
- **Storage site –** mostly liver and muscles.
- **Daily requirement –** 500gm approx.

Types of carbohydrates

Carbohydrates are of three types.

1. Monosaccharides **2.** Oligosaccharides **3.** Polysaccharides

1. Monosaccharides

These are simple sugars. Monosaccharides are the simplest and smallest carbohydrates. These are colourless or white, mostly sweet and crystalline solids which are freely soluble in water. Monosaccharide molecules have the general formula, $C_nH_{2n}O_n$ or $C_n\ (H_2O)_n$. They do not undergo hydrolysis but oxidize to CO_2 & H_2O. They contain 3 to 7 carbons.

Suffix - Ose is used in their nomenclature.

On the basis of nature of functional group, they are classified in two groups.

i. Aldoses: They have aldehyde group (–CHO).

ii. Ketoses: They have ketone group (–C=O).

Classification based on number of Carbon atoms.

A. Trioses: They have 3 carbon atoms, $C_3H_6O_3$ e.g., dihydroxyacetone and glyceraldehyde.

B. Tetroses: Tetroses contain 4 carbon atoms, $C_4H_8O_4$ e.g. erythrose, erythrulose.

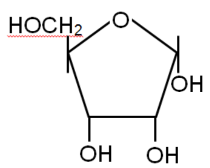
C. Pentoses: They contain 5 Carbon atoms, $C_5H_{10}O_5$ e.g. ribose, deoxyribose, xylose, ribulose, arabinose (Gum arabic).

D. Hexoses: They have 6 carbon atoms, $C_6H_{12}O_6$ e.g. glucose, fructose, galactose and mannose. In aqueous solutions, glucose occurs in cyclic structure.

E. Heptoses: They have 7 carbon atoms $C_7H_{14}O_7$ e.g. sedoheptulose.

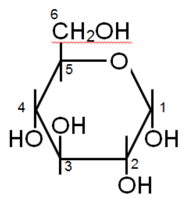
Resonate the Concept
• Haworth gave cyclic structure of monosaccharides.

Furanose:



Five member ring sugar e.g. Ribose ($C_5H_{10}O_5$).

Pyranose:



Six member ring sugar e.g. Glucose ($C_6H_{12}O_6$).

Few Important Monosaccharides

i. Glucose

Glucose is dextrorotatory so it is called “dextrose”. Glucose is aldose sugar having –CHO group. Glucose is found in grapes in abundant quantity so it is also known as “Grape sugar”. Glucose is the main respiratory substrate in the body. Other types of hexoses are converted into glucose in liver.

ii. Fructose

Fructose is levorotatory so it is called “Levulose”. Fructose is a ketose sugar having C=O group. Fructose is found in honey (32 - 40%) and sweet fruits so it is called as “Fruit Sugar”. Fructose is the sweetest natural sugar. Fructose is source of energy for sperms and semen.

iii. Galactose

Galactose is not found in free-state. In mammalian body galactose is found in milk sugar lactose. Galactose is also found as a component of galactolipids i.e. In cerebrosides and gangliosides.

iv. Mannose

Mannose is not found in free-state. It occurs with albumin of egg and in wood as component of hemicellulose.

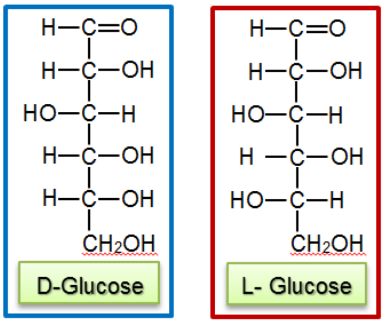
v. Ribose and Deoxyribose

They are found in nucleic acid, ATP, NAD, NADP, FAD, FMN and Vitamin B_2.

Isomerism in Carbohydrates

A. D and L isomerism

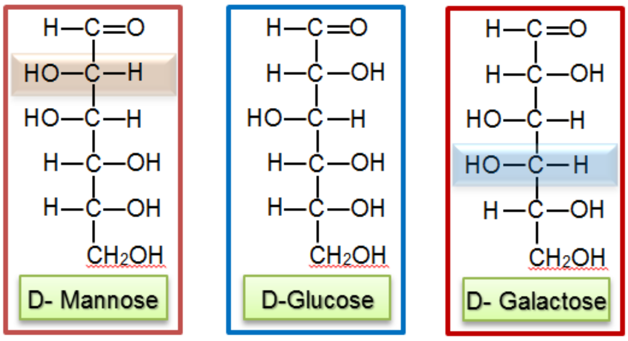
The D and L isomers are mirror images of each other. The special orientation of –OH groups on the carbon atom (C_5 for glucose) that is adjacent to the terminal primary alcohol carbon determines whether the sugar is D- or L - isomer. If the –OH groups is on the right side, the sugar is of D-series and if on the left side, if belongs to L-series.



B. Epimerism

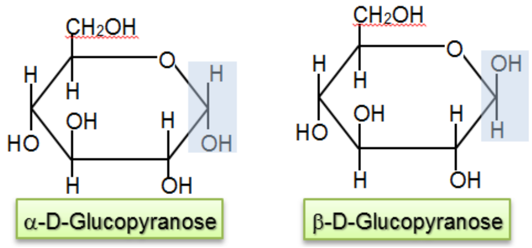
If two monosaccharides differ from each other in their configuration around a single specific carbon (other than anomeric) atom, they are referred to as epimers to each other. For instance, **glucose and galactose are epimers** with regard to carbon 4 (C_4-epimers). This is, they differ in the arrangements of –OH group at C_4. Glucose and mannose are epimers with regard to carbon 2 (C_2– epimers).

The interconversion of epimers (eg.g. glucose to galactose and vice versa) is known as epimerization and a group of enzymes –namely–**epimerases** catalyse this reaction.



C. Anomerism

The α and β cyclic forms of D-glucose are known as *anomers*. They differ from each other in the configuration only around C_1 known as anomeric carbon (hemiacetal carbon). In case of α anomer, the –OH group held by anomeric carbon is on the opposite side of the group $–CH_2OH$ of sugar ring. The reverse is true for β-anomer. The anomers differ in certain physical and chemical properties.



2. Oligosaccharides

Oligosaccharides are formed by condensation of 2 to 10 molecules of monosaccharides. Oligosaccharides on hydrolysis yield 2 to 10 monosaccharide units (monomers). In oligosaccharides, monosaccharides are linked together by glycosidic bonds. Aldehyde or ketone group of one monosaccharide reacts with alcoholic group of another monosaccharide to form glycosidic bond. One molecule of H_2O eliminates during glycosidic bond formation.

Types of Oligosaccharides

A. Disaccharides

They are formed by condensation of two molecules of monosaccharides e.g. sucrose, maltose, lactose.

B. Trisaccharides

They are formed by 3 monosaccharide molecules e.g. raffinose, rhaminose and gentianose.

C. Tetrasaccharides

They are formed by condensation of four molecules of monosaccharides e.g., scorodose and stachyose.

D. Pentasaccharides

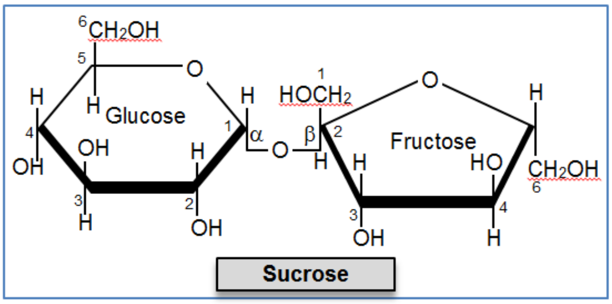
e.g. verbinose, barbacose (Galactose + Galactose + Glucose + Glucose + Fructose).

Few Important Disaccharides

i. Sucrose (Cane Sugar)

Sucrose is obtained from sugar cane and sugar beet, called cane sugar. Sucrose is a commercial sugar. It is the storage product of photosynthesis in plants. Sucrose is formed by the condensation of one molecule each of glucose and fructose with the removal of one molecule of water. (α-D-Glucose + β-L fructose) α, β–1, 2 glycosidic bond is formed between glucose and fructose. It is a non-reducing sugar. Also called invert sugar.

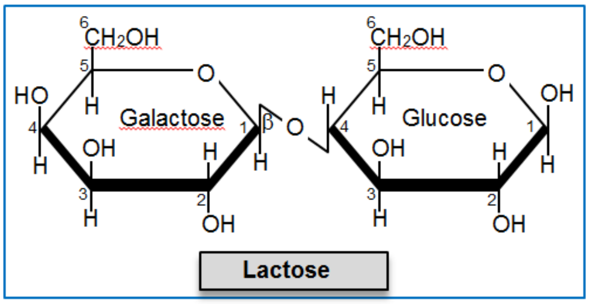
$$\underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Fructose}}{C_6H_{12}O_6} \rightarrow \underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + H_2O$$



Sucrose

ii. Lactose (Milk Sugar)

Lactose or Milk sugar is found naturally in mammalian milk. Lactose is a reducing sugar.

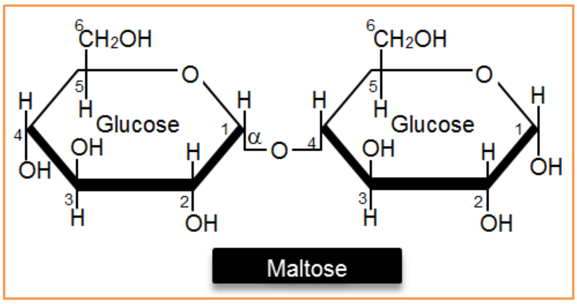


Lactose

Lactose is formed inside mammary glands by condensation of one molecule each of glucose and galactose (β-D glucose + β-D-galactose). Lactose have β-1- 4 glycosidic linkage between glucose and galactose.

iii. Maltose (Malt sugar)

Maltose or malt sugar is found in germinating starchy seeds. Maltose is formed by condensation of two molecules of α-D glucose by α 1, 4 glycosidic bond. It is reducing sugar.



Maltose

3. Polysaccharides

These are complex carbohydrates. They are formed by polymerisation of 11 to thousands of monosaccharide monomers.

$C_6H_{12}O_6)_n \longrightarrow (C_6H_{10}O_5)_n + (H_2O)_{n-1}$

Monosaccharide Polysaccharide

General formula $(C_6H_{10}O_5)_n$. They are tasteless and insoluble in water. Suffix-ans is used in nomenclature. Normally they are called as glycans. In a polysaccharide chain (like glycogen), the right end is called the reducing end and the left end is called non-reducing end.

Depending upon the composition, polysaccharides are of two types.

A. Homopolysaccharides or Homoglycans

Made up of only one type of monosaccharide monomers. For example - starch, cellulose, glycogen, inulin, chitin.

B. Heteropolysaccharides or Heteroglycans

These are formed by condensation of more than one type of monosaccharide monomers. e.g., agar, hemicellulose, arabagalactans, arabaxylans, pectin etc.

Based on function, polysaccharides are grouped into three categories: Storage, structural and mucopolysaccharides.

A. Food storage polysaccharides

They are those polysaccharides, which act as reserve food in the living organisms. The main storage polysaccharides are starch, glycogen and inulin.

i. Starch

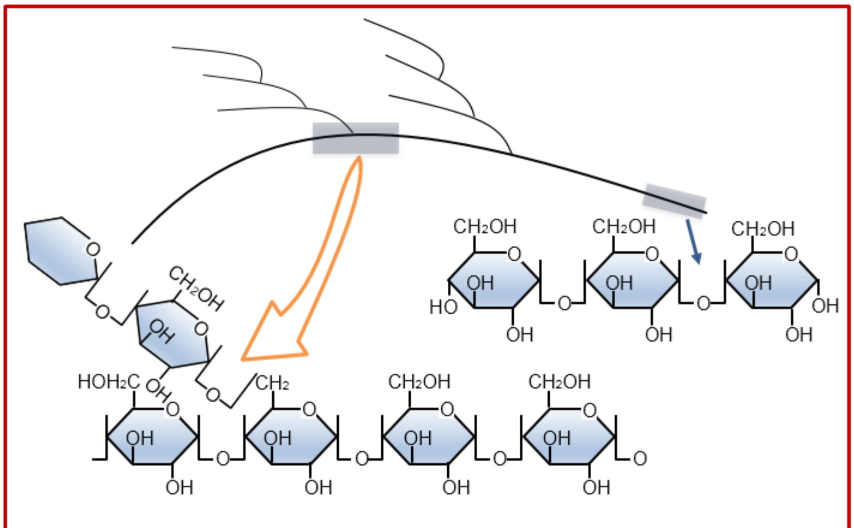
This is the reserve food in plants. It is found in abundance in cereal grains (wheat, rice, maize), legumes (pea, gram, beans), potato, banana etc. Starch consists of two components: amylose and amylopectin (both glucose polymers). Amylose is more soluble in water but amylopectin is insoluble. Amylose have 250-300 glucose units arranged in an unbranched chain by α 1-4 linkage. Amylopectin is a branched chain molecule. Approximately 30 glucose units are linked in one branch by α-1,4 and α-1,6 linkage. Starch can hold I_2 molecules in the helical portion and starch-I_2 is blue in colour.

Starch present in potato contains 20% amylose and 80% amylopectin.

ii. Glycogen

It is a main reserve food in animals, bacteria and fungi. It is also known as animal starch. Glycogen is stored in muscle cells and liver cells. Liver of an adult human may store upto 0.91 kg of glycogen. Glycogen gives red colour with iodine.

It is highly branched polymer with α–1, 4– glycosidic bonds & α –1, 6 – glycosidic bonds.



Diagrammatic representation of a portion of glycogen

iii. Inulin

Linear polymer of fructose units linked with β-1,2 bonds, Inulin is found in roots of Dahalia and Artichoke. It is water soluble polysaccharide. It is not metabolised in human body and filtered through kidney. It is therefore, used in testing of kidney function (glomerular filtration).

B. Structural polysaccharides

i. Cellulose

It is a homopolysaccharide of β-D glucose, having β 1, 4 glycosidic bonds. The chains are unbranched. It is the main structural component of cell wall of plants, some fungi and protists. Tunicin of tunicate (marine chordate) is related to cellulose (also called as animal cellulose) Cellulose is the most abundant organic substance of the plants & also on earth. Cotton fibres have about 90% of cellulose & Wood contains 25-50% of cellulose. Cellulose is fibrous polysaccharide with a high tensile strength. A cellulose molecule consists of an unbranched and linear chain of 6000 or more glucose residues with molecular weight between 0.5 to 2.5 million. Cellulose forms the bulk of human food and most of the herbivores. It cannot be digested by the human beings, because they lack the enzyme cellulase, required to digest cellulose. Cellulose is an important constituent of diet of ruminates such as cows and buffaloes.

Cellulose rich wood is used in production of paper and as fuel. Cellulose containing fibres of cotton, linen and jute are used for textile and ropes. Cellulose nitrate is used in propellant explosives. Cellulose does not contain complex helices and hence cannot hold I_2.

ii. Chitin

Chitin is the second most abundant organic compound in nature. It is present in the exoskeleton of arthropods and in the cell walls of fungi. In fungal walls, the chitin is often known as fungus cellulose. The monomer of chitin is not glucose but nitrogen containing glucose derivative known as N-acetyl glucosamine.

iii. Pectin

It is a heteropolysaccharide composed of sugars arabinose and galactose. Pectin is found in cell wall where it binds cellulose fibrils in bundles. Salts of pectin i.e. Ca and Mg-pectates form middle lamella in plants.

iv. Hemicellulose

It is a mixture of polysaccharides xylans, galactans, arabagalactans and glucomannans. It is found in the cell wall. It is the hardest known carbohydrate.

v. Hyaluronic acid (Animal cement)

It is found in skin, vitreous humour of the eye, the umbilical cord, synovial fluid. It is a linear polymer of disaccharide repeat units linked with the help of β-1, 4 glycosidic bonds. Disaccharides repeat units are D-glucoronic acid and N-acetyl -D- glucosamine.

vi. Chondriotin sulphates

They are found in cornea, cartilage, tendons, skin, heart, saliva etc. The repeating units are disaccharides consisting of glucoronic acid and sulphate ester of N-acetyl galactosamines, linked through a β-1, 4 bond. The disaccharides are linked with each other by β-1, 4 bonds.

vii. Heparin

It is secreted by mast cells in the intestinal mucosa, liver, lung, spleen and kidney. It is an anticoagulant.

viii. Agar-Agar

It is a polysaccharide found in few red algae such as *Gracillaria*, *Gelidium* etc. It is made up of sulphated galactose. It is important as tissue culture medium.

ix. Tunicin

It is cellulose like glycan. It constitutes exoskeleton like covering on Urochordata.

C. Mucopolysaccharides

They contain acidic or aminated polysaccharides formed from galactose, mannose, sugar derivatives and uronic acids. These are jelly like compounds important in packing and connection. Mucopolysaccharides are found in the cell walls of bacteria and in the connective tissues of animals as well as in body fluids. Hyaluronic acid, chondroitin sulphate, agar-agar and heparin are comon mucopolysaccharides.

Functions of carbohydrates

i. They are the primary source of energy. Normally body obtains 58 to 65% of its required energy from the carbohydrate. Glucose acts as most common respiratory substrate.

ii. Ribose & Deoxyribose are used in the formation of RNA, DNA, ATP, NAD, FAD etc.

iii. Starch in plants & glycogen in animals are the stored form of food.

iv. Cellulose is used in the formation of cell wall. Chitin forms exoskeleton in arthropods and few fungal cell wall.

Test your Resonance with concept

1. Callose is polymer of-

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

2. Where is glycogen stored?

(1) Liver and muscles (2) Liver only (3) Muscles only (4) Pancreas

Answers

1. (3) **2.** (1)

PROTEINS

Essential elements in protein are C, H, O, N, (sulphur is also present in less amount). After water, proteins are most abundant compounds in protoplasm (10-15%).

Resonate the Concept

- Different elements in simple proteins have following proportion as Carbon- 50-55%, Hydrogen- 7%, Oxygen- 20-24%, Nitrogen-14-18%, Sulphur- 0.3-0.5%.
- **Calorfic value -** 4 kcal/gm
- **Daily requirement -** 70 - 100gm

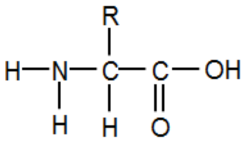
Proteins are polymers of amino acids. They are heteropolymers and not homopolymers.

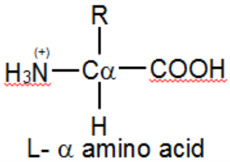
Resonate the Concept

- Collagen is the most abundant protein in animal world.
- Ribulose bisphosphate carboxylase-oxygenase (RUBISCO) is the most abundant protein in the whole of the biosphere and of plant kingdom.

Amino Acids

Amino acids are organic acids. All amino acids contain carboxylic acid group and amino acid group, both linked to a single carbon atom called α carbon.



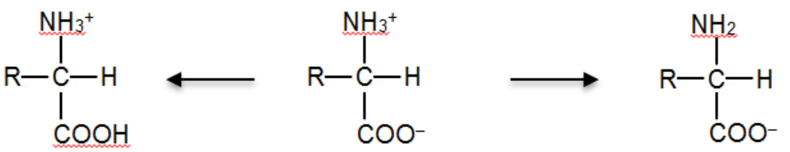


General structure of a amino acid

Number of known amino acids are more than 100. Only 20 amino acids are commonly found in proteins of organisms (Magic 20). These 20 amino acids can be classified into two types.

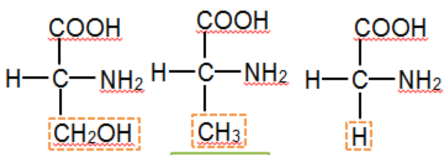
Essential Amino Acids	Non-essential Amino Acids
They are not synthesized in the animal cells. Hence, their presence in the food is essential.	Are those amino acids which are synthesized in animal cells. Hence their presence in the food is not essential.
They are Threonine, Leucine, Lysine, Tryptophan, Phenylalanine, Valine, Isoleucine, Methinonine Semi essential – Arginine, Histidine.	They are glycine, serine, aspartic acid, asperagine, proline, alanine, cysteine, glutamic acid, tyrosine, glutamine.

Semi essential amino acids are those amino acids which are synthesized in animal cells but not in sufficient quantity, thus their presence in food is essential. They are - **Arginine** and **Histidine**. Amino acids are amphoteric compounds which exhibit both the acidic (due to –COOH group) and basic (due to $-NH_2$ group) properties. They are also called as dipolar or zwitter ions.



Cation in acid Zwitterion at isoelectric Anion in alkaline

When R group of such proteinaceous amino acid is a hydrogen, then amino acid is called glycine, if methyl group then alanine amino acid and if hydroxy methyl in place of R group then amino acid is serine and their structures are

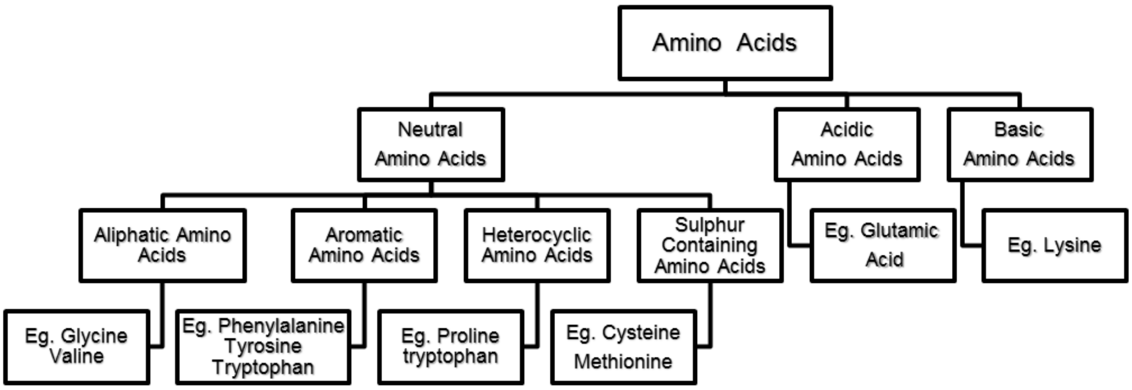


Serin Alanin Glycin

Classification of Amino Acids

Amino acids can be classified into three groups depending on their NH_2 or –COOH group number.

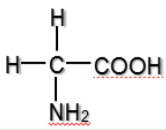
1. Neutral **2.** Acidic and **3.** Basic



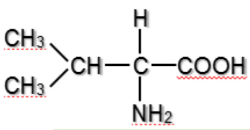
1. Neutral amino acids

This comprises the largest group and can be further subdivided into aliphatic, aromatic, heterocyclic and sulphur containing amino acids. They have equal number of amino and carboxylic acid groups.

A. Aliphatic Amino Acids

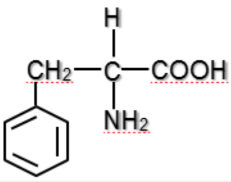


Glycine (Gly) G
(Aminoacetic acid)

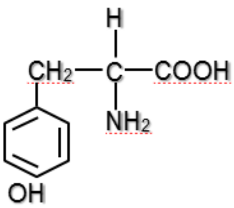


Valine (Val) V
(α-aminoisovaleric acid)

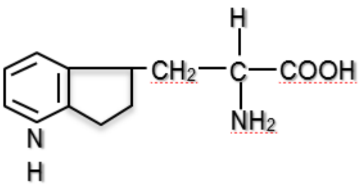
B. Aromatic Amino Acids



Phenylalanine (Phe) F
(α-amino, β-phenyl propionic acid)

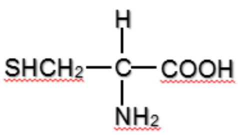


Tyrosine (Tyr) Y
(p-hydroxyphenylalanine)



Tryptophan (Trp) W
(α-amino, β -indole propionic acid)

C. Heterocyclic Amino Acid

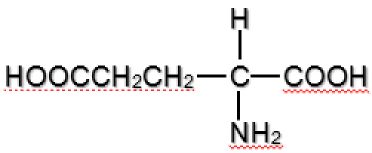


Cysteine (Cys) C
(α-amino, β-mercapto propionic acid)

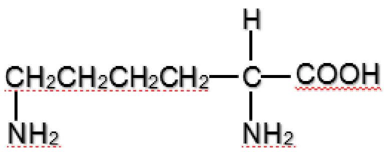
D. Sulphur containing amino acids

e.g. Cysteine & methionine

2. Acidic Amino Acids



Glutamic acid (Glu) E
(α-aminoglutaric acid)



Lysine (Lys) K
(α, ε-diaminocaproic acid)

Structure of proteins

1. Primary Structure

A straight chain of amino acids linked by peptide bonds forms primary structure of proteins. This structure of proteins is most unstable. Newly formed proteins on ribosomes have primary structure.

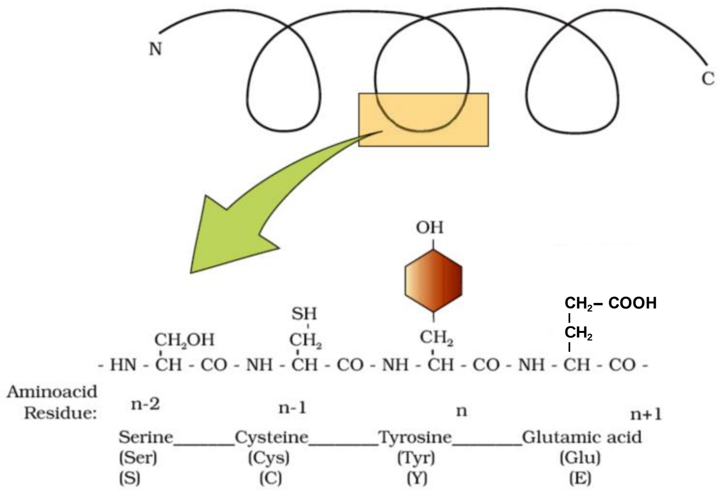


Fig. Primary structure of a portion of a hypothetical protein. N and C refer to the two terminal of every protein. Single letter codes and three letter abbreviations for amino acids are also indicated

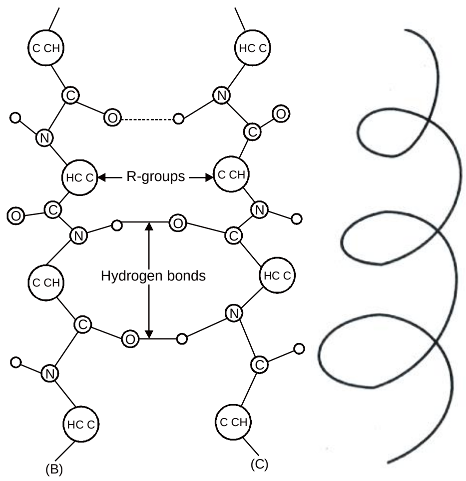
2. Secondary Structure

Protein molecules are spirally coiled. In addition to peptide bonds, amino acids are linked by hydrogen bonds formed between oxygen of carboxylic group and hydrogen of amide group.

This structure is of two types

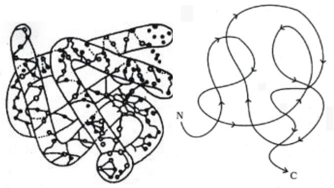
A. **α - Helix:** Right handed rotation of spirally coiled chain with approximately 3½ amino acids in each turn. This structure has intramolecular hydrogen bonding i.e. between two amino acids of same chain e.g. Keratin, Myosin, Tropomyosin.

B. **β-Helix or β-pleated Structure:** Protein molecules have zig-zag structure.Two or more protein molecules are held together by intermolecular hydrogen bonding, e.g. fibroin (silk).



SECONDARY STRUCTURE OF PROTEIN

Proteins of secondary structure are insoluble in water and fibrous in appearance. Keratin is a fibrous, tough and resistant to digestion, sclero protein. Hardness of keratin is due to abundance of cysteine amino acid in its structure.



TERTIARY STRUCTURE OF PROTEIN

3. Tertiary structure

Proteins of tertiary structure are highly folded to give a globular appearance.

Mostly are water soluble.

This structure of protein has following bonds-

A. Peptide bonds

B. Hydrogen bonds

C. Disulphide bonds

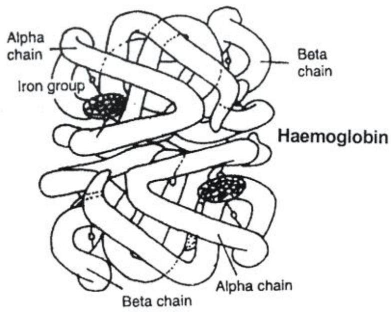
D. Hydrophobic bonds

E. Ionic bonds

The tertiary structure of the protein molecules are so arranged as to hide non-polar sides inside and expose the polar side chains. Majority of proteins and enzymes in protoplasm exhibit tertiary structure.

4. Quaternary Structure

Two or more poly peptide chains of tertiary structure unite by different types of bonds to form quaternary structure of protein. Different polypeptide chains may be similar (lactic dehydrogenase) or dissimilar types (Haemoglobin, insulin). Quaternary structure is most stable structure of protein.



QUATERNARY STRUCTURE OF PROTEIN

Adult human haemoglobin consists of 4 subunits (two of these are identical to each other). Hence, two subunits of α type and two subunits of β type.

Properties of proteins

Proteins are large sized molecules.

Many proteins form colloidal solutions.

A protein may bind as well as react with a variety of chemicals.

Proteins cannot pass through cell membranes.

The disruption of bonds of tertiary proteins structure is called denaturation.

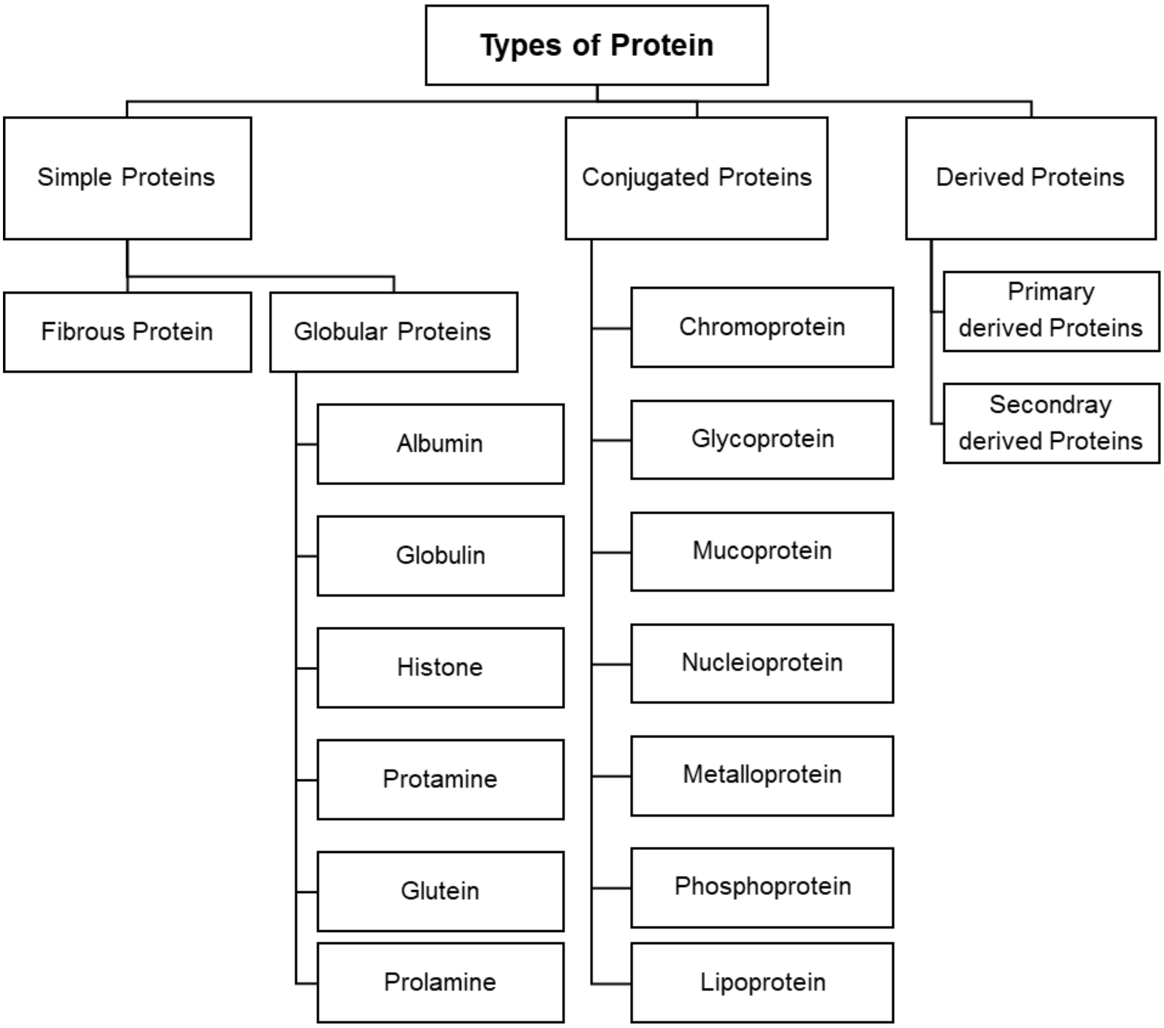
Types of Proteins

Proteins are of three types-

1. Simple proteins

2. Conjugated proteins

3. Derived proteins



1. Simple Proteins

They are made up of only amino acids. They are of two types - Fibrous and globular proteins.

A. Fibrous Proteins

They are thread like structural proteins. Fibrous proteins generally contain secondary structure and are insoluble in water e.g., collagen of connective tissue, actin and myosin of muscles, keratin of scales, feathers, hairs, claws, nails, horns and hoofs, silk of spider web.

B. Globular proteins

They are spherical non-contractile proteins which may be enzymatic or non-enzymatic. They have tertiary or quaternary structure. Smaller globular proteins are usually soluble in water and are not coagulated by heat e.g., histones. Egg albumin, serum globulins and glutelins are examples of large globular proteins, which get coagulated by heat.

i. **Albumins:** They are water soluble and occur as serum albumin in blood plasma and loctoalbumin in milk.

ii. **Globulins:** They are soluble in weak acids and alkaline solution but insoluble in water e.g. lactoglobulin in milk.

iii. **Histones:** They are water soluble and are rich in lysine and arginine (amino acids). They occur in eukaryotic DNA.

iv. **Protamines :** These water soluble arginine rich proteins occur in DNA of spermatozoa of some fishes e.g. salmine in Salmon.

v. **Gluteins:** They occur only in plants like wheat e.g., glutenin.

vi. **Prolamines:** They occur only in plants e.g., zein in corn and gliadin in wheat.

2. **Conjugated proteins**

These are formed by the binding of a simple protein with a non-protein called the prosthetic group.

These are of following types-

i. **Chromoproteins :** These proteins contain pigment (coloured) as prosthetic group e.g., haemoglobin, haemocyanin, cytochrome, flavoprotein and rhodopsin.

ii. **Glycoproteins :** Contain protein + carbohydrate less than 4% eg., plasma glycoprotein secreted from liver and immunoglobulin produced by lymphocytes.

iii. **Mucoprotein** : They have carbohydrate more than 4% e.g., Muerins of bacteria cell wall, ossomucoid in bones, tendenomucoid in tendons, chondromucoid in cartilage. Various mucoproteins are found in vitreous humor, synovial fluid etc.

iv. **Nucleoproteins :** Contain protein + nucleic acid. e.g., histone and non-histone protein join with DNA to make chromosomes.

v. **Metalloproteins :** Contain protein + metal ions e.g., Arginase (Mn & Mg), Carbonic anhydrase (Zn), Tyrosinase (Cu), Xanthine oxidase (Mo) etc.

vi. **Phosphoproteins :** Contain protein + phosphate e.g., casein in milk and ovo-vitellin in eggs.

vii. **Lipoproteins :** Contain protein + lipids e.g., high density lipoprotein (HDL), low density lipoprotein (LDL) and very low density lipoprotein (VLDL). Mostly important in membranes.

3. **Derived proteins**

These are denatured or hydrolysed proteins.

Primary derived proteins: Denatured products e.g. Fibrin, Myosan

Secondary derived proteins: Digestion products of proteins eg. Peptones, Proteose, di & tripeptide.

Functions of Proteins

i. **Structural Proteins**

Many proteins serve as building material of cells and tissues. Some proteins form supporting structures e.g., elastin of ligaments, collagen of tendons, cartilages, cartilage bone and connective tissue.

Some Proteins and their Functions	
Protein	**Functions**
Collagen	Intercellular ground substance
Trypsin	Enzyme
Insulin	Hormone
Antibody	Fights infectious agents
Receptor	Sensory reception (smell, taste, hormone, etc.)
GLUT – 4	Enables glucose transport into cells

ii. **Protective Structure:** Fibrous protein keratin is the major constituent of external protective structure of animals like hair, feather, horny layer of skin, nails, claws, hoofs etc.

iii. **Enzymes:** Many proteins function as enzymes to catalyse biochemical reactions.

iv. **Carrier proteins:** Some proteins act as carriers which bind and transport specific molecules across a membrane or in a body fluid. Haemoglobin transports oxygen in the body, α-globulin of blood carries thyroxine, bilirubin and β-globulin transports vitamin A, D and K.

v. **Receptor proteins:** A number of proteins present on the external surface of cell membrane act as receptor molecules.

vi. **Hormones:** Some hormones are proteinaceous e.g., insulin.

vii. **Contractile proteins:** Myosin and actin make the muscle fibres contractile to bring about movements and locomotion.

viii. **Defence:** Some proteins act as antibodies that participate in the defence mechanism of the body.

ix. **Storage proteins:** These occur in milk, eggs and seeds to nourish the young ones. Iron storing protein commonly found in animal tissue is ferritin.

x. **Protein Buffers:** Proteins also help in maintaining a balance of acidity and alkalinity by combining with excess acids and bases.

xi. **Visual pigments:** Rhodopsin and iodopsin are protein pigments.

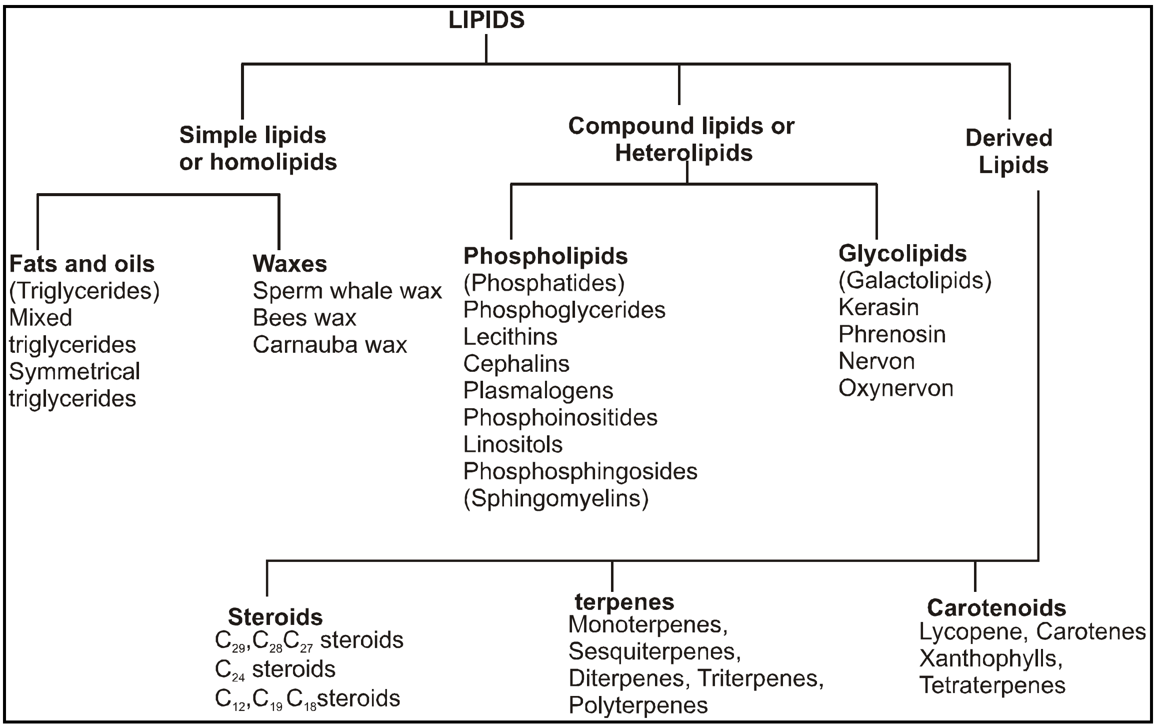
xii. **Toxins :** Many toxins of microbes, plants and animals are proteins.

xiii. **Blood clotting proteins :** The proteins fibrinogen and thrombin help in blood clotting to check bleeding from injuries.

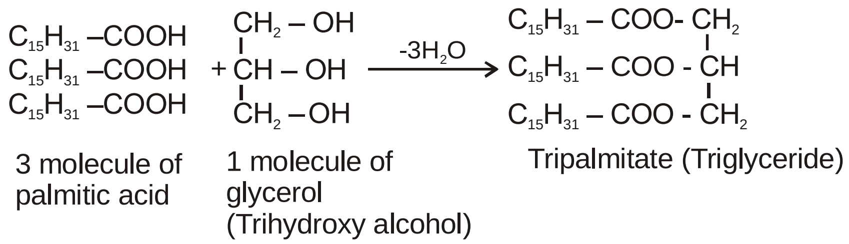
xiv. **Sweetest substance:** Monellin, a protein derived from an African berry is 2000 times sweeter than sucrose.

xv. **Repressor:** Most of the repressors that regulate genes (operon concept) are proteins in nature.

LIPIDS



They are made of carbon, hydrogen and oxygen. Hydrogen and Oxygen ratio is never same as H_2O. The number of oxygen atoms in a lipid molecule is always less than the number of hydrogen and carbon atoms. Sometimes small amount of phosphorus, nitrogen and sulphur are also present. Lipids are esters of fatty acids and related substances.



They include substances like cooking oil, butter, ghee, natural rubber, cholesterol etc. Lipids exhibit a variety of structures but have certain common characteristics. Lipids are insoluble in water, but soluble in organic solvents like chloroform, benzene and acetone.

The basic components of all lipids are fatty acids and many lipids have both glycerol (tri hydroxy propane) and fatty acids.

Structure of Glycerol

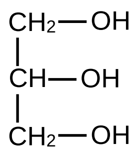
Calorific value - 9 Kcal/gm

Storage site – subcutaneous fat, adipose cells

Daily requirement – 50gm

Lipids in protoplasm are about 2%. These are present as small globules in protoplasm.

They do not undergo further polymerisation.



Glycerol

Fatty Acids

Fatty acids are organic acids with a hydrocarbon chain ending in carboxylic group (–COOH).

The hydrocarbon chains of fatty acids may possess straight or ring structure.

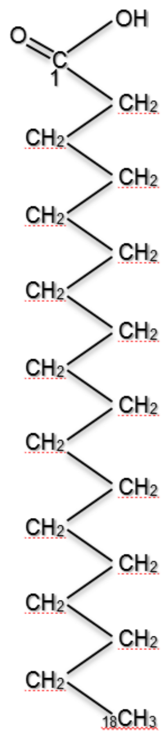
Most fatty acids have an even number of carbon atoms between 14 and 22, mostly 16 or 18.

Plants and few animals can synthesise all types of fatty acids.

Some animals including man cannot synthesise few fatty acids eg. linoleic acid, linolenic acid and arachidonic acids. These fatty acids are called essential fatty acids (EFA). They obtain these fatty acids through edible oils eg. sunflower, groundnut, cotton seed, coconut oils etc.

Fatty acids are of two types:

i. Saturated fatty acids **ii.** Unsaturated fatty acids



Stearic Acid

1. Saturated Fatty Acids

They do not have double bonds in their carbon chains. They have higher melting points and are solid at room temperature. Saturated fatty acids have general formula $C_nH_{2n}O_2$.

The most common fatty acids are palmitic acid ($C_{16}H_{32}O_2$) or $CH_3(CH_2)_{14}COOH$ or $C_{15}H_{31}$–COOH and stearic acid ($C_{18}H_{36}O_2$) or $CH_3(CH_2)_{16}COOH$ or $C_{17}H_{35}$–COOH

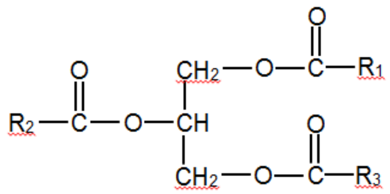
Animals that live in warm climate have large quantity of saturated fatty acids.

2. Unsaturated Fatty Acids

They have one or more double or triple bonds in their carbon chains. Most common unsaturated fatty acids are oleic acid ($C_{18}H_{34}O_2$), linoleic acid ($C_{18}H_{32}O_2$) and arachidonic acid ($C_{20}H_{32}O_2$). (Most essential fatty acids). The unsaturated fatty acids have lower melting points and are liquid at room temperature. More unsaturated fatty acids are found in higher plants and in animals that live at low temperature. In hydrogenation, unsaturated fatty acids are changed to saturated and the oil becomes a solid fat.

Resonate the Concept

- Oils have lower melting point (e.g., gingely oil) and hence remain as liquid in winters.
- The fatty acids are found esterified with glycerol. They can be monoglycerides, diglycerides and triglycerides.



Structure of Triglyceride
(R_1, R_2 and R_3 are fatty acids)

Classification of lipids

Bloor (1943) classified lipids into three types-simple, compound and derived.

1. Simple Lipids

Simple lipids are formed of fatty acids and organic alcohol only.

Simple lipids are of following types-

A. Neutral or true fats- (Glycerides and triglycerides)

Fats are esters of fatty acid and glycerol. Each molecule of glycerol can react with three molecules of fatty acids. Fatty acid (3 molecules) + glycerol (one molecule) $\rightarrow$ Lipid (one molecule) + water (three molecule). Triglycerides are the most common fats in cells. Mono-and di-glycerides occur as intermediates in certain biosynthetic reactions. The three fatty acids are similar only in few fats. They are called pure fats. Most fats have dissimilar or two of the three fatty acids are similar. They are called mixed fats (e.g., butter).

Depending on the physical nature, fats are differentiated into oils and hard fats.

i. Oils are generally liquid at room temperature. Oils are rich in unsaturated fatty acids and short chain fatty acids. e.g., groundnut oil, rape seed oil, mustard oil. The oils having a tendency to solidify are called drying oils.

ii Hard fats are solid at room temperature. Hard fats contain long chain saturated fatty acids and have high melting point e.g., animal fat.

B. Waxes

Waxes are highly insoluble esters of long-chain fatty acids and monohydroxy alcohol. Waxes are esters of fatty acids of high molecular weight with alcohol except glycerol. Waxes have a higher melting point than neutral fats. Sebaceous glands of mammalian skin secrete waxy sebum which acts as a lubricant to keep the hair and skin soft.

The sebum secreted by skin glands of wooly mammals is commonly called lanolin or “wool oil”. Ceruminous and sebaceous glands of the skin that covers the external ear passage in mammals secretes ear wax. Spermaceti, is a wax found in skull of whale & dolphin. Honey bees construct their bee hives with bees wax (myricyl palmitate) secreted by their abdominal glands. Paraffin wax is obtained from petroleum. Candles are made of paraffin wax and stearic acid. Carnauba wax (myricyl cerotate) is obtained from leaves of carnauba palm.

2. Compound Lipids

The compound lipids contain fatty acids, alcohols and other compounds as phosphorus, aminonitrogen, carbohydrates. Compound lipids are of following types-

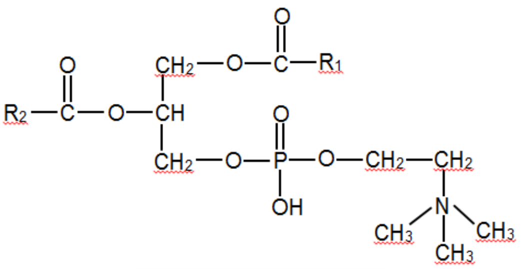
A. Phospholipids (Fatty acids + Glycerol + H_3PO_4 + Other compound)

These are triglyceride lipids in which one fatty acid is replaced by a phosphate group. Some phospholipids also have a nitrogenous compound such as choline (in lecithin), ethanolamine (in cephalin). Phospholipids are amphipathic carrying both hydrophillic (water attracting) polar and hydrophobic (water repellant) non-polar groups & because of this property they form bilayers. In aqueous medium, phospholipid molecules arrange in a double layered membrane or lipid bilayer.

Few examples of phospholipids are-

i. Lecithin

It is formed by one molecule of glycerol, two molecules of fatty acids and one molecule of phosphoric acid. Choline is attached with phosphoric acid. Lecithin is found in yolk, brain, soyabean membrane. It also acts as lipid carrier in blood.



Phospholipid (Lecithin)

ii. Cephalin: It is like lecithin but choline is replaced by amino ethyl alcohol(Ethanol amine). Cephalin is found in yolk, blood platelets and nerve tissues.

iii. Plasmalogens : Occur in vertebrate cardiac muscles, ciliate protists and certain cells of invertebrates. The plasmalogen is platelet-activating factor (PAF) which is released from basophils (WBC in vertebrates) to stimulate the blood platelets.

iv. Sphingolipid : It is similar to lecithin but has sphingosin in place of glycerol. Sphingomyelins are important for myelin sheath.

B. Glycolipids

They contain fatty acids, and amino alcohol and one or more simple sugars. The glycolipids are components of cell membranes, myelin sheath of nerve fibres and membrane of chloroplasts. Animal cells contain cerebrosides and gangliosides.

i. **Cerebrosides** are important lipids of white matter of brain and myelin sheath of the nerve fibres.

ii. **Gangliosides** are found in grey matter of the brain, membrane of RBCs, spleen. They also have neuraminic acid.

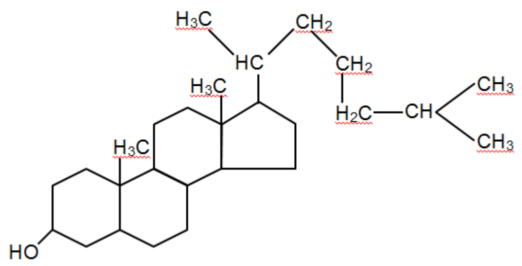
C. Lipoproteins: They are composed of lipids (mainly phospholipids) and proteins. They are present in the blood, milk and egg yolk.

D. Cutin and suberin: Cutin is a complex lipid found in plant cell walls and cuticle. It binds epidermal cells and reduces transpiration. Suberin is a mixture of fatty substances. It is present in the wall of cork cells and endodermal cells. It makes cell wall strong and impermeable to water.

3. Derived lipids

These lipids are obtained by the hydrolysis of simple or compound lipids. Although these are the products of hydrolysis of lipids, but even then they have some properties of lipids. Derived lipids are of following types.

A. Steroids: Important steroids which have ketone group are called as sterone eg. Testosterone, while sterols have – OH group eg. cholesterol. Sterols are lipids of high molecular weight e.g., cholesterol, ergosterol, stigmasterol, campesterol etc. Cholesterol ($C_{27}H_{45}OH$) is the common sterol found in many animals, human beings and some plants e.g, Potato. Cholesterol and its esters are insoluble in water. Some steroids are hormones like progesterone, estrogen, testosterone and corticosterone. Cholesterol forms vitamin D on exposure to ultraviolet rays. Cholesterol in an essential component of animal cell membrane and the cell membrane of mycoplasmas. Ergosterol and stigmasterol are found in plants and fungi.



STRUCTURE OF CHOLESTEROL

B. Terpenes : They are lipid like hydrocarbons formed of isoprene (C_5H_8) units. They are major components of 'essential oils' produced by certain plants. The terpenes include certain fat soluble vitamins like A, E, K, carotenoids and certain coenzymes like coenzyme Q.

C. Prostaglandins : They are hormone like compounds derived from 20 carbon polysaturated fatty acids such as arachidonic acid. They are present in human seminal fluid, testis, kidney, placenta, uterus, stomach, lung, brain and heart. The main function of prostaglandins is binding of hormones to membranes of target cells.

Functions of Lipids

i. **Food material:** Lipids provide food, highly rich in calorific value. One gram lipid produces 9 kilocalories of energy.

ii. **Food reserve:** Lipids are insoluble in aqueous solutions, and therefore can be stored readily in the body as a food reserve.

iii. **Structural components:** They make an important constituent of the cell membrane.

iv. Heat insulation: The fats are characterised for their high insulating capacity. Great quantities of fat are deposited in the sub-cutaneous layers in aquatic mammals such as whale and in animals living in cold climates.

v. Fatty acid absorption: Phospholipids play important role in the absorption and transportation of fatty acids & fat soluble vitamins.

vi. Hormone synthesis: The sex hormones, adrenocorticoids, cholic acids and also vitamin D are all synthesised from cholesterol, a steroidal lipid.

vii. Vitamin carriers: Lipids act as carriers of natural fat-soluble vitamins such as vitamin A, D and E.

Test your Resonance with concept

1. In infants of under 6 months of age, deficiency of protein may cause -

(1) Marasmus (2) Kwashiorkar (3) Rickets (4) Galactosemia

2. Cholesterol is synthesized in

(1) Pancreas (2) Brunner's gland (3) Spleen (4) Liver

3. Fats in the body are formed when

(1) Glycogen is formed from glucose

(2) Sugar level becomes stable in blood

(3) Extra glycogen storage in liver and muscles is stopped

(4) All are correct

Answers

1. (1) **2.** (4) **3**. (3)