BIOMOLECULES

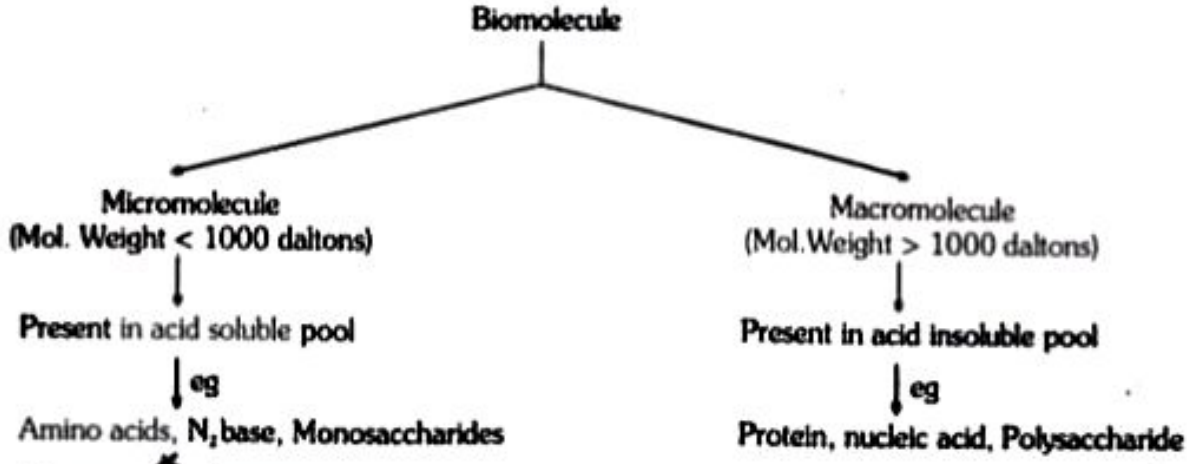
INTRODUCTION

All living organisms are made up of the same elements and compounds. If we perform an analysis of a plant tissue, animal tissue or a microbial paste, carbon, hydrogen, oxygen and several other elements are obtained. The same analysis made on a non-living matter like a piece of earth's crust, gives a list of similar chemicals. A close examination reveals that the relative abundance of carbon and Hydrogen with respect to other elements is higher in living beings than in earth's crust.

HOW TO ANALYSE CHEMICAL COMPOSITION

- Various biomolecules present in a living tissue (like a vegetable or a piece of liver) can be studied by their chemical analysis.
- Take a living tissue and grind it in **trichloroacetic acid** (Cl_3CCOOH) using a mortar and pestle. We obtain a thick slurry.
- When we strain this slurry through cheese cloth or cotton, it gives two fractions.
- One is called filtrate or acid soluble pool having thousands of organic compounds.
- Other fraction is called retentate or acid insoluble pool containing proteins, nucleic acid, polysaccharides etc.
- The acid soluble pool contains chemicals with small molecular mass of 18–800 daltons approximately. They are called **micromolecules** or **biomicromolecules.** They include amino acids, sugars, nucleotides etc.
- The acid-insoluble fraction contains organic compounds that have molecular weights in the range of ten thousand daltons and above. They are known as **macromolecules** or **biomacromolecules.** They include **polysaccharides, proteins, nucleic acids.**
- *Lipids are not strictly macromolecules, their molecular weight do not exceed 800 Da, but they come under the macromolecular fraction because when we grind a tissue, cell membrane and other membrances are broken into pieces and form vesicles which are not water soluble (lipids are also present in structures like cell membrane and other membranes).
- The acid-soluble fraction represents roughly the cytoplasmic composition (without organelles), while the acid-insoluble fraction represents the macromolecules of the cytoplasm and cell organelles. **The two fractions together** represent the entire chemical composition of living tissues or organisms.

Biomolecule→ All the carbon compound that present in living tissue.



Special note : Lipids are micromolecules but obtained under macromolecular fraction due to their insoluble nature in aqueous medium of a cell.

Table : Average composition of cells

Component	% of the total cellular mass
Water	70-90
Proteins	10-15
Carbohydrates	3
Lipids	2
Nucleic acids	5-7
Ions	1

- All carbon compounds that we get from living tissue can be called - Biomolecules.
- Inorganic elements and compounds are also present in the living organisms which can be known with the help of **'ash'** analysis technique.
- A small amount of a living tissue (e.g. Leaf or liver and this is called wet weight) is weighed and dried. All the water evaporates.
- When the tissue is fully burnt, the carbon compounds are oxidised to gaseous form like CO_2, water vapour are removed and the remnant is called 'ash'. This ash contains many inorganic elements like calcium, magnesium etc.
- In the acid-soluble fraction - inorganic compounds like sulphates, phosphates etc are also present.
- Elemental analysis gives composition of living tissue in the form of O, C, H, N etc.
- Analysis of compounds gives an idea of the kind of organic and inorganic constituents as mentained in the table.

Table : A comparison of elements present in non-living and living matter

Element	%weight of	
	Earth's crust	Human body
Hydrogen (H)	0.14	0.5
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 (Si)	27.7	Negligible

Table : A list of representative inorganic constituents of living tissues.

Component	Formula
Sodium	Na^+
Potassium	K^+
Calcium	Ca^{++}
Magnesium	Mg^{++}
Water	H_2O
Compounds	$NaCl, CaCO_3$, PO_4^{3-}, SO_4^{2-}

- From a biological point of view we can classify the biomolecules into **micromolecules** and **macromolecules**.
- Water is the most abundant chemical in living organisms.

PRIMARY AND SECONDARY METABOLITES

- Living organisms produce thousands of organic compounds (biomolecules) including amino acids, sugars, chlorophylls, haems etc. these are required for their basic or primary metabolic processes like photosynthesis, respiration, protein and lipid metabolism etc. these are called **primary metabolites.**
- Many plants, fungi and microbes of certain genera and families synthesize a number of organic compounds (biomolecules) which are not involved in primary metabolism and seem to have no direct function in growth and development of organisms. Such compounds are called **secondary metabolites.**
- Thus, primary metabolites have identifiable functions and play known roles in normal physiological processes. The functions or role of secondary metabolites in host organisms are not understood. However many of them are useful to human welfare (e.g., rubber, drugs, spices, scents and pigments).

Table : 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

COMPOUNDS OF PROTOPLASM

Although some elements occur in protoplasm as free ions but mostly two or more elements are variously combined to form different kinds of compounds.

WATER :

(1) It is a best solvent in nature, it forms the fluid matrix of protoplasm. All other constituents of protoplasm are its solutes.

(2) It itself participates in certain types of chemical reactions particularly in the hydrolytic breakdown of complex compounds.

(3) Of total water, 95% water is free water and 5% water occurs as bound water.

(4) In animal kingdom - Hardest material : Enamel

(5) In plant kingdom - Hardest material : Sporopollenin

SALTS :

(1) These help in formation of linkage or chemical bonds. Such type of linkage is called as **"Salt linkage".**

(2) Some ions also act as co-factor :

Zn^{+2} – Carbonic anhydrase

Cu^{+2} – Tyrosinase [CBSE 2004]

(3) Some other functions of ions :

Ca^{+2} ion – Blood clotting, Bone formation

– Most abundant mineral element in animal body

ORGANIC COMPOUNDS OF PROTOPLASM :

CARBOHYDRATES

→ Main source of energy.

→ First respiratory substrate – carbohydrate

→ Compounds of Carbon, Hydrogen and Oxygen with ratio of H and O is 2:1, so they are also called as **hydrates of carbon**.

→ Generalised formula of carbohydrates is $C_x(H_2O)_y$.

→ Chemically all carbohydrates are polyhydroxy aldehyde or ketones.

→ Simple carbohydrates which are soluble in water and sweet in taste are called **"Sugar"**.

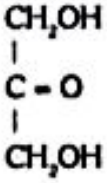
→ Carbohydrates are main source of energy in body. In a normal man 55-65% of energy is available to him is in the form of carbohydrates present in his diet.

CLASSIFICATION OF CARBOHYDRATES :

On the basis of number of saccharide units obtained upon hydrolysis, Carbohydrates are classified as Monosaccharides, Oligo saccharides and Polysaccharides.

A. MONOSACCHARIDES

1. They are simplest sugars which can not be further hydrolysed.
2. In their generalised formula x is mostly equal to y i.e. number of Carbon and Oxygen atoms same.
3. First step of oxidation – Phosphorylation
4. All monosaccharides occur in d and l form, except the Dihydroxy acetone.

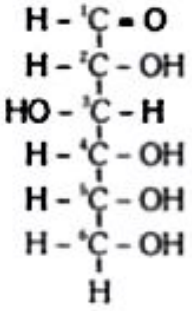


Dihydroxy acetone

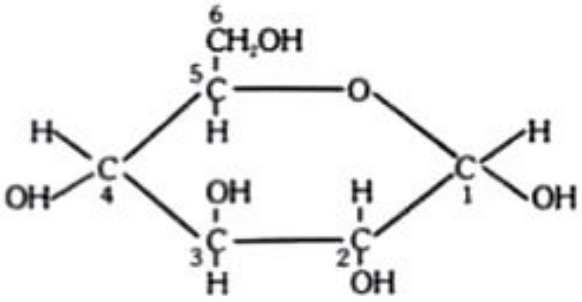
5. The structure of saccharides is either ring or straight chain.
6. A six membered ring is known as **pyranose** and five membered ring is **furanose**.

Pyranose and furanose names were given by **"Haworth."**

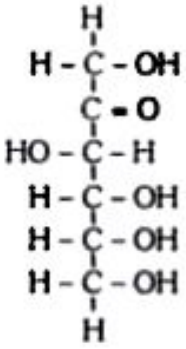
7. **Anomer** – In aqueous solution, Glucose occurs in cyclic structure. In anomers of glucose, position of –H and –OH groups are changed on C_1 carbon atom.



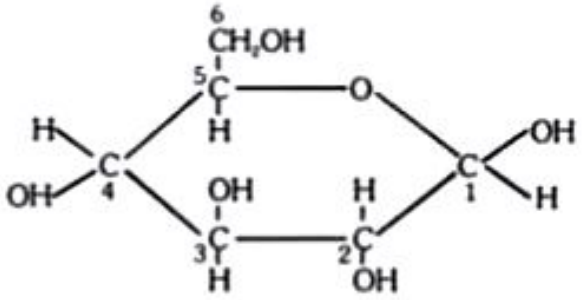
Glucose (Straight chain)



α-Glucose (Pyranose structure)



Fructose (Straight chain)



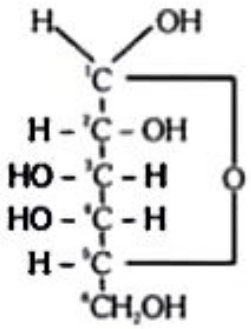
β-Glucose

Epimer : Isomer formed as a result of interchange of the –OH and –H groups on carbon atom 2, 3 and 4 of glucose, are known as epimer.

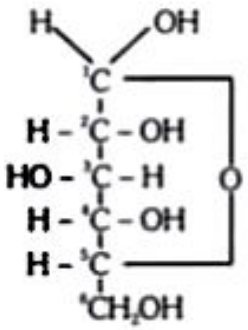
Epimer of Glucose :

Mannose (Difference on C_2 carbon)

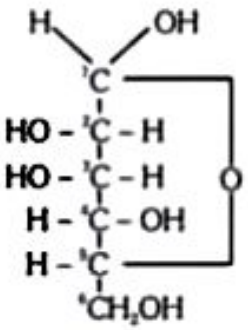
Galactose (Difference on C_4 carbon)



Galactose



Glucose



Mannose

- Monosaccharides with free aldehyde group are termed as ***Aldoses*** (PGAL, Erythrose, Ribose, Arabinose, Deoxyribose, Glucose, Galactose, Mannose).
- While monosaccharides with free ketone group are called ***ketoses*** (DHAP, Erythrulose, Ribulose, Xylulose, Fructose, Sedoheptulose).

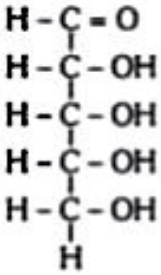
All monosaccharides are **"reducing sugars"** as their free aldehyde or ketone groups are capable of reducing Cu^{++} to Cu^{+}.

This property is the basis of Benedict's test or fehling's test used to detect the presence of glucose in urine.

Classification of monosaccharides on the basis of number of carbons :

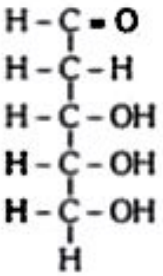
1. **Trioses :** Number of carbons = 3 (Simplest monosaccharide)
   - Common formula = $C_3H_6O_3$
   - e.g. DHAP , PGAL
2. **Tetroses :** Number of carbons = 4
   - Common formula = $C_4H_8O_4$
   - e.g. Erythrose , Erythrulose
3. **Pentose :** Number of carbons = 5
   - Common formula = $C_5H_{10}O_5$
   - e.g. Xylose
     Xylulose
     Deoxyribose
     Arabinose
     Ribose
     Ribulose

Ribose



- Present in RNA, ATP, FAD, FMN, NAD
- Molecular formula = $C_5H_{10}O_5$

Deoxyribose



- Present in DNA
- Molecular formula = $C_5H_{10}O_4$ (Exception)

4. **Hexoses :** Number of carbons = 6

   Common formula = $C_6H_{12}O_6$

   e.g. Glucose
   Fructose
   Galactose

Glucose : It is abundant in grapes so known as grape sugar.

- It is abundant in blood also so known as blood sugar.
- Main respiratory substance.
- It rotates PPL in right (clockwise) direction so it is dextrorotatory and also known as dextrose.

Fructose :

- Sweetest carbohydrate
- More abundant in honey and sweet fruits so also known as fruit sugar.
- Rotates PPL in left (anti-clockwise) direction so it is laevorotatory and also known as 'Laevulose'.

Galactose :

- Most abundant in brain and nervous tissue so called as 'brain sugar'.
- It never occurs in free form. It always occurs as a component of some compounds.

e.g. Lactose

5. **Heptoses :** Number of carbons = 7 (Largest monosaccharide)
   Common formulae = $C_7H_{14}O_7$
   e.g. Sedoheptulose

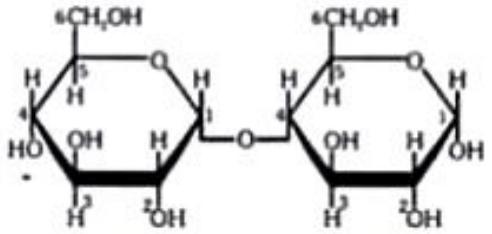
B. OLIGO - SACCHARIDES

Oligo – Saccharides are those carbohydrates which 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 (dehydration synthesis). Direction of glycosidic bond is mostly 1'-4".

When another monosaccharide unit is fructose then the direction of linkage is 1'-2". (Non reducing sugars). For e.g. Sucrose

Disaccharides – composed of two monosaccharide units. e.g. Maltose, Sucrose, Lactose, Trehalose.

- All disaccharides are water soluble and sweet in taste, so they are known as **sugar**.



Maltose

(I) Maltose

- Maltose is commonly called **malt sugar**. It is intermediate compound in starch digestion. Maltose has 1'-4" glycosidic linkage between α -D glucose and α-D glucose

(II) Lactose

- Lactose is milk sugar with β -1'-4" glycosidic linkage between glucose and galactose
- Lactose is least sweet sugar.
- Maximum % of lactose = Human milk = 7%

(III) Sucrose

- In plants transport of sugars mainly occurs in the form of sucrose.
- Sucrose is also known as **invert sugar**.
- Sucrose is called Cane Sugar or Table Sugar or Commercial Sugar. Sucrose is composed of α -D Glucose and β-D-fructose.

(IV) Trehalose

- Trehalose is present in haemolymph of insects. It has glycosidic linkage between two anomeric carbons of two α-Glucose units (1–1 linkage).

C. POLYSACCHARIDES

- Polysaccharides are composed of large number of monosaccharide units.
- Suffix '—an' is added in their names and they are known as **glycans**.
- Pentose polysaccharides are called **pentosans** for e.g.

  araban (from L- arabinose), xylan (from D-xylose), all these found in cell wall.
- Hexose polysaccharides are called **"hexans"**. for e.g. mannan (from mannose) cellulose, starch etc.
- Polysaccharides are insoluble in water and do not taste sweet.
- All polysaccharide are non-reducing
- Although polysaccharides are non reducing but in a polysaccharide chain one end is reducing and another end is non-reducing.
- According to function, they are classified as nutritive and structural.

  On structural basis polysaccharides are of two types.

(I) **Homopolysaccharides :–**

Composed of same monomers. Biologically important homopolysaccharides are as follows:

(a) **Cellulose :–** Linear polymer of β -D-glucose units (6000 to 10,000). It has β 1'-4" linkage.

Cellulose is main component of plant cell wall. In wood, cellulose is 50% and in cotton, it is 90%.

- Most abundant organic molecule on earth.
- It is also used to form **Rayon fibre** (Artificial silk).
- Paper made from plant pulp is cellulose.

(b) **Starch** – It is main stored food in plants. Starch is polymer of α -D-glucose units. Starch consists of two types of chains.

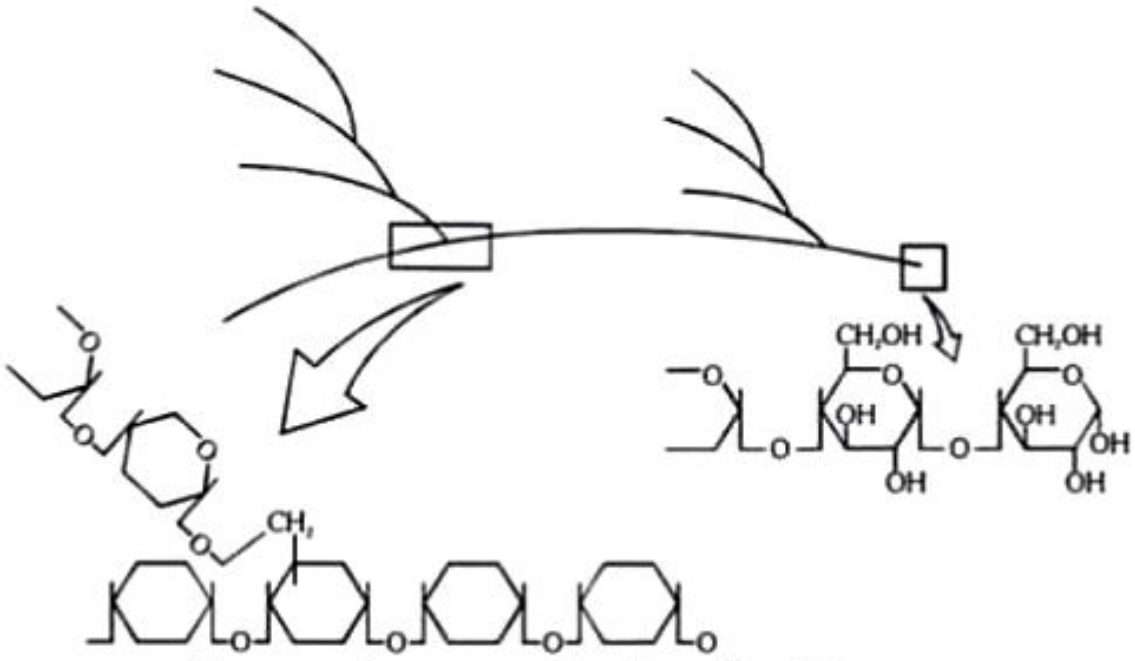
(i) **Amylose :–** 250-300 glucose units are arranged in an unbranched chain by α 1'-4" linkage.

(ii) **Amylopectin :–** A branched chain molecule. Approximately 30 glucose units are linked by α - 1',4" and α - 1', 6" linkage.

- Amylose gives blue colour with iodine.
- Amylopectin gives red colour with iodine.
- Starch present in potato contains 20% amylose and 80% amylopectin.
- Starch forms helical structure so starch can hold I_2 molecules in the helical portion. So starch-I_2 is blue – violet in colour. While cellulose has linear structure so it cannot hold I_2 and does not give iodine test.

(c) **Glycogen :–** Storage form of carbohydrate in animals, storage region of glycogen is liver and muscles. Storage of glycogen liver > muscle. Glycogen is also called as **animal starch**. Glycogen is highly branched polymer of α -D-glucose.

- Glycogen is formed by the 1',4" bond linkage in long chain and 1',6" bond linkage at branching point.
- Glycogen gives red colour with iodine.
- Glycogen is stored food of fungi.



Diagrammatic representation of a portion of glycogen

(d) **Chitin :–** Linear polymer of N-acetyl- D-glucosamine with β–1', 4"–linkage.

- N-acetyl D-glucosamine is an amino acyl (-NH-CO-CH_3)derivative of β-D-glucose.
- Chitin is an important component of exoskeleton of Arthropods and cell walls of fungi.
- Second most abundant organic molecule on earth.
- It is also called **Fungal cellulose**.

(e) **Inulin :–** Linear polymer of fructose units linked with β -1',2" bonds. Inulin is found in roots of ***Dahlia*** and **Artichoke**. It is water soluble polysaccharide and it is used to know the glomerular filteration rate.

- It is smallest storage polysaccharide.

(f) **Dextrin** – Dextrin is an intermediate substance in the digestion of glycogen and starch. By hydrolysis of dextrin, glucose and maltose are formed. It also occurs as stored food in yeast and bacteria.

(II) **Heteropolysaccharide :–**

Composed of different monosaccharide units.

(a) **Hyaluronic acid –** Found in vitreous humour, umbilical cord, joints and connective tissue in the form of lubricating agent. It also occurs in animal cell coat as binding material **(Animal cement)**.

(b) **Chondroitin –**

- Chondroitin occurs in connective tissue.

(c) **Heparin –** It is anticoagulant of blood.

(d) **Pectins –**

- Pectin is found in cell wall.
- Salts of pectin i.e. Ca and Mg-pectates form middle lamella in plants.
- It is also called **Plant cement**.

(e) **Hemicellulose –**

- It is a stored material in ***Phytelephas*** **(Ivory palm).** Hemicelluiose which is obtained from this plant is white, hard and shiny and it is used to form billiard balls and artificial ivory.

MUCOPOLYSACCHARIDES

Slimy polysaccharides with capacity to bind proteins and water are called mucopolysaccharides. In plants, mucilage is a common mucopolysaccharide.

Special Points :

1. **Peptidoglycan** – Present in cell wall of bacteria.

   – Composed of N - acetyl Glucosamine + N - acetyl muramic acid + peptide chain of 4-5 amino acids

2. **Agar-Agar** – It is a mucopolysaccharide which is obtained from some red algae – ***Gracilaria, Gelidium, Chondrus.*** It is composed of D-galactose and L-galactose unit (1, 3 linkage) and after every 10th unit a sulphate group is present. It is used for preparing culture medium.

3. **Difference between gums and fevicol :** Gums are natural mucoplysaccharides while fevicol is synthetic rubber based adhesive.

BEGINNER'S BOX-1

STARTING TO CARBOHYDRATE

1. Which is not true about monosaccharides ?

   (1) reducing nature (2) soluble in water

   (3) sweet in taste (4) always ketose

2. Glucose and galactose are two isomeric monosaccharides known as :

   (1) Anomers (2) Epimers (3) Sugars (4) Amino sugars

3. Choose the mis-match :

   (1) Amylose → contains α-1,4 glycosidic bond.

   (2) K^+ → most abundant mineral element in ICF.

   (3) Na^+ → most abundant mineral element in ECF.

   (4) Cellulose → violet colour with iodine solution.

4. Sum total of all the reactions that are taking place in a cell is known as

   (1) catabolism (2) anabolism

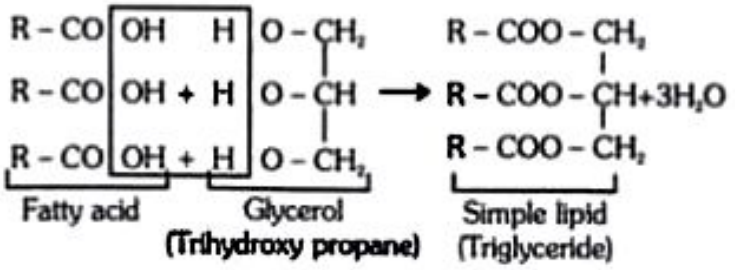
   (3) metabolism (4) redox reaction

LIPIDS

- Fat and its derivatives are combinaly known as lipid.
- Compounds of C, H, O but the ratio of Hydrogen and Oxygen is not 2:1. The amount of oxygen is considerably very less.
- Lipids are insoluble in water and soluble in organic solvents like acetones, chloroform, benzene, hot alcohol, ether etc.
- Lipids occur in protoplasm as minute globules.
- Lipids do not form polymer.
- Lipids provide more than double energy as compared to carbohydrate.
- In animals, fat are present in subcutaneous layer and work as food reservoir and shock-absorber.
- Lipid requires less space for storage as compared to carbohydrate because lipid molecule is hydrophobic and condense.
- Animals store maximum amount of food in the form of lipid.
- Lipids are micromolecules.
- Lipids are calleds fats and oils on the basis of melting point. Oils have lower melting point and fats have higher melting point.
- Some lipids also have phosphorus like lecithin.

(A) Simple Lipid or Neutral Fats :-

- These-are esters of long chain fatty acids and alcohol. In majority of simple lipids, the alcohol is a trihydroxy sugar alcohol i.e. glycerol.
- Three molecules of fatty acid linked with one molecule of glycerol. The linkage is called "ester bond". Such type of lipids are called as Triglycerides. Three molecules of water are released during formation of triglycerides (dehydration synthesis)
- Glycerol is also known as trihydroxy propane.
- Similar or different fatty acids participate in the composition of a fat molecule. Simple lipids contain two types of fatty acids.



- Simple lipids contain two types of fatty acids.

Saturated fatty acid	Unsaturated fatty acid
(a) Only single bond, single bonds are present between C-C atoms	(a) Doble bonds also present with single bonds between C-C atoms.
(b) Also known as non essential fatty acid, because they can be synthesized in animal body, so it is not essential to take them with food.	(b) Also known as essential Fatty acid becuase they can't be synthesied in animal body, so it is essential to take them with food.
(c) Lipids with more amount of saturated fatty acids are mostly present in solid form at normal temperature. e.g. Butter, Ghee	(c) Lipids with more amount of unsaturated fatty acids are mostly present in liquid form at normal temperature. e.g. Coconut oil, Mustard oil.
(d) Metabolically they are very less reactive. So mostly don't participate in metabolism. So have tendency to store in animal body and cause obesity. Some amount of saturated fatty acids convert into cholesterol in liver. This cholesterol deposit on inner wall of blood vessels, so cause high blood pressure & different types of cardio-vasular disease.	(d) Metabolicaly they are highly reactive, so mostly participate in metabolic reactions. So don't have tendency to store in animal body. So no obesity, no cholesterol formation, no cardio vascular disease, no high B.P. & no harmful effect.
(e) Mostly animal fat contains high amount of saturated fatty acids. Examples — No. of C Palmitic acid = 16 Stearic acid = 18	(e) Mostly paint fat contains high amount of unsaturated fatty acids.
	(f) Example — No. of double bonds Oleic acid = 1 — MUFA (Monounsaturated fatty acid) Linoleic acid = 2 Linolenic acid = 3 Arachidonic acid = 4 PUFA (Polyunsaturated fatty acid)

Waxes are monoesters with only one molecule of fatty acid attached to a monohydroxy alcohol.

e.g.

Spermaceti In skull of whale and Dolphin.

(B) Conjugated or Compound Lipids :-

(1) Phospholipids or phosphatide or phospholipins :-

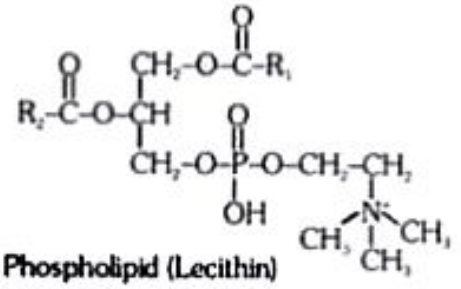
2 Molecules of fatty acid + Glycerol + H_3PO_4 + Nitrogenous compound. Phospholipids are most abundant type of lipids in protoplasm.

Phospholipids have both hydrophilic polar end (H_3PO_4 and nitrogenous compound) and hydrophobic non polar end (fatty acids). Such molecules are called amphipathic. Due to this property, phospholipids form bimolecular layer in cell membrane.

Some biologically important phospholipids are as following :

(a) **Lecithin or Phosphatidyl choline**

- Nitrogenous compound in lecithin is **choline**



Phospholipid (Lecithin)

(b) **Cephalin**-Similar to lecithin but the nitrogenous compound is **ethanolamine**, cephalin occurs in nervous tissue, egg yolk and blood platelets.

(c) **Sphingolipids** or **sphingomyelins** similar to lecithin but in place of glycerol it contains an amino alcohol **sphingosine**.

Sphingolipids occur in **myelin** - **sheath** of nerves.

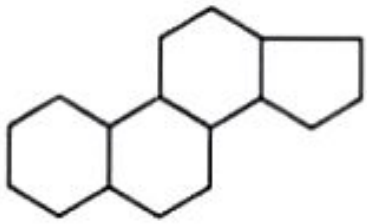
(2) **Glycolipid** :- 1 fatty acid + sphingosine + galactose

eg. **Cerebroiside** which occurs in white matter of brain -

Gangliosides - These occur in nerve ganglia and spleen.

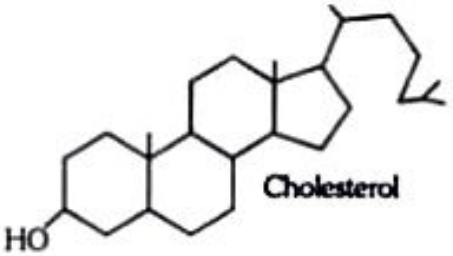
(c) **Derived Lipids** :- Lipid derived from simple or conjugated lipid .Derived lipids are complex in structure. They are insoluble in water and soluble in organic solvents

(1) **Steroids** :- Steroids exhibit tetracyclic structure called "Cyclo pentano perhydrophenanthrene nucleus"
On the basis of functional group, steroids are of two types -



(a) **Sterols** :- Alcoholic steroids e.g. **cholesterol** - Cholesterol abundantly occurs in brain, nervous tissue , Adrenal gland and skin. Cholesterol is a parent steroid. Several other biologically important steroids are derived from cholesterol. 7 - dehydro cholesterol which occurs in skin is a provitamin. On exposure to ultraviolet radiation, it transforms in cholecalciferol i. e vitamin D

- Cholesterol is also called **"most decorated micromolecule in biology".**



Cholesterol

(b) **Sterones** :- Ketonic steroids, for e. g. sex hormones, Adreno corticoids , ecdyson hormone of insects

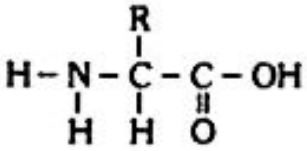
(2) **Chromolipid** = It is also called **terpene.**

- Most complex lipid in protoplasm.
- Chromolipids composed of repeated isoprene units

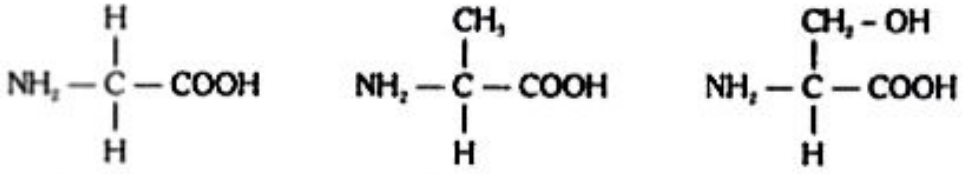
PROTEINS

Protein name is derived from a greek word which means **" holding first place"** (Berzelius and Mulder)

- Essential elements in protein are C , H , O, N,
- Most of the proteins contain sulphur. In some proteins iodine , iron and phosphorus are present.
- After water, proteins are most abundant compounds in protoplasm. (7-14%) amount of proteins.
- Proteins are polymers of amino acids (Fisher and Hofmeister). There are approximately 300 amino acids known to exist but only 20 types of amino acids are used in formation of proteins

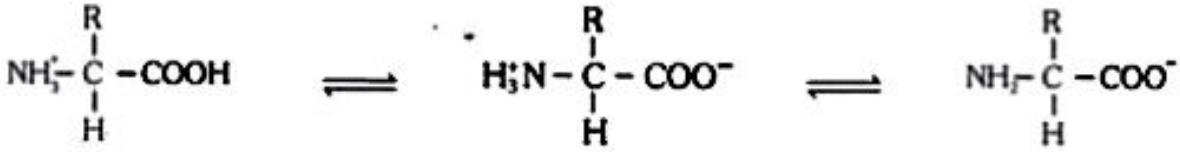


- Proteins are **heteropolymers** of amino acid.
- Amino acids contain an amino group and carboxylic group on the same carbon i.e. the α-carbon so they are called **α-amino acids.**
- Amino acids are **substituted methanes.**



Glycine Alanine Serine

- Amino acids is amphoteric compound because it contains one acidic -COOH and an alkaline group -NH_2
- At isoelectric point, amino acid is present in form of zwitter ion.



Zwitter ion

- Iso electric point is that point of pH at which amino acids do not move in electric field.
- Out of 20 amino acids, 10 amino acids are not synthesized in body of animals so they are must in diet. These are called **Essential amino acid** . e. g. Threonine , Valine, Leucine, Isoleucine, Lysine, Methionine, Phenylalanine Tryptophan, Arginine, Histidine. **Arginine and Histidine are semi essential.**
- 10 amino acids are synthesized in animal body so these are called **Non essential amino acids.** for e.g.

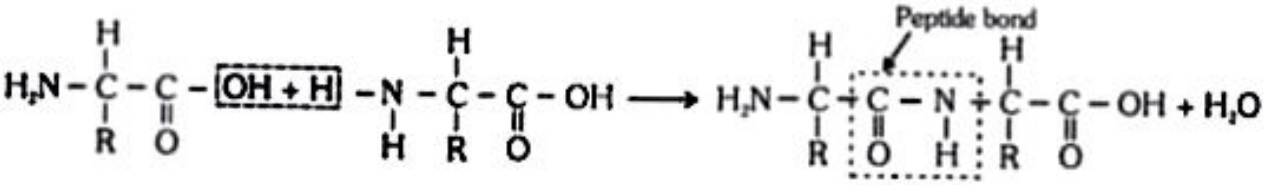
Glycine, Alanine, Serine, Cysteine,Aspartic acid, Glutamic acid, Asparagine, Glutamine, Tyrosine, Proline

Except glycine, each amino acid has two enantiomeric isomers

D-amino acid L-amino acid

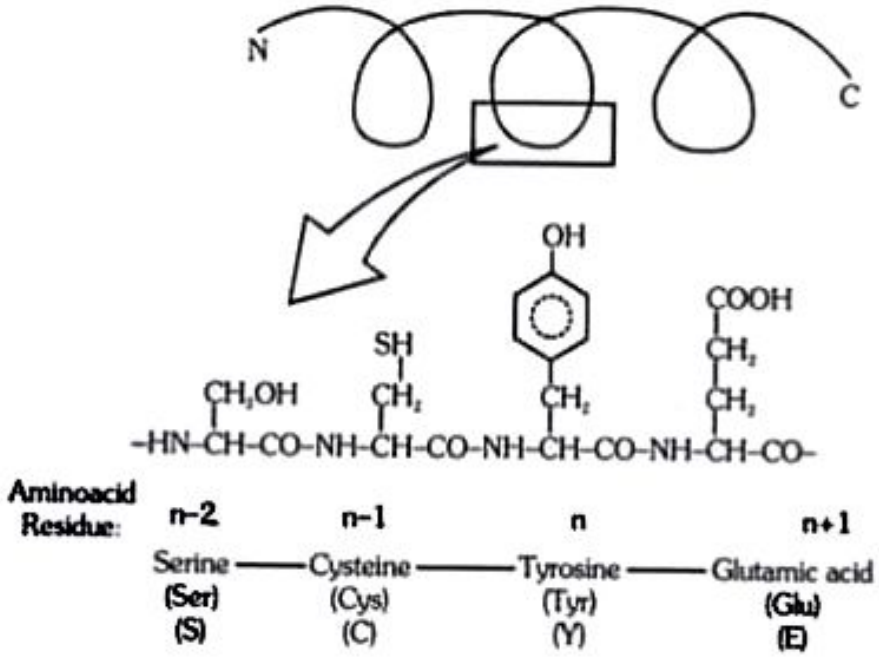
- Most proteins have L- amino acids while D- amino acids occur in peptidoglycan of bacterial cell wall and antibodies.

Amino acids are joined with peptide bond to form **proteins.**



Dipeptide

- Peptidyl transferase enzyme catalyses the synthesis of peptide bond.
- Property of protein depends **(I) on sequence of amino acid** and **(II) configuration of protein molecules.**

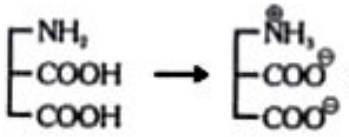


Primary structure of a portion of a hypothetical protein. N and C refer to the two termini of every protein. Single letter codes and three letter abbreviations for amino acids are also indicated.

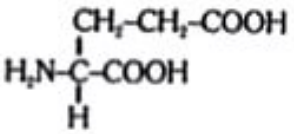
Classification of amino acids on the basis of number of carboxylic groups and Amino groups.

1. Acidic amino acid

- They have one amino and two carboxylic groups in their structure.



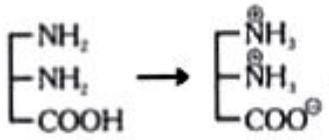
Net charge = -ve, so they move towards anode in electric field.

e.g. - Glutamic acid → 

- Aspartic acid

2. Alkaline amino acid

- They have two amino and one carboxylic group.



→ Net charge = +ve, so they move towards cathode in electric field.

e.g. Histidine
Arginine
Lysine

3. Neutral AA

- They have one amino and one carboxylic group.
- They are present in the form of zwitter ion and show no movement in electric field.

e.g. Rest 15 AA

Special Points on Amino acid :

1. **Tryptophan :** Most complex amino acid and helpful in synthesis of I.A.A. (Indole-3-Acetic Acid) which is plant growth hormone.
2. **Tyrosine :** Helps in synthesis of melanin pigment, Thyroxine hormone, Adrenaline (epinephrine) hormone, Nor adrenaline (Nor epinephrine) Hormone.
3. In proline amino acids, imino group (–$\underset{|}{N}$H) is present instead of amino (–NH_2) group so these two amino acids are also known as imino acids.
4. Cysteine and methionine are sulphur containing amino acids.
5. Tyrosine, Tryptophan, Phenyl alanine } Aromatic AA because they have benzene ring in their structure.
6. Except glycine all amino acids are laevorotatory.
7. Glycine is the simplest and Tryptophan is most complex Amino acid.
8. Amino acids which participate in protein synthesis are called as protein Amino acids and those which do not participate are called as non-protein amino acids.
   eg. GABA, Ornithine, Citrulline.

Configuration of Protein Molecule :-

(1) **Primary configuration or structure :-** A straight chain of amino acids linked by peptide bonds form primary structure of proteins. This structure of proteins is most unstable. Newly formed proteins on ribosomes have primary structure.

(2) **Secondary configuration :-** Protein molecules of sec. structure are spirally coiled. In addition to peptide bond, **amino acids are linked by hydrogen bonds between oxygen of one amide group and hydrogen of another amide group.** This structure is of two types -

(i) **α-Helix :-** Right handed rotation of spirally coiled chain with approximately $3\frac{1}{2}$ 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.

(ii) **β– Helix or pleated sheath structure** :- Protein molecule has zig – zag structure. Two or more protein molecules are held together by intermolecular hydrogen bonding. **e.g.** Fibroin (silk).

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

(3) **Tertiary Structure** :– Proteins of tertiary structure are highly folded to give a globular appearance. They are soluble in water (colloid solution). This structure of protein has following bonds–

(i) Peptide bonds = strongest bond in proteins.

(ii) Hydrogen bonds

(iii) **Disulphide bond** :– These bonds are formed between - SH group of amino acid (Cysteine). These bonds are **second strongest bond** and stabilise tertiary structure of protein.

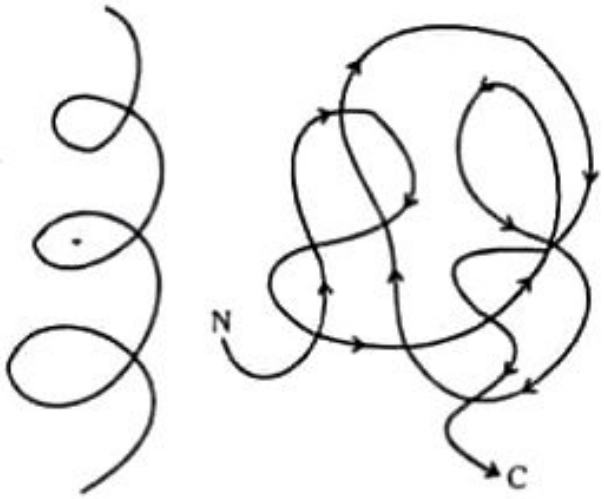
(iv) **Hydrophobic bond** : Between amino acids which have hydrophobic side chains for **e.g.** Aromatic amino acid

(v) **Ionic bond** : Formation of ionic bond occurs between two opposite ends of protein molecule due to electrostatic attraction

Majority of proteins and enzymes in protoplasm exhibit tertiary structure.

(4) **Quaternary Structure** :– Two or more polypeptide chains of tertiary structure unite by different types of bond to form quaternary structure of protein. Different polypeptide chains may be similar (lactic-dehydrogenase) or disimilar types (Haemoglobin, insulin).

Quaternary structure is most stable structure of protein.



Cartoon showing : (a) A secondary structure and
(b) A tertiary structure of proteins

Denaturation of protein :-

Besides changes in pH, salts, heavy metals, temperature, pressure, etc. also cause precipitation of proteins. Because of these changes, the secondary and tertiary configuration of proteins is destroyed. Such alternations in the physical state of proteins is called denaturation. If the change in the medium of protein is mild and for a short period, then denaturation of the protein is also temporary, however, if the change in medium is strong and prolonged then denaturation is permanent and the protein becomes coagulated. For example, the white or albumen of egg is a soluble globular protein but on heating it permanently coagulates into fibrous insoluble form. It is clear, that strong alternations result in the denaturation of proteins and they lose their biological properties and significance. It is this reason, that cells of organisms are unable to bear strong changes and they ultimately die.

TYPES OF PROTEINS

Types of protein

- **Simple** (made up of only amino acids)
  - **Fibrous** — Long, Coiled & Thread like
    - **Collagen :-**
      - Most abundant protein in animal body
      - 1/3 part of total proteins
      - Present in connective tissue
      - Threads of collagen known as Tendon
    - **Elastin :-**
      - In connective tissue
      - Threads of Elastin known as Ligament
    - **Keratin**
  - **Globular**
    - **Rubisco :-**
      - Present in chloroplast.
      - Most abundant protein on the earth.
    - **Albumin :-**
      - Maintain B.C.O.P.
      - In milk as Lactoalbumin
      - In egg yolk as Ovalbumin
      - In blood as Serum albumin
    - **Globin :-** Present in Haemoglobin.
    - **Histone protein :-** Present with eukaryotic DNA.
      - In it Lysine & Arginine A.A. are present in more amount.
- **Compound**
- **Derived**

Compound protein

- Protein part, Made up of A.A.
- Non-protein part, non amino acid part (Prosthetic group)

- **Types of compound protein on the basis of prosthetic group.**

1. **Nucleoprotein :-** Prosthetic group is nucleic acid.

   eg. Chromosome = DNA + RNA + Protein

   Ribosome = rRNA + Protein

   Virus

2. **Chromoprotein :-** Prosthetic group is Porphyrin pigment (metal + porphyrin ring)

eg.	Metal	Colour
Haemoglobin	Fe	Red
Cytochrome	Fe	Red
Haemocyanin	Cu	Blue

3. **Lipoprotein :-** Prosthetic group is lipid

   eg. Plasma membrane

4. **Phosphoprotein** :- Prosthetic group is phosphoric acid (H_3PO_4)

   → Caseinogen - Milk

   → Pepsin - Protein digesting enzyme.

5. **Lecithoprotein** :- Prosthetic group is Lecithin

   eg. Fibrinogen - Blood

6. **Metalloprotein** :- Prosthetic group is metal

   eg. Enzyme with its co-factor

7. **Glycoprotein** :- Prosthetic group is carbohydrate (less than 4% carbohydrate)

   eg. (1) α, β, γ globulin of blood.

Glycoproteins which are present on cell surface are helpful in cell recognition.

Human = Egg surface - Fertilizin - Glycoprotein

Sperm surface - Antifertilizin - Simple protein.

8. **Mucoprotein** Prosthetic group is carbohydrate (more than 4% carbohydrate)

Special Points on Protein :

- **Monomeric protein :** Protein composed of one polypeptide chain.
- **Oligomeric/Polymeric/Multimeric protein :** Protein composed of more then one polypeptide chains.

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

GOLDEN KEY POINTS

- Chitin is an example of Homopolysaccharide.
- In proteins only right handed helix are observed.
- Cellulose never show iodine test.
- Phospholipids are most abundant lipid in cell membrane.
- Thaumatine is sweetest chemical substance which is obtained from ***Thaumatococcus daniellii*** bacteria.
- Aspartame/Aspartin is most commonly used artificial sweetener. It is non carcinogenic.

BEGINNER'S BOX-2

LIPID TO PROTEIN

1. The most abundant lipids in eukaryotic cell membrane are
   (1) cholestrol
   (2) glycolipids
   (3) phospholipids
   (4) lipopolysaccharide

2. Which of the following is alkaline amino acid
   (1) glycine
   (2) valine
   (3) alanine
   (4) arginine

3. Which biomolecule release maximum energy during oxidation
   (1) lipid
   (2) protein
   (3) nucleic acid
   (4) carbohydrate

4. An alpha helix represents
   (1) primary structure of protein
   (2) aggregation of protein
   (3) secondary structure of protein
   (4) tertiary structure of protein

5. Which of the following bond is/are found in tertiary structure of protein
   (1) peptide bond & hydrogen bond
   (2) disulphide & hydrophobic bond
   (3) ionic bond
   (4) all the above

NCERT BASED PROBLEMS

1. What are macromolecules? Give examples.

Ans. Macromolecules are large sized, high molecular weight, complex molecules, which are formed by polymerisation or condensation of small sized, low molecular weight, simple molecules.
e.g. Protein, Nucleic acid and Polysaccharides.

2. Protein having primary structure. If you are given a method to know, which amino acid is at either of the two termini (ends) of a protein. Can you connect this information to purity or homogeney of a protein?

Ans. No, because we know about the first and last amino acids, but in between them any type of amino acids may present, for those we can not be sure.

3. Find out and make a list of proteins, used as therapeutic agents.

Ans. Proteins those are engineered in the laboratory for pharmaceutical uses are known as therapeutic proteins.
e.g. Monoclonal antibodies, Interferons, Insulin, Erythropoetin.

4. Can you describe, what happens ? when milk is converted into curd or yoghurt, from your understanding of proteins ?

Ans. Denaturation (Coagulation) of proteins, present in milk, due to change in pH and temperature.

5. Can you attempt models of biomolecules, using commercially, available atomic models (ball and stick models).

Ans. In ball and stick model, ball is used for atoms and short rod of wood / plastic is used to represent bonds of a compound.

6. What are gums made of ? Is fevicol different ?

Ans. Gums are colloidal exudates of plant, which are chemically polysaccharide, while fevicol is synthetic rubber based adhesive.

7. Find out a qualitative test for protein, fat, oils and amino acid.

Ans. **Protein** → Biuret test
→ Alkaline $CuSO_4$ - reagent test
→ Violet colour test

Fat and Oils

Grease spot test → A drop of oil placed over a piece of simple paper, a translucent spot is visible. This indicates the presence of fat.

Amino acids → There are different tests available for different amino acids.

Ex :

Test	Reagents	Colour	Amino acid
Millon's test	$HgNO_3$ in HNO_2	Red	Tyrosine and Tryptophan
Xanthoproteic test	Conc. HNO_3	Yellow	Tyrosine, Tryptophan, Phenylalanine

8. Briefly describe the bioinformatics.

Ans. Bioinformatics is the collecting, storage and analysis of large amount of biological data in computer, to make useful conclusions. These data contain mapping and phenotype informations, nucleotide and amino acids sequence and structure and function of proteins.

ANSWER KEY

BEGINNER'S BOX-1	Que.	1	2	3	4						
	Ans.	4	2	4	3						
BEGINNER'S BOX-2	Que.	1	2	3	4	5					
	Ans.	3	4	1	3	4					