Unit - IV - Biomolecules and secondary metabolites

(1)

★ Carbohydrates :-

Carbohydrates are most widely distribute in plants & animals. It is a group of organic compounds consisting of C, H & O in the ratio 1:2:1. eg. starch, Cellulose, etc. Primarily the carbohydrates were considered as hydrates of carbon & correspond to general formula $C_6H_{12}O_6$. Although this is true for a larger number of carbohydrates, some compounds d not confirm to the formula, although they are regarded as carbohydrates. The proportion of oxygen is lower in a few carbohydrates.

Carbohydrates are aldehyde or ketone derivatives of polyhydroxy alcohols & referred to as polyhydroxyaldehydes & polyhydroxyketone ~~Monosaccha~~ Carbohydrates are classified int three categories, viz.: Monosaccharides, Oligo-saccharides and polysaccharides.

1 Monosaccharides :-

Monosaccharides are the simplest carbohydrate & known as simple sugars. They can not be hydrolys further into any other simple carbohydrate. They are the building units of oligosaccharides or polysaccharid They have an aldehyde or ketone group & hence reducing in nature. Sugars having aldehyde group are called aldose sugars / aldoses and those having ketone group are called ketose sugars or ketoses. Monosacch. are sweet testing, crystalline & soluble in water.

Depending on the number of carbon atoms, the monosaccharides are further classified as follows :-

i) Trioses :- 3 C atoms in the chain. - $C_3H_6O_3$
eg: Glyceraldehyde, Dihydroxyacet

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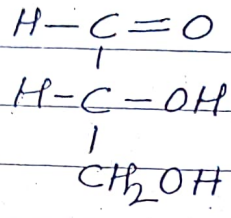
ii) Tetroses : 4 C atoms in the chain, - $C_4H_8O_4$
eg: Erythrose, Threose

iii) Pentoses : 5 C atoms in the chain. - $C_5H_{10}O_5$
eg: Ribose, Deoxyribose, Arabinose, xylose, Xylulose.

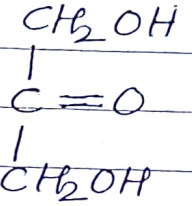
iv) Hexoses : 6 C atoms in the chain — $C_6H_{12}O_6$
eg: Glucose, Fructose, Galactose, Mannose

v) Heptoses : 7 C atoms in the chain — $C_7H_{14}O_7$
eg: Sedoheptulose.

i) Trioses :- Contain three carbon atoms.

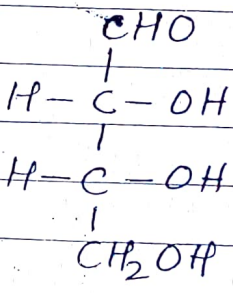


Glyceraldehyde

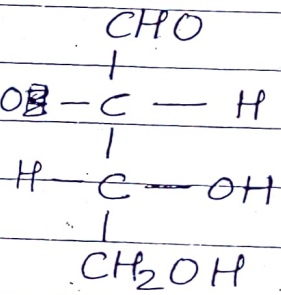


Dihydroxyacetone

ii) Tetroses :- Contain four carbon atoms.

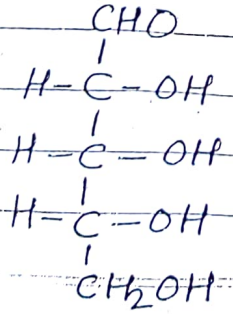


D-Erythrose

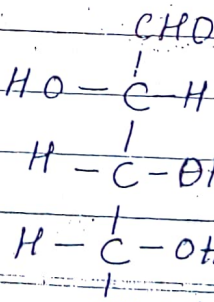


D-Threose

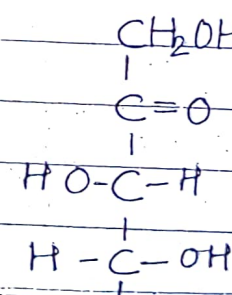
iii) Pentoses :- Contain five carbon atoms



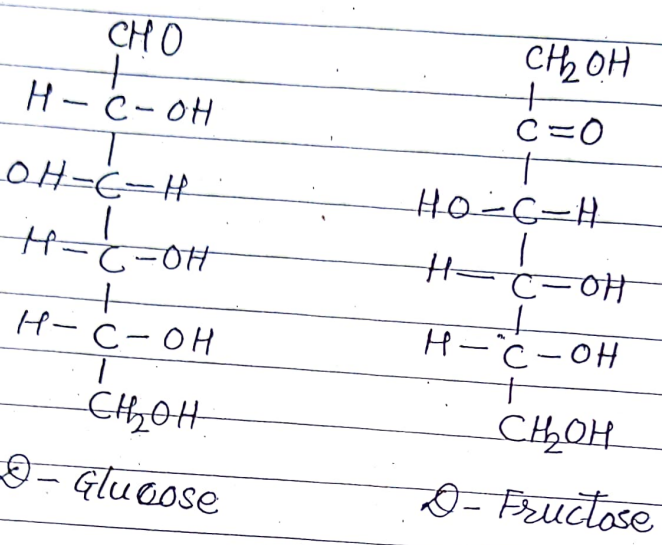
D-Ribose



D-Arabinose



iv) Hexoses :-



D- Glucose

D- Fructose

2 Oligosaccharides :-

Oligosaccharides consist of two, three or four molecules of monosaccharides joined to each-other by glycosidic bonds. On hydrolysis, they yield the monosaccharide units which may be similar or dissimilar. Oligosacch^{s} are also sweet testing, crystalline & soluble in water.

Depending upon no. of monosaccharide molecule oligosaccharides are classified into 3 categories :-

i) Disaccharides - Two monosaccharides molecule
- $C_{12}H_{22}O_{11}$ eg: Sucrose, Maltose, Lactose, Cellobiose

ii) Trisaccharides : 3 monosaccharide molecules
- $C_{18}H_{32}O_{16}$ eg: Raffinose, Gelatinose, etc.

iii) Tetrasaccharides : 4 monosacch. molecules.
- eg: Stachyose.

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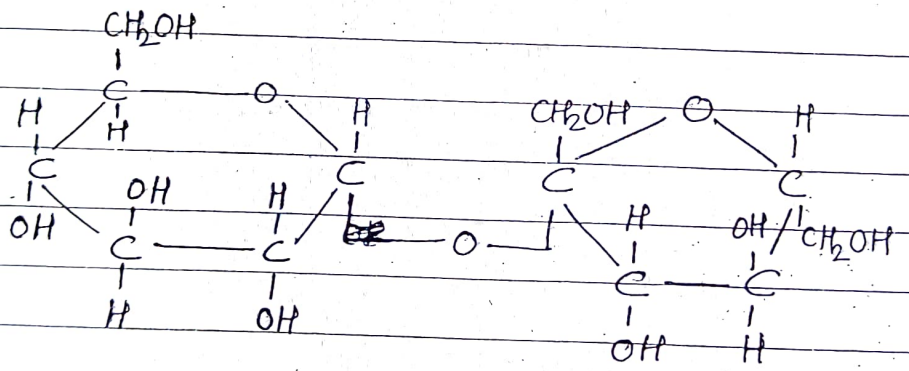
Disaccharides :-

These are made up of 2 monosaccharide molecules joined by glycosidic linkage. On hydrolysis, they yield Two monosaccharide units, which may be similar or dissimilar.

(a) Sucrose :-

- Sucrose is formed as a result of linking glucose & fructose units together & eliminating a water molecule.
- In sucrose unit, glucose occurs as a six-membered ring (pyranose ring) & fructose as a five-membered ring.
- Sucrose is commonly called as cane sugar.
- It is widely distributed in higher plants, but the commercial sources are sugarcane and beet.

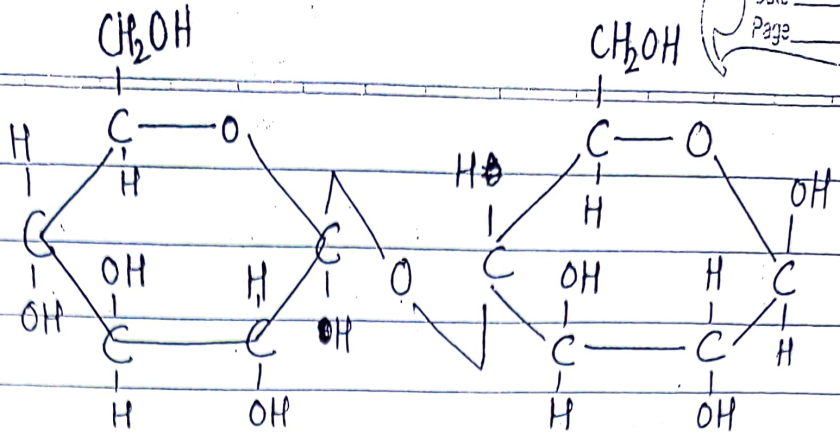


Glucose + Fructose

Fig. : Sucrose.

(b) Lactose :-

- It is also known as milk sugar.
- It is found in milk of mammals.
- Lactose is made up of glucose & galactose.



Glucose + Galactose

Fig: Lactose

3 Polysaccharides :-

The term polysaccharide is usually employ for polymers containing large number of (thousand of) monosaccharide units. If polysaccharides consists of similar sugar units, these are called as homopolysaccharides. (eg: starch, cellulose & glycogen). If polysaccharides consist of dissimilar units, these are called heteropolysaccharides. (eg: pectin, chitin & hemicellulose).

Polysaccharides are usually amorphous, tasteless, non-sugars & insoluble in water. They are of two types :-

i) Structural polysaccharides
(eg: cellulose, hemicellulose, chitin, pectin, etc.)

ii) Storage polysaccharides
(eg: starch, glycogen, etc.)

a) Starch :- Starch is stored in the form of grains and it is used as food.

- Starch is made up of large number of glucose units. The glucose units are arranged in two components. - amylose & amylopectin.
- Both amylose & amylopectin are formed by the condensation of α-D-glucose. Amylose is in the form of straight chain containing of 2,000 glucose units,

while amylopectin is branched having about 1,00,0 α-D-glucose units. Treating ~~water~~ starch with hot water dissolves amylose, while amylopectin remains insoluble.

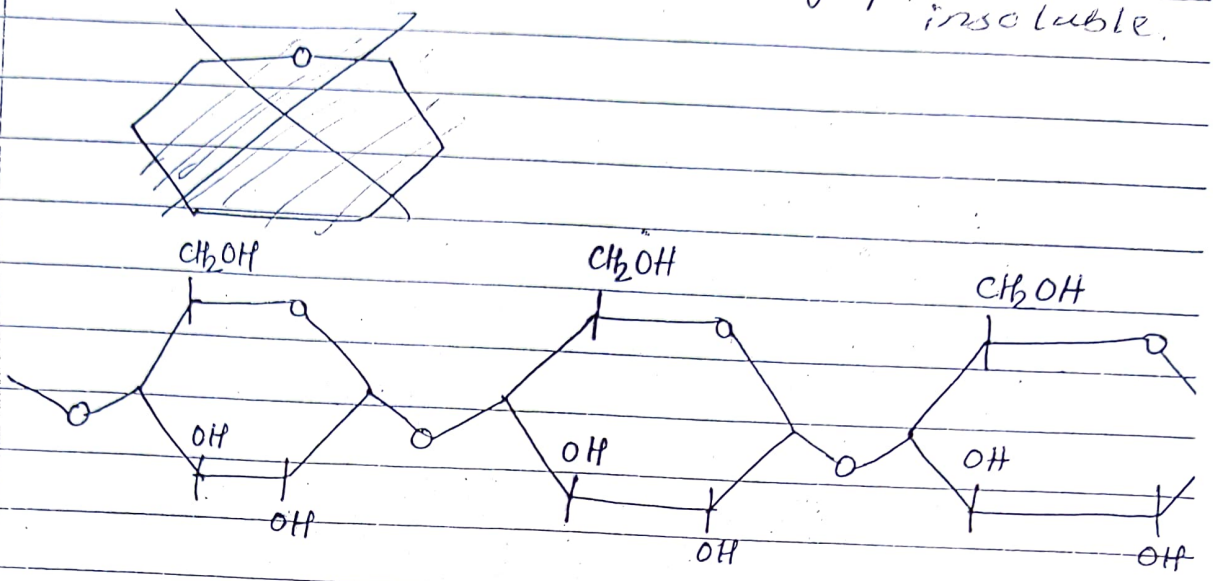


Fig: Starch

b) Cellulose :- Cellulose is most abundant organ compound found on earth.
- It is the main constituent of cell-wall of autotrophic plants.
- It is made up of 500-20,000 β-glucose units, linked together by β-1,4-linkages.

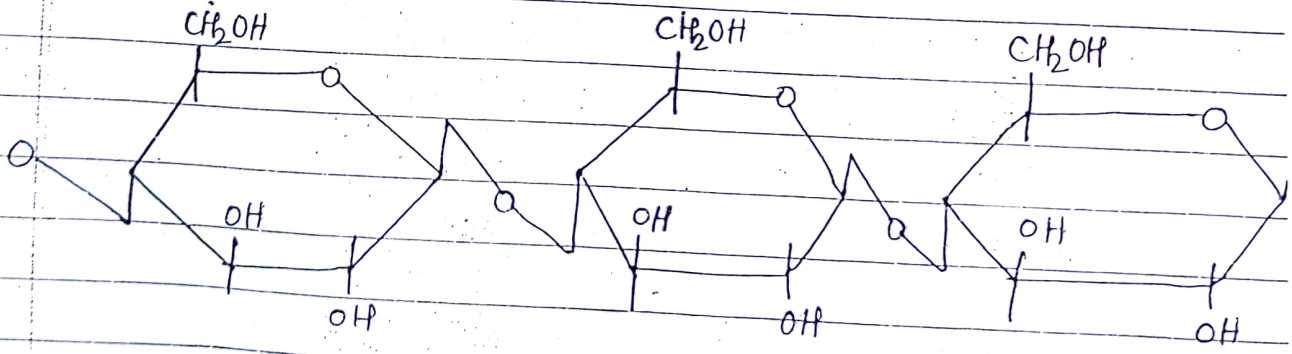


Fig: Cellulose

Polysaccharides - (7)

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Biological functions of starch :-

1) Starch is stored mostly in the form of grains & it is stored as a food.
2) Clothing or laundry starch is prepared by mixing a vegetable starch in water.
3) Starch is used in paper-making.
4) In industry, starch is used in gypsum wall board manufacturing process.
5) Starch is used in manufacture of adhesives or glues for book-binding, wall paper adhesives, envelope adhesives, etc.
6) It is abundantly found in rice, wheat and other cereals, grams, legumes, potatoes & bananas.
7) Starch is used to produce various bio-plastics, which are biodegradable. eg: polylactic acid.
8) By use of starch, bioethanol production is carried out by fermentation process.

Biological functions of cellulose :-

1) Cellulose is used in the industries for preparation of ice-creams, cosmetics & medicines.
2) Cellulose provides roughage to food & helps the peristaltic movements of the digestive tract.
3) Cellulose is found in cereals, fruits & vegetables such as legumes, nuts, peas, cabbage & apple skins.
4) Cellulose can also be used as a commodity, the main source being cotton, hemp, & jute.
5) It can be used to produce rayon & transparent film called cellophane.
6) It is formed by photosynthesis & is used for energy or it can be used as starch to be used later.
7) The artificial fibre is manufactured by dissolving cellulosic materials in alkali & by extruding & coagulating the fib

Pericinal – Parallel to the surface of an orga or part.
Anticlinal – Right angles to the surface of an organ or part.

* Apical dominance :- Phenomenon by which the main, ~~stem~~ central stem of the plant is dominant over th side stems (branches).

Senescence of leaves – the deterioration that en the function life of an organism or an organ.

Abscission – Separation / detachment of leaves, flowers, fruits or seeds.

After-ripening – (AR) is a time & environment regulated process occuring in dry seed which determines the germination potential of the seed.
- biochemical or physical changes that occur in a seed to ensure germination & in fruits after harvesting.
- Scarification - [illegible]
- Chilling - [illegible], Stratification - [illegible]

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Biological Importance/functions of Carbohydrates

(1) **Storage of potential energy** :- Carbohydrates are the storage substances of potential energy. Starch is stored ~~as~~ in the form of grains & used as food. Glucose provides immediate energy needed for tissue. In animals & human, carbohydrates are stored in the form of glycogen.

(2) **Structural component** :- The cell-wall of plants and capsule in bacteria are carbohydrates. Monosaccharides are important constituents of nucleic acids, coenzyme, flavoproteins & blood group substances. Heparin prevents clotting of blood. Glycosides are components of steroids.

(3) **Protein-sparing function** :- Carbohydrate is used as source of energy as long as it is present in the required quantity. This spares protein for building of tissue. When there is deficiency of calories in the diet, fat & then proteins are utilized for supplying energy.

(4) **Role in gastro-intestinal function** :- Indigestible substances like cellulose, hemicellulose & pectins provide the bulk or roughage to food & thus help the peristaltic movements of the digestive tract. Lactose promotes the growth of desirable bacteria in the small intestine. These bacteria synthesize certain B-complex vitamins.

(5) Starch is used in manufacture of adhesives or glues for book-binding, wall paper adhasives, etc.

(6) Starch is used in paper making.

(7) cellulose is used for preparation of ice-creams, cosmetics & medicines.

(8) Cellulose can be used for production of rayon & transparent film called cellophane.

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★ Lipids :—

Lipids are naturally occuring hydrophobic molecules. They are heterogenous group of compo related to fatty acids. They includes oils, waxes, phospholipids, etc. The lipids are widely distri -buted substances found in plants & animals. Lipids consist of fats & their derivatives.

The term lipid was proposed by Bloor (1943) & states that, " lipids are naturally occuring compounds, which are insoluble in water an soluble in one or more organic ~~compound~~ solve such as benzene, chloroform, ether or acetone Cooking oil, butter, ghee, waxes, natural rubber, cholesterol, etc. belong to this categor

Lipids contain fatty acids. Fatty acids are organic hydrocarbon chain ending in a carbox (-COOH) group.

General characters of lipids :—

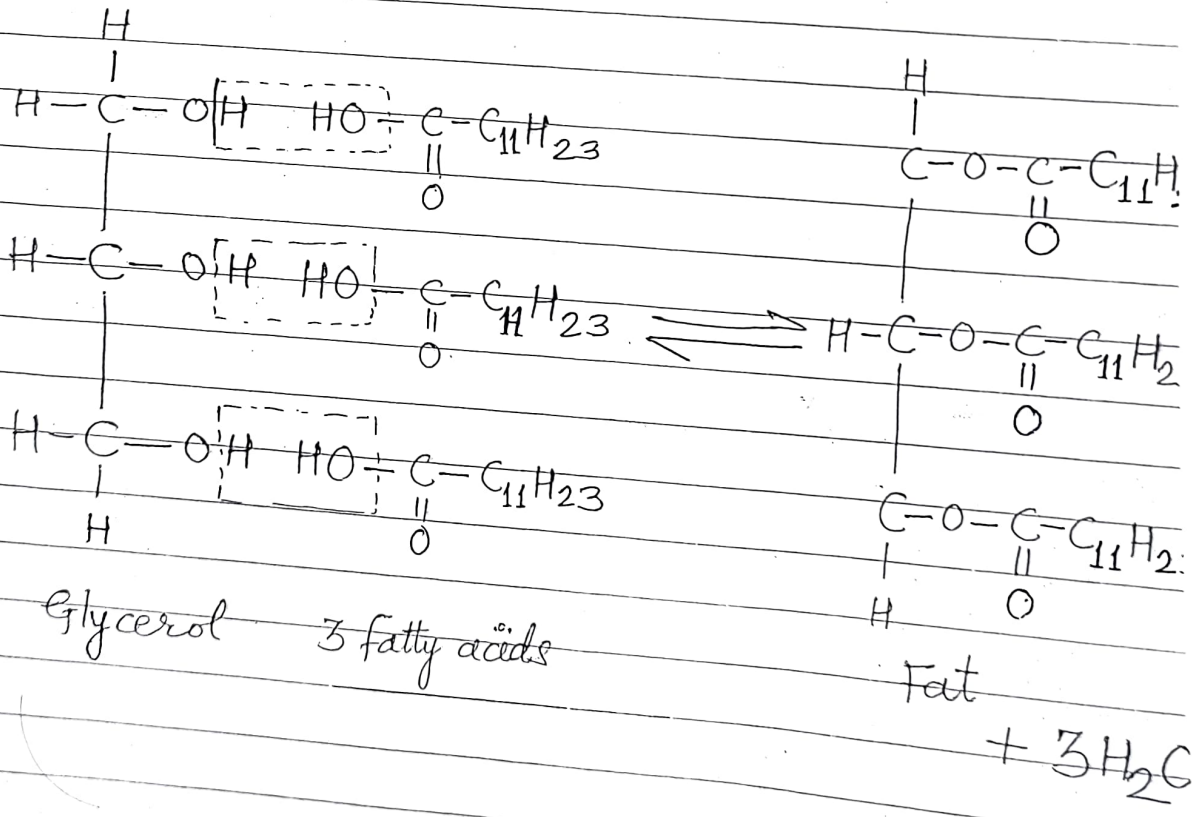
1) Lipids are insoluble in water & hence hydroph
2) They are soluble in non-polar solvents, like ether, chloroform, benzene, ~~etc~~ methanol; etc.
3) Lipids have high energy content & are metabo -lised to release calories.
4) Fats are bad conductors of heat.
5) Fats are hydrolyzed by the enzymes lipase to yield fatty acids and glycerol.
6) The hydrolysis of fats by alkali is called as saponification. It results in formation of glycerol & salts of fatty acids called soaps.
7) Pure fats are colorless & extremely bland in tast
8) The melting point of fats depends on the length of chain of fatty acids and the degree of unsaturation.

Structure of lipids :-

Lipid has no common single structure. The most commonly occuring lipids are triglycerides and phospholipids.

i) Triglycerides are fats & oils. They have glycerol bonded to three fatty acids. If three fatty acids are similar, the triglyceride is called as simple triglyceraldehyde. If the fatty acids are not similar the triglyceride is called mixed triglyceride.

ii) Phospholipids are found in membranes of animals and plants. They are lecithine & cephaline. Phospholipids contain glycerol & fatty acid & also contain phosphoric acids and a low molecular weight alcohol.



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Functions of lipids :-

1) Lipids are more important source of energy & provides more energy than carbohydrates & protein.
2) Triglycerides serve as reserve energy of the body.
3) Lipids are important component of cell-membrane structure in eukaryotes.
4) Layers of fat in sub-cutaneous layer, provides insulation & protection from ~~cold~~ external heat.
5) Some lipids are important as vitamins.
6) Lipids are components of some enzyme system.
7) Some hormones are lipids (eg. : steroids).
8) Some lipids like waxes give a protective covering on the surface of leaves, stems & fruits.

Unit-IV : Biomolecules & Secondary metabolites

☆ Proteins :—

Proteins are polymers made up of amino acids covalently linked through peptide bonds. These are most important organic substances in a living cell. They have high molecular weight, ranging up to several millions. Proteins perform various functions, such as catalysts (enzymes), hormones etc.

Amino acids :—

Amino acids are building blocks of proteins. They have one amino group & one carboxyl group. Other functional group may also be present. There are 20 different amino acids that make up all proteins on earth.

Each amino acid is composed of a central carbon atom bonded to — a hydrogen, a carboxyl group, an amino group & a unique side chain or R-group. The general formula for amino acids is as follows —

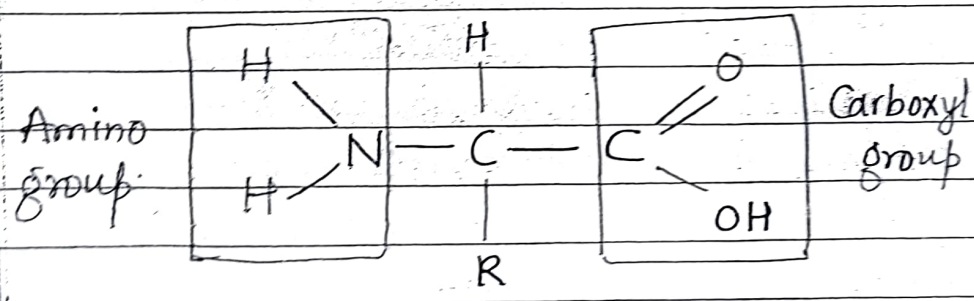

Fig. : Structure of amino acid

(R represents any one of the functional groups, eg.: in glycine R-H, in serine R-OH and in alanine R-CH).

The amino acids differ in structure by the substituent on their side chains. Thus, one amino

acid is distinguished from another in its unique side chain.

Structure of a peptide :—

On hydrolysis of proteins, peptides are formed. Peptides are made up of amino acids. They are covalently bonded together by peptide bonds. If the chain length is short (less than 30 amino acids), it is called peptide, while longer chains are called polypeptides or proteins.

Peptide bonds are formed between carboxyl group of one amino acid & the amino group of the next amino acid. Peptide bond formation occurs in a condensation reaction involving loss of a water molecule.

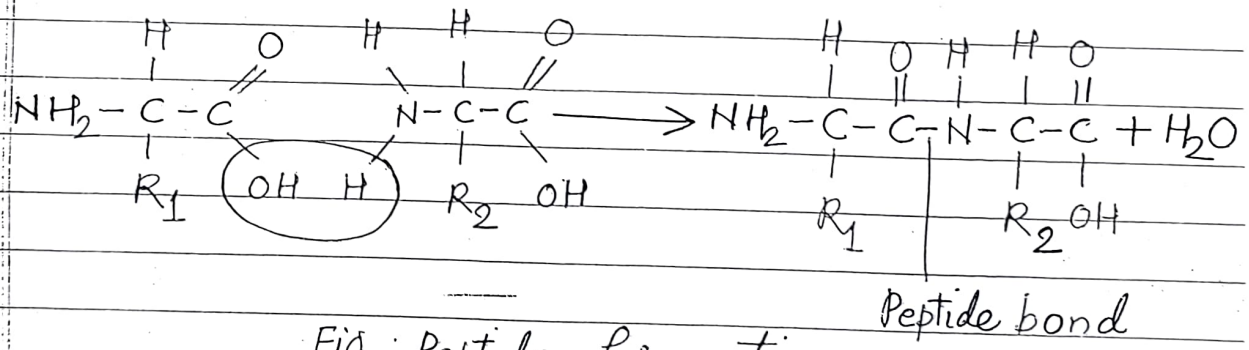

Fig. : Peptide formation

Structure of protein :—

Proteins are chains of amino acids still larger than peptides. These compounds appear as giant macromolecules with molecular weights in the range of $10^4 - 10^7$. The number and sequence of amino acids in the proteins is variable in each protein. Proteins may differ in number of peptide chains per protein molecule.

Levels of protein structure :—

Four basic structural levels of proteins are recognised by modern biochemists. They are called as the primary, secondary, tertiary & quaternary structures.

(1) Primary structure :—

It is a linear sequence of amino acids forming a polypeptide chain. When a polypeptide chain is synthesized on a ribosome, it has a certain specific number and sequence of amino acids. Only a few plant proteins exist in this form.

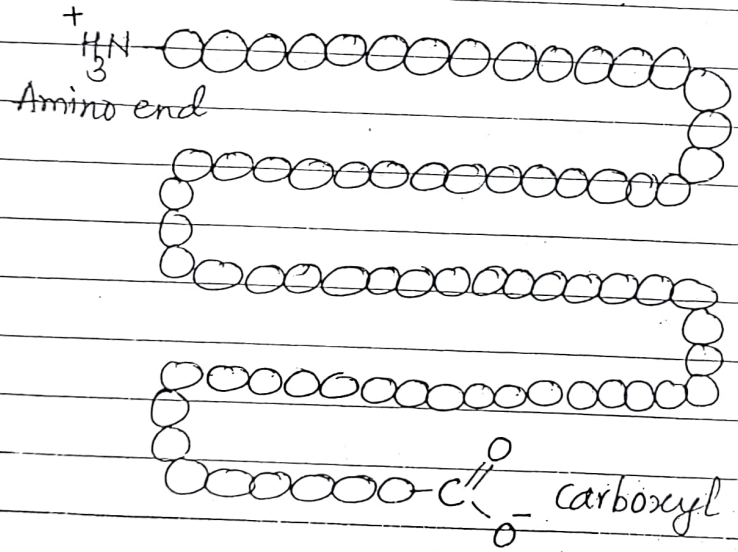

Fig. : Primary structure of protein

(2) Secondary structure :—

Most long polypeptide chains are folded or coiled. This brings out the secondary structure. The folding of the polypeptide chain is maintained by hydrogen bonds formed between adjacent amino acids. The hydrogen bonds are formed between

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oxygen atom of one amino acid and hydrogen atom of other amino acid.

The peptide chain is of two types: right-handed α-helix and β-pleated sheet.

(a) α-helix :-

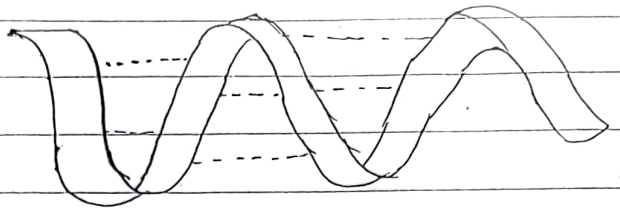

Fig.: α-helix

The α-helix is the most common form of coiling. It is the right-handed coiled strand. The structure is stabilized by hydrogen bonds between ~~hydrogen~~ of $-NH_2$ group and the ~~hydrogen~~ oxygen of $-CO$ group of the fourth amino acid away in the peptide chain. Although hydrogen bond is fairly weak, the large number of bonds involved maintains a stable structure. α-helix proteins are common in ~~keratin~~ Keratin in hair, myosin in muscles, etc.

(b) β-pleated sheet :-

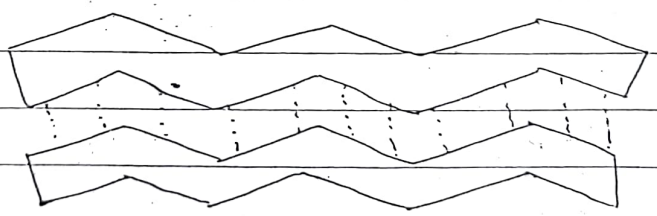

Fig.: β-pleated sheet

The β-pleated sheet is a sheet-like structure & not rod-like structure. The polypeptide chain is fully extended & not coiled as in α-helix. The hydrogen bonding is in between strands (inter-strand) rather than within strands (intra-strand).

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The sheet conformation consists of pairs of strands lying side-by-side. The hydrogen bond occurs between carbonyl oxygen of one strand and amino hydrogen of other strand. The two strands may be either parallel or antiparallel. The β-pleated sheets are found in silk-fibroin.

(c) Tertiary structure :- (eg:- myoglobin)

The third structural level of protein is known as tertiary structure, which involves the folding and coiling of a polypeptide chain to produce a complex globular shape. The folding brings together active amino acids, which are otherwise scattered along the chain.

The tertiary structure is maintained by 4 types of bonds.

i) Disulphide bonds :- A disulphide bond (-S-S-) is formed between 2 cystein residues.

ii) Hydrogen bonds :- Hydrogen bonds are formed between amide hydrogen & carbonyl oxygen of the polypeptide backbone.

iii) Ionic bonds :- These bonds are formed when an acidic and basic amino acid are ionised and lie close together.

iv) Hydrophobic bonds :- These are formed because of tendency of the non-polar side chains of neutral amino acids to closely associate with one another.

(d) Quaternary structure :-

It refers to the association of more than one polypeptide chains to form a stable unit. If the protein consists of identical units, it is ~~called~~

said to have a homogenous quaternary structure eg.: the isozymes H_4 & M_4 of lactic dehydrogenase. If the units are dissimilar, the protein is said to have heterogenous quaternary structure. eg.:- haemoglobin, which consists of two α-chains and two β-chains.

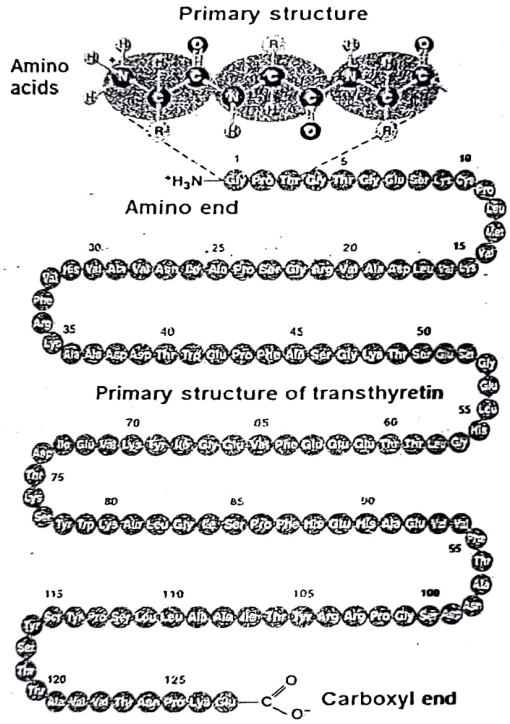


Fig. 14.3 Primary structure of protein

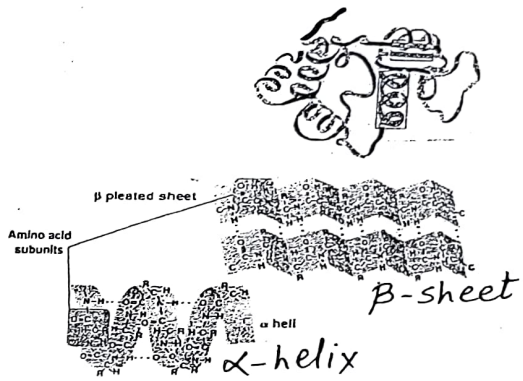
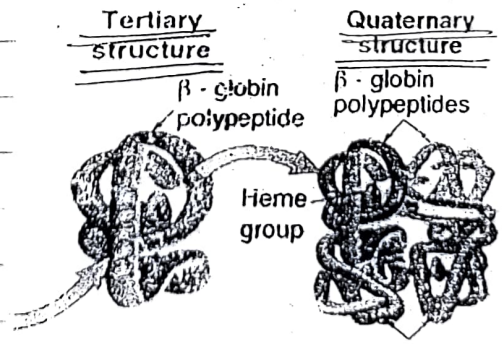


Fig. 14.4 α-helix and ß-sheet.

Secondary structure



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Biological functions of proteins :-

Proteins are present in all the tissues. Many proteins have special physiological functions.

(1) Membrane proteins :- Proteins & lipids form the major structural component of cell membranes. Many enzymes are associated with the membrane.

(2) Enzymes :- Enzymes are special proteins which are capable of catalysing specific reactions. They are biocatalysts, which influence the rate of a chemical reaction, without undergoing any change themselves. All enzymes are proteins.

(3) Hormones :- Several hormones are peptides and proteins. They play an important role in regulation of metabolic reactions.

(4) Blood proteins :- The blood proteins include the plasma proteins and haemoglobine.

(5) Antibiotics :- Some antibiotics like gramicidin S, Tyrosidin & penicillin G are peptides.

(6) Nucleoproteins :- These are conjugated proteins (protein + nucleic acid) of cell nuclei.

* Secondary Metabolites :-

Plants produce a variety of compounds, that can be divided into primary metabolites & secondary metabolites. Primary metabolites are essential for the survival of the plant. They include sugars, proteins and amino acids.

Secondary metabolites are the compounds which are not directly involved in the normal growth, development & reproduction of the plants. They includes tannins, terpenoids, flavonoids, alkaloids, essential oils & organic acids.

(1) Biological functions of tannins :-

- Tannins are distributed in species throughout the plant kingdom. They are found in root, stem, leaves, seeds and buds. They are commonly found in the bark of both gymnosperms as well as angiosperms. High concentration is present in bark of oak, Mimosa and chestnut trees. Some families like Boraginaceae, Cucurbitaceae and Papaveraceae contain no tannin.
- The best known human dietary sources of tannins are tea and wine. Apple juice & grape juice are high in tannins. Coffee pulp also contains low to trace amount of tannins.
- Tannic acid is used as aroma ingredient in alcoholic drinks.
- Tannins are also used as clarifying agents in the wine industry & soft drinks or juices.
- Tannins are used in tanning of leather.
- They are used in production of wood adhesive.
- Tannins protect the plant from pathogens.
- Tannins are effective in enhancing milk production & wool & also effective against gastrointestinal parasites of animals.

- Tannins have shown potential antiviral, antibacterial & antiparasitic effects.
- Tannins can be used as rust inhibitor on the surface of steel.

(2) Biological functions of terpenoids :-

- Terpenoids are made up of isoprene units and are found in all plants. They are the largest group of secondary metabolites & are volatile ie. they evaporate easily.
- Terpenoids contribute the scent of Eucalyptus, the flavour of Cinnamon, cloves and ginger, Menthol, camphor, turmeric & mustard also contain terpenoid.
- Isoprene is a gas produced in chloroplasts & released by leaves. It is thought to protect the plant from heat.
- Taxol from the bark of the Pacific yew tree is used to treat ovarian and breast cancer.
- Rubber, which is obtained from the latex of plant Hevea brasiliensis, is also terpenoid. The uses of rubber are numerous. The rubber is used in shoes, erasers, tyres, etc.

(3) Biological functions of flavonoids :-

- Flavonoids are a important class of plant secondary metabolites. They are widely distributed in plants & have many functions.
- Over 6,000 unique flavonoids have been identified in research studies.
- They are highly bioactive and play different role the health of plants, animals & human health.
- Fruits and vegetables are the main sources of the flavonoids for humans, along with tea and wine.
- Many flavonoids are shown to have antioxidant activity, coronary heart disease prevention and anticancer ~~activity~~, antiviral, antibacterial & anti-inflammatory activity.
- Flavonoids are most important plant pigments for flower coloration. They produce yellow or red/blue pigmentation in petals, which helps in the attraction of insects for pollination.
- In higher plants; flavonoids are involved in symbiotic nitrogen fixation. Flavonoids secreted by root of legume plants help to grow Rhizobium & also helps to develop symbiotic relationship with legumes like peas, beans, groundnut, soybean, etc.
- Some flavonoids ~~are~~ have inhibitory activity against organisms causing plant diseases, such as Fusarium oxysporum.

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(4) Biological functions of alkaloids :—

- Alkaloids are nitrogen-containing chemical compounds. They are widely used in medicine.
- 'Morphine' was the first alkaloid to be found. It comes from the plant Papaver somniferum (opium poppy). It is used as pain reliever in patients with severe pain level. It is also used as cough suppressant.
- About 2,500 alkaloids have been isolated so far. They are poorly found in pteridophytes & gymnosperms. They are mainly found in dicot angiosperms of ~~families~~ Magnoliales, Ranunculales, Papaveraceae, Leguminosae, Papilionaceae & Rutaceae. Among monocots, alkaloids are found in Liliaceae & Graminae.
- The alkaloid 'cocaine' is highly dangerous and ~~addictive~~ addictive. However, it is used as anaesthetic. Cocaine derivatives are dangerous when habitually used they can be deadly.
- Perhaps most loved & known alkaloid is 'caffeine', which come from cocoa, coffee and tea. Caffeine has been thought to reduce the risk of diabetes & heart disease. It is stimulant
- The alkaloid 'quinine' is antipyretic and antimalerial. It is obtained from Cinchona tree
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(5) Biological functions of essential oils :-

- Most vegetative oils are rich in linoleic acid (safflower, sunflower etc.). Alpha linoleic acid is found in green leaves of plants & in selected seed nuts & legumes. (particularly flax (अलसी), rapeseed & soy.
- Fish oils are rich in omega-3 fatty acids, which are beneficial on infant development, cancer, cardio-vascular diseases, mental illness such as depression etc.
- Consumption of trans fats, such as those present in partially hydrogenated vegetable oils, are a risk factor for cardiovascular diseases.
- Oil is used as essential nutrients much needed by the body. It helps the body detoxify, maintain circulation & improve immune system & health.
- Oils are not a food group, but they provide essential nutrients. So, only small amount of oils are recommended. Oils contain essential fatty acids.
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(6) Biological functions of organic acids :-

- Organic acids are used in food preservation because they have capacity to inhibit the growth of bacteria.
- Lactic acid & its salts sodium lactate ~~are~~ & potassium lactate are widely used as antimicrobials in food products, particularly meat and poultry.
- Organic acids have been used successfully in pig production for more than 25 years.
- The use of organic acids has also been found to be effective in poultry production.
- Organic acids have preventive effect on the necrotic enteritis in chickens and Escherichia coli infection in pigs.