ZOOLOGY

UNIT I

STRUCTURE & FUNCTION OF BIOMOLECULES

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DR. WKB'S ZOOLOGY STUDY MATERIAL

UG SEMESTER-I UNDER NEP-2020 (ZOOLOGY)

AUTHORED BY: DR. WAHIED KHAWAR BALWAN

M.Sc., Ph.D., D.Litt., D.Sc., PDF-H, FZSI, FSLSc., FAELS, FBPS, FSASS, FABRF, FGESA, FC-ISCA, FIARA, FGT, FIIOR, FIOASD

Senior Asstt. Professor Zoology, Higher Education Department, Jammu and Kashmir

E-Mail: wahied_kb@yahoo.co.in

Mob. No.: +91-94193-69557

Biomolecule is any molecule that is produced by a living organism, including large molecules such as protein, polysaccharides, lipids and nucleic acids as well as small molecules such as primary metabolites, secondary metabolites and natural products. A more general name for this class of molecule is biogenic substance.

Biomolecules which are larger in size, have complex structures and high molecular weight (usually 10,000 Daltons) are called macromolecules like carbohydrates, proteins, lipids, nucleic acids etc. Biomolecules which are smaller in size, having low molecular weight (18-1800 Daltons) are called micromolecules. They include water, gases, minerals, amino acids, simple sugars, nucleotides etc.

CARBOHYDRATES

Carbohydrates are defined as optically active polyhydroxy aldehydes or ketones or substances giving polyhydroxy aldehydes or ketones on hydrolysis. Carbohydrates are hydrates of carbon. They contain carbon, hydrogen and oxygen in the ratio of 1:2:1. Carbohydrates are represented by the general formula $C_n(H2O)_n$. They are also called saccharides as their basic component is sugar.

SOURCES OF CARBOHYDRATES

Carbohydrates are an important part of any human's diet. Some common sources of carbohydrates are potatoes, maize, milk, popcorn and bread etc.

Classification of Carbohydrates

Carbohydrates are classified into two types namely small (monosaccharides and oligosaccharides) and complex (polysaccharides).

Monosaccharides

They are simple sugars. They cannot be hydrolysed into simple sugars. They are sweet in taste and soluble in water. For Example, Glucose, Fructose, Galactose etc.

Oligosaccharides

They are sugars which yield 2 to 10 monosaccharides on hydrolysis. They are sweet in taste and soluble in water e.g., Maltose (formed of two molecules of glucose), Lactose (formed of galactose and glucose), Sucrose (formed of glucose and fructose) etc. Depending upon the number of sugars, oligosaccharides are classified into disaccharides (having two monosaccharide unit), trisaccharide (having three monosaccharide units and so on.

Polysaccharides

They have large number of monosaccharides joined together by glycosidic bond. Polysaccharides are of two types namely Homopolysaccharide and Hetropolysaccharide.

- **Homopolysaccharide:** It is formed by the linking of a single type of monosaccharides.

On hydrolysis, they yield only one type of monosaccharide e.g. Starch, Glycogen, Inulin, cellulose, pectin, chitin etc.

- **Heteropolysaccharides**: It is composed of a mixture of monosaccharides. On hydrolysis, they yield a mixture of monosaccharides e.g. Hyaluronic acid, Chondroitin, Heparin, Agar agar etc.

STRUCTURE OF CARBOHYDRATES

Glucose

One of the most important monosaccharides is glucose. The two commonly used methods for the preparation of glucose are

1. **From Sucrose:** If sucrose is boiled with dilute acid in an alcoholic solution then we obtain glucose and fructose.
2. **From Starch:** We can obtain glucose by hydrolysis of starch and by boiling it with dilute H_2SO_4 at 393K under elevated pressure.

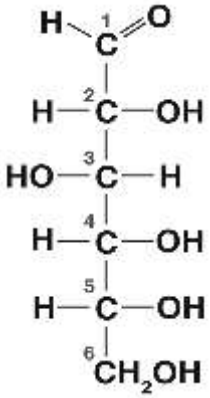


Fig.: Glucose

- Glucose is also called aldohexose and dextrose and is abundant on earth.
- Glucose is named as D (+)-glucose, D represents the configuration whereas (+) represents the ***dextrorotatory*** nature of the molecule.
- The ring structure of glucose can explain many properties of glucose which cannot be figured by open-chain structure.
- The two cyclic structures differ in the configuration of the hydroxyl group at C_1 called anomeric carbon. Such isomers i.e. α and β form are known as anomers.
- The cyclic structure is also called pyranose structure due to its analogy with pyran.

The cyclic structure of glucose is given below:

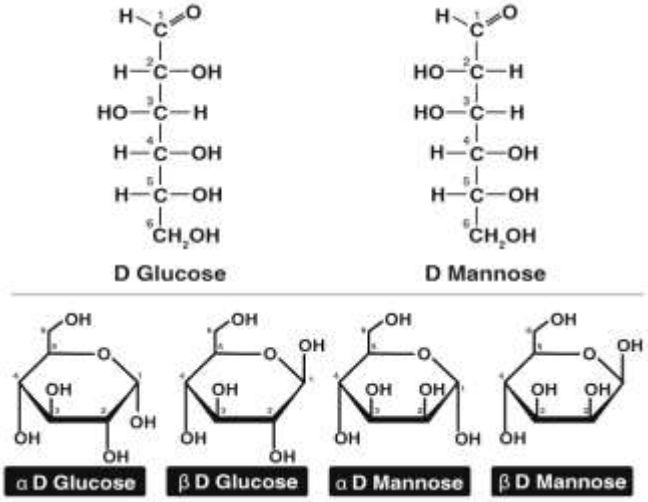


Fig.: Structure of Monosaccharides

Fructose

It is an important ketohexose. The molecular formula of fructose is $C_6H_{12}O_6$ and contains a ketonic functional group at

carbon number 2 and has six carbon atoms in a straight chain. The ring member of fructose is in analogy to the compound furan and is named furanose. The cyclic structure of fructose is shown below:

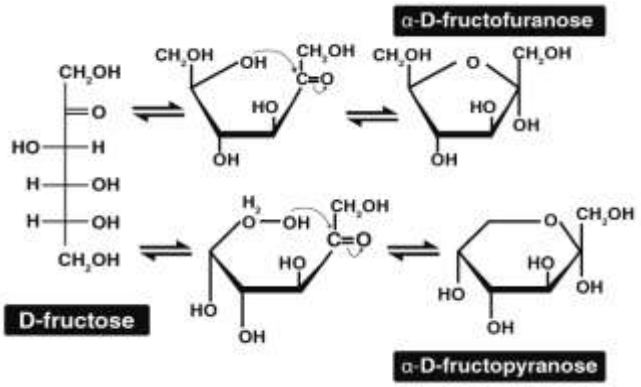


Fig.: Structure of Monosaccharides

Sucrose

Sucrose being dextrorotatory in nature gives dextrorotatory glucose as well as laevorotatory fructose on hydrolysis. The overall mixture is laevorotatory and this is because the laevorotation of fructose (-92.4) is more than the dextrorotation of glucose (+52.5).

Maltose

Maltose is also one of the disaccharides which have two α -D-glucose units which are connected by the first carbon of the glucose and also linked to the fourth carbon of another glucose unit. In the solution, a free aldehyde can be produced at the first carbon of the second glucose of the solution and it is a reducing sugar as it shows reducing properties.

Lactose

Commonly it is called milk sugar as this disaccharide is found in milk. It is made up of Beta-D-galactose and β -D-glucose. The bond is between the first carbon of galactose and the fourth carbon of glucose. This is also a reducing sugar.

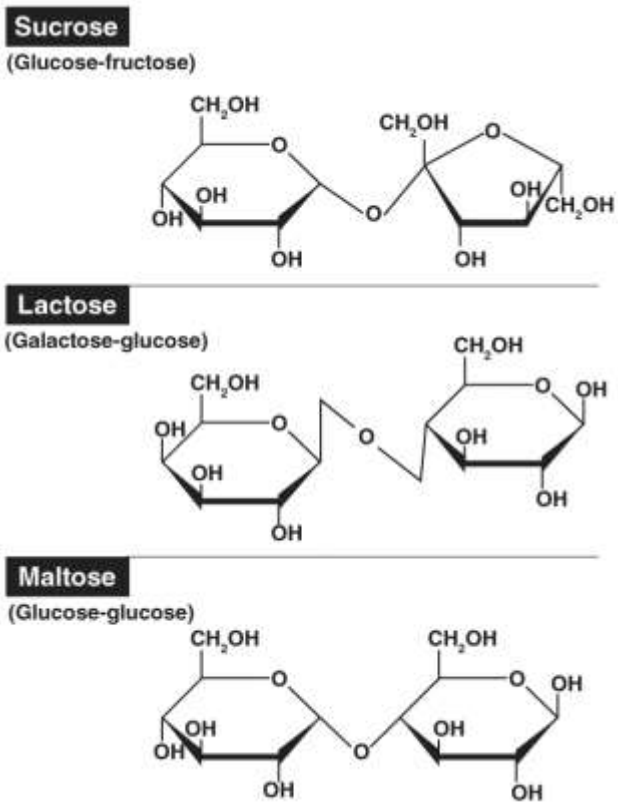


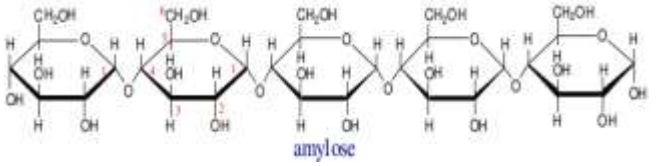
Fig.: Structure of Disaccharides

Starch

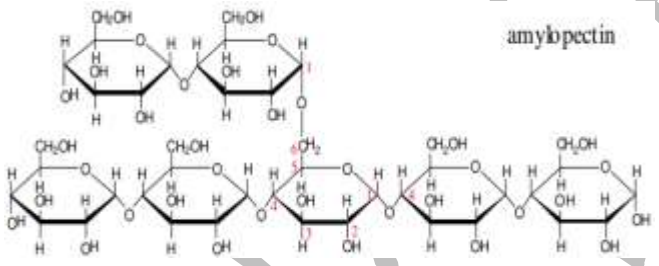
Starch is a polymer consisting of D-glucose units. Starches (and other glucose polymers) are usually insoluble in water because of the high molecular weight, but they can form thick colloidal suspensions with water.

Starch is a storage compound in plants, and made of glucose units. It is a

homopolysaccharide made up of two components: amylose and amylopectin. Most starch is 10-30% amylose and 70-90% amylopectin. Amylose – a straight chain structure formed by 1, 4 glycosidic bonds between α-D-glucose molecules.



The amylose chain forms a helix. This causes the blue colour change on reaction with iodine. Amylose is poorly soluble in water, but forms micellar suspensions. Amylopectin-a glucose polymer with mainly α - (1→4) linkages, but it also has branches formed by α -(1→6) linkages.



Amylopectin causes a red-violet colour change on reaction with iodine. This change is usually masked by the much darker reaction of amylose to iodine.

BIOLOGICAL IMPORTANCE OF CARBOHYDRATES

1. Carbohydrates are chief energy source, in many animals, they are instant source of energy. Glucose is broken down by glycolysis/ Kreb's cycle to yield ATP.
2. Glucose is the source of storage of energy. It is stored as glycogen in animals and starch in plants.
3. Stored carbohydrates act as energy source instead of proteins.
4. Carbohydrates are intermediates in biosynthesis of fats and proteins.
5. Carbohydrates aid in regulation of nerve tissue and are the energy source for brain.
6. Carbohydrates get associated with lipids and proteins to form surface antigens, receptor molecules, vitamins and antibiotics.
7. They form structural and protective components, like in cell wall of plants and microorganisms.
8. In animals they are important constituent of connective tissues.
9. They participate in biological transport, cell-cell communication and activation of growth factors.
10. Carbohydrates that are rich in fibre content help to prevent constipation.
11. Also they help in modulation of immune system.

AMINO ACIDS

Amino Acids are the organic compounds that combine to form proteins, hence they are referred to as the building

components of proteins. These biomolecules are involved in several biological and chemical functions in the human body and are the necessary ingredients for the growth and development of human beings. There are about 300 amino acids that occur in nature.

Amino acids are organic compounds containing the basic amino groups (-NH2) and carboxyl groups (-COOH). The ingredients present in proteins are amino acids. Both peptides and proteins are long chains of amino acids. Altogether, there are twenty amino acids, which are involved in the construction of proteins.

Alanine	$C_3H_7NO_2$	Leucine	$C_6H_{13}NO_2$
Aspartic Acid	$C_4H_7NO_4$	Lysine	$C_6H_{14}N_2O_2$
Asparagine	$C_4H_8N_2O_3$	Methionine	$C_5H_{11}NO_2S$
Arginine	$C_6H_{14}N_4O_2$	Proline	$C_5H_9NO_2$
Cytosine	$C_4H_5N_3O$	Phenylalanine	$C_9H_{11}NO_2$
Cysteine	$C_3H_7NO_2S$	Serine	$C_3H_7NO_3$
Glycine	$C_2H_5NO_2$	Tyrosine	$C_9H_{11}NO_3$
Glutamine	$C_5H_{10}N_2O_3$	Threonine	$C_4H_9NO_3$
Histidine	$C_6H_9N_3O_2$	Tryptophan	$C_{11}H_{12}N_2O_2$
Isoleucine	$C_6H_{13}NO_2$	Valine	$C_5H_{11}NO_2$

General properties of Amino acids

1. They have a very high melting and boiling point.
2. Amino acids are white crystalline solid substances.
3. In taste, few Amino acids are sweet, tasteless, and bitter.
4. Most of the amino acids are soluble in water and are insoluble in organic solvents.

Sources of Amino Acids

Amino acids play an important role in performing several biological and chemical functions in different parts of our body, including building and repairing the tissues, the formation and function of enzymes, food digestion, the transportation of molecules, etc. Our body can synthesize only certain amino acids and the rest of the amino acids which are called essential amino acids should be supplied through protein-rich foods in our daily diet.

Foods rich in amino acids include plant-based products like broccoli, beans, beetroots, pumpkin, cabbage, nuts, dry fruits, chia seeds, oats, peas, carrots, cucumber, green leafy vegetables, onions, soybeans, whole grain, peanuts legumes, lentils, etc. Fruits rich in amino acids are apples, bananas, berries, figs, grapes, melons, oranges, papaya, pineapple, and pomegranates. Other animal products include dairy products, eggs, seafood, chicken, meat, pork etc.

Structure of amino Acids

The general structure of Amino acids is H_2NCH RCOOH, and it can be written as:

COOH

|

H2N – –C – – H

|

R

There are 20 naturally occurring amino acids and all have common structural features – an amino group ($-NH_3^+$), a carboxylate ($-COO^-$) group and a hydrogen-bonded to the same carbon atom. They differ from each other in their side-chain called the R group. Each amino acid has 4 different groups attached to α- carbon.

These 4 groups are amino group, COOH group, Hydrogen atom and Side chain (R).

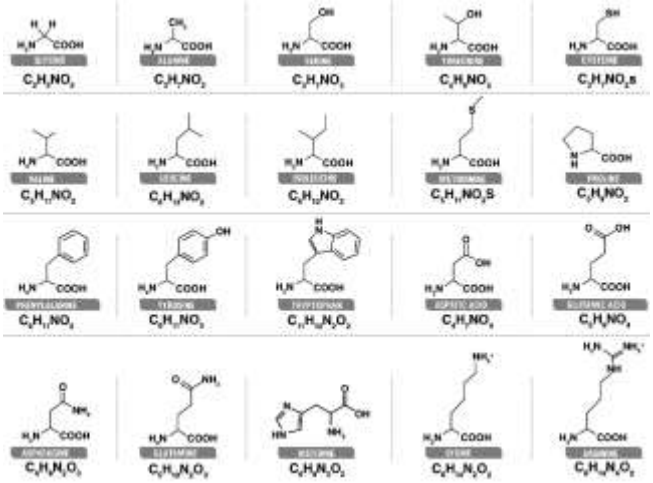


Fig.: Structure of Twenty Amino Acids

Essential and Non-essential Amino acids

Out of 20 amino acids, our body can easily synthesize a few on its own, which are called non-essential amino acids. These include alanine, asparagine, arginine, aspartic acid, glutamic acid, **cysteine**, glutamine, proline, glycine, serine, and tyrosine.

Apart from these, there are other nine amino acids, which are very much essential as they cannot be synthesized by our body. They are called essential amino acids, and they include Isoleucine, Histidine, Lysine, Leucine, Phenylalanine, Tryptophan, Methionine, Threonine and Valine.

Functions of Amino Acids

Functions of Essential Amino acids

1. Phenylalanine helps in maintaining a healthy nervous system and in boosting memory power.
2. Valine acts as an important component in promoting muscle growth.
3. Threonine helps in promoting the functions of the immune system.
4. Tryptophan is involved in the production of vitamin B3 and serotonin hormones. This serotonin hormone plays a vital role in maintaining our appetite, regulating sleep and boosting our moods.
5. Isoleucine plays a vital role in the formation of haemoglobin, stimulating the pancreas to synthesize insulin, and transporting oxygen from the lungs to the various parts.

6. Methionine is used in the treatment of kidney stones, maintaining healthy skin and also used in controlling invade of pathogenic bacteria.
7. Leucine is involved in promoting protein synthesis and growth hormones.
8. Lysine is necessary for promoting the formation of antibodies, hormones, and enzymes and in the development and fixation of calcium in bones.
9. Histidine is involved in many enzymatic processes and in the synthesizing of both red blood cells (erythrocytes) and white blood cells (leukocytes).

Functions of Non-Essential Amino acids

1. Alanine functions by removing toxins from our body and in the production of glucose and other amino acids.
2. Cysteine acts as an antioxidant and provides resistance to our body; it is important for making collagen. It affects the texture and elasticity of the skin
3. Glutamine promotes a healthy brain function and is necessary for the synthesis of nucleic acids – DNA and RNA.
4. Glycine is helpful in maintaining the proper cell growth, and its function, and it also plays a vital role in healing wounds. It acts as a neurotransmitter.
5. Glutamic acid acts as a neurotransmitter and is mainly involved in the development and functioning of the human brain.
6. Arginine helps in promoting the synthesis of proteins and hormones, detoxification in the kidneys, healing wounds, and maintaining a healthy immune system.
7. Tyrosine plays a vital role in the production of the thyroid hormones -T_3 and T_4, in synthesizing a class of neurotransmitters and melanin, which are natural pigments found in our eyes, hair, and skin.
8. Serine helps in promoting muscle growth and in the synthesis of immune system proteins.
9. Asparagine is mainly involved in the transportation of nitrogen into our body cells, formations of purines and pyrimidine for the synthesis of DNA, the development of the nervous system and improving our body stamina.

10. Aspartic acid plays a major role in metabolism and in promoting the synthesis of other amino acids.
11. Proline is mainly involved in the repairing of the tissues in the formation of collagen, preventing the thickening and hardening of the walls of the arteries (arteriosclerosis) and in the regeneration of new skin.

DEFICIENCY OF AMINO ACIDS

Amino acids are the building blocks of proteins and proteins play a fundamental role in almost all **life processes**. Therefore, it is necessary to include all nine essential amino acids in our daily diet to maintain a healthy and proper function of our body. The deficiency of amino acids may include different pathological disorders, including:

- Edema
- Anemia
- Insomnia
- Diarrhea
- Depression
- Hypoglycaemia
- Loss of Appetite
- Fat deposit in the liver
- Skin and hair related problems
- Headache, weakness, irritability and fatigue.

PROTEINS

Proteins are macromolecules composed of one or more polypeptide chains possessing a characteristic amino acid sequence. It is a polymer of amino acids. In proteins one amino acid is binded to the other amino acid by peptide (-CO-NH-) bond which is formed between amino group of one amino acid and carboxyl group of other amino acid. The term protein was coined by Jons Jacob Berzelius in 1838.

SOURCES OF PROTEINS

Proteins are obtained from animal and plant source. The animal sources of proteins include milk, egg, meat, fish, liver etc. Plant sources of proteins are pulses, nuts and cereals.

CLASSIFICATION OF PROTEINS

On the basis of solubility and shape, proteins are classified into two types namely Globular and Fibrous Proteins:

- **Globular Proteins**: They are spherical in shape and soluble in water. They are highly branched. The polypeptide chains are cross linked by the usual peptide bonds. These proteins are tightly folded into spherical or globular shape. The globular proteins include enzymes, protein hormones, antibodies, haemoglobin and myoglobin.
- **Fibrous Proteins**: They are in the form of fibres and insoluble in water. They are

unbranched. They are highly resistant to digestion by proteolytic enzymes. They are linear molecules. The long linear protein chains are held together by intermolecular H-bonds. They serve as structural proteins. The common fibrous proteins are collagen of tendons, elastin of connective tissue, fibroin of silk, keratin of hair, actin and myosin.

On the basis of increasing complexity of structure, proteins are classified into three groups namely simple proteins, conjugated proteins and derived proteins.

- **Simple Proteins**: The proteins which yield amino acids or their derivatives on hydrolysis are called simple proteins or the proteins which are made up of amino acid only. For Example, Histones, Keratins.
- **Conjugated Proteins**: These are proteins united with non-protein substances. The non-protein substances linked to proteins are referred to as *prosthetic group*. The protein part is called *apoprotein*. The prosthetic group and apoprotein are together called *haloprotein*. So conjugated proteins on hydrolysis yield non-protein substances in addition to amino acids. For Example, Glycoproteins (contain carbohydrates) like mucin in saliva, egg albumin, serum albumin and serum globulin, Phosphoproteins (Contain phosphoric acid) like casein in milk and vitelline in egg yolk.
- **Derived Proteins**: They are intermediate products formed from natural proteins when they are hydrolysed by heat, acids, alkalis or enzymes. For Example, Fibrin.

STRUCTURE OF PROTEINS

Every protein has a three dimensional structure that can have upto four levels of organisation:

Primary Structure

It is the basic linear sequence of amino acids in a polypeptide chain. For Example, Fibroin of Silk.

Secondary Structure

It is the development of new stearic relationships of amino acids present in the linear sequence inside the polypeptides like in Keratin. These are of two types namely α-helix and β-pleated. These are accomplished through hydrogen bonding between amino acids.

α-helix is formed by a series of amino acid residues woven into a spiral chain. The helical structure of protein is formed by the hydrogen bonds between the peptide groups of every first and fourth amino acid residues.

β-pleated is formed from H-bonding between two peptide chains. This bonding leads to the formation of sheets of parallel

chains in the form of pleated sheets. In pleated sheet structure, the chains may be parallel or antiparallel. In a parallel chain pleated sheet structure, the N-terminal end of the polypeptide chains point in the same direction. In antiparallel chain pleated sheet structure, the N-terminal ends of the polypeptide chains point in opposite directions.

Tertiary Structure

It is the bending and folding of secondary strand of polypeptide to various types of structures. It is stabilized by several types of bonds like hydrogen bonds, ionic bonds, van der Waals interactions, disulphide, hydrophobic bonds etc. Myoglobin, Ribonulcease, Chymotrypsin, Cytochrome C etc. shows tertiary structure.

Quaternary Structure

It is found in multimeric proteins. Each polypeptide develops its own tertiary structure and functions as subunits of proteins. It is exhibited by proteins containing more than one polypeptide chain like haemoglobin.

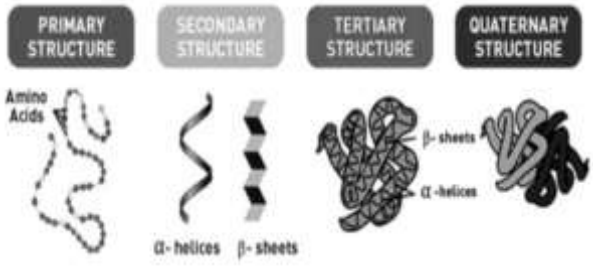


Fig.: Structural Organization of Proteins

PROPERTIES OF PROTEINS

Denaturation

Partial or complete unfolding of the native (natural) conformation of the polypeptide chain is known as denaturation. This is caused by heat, acids, alkalies, alcohol, acetone, urea, beta-mercaptoethanol.

Coagulation

When proteins are denatured by heat, they form insoluble aggregates known as coagulum. All the proteins are not heat coagulable, only a few like the albumins, globulins are heat coagulable.

Isoelectric pH (pH^1)

The pH at which a protein has equal number of positive and negative charges is known as isoelectric pH. When subjected to an electric field the proteins do not move either towards anode or cathode, hence this property is used to isolate proteins. The proteins become least soluble at pH^I and get precipitated. The pH^I of casein is 4.5 and at this pH the casein in milk curdles producing the curd.

Molecular Weights of Proteins

The average molecular weight of an amino acid is taken to be 110. The total number of amino acids in a protein multiplied by 110 gives the approximate molecular weight of that protein. Different

proteins have different amino acid composition and hence their molecular weights differ. The molecular weights of proteins range from 5000 to 10^9 Daltons.

FUNCTIONS OF PROTEINS

Proteins play various important roles which are the following:

1. **Enzyme Catalysts**: Almost all chemical reactions in the biological system are catalyzed by enzymes. All enzymes are proteins.
2. **Transport:** Proteins transport ions and small molecules e.g. Haemoglobin a conjugated protein of blood transport oxygen.
3. **Storage:** Certain proteins function as a storage molecule e.g. ferritin, a protein stores iron in liver.
4. **Contraction and Movement:** The contraction of muscle is brought about by two fibrous proteins called actin and myosin. The microtubules of flagella and cilia are built on tubulin, a protein.
5. **Mechanical Support:** Many proteins serve as supporting filaments, cables or sheets to give biological structures strength, support and protection e.g., collagen a fibrous protein is the major component of hair, finger nails and feathers.
6. **Immune Protection:** Many proteins defend organisms against invasion by other species. Invading bacteria, virus etc. elicit the production of antibodies by lymphocytes. Antibodies neutralize the foreign germs. Antibodies are proteins.
7. **Blood Clotting:** Bleeding is stopped by the formation of clot. Clotting is brought about by clotting proteins such as fibrinogen and thrombin.
8. **Transmission of Nerve Impulse:** The nerve impulse is transmitted with the help of receptor protein through synapse.
9. **Hormonal action:** Many hormones are proteins e.g., insulin, growth hormone, parathyroid hormone etc.
10. **Thermoregulation:** The blood plasma of some Antarctic fish contains antifreeze proteins which prevent the blood from freezing.

LIPIDS

Lipids are group of molecules that are insoluble in polar solvents such as water but soluble in non-polar solvents such as benzene and ether. Lipids contain relatively long hydrocarbon chains that are non-polar and thus hydrophobic. The term lipid was first introduced by Bloor in 1943. The lipids are important constituents of diet due to their high energy value. One gram of lipid yields 9.3 kilo calories of heat. The lipids are found in all organisms including virus.

PROPERTIES OF LIPIDS

Lipids have three important properties. They are:

1. Lipids are insoluble in water but soluble in non-polar organic solvents, such as acetone, alcohol, chloroform, benzene and ether.
2. They contain a large proportion of carbon and hydrogen bonds and release large amount of energy on breakdown.
3. On alkaline hydrolysis, lipids yield alcohol and fatty acids.

The common lipids are fats, oils, waxes, phospholipids, glycolipids, cerebrosides, sulfolipids, aminolipids, steroids, terpenes, carotenoids, some hormones and some vitamins.

CLASSIFICATION OF LIPIDS

Lipids are generally classified into three types namely simple lipids, compound lipis and derived lipids.

Simple Lipids or Homolipids

These are esters of fatty acids with alcohol like glycerol (in neutral fats) and cetyl alcohol (in waxes). Fats, oils and waxes are simple lipids.

Neutral or True Fats: They are simple lipids. They are solid or semi-solid at room temperature. They are the esters of fatty acids with glycerol. A fat is made up of a glycerol molecule and thee fatty acids. It is called triglyceride. They form insulation to temperature loss. They are found in liver, seeds, fruits etc. If the three molecules of fatty acids are same, the fat is *simple glyceride*. If the fatty acids are different, then the fat is a *mixed glyceride*. If the glycerides have no free acid or basic groups the fat is termed *neutral fat*. Fats have high melting point and are insoluble in water. They float in water. They form soap with alkali. The process of formation of soap is called *saponification*. They develop unpleasant odour on aging. It is called rancidity. Rancidity is caused by oxidation and hydrolysis.

Fats are two types namely Animal fats and Plant fats.

Animal Fats are relatively rich in saturated fatty acids (with C_{16} and C_{18} acids).

Plant Fats are relatively rich in unsaturated fatty acids (poly unsaturated acids).

Oils: They are liquid fats. They are simple lipids. They are esters of fatty acids and glycerol. One glycerol molecule is linked to three fatty acids. The oils are found in both plants and animals. The oils found in plants are

called *vegetable oils* e.g., coconut oil, groundnut oil, cotton seed oil etc. The oils found in animals are called *animal oils* e.g., fish liver oil etc. Oil remains liquid at room temperature and in tropical countries. The fatty acids found in oils are mostly unsaturated fatty acids. If the three fatty acids of oil are similar, the oil is called *simple oil*. When the fatty acids are dissimilar, the oil is called *mixed oil*. Oils have low melting point. They are insoluble in water and spread uniformly on water. They are soluble in organic solvent. In water, oils are broken into minute droplets and dispersed. This is called *emulsification*.

Waxes: Waxes are simple lipid, solid lipids. They are esters of fatty acids with monohydric alcohols of higher molecular weight. Waxes are secreted by bees, cutaneous glands and plants. Waxes are acting as a protective coating to keep the skin pliable, lubricated and water proof.

The common examples are bee wax, sperm whale wax (spermaceti), carnauba wax.

The bee wax contains plamitic acid and myricyl alcohol and it is called myricyl palmitate.

The sperm whale wax contains plamitic acid and cetyl alcohol and is called cetyl palmitate.

Carnauba wax is the hardest known wax and contains fatty acid esterified with tetracosanol and tetratriacontanol.

Waxes are insoluble in water and resistant to atmospheric oxidation. They have high melting point.

Compound Lipids or Heterolipids

They are the lipids linked to non-lipids. They consist of three components namely glycerol, fatty acid and a non-lipid. The non-lipid may be phosphoric acid or a carbohydrate. Compound lipids are of two types namely Phospholipids (Phosphatids) and Glycolipids (Cerebrosides).

1. **Phospholipids:** These are the compound lipids formed by glycerol, phosphoric acid and fatty acids. They include Lecithins (found in the brain, nervous tissues, sperm and egg yolk, seeds, sprouts), Cepahalins (found in animal tissues, soyabean oil); Plasmologens (found in brain, muscle and seeds of higher plants); Phosphoinositides (found in in brain tissues, soyabean); Phosphingosides or Sphingomyelins (myelin sheath of the nerve, spinal cord and in plant seeds).

2. **Glycolipid or Galactolipids or Cerebrosides or Glycosphingosides:** These are compound lipids containing sugars and fatty acids like sphingosine and no phosphoric acid. It is found in brain, adrenals, kidney, spleen, liver, thymus, egg yolk, lungs, retina and fish sperm and leucocytes e.g. Gangliosides found in brain tissue. Gangliosides contain ceramide, N-acetyl neuraminic acid (NANA), N-acetyl galactosamine, Carbohydrates (hexoses like glucose and galactose).

Derived Lipids

They are the products of hydrolysis of simple lipids and compound lipids and include compound like steroids (cholesterol), terpenes, coprostanol (occurs in faeces), carotenoids, ergasterol (Ergot and Yeast).

FUNCTIONS OF LIPIDS

1. Lipids contains large amount of energy so are good source of energy.
2. Lipids are insoluble in water, so they are readily stored in the body as a food reserve.
3. Lipids constitute an important component of cell membrane.
4. Lipids serve as an electroinsulating material in the myelin sheath of neurons.
5. Subcutaneous fats of mammals act as an insulator against the excessive heat loss to the environment.
6. Lipids of connective tissue of internal organs protect them from the eventual damage on exposure to mechanical action.
7. The major group of hormones is formed of steroids. They regulate the large variety of physiological functions e.g., sex hormones and adrenocorticoids.
8. Lipids acts as carriers of natural fat soluble vitamins such as A, D and E.
9. Lipids are essential for activation of enzymes like glucose-6-phosphate etc.

FATTY ACIDS

Fatty acids are aliphatic straight chain hydrocarbon compounds with a terminal carboxyl group. They are the building blocks of lipids. There are about 200 fatty acids. They have single carboxyl group and a long non-polar (=Hydrophobic or Water hating) hydrocarbon tail. This non-polar tail gives most lipids their water insoluble and oily or greasy nature. Fatty acids are classified into two groups based on the

presence or absence of double bonds namely:

- **Saturated Fatty Acids**: they have single bonds i.e. they are without double bond. At one end there will be an acid (-COOH) group and at the other end there will be methyl (-CH_3) group. In between these two groups, there will be CH_2 groups. These fatty acids ends with suffix 'anoic' e.g., Stearic acid (common source animal and plant fat), Decanoic acid (Common source Coconut and palm oil), Palmitic acid (common source animal and plant fat).
- **Unsaturated Fatty Acids**: They have one or more double bonds i.e. 1 to 6 double bonds. These double bonds may occur after 9,12,15,18 etc. carbon atoms. These fatty acids end with suffix 'enoic'. Based on the number of double bonds, these unsaturated fatty acids may be called as monoenoic (one double bond), dienoic (two double bonds), trienoic (three double bonds), and tetraenoic (four double bonds) and so on.

  Unsaturated fatty acids in general containing more than one double bond is called polyunsaturated fatty acid (PUFA) e.g. Linoleic acid, Oleic acid, Arachidonic acid etc.

Besides fatty acids are further classified into following types namely:

- **Hydroxy or Oxygenated Fatty Acids**: Fatty acids containing hydroxy group e.g., Ricinoleic acid, Cerebronic acid.
- **Cyclic Fatty Acids**: fatty acids with cyclic structures e.g., Chaulmoogric acid, Hydnocarpic acid, Lactobacillic acid.
- **Essential Fatty Acids**: The fatty acids which are not synthesized by man, but they must be included in the diet are called essential fatty acids e.g., Linoleic acid, Linolenic acid and Arachidonic acid.
- **Non-Essential Fatty Acids**: Certain fatty acids can be synthesized in the tissues from other fatty acids. These fatty acids need not be included in the diet. Hence they are called non-essential fatty acids e.g., Oleic acid, Palmitoleic acid.

ENZYMES

Enzymes are macromolecular biological catalysts that accelerate chemical reactions without being utilized themselves. The term enzyme was first introduced by Wilhelm Kuhne in 1877. But first enzyme to be discovered was diastase by Anselme Payen in 1833.The study of enzyme is known as enzymology.

NOMENCLATURE OF ENZYMES

The International Union of Biochemistry and Molecular Biology is entrusted with designating names to enzymes in addition to assigning a number in order to identify them.

Apart from a few originally studied enzymes such as rennin, pepsin and trypsin, almost all the enzyme names end in 'ase'. As per the standards, focal points of nomenclature of enzymes are both the type of reaction catalyzed and the substrate acted upon.

Most commonly, enzymes are named to provide data on the function as opposed to the structure of the enzyme. However, there are three significant features of the nomenclature process of enzymes, which are:

1. Suffix *-ase* recognizes a substance as that of an enzyme
    - Suffix - in is observed in the name of first enzymes learnt as pepsin, chymotrypsin, trypsin
2. Prefix is identified by the type of reaction the enzyme catalyzes
    - Enzyme hydrolase : Catalyzes a hydrolysis reaction
    - Enzyme oxidase : Catalyzes an oxidation reaction
3. In addition to the type of reaction, the identity of the substrate is taken into consideration

a. Glucose oxidase: Catalysis of glucose oxidation.
b. Lactate dehydrogenase: Catalysis of eliminating hydrogen from lactate ion.
c. Lactase: Hydrolysis of lactose is catalyzed.
d. Urease: Hydrolysis of urea is catalyzed.

Example of Naming

As per the standard International Union of Biochemistry, the name of the enzyme comprises two parts namely:

1. Name of the substrate for the enzyme
2. Type of reaction catalyzed by the enzyme. The second part, therefore, ends with 'ase' suffix

For Example: Lactate Dehydrogenase

Conventions of Naming– EC Numbers

The nomenclature developed by the International Union of Biochemistry and Molecular Biology has something called EC numbers where each enzyme is preceded by EC. The first number in this series classifies this enzyme on the basis of its mechanism.

EC Numbers

There are six groups of enzymes as per the reaction that is being catalyzed. Therefore, all enzymes are designated as "EC numbers". This classification does not consider protein structure, amino acid sequence or even the chemical mechanism.

EC number is a 4 digit number for instance – a.b.c.d. Here "a" is class, "b" is subclass, "c" is sub-subclass and "d" is the sub-sub-subclass. The "b" and "c" part of the EC number describes the reaction, "d" differentiates between different enzymes with similar function on the basis of the actual substrate in the reaction.

For Example: EC number of Alcohol: NAD+ oxidoreductase is 1.1.1.1

CLASSIFICATION OF ENZYMES

In 1961, the enzyme commission of the International Union of Biochemistry (IUB) proposed a comprehensive system for the classification of enzyme. According to this system, enzymes are classified into six major classes namely:

1. **Oxidoreductases**: They are enzymes which are involved in biological oxidations and reductions. For Example, Dehydrogenases, Oxidases, Oxygenases etc.
2. **Transferases**: These enzymes transfer a group from one substrate to another substrate. For Example, Transaminase, Creatine phosphoryl transferase etc.
3. **Hydrolases**: These are enzymes which catalyse hydrolysis i.e. direct addition of water molecules across a bond which is cleaved. For Example, Proteases, Carbohydrases, Esterases etc.
4. **Lyases**: These are the enzymes which catalyse either the removal of a group of atoms from their substrate leaving double bonds or add groups to double bonds without hydrolysis, oxidation or reduction. For Example, Aldolase, Enolase, Fumarase etc.
5. **Isomerases or Mutases**: These are enzymes which catalyse the inter-conversion of a compound to one of its isomers. For Example, Phosphoisomerase.
6. **Ligases or Synthetases**: These enzymes catalyze synthesis reactions by joining two molecules coupled with the breakdown of a pyrophosphate bond of ATP to ADP. For Example, DNA ligase, RNA synthetase, Glutamine synthetase.

MECHANISM OF ENZYME ACTION

The breaking of substrate into end products by an enzyme is called enzyme action. Michaelis and Mention proposed a hypothesis for enzyme reaction. The enzyme action involves the following steps:

1. The enzyme molecule (E) combines with a substrate molecule (S) to form an enzyme-substrate complex (ES). It is also called as Michaelis complex.
2. The enzyme contains specific sites for the attachment of substrate. These sites are called active sites or

catalytic centres. They are made up of amino acid residues.

3. The active sites loosen the chemical bonds in the substrate and this leads to the breaking of substrate into end products.
4. Finally, the enzyme dissociates from the end products.
5. The enzyme is now free to combine with another molecule of substrate.

There are two hypotheses which explain the mechanism of the formation of the enzyme substrate complex:

Lock and Key Hypothesis

It was proposed by Emil Fisher in 1914. According to this hypothesis, the enzyme molecule has one or more specific points. These points are called active sites or active centres. The active sites exist in the enzyme in a rigid and proper conformation even in the absence of substrate. During enzyme action, the substrate fits into the active site of the enzyme as a key fits into the lock.

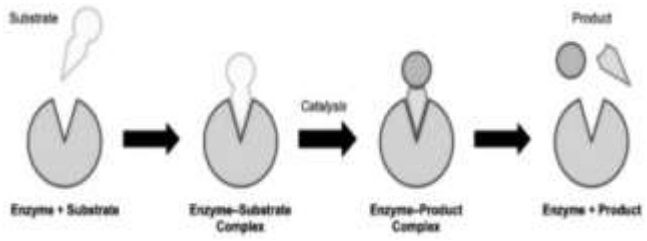


Fig.: Lock and Key Hypothesis

Induced Fit Hypothesis

It was proposed by Koshland n 1963. This theory says that the active site does not possess a rigid and performed structure. The region of the active sites is flexible. When the enzyme reacts with the substrate, the substrate induces a conformational change in the active site of the enzyme. The change results in the development of attraction between enzyme and the substrate so that an enzyme substrate complex is formed. It leads to the loosening of the chemical bonds linking the components of the substrate. As the reaction is completed the substrate is split into end products and enzyme is released.

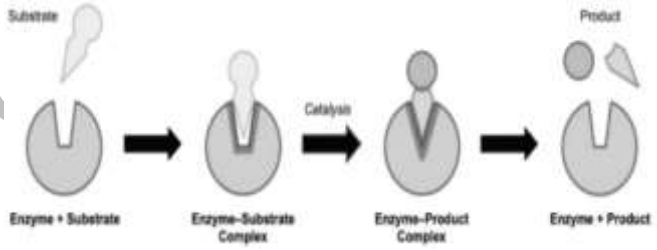


Fig.: Induced Fit Hypothesis

PROPERTIES OF ENZYMES

1. Most of the enzymes are simple or conjugated protein. They exhibit all the properties of proteins.
2. Enzymes are colloidal in nature.
3. Enzymes undergo denaturation when subjected to changes in pH or increase in temperature.
4. Enzyme accelerates speed of reactions.

5. The enzyme promotes a given reaction, but itself remains unchanged at the end of the reaction.
6. Only small amount of enzyme is required by a biological system for a complete reaction.
7. Every enzyme has an optimum temperature at which the rate of activity is maximum.
8. Most of the enzyme are characterized by the reversibility of their actions i.e. enzymes act in either direction e.g. phosphoglucomutase.
9. Each enzyme will react with only one type of substrate or group of related substrate. This property of enzyme is called specificity of enzymes e.g., lactase acts only on lactose.

Any Error in this document is silent testimony of the fact that it was a human effort"

"Dr. WKB"

Dr. Wahied Khawar Balwan's Zoology Study Material
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