BIOMOLECULES

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CLASS: XI **BIOLOGY**

How will you analyse the chemical composition of a living material?

We can take any living tissue (a vegetable or a piece of liver, etc.) and grind it in trichloroacetic acid using a mortar and a pestle.

We obtain thick slurry. If we strain this through a cheese cloth or cotton we would obtain two fractions.

One is called the filtrate or more technically, the acid-soluble pool, and the second, the retentate or the acid-insoluble fraction.

Scientists have found thousands of organic compounds in the acid-soluble pool.

LIPIDS

What are lipids?

Many lipids have both glycerol and fatty acids. Here the fatty acids are found esterified with glycerol.

They can be then monoglycerides, diglycerides and triglycerides.

Differentiate between saturated and unsaturated fatty acids.

Saturated Fatty acids	Unsaturated Fattty acids
Fatty acids that do not have double bond between the carbon atoms are saturated fatty acids.	Fatty acids that have one or more double bonds between the carbon atoms are unsaturated fatty acids. (one or more C=C double bonds).
They have higher melting point and remain as solid during winter. eg., Coconut oil.	They have lower melting point and hence remain as liquid during winter. e.g., gingely oil.

These are also called fats and oils based on melting point.

Oils have lower melting point (e.g., gingely oil) and hence remain as oil in winters.

What are phospholipids? Where are they found? Give an example.

Lipids that have phosphorous and a phosphorylated organic compound in them are called phospholipids. They are found in cell membrane. Eg., Lecithin.

Name the tissues which have lipids with more complex structures.

Some tissues especially the neural tissues have lipids with more complex structures.

Primary and Secondary Metabolites

Differentiate between Primary and Secondary Metabolites.

Primary Metabolites	Secondary Metabolites
The biomolecules that have identifiable functions and play known roles in normal physiologial processes are primary metabolites.	The molecules whose functions are not known at the moment are known as secondary metabolites.
Eg., amino acids, sugars, etc.	e.g. alkaloids, flavonoides, rubber, essential oils, antibiotics, coloured pigments, scents, gums, spices.

List 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**

Differentiate between micromolecules and macromolecules.

Micromolecules	Macromolecules
Those molecules which have molecular weights less than one thousand dalton are classified as micromolecules	Those molecules which have molecular weights more than one thousand dalton are classified as macromolecules
Usually they have molecular weights ranging from 18 to around 800 daltons (Da).	They have molecular weights in the range of ten thousand daltons and above except lipids.
They come under acid soluble pool.	They come under acid insoluble pool.
The acid soluble pool represents the cytoplasmic composition.	The acid insoluble pool represents the macromolecules from cytoplasm and organelles.
Amino acids, sugars, nucleotide bases, fatty acids, etc.	eg., Polysaccharides, lipids, proteins and nucleic acids. Lipids are not strictly macromolecules.

Why do lipids, whose molecular weights do not exceed 800 Da, come under acid insoluble fraction, i.e., macromolecular fraction?

Lipids are indeed small molecular weight compounds and are present not only as such but also arranged into structures like cell membrane and other membranes.

When we grind a tissue, we are disrupting the cell structure.

Cell membrane and other membranes are broken into pieces, and form vesicles which are not water soluble.

Therefore, these membrane fragments in the form of vesicles get separated along with the acid insoluble pool and hence in the macromolecular fraction.

Lipids are not strictly macromolecules.

PROTEINS

Give an account of aminoacids.

Amino acids are organic compounds containing an amino group and an acidic group. These are hydrogen, carboxyl group, amino group and a variable group designated as R group.

Based on the nature of R group there are many amino acids.

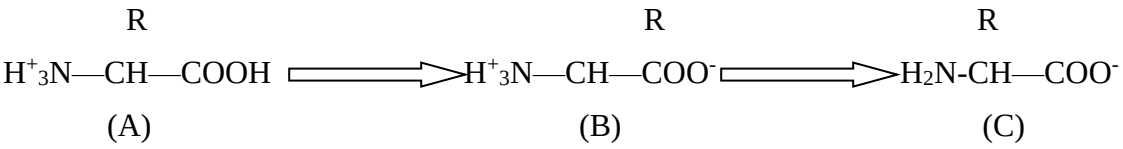
The R group in these proteinaceous amino acids could be a hydrogen (the amino acid is called glycine), a methyl group (alanine), hydroxy methyl (serine), etc.

The chemical and physical properties of amino acids are essentially of the amino, carboxyl and the R functional groups.

Based on number of amino and carboxyl groups, there are acidic (e.g., glutamic acid), basic (lysine) and neutral (valine) amino acids.

Similarly, there are aromatic amino acids (tyrosine, phenylalanine, and tryptophan).

A particular property of amino acids is the ionizable nature of $-NH_2$ and -COOH groups. Hence in solutions of different pHs, the structure of amino acids changes.



B is called zwitterionic form.

Name the different kinds of aminoacids based on the nature of R group.

When the R group in the amino acid is a hydrogen, the amino acid is called glycine. When the R group is a methyl group, the amino acid is called alanine and when the R group is a hydroxy methyl, the amino acid is called serine.

How many amino acids are involved in protein synthesis?

Twenty amino acids are involved in protein synthesis.

How are the aminoacids classified based on the number of amino and carboxyl groups? Give an example each.

Based on number of amino and carboxyl groups, aminoacids are classified into acidic, basic and neutral amino acids.

Acidic amino acid. e.g., glutamic acid

Basic amino acid. eg., lysine

Neutral amino acid. eg., valine

Name the aromatic amino acids.

Tyrosine, phenylalanine, and tryptophan.

Why does the structure of aminoacids change?

Due to ionizable nature of $-NH_2$ and -COOH groups of aminoacids in solutions of different pHs, the structure of amino acids changes

What is zwitterionic form of aminoacid?

The ionized form of aminoacid which has both positive and negative poles is called zwitterionic form of aminoacid.

What are proteins?

Proteins are polypeptides. They are linear chains of amino acids linked by peptide bonds.

Each protein is a polymer of amino acids. As there are 20 types of amino acids (e.g., alanine, cysteine, proline, tryptophan, lysine, etc.), a protein is a heteropolymer and not a homopolymer.

What is a homopolymer?

A homopolymer has only one type of monomer repeating number of times.

Differentiate between essential and non-essential aminoacids.

Essential aminoacids	Non-Essential aminoacids
The amino acids that are essential for our health and have to be supplied only through the diet.	The amino acids which our body can make are called non-essential amino acids.

Name the most abundant protein in animal world and the most abundant protein in the whole of the biosphere.

Collagen is the most abundant protein in animal world and Ribulose bisphosphate Carboxylase-Oxygenase (RUBISCO) is the most abundant protein in the whole of the biosphere.

List some proteins and their functions.

Proteins carry out many functions in living organisms, some transport nutrients across cell membrane, some fight infectious organisms, some are hormones, some are enzymes, etc.

Protein	Functions
Collagen	Intercellular ground substance
Trypsin	Enzyme
Insulin	Hormone
Antibody	Fights against infectious agents
Receptor	Sensory reception(smell, taste, hormone,etc)
GLUT-4	Enables glucose transport into cells

Structure of Proteins

Primary structure

The protein exists as a long chain of amino acids arranged in a particular sequence. They are non-functional proteins. The left end is represented by the first amino acid and the right end is represented by the last amino acid.

The first aminoacid is also called as N-terminal amino acid. The last amino acid is called the C-terminal amino acid.

Secondary structure

Some portions of the protein thread are **folded and arranged in the form of a helix**. (similar to a revolving staircase) Other regions of the protein thread are folded into other forms. This structure is called the pleated sheet. Example: silk fibres. In proteins, only right-handed helices are found.

Tertiary structure

The long protein chain is also folded upon itself like a **hollow woollen ball**, giving rise to the tertiary structure. This gives a 3-dimensional view of a protein. Tertiary structure is absolutely necessary for the many biological activities of proteins.

Quaternary structure

The proteins are an assembly of **more than one polypeptide or subunits.** The manner in which these individual folded polypeptides are arranged with respect to each other (e.g. linear string of spheres, spheres arranged one upon each other in the form of a cube or plate etc.) is called the **quaternary structure** of a protein. Example: Haemoglobin, insulin.

How is adult haemoglobin made of?

Adult human haemoglobin is made of 4 subunits. Two of these are identical to each other. Hence, two subunits of α type and two subunits of β type join together to form the human haemoglobin (Hb).

POLYSACCHARIDES

What are polysaccharides?

Polysaccharides are long chains of sugars containing different monosaccharides as building blocks.

For example cellulose is a polymeric polysaccharide consisting of only one type of monosaccharide i.e., glucose.

In a polysaccharide chain (say glycogen), the right end is called the reducing end and the left end is called the non-reducing end.

Starch

Starch is a store house of energy in plant tissues.

It forms helical secondary structures.

It can hold I_2 molecules in the helical portion. The starch-I_2 is blue in colour.

Cellulose

Cellulose is a polymeric polysaccharide

It is a homopolymer, consisting of only one type of monosaccharide i.e., glucose.

It does not contain complex helices and hence cannot hold I_2.

Plant cell walls are made of cellulose.

Paper made from plant pulp is cellulose.

Cotton fibre is cellulose.

Name the complex polysaccharide which forms the exoskeleton of arthropods.

The complex polysaccharide which forms the exoskeleton of arthropods is chitin.

NUCLEIC ACIDS

What are nucleic acids? What are their components?

Nucleic acids are long polymers made of nucleotides. A nucleotide has three chemically distinct components.

One is a **heterocyclic compound**, the second is a **monosaccharide** and the third a **phosphoric acid or phosphate**

The heterocyclic compounds in nucleic acids are the nitrogenous bases named adenine, guanine, cytosine, thymine and uracil.

Adenine and guanine are purines while cytosine, thymine and uracil are pyrimidines.

The skeletal heterocyclic ring is called as purine and pyrimidine respectively.

The sugar found in polynucleotides is either ribose (a monosaccharide pentose) or 2 deoxyribose.

A nucleic acid containing deoxyribose is called deoxyribonucleic acid (DNA) while that which contains ribose is called ribonucleic acid (RNA).

Describe the secondary structure of nucleic acid proposed by Watson and Crick

Nucleic acids exhibit a wide variety of secondary structures.

Watson - Crick Model says that DNA exists as a double stranded helix.

The two strands of polynucleotides are antiparallel i.e., run in the opposite direction.

The backbone is formed by the sugar-phosphate-sugar chain.

The nitrogen bases are attached more or less perpendicular to this backbone but face inside.

Adenine pairs with Thymine by two hydrogen bonds. Guanine pairs with Cytosine by three hydrogen bonds.

Each strand appears like a helical staircase. Each step of ascent is represented by a pair of bases. At each step of ascent, the strand turns 36°.

One full turn of the helical strand would involve ten steps or ten base pairs. The pitch would be 34A^{o}.

The rise per base pair would be 3.4A^{o}. This form of DNA is called B-DNA.

ENZYMES

What are enzymes? What are they made of?

Enzymes are biocatalysts, they speed up the biochemical reaction. Almost all enzymes are made of proteins.

What are ribozymes?

There are some nucleic acids that behave like enzymes. These are called ribozymes.

Mention the similarity of enzyme with that of proteins.

An enzyme like any protein has a primary structure, i.e., amino acid sequence of the protein.

An enzyme like any protein has the secondary and the tertiary structure.

The backbone of the protein chain folds upon itself, the chain criss-crosses itself and hence, many crevices or pockets are made.

What is an active site of enzyme?

An active site of an enzyme is a crevice or pocket into which the substrate fits. The enzymes, through their active site, catalyse reactions at a high rate.

How do enzyme catalysts differ from inorganic catalysts?

Inorganic catalysts work efficiently at high temperatures and high pressures, while enzymes get damaged at high temperatures (say above 40°C).

What is the importance of enzymes isolated from organisms that normally live under extremely high temperatures?

Enzymes isolated from organisms that normally live under extremely high temperatures (e.g., hot vents and sulphur springs), are stable and retain their catalytic power even at high temperatures (upto 80°-90°C).

Where can you find thermostable organisms?

Thermostable or thermophilic organisms are found in hot vents and sulphur springs.

"The power of enzymes is incredible indeed!" Justify the statement giving an example.

OR

How do enzymes bring about high rates of chemical conversions? Explain.

The rate of enzyme catalysed reactions, are vastly higher than the uncatalysed reactions. For example

$$\underset{\text{carbon dioxide}}{CO_2} + \underset{\text{water}}{H_2O} \xrightarrow{\text{Carbonic anhydrase}} \underset{\text{carbonic acid}}{H_2CO_3}$$

In the absence of any enzyme this reaction is very slow, with about 200 molecules of H_2CO_3 being formed in an hour.

However, by using the enzyme present within the cytoplasm called **carbonic anhydrase**, the reaction speeds dramatically with about 600,000 molecules being formed every second.

The enzyme has accelerated the reaction rate by about 10 million times. Hence the power of enzymes is incredible indeed!

What is a metabolic pathway? Give an example.

A multistep chemical reaction, when each of the steps is catalysed by the same enzyme complex or different enzymes, is called a **metabolic pathway**. For example,

$$\text{Glucose} \rightarrow 2 \text{ Pyruvic acid}$$

$$C_6H_{12}O_6 + O_2 \rightarrow 2C_3H_4O_3 + 2H_2O$$

At different conditions different products are possible during a metabolic pathway. Give examples.

In our skeletal muscle, under anaerobic conditions, lactic acid is formed. Under normal aerobic conditions, pyruvic acid is formed. In yeast, during fermentation, the same pathway leads to the production of ethanol (alcohol). Hence, in different conditions different products are possible.

Describe the catalytic cycle of an enzyme action or mechanism of enzyme action.

- First, the substrate binds to the active site of the enzyme, fitting into the active site.
- The binding of the substrate induces the enzyme to alter its shape, fitting more tightly around the substrate.
- The active site of the enzyme, now in close proximity of the substrate breaks the chemical bonds of the substrate and the new enzyme- product complex is formed.
- The enzyme releases the products of the reaction and the free enzyme is ready to bind to another molecule of the substrate and run through the catalytic cycle once again.

The activity of an enzyme can be affected by a change in the conditions which can alter the tertiary structure of the protein. Explain the factors affecting enzyme activity.

Factors Affecting Enzyme Activity

These include temperature, pH, and change in substrate concentration or binding of specific chemicals that regulate its activity.

Temperature and pH

Enzymes function in a narrow range of temperature and pH.

The highest rate of enzymatic activity occurs at a particular temperature and pH called the optimum temperature and optimum pH.

Enzymatic activity declines both above and below the optimum value. At high temperature the enzymes get denatured whereas at low temperature the enzymes become inactive.

Concentration of Substrate

With the increase in substrate concentration, the velocity of the enzymatic reaction rises at first. The reaction ultimately reaches a maximum velocity (V) which is not exceeded by any further rise in concentration of the substrate.

This is because the enzyme molecules are fewer than the substrate molecules and after saturation of these molecules; there are no free enzyme molecules to bind with the additional substrate molecules.

Inhibitor

The activity of an enzyme is also sensitive to the presence of specific chemicals that bind to the enzyme.

The chemical which stops the enzymatic activity is called an inhibitor and the process is called inhibition.

Competitive Inhibitor.

When the inhibitor closely resembles the substrate in its molecular structure and inhibits the activity of the enzyme, it is known as competitive inhibitor.

Due to its close structural similarity with the substrate, the inhibitor competes with the substrate for the active site of the enzyme. Consequently, the substrate cannot bind and as a result, the enzyme action declines.

e.g., Inhibition of **succinic dehydrogenase by malonate,** which closely resembles the substrate succinate in structure.

Such competitive inhibitors are often used in the control of bacterial pathogens.

Classification and Nomenclature of Enzymes

Thousands of enzymes have been discovered, isolated and studied. Most of these enzymes have been classified into different groups based on the type of reactions they catalyse. Explain the classification and nomenclature of enzymes.

Enzymes are divided into 6 classes each with 4-13 subclasses and named accordingly by a four-digit number.

Oxidoreductases/dehydrogenases: Enzymes which catalyse oxidoreduction between two substrates. S and S'

$$\text{S reduced} + \text{S' oxidised} \longrightarrow \text{S oxidised} + \text{S' reduced.}$$

Transferases: Enzymes catalysing a transfer of a group, G (other than hydrogen) between a pair of substrate S and S'

$$S - G + S' \rightarrow S + S' - G$$

$$S - G + S' \longrightarrow S + S' - G$$

Hydrolases: Enzymes catalysing hydrolysis of ester, ether, peptide, glycosidic, C-C, C-halide or P-N bonds.

Lyases: Enzymes that catalyse removal of groups from substrates by mechanisms other than hydrolysis leaving double bonds.

$$\begin{array}{l} X \quad Y \\ | \quad | \\ C-C \end{array} \longrightarrow X - Y + C = C$$

Isomerases: Includes all enzymes catalysing inter -conversion of optical, geometric or positional isomers.

Ligases: Enzymes catalysing the linking together of 2 compounds, e.g., enzymes which catalyse joining of C-O, C-S, C-N, P-O etc. bonds.

Enzymes are composed of one or more polypeptide chains. However, there are non-protein constituents bound to the enzyme to make the enzyme catalytically active. Describe the various components of enzyme, which make the enzyme catalytically active.

The **protein portion of the enzymes is called the apoenzyme.**

The **non-protein components** of the enzyme are called **cofactors**.

The cofactors are of three kinds: **prosthetic groups, co-enzymes and metal ions.**

Prosthetic groups are organic compounds that they are tightly bound to the apoenzyme.

For example, in peroxidase and catalase, which catalyze the breakdown of hydrogen peroxide to water and oxygen, haem is the prosthetic group and it is a part of the active site of the enzyme.

Co-enzymes are organic compounds that they are loosely bound to the apoenzyme. (their association with the apoenzyme is only transient, usually occurring during the course of catalysis).

Furthermore, co-enzymes serve as co-factors in a number of different enzyme catalyzed reactions.

The essential chemical components of many coenzymes are vitamins, e.g., coenzyme nicotinamide adenine dinucleotide (NAD) and NADP contain the vitamin niacin.

Metal ions form coordination bonds with side chains at the active site and at the same time form one or more coordination bonds with the substrate, e.g., zinc is a cofactor for the proteolytic enzyme carboxypeptidase.

Catalytic activity is lost when the co-factor is removed from the enzyme which testifies that they play a crucial role in the catalytic activity of the enzyme.

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