Biomolecules

Biomicromolecules

Analysis of Chemical Composition

- Chemical analysis is done to find out the types of organic compounds (compounds containing carbons) found in living tissues.
- Living tissue taken
- Grinded in trichloro acetic acid to obtain slurry
- Slurry is filtered to get filtrate (acid-soluble fraction: contains biomacromolecules) and retentate.
- Thousands of organic compounds found in filtrate
- Separation techniques used for separating one compound from another
- Molecular formula and probable structure of the compound found by using analytical techniques
- All carbon-containing compounds that we get from living tissues are called biomolecules.
- Analysis of inorganic compounds:
- Living tissue taken
- It is dried to evaporate all water, and the remaining material gives its dry weight.
- The dried material is burnt.
- All organic compounds are oxidised to gaseous compounds and are removed to leave “ash”.
- Ash contains many inorganic elements like Ca, Mg, etc.

Biomolecules

- Chemistry point of view: Functional groups like aldehydes, ketones etc., can be recognised
- Biology point of view: Organic and inorganic constituents of living cells are classified as amino acids, fatty acids, nucleotide bases, etc.

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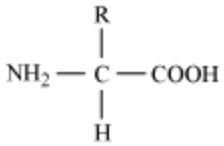
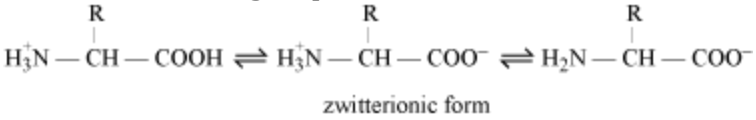
- Recognition of biomolecules, which can be micromolecules or macromolecules
- Molecules with weight more than thousands – biomacromolecules
- Molecules with weight less than thousands – biomicromolecules

Amino Acids

- In these compounds, α-carbon has the substituents as hydrogen, carboxyl group, amino group and a variable group R.



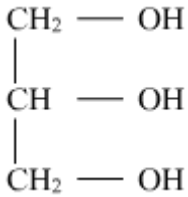
- Based on the R group, there are 20 amino acids
  When R is H – glycine (the simplest amino acid)
  When R is CH_3 – alanine
- The chemical and physical properties of amino acids depend upon their amino group, carboxyl group and R group.
- Based on the number of amino and carboxyl groups, amino acids could be acidic (glutamic acid), basic (lysine) or neutral (valine).
- More carboxylic group – acidic amino acid
- More amino group – basic amino acid
- Equal amino and carboxylic groups – neutral amino acid
- Aromatic amino acids – e.g., tyrosine, phenylalanine and tryptophan
- At different pH, the structures of amino acids change because of ionisable nature of $-NH_2$ and –COOH groups.



Fatty Acids

- Have carboxylic group linked to an R group; R (any $-CH_2$ group with 1 to 19 carbons)

- Fatty acids could be saturated (without double bond) or unsaturated (with double bond)
- Glycerol – this is trihydroxy propane

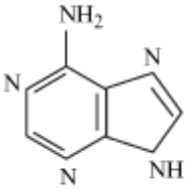


- Lipids have both fatty acids and glycerol, and based on the number of glycerols, lipids could be monoglycerides, diglycerides, triglycerides, etc.
- Some lipids are phosphorylated; they contain phosphorus, e.g., lecithin

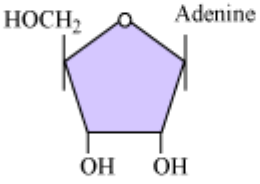
Nitrogenous Bases

- Carbon compounds with heterocyclic rings; e.g., adenine, thymine, guanine
- Nucleosides = Nitrogenous Bases + Sugar
  e.g., adenosine, thymidine, guanosine, uridine and cytidine.
- Nucleotides = Nucleosides + Phosphate groups

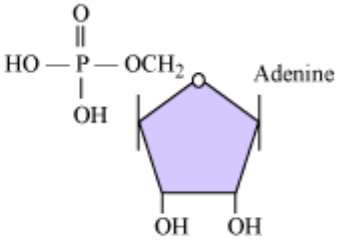
  OR
  Nitrogenous base + Sugar + Phosphate group
  e.g., adenylic acid, thymidylic acid, guanylic acid, uridylic acid and cytidylic acid.
- Nucleic acids like DNA and RNA are polymers of nucleotides.



Adenine



Adenosine



Adenylic acid

Biomacromolecules

Biomacromolecules

- Compounds found in an acid soluble pool; have a molecular weight ranging from 18 to 800 Da approx.

- The biomacromolecules which fall in the acid insoluble fraction include proteins, nucleic acids, polysaccharides and lipids.
- All biomacromolecules have molecular weight more than 10,000 Da, except lipids. This is because except lipids, all are polymeric substances.

The case of lipids

Lipids have a molecular weight of 800 Da, yet they come in the acid insoluble fraction because they are water insoluble. Lipids are not strictly macromolecules.

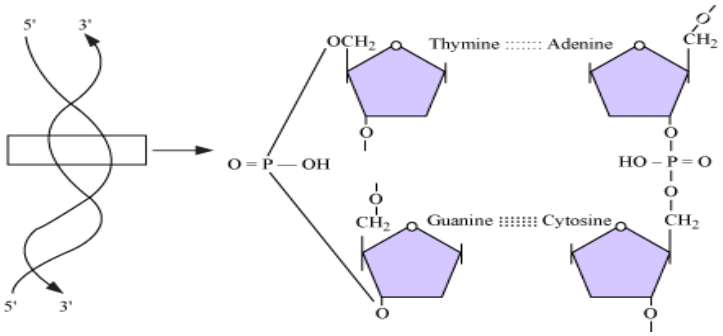
Polysaccharides

- Polysaccharides are the polymers of monosaccharides.
- Polysaccharides can be homopolymer (cellulose) or heteropolymer (chitin) of monosaccharides.
- Cellulose:
- Homopolymer of glucose
- Constitutes the plant cell wall, paper made from plant pulp, cotton fibre, etc.
- Starch:
- consists of amylose and amylopectin
- storehouse of energy in plants
- Starch forms helical secondary structures and can hold I_2 molecules in the helical portion; the starch–I_2 complex is blue in colour, forming the basis of the confirmatory test to detect starch.
- Inulin: Polymer of fructose
- Glycogen is a polymer of glucose, found as a storage polysaccharide in animals.

Nucleic Acid

- Nucleic acids are the polymers of nucleotides.

- Nucleotide = Heterocyclic compound (nitrogenous base) + Sugar + Phosphate group
- Nitrogenous bases – Two types:
- Purines – adenine and guanine
- Pyrimidines – thymine, cytosine, uracil
- Sugar – Two types:
- Ribose (forms RNA)
- 2’ deoxyribose (forms DNA)
- The secondary structure exhibited by DNA is given by the Watson and Crick model.
- Salient features of the Watson and Crick model are as follows:
- DNA is a double helix. In the helix, two polynucleotide chains are anti-parallel (one is $5'$ to $3'$, and the other is $3'$ to $5'$)
- Backbone of the helix is formed by the sugar–phosphate–sugar chain; while bases project inwards, perpendicular to the backbone
- A binds to T; 2 hydrogen bonds occur between them.
  G binds to C; 3 hydrogen bonds occur between them.
- One full turn of the helical strand involves 10 bases, and at each step, the strand turns by 36°.
- Rise per base pair – 3.4A°
  Pitch per base pair – 34A°



Proteins

- Proteins are polymers of amino acids.
- Proteins are polypeptides where amino acids are linked by peptide bonds in the form of a linear chain.
- Proteins are heteropolymers because the polypeptide chain consists of different types of amino acids.
- Amino acids – 2 types:
- Essential – which the body cannot make; supplied by diet
- Non-essential – which the body can make
- Functions of proteins:
- Transportation of nutrients across membranes
- Fight infections (Antibiotics)
- Act as hormones and enzymes

Protein	**Function**
Collagen	Intercellular ground substance
Trypsin	Enzyme
Insulin	Hormone
Antibody	Fights infectious agents

Receptor	Sensory reception (smell, taste, etc.)
GLUT – 4	Enables glucose transport into cells

- Collagen – most abundant protein in the human body
- RuBisCO – most abundant protein in the biosphere

Structure of Proteins

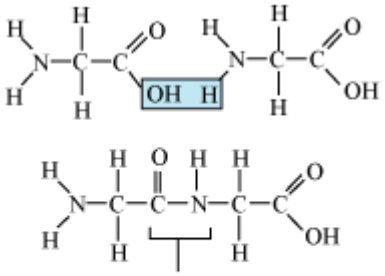
- **Structure Of Protein is Studied at Four Levels**
- Primary structure
- Secondary structure
- Tertiary structure
- Quaternary structure
- **Primary Structure**
- It refers simply to the positional information about the sequence of amino acids in a protein.
- The protein has amino acids arranged as a line, with the first amino acid as the N terminal amino acid and the last as the C terminal amino acid.
- **Secondary Structure**
- Secondary structures are formed when the flexible positional thread folds to form structures like helices and sheets.
- **Tertiary Structure**
- Tertiary structures are formed when the positional thread folds more intensively to form three-dimensional structures.
- Protein is biologically active at this stage.

- **Quaternary Structure**
- Some proteins may have more than one assembly or sub-units.
- The manner in which these sub-units are arranged with respect to each other forms the quaternary structure of a protein.
- Example – Adult human haemoglobin consists of 4 sub-units (2 α and 2β)

Nature of Bonds Linking Monomers

Nature of Bonds Linking Monomers in a Polymer

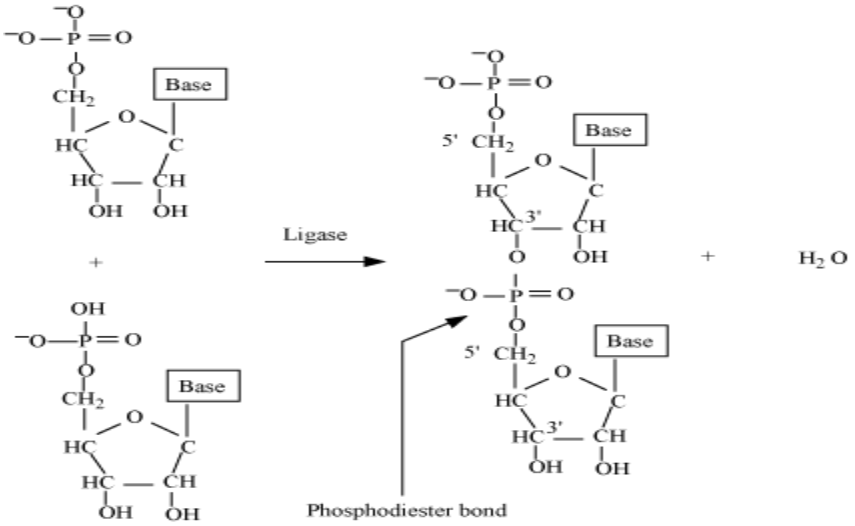
- **Peptide Bond**
- Links amino acids in a polypeptide chain
- This bond is formed when the carboxyl group of one amino acid reacts with the amino group of the next amino acid, with the elimination of water moiety (dehydration).



A molecule of water is removed from two glycine amino acids to form a peptide bond

- **Glycosidic Bond**
- Links two carbon atoms of adjacent monosaccharides to form polysaccharides
- This also involves dehydration
- **Phosphodiester Bond**
- Links two nucleotides to form nucleic acids
- This bond is formed between the phosphate and hydroxyl groups of sugar.

- The phosphate group links the 5’ carbon of one sugar of one nucleotide to the 3’ carbon of one sugar of another nucleotide.



Metabolism

The Living State

- Living state is a non-equilibrium steady state to be able to perform work.
- Systems at equilibrium cannot perform work. Therefore, life processes occurring in an individual are constant efforts to avoid equilibrium state.
- Avoiding equilibrium state requires input of energy provided by metabolism.
- Hence, without metabolism, living state is not possible.

Concept of metabolism

- All biomolecules present in body have a turnover.
- Turnover of biomolecules - They are constantly being converted to some other biomolecules and also made from some other biomolecules.
- Metabolism – All the chemical reactions that are involved in making and breaking of biomolecules.
- Usually the metabolic reactions are interlinked and constitute a metabolic pathway whose flow may be linear or circular.

- This metabolite flow is known as dynamic state of body constituents.
- The metabolic reactions are always catalysed. The catalysts that enhance the rate of metabolic reactions are called enzymes.
- Example of metabolic reaction – Reactions involved in glycolysis and Kreb's cycle

Metabolic Basis for Living

- Metabolic reactions are of two types – anabolic and catabolic

Anabolic Pathways	Catabolic Pathways
Biosynthetic pathways	Degradation pathways
Formation of complex structure from simpler structures	Formation of simpler structures from a complex structure
Involves consumption of energy	Involves release of energy
Example – Assembly of protein from amino acids	Example – Glycolysis (glucose → Lactic acid)

- ATP (Adenosine triphosphate) – Energy currency in living systems. This energy is stored in the form of chemical bonds in ATP. This bond energy is utilised for biosynthetic, osmotic and mechanical work that we perform.

Primary and Secondary Metabolites

- *Primary Metabolites* **–** Intermediates or products of metabolism directly involved in growth, development, and reproduction
  Example – Fatty acids, amino acids, etc.
- *Secondary Metabolites* – Intermediates or products of metabolism not involved directly in growth, development, and reproduction
  Example – Pigments such as carotenoids, toxins, drugs, and essential oils.

- The roles of secondary metabolites are not directly identifiable. Some of them are things for human utility such as rubber, pigments, spices, drugs, etc., while some others may have ecological importance.
  Some Secondary metabolites

  - Pigments – Carotenoids, Anthocyanins
  - Alkaloids – Morphine, Codeine
  - Terpenoids – Monoterpenes, Diterpenes
  - Essential oils – Lemon grass oil
  - Toxins – Ricin
  - Lectins – Concanavalin A

  Enzymes: Basic Characters and Classification

  Enzymes

- Almost all enzymes are proteins, except ribozymes (nucleic acids acting like enzymes).

  Like all proteins, enzymes also have primary, secondary and tertiary structures. In tertiary structure, the protein (enzyme) folds in such a criss-cross way that many crevices or pockets are made. One such pocket is called active site.

- In an active site, the substrate fits in and reaction is catalysed at a high rate.

- Unlike inorganic catalysts, enzymes get damaged at high temperatures, except those isolated from thermophilic organisms.

  Chemical Reactions

- A change could be physical (change in shape without breaking of bonds) or chemical (involves making and breaking of bonds).

- Rate of reaction: Amount of product formed per unit time
  Rate of reaction $= \frac{\delta P}{\delta t}$

- Temperature directly influences the rate of reaction. Rate doubles or halves for every 10°C change in either direction.

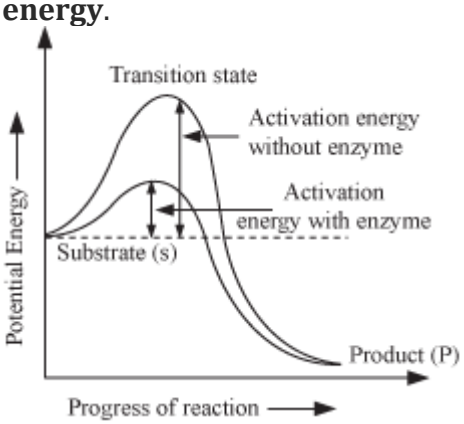
- Using a catalyst (enzyme), the rate of reaction can be increased by about 10 million times in certain cases.
- In a metabolic pathway, specific enzymes catalyse particular metabolic reactions.

Process of Enzyme Action

- Substrate (S) is the chemical that is converted into product (P) by the action of an enzyme (E).

$$S \xrightarrow{E} P$$

- First of all, the substrate 'S' binds to the enzyme 'E' at its active site. This leads to the formation of the Enzyme–Substrate 'ES' complex.
- Transition state structure is the new structure of the substrate being formed during the state when the substrate is bound to the enzyme. It is the transitional structure between the substrate and the product.
- Finally, the structure of the substrate gets converted into the structure of the product, and the product is released from the active site.
- Transition state is the state of higher energy and lesser stability as compared to the product.
- The difference in average energy content of 'S' from its transition state is called **activation energy**.



Catalytic Cycle of Enzyme

- Substrate binds to the active site of an enzyme, fitting into the active site.
- Shape of the enzyme is altered by the binding of the substrate, and it fits more tightly around the substrate.

- Bond between the enzyme and the substrate is broken and a new enzyme–product complex is formed.

- Product is released from the enzyme, and free enzyme is now ready to enter a new catalytic cycle by binding with a new substrate.
  $E + S \longleftrightarrow ES \rightarrow EP \rightarrow E + P$

Classification and Nomenclature of Enzymes

- Enzymes are classified into 6 classes based on the reactions they catalyse.

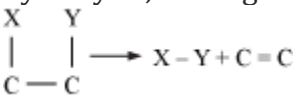
- These 6 classes, each having 4–13 subclasses, are named by four digits numbers.

- 6 classes of enzymes are as follows:

- ***Oxidoreductases /dehydrogenases*** – catalyse redox reactions between two substrates
  S reduced + S' oxidised → S oxidised + S' reduced

- ***Transferases*** – catalyse the transfer of a group (G) between two substrates S and S'. G is any group other than hydrogen
  $S - G + S' \rightarrow S + S' - G$

- ***Hydrolases***– catalyse hydrolysis of bonds like ester, peptide, C – C, glycosidic, etc.

- ***Lyases*** – catalyse the removal of groups from the substrate by mechanisms other than hydrolysis, leaving double bonds
  

- ***Isomerases***– catalyse inter-conversion among various isomeric forms

- ***Ligases***– catalyse the linking together of 2 compounds; e.g., enzymes catalysing the joining of C – O, C – S, C – N bonds.

Cofactors

- Cofactors are the non-protein components bound to enzymes to make them catalytically active.

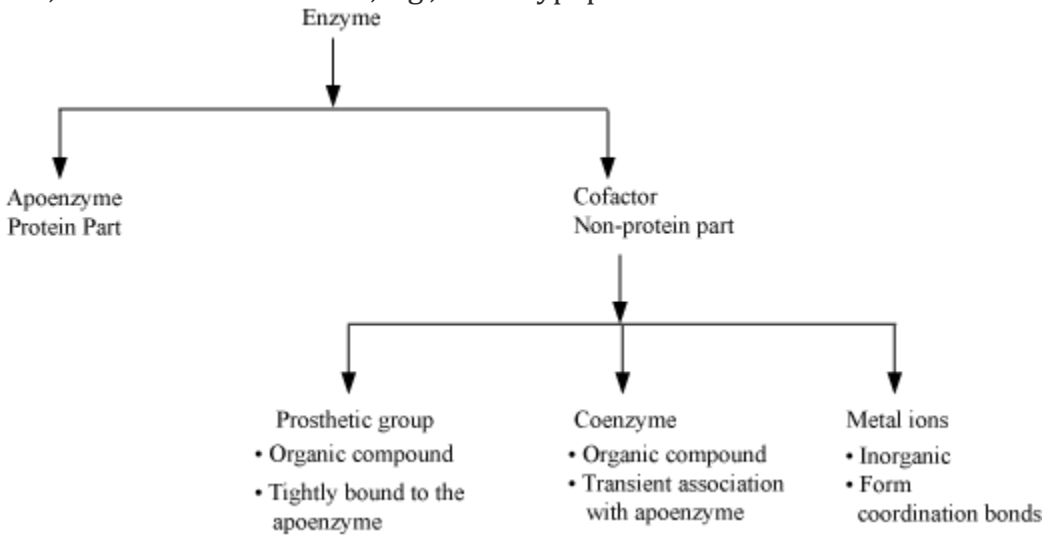
- Protein portion of an enzyme is called apoenzyme.

- 3 kinds of co-factors: prosthetic groups, co-enzyme and metal ions

- *Prosthetic group* – binds tightly to the apoenzyme; e.g., haem (part of the active site of an enzyme)

- *Co-enzyme* – association with apoenzyme is transient; occurs only during the course of catalysis; e.g., NAD and NADP

- *Metal ions* – basically required to form coordination bonds with side chains of the active site, and with the substrate; e.g., carboxypeptidase contains zinc.



Factors Affecting Enzyme Activity

Factors Affecting Enzyme Activity

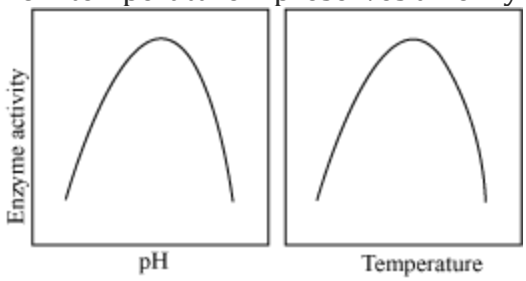
FACTORS AFFECTING ENZYME ACTIVITY

- Temperature
- pH
- Change in substrate concentration
- Binding of specific chemicals

Temperature and pH

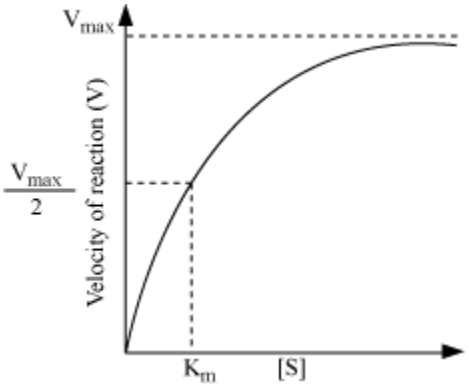
- Enzymes have a narrow range of temperature and pH optima. At this optimum temperature and optimum pressure, enzyme activity is the highest.
- Below and above this optimum value, the activity of an enzyme declines.

- High temperature – denatures an enzyme
- Low temperature – preserves an enzyme in a temporarily inactive state



Concentration of Substrate

- With an increase in substrate concentration, the velocity of enzymatic reaction increases at a very fast rate, and then reaches its maximum velocity (V_{max}).
- Velocity does not increase beyond V_{max} even if concentration of substrate is increased further.



- This happens because enzyme molecules saturate with substrate molecules, and no enzyme molecules are left to bind with the additional substrate molecules.

Binding of Certain Chemicals

- Inhibitors are the chemicals that shut down enzymatic activity by a process called inhibition.
- Competitive inhibition: Here, the inhibitor closely resembles the substrate, and binds with the active sites of enzymes. Hence, inhibiting the enzyme activity.
  Example – Malonate resembles succinate structurally, and hence, blocks the activity of the

enzyme succinic dehydrogenase.