BIOMOLECULES

BIOMOLECULE

- All the carbon compounds that we get from living tissues can be called **'biomolecules'**. However, living organisms have also got **inorganic elements** and **compounds** in them.

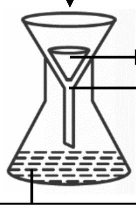
Chemical Analysis

Living tissue
(Plant tissue/animal tissue/microbial paste)

+

Trichloroacetic acid
(Cl_3CCOOH)

Thick slurry



Cheese cloth

Entire chemical composition of living tissues or organism

Filtrate (Acid soluble)
Roughly **cytoplasmic components**

Retentate
(Acid insoluble)
(Macromolecules from Cytoplasm and organelles)

Inorganic	**Organic Biomicromolecules**	**Organic Biomacromolecules**
• Water • Ions (e.g., Na^+, K^+, Ca^{2+}, Mg^{2+}, PO_4^{3-}, SO_4^{2-}, etc.) • Gases	• M.wt. – 18-800 Da • Monomeric form E.g., Simple sugars Nucleotides Amino acids	• M.wt. ->10,000 Da • Polymeric form Polysaccharides Nucleic acids Proteins

• Relative abundance of carbon and hydrogen of living organism > Earth crust		**Lipids (Not a polymer)** ↓ • Not strictly biomacromolecule • M.wt < 800 Da • Cell membrane fragments form vesicles which are not water soluble.

ELEMENT ALANALYSIS

➢ Elemental analysis gives elemental composition of living tissues in the form of hydrogen, oxygen, chlorine, carbon etc.

➢ Living tissue $\xrightarrow{\text{Weight}}$ **Wet weight**; $\xrightarrow{\text{Dry}}$ **Dry weight**

➢ Dried living tissue $\xrightarrow[\text{All carbon compounds oxidise to } CO_2 \text{ and } H_2O]{\text{Burn}}$ **'Ash' (contains only Inorganic elements)**

Comparison of Elements Present in Non-living and Living Matter

Element	% Weight of Earth's crust	Human body
Hydrogen (H)	0.14	0.5
Carbon (C)	0.03	18.5
Oxygen (O)	**46.6**	**65.0**
Nitrogen (N)	very little	3.3
Sulphus (S)	0.03	0.3
Sodium (Na)	2.8	0.2

Calcium (Ca)	3.6	1.5
Magnesium (Mg)	2.1	0.1
Silicon (Si)	27.7	negligible

- Order of element in Earth crust → O > Si > Ca > Na > Mg > H > C > S > N
- Order of element in Human body → O > C > N > Ca > H > S > Na > Mg > Si
- Analytical technique → Molecular formula
  → Structure of compound

Average Composition of Cells in Descending order

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

True Macromolecular fraction = Polysaccharides + Polypeptides + Polynucleotides

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Water is the most abundant chemical in living organism
Oxygen is the most abundant element in living organism

METABOLITES

Primary metabolite	Secondary metabolite
❖ Identifiable functions ❖ Play known **roles in physiological** processes	❖ Not involved in primary metabolism

E.g., Sugars, amino acids lipids, nitrogen bases, etc.	❖ Seems to have no **direct function** in growth and development of organisms ❖ Many of them are useful to **human welfare** E.g., Rubber, drugs, spices and pigments ❖ Some have **ecological importance** ❖ E.g., Flavonoids, antibiotics etc.

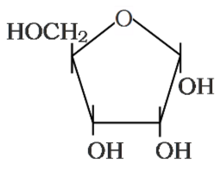
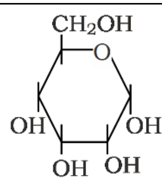
Some Secondary Metabolites

Pigments	Carotenoids, Anthocyanins
Alkaloids	Morphine, Codeine
Terpenoides	Monoterpenes, Diterpenes
Essential oils	Lemon grass oil
Toxins	Abrin, Ricin
Lectins	Concanavalin A
Drugs	Vinblastine, curcumin
Polymeric substances	Rubber, gums, cellulose

CARBOHYDRATES

1. Monosaccharides/sugar

❖ Single unit

No. of Carbon	$5C$	$6C$
Formula	$C_5H_{10}O_5$	$C_6H_{12}O_6$
Example	Ribose	Glucose
Structure		

2. Polysaccharides

- ❖ Acid-insoluble pool
- ❖ Long chains of sugars
- ❖ Linked together by **glycosidic bond** formed by **dehydration**

Homopolysaccharides

❋ Same monomer units

Heteropolysaccharides

❋ Different monomer units

Features	**Glycogen**	**Starch**	**Inulin**	**Cellulose**	**Chitin**
Found in	Animals	Plants	Plants	Plants	Animals
Function	Storage	Storage		Cell wall (Structural)	**Exoskeleton of arthropods**
Monomer	Glucose		Fructose	Glucose	**N-acetyl glucosamine**
Colour with I_2	Red	Blue		No	No

Chitin-Building blocks of Glycosamine and N-acetylgalatcosamine

– Complex polysaccharide

– Exoskeleton of arthropods – Homopolymers

- Glycogen → **Right end** is **reducing** while **left end** is **non-reducing**
- Starch hold I_2 in helical portion
- Cellulose can not hold I_2 as no helical portion
- Cotton fibre → Cellulose
- Paper is made from plant pulp

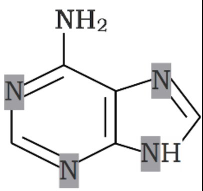
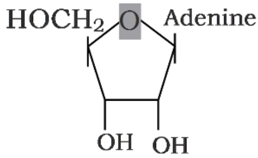
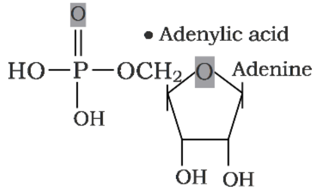
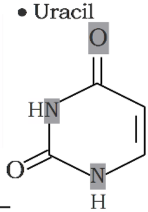
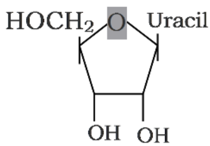
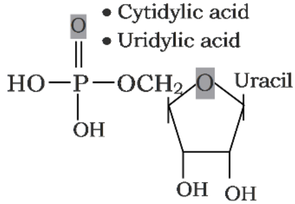
NUCLEIC ACIDS (Acid Insoluble Fraction)

➢ **Polymer of nucleotides**

➢ Each nucleotide comprises — Sugar/monosaccharide, Heterocyclic nitrogenous base, Phosphate

Sugar/monosaccharide + Heterocyclic nitrogenous base → Nucleoside

Nucleoside + Phosphate → Nucleotide

Nitrogenous base	Nucleoside	Nucleotide
Substituted Purines • Adenine  • Guanine	• Adenosine  • Guanosine	• Adenylic acid  • Guanylic acid
Substituted Pyrimidine • Thymine • Cytosine • Uracil 	• Thymidine • Cytidine • Uridine 	• Thymidylic acid • Cytidylic acid • Uridylic acid 

Watson-Crick model of B-DNA

➢ DNA exists as double helix **(secondary structure)**.

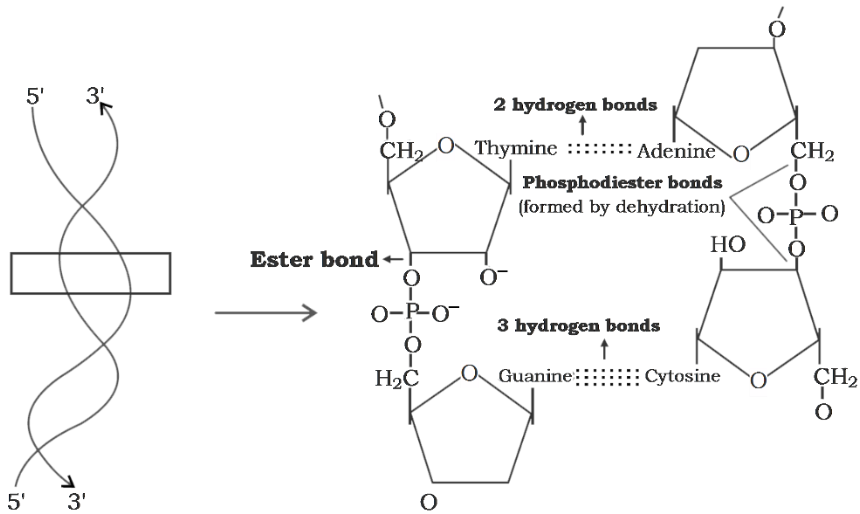
➢ Two polynucleotide strands are **helically coiled around a common axis**.

➢ The two polynucleotide strands are **antiparallel** i.e., run in opposite direction and **complementary** to each other.

➢ Ribose sugar and uracil exist in RNA (Ribonucleic acid)

➢ 2’-deoxyribose sugar and thymine exists in DNA [Deoxyribonucleic Acid]

- DNA and RNA act as genetic material.
- Phosphate moiety links **3'-carbon** of one sugar of one nucleotide to **5'-carbon** of sugar of succeeding nucleotide.
- Nitrogen bases are perpendicular to backbone and **faces inside**.
- At each step of ascent, strand turns **36°**.
- **1 turn = 10 base pairs**
- **1 complete turn = 34Å**
- **Rise per base pair = 3.4 Å**



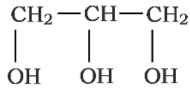
LIPIDS

- Generally **water insoluble**
- Could be simple fatty acids (R – COOH) where R group could be
  - Methyl ($-CH_3$), ethyl ($-C_2H_5$), higher no. of $-CH_2$ (C–1 to 19)
- Types of fatty acids

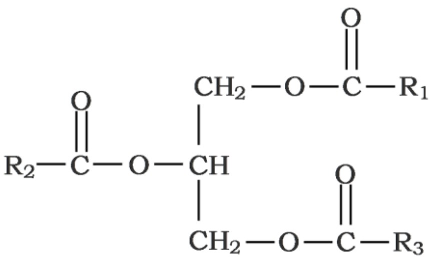
Parameter	**Saturated**	**Unsaturated**
No. of C = C double bonds	No	One or more

Example	**Palmitic acid** (**16** carbon including carboxyl carbon) $CH_3-(CH_2)_{14}-COOH$	**Arachidonic acid** (**20** carbon including carboxyl carbon)

Many lipids are esters of fatty acids and glycerol

Type	**No. of fatty acids**	**Glycerol (trihydroxy propane)**
Monoglyceride	1	1 1 1 
Diglyceride	2	
Triglyceride	3	

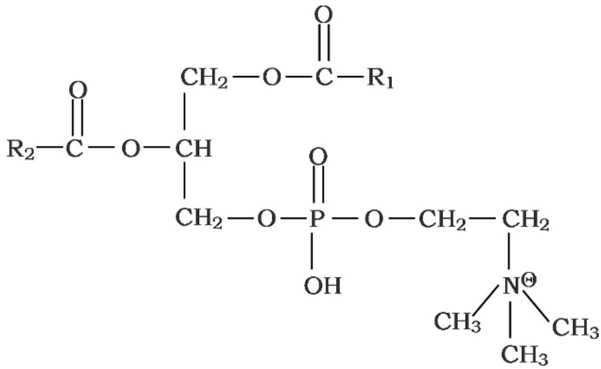
	Melting point	**State in winters**	**Examples**
Fats	Higher	Solid	Ghee, Butter
Oils	Lower	Liquid	Gingelly oil



Triglyceride (R , R and R are fatty acids)

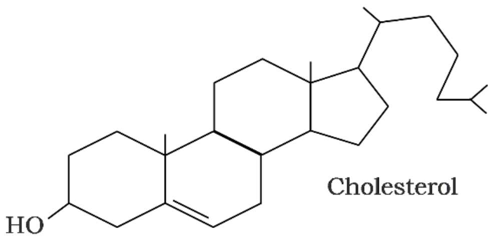
Some lipids have phosphorous and phosphorylated organic compound called **phospholipids** e.g., Lecithin - **found in cell membrane**

Neural tissues structure - More complex lipids



Phospholipid (Lecithin)

Cholesterol have lipid like properties



Cholesterol

AMINO ACIDS

- Organic compounds containing an amino group and an acidic group as substituents on same carbon i.e., α-**carbon**, hence called α-amino acids.
- **Substituted methane**, four substituent groups occupying four valency positions.
- Chemical and physical properties of amino acids are essentially of amino, carboxyl and R-functional groups.

Types of amino acids

I. On the basis of **R-group**

R-group	Amino acids
$-H$	Glycine
$-CH_3$	Alanine

(methyl)	
$-CH_2-OH$ (hydroxy methyl)	Serine

II. On the basis of **Nature** of amino acids

Nature	**Amino acids**
Acidic	Glutamic acid
Basic	Lysine
Neutral	Valine
Aromatic	Tyrosine, tryptophan, phenylalanine

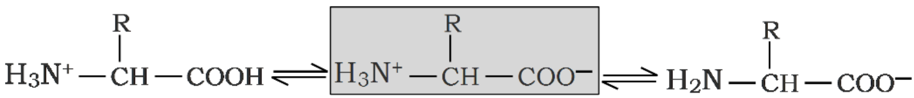
III. On the basis of **Body's requirement**

Non-essential	**Essential**
Synthesised by body	Not synthesised by body
Not required in diet	Required in diet
10 in number	10 in number

Mnemonics:
VILL PMT THA

Zwitterionic Form

- A particular property of amino acids is the ionisable nature of $-NH_2$ and $-COOH$ group.
- In solutions of different pH, the structure of amino acids changes.

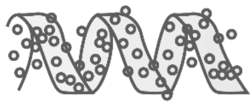
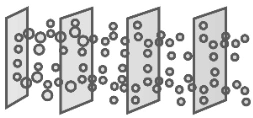
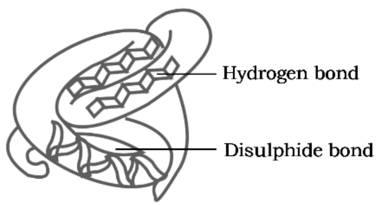


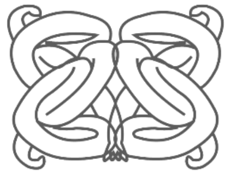
Zwitterionic form

(Both positive and negative charge)

STRUCTURE OF PROTEINS

- Each protein is a **heteropolymer** of amino acids linked by **peptide bonds** (formed by **dehydration**) and only 20 types of amino acids participate in their formation.
- Dietary proteins are the source of essential amino acids.
- Biologists describe structure of proteins at four levels:

Level	**Typical**	**Structure**
Primary	❖ Positional information of sequence of amino acids ❖ Protein thread as extended rigid rod	 N-terminal • C-terminal • First amino acid • Last amino acid
Secondary	❖ Thread folded in the form of a helix i.e., similar to revolving stair case ❖ **Only right handed** helices observed in **proteins**	 Alpha-Helix  Beta-plate sheet
Tertiary	❖ 3-dimensional view, like hollow woolen ball ❖ This structure is **absolutely necessary for**	

	many biological activities of proteins	
Quaternary	❖ More than one polypeptide chains are involved e.g., **Haemoglobin consists of 4 subunits: 2α and 2β**. ❖ It is based on how individual polypeptide are arranged with respect to each other.	

SOME PROTEINS AND THEIR FUNCTIONS

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

- **Collagen** is the most abundant protein in **animal** world.
- **RuBisCO** is the most abundant protein in the whole of the **biosphere**.

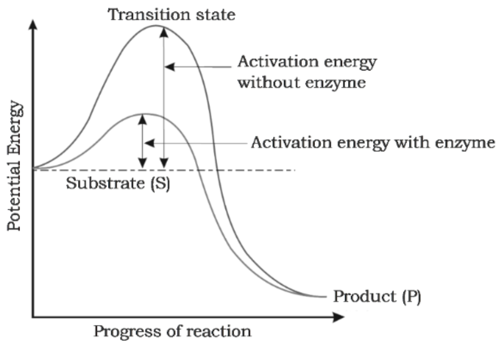
ENZYMES (BIOCATALYST)

Properties:

- **Tertiary** structure.
- **Highly specific.**
- **Unchanged** at the end of reaction.
- **Not used up** in the reaction.
- Proteinaceous in nature except **ribozymes (nucleic acids).**
- Increases rate of reaction by **lowering activation energy**.
- Have **active site**/pockets where **substrate** binds.
- **Inorganic catalysis** work efficiently at high temperatures and high pressures while enzymes get **denatured** at high temperature ($> \mathbf{40°C}$) except enzymes of **thermophilic** organisms (can **tolerate 80° − 90°C**).
- For metabolic conversion, substrate **'S'** has to bind the enzyme at its active site and results in **obligatory** formation of **'ES' complex (Transient phenomenon)**, essential for catalysis.
- Structure of substrate gets transformed into structure of products(s).

$$E + S \rightleftharpoons ES \rightarrow EP \rightarrow E + P$$

'**Altered structural states**'
(unstable)



- Difference in average energy content of 'S' from that of transition state is called '**Activation energy**'.
- **Transition state – High energy unstable state**.

- 'P' is at lower level than 'S' – Reaction is **exothermic**.
- 'S' is at lower level than 'P' – Reaction is **endothermic**.

FACTORS AFFECTING ENZYME ACTIVITY

- **Temperature**
  - Enzyme shows **highest activity at optimum** temperature.
  - Low temperature → Enzyme is temporarily **inactive**.
  - High temperature → Tertiary structure of enzymes destroyed due to **denaturation**.
- **pH**
  - Enzyme shows highest activity at optimum pH.
  - Rate of reaction declines both below and above optimum pH.
- **Substrate concentration**

  Initially rate of reaction increases with increase in substrate concentration but becomes constant when all enzymes get saturated with substrate.
- **Binding of specific chemicals (Inhibitors)**

  When binding of chemicals shuts off enzyme activity, the process is called **inhibition** and chemical is called **inhibitor**.

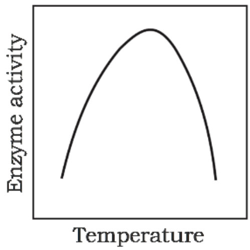
  V_{max} = Maximum rate of reaction

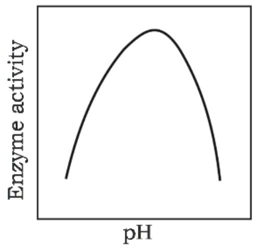
  Michaelis constant $[K_M]$ = Concentration at which the reaction velocity reaches half its maximum velocity.

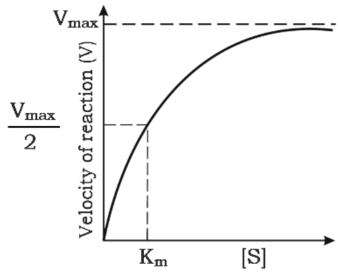
Competitive inhibitor:

- Inhibitor resemble the substrate and compete with substrate for the active site of enzymes.
- Closely **resembles substrate** in molecular structure and inhibits enzyme activity.

- ❖ Consequently, substrate can not bind and as a result enzyme action declines.
- ❖ E.g.,Malonate closely resembles the substrate succinate in structure.
- ❖ Inhibition of succinic dehydrogenase by malonate.
  Application: Control of bacterial pathogens.







Note: Effect of the competitive inbibitor can be reversed by increasing the concentration of the substrate.

CLASSIFICATION AND NOMENCLATURE OF ENZYMES

- ➢ Most of these enzymes have been classified into different groups based on the type of reactions they catalyse. Enzymes are divided into **6 classes** each with **4-13 subclasses** and named accordingly by a **four-digit number**.

Class	Name	Function
I	**Oxidoreductases/ dehydrogenases:**	Enzymes which catalyse oxidoreduction between two substrates S and S' S reduced + S' oxidised → S oxidised + S' reduced
II	**Transferases:**	Catalyse a transfer of a group, G (other than hydrogen) between a pair of substrates S and S' $S - G + S' \rightarrow S + S' - G$

III	**Hydrolases:**	Catalyse hydrolysis of ester, ether, peptide, glycosidic, $C-C, C$ – halide or P-N bonds.
IV	**Lyases:**	Catalyse removal of groups from sub-strates by mechanisms other than hydrolysis **leaving double bonds**. $$\underset{\text{C}-\text{C}}{\overset{\text{X}\quad\text{C}}{\vert\quad\ \vert}} \rightarrow \text{X}-\text{Y}+\text{C}=\text{C}$$
V	**Isomerases:**	Catalyse inter-conversion of optical, geometric or positional isomers.
VI	**Ligases:**	Catalyse the linking together of two compounds, e.g., enzymes which catalyse joining of C-O, C-S, C-N, P-O etc. bonds.

CO-FACTORS

Enzymes

Simple enzymes
- ❖ Only protein

Conjugated enzymes

Apo-enzyme (inactive)
- ❖ Protein part

Co-factor
- ❖ Non-protein part

Catalytically active

Co-factor

- ➢ **Prosthetic group**
  - ❖ Organic, **tightly bound** to apoenzyme
  - ❖ **Haem** is prosthetic group for **catalase** and **peroxidase**
- ➢ **Co-enzyme**
  - ❖ Organic, **loosely bound** to apo-enzyme for transient period (just during catalysis
  - ❖ e.g., **NAD** , **NADP** (Contain **niacin vitamin**)
- ➢ **Metal ions**
  - ❖ Form **coordination bond** with active site and one or more coordination bond with substrate
  - ❖ $\mathbf{Zn^{+2}}$ for carboxypeptidase

Catalytic activity is lost if co-factor is removed
