Biomolecules

1 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.

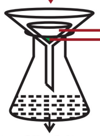
Chemical Analysis

Living tissue (Plant tissue/animal tissue/microbial paste) + **Trichloroacetic acid (Cl_3CCOOH)**

↓

Thick slurry

↓



→ Cheese cloth

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

Retentate (Acid insoluble)

Filtrate → Inorganic and Organic Biomicromolecules; Retentate → Organic Biomacromolecules

Inorganic
- Water
- Ions (e.g. Na^+, K^+, Ca^{+2}, Mg^{+2}, PO_4^{-3}, SO_4^{-2}, etc.)
- Gases

Organic Biomicromolecules
- M.wt - 18-800 Da
- Monomeric form

E.g., Simple sugars → Polysaccharides

Nucleotides → Nucleic acids

Amino acids → Proteins

Organic Biomacromolecules
- M.wt - > 10,000 Da
- Polymeric form

Polysaccharides

Nucleic acids

Proteins

Lipids (Not a polymer)
- Not strictly biomacromolecule
- M.wt < 800 Da
- Cell membrane fragments form vesicles which are not water soluble

2 ELEMENTAL ANALYSIS

- Elemental analysis gives elemental composition of living tissues in the form of hydrogen, oxygen, chlorine, carbon etc.
- Living tissue —Weigh→ **Wet weight**; —Dry (All water evoporates)→ **Dry weight**
- Dried living tissue —Burn (All carbon compounds oxidise to CO_2 and H_2O)→ **'Ash' (contains only inorganic elements)**
- Carbon and hydrogen with respect to other elements are more in any living organisms than in earth's crust
- **Oxygen is the most abundant element in living organism**
- Analytical technique gives an idea about the molecular formula and the probable structure of the compound.

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
Sulphur (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

Average Composition of Cells

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

Water **is the most abundant chemical** in living organisms

3 METABOLITES (BIOMOLECULES)

Primary metabolite
- Identifiable functions
- Play known **roles in physiological** processes e.g. sugars, amino acids lipids, nitrogen bases, etc.

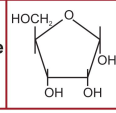
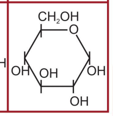
Secondary metabolite
- Not involved in primary metabolism
- Seems to have **no direct function** in growth and development of organisms
- Many of them are useful to **human welfare** e.g., rubber, drugs, spices and pigments. Some have **ecological importance**
- E.g., Flavonoids, antibiotics etc.

Some Secondary Metabolites

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

4 CARBOHYDRATES

Monosaccharides/sugar
- Single unit

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

- 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

Polysaccharides
- Many units/long chains of sugars
- Units linked together by **glycosidic bond** formed by **dehydration**.

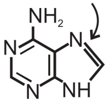
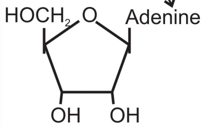
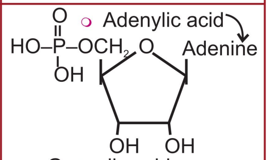
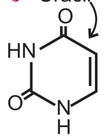
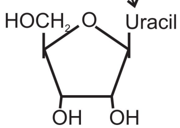
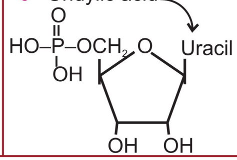
Homopolysaccharides
- Same monomer units

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**
Branching	✓				
Colour with I_2	Red	Blue		X	

5 NUCLEIC ACIDS

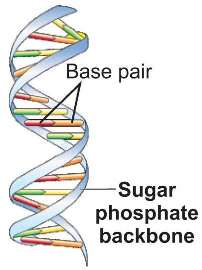
- **Polymer of nucleotides**
- Each nucleotide comprises – Sugar/monosaccharide, Heterocyclic nitrogenous base (together: **Nucleoside**), Phosphate (all together: **Nucleotide**)

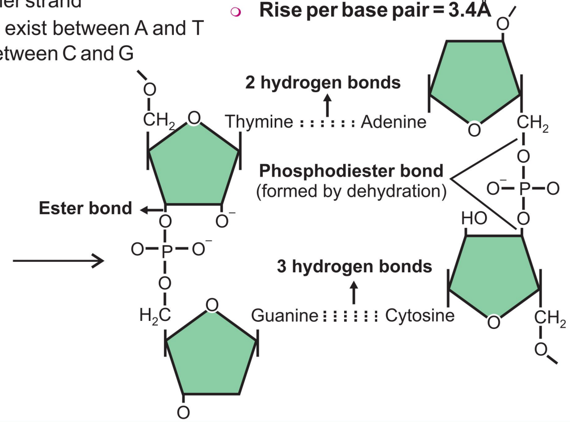
Nitrogenous base	Nucleoside	Nucleotide
Substituted **Purines**: Adenine, Guanine 	Adenosine, Guanosine 	Adenylic acid, Guanylic acid 
Substituted **Pyrimidine**: Thymine, Cytosine, Uracil 	Thymidine, Cytidine, Uridine 	Thymidylic acid, Cytidylic acid, Uridylic acid 

- **Ribose sugar** and **uracil** exist in **RNA** (Ribonucleic acid)
- 2′-deoxyribose sugar and thymine exist in DNA (Deoxyribonucleic acid)
- DNA and RNA function as genetic material

Wastson-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
- A and G of one stand compulsorily base pairs with T and C respectively, on the other strand
- Always two hydrogen bonds exist between A and T and three hydrogen bonds between C and G
- **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 = 3.4Å**





6 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

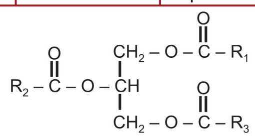
Parameter	Saturated	Unsaturated
No. of C = C double bonds	X	One or more
Example	**Palmitic acid** (**16** carbon including carboxyl carbon) $CH_3-(CH_2)_{14}-COOH$	**Arachidonic acid** (**20** carbon including carboxyl carbon)

I. Many lipids are **esters of fatty acids and glycerol**

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

Glycerol: $CH_2-CH-CH_2$ with OH, OH, OH

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

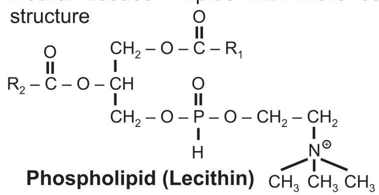


Triglyceride (R_1 R_2 and R_3 are fatty acids)

II. Some lipids have phosphorous and phosphorylated organic compound called **phospholipids**

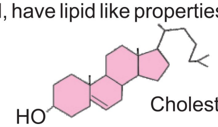
e.g., Lecithin - **found in cell membrane**

Neural tissues - lipids with more complex structure



Phospholipid (Lecithin)

III. Cholesterol, have lipid like properties



Cholesterol

⑦ 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
$-CH_3$ (methyl)	Alanine
$-CH_2-OH$ (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

Zwitterionic Form

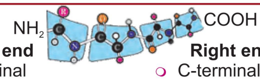
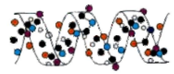
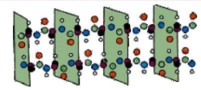
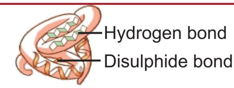
- A particular property of amino acids is the ionisable nature of $-NH_2$ and –COOH group.
- In solutions of different pH the structure of amino acids changes.

$$H_3\overset{+}{N}-\underset{}{\overset{R}{\overset{|}{C}}}H-COOH \rightleftharpoons H_3\overset{+}{N}-\overset{R}{\overset{|}{C}}H-COO^- \rightleftharpoons H_2N-\overset{R}{\overset{|}{C}}H-COO^-$$

Zwitterionic form
(Both positive and negative charge)

⑧ 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.
- 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	 **Left end** • N-terminal • First amino acid **Right end** • C-terminal • 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-pleated 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 eg. **Haemoglobin** consists of **4 subunits: 2α and 2β** • It is based on how individual polypeptide are arranged with respect to each other	

⑨ SOME PROTEINS AND THEIR FUNCTIONS

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

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

⑩ DYNAMIC STATE OF BODY CONSTITUENTS

- Living state is a **non-equilibrium steady** state to be able to perform work
- Living process is constant effort to prevent falling into equilibrium
- Living state and metabolism are synonymous.
- Without metabolism there can not be a living state
- **Metabolism** is sum total of **all the reactions** in the body
- There is **no uncatalysed metabolic conversion** in living system

Metabolic pathways (Series of linked reactions)

Catabolic pathways

- **Degradation** pathways
- Complex structure converts into simpler structure
- Energy released (stored in ATP)
- Examples
  - Glucose $\xrightarrow{\text{anaerobic}}$ Lactic acid (skeletal muscle)
  - Glucose $\xrightarrow{\text{anaerobic}}$ Ethanol (In yeast)
  - Glucose $\xrightarrow[\text{10 steps}]{\text{Glycolysis}}$ Pyruvic acid

Anabolic pathways

- **Biosynthetic** pathways
- Formation of complex structure from simple structures
- Energy is used
- Examples
  - Acetic acid $\rightarrow$ Cholesterol
  - Amino acids $\rightarrow$ Proteins

$$CO_2 + H_2O \xrightleftharpoons{\text{Carbonic anhydrase}} H_2CO_3$$

- Carbonic anhydrase is present in cytoplasm
- With enzyme - 6,00,000 molecules of H_2CO_3 formed in 1 sec, Rate increases 10 million times
- Without enzyme - 200 molecules/hr

- Rate refers to the amount of product formed per unit time, expressed as rate = $\delta P/\delta t$
- Rate double or decreases by half for every 10°C change in either direction.
- Flow of metabolites through metabolic pathways has a definite direction, this is called dynamic state of body constituents
- Biomolecules are constantly being changed into some other biomolecules and also made from some other biomolecules called **turnover**
- Glucose concentration in blood : **4.2 - 6.1 m mol/L**

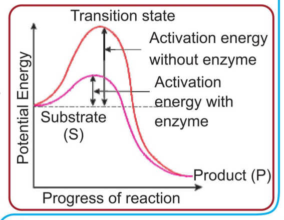
11 ENZYMES (BIOCATALYST)

Properties:

- **Tertiary** structure
- **Unchanged** at the end of reaction
- **Highly specific**
- **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 catalysts work efficiently at high temperatures and high pressures while enzymes get **denatured** at high temperature **(> 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 product(s)

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

ES, EP → **'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**

13 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. 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:**	Enzymes catalysing a transfer of a group, G (other than hydrogen) between a pair of substrate S and S'. $S - G + S' \longrightarrow S + S' - G$
III	**Hydrolases:**	Enzymes catalysing hydrolysis of ester, ether, peptide, glycosidic, C – C, C – halide or P-N bonds.
IV	**Lyases:**	Enzymes that catalyse removal of groups from substrates by mechanisms other than hydrolysis **leaving double bonds**. X–C–C–Y (X on one C, Y on the other) → X – Y + C = C
V	**Isomerases:**	Includes all enzymes catalysing inter-conversion of optical, geometric or positional isomers.
VI	**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.

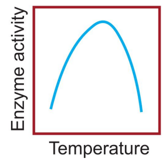
12 FACTORS AFFECTING ENZYME ACTIVITY

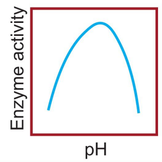
(1) **Temperature**

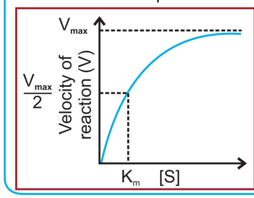
- Enzyme shows **highest activity at optimum** temperature
- Enzyme activity declines both below and above optimum value
- Low temperature preserves enzymes in temporarily **inactive** state
- High temperature destroys enzymatic activity by **denaturing** their structure

(2) **pH**

- Enzyme shows highest activity at optimum pH
- Rate of reaction declines both below and above optimum pH







(3) **Substrate concentration**

Initially rate of reaction increases with increase in substrate concentration but becomes constant when all enzymes get saturated with substrate

(4) **Binding of specific chemicals**

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

Competitive inhibitor:

- Inhibitor compete with substrate for active site
- Closely **resembles substrate** in molecular structure and inhibits enzyme activity
- Consequently, substrate can not bind and as a result enzyme action declines.
- e.g., (1) Inhibition of succinic dehydrogenase by malonate
  (2) Control of bacterial pathogens by competitive inhibitor

14 CO-FACTORS

Enzymes → Simple enzymes; Conjugated enzymes

Simple enzymes
- Only protein

Conjugated enzymes → **Apo-enzyme** (inactive); **Co-factor**

Apo-enzyme (inactive)
- Protein part

Co-factor
- Non-protein part

Apo-enzyme + Co-factor → **Catalytically active enzyme**

Catalytic activity is lost if co-factor is removed

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
- Zn^{+2} for carboxypeptidase