Aakash + BYJU'S NOTES

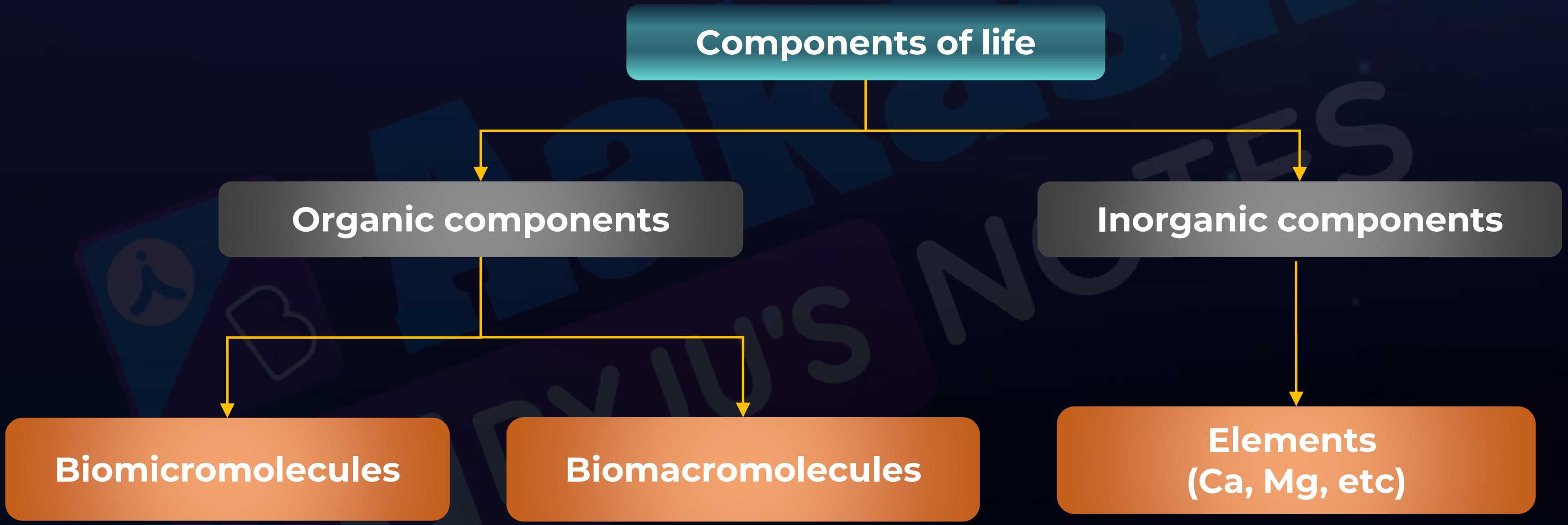
Biomolecules

Key Takeaways

1. Biomolecules
2. Metabolites
3. Carbohydrates
4. Lipids
5. Nucleic Acids
6. Amino Acids and Protein
7. Metabolism
8. Enzymes

Summary

Components of Life



Biomolecules

Biomolecules: Carbon containing compounds which form the basic chemical structure of all life forms

Biomolecules

- **Micromolecules**
  - Small size
  - Low mol wt.
  - 18 - 800 Daltons
  - Found in the acid soluble pool
  - E.g., Simple sugars, amino acids, nucleotides
- **Macromolecules**
  - Large size
  - High mol wt.
  - >1000 Daltons
  - Found in the acid insoluble pool
  - E.g., Complex carbohydrate, lipid, protein, nucleic acids

Metabolites

- Carbon content of a cell - **Metabolite content**
- Metabolites - Molecules that take part in metabolic reaction
- **Metabolism** : Sum total of all the chemical reactions occurring in the body

Metabolites

Primary metabolites

Involved **directly** in growth

- Carbohydrates
- Lipids
- Proteins
- Nucleic acids

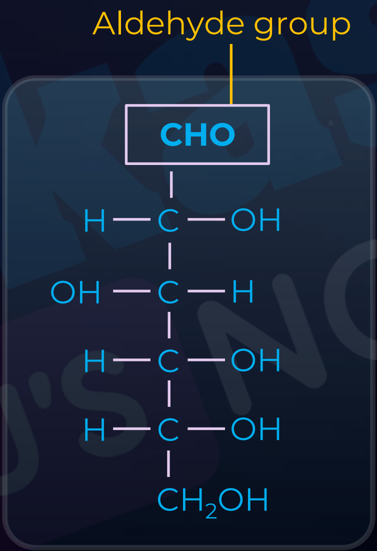
Secondary metabolites

Produced for **defence purposes and stress responses**

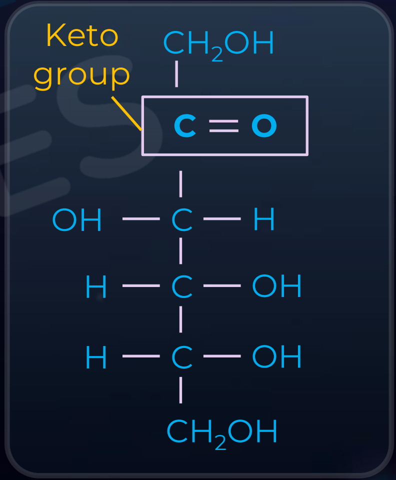
- Coloured pigments - Carotenoids
- Alkaloids - Morphine
- Polymeric substances - Rubber, Gums
- Essential oils - Lemongrass oil
- Antibiotics, toxin, scents, spices etc

Carbohydrates

- Carbohydrates are the **hydrates of carbon**
- Have carbon, hydrogen and oxygen in the ratio 1:2:1
- Contain at least 3 carbon atoms
- Have multiple –OH groups
- General formula- **$C_n(H_2O)_n$**
- Can be aldehydes or ketones
- Can be classified based on the number of monomeric units
- **Saccharide = Sugar**



Glucose ($C_6H_{12}O_6$) : Aldose



Fructose ($C_6H_{12}O_6$) Ketose

Carbohydrates

Types of carbohydrates

Monosaccharides

E.g., glucose, fructose, mannose, galactose, etc

Polysaccharides

E.g., glycogen, starch, hyaluronic acid, cellulose, etc

Derived monosaccharides

E.g., deoxyribose, glucosamine, mannitol, etc

Disaccharides

E.g., sucrose

Oligosaccharides

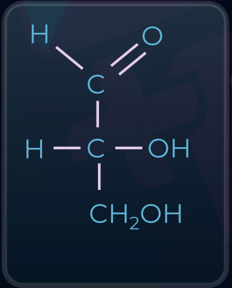
E.g., raffinose, stachyose, etc

Monosaccharides

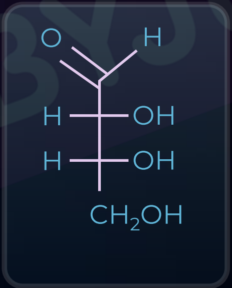
- Simplest carbohydrates
- Form the building blocks of larger carbohydrates
- **Cannot be hydrolysed into smaller units**
- Glucose (universal sugar) , fructose (fruit sugar), mannose, galactose are hexoses

Monosaccharides

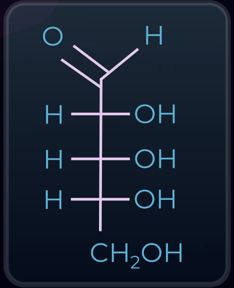
- **Trioses** – Have 3 carbon atoms
- **Tetroses** – Have 4 carbon atoms
- **Pentoses** – Have 5 carbon atoms
- **Hexoses** – Have 6 carbon atoms



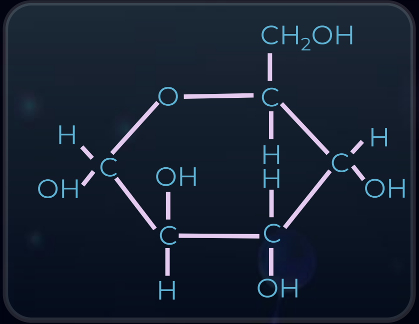
Glyceraldehyde



Erythrose



Ribose

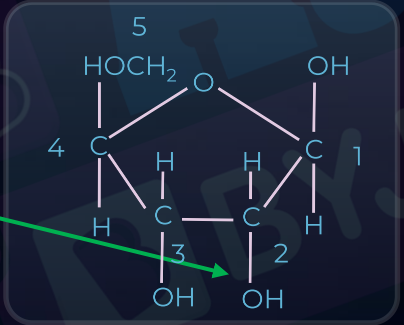


Glucose

Derived monosaccharides

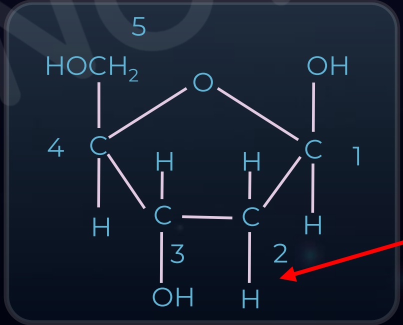
- Modified monosaccharides
- Deoxy sugar : e.g., deoxyribose
- Amino sugar : e.g., glucosamine
- Sugar acid : e.g., glucuronic acid, ascorbic acid
- Sugar alcohol : e.g., mannitol (present in brown algae)

OH on Carbon 2



Ribose (C_5)

Deoxygenation



Deoxyribose (C_5)
Constituent of DNA

No OH on Carbon 2

Disaccharides

- Polymers of monosaccharides with **2** monomeric units
- Di = Two; Saccharide = Sugar unit
- Two monosaccharide units join with a **glycosidic bond**

Examples:

Sucrose = Glucose + Fructose

Lactose = Glucose + Galactose

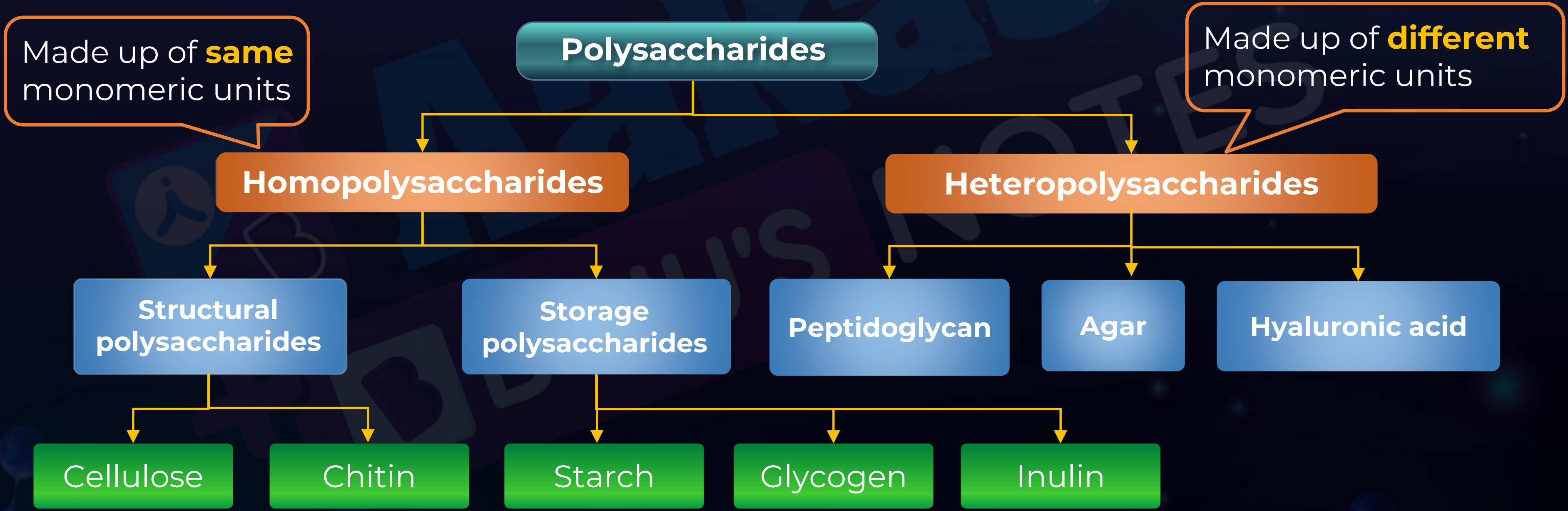
Monosaccharide (Glucose) **Monosaccharide (Glucose)** **Disaccharide (Maltose)**

Oligosaccharides

- Oligosaccharides are the polymers of monosaccharides with **3 - 9** monomeric units.
- Monosaccharides unit are bound together by **glycosidic bond.**
- Depending on the number of monosaccharide molecules, there are different types of oligosaccharides.
- E.g. - Raffinose with 3 monomeric units is referred to as a **trisaccharide.**
- Similarly, stachyose with 4 monomeric units is referred to as a **tetrasaccharide.**

Polysaccharides

- Polysaccharides are the polymers of monosaccharides with **10 or more** monomeric units.
- They have a **reducing end** and a **non-reducing end** in their chemical structure.



Homopolysaccharides

Storage polysaccharides

Starch
- Polymer of **glucose**
- Gives blue colour with iodine
- Major reserve food in plants
- Consists of **amylopectin** and **amylose**

Glycogen
- Polymer of **glucose**
- Food reserve in animals
- Highly branched
- Stored in liver and muscles

Inulin
- Polymer of **fructose**
- Not metabolised in human body
- Stored in *Dahlia*, dandelion and artichoke

Structural polysaccharides

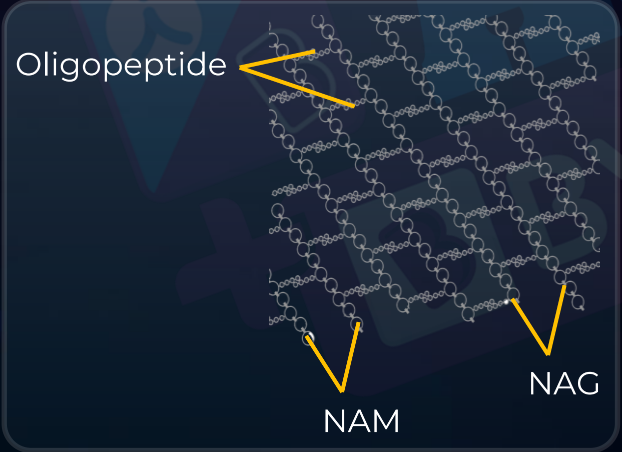
Cellulose
- Polymer of **glucose**
- **Forms structural part of plants** (cell wall)
- Straight chain and unbranched
- Cotton fibres contain 90% of cellulose

Chitin
- Polymer of **N-acetyl-D-glucosamine**
- Form structural part of living organisms **(exoskeleton of arthropods)**
- Complex polysaccharide

Homopolysaccharides

Peptidoglycan

- Component of **bacterial cell wall,** which is degraded by **lysozyme**
- Made of two different repeating units
  - N-Acetyl glucosamine (NAG)
  - N-Acetyl muramic acid (NAM)



Agar

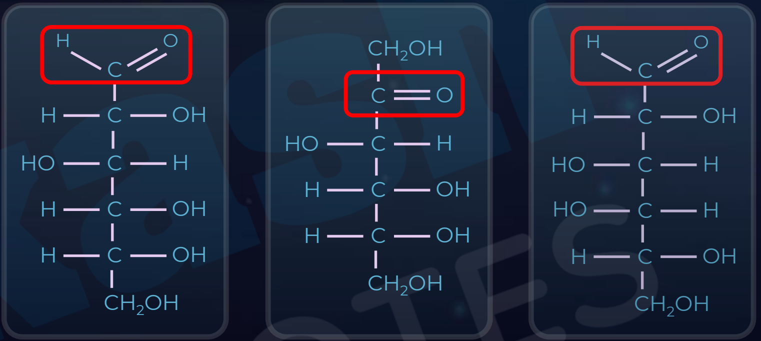
- Obtained from the **red algae** - *Gelidium* and *Gracilaria*
- Agar is a mixture of agarose and agaropectin
- Used as medium in labs

Hyaluronic acid

- Responsible for the toughness and flexibility of **cartilage** and **tendon**
- Made of two different units
  - D-glucuronic acid
  - N-acetyl-D-glucosamine

Reducing Sugars

- Reducing sugars: **Free aldehyde (CHO) /ketone group (C=O) present**
- Benedict and Fehling's test: reducing sugars reduce the Cu^{2+} ions to Cu^{+} which gives brick red colour
- **All monosaccharides are reducing sugars**



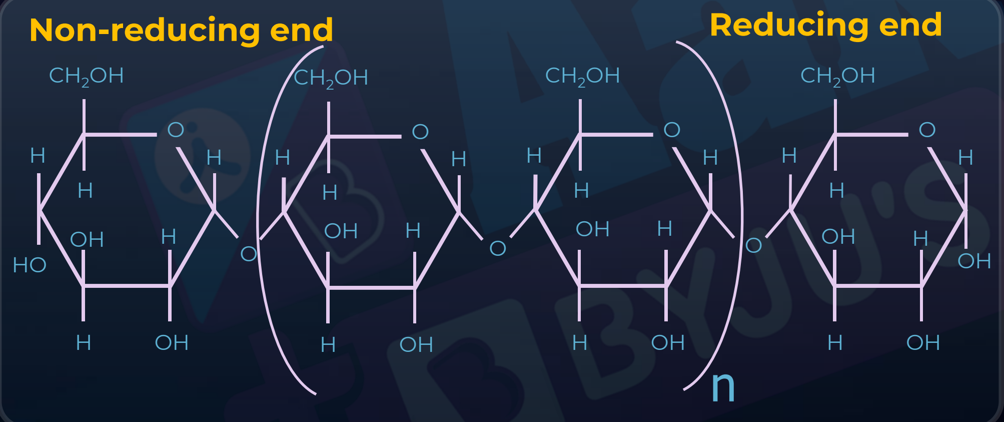
Glucose Fructose Galactose

Monosaccharide

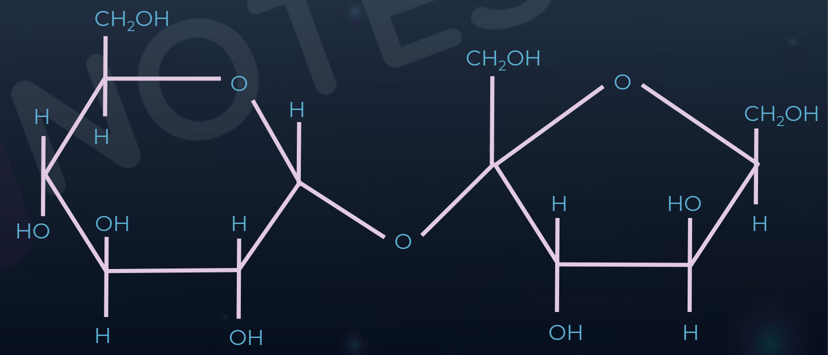
About 2ml of test solution (glucose) **Heat in water bath** **Brick red precipitate**

Non-Reducing Sugars

- Non-reducing sugars: **No free aldehyde/ketone group**
- **All polysaccharides and sucrose** are non-reducing
- Among disaccharides, only sucrose is non-reducing sugars



Polysaccharide



Disaccharide: Sucrose

Lipids

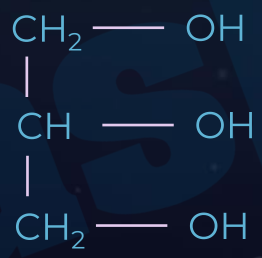
- Water insoluble organic compounds
- Consists of **carbon, hydrogen** and **oxygen**
- Molecular weight is less than **800 daltons**
- They are **insoluble in water**
- They are **not polymeric like polysaccharides** (carbohydrates)

Classification of lipids

- **Simple**
  - Neutral/ True fats
  - Waxes
- **Compound**
  - Phospholipids
  - Glycolipids
  - Lipoprotein
  - Chromolipids
- **Derived**

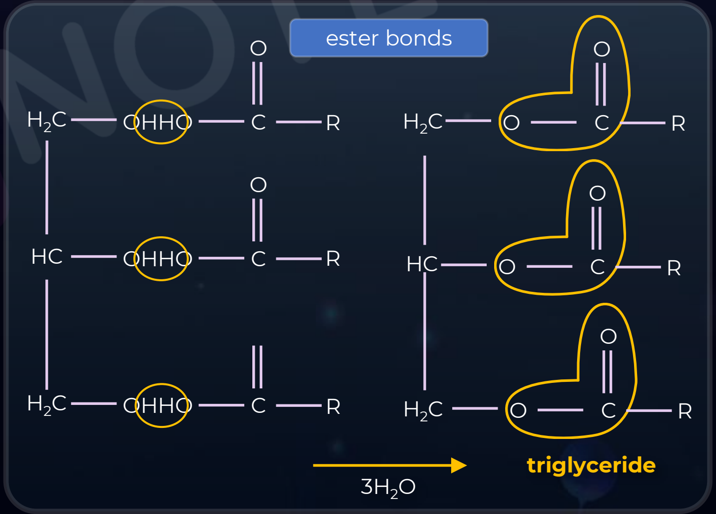
Simple Lipids

- **Simple lipids** are esters (organic acid and alcohol react to form esters) of fatty acids with various alcohol.
- **Neutral or true fats** are **esters of fatty acids** with glycerol, called **glycerides**
  - **Glycerol** is an alcohol with three carbons, five hydrogens, and three hydroxyl (OH) groups (Trihydroxypropane)
  - **Fatty acids:** Carboxylic acid with an R group attached. R groups can be
    - Methyl ($-CH_3$)
    - Ethyl ($-C_2H_5$)
    - 1- 19 ($-CH_2$) groups



Glycerol

Fatty acid structure



Esterification reaction

Simple Lipids

Glycerides

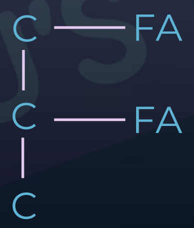
Monoglycerides

Condensation of one fatty acid and glycerol

Monoglyceride

Diglycerides

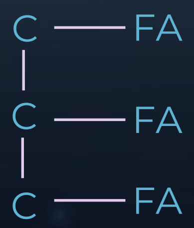
Condensation of two fatty acid and glycerol



Diglyceride

Triglycerides

Condensation of three fatty acid and glycerol



Triglyceride

Simple Lipids

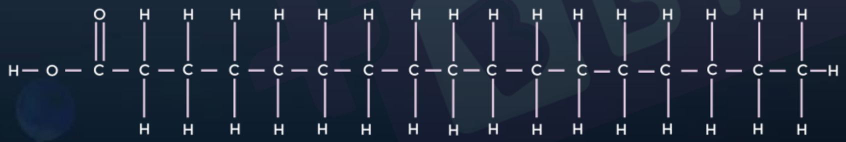
Fatty acids (Based on structure)

Saturated

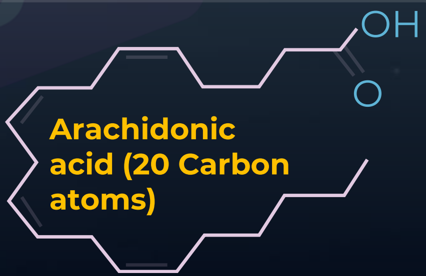
- **Without** a double bond
- Mostly **solid** at room temperature
- Higher melting point

Unsaturated

- **With** a double bond
- Mostly **liquid** at room temperature
- Lower melting point



Palmitic acid (16 Carbon atoms)



Arachidonic acid (20 Carbon atoms)

Essential fatty acids: Cannot be synthesised by the body, so they must be obtained from diet E.g., Linoleate

Non-essential fatty acids: Can be synthesised by the body

Simple Lipids

Simple lipids

- **Fats and oils**
  Esters of fatty acids and glycerol
  E.g.,- Butter, ghee, oils
- **Waxes**
  Esters of long chain fatty acids and fatty alcohol
  E.g.,- Bee wax

	Fats	Oils
Similarities	Triglycerides	Triglycerides
Differences	**Solid at room temperature**	**Liquid at room temperature**
	Mainly from animal sources	Mainly from plant sources
	Relatively more saturated	Relatively more unsaturated
	High melting point E.g., Ghee	**Low melting point E.g., Oil**

Compound Lipids

- **Esters of fatty acids and alcohol** with **additional groups**
- Additional groups could be phosphorus, proteins or sugar
- Usually found in **cell membrane**

Compound lipids

Phospholipids

- Phosphate group + nitrogen choline + fatty acid
- Major component of cell membranes
- E.g., **Lecithin**

Glycolipids

- Glycolipid = fatty acid + alcohol + carbohydrate group
- Found on the cell membrane surface
- Help in cell recognition

Lipoproteins

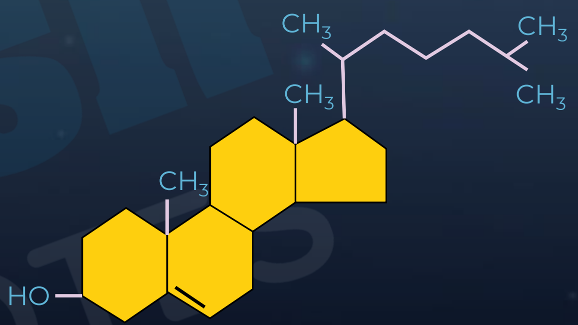
- Contain lipids (phospholipids) and proteins
- Membranes are composed of proteins

Chromolipids

- Contains pigment such as carotenoids
- E.g., **Carotene** and **vitamin A**

Derived Lipids

- Lipids derived from simple or conjugated lipids
- Steroids do not contain fatty acids yet have fat like properties
- Most common steroids are sterols
- Complex in structure
- E.g., **Cholesterol**
  - Most common **sterols**
  - **Tetracyclic in nature**
  - Essential component of animal plasma membrane, also synthesised in live
- E.g., **Prostaglandins**
  - Derived from **arachidonic acid**
  - Group of hormone which function as messenger substance between the cell



Cholesterol

Lipids

Functions of lipids

- Long term energy storage
- Protection against heat loss (insulation)
- Protection against physical shock
- Protection against water loss
- Chemical messengers (hormones)
- Major component of membranes (phospholipids)

Nucleic Acids

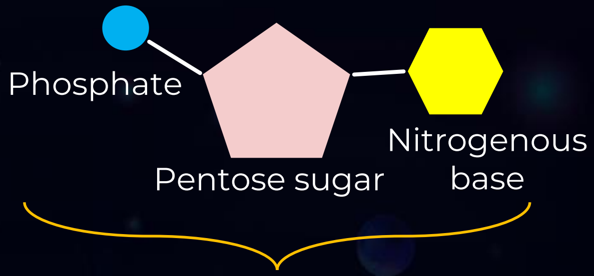
- Nucleic acids are polymers of **macromolecules**
- **Polymers** of repeating units of nucleotides (building blocks)

Nucleic acids
- **DNA** – Deoxyribonucleic acid

- **RNA** – Ribonucleic acid

Nucleotide – Monomers of nucleic acid
- **Pentose sugar**
- **Nitrogenous base**
- **Phosphoric acid**

Pentose sugar + Nitrogenous base → Nucleoside



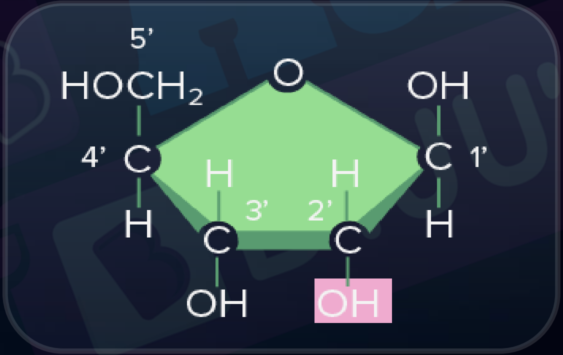
Nucleotide

Nucleic Acids

Pentose sugar

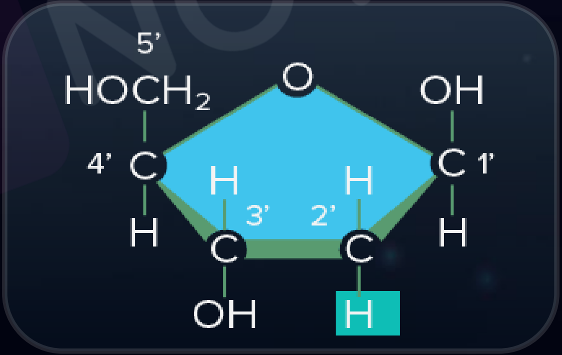
- **5-Carbon** monosaccharide
- Central molecule in a nucleotide

RNA has ribose sugar



Ribose

DNA has deoxyribose sugar



Deoxyribose

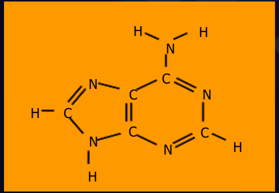
Nucleic Acids

Nitrogenous bases

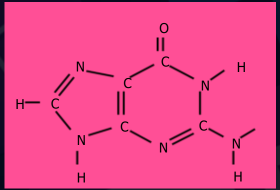
Heterocyclic Nitrogen-containing compounds

Purines

Have double ringed structure



Adenine (A)

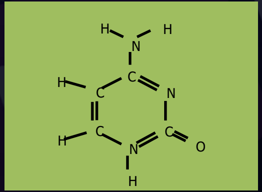


Guanine (G)

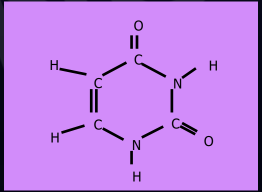
- In both DNA and RNA

Pyrimidines

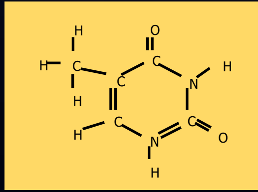
Have single ringed structure



Cytosine (C)



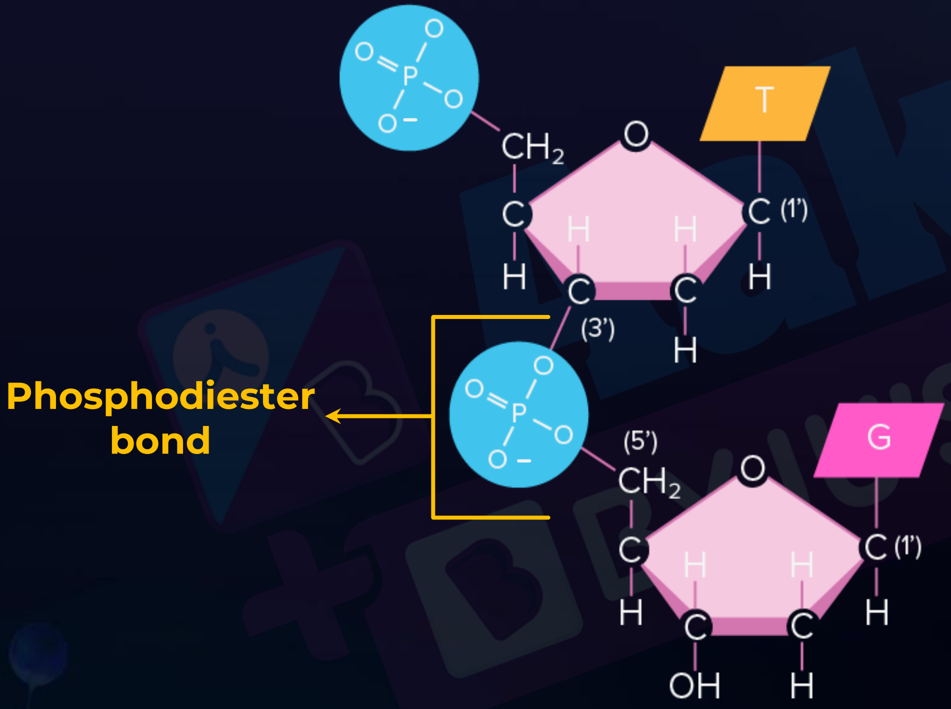
Uracil (U)



Thymine (T)

- In DNA, cytosine and thymine are found
- In RNA, cytosine and uracil are found

Nucleic Acids



Phosphodiester Bond

- **Ester bond** formed between the **phosphate group** of one nucleotide and **hydroxyl group** of the sugar of the next nucleotide
- Connecting link between two consecutive nucleotides

Double Helix Model

- Made up of **two polynucleotide chains**, existing as a double helix
- Two polynucleotide strands are joined together by **hydrogen bonds between purines and pyrimidines**

Antiparallel strands

5’ end - 5th carbon of pentose sugar is free

3’ end - 3rd carbon of pentose sugar is free

Each base pair strand turns 36 degree

Full turn involves 10 base pairs

Backbone of DNA

Sugar – phosphate backbone

Right-handed coiling

Helix diameter 2 nm

Helical rise 0.34 nm

Helical pitch 3.4 nm

Nitrogen bases facing inside

Purines

Pyrimidines

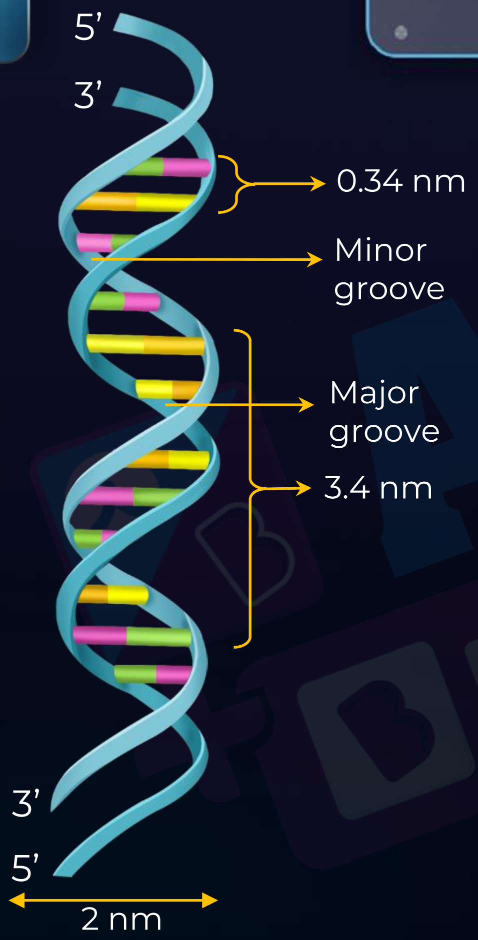
Complementary base pairing

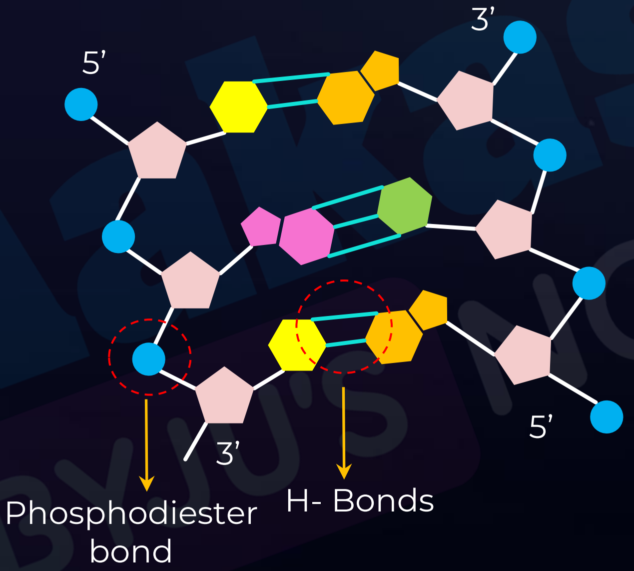
A = T

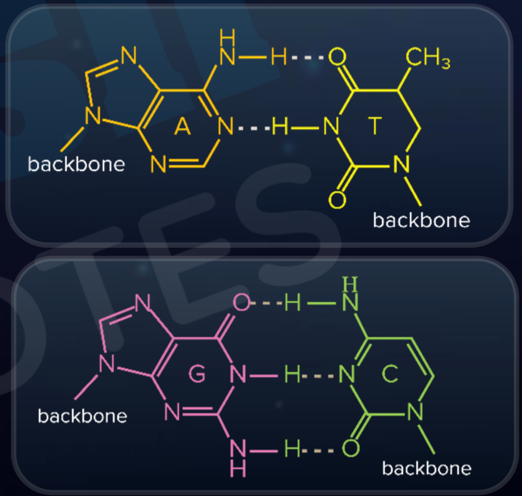
C ≡ G

Hydrogen bonds

Double Helix Model







T — A: Forms two hydrogen bonds

C — G: Forms three hydrogen bonds

DNA

Forms of DNA (with right handed coiling)

B - form	A - form	C - form	D - form
• Usual DNA • 10 base pairs per turn	• 11 base pairs per turn • Not perpendicular to the axis but slightly tilted	• Like B-form • 9 base pairs per turn	• Like B-form • 8 base pairs per turn

- DNA with **left-handed coiling** is called **Z - DNA** with **12 base pairs**

Chargaff's rule

- Concluded by Erwin Chargaff for DNA molecule
- (A + G) Purines = Pyrimidine (T + C)
- A = T and G = C
- (A+T)/ (G+C) constant for a given species only
- Equal proportion of deoxyribose sugar and pentose sugar

RNA

- Usually **single stranded** but sometimes double stranded (Reovirus and Rice dwarf virus)
- **Does not follow Chargaff's rule**

Forms of RNA

Messenger (m- RNA)

- 5% of total cellular RNA

Ribosomal (r- RNA)

- 80% of total cellular RNA

Transfer/ soluble (s- RNA, t- RNA)

- 10-15% of total cellular RNA

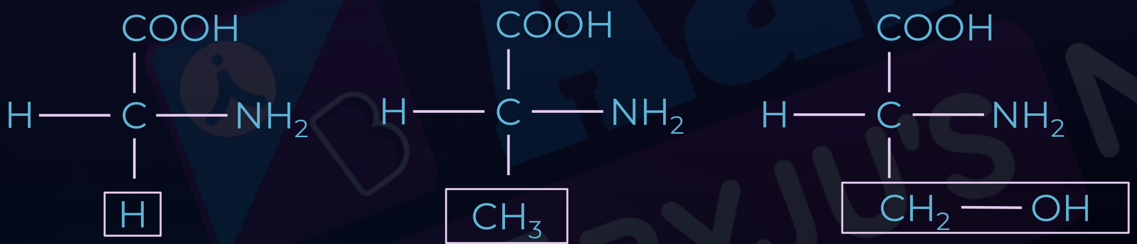
Amino Acids

Amino acids

Amino acids are substituted methanes

General structure: Four substituent groups occupying the four valency positions

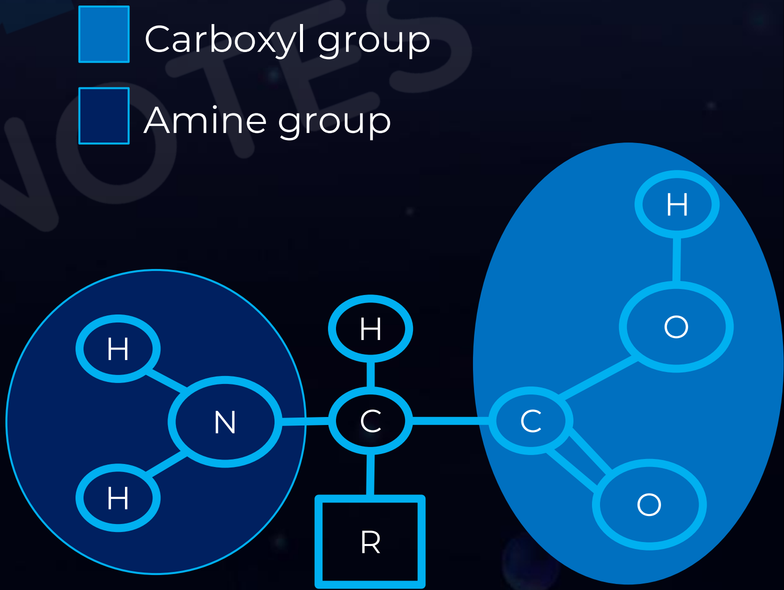
Based on nature of R group there are many amino acids. For e.g.,



Glycine → R = H

Alanine → R = CH_3

Serine → R = CH_2-OH

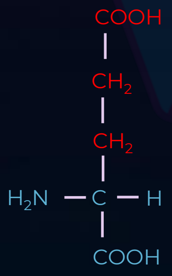


Classification of Amino Acids

Based on number of amine and carboxyl groups

Acidic

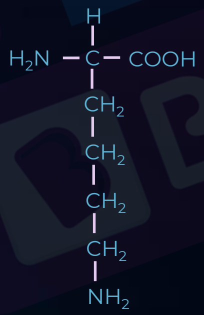
2 carboxyl and 1 amine group E.g., glutamic acid, aspartate



Aspartic acid

Basic

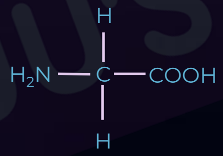
1 carboxyl and 2 amine group E.g., lysine, arginine and histidine



Lysine

Neutral

1 carboxyl and 1 amine group E.g., valine, alanine and glycine



Glycine

Based on the presence of aromatic ring

Non-aromatic

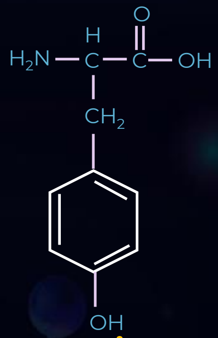
Have straight chains and no aromatic rings

Aromatic

Have aromatic (benzene) rings E.g., tyrosine, phenylalanine, tryptophan

Phenylalanine

Tryptophan



Tyrosine

Amino Acids

Amino acids

Essential

Obtained through diet; body does not synthesise

Non-essential

Synthesised by the body

Semi-essential amino acid:

Synthesised very slowly by human beings.

E.g., arginine and histidine

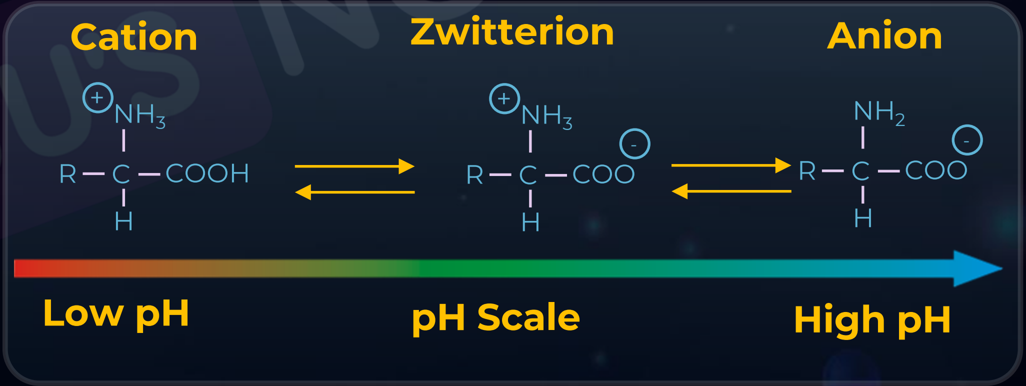
Essential	Non essential
Phenylalanine	Proline
Valine	Alanine
Threonine	Glycine
Tryptophan	Glutamate
Isoleucine	Cysteine
Methionine	Serine
Lysine	

Amino Acids

Zwitterions:

- Molecule with **one functional group** having **positive charge** and the other having **negative charge**
- Positive charge = Negative charge
- Net charge = **Zero**
- **-NH_2** is a **strong base** and can pick up protons **(H^+)** from **-COOH group**
    - Due to this, NH_2 acquires **positive charge (NH^{3+})** and **COOH** acquires **negative charge (COO-)**

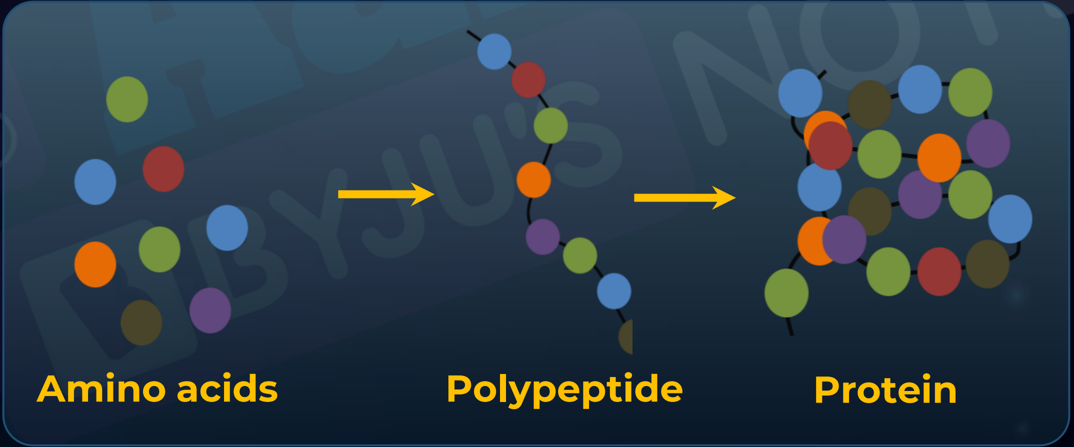
Amino acids ⟷ **Zwitterions**



Different pH = Different states of amino acids

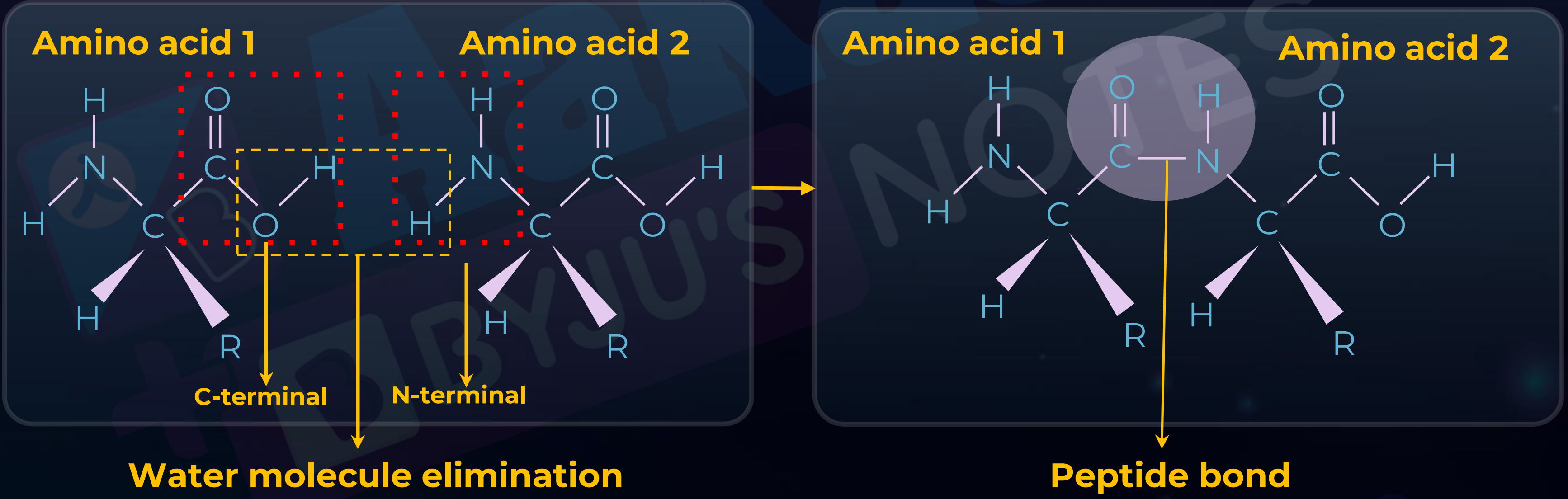
Proteins

- **Polypeptides** are **linear chains of amino acids** linked by **peptide bonds.**
- Polypeptides undergo **modification** to form **proteins.**
- Proteins are **heteropolymers** made by different amino acids.
- There are 20 types amino acids, **a protein is a heteropolymer and not a homopolymer.**



Proteins

Formation of peptide bond



Proteins

Structure of proteins

Four levels of protein structure

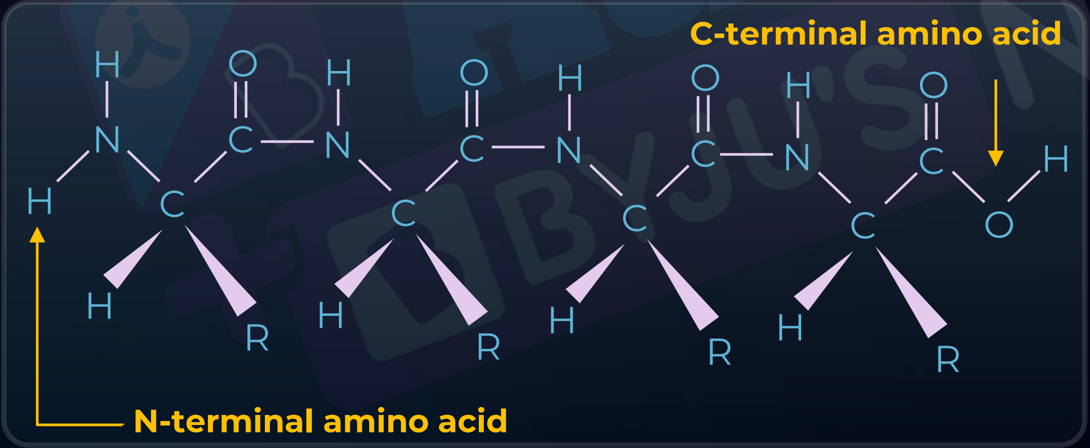
Complexity ↓

- Primary structure
- Secondary structure
- Tertiary structure
- Quaternary structure

Proteins

Primary structure

- Linear chain of amino acids
- Positional information
- **N- Terminal :** Free Amine group with alpha carbon
- **C-Terminal :** Free Carboxyl group with alpha carbon



Proteins

Secondary structure

- Folding of the polypeptide chain due to interactions between amino acids

Secondary structure

Alpha-helix

α-helices

Polypeptide chain folds in the form of **right-handed helices** resembling a spring. E.g., Keratin

Beta- pleated sheet

Segments of polypeptide chain line up next to each other resembling **pleated paper.** E.g.,Fibroin

β-sheets

Proteins

Tertiary structure

- **Three-dimensional** structure
- Protein is **folded upon itself** like a hollow woollen ball
- **Biologically active**
- **E.g., Globular protein, Myoglobin**

Tertiary structure

Quaternary structure

- **Two or more** polypeptide chains
- Each chain = **Subunit**
- Arrangement of each folded polypeptide chains with respect to each other determines the structure
- Adult human haemoglobin consists of 4 subunits
  - two subunits of α type
  - two subunits of β type
- **E.g., Haemoglobin**

Quaternary structure

Types of Proteins

Based on composition

Simple

Composed of **long chains of amino acids**

Conjugated

Protein part + Non-protein part (Prosthetic group)

Simple proteins	Conjugated proteins
Collagen found in the skin	Nucleoproteins (prosthetic group-nucleic acid) e.g., Protamines.
Myosin found in the muscles	Metalloproteins (prosthetic group-metals) e.g., Ferritin.
Insulin produced by the pancreas	Chromoproteins (prosthetic group-pigment) e.g. Cytochromes.
Keratin found in the hair	Phosphoproteins (prosthetic group-phosphoric acid) e.g., Casein of milk.
Egg albumin	Lipoproteins (prosthetic group-lipids) e.g., Chylomicron.
Serum globulins	Glycoproteins (prosthetic group-carbohydrates) e.g., Mucin.

Types of Proteins

Based on shape and structure

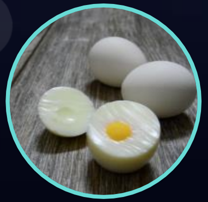
Fibrous

- Form **long and narrow fibers**
- Provide **structural support**
- Examples: Keratin, collagen, fibroin, elastin

Elastin found in the skin

Globular

- **Round or spherical** in shape
- Have **multi-functional role**
- Examples: Haemoglobin, insulin, ovalbumin



Ovalbumin found in egg whites

Types of Proteins

Based on function

Structural
Examples: Elastin, keratin, collagen

Contractile
Examples: Actin and myosin

Nutrient
Examples: Casein, and whey

Regulatory
Examples: Hormones (like insulin, glucagon) and their receptors

Defence
Examples: Antibodies

Transport
Examples: Haemoglobin and hemocyanin

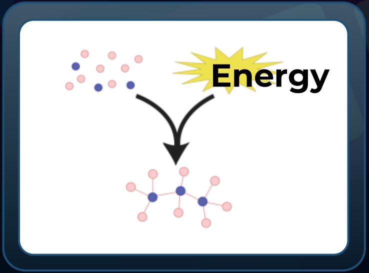
Catalytic
Examples: Enzymes such as trypsin

Note:
Most abundant animal protein: Collagen
Most abundant protein in the biosphere: RuBisCO

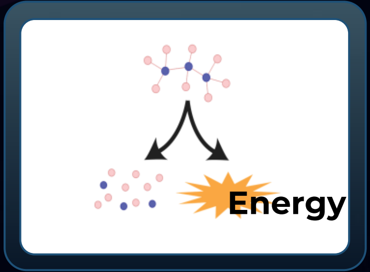
Metabolism

Metabolism: All the chemical reactions occurring in a living organism

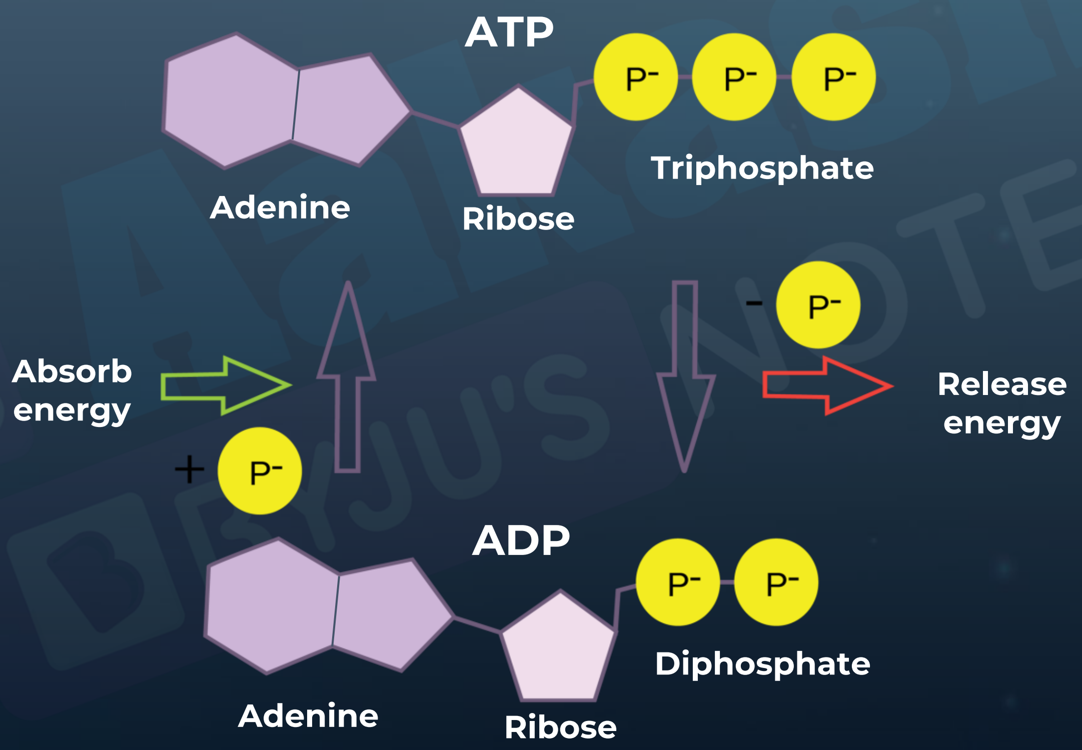
Anabolism
- **Biosynthetic** pathways
- **Endothermic**



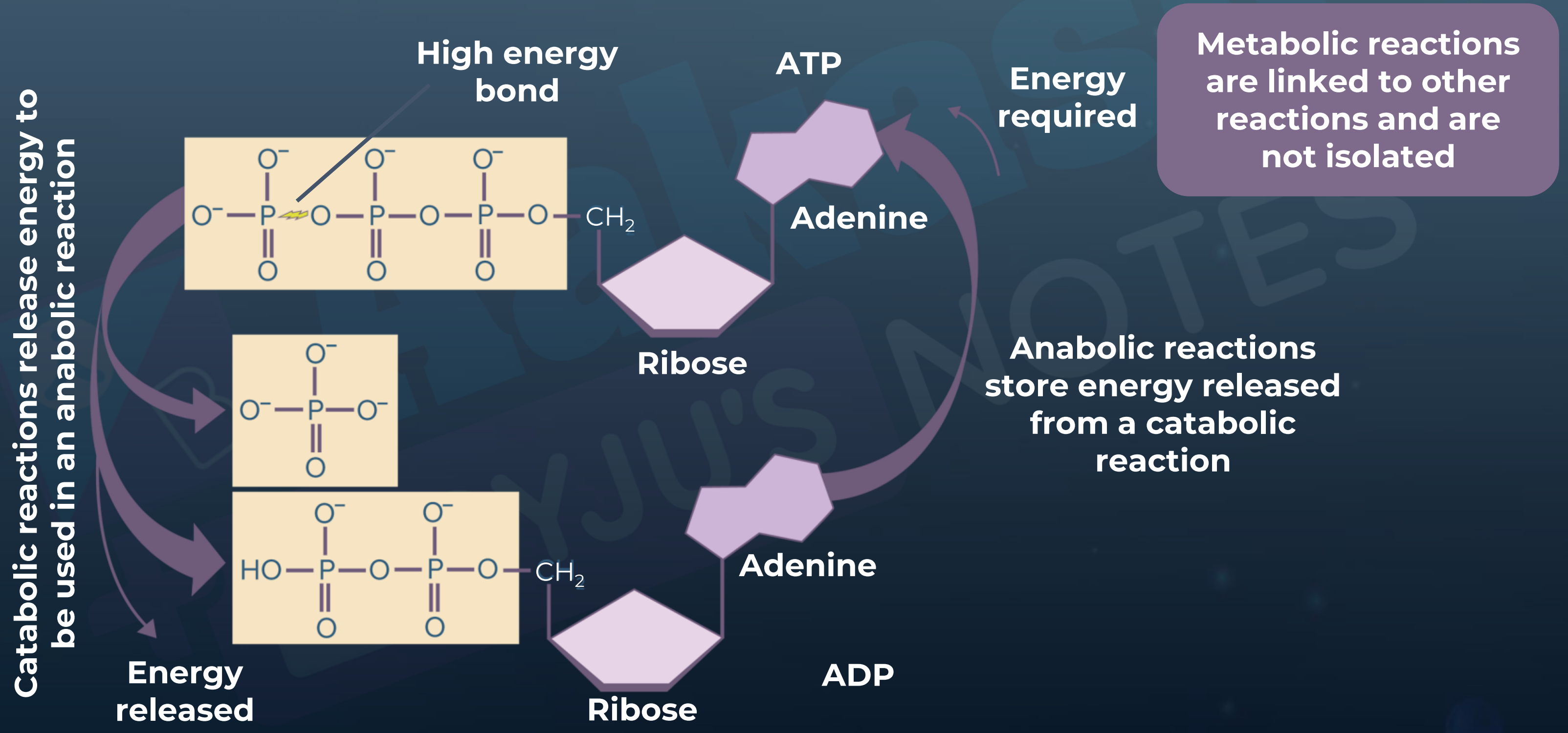
Catabolism
- **Breakdown or degradation** pathway
- **Exothermic**



ATP - Energy Currency

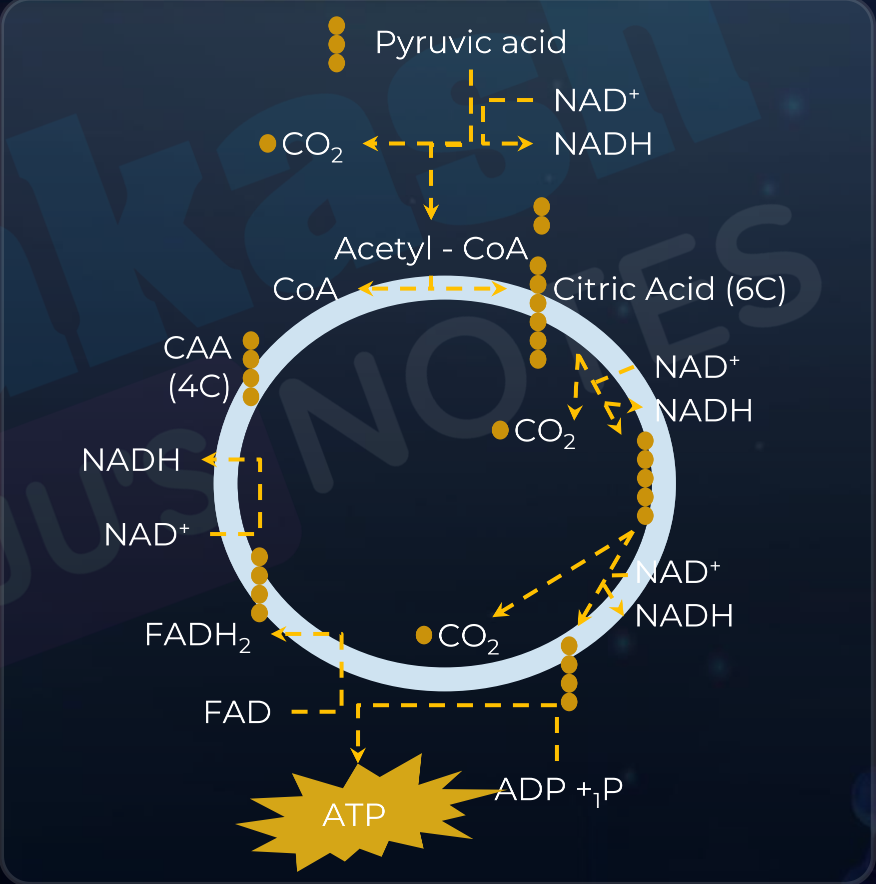


Metabolic Pathways



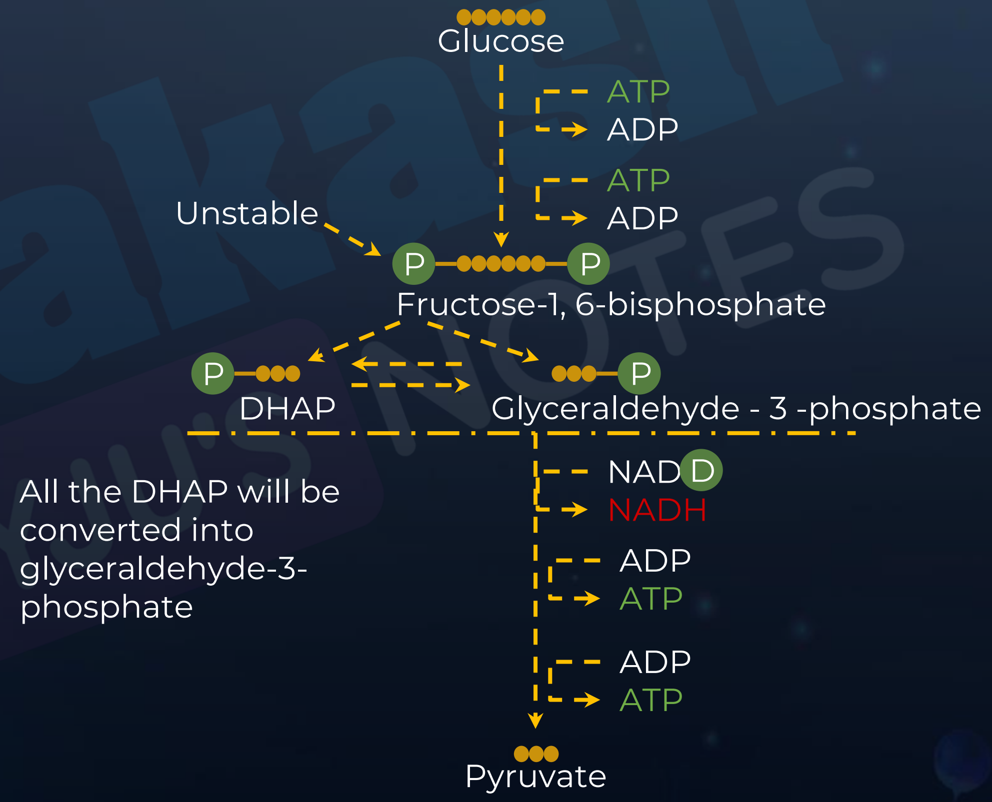
Metabolic Pathways

Metabolic pathways can be cyclic
(E.g., Krebs cycle)



Metabolic Pathways

Metabolic pathways can be linear (E.g., Glycolysis)



Living State

- Living organisms exists in **steady state**
- Living organisms = **non-equilibrium steady state to be able to perform work**
- Biomolecules in steady state = **Metabolic flux**
- Metabolic flux : **rate of turnover of molecules through a metabolic pathway**

Enzymes

- Enzymes are usually **proteins** and act as **catalysts** (speed up a process or reaction without getting consumed) also known as **biocatalysts.**
- Exceptions of enzyme (non-proteinaceous in nature)
  - Ribozymes (RNA enzyme)
  - Ribonuclease P (RNA enzyme)
- There are two types of catalysts: organic and inorganic.
- They are **unused in reaction.**
- They are **highly specific in action** due to the presence of **active site** (Crevice or pocket for binding the substrate).
- Enzymes isolated from thermophilic organisms shows **thermal stability** even at 80-90^{0}C.

Organic catalysts (Enzymes)	Inorganic catalysts
Proteins	Metal ions or complex molecules
Most of them are damaged at high temperatures (>40 degree celsius)	Work efficiently at high temperatures and pressures
Example: Lipases, chymosin, etc.	Example: Platinum, palladium, etc.

Enzymes

Made up entirely of amino acids. For e.g., "pepsin"

Made up of amino acids and a prosthetic group

Enzymes
- Simple
- Conjugated
  - Apoenzyme (Protein part) + Cofactor (Non-protein part)

Apoenzyme (Protein part)	Cofactor (Non-protein part)
Biologically inactive	Activates catalytic activity

Holoenzyme = Apoenzyme + Cofactor

The **complete, biologically active** conjugated enzyme where both apoenzyme and cofactor are present is known as **holoenzyme**.

- A coenzyme or metal ion that is very tightly (covalently or noncovalently) bound to the enzyme protein is called a **prosthetic group.**
- It is a type of the cofactor.
- For example, in peroxidase and catalase, which catalyse 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.**

Enzymes

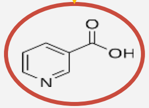
Types of Cofactor (Non-protein part)

Prosthetic group

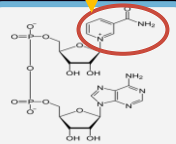
- Organic compound, tightly bound with apoenzyme
- For e.g., **Haem** (present in peroxidase, it catalyses hydrogen peroxide)

Coenzymes (Organic)

- Organic compound, associated with apoenzyme for a short period of time
- For e.g., NAD and NADP, contain vitamin **niacin**



Niacin



NAD^+

Metal ion

- For e.g.; enzyme named **carboxypeptidase is associated with zinc**
- Form coordination bonds
    - with side chains at the active site
    - one or more coordination bonds with the substrate

Zn tightly bound carboxypeptidase

Coordination bond

Chemical Reaction

Chemical reaction: Process of formation or breaking of bonds

Reactant 1 (Substrate 1) + Reactant 2 (Substrate 2) → Product (P)

- **Rate of reaction:** The amount of **product formed per unit time**
- **Catalysed reactions proceed at rates vastly higher than that of uncatalysed one**

Without catalyst:

CO_2 + H_2O → H_2CO_3-

200 molecules

With catalyst:

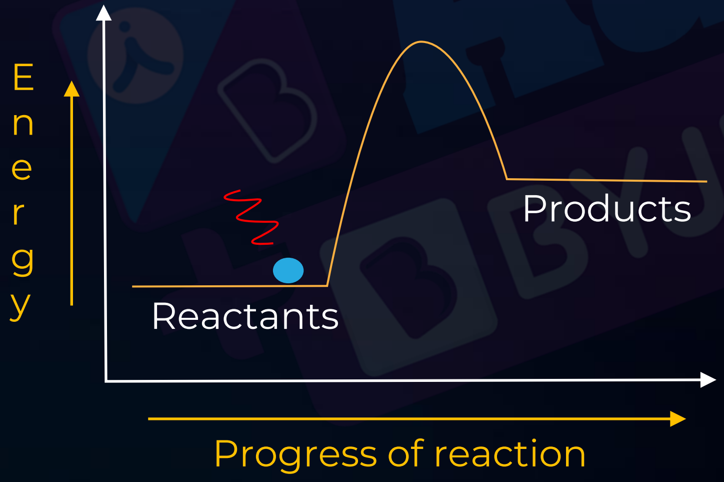
CO_2 + H_2O ⇌ (carbonic anhydrase) H_2CO_3-

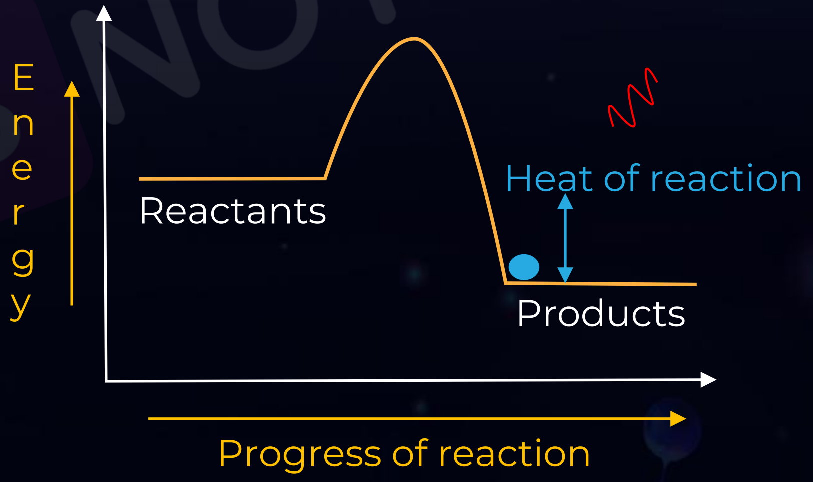
2,160,000,000 molecules

Chemical Reaction

Chemical Reaction

Endothermic	Exothermic
Energy (heat) needed	Energy (heat) released





Enzymes

Mechanism of action

Substrate (S) + Enzyme (E)

↓

E-S Complex

↓

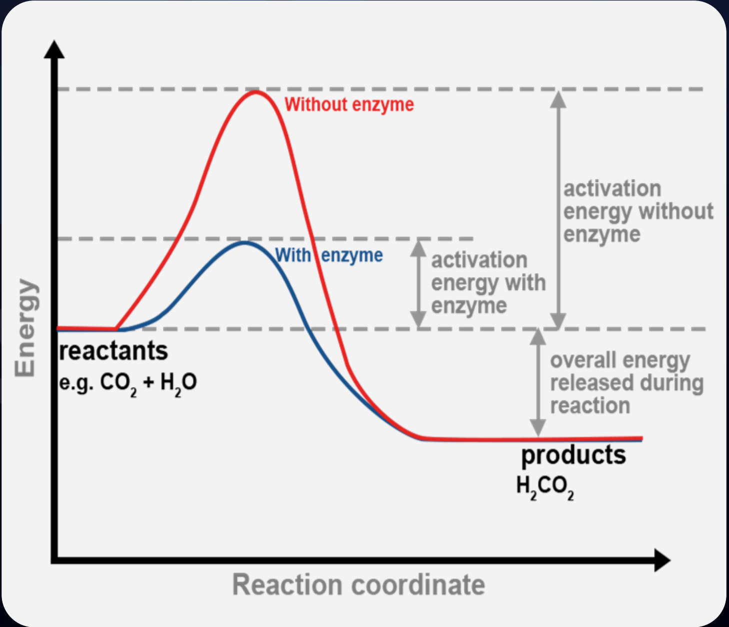
E-P Complex

↓

Enzyme (E) + Product (P)

Activation energy:

The difference in free energy between the transition state and that of reactant



Enzymes increase the rate of reaction by:

- **Decreasing** the **activation energy**
- **Forming weak bonds** with the substrate

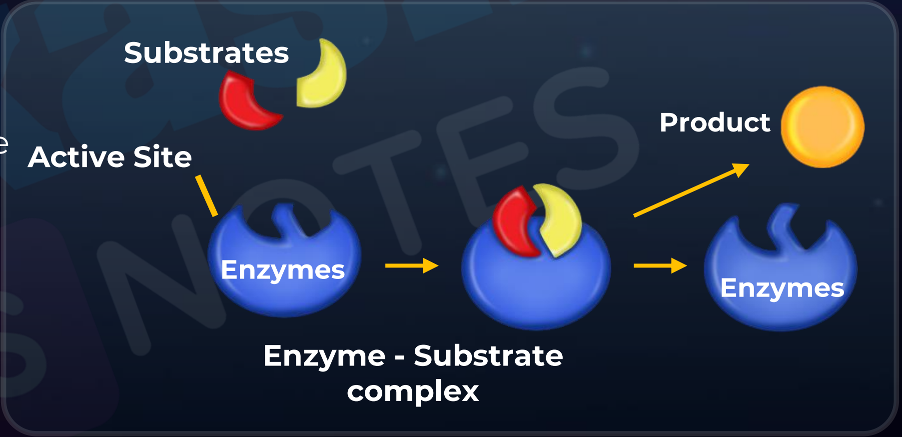
Enzymes

Enzyme-Substrate complex:

Two important model have been proposed to describe the enzyme and substrate binding.

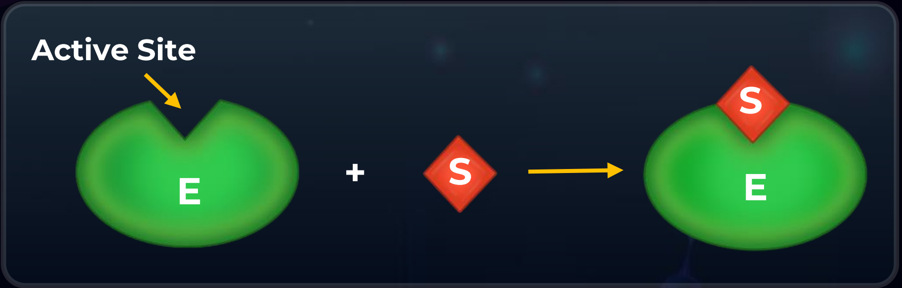
1. Lock and key model:

- Proposed by **Fischer**
- Enzymes have an active site at which the substrate binds.
- The binding of substrate and active site can be compared to a **lock and key mechanism**.
- Every active site has a specific substrate which can bind to it.



2. Induced fit model:

- Proposed by **Koshland**
- The enzyme changes shape on substrate binding.
- Enzymes have two groups
  - Buttressing (for support)
  - Catalytic (for catalysis)



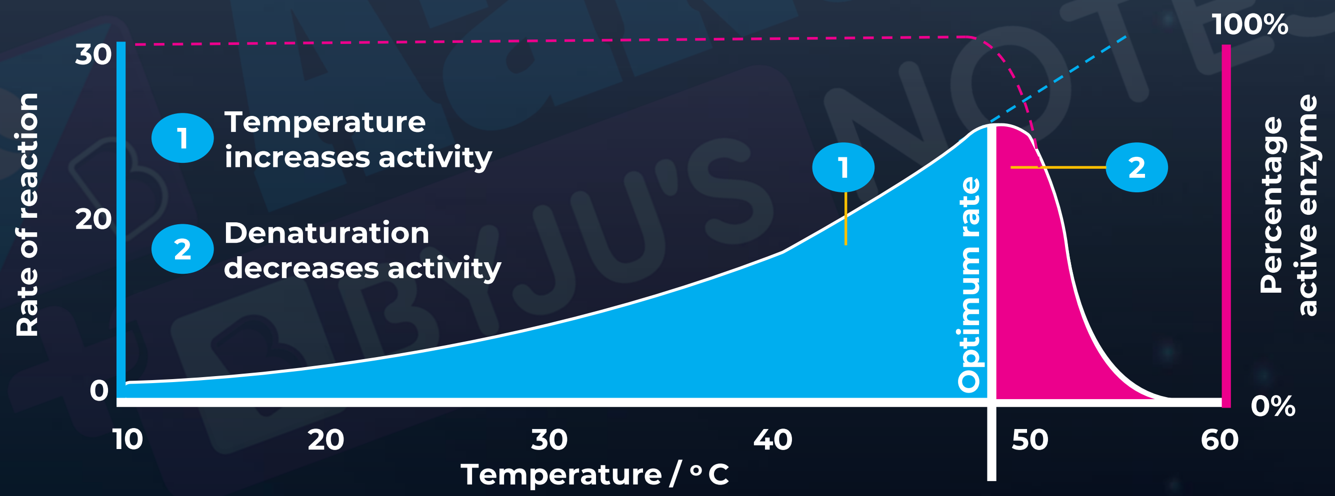
Factors Affecting Enzyme Activity

Temperature

- High temperature : **Denaturation**
- Low temperature : **Temporary inactive state**

pH

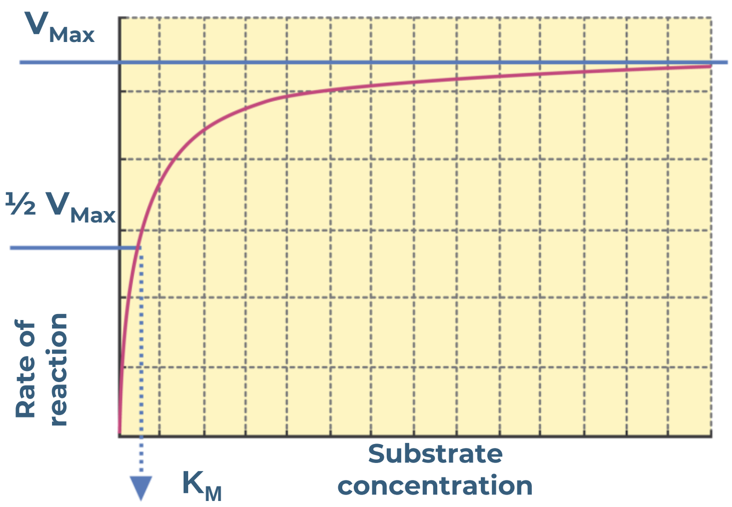
- Enzymes are **sensitive to pH**
- Rise or fall in pH : **reduces enzyme activity**
- Optimum pH : **maximum action**



Factors Affecting Enzyme Activity

Substrate concentration

- Low substrate concentration: **Low enzyme activity**
- Optimum substrate concentration: **Maximum enzyme activity**
- Higher substrate concentration: **No change in maximum activity**
- **K_M (Michaelis constant)** : Indicates the substrate concentration at which the chemical reaction catalysed by an enzyme attains half its maximum velocity (V_{max})



Factors Affecting Enzyme Activity

Inhibitors : Chemicals that shut off enzyme activity

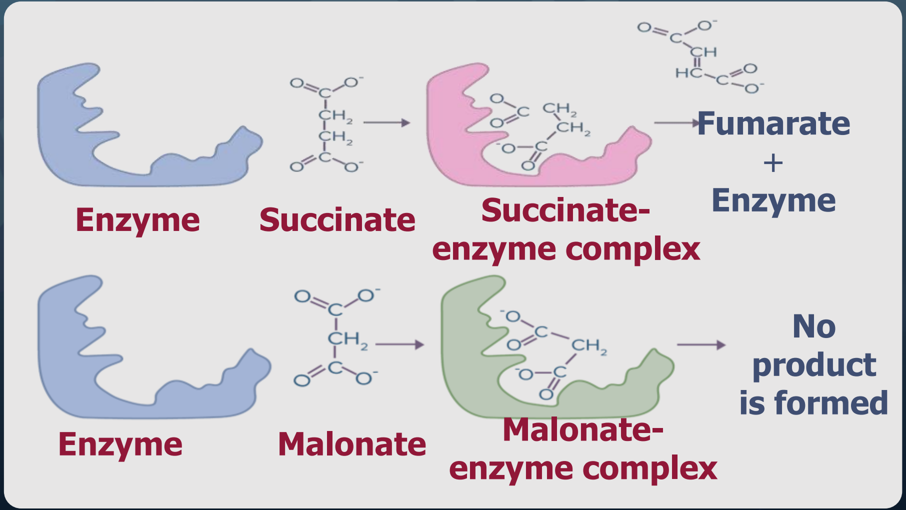
Inhibitors

Non-competitive	Competitive	Allosteric modulation
Changes the shape of active site such that substrate is not able to bind	Resembles the substrate Competes with substrate for active site	Binds to the enzyme at sites other than active site Low molecular weight substance

Inhibitors

Competitive inhibitors

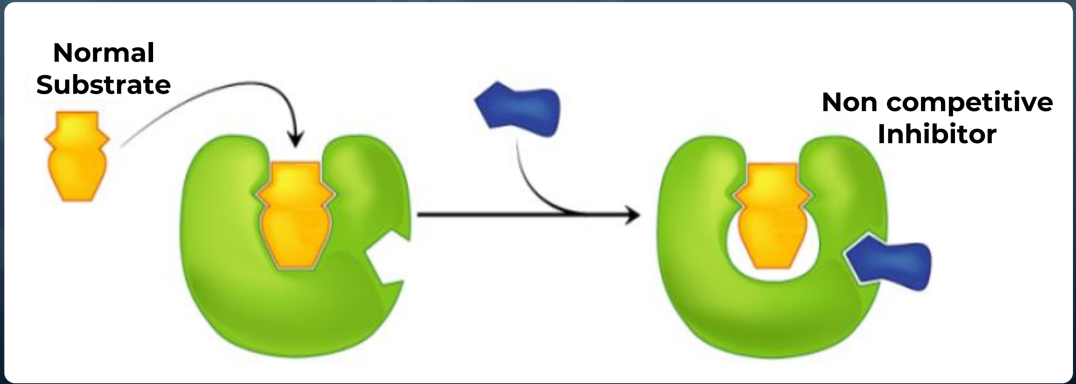
- **Effect on V_{max}:** Decreases
- **Effect on K_m:** Increases for a given substrate
- In the presence of competitive inhibitor more substrate is needed to achieve 1/2 V_{max}
- **Examples:**
  - Max inhibition of alcohol dehydrogenase by ethanol in methanol poisoning
  - Sulpha drugs for folic acid synthesis in bacteria
  - Inhibition of succinic dehydrogenase by malonate and oxaloacetate.



Inhibitors

Non-competitive inhibitors

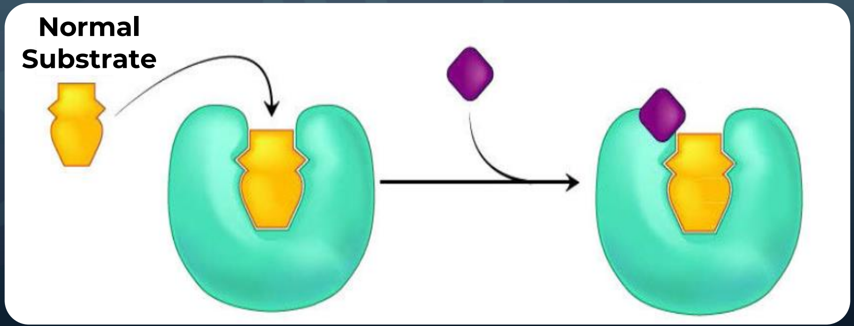
- **Effect on V_{max}**: Decreases
- **Effect on K_m**: Remain same
- Increased substrate levels will not be able to reverse the inhibitor's action since the inhibitor is not in direct competition with the substrate
- **Examples:** Cyanide kills an animal by inhibiting cytochrome oxidase



Inhibitors

Allosteric modulation

- Also known as **feedback inhibition**
- After binding, they can **increase or decrease** the enzyme action
- **Examples:**
  - Allosteric inhibition of hexokinase by glucose 6- phosphate
  - Phosphofructokinase activated by ADP and inhibited by ATP
  - Inhibition of threonine deaminase by isoleucine



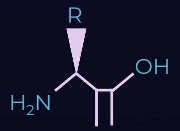
Classification and Nomenclature of Enzymes

Enzyme	Function	Example
Oxidoreductase	Catalyses oxidation-reduction reactions $A_{red} + B_{ox} \rightarrow A_{ox} + B_{red}$	Dehydrogenase
Transferases	Catalyses transfer of groups between molecules $A\text{-}B + C \rightarrow A + B\text{-}C$	Transaminase
Hydrolases	Catalyses breaking of bonds by adding water $A\text{-}B + H_2O \rightarrow A\text{-}H + B\text{-}OH$	Proteases
Lyases	Catalyses breaking of bonds without using water $A{=}B + HX \rightarrow A\text{-}X + B\text{-}H$	Aldolase
Isomerases	Catalyses the switch between isomers $AB \rightarrow BA$	Isomerase
Ligases	Catalyses joining of molecules by forming bonds $A + B + ATP \rightarrow A\text{-}B + ADP$	Ligase

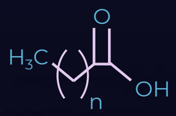
Summary

Metabolites

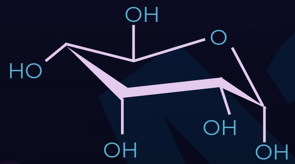
Primary metabolites



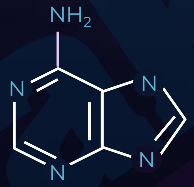
Amino acids → Proteins



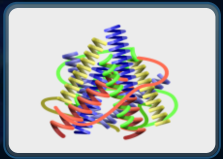
Fatty acids → Lipids

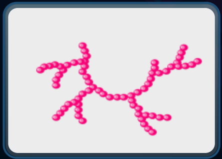


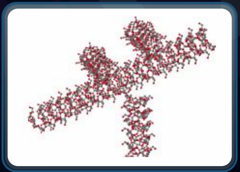
Mono saccharides → Complex carbohydrate

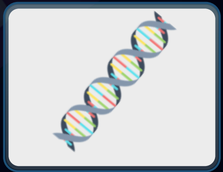


Nucleobases → Nucleotides → Nucleic acids









Secondary metabolites

Pigments	Carotenoids, Anthocyanins, etc.
Alkaloids	Morphine, Codeine, etc
Terpenoids	Monoterpenes, Diterpenes, etc.
Essential oils	Lemongrass oil, etc,
Toxins	Abrin, Ricin
Lectins	Concanavalin A
Drugs	Vinblastine, Curcumin, etc
Polymeric substances	Rubber, gums, cellulose

Summary

Types of carbohydrates

- Monosaccharides
- Polysaccharides
- Derived monosaccharides
- Derived monosaccharides
- Oligosaccharides

Classification of lipids

- Simple
  - Neutral/ True fats
  - Waxes
- Compound
  - Phospholipids
  - Glycolipids
  - Lipoprotein
  - Chromolipids
- Derived

Summary

Amino acids

Amino acids

Essential

Obtained through diet; body does not synthesise

Non-essential

Synthesised by the body

Semi-essential amino acid:

Synthesised very slowly by human beings.

E.g., arginine and histidine

Essential	Non essential
Phenylalanine	Proline
Valine	Alanine
Threonine	Glycine
Tryptophan	Glutamate
Isoleucine	Cysteine
Methionine	Serine
Lysine	

Summary

Nucleic acids

Nucleic acids

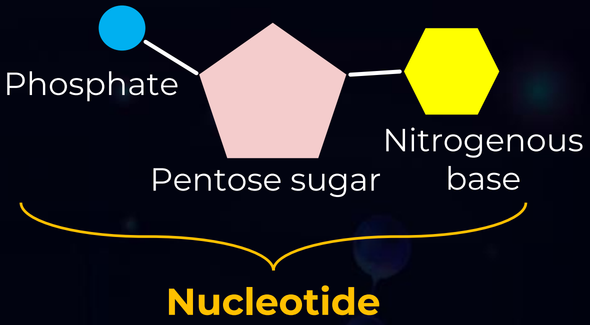
- **DNA** – Deoxyribonucleic acid

- **RNA** – Ribonucleic acid

Nucleotide – Monomers of nucleic acid

- **Pentose sugar**
- **Nitrogenous base**
- **Phosphoric acid**

Pentose sugar + Nitrogenous base → **Nucleoside**



Summary

Double helix model

- Antiparallel strands
- 5’ end - 5th carbon of pentose sugar is free
- 3’ end - 3rd carbon of pentose sugar is free
- Each base pair strand turns 36 degree
- Full turn involves 10 base pairs

Backbone of DNA

Sugar – phosphate backbone

- Right-handed coiling
- Helix diameter 2 nm
- Helical rise 0.34 nm
- Helical pitch 3.4 nm

Nitrogen bases facing inside

- Purines
- Pyrimidines

Complementary base pairing

- A = T
- C ≡ G

Hydrogen bonds

Summary

Forms of DNA (with right handed coiling)

B - form
- Usual DNA
- 10 base pairs per turn

A - form
- 11 base pairs per turn
- Not perpendicular to the axis but slightly tilted

C - form
- Like B-form
- 9 base pairs per turn

D - form
- Like B-form
- 8 base pairs per turn

Forms of RNA

- Messenger (m- RNA)
- Ribosomal (r- RNA)
- Transfer/ soluble (s- RNA, t- RNA)

Summary

Types of proteins

Based on shape and structure

- Fibrous
- Globular

Based on function

- Structural
- Contractile
- Nutrient
- Regulatory
- Defence
- Transport
- Catalytic

Summary

Inhibitors

Non-competitive	Competitive	Allosteric modulation
Changes the shape of active site such that substrate is not able to bind	Resembles the substrate Competes with substrate for active site	Binds to the enzyme at sites other than active site Low molecular weight substance