BIOCHEMISTRY

UNIT 1 NOTES

- BIOMOLECULES
- BIOENERGETICS

Rx Pharma Education

BIOCHEMISTRY

- The term Biochemistry is made up of two words (Bio + Chemistry).
- In which the term Bio → refers to 'living beings'
  and Chemistry → 'Chemical reactions'

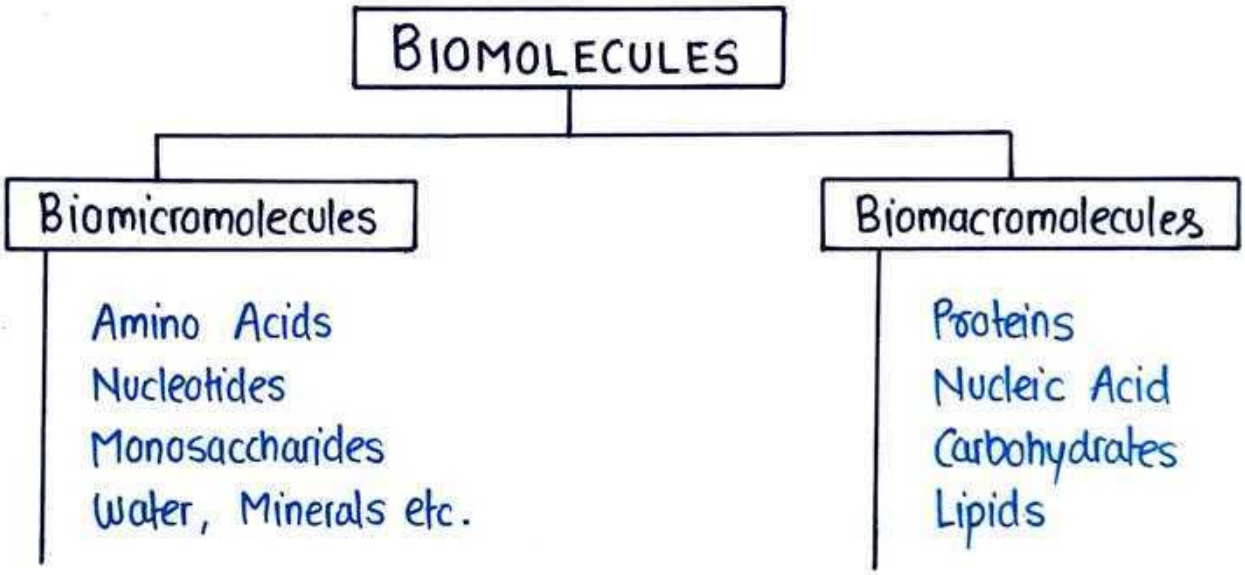
- Hence, we can simply say the study of all the chemical reactions and processes occuring inside the living body is known as Biochemistry.
- The term biochemistry was first introduced by 'Carl Alexander Neuberg.

Importance of Biochemistry

- To understand all the activities occurs inside our body.
- To analyze our body.
- To know how living beings are made, how life began, how they work and what chemicals our body have.
- To diagnose the disease.

BIOMOLECULES

- Biomolecules are the molecules that occurs naturally inside the living organism.
- Generally most of the biomolecules contains Carbon as major element.
- Other than carbon, biomolecules generally contain H, N, O, P, S.



Biomicromolecules

- They are the smallest molecules.
- They are the building blocks of macromolecules.
- They are also known as 'Monomers'

Biomacromolecules

- They are large molecules.
- They are made from many smaller building blocks.

Types of Biomolecules (Acc. to Syllabus)

There are mainly 4 major biomolecules occurs inside our body.

① Carbohydrates.
② Lipids
③ Proteins
④ Nucleic Acid

BIOMOLECULES	BUILDING BLOCKS
Carbohydrates	Simple Sugars
Lipids	Fatty Acids
Proteins	Amino Acids
Nucleic Acid	Nucleotides

CARBOHYDRATES

- Carbohydrates are the most abundant naturally occuring organic compounds or molecules in nature.
- Carbohydrates are simply defined as the biomolecules containing Carbon, hydrogen and oxygen in the ratio of 1:2:1.
- They are also known as 'Hydrates of Carbon'.
- Since, most of the carbohydrates are sweet in taste, hence they are also known as 'Sugar' i.e., sucrose, lactose.
- Carbohydrates are also called saccharides.

General Formula : $C_n(H_2O)_n$

- Chemically, carbohydrates are defined as 'optically active polyhydroxy aldehydes or ketones or the compounds which give such units on hydrolysis'.

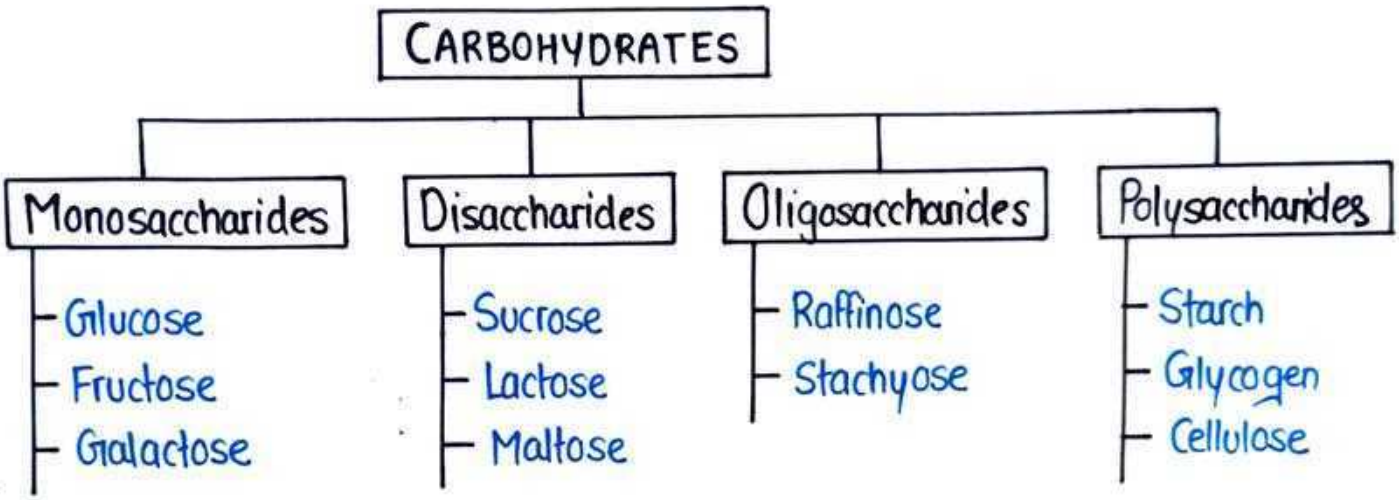
Functions of Carbohydrates

- They are the most abundant source of energy.
- They are also used as stored form of energy (glycogen).
- Sugars like ribose and deoxyribose forms genetic material DNA and RNA.
- They are used as sugar in our home. (sucrose)
- They serves as important constituents in connective tissues.

Classification of Carbohydrates

Carbohydrates are generally classified into 4 categories :

- Monosaccharides
- Disaccharides
- Oligosaccharides
- Polysaccharides



MONOSACCHARIDES

- Monosaccharides are the simple sugars or simplest form of carbohydrates.
- They cannot be further hydrolysed.
- About 20 monosaccharides are known to occur in nature.
- They are generally sweet in taste.
- Examples : Glucose, Fructose, Galactose.

Classification of Monosaccharides

Monosaccharides can be classified on the basis of two categories :

- Based on no of Carbon atoms
- Based on Functional Groups

Based on no of carbon atoms

Trioses : $C_3H_6O_3$ (Glyceraldehyde)

Tetroses : $C_4H_8O_4$ (Erythrose)

Pentoses : $C_5H_{10}O_5$ (Ribulose)

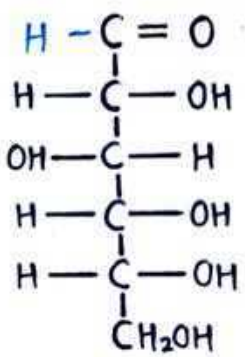
Hexoses : $C_6H_{12}O_6$ (Glucose)

Heptoses : $C_7H_{14}O_7$ (Glucoheptose)

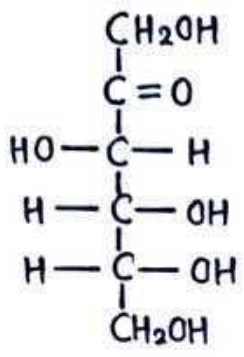
Based on no of functional group

On the basis of functional group they are of two types :

- Aldoses (Aldehyde Group)
- ketoses (ketone Group)



Aldoses



Ketoses

DISACCHARIDES

- Two monosaccharides forms disaccharides or we can say disaccharides gives two monosaccharides on hydrolysis.
- In disaccharides, the 2 monosaccharides units are held together by glycosidic bond.
- They are crystalline, water soluble ~~in~~ ~~taste~~ and sweet in taste.
- Example : Sucrose, Lactose, Maltose etc.

OLIGOSACCHARIDES

- Oligosaccharides contains 2-10 monosaccharide units.
- They are less sweet and less water soluble.
- Example : Raffinose, Stachyose etc.

POLYSACCHARIDES

- Polysaccharides contains several (more than 10) repeating monosaccharide units.
- They contain hundreds or thousands of monosaccharide units.
- They are generally not sweet in taste.
- They are also called Glycans.
- Example : Starch, Glycogen etc.

LIPIDS

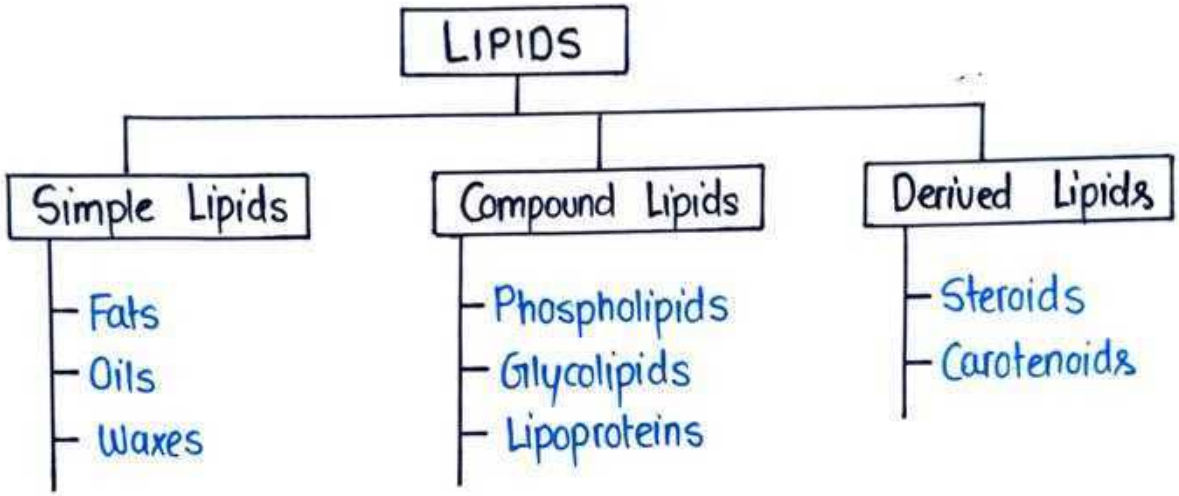
- The word Lipid is derived from a greek word 'lipos' which means Fat.
- Lipids can be defined as organic substances that are relatively insoluble in water but soluble in organic solvents (Such as ether, chloroform or benzene).
- They are hydrophobic in nature.
- Unlike the proteins, nucleic acid and carbohydrates, Lipids are not polymer.
- Example : Fats and Oils

Functions of Lipids

- They are used as stored form of energy.
- Cell membrane or plasma membrane is made up of lipids (phospholipids)
- They are the precursor of harmones (e.g. testosterone, progestron, estrogen).
- They provide metabolic fuel to body.
- They helps in the absorbtion of fat soluble vitamins.
- They are used as taste enhancer.

Classification of Lipids

① Simple Lipids
② Compound Lipids
③ Derived Lipids



SIMPLE LIPIDS

- They are the esters of fatty acids and alcohol.
- The simple lipid includes, fat, waxes and oils.
- Fats & Oils : Esters of fatty acids & glycerols.
- Waxes : Ester of fatty acids & alcohols other than glycerol.

DERIVED LIPIDS

- Derived lipids are the substances that are derived from simple & compound lipids by hydrolysis
- They do not resembles fat structurally but have fat like properties.
- They include steroids, carotenoids etc.

Compound Lipids

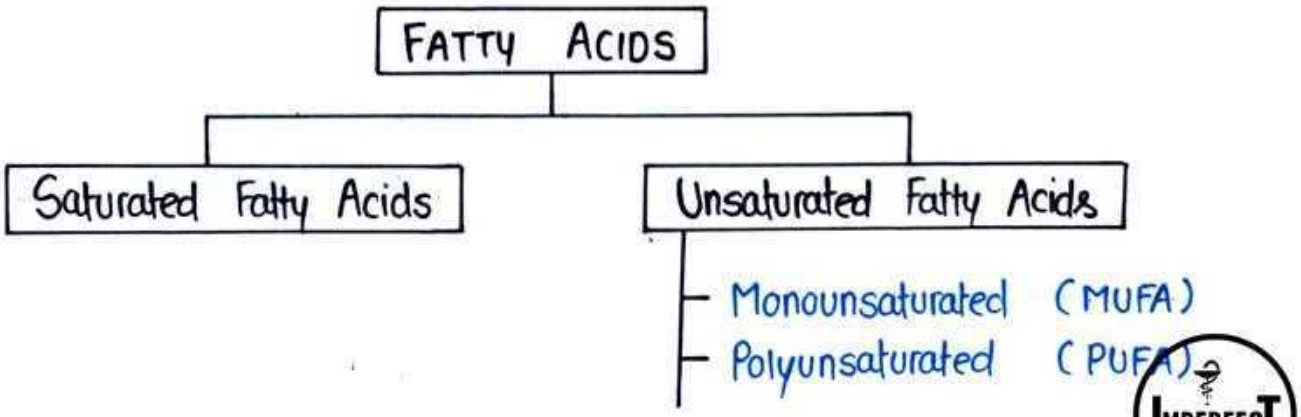
- They are the esters of fatty acids and alcohols containing additional groups such as phosphate, sugars etc.
- They mainly include Phospholipids, Glycolipids etc.
- Phospholipids : Contains phosphoric acid
- Glycolipids : Contains carbohydrates

Fatty Acids

- The long chain Hydrocarbons which contains carboxylic acid group at the end are known as fatty acids.
- Fatty acids combines with alcohol (glycerol) to form Fats & Oils.
- We can say that Fatty acids are the building blocks of lipids.

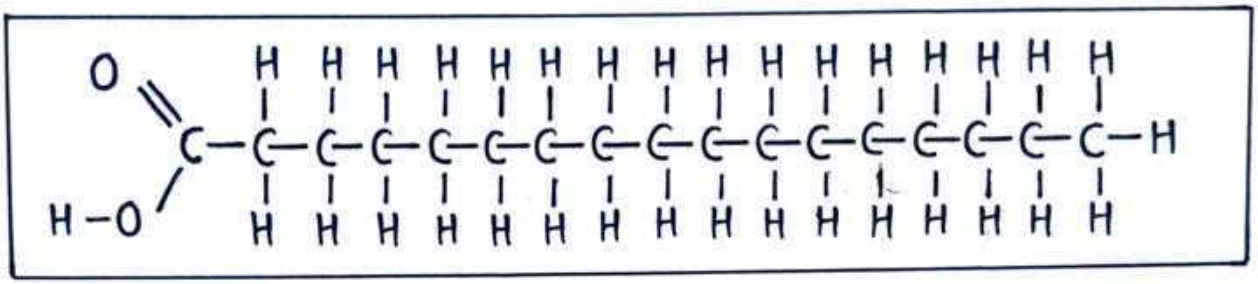
Classification of Fatty Acids.

They can be classified as follows :



SATURATED FA

- These fatty acids do not contain any double bond in the chain.
- They have higher melting points.
- They are solid at room temperature.
- Examples : Lauric Acid, Palmitic Acid etc.

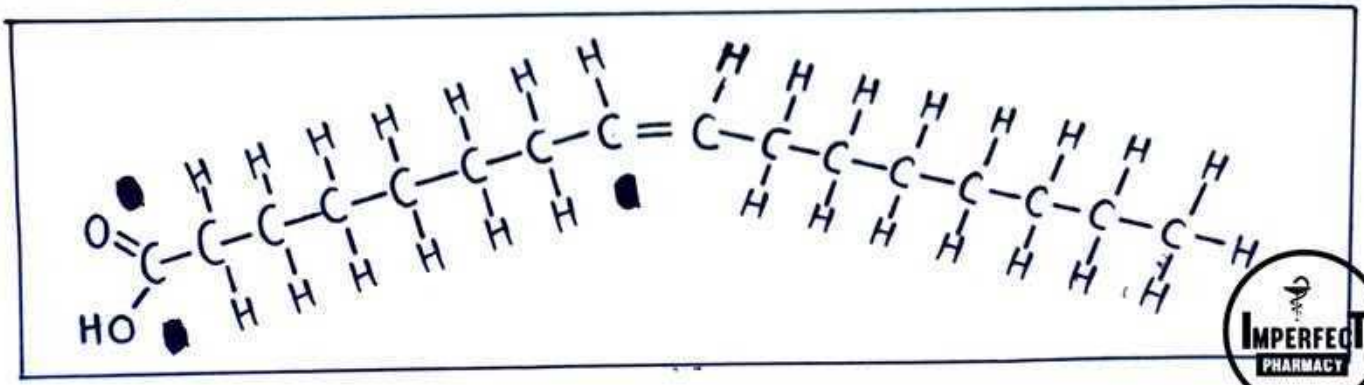


UNSATURATED FA

- These fatty acids contain one or more double bond in the hydrocarbon chain.
- They are liquid at room temperature
- They have low melting point.
- Example : Oleic Acid

Types of Unsaturated Fatty Acids

- Monounsaturated Fatty Acids (MUFA)
- Polyunsaturated Fatty Acids (PUFA)



NUCLEIC ACID

- Nucleic acid are naturally occurring primary information carrying biomolecules which forms the genetic material.
- Nucleic acid is made from nucleotides.
- Nucleotides are the monomers or building blocks of nucleic acid.
- Nucleic acid is the polymer of nucleotides or it is also known as Polynucleotides.

- Since, it is found in the nucleus (nuclei) of the cell and acidic in nature, hence it is known as Nucleic Acid.

Types of Nucleic Acid

① DNA (Deoxyribonucleic Acid)
② RNA (Ribonucleic Acid)

NUCLEOTIDES

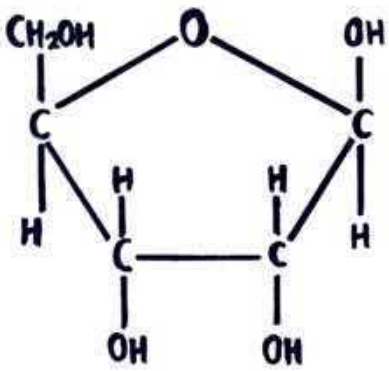
- Nucleotides are the monomeric unit of nucleic acid.
- A nucleotide is composed of 3 units.

① A Pentose Sugar
② Phosphoric Acid
③ A Nitrogenous Base

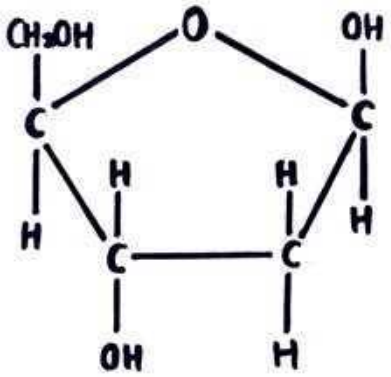
PENTOSE SUGAR

- It is a component of nucleotide.
- It named pentose because it contains 5 carbons.
- Pentose sugar is nothing but a monosaccharide with 5 carbon atoms.
- It is of two types.

① Ribose
② Deoxyribose



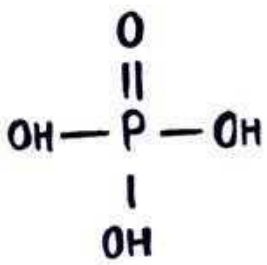
RIBOSE



DEOXYRIBOSE

PHOSPHORIC ACID

- It is also a component of nucleotide.
- Molecular formula = H_3PO_4
- It contains three hydroxyl group and one oxygen atom linked with a phosphorus atom.

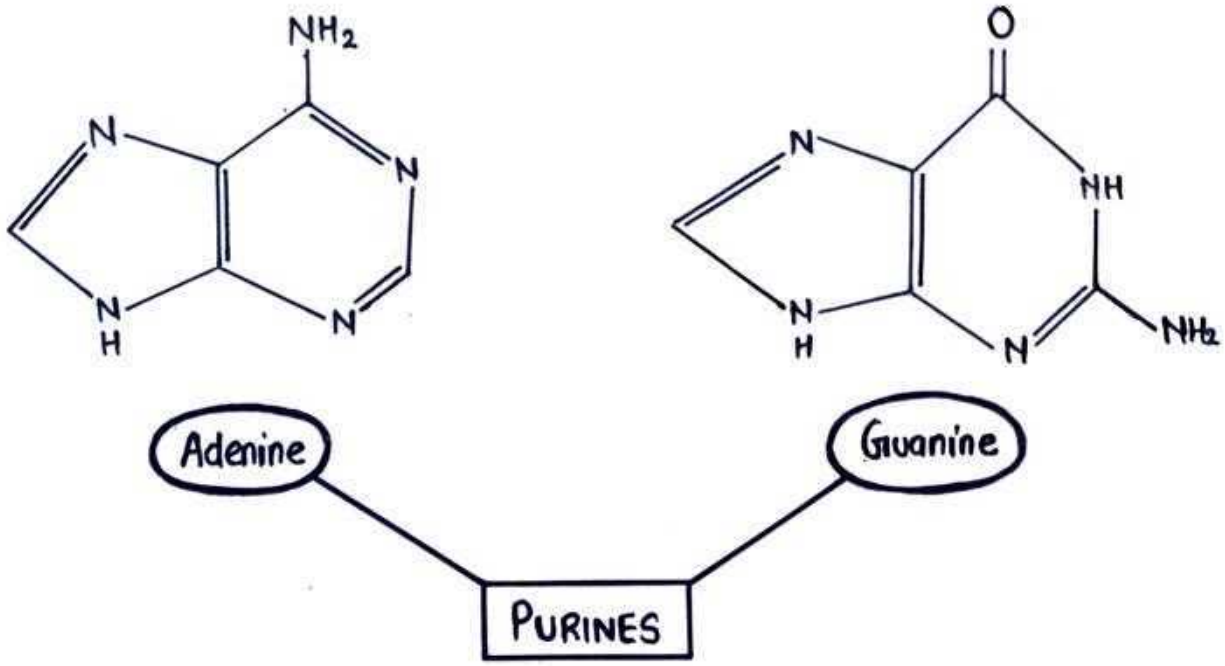


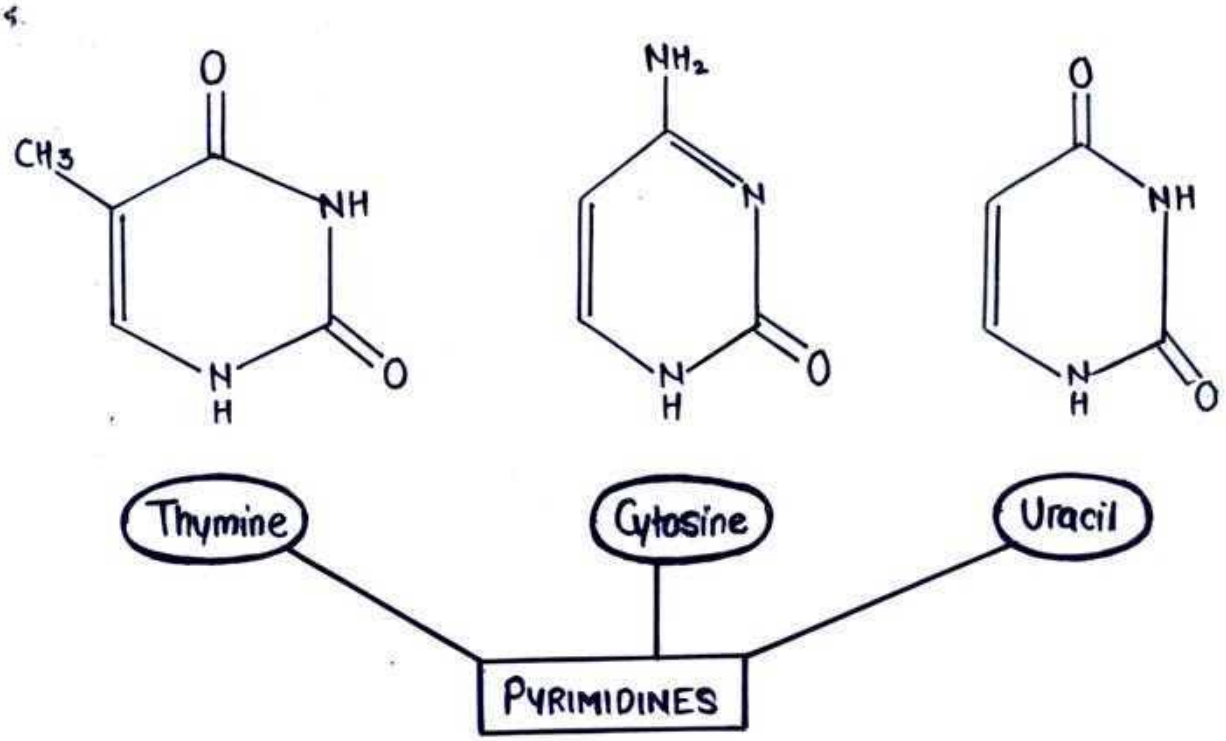
NITROGENOUS BASE

- Nitrogenous base is the component of nucleotide containing nitrogen.
- There are two types of nitrogenous base :

① PURINES (Adenine, Guanine)

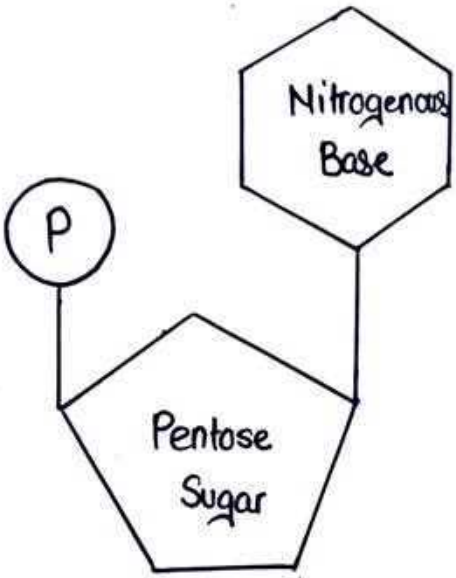
② PYRIMIDINES (Urasil, Thymine and Cytosine)



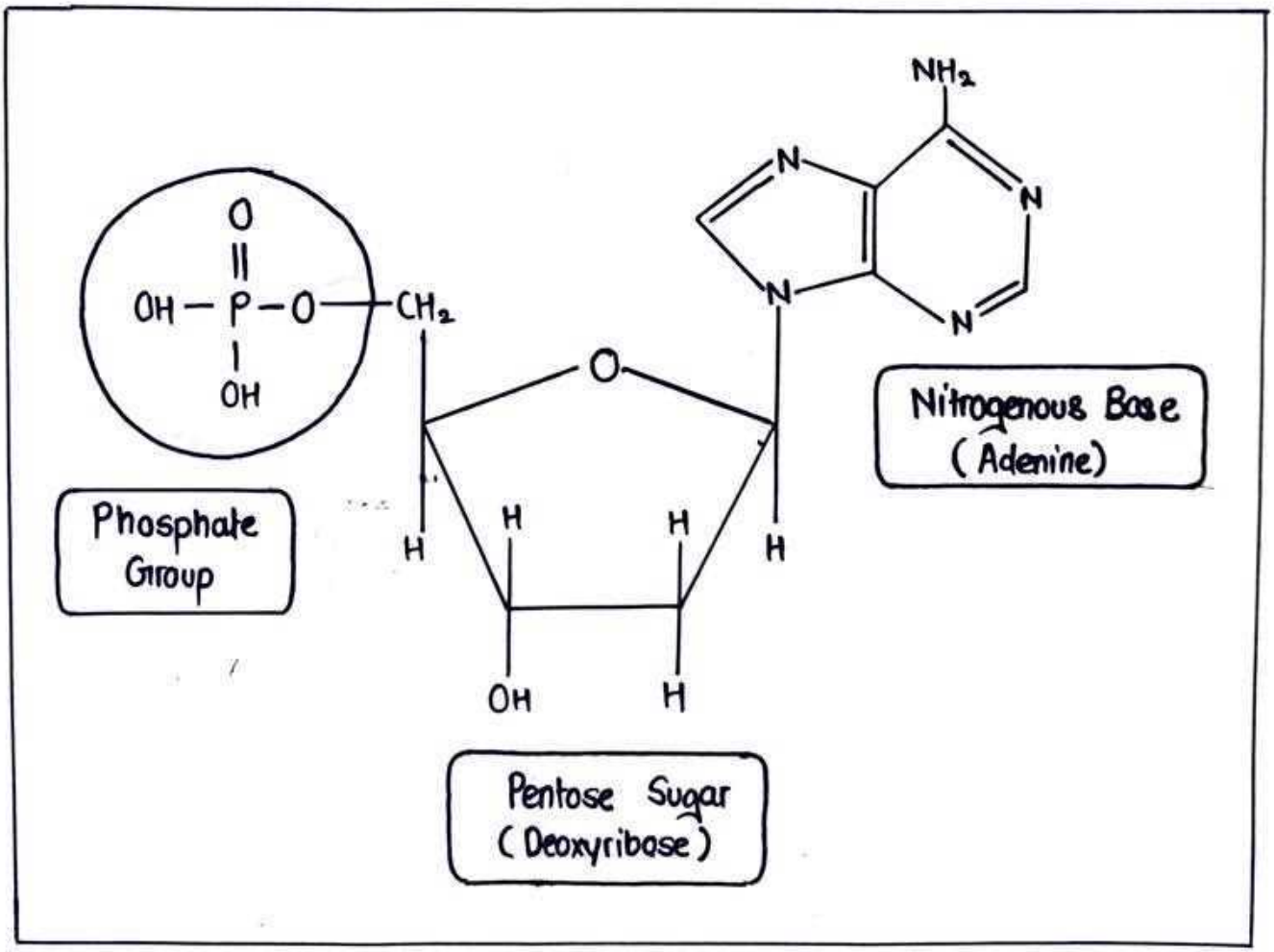


Stoucture of Nucleotide

A nucleotide is made from combination of Pentose sugar, Nitrogenous base and phosphoric acid.



GIENERAL STRUCTURE



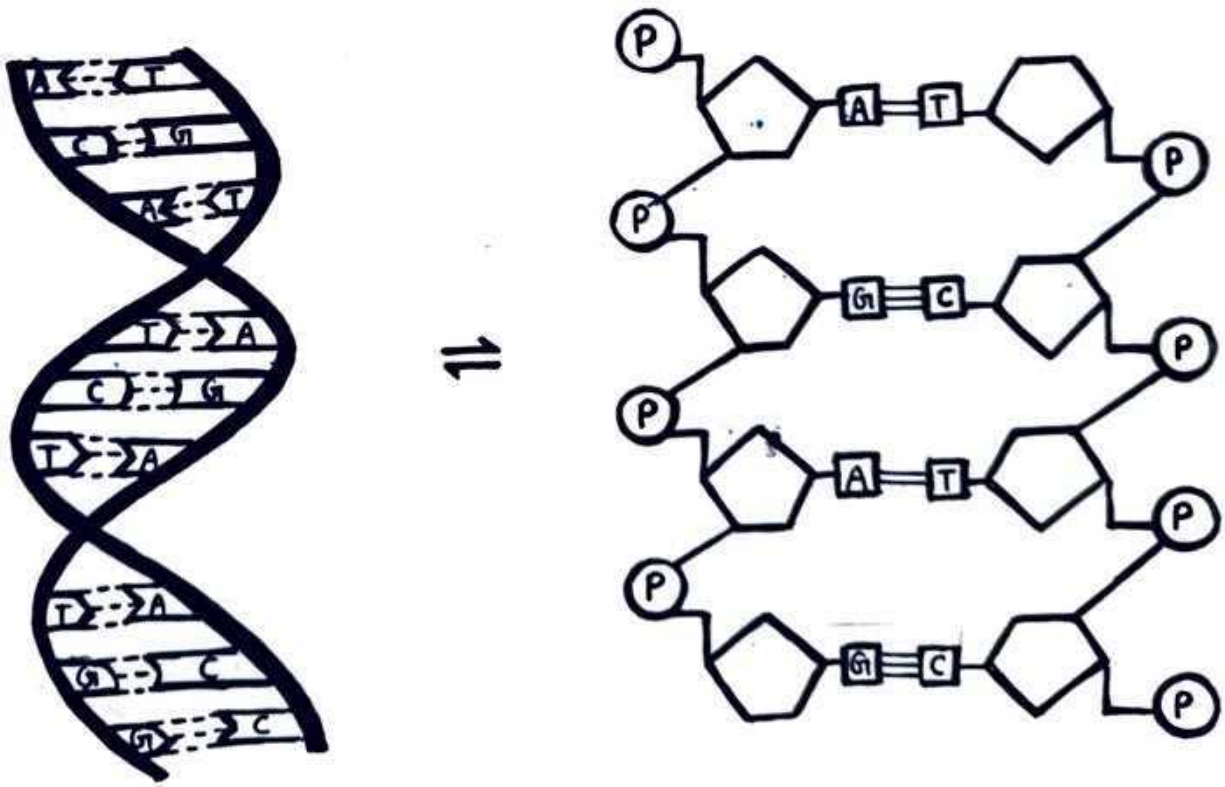
NUCLEOTIDE

NOTE : Pentose Sugar + Nitrogenous Base + Phosphate Group = Nucleotide.
Pentose Sugar + Nitrogenous Base = Nucleoside.

Or, we can say Nucleotide = Nucleoside + Phosphate Group.

DNA

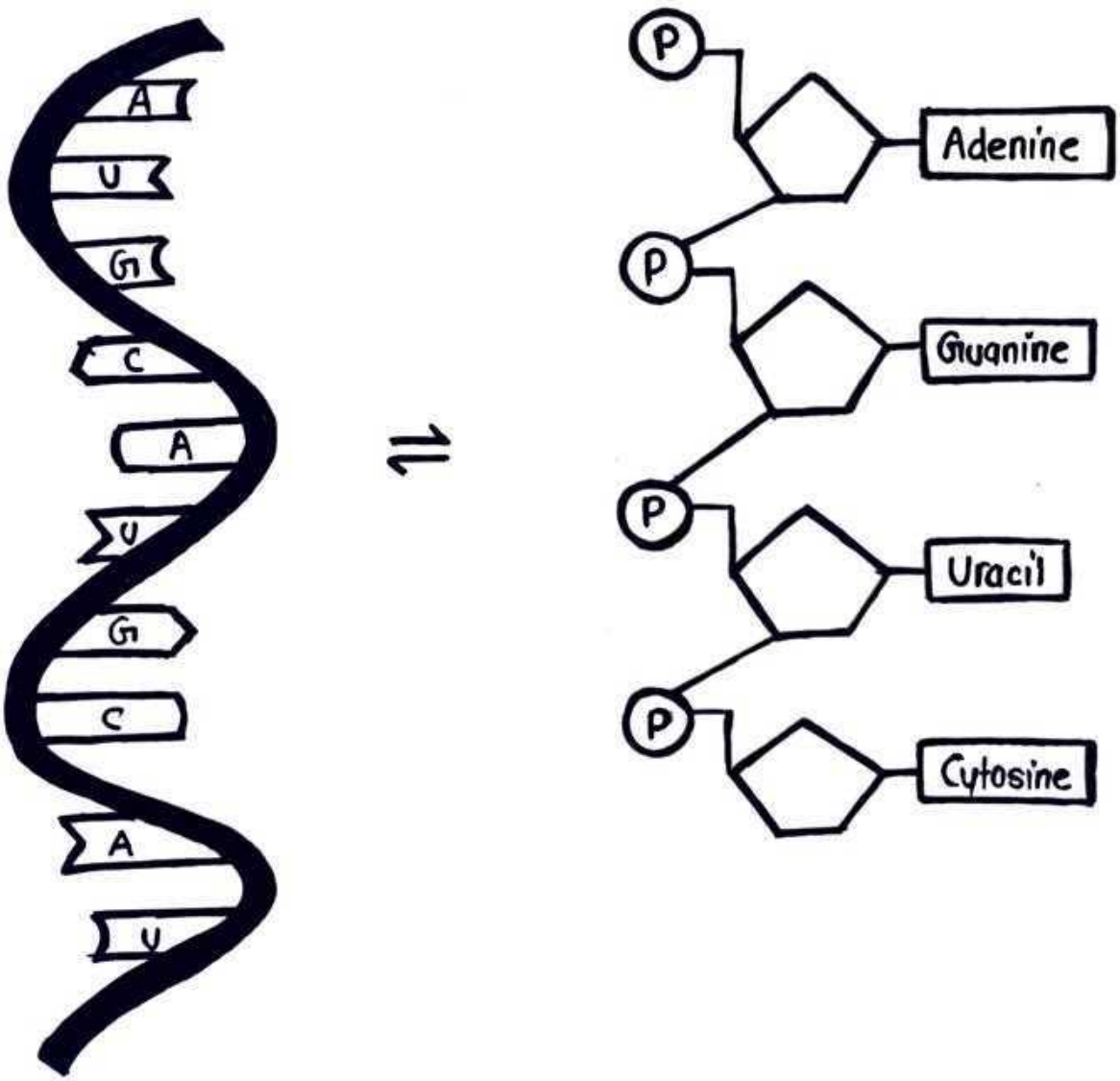
- The word DNA stands for Deoxyribonucleic Acid.
- It contains deoxyribose sugar.
- Nitrogenous Bases in DNA are : Adenine, Guanine, Cytosine, Thymine
- They are usually double stranded.
- It acts as genetic material & carries genetic information.



RNA

- RNA stands for Ribonucleic Acid.
- It contains ribose sugar.
- Nitrogenous Bases in RNA are : Adenine, Guanine, Cytosine, Uracil
- RNA is mainly responsible for protein synthesis.
- There are generally single stranded.
- There are mainly three types of RNA involved in protein synthesis

① mRNA (messenger RNA)
② tRNA (transfer RNA)
③ rRNA (ribosomal RNA)



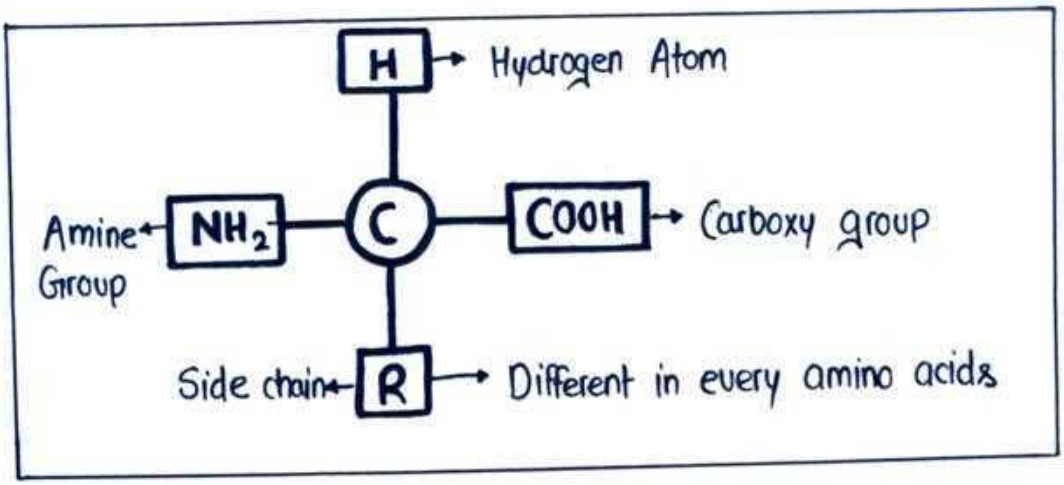
PROTEINS

- Proteins are the most abundant organic molecules in the living system.
- They constitute about 50% of dry cellular weight.
- They are essential for the structure, function and regulation of body's tissues and organs.
- Proteins are made up of smaller units called **Amino Acids**.
- Amino acids are the monomers of proteins or we can say proteins are the polymers of amino acids.

AMINO ACIDS

- Amino acids are the building blocks of ~~amino acids~~.
- Amino acids are the organic compounds contains :
  - An amino group ($-NH_2$)
  - A Carboxyl group ($-COOH$)
  - A Hydrogen atom ($-H$)
  - A Side chain ($-R$)

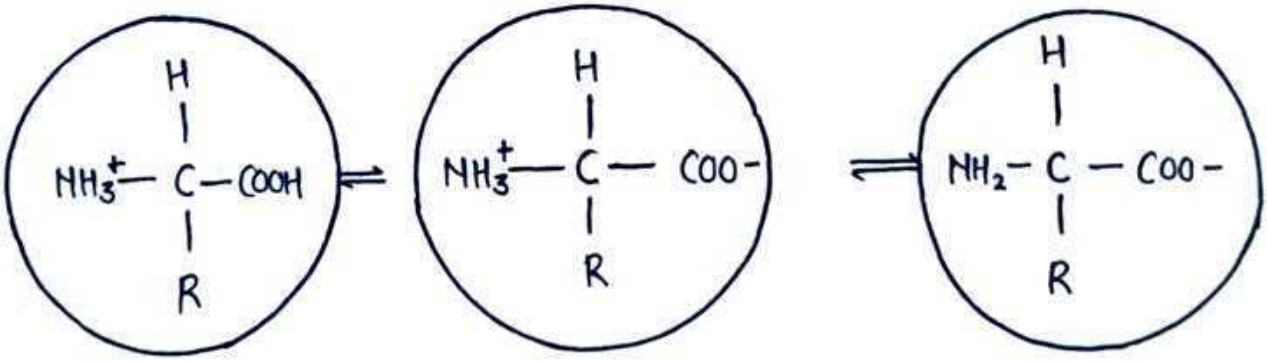
- The major key elements of amino acids are carbon, hydrogen, nitrogen & oxygen.
- Although there are about 300-400 amino acids are known but still only 20 amino acids participates in the protein formation.
- Unlike other organic compounds they are soluble in water.



Amino Acid Structure

Zwitter ionic form of amino acids

- When an amino acid is dissolved in water it exist as zwitter ion form (A zwitter ion is a molecule that includes both positive and negative charge).



Cation (At low pH)

Zwitter Ion

Anion (At high pH)

- We can also say amino acids are amphoteric in nature.

Classification of Amino Acids

Amino acids can be classified on the basis of two categories :

① Based on structure
② Based on Nutritional Requirement

Structural Classification

Structurally it can be classified into following types :

- Aliphatic amino acids.
- Alcoholic amino acids
- Sulpher containing amino acids
- Acidic amino acids
- Basic amino acids
- Aromatic amino acids
- Neutral amino acids

Nutritional Classification

On the basis of nutritional requirment, it can be classified into three categories :

- Essential Amino Acids.
- Non- Essential Amino Acids.
- Semi- Essential Amino Acids.

Essential Amino Acids

These amino acids cannot be synthesized in our body, so it is essential to eat them.

example : Valine, Leucine, Lysine etc.

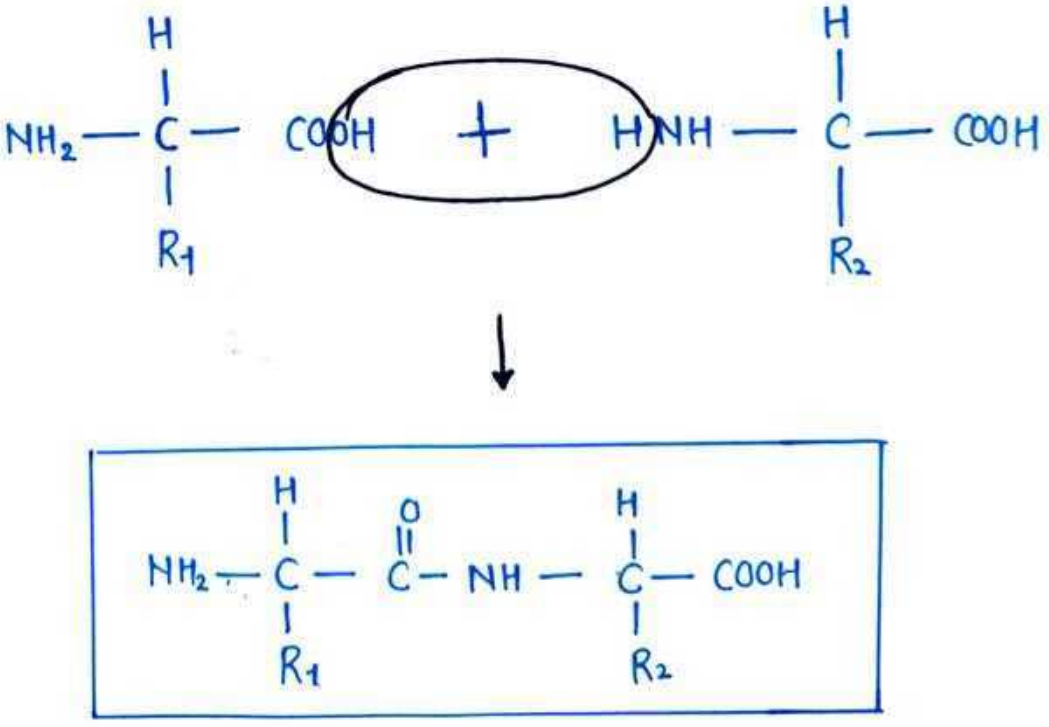
Non- Essential Amino Acids

Non- essential amino acids are those that can be synthesized by our body, so it is not essential to eat them.
example: Alanine, Glutamate etc.

Semi- Essential Amino Acids

These amino acids can be synthesized by our body, but the rate of synthesis is lesser than the requirment.
example: Histidine, Arginine etc.

PEPTIDE BOND FORMATION



Biological Role / Importance of Amino Acids

- Amino acids serves as building blocks of proteins.
- They also serves as precursor of hormones, purines, pyrimidines vitamins etc.
- Peptides have many important biological functions, they are used as antibiotics and antitumor agents.
- Some peptides are required for detoxification reaction.
- Peptides also serves as Neurotransmitters.
- They also involves in regulation of cell cycle.

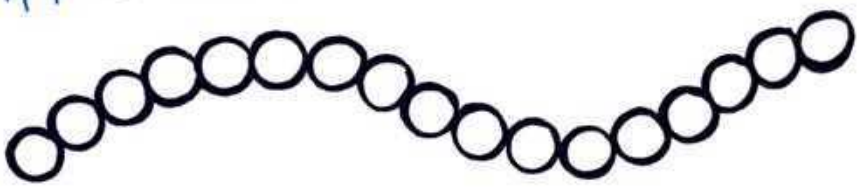
Structure Of Protein

The structure of protein can be divided into 4 classes / levels.

① Primary Structure
② Secondary Structure
③ Tertiary Structure
④ Quaternary Structure

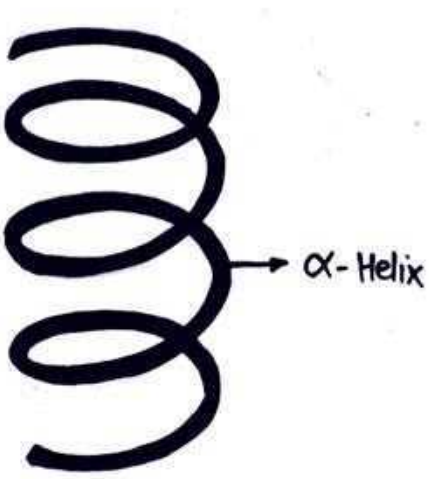
Primary Structure

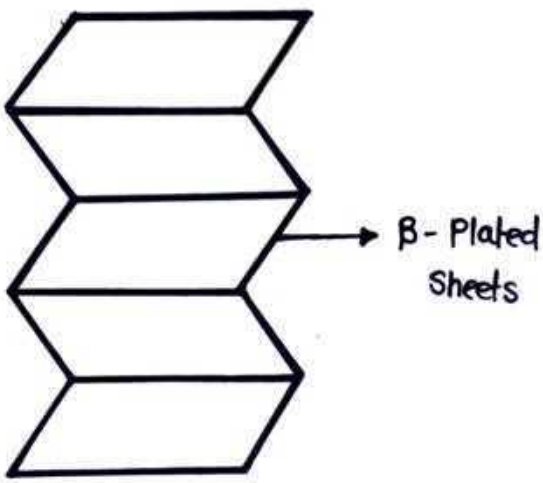
This is the simplest level of protein structure.
Primary structure simply contains the sequences of amino acids in a polypeptide chain.



Secondary Structure

Secondary structure of protein is formed by folding & twisting of amino acids.
The most common types are : α- helix & β plated sheets.



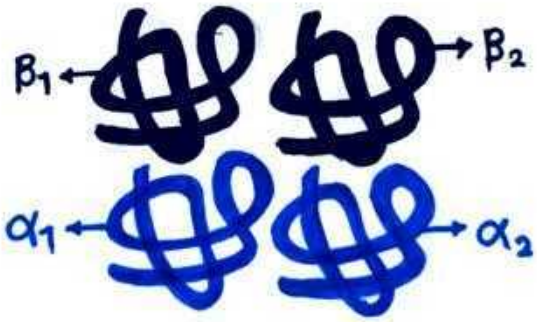


Teritiary Structure

- Teritiary structure of proteins are formed when the twists and folds of secondary structure folds again to form a larger three dimensional structure.

Quaternary Structure

- The quaternary structure of proteins is formed by combination of two or more teritiary units.
- Haemoglobin consist of two α and two β chains is the best example of quaternary structure.



Classification of Protein

Proteins can also be classified on the basis of two categories

① On the basis of structure
② On the basis of composition

On the basis of structure

On structural basis they can be classified into two categories:

- Fibrous Protein
- Globular Protein

Fibrous Protein : They are made up of elongated or fibrous polypeptide chains which forms fibre or sheet like structure.

Globular Protein : Globular proteins are generally spherical in shape due to tightly folded polypeptide chains.

On the basis of composition

On the basis of composition, again they can be classified into two categories :

- Simple Protein
- Conjugated Protein

Simple Proteins : Simple proteins are made up of only amino acid units joined by peptide bond
example : Albumins, Globulins etc.

Conjugated Proteins : Along with amino acids some other groups are also attached in conjugated proteins.
example : Glycoprotein , Lipoprotein etc.

Importance / Biological Role of Protein

- Plasma membrane proteins regulates the transfer of substance ~~along~~ cell across cell membrane.
- All receptors are made up of proteins.
- All enzymes are made up of proteins.
- All antibodies are protein in nature.
- Most of hormones are protein in nature.
- Haemoglobin is a protein carries O_2 in blood.
- Actin & myosin are proteins help in muscle contraction.

BIOENERGETICS

- The term **Bioenergetics** is made up of two words 'Bio + Energetics'
  - Bio → Life or Living being
  - Energetics → Study of Energy.

- Bioenergetics is nothing but the study of change in energy takes place during biological reactions.
- The term Bioenergetics can also be known as **Biochemical Thermodynamics.**
- The sum of all the chemical reactions takes place inside a living organism is called **Metabolism.**

PRINCIPLE OF BIOENERGETICS

- Bioenergetics (Biological energy transformations) obeys the law of thermodynamics.
- Now there are basically 4 laws of thermodynamics.
  - Zeroth Law
  - First Law
  - Second Law
  - Third Law

- But Bioenergetics mainly focuses on First Law and Second Law of thermodynamics.

① First Law Of Thermodynamics

The first law of thermodynamics is based upon the Poinciple of conservation of Energy.
According to this, Energy can neither be created nor be destroyed but it can only be transformed from one form to another.

② Second Law of Thermodynamics

According to the second law of thermodynamics 'In all natural or Spontaneous process, the entropy of the system always increases.

RELATIONSHIP B/W FREE ENERGY, ENTHALPY, ENTROPY

① Enthalpy

- Enthalpy is defined as amount of heat taken or released by a system during a chemical process.
- The change in enthalpy is denoted by ΔH

Now,

If $\Delta H \rightarrow$ Negative

- Heat / Energy released
- Exothermic reaction
- Spontaneous Process

If $\Delta H \rightarrow$ Positive

- Heat / Energy absorbed
- Endothermic reaction
- Non-spontaneous process

② Entropy

- Entropy is simply defined as measurment of randomness/ disorder of the system.
- The change in entropy is denoted by ΔS.

Now

If ΔS is Positive

- Randomness Increases
- Exo Spontaneous Process

If ΔS is negative

- Randomness Decreases
- Non- spontaneous Process

③ Free Energy

- The free energy of a system is defined as energy that is actually available to do work
- It is also known as Gibb's Free Energy.
- Change in Gibb's Free energy is denoted by ΔG

Now.

If ΔG is Negative

- Spontaneous Process.
- Exothermic / Exergonic Reaction

If ΔG is Positive

- Non- spontaneous process.
- Endothermic / Endergonic Reaction

Relationship Formula b/w Change in Free Energy, Enthalpy & Entropy

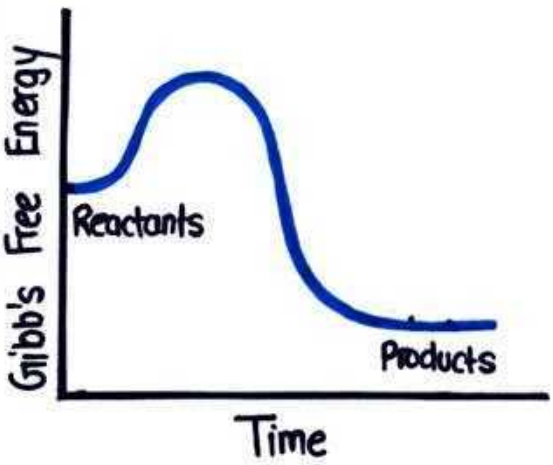
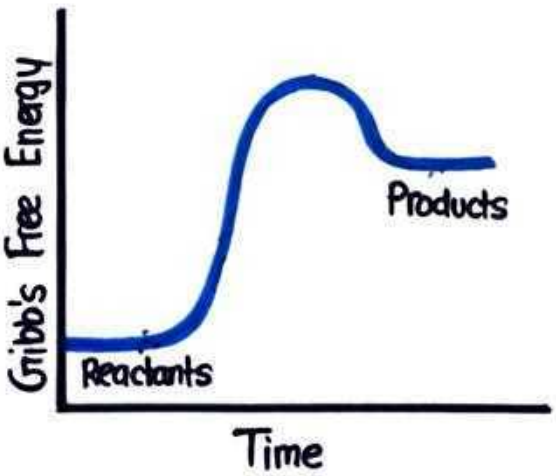
- Most of the biological reactions occurs under a constant temperature and constant pressure.
- Now at constant temperature and constant pressure the relationship between Gibb's Free Energy, Enthalpy & Entropy can be defined by following expression :

$$\Delta G = \Delta H - T\Delta S$$

Here, In the above Formula.

- ΔG = Change in gibb's free energy
- ΔH = Change in Enthalpy
- T = Temperature (in kelvin)
- ΔS = Change in Entropy

Difference between Exothermic and Endothermic Reactions

Exothermic Reactions	Endothermic Reactions
• Exothermic reactions represents a spontaneous process. • Exothermic reactions release heat energy to the surroundings. • They do not need energy to begin the reaction. • Entropy of exothermic reaction increased (positive) • Enthalpy of exothermic reaction is negative • Gibb's Free Energy of exotherm reaction is always negative • They are also known as Exergonic Reactions.	• Endothermic reactions represents Non-spontaneous process. • Endothermic reactions absorbs heat energy from the surroundings. • They always need energy to begin the reaction. • Entropy of endothermic reaction decreased. (Negative) • Enthalpy of endothermic reaction is positive. • Gibb's Free Energy of Endothermic reactions is always positive. • They are also known as Endergonic Reaction.
	

REDOX POTENTIAL

- The term Redox Potential is made up of two words 'Redox' & 'Potential'
- Now Redox → Reduction + Oxidation.
  (Gain of e-) (loss of e-)

- Redox Potential is also known as Oxidation - Reduction Potential.
- Redox potential is simply a measure of tendency of a redox couple to donate or accept electrons under standard conditions.

What is Redox Couple ?

When a substance exists in both oxidized and reduced state then the pair is called Redox Couple.

example :

NAD^+ / NADH

↓ Oxidized Form

↓ Reduced Form

Two Conditions of Redox Potential

- **Negative Redox Potential** : Greater tendency to loose electrons
- **Positive Redox Potential** : Greater tendency to accept electrons.

Note : Electron always flow from negative redox potential to positive redox potential.

Energy Rich Compounds

- They are also known as High- Energy compounds.
- Those compounds which releases at least or more than 7 Cal/mol energy at pH 7.0 are known as Energy Rich Compounds.
- Now, Since most energy rich compounds contain phosphate group, hence they are also known as High Energy Phosphates.

- Now Certain other compounds which liberates less than 7.0 cal/mol energy are reffered as Low Energy Compounds.

Classification of Energy rich compounds

There are basically five types of high energy or energy rich compounds.

① Pyrophosphates
② Acyl Phosphates
③ Enol Phosphates
④ Thiol Esters (Thioesters)
⑤ Guanido Phosphates

Pyrophosphates

- The energy bonds in pyrophosphates are acid anhydride bonds.
- These bonds are formed by the condensation of acid groups (mainly phosphoric acid)
- Example: ATP (It has two high energy phosphoanhydride bonds)

Acyl Phosphates

- The high energy bonds in this compound is formed by reaction between carboxylic acid group & phosphate group.
- example : 1,3- Biphosphoglycerate.

Enol Phosphates

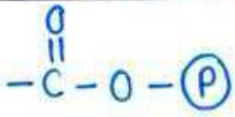
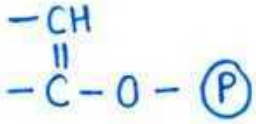
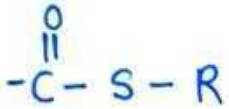
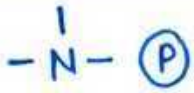
- The high energy bond present here is enolphosphate bond.
- It is formed when phosphate group attached to a hydroxyl group which is bonded to a carbon atom having double bond.
- example : Phosphoenolpyruvate

Thiol Esters

- In this compound there is no phosphate group, instead it has high energy thioester bond.
- Thioester bond results from the reaction between thiol and carboxylic acid group.
- example : Acetyl CoA

Guanido Phosphates

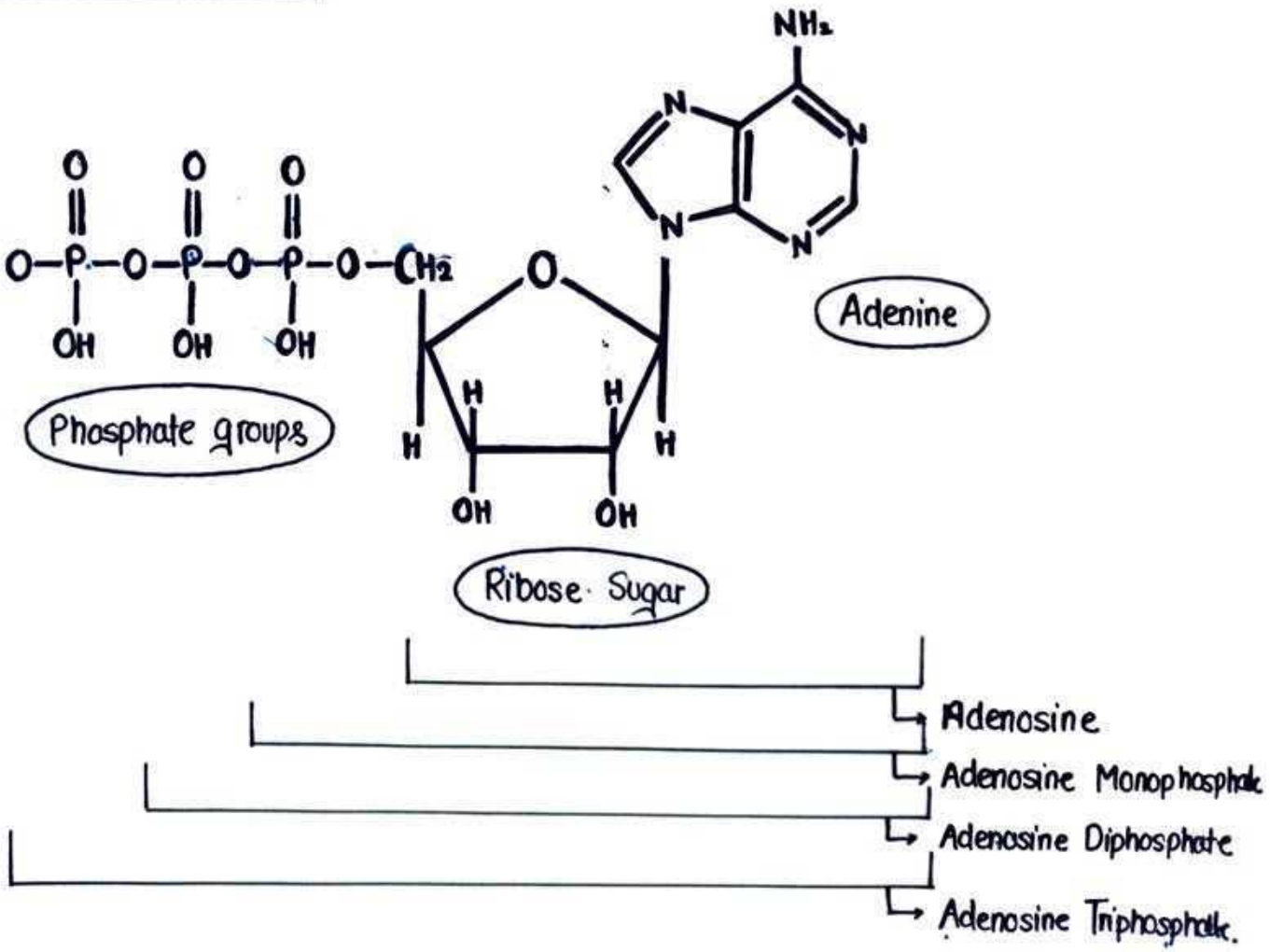
- They are also known as Phosphagens.
- The high energy bond here is guanidine phosphate bonds.
- example Phosphocreatine.

CLASS	BOND	EXAMPLE
Pyrophosphates		ATP
Acyl Phosphates		1,3 - Biphosphoglycerate
Enol Phosphates		Phosphoenol Pyruvate
Thiol Esters		Acetyl CoA
Guanido Phosphates		Phosphocreatine

ATP

- The full form of ATP is Adenosine Tri Phosphate.
- It is a multifunctional nucleotide coenzyme.
- It is the most important form of chemical energy in all cells.
- It is also known as Energy currency of cell.
- It is produced by phosphorylation and cellular respiration.
- It is used by enzymes and structural proteins in many cellular process.
- One molecule of ATP contains 3 phosphate groups.

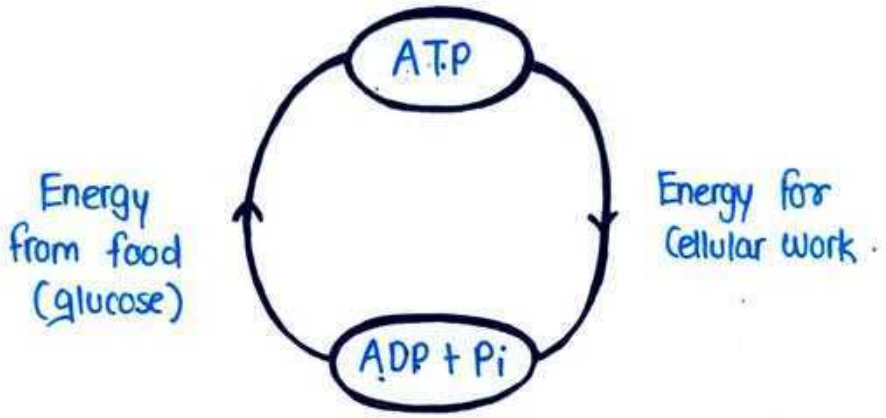
Structure of ATP



- The energy from ATP is released by breaking of high energy phosphoanhydride bonds via hydrolysis.

- $ATP + H_2O \rightarrow ADP + Pi$
- $ADP + H_2O \rightarrow AMP + Pi$
- $ATP + H_2O \rightarrow AMP + PPi$

ATP- ADP Cycle

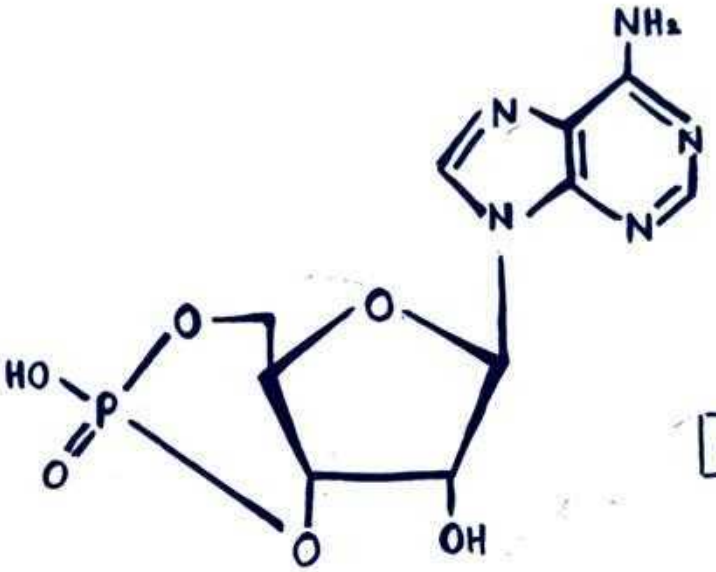


Biological Significance / Functions of ATP

- ATP is the biggest source of energy within all living organism.
- It is used in the muscle contraction.
- It is used in active transport across cell membrane.
- It is used in impulse formation.
- It is used in the metabollic processess.
- It is the precursor of C- AMP.

cAMP

- cAMP known as Cyclic AMP is a cyclic nucleotide.
- The full form of cAMP is cyclic adenosine monophosphate.
- It is synthesized from ATP under the influence of ADENYL CYCLASE.
- It is a type of secondary messenger.



cAMP Structure

Biological Significance

- It works as secondary messenger which helps in intracellular signalling.
- The harmones are unable to pass through plasma membrane that's why they require secondary messenger like cAMP.
- cAMP binds to ion channels and regulates the passage of specific ions through it.
- It also helps in activation of protein kinase enzymes.
- It activates the Ca- channel.