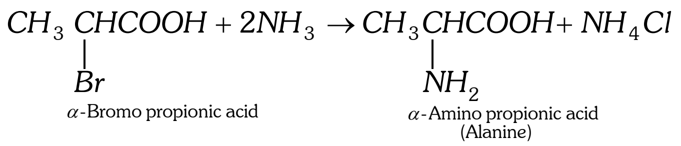
Biomolecules Part 2

(1) Methods of preparation of α-amino acids

(i) ***Amination of α-halo acids*** :



$$\underset{\alpha\text{-Bromo propionic acid}}{CH_3\underset{\underset{Br}{|}}{C}HCOOH} + 2NH_3 \rightarrow \underset{\substack{\alpha\text{-Amino propionic acid}\\ \text{(Alanine)}}}{CH_3\underset{\underset{NH_2}{|}}{C}HCOOH} + NH_4Cl$$

Lab preparation of glycine : $\underset{\alpha\text{-Chloro acetic acid}}{Cl.CH_2COOH} + \underset{\text{liquid}}{3NH_3} \xrightarrow{50°C} \underset{\text{Amm. salt of glycine}}{H_2N.CH_2COONH_4} + NH_4Cl$

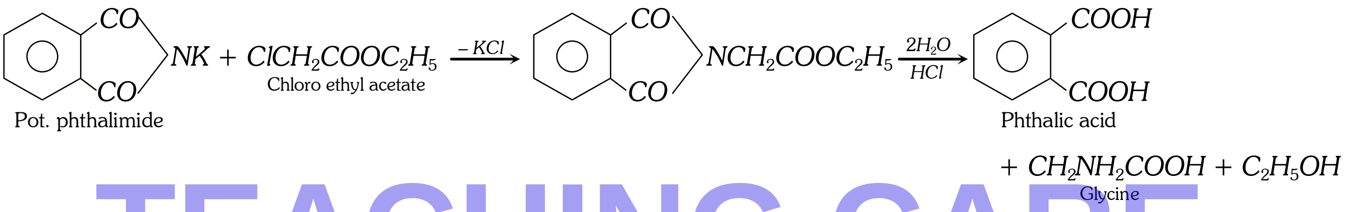
The ammonium salt so obtained is boiled with copper carbonate and cooled when blue colour needles of copper salt of glycine are obtained.

$$2[H_2N - CH_2COONH_4] + CuCO_3 \xrightarrow{\text{Boiled}} \underset{\text{Copper salt of glycine}}{(H_2NCH_2COO)_2Cu} + (NH_4)_2CO_3$$

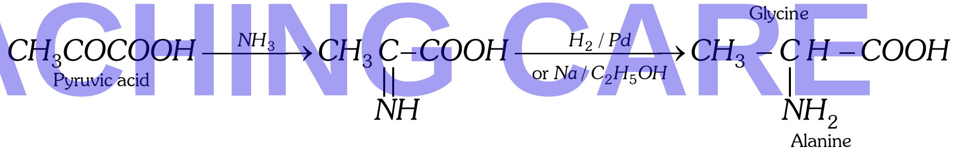
It is now dissolved in water and H_2S is passed till whole of the copper precipitates as copper sulphide leaving glycine as the aqueous solution.

$$(H_2N - CH_2COO)_2Cu + H_2S \rightarrow \underset{\text{Glycine}}{2H_2NCH_2COOH} + \underset{\text{Black ppt.}}{CuS} \downarrow$$

(ii) ***Gabriel pthalimide synthesis***

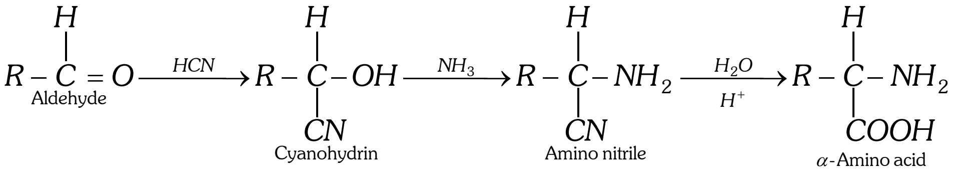


(iii) ***Knoop synthesis*** :



$$\underset{\text{Pyruvic acid}}{CH_3COCOOH} \xrightarrow{NH_3} CH_3\underset{\underset{NH}{||}}{C}-COOH \xrightarrow[\text{or } Na/C_2H_5OH]{H_2/Pd} \underset{\text{Alanine}}{CH_3-\underset{\underset{NH_2}{|}}{C}H-COOH}$$

(iv) ***Streker synthesis*** :



$$\underset{\text{Aldehyde}}{R-\overset{\overset{H}{|}}{C}=O} \xrightarrow{HCN} \underset{\text{Cyanohydrin}}{R-\overset{\overset{H}{|}}{\underset{\underset{CN}{|}}{C}}-OH} \xrightarrow{NH_3} \underset{\text{Amino nitrile}}{R-\overset{\overset{H}{|}}{\underset{\underset{CN}{|}}{C}}-NH_2} \xrightarrow[H^+]{H_2O} \underset{\alpha\text{-Amino acid}}{R-\overset{\overset{H}{|}}{\underset{\underset{COOH}{|}}{C}}-NH_2}$$

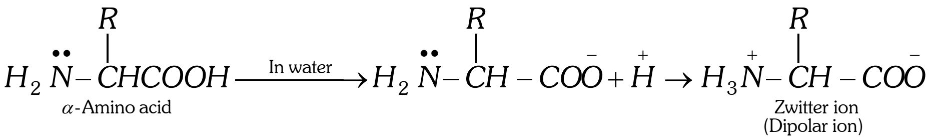
(v) ***From natural protein*** : Natural proteins are hydrolysed with dil. HCl or H_2SO_4 at 250°C in an autoclave when a mixture of α-amino acids is obtained. This mixture is esterified and the various esters are separated by fractional distillation. The esters are then hydrolysed into respective α-amino acids.

(2) Physical properties

(i) Amino acids are colourless, crystalline substances having sweet taste. They melt with decomposition at higher temperature (more than 200°C). They are soluble in water but insoluble in organic solvents.

(ii) Except glycine, all the α-amino acids are optically active and have an asymmetric carbon atom (α-carbon atom). Hence, each of these amino acids can exist in two optical isomers. In proteins, however, only one isomer of each is commonly involved.

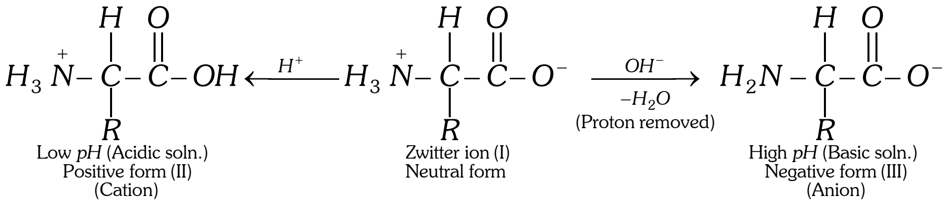
(iii) ***Zwitter ion and isoelectric point*** : Since the $-NH_2$ group is basic and $-COOH$ group is acidic, in neutral solution it exists in an internal ionic form called a **Zwitter ion** where the proton of $-COOH$ group is transferred to the $-NH_2$ group to form **inner salt**, also known as **dipolar ion**.



$$\underset{\alpha\text{-Amino acid}}{H_2\ddot{N}-\overset{\overset{R}{|}}{C}HCOOH} \xrightarrow{\text{In water}} H_2\ddot{N}-\overset{\overset{R}{|}}{C}H-C\overset{-}{O}O + \overset{+}{H} \rightarrow \underset{\substack{\text{Zwitter ion}\\ \text{(Dipolar ion)}}}{H_3\overset{+}{N}-\overset{\overset{R}{|}}{C}H-CO\overset{-}{O}}$$

The Zwitter ion is dipolar, charged but overall electrically neutral and contains both a positive and negative charge.

(3) **Chemical properties :** Amino acids are amphoteric in nature. Depending on the *pH* of the solution, the amino acid can donate or accept proton.



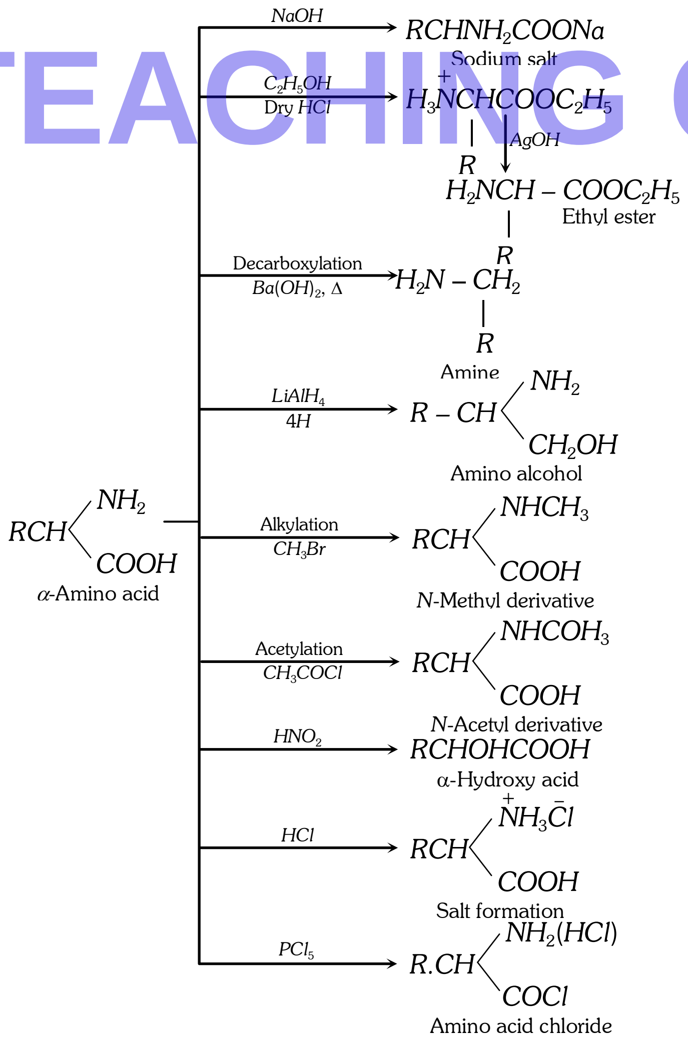
$$H_3\overset{+}{N}-\underset{R}{\overset{H}{C}}-\overset{O}{\overset{\|}{C}}-OH \xleftarrow{H^+} H_3\overset{+}{N}-\underset{R}{\overset{H}{C}}-\overset{O}{\overset{\|}{C}}-O^- \xrightarrow[-H_2O]{OH^-} H_2N-\underset{R}{\overset{H}{C}}-\overset{O}{\overset{\|}{C}}-O^-$$

When an ionised form of amino acid is placed in an electric field, it will migrate towards the opposite electrode. Depending on the *pH* of the medium, following three things may happen

- In acidic solution (low *pH*), the positive ion moves towards cathode.
- In basic solution (high *pH*), the negative ion moves towards anode.
- The Zwitter ion does not move towards any of the electrodes.

The intermediate *pH* at which the amino acid shows no tendency to migrate towards any of the electrodes and exists the equilibrium when placed in an electric field is known as isoelectric point. This is characteristic of a given amino acid and depends on the nature of *R*-linked to *α*-carbon atom.

(i) ***α-amino acids show the reactions of –NH_2 group, –COOH groups and in which both the groups are involved. A summary of chemical properties is given below***

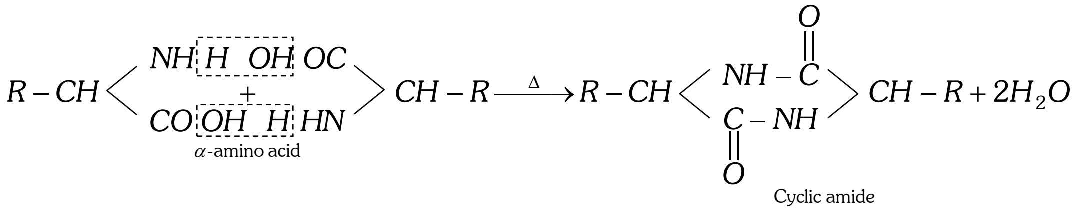


Note : ✸ Proline is the only natural α-amino acid which is a secondary amine.

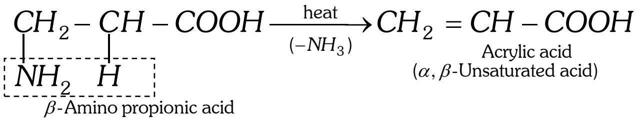
✸ Only achiral α-amino acid found in protein is glycine.

(ii) *Action of heat*

(a) *For α-amino acids*



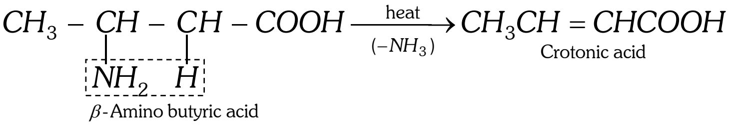
(b) *For β-amino acids* **:**



$$\underset{NH_2}{CH_2}-\underset{H}{CH}-COOH \xrightarrow[(-NH_3)]{\text{heat}} CH_2=CH-COOH$$

β-Amino propionic acid

Acrylic acid (α, β-Unsaturated acid)

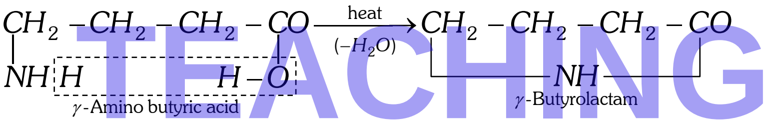


$$CH_3-\underset{NH_2}{CH}-\underset{H}{CH}-COOH \xrightarrow[(-NH_3)]{\text{heat}} CH_3CH=CHCOOH$$

β-Amino butyric acid

Crotonic acid

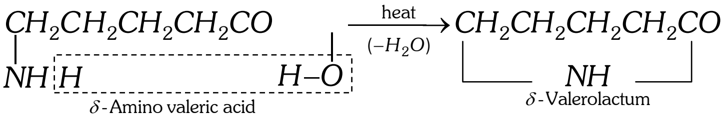
(c) *For γ and δ amino acids*



$$\underset{NH\,H}{CH_2}-CH_2-CH_2-\underset{H-O}{CO} \xrightarrow[(-H_2O)]{\text{heat}} CH_2-CH_2-CH_2-CO \;(-NH-)$$

γ-Amino butyric acid

γ-Butyrolactam



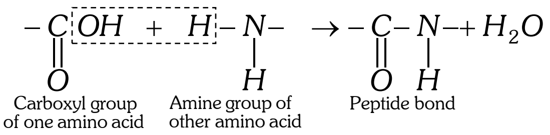
$$\underset{NH\,H}{CH_2}CH_2CH_2CH_2\underset{H-O}{CO} \xrightarrow[(-H_2O)]{\text{heat}} CH_2CH_2CH_2CH_2CO \;(-NH-)$$

δ-Amino valeric acid

δ-Valerolactum

These lactams have stable five or six membered rings.

(iii) ***Formation of proteins-peptide bond*** **:** Proteins are formed by joining the carboxyl group of one amino acid to the α-amino group of another amino acid. **The bond formed between two amino acids by the elimination of a water molecule is called a peptide linkage or bond**. The peptide bond is simply another name for amide bond.



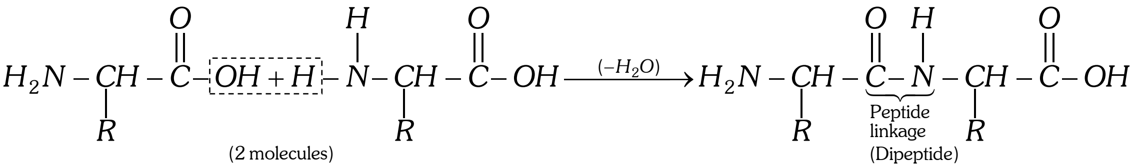
$$-\underset{O}{\underset{\|}{C}}\boxed{OH + H}-\underset{H}{\underset{|}{N}}- \rightarrow -\underset{O}{\underset{\|}{C}}-\underset{H}{\underset{|}{N}}-+H_2O$$

Carboxyl group of one amino acid

Amine group of other amino acid

Peptide bond

The product formed by linking amino acid molecules through peptide linkages, $-CO-NH-$, is called a **peptide**. Peptides are further designated as *di*, *tri*, *tetra* or *penta* peptides accordingly as they contain two, three, four or five amino acid molecules, same or different, joined together in the following fashions.

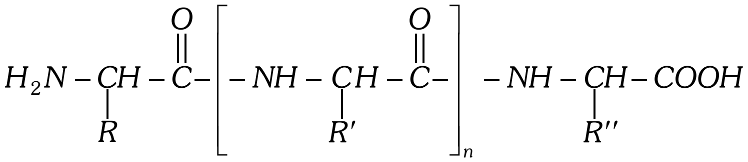


$$H_2N-\underset{R}{CH}-\overset{O}{\overset{\|}{C}}-\boxed{OH+H}-\overset{H}{\overset{|}{N}}-\underset{R}{CH}-\overset{O}{\overset{\|}{C}}-OH \xrightarrow{(-H_2O)} H_2N-\underset{R}{CH}-\underbrace{\overset{O}{\overset{\|}{C}}-\overset{H}{\overset{|}{N}}}_{\text{Peptide linkage}}-\underset{R}{CH}-\overset{O}{\overset{\|}{C}}-OH$$

(2 molecules)

(Dipeptide)

When the number of amino molecules is large, the product is termed polypeptide which may be represented as,

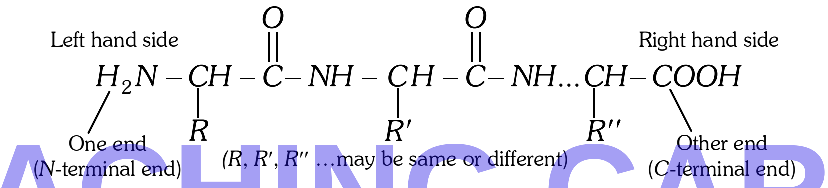


$$H_2N-\underset{R}{CH}-\overset{O}{\overset{\|}{C}}-\left[-NH-\underset{R'}{CH}-\overset{O}{\overset{\|}{C}}-\right]_n-NH-\underset{R''}{CH}-COOH$$

(4) Composition : Composition of a protein varies with source. An approximate composition is as follows :

Carbon 50-53%; hydrogen 6-7%; oxygen 23-25%; nitrogen 16-17%; Sulphur about 1%. Other elements may also be present, *e.g.*, phosphorus (in nucleoproteins), iodine (in thyroid proteins) and iron (in haemoglobin).

(5) Structure of proteins : The structure of proteins is very complex. **The primary structure of a protein refers to the number and sequence of the amino acids in its polypeptide chains** (discussed in the formation of proteins). The primary structure is represented beginning with the amino acid whose amino group is free (the *N*-terminal end) and it forms the one end of the chain. Free carboxyl group (*C*-terminal end) forms the other end of the chain.



$$H_2N-\underset{R}{CH}-\overset{O}{\overset{\|}{C}}-NH-\underset{R'}{CH}-\overset{O}{\overset{\|}{C}}-NH\ldots\underset{R''}{CH}-COOH$$

Side chains may have basic groups or acidic groups as $-NH_2$ in lysine and $-COOH$ in aspartic acid. Because of these acidic and basic side chains, there are positively and negatively charged centres. Though the peptide linkage is stable, the reactivity is due to these charged centres in the side chains.

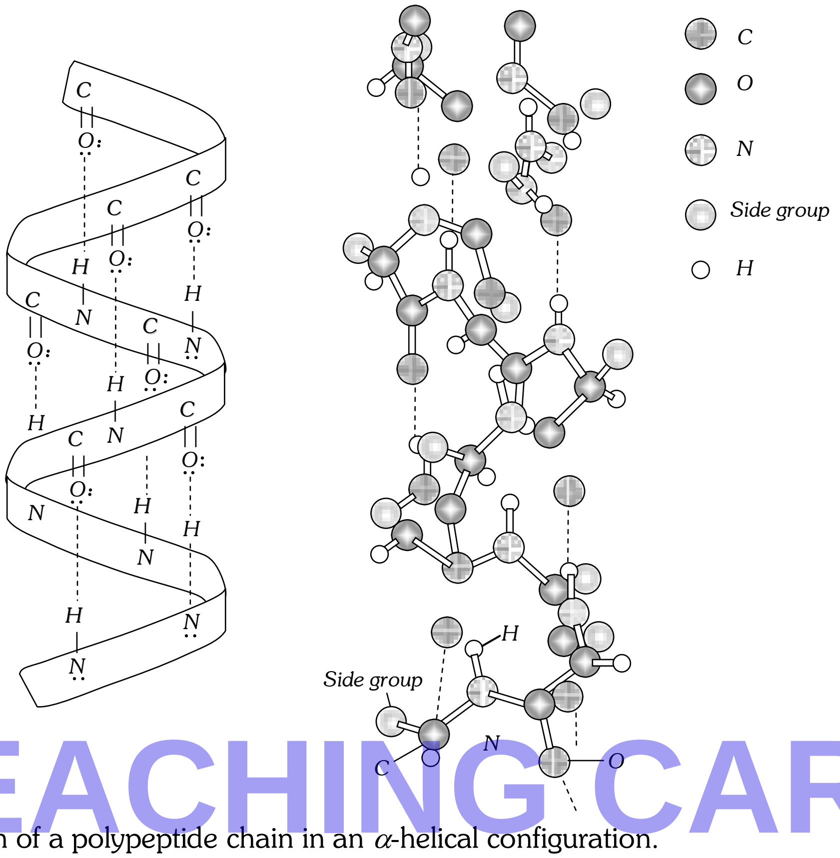
Primary structure tells us nothing about the shape or conformation of the molecule. Most of the bonds in protein molecules being single bonds can assume infinite number of shapes due to free rotation about single bonds. However, it has been confirmed that each protein has only a single three dimensional conformation. **The fixed configuration of a polypeptide skeleton is referred to as the secondary structure of a protein**. It gives information :

- About the manner in which the protein chain is folded and bent;
- About the nature of the bonds which stabilise this structure.

Secondary structure of protein is mainly of two types

(i) ***α-helix* :** This structure is formed when the chain of α-amino acids coils as a right handed screw (called α-helix) because of the formation of **hydrogen bonds** between amide groups of the same peptide chain, *i.e.*, *NH* group in one unit is linked to carbonyl oxygen of the third unit by hydrogen bonding. This hydrogen bonding between different units is responsible for holding helix in a position. The side chains of these units project outward from the coiled backbone.

Such proteins are elastic, *i.e.*, they can be stretched. On stretching weak hydrogen bonds break up and the peptide chain acts like a spring. The hydrogen bonds are reformed on releasing the tension. Wool and hair have α-helix structure.

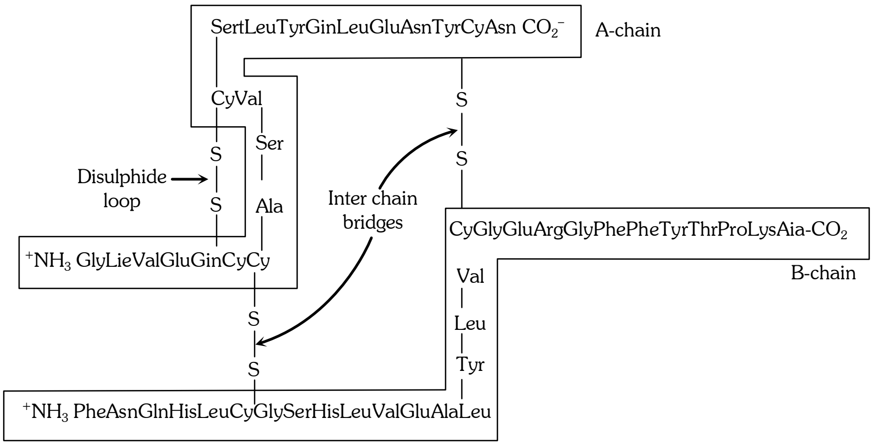


(a) Representation of a polypeptide chain in an α-helical configuration.

(b) Stabilization of an α-helical configuration by hydrogen bonding. The shaded spheres represent carbon-atoms or residues (R) of amino acids.

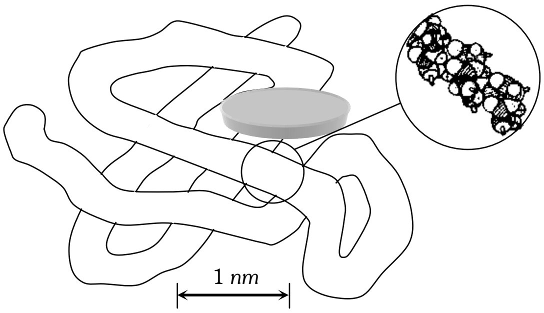
(ii) ***β-pleated sheet*** **:** A different type of secondary structure is possible when polypeptide chains are arranged side by side. The chains are held together by a very large number of hydrogen bonds between $C = O$ and NH of different chains. Thus, the chains are bonded together forming a sheet. These sheets can slide over each other to form a three dimensional structure called a beta pleated sheet. Silk has a beta pleated structure.

The beta pleated sheet structure of proteins



Tertiary Structure of proteins

Further folding and bending of secondary structure is called the tertiary structure of proteins



Tertiary structure of proteins

Globular proteins possess tertiary structure. In general globular proteins are very tightly folded into a compact spherical form.

(6) **Classification of proteins :** According to chemical composition, proteins are divided into two classes

(i) ***Simple proteins*** **:** Simple proteins are composed of chains of amino acid units only joined by peptide linkages. These proteins on hydrolysis yield only mixture of amino acids. Examples are

Egg albumin, serum globulins, glutelin in wheat, coryzenin in rice, tissue globulin, etc.

(ii) ***Conjugated proteins*** **:** The molecules of conjugated proteins are composed of simple proteins and non protein material. The non-protein material is called **prosthetic group** or **cofactor**. These proteins on hydrolysis yield amino acids and non-protein material. Examples are

Mucin in saliva (prosthetic group, carbohydrate), casein in milk (prosthetic group, phosphoric acid), haemoglobin in blood (prosthetic group, iron pigment), etc.

According to molecular shape, proteins are divided into two types

(i) **Fibrous proteins :** These are made up of polypeptide chains that run parallel to the axis and are held together by strong hydrogen and disulphide bonds. They can be stretched and contracted like a thread. These are usually insoluble in water. Examples are : α-keratin (hair, wool, silk and nails); myosin (muscles); collagen (tendons, bones), etc.

(ii) **Globular proteins :** These have more or less spherical shape (compact structure). α-helics are tightly held up by weak attractive forces of various types: Hydrogen bonding, disulphide bridges, ionic or salt bridges. These are usually soluble in water. Examples are: Insulin, pepsin, haemoglobin, cytochromes, albumins, etc.

Proteins can also be classified on the basis of their function

Protein	***Function***	***Examples***
Enzymes	**Biological catalysts, vital to all living systems.**	**Trypsin, pepsin.**
Structural proteins	**Proteins that hold living systems together.**	**Collagen.**
Hormones	**Act as messengers.**	**Insulin.**
Transport proteins	**Carry ions or molecules from place to another in the living system.**	**Haemoglobin.**
Protective proteins (antibiotics)	**Destroy any foreign substance released into the living system.**	**Gamma globulin.**
Toxins	**Poisonous in nature.**	**Snake venom.**

(7) General and physical characteristic of proteins

(i) Most of them (except chromoproteins) are colourless, tasteless, and odourless. Many are amorphous but few are crystalline. They are nonvolatile and do not have a sharp melting point .

(ii) Most of them are insoluble in water and alcohol. But many of them dissolve in salt solutions, dilute acids and alkalies. Some proteins such as keratins (skin, hair and nails) are completely insoluble.

(iii) Protein molecules are very complex and possess very high molecular masses. They are hydrophilic colloids which cannot pass through vegetable or animal membrane. On addition of sodium chloride, ammonium sulphate magnesium sulphate, etc., some proteins are precipitated. The precipitate can be filtered and redissolved in water.

(iv) The solution of proteins are optically active. Most of them are laevorotatory. The optical activity is due to the presence of asymmetric carbon atoms in the constituent α-amino acids.

(v) ***Isoelectric point*** **:** Every protein has a characteristic isoelectric point at which its ionisation is minimum. Like amino acids, proteins, having charged groups ($\overset{+}{N}H_3$ and COO^-) at the ends of the peptide chain, are amphoteric in nature. In strong acid solution, protein molecule accepts a proton while in strong basic solution it loses a proton. **The *pH* at which the protein molecule has no net charge is called its isoelectric point**. This property can be used to separate proteins from mixture by electrophoresis.

(vi) ***Denaturation*** **:** The structure of the natural proteins is responsible for their biological activity. These structures are maintained by various attractive forces between different parts of the polypeptide chains. The breaking of these forces by a physical or a chemical change makes the proteins to lose all or part of their biological activity. This is called denaturation of proteins. The denaturing of proteins can be done by adding chemicals such as acids, bases, organic solvents, heavy metal ions, or urea. It can also be done with the help of heat and ultraviolet light. Denaturation can be irreversible or reversible. In irreversible denaturation, the denaturated protein does not return to its original shape. For example, the heating of white of an egg (water soluble) gives a hard and rubbery insoluble mass.

(8) Chemical properties

(i) ***Salt formation*** **:** Due to presence of both $-NH_2$ and $-COOH$ groups in proteins, they form salts with acids and bases. Casein is present in milk as calcium salt.

(ii) ***Hydrolysis*** **:** The simple proteins are hydrolysed by acids, alkalies or enzymes to produce amino acids. Following steps are involved in the hydrolysis and the final product is a mixture of amino acids.

Protein → Proteose → Peptone → Polypeptide → Simple peptide → Mixture of amino acids

(iii) ***Oxidation*** **:** Proteins are oxidised on burning and putrefaction. The products include amines, nitrogen, carbon dioxide and water. The bad smell from decaying dead animals is largely due to the formation of amines by bacterial oxidation of body proteins.

(9) Test of proteins

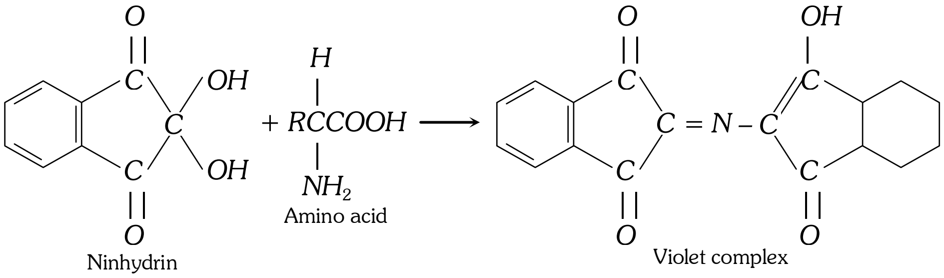
(i) ***Biuret test*** **:** On adding a dilute solution of copper sulphate to alkaline solution of protein, a violet colour is developed. This test is due to the presence of peptide ($-CO-NH-$) linkage.

(ii) ***Xanthoproteic test*** **:** Some proteins give yellow colour with concentrated nitric acid (formation of yellow stains on fingers while working with nitric acid in laboratory). The formation of yellow colour is due to reaction of nitric acid with benzenoid structures. Thus, when a protein solution is warmed with nitric acid a yellow colour may be developed which turns orange on addition of NH_4OH solution.

(iii) ***Millon's test*** **:** When millon's reagent (mercurous and mercuric nitrate in nitric acid) is added to a protein solution, a white precipitate which turns brick red on heating, may be formed. This test is given by proteins which yield tyrosine on hydrolysis. This is due to presence of phenolic group.

(iv) ***Ninhydrin test* : This test is given by all proteins**. When a protein is boiled with a dilute solution of ninhydrin, a violet colour is produced.

(v) ***Nitroprusside test* :** Proteins containing $-SH$ group give this test. When sodium nitroprusside solution is added to proteins having $-SH$ group, a violet colour is developed.



(vi) ***Molisch's test* :** This test is given by those proteins which contain carbohydrate residue. On adding a few drops of alcoholic solution of α-naphthol and concentrated sulphuric acid to the protein solution, a violet ring is formed.

(vii) ***Hopkins-Cole test* :** On adding concentrated sulphuric acid down the side containing a solution of protein and glyoxalic acid, a violet colour is developed.

(10) Uses

(i) Proteins constitute as essential part of our food. Meat, eggs, fish, cheese provide proteins to human beings.

(ii) ***In textile* :** Casein (a milk protein) is used in the manufacture of artificial wool and silk.

(iii) ***In the manufacture of amino acids* :** Amino acids, needed for medicinal use and feeding experiments, are prepared by hydrolysis of proteins.

(iv) ***In industry* :** Gelatin (protein) is used in food products, capsules and photographic plates. Glue (protein) is used as adhesive and in sizing paper. Leather is obtained by tanning the proteins of animal hides.

(v) ***In controlling body processes* :** Haemoglobin present in blood is responsible for carrying oxygen and carbon dioxide. Hormones (proteins) control various body processes.

(vi) ***As enzymes* :** Reactions in living systems always occur with the aid of substances called enzymes. **Enzymes are proteins produced by living systems and catalyse specific biological reactions**.

Important enzymes are

Enzymes	***Reaction catalysed***
Urease	**Urea → CO_2 + NH_3**
Invertase	**Sucrose → Glucose + Fructose**
Maltase	**Maltose → 2 Glucose**
Amylase	**Starch → n Glucose**
Pepsin	**Proteins → Amino acids**
Trypsin	**Proteins → Amino acids**
Carbonic anhydrase	**$H_2CO_3 \rightarrow H_2O + CO_2$**
Nuclease	**DNA, RNA → Nucleotides**

Nucleic acids.

In every living cell there are found nucleo-proteins which are made up of proteins and natural polymers of great biological importance called nucleic acids. Nucleic acids are complex compounds of carbon, hydrogen, oxygen, nitrogen and phosphorus. They play an essential role in transmission of the hereditary characteristics and biosynthesis of proteins. The genetic information coded in nucleic acids programmes the structure of all proteins including enzymes and thereby all metabolic activity of living organisms.

Two types of nucleic acids are found in biological systems, these are

Deoxyribonucleic acid (DNA) and

Ribonucleic acid (RNA)

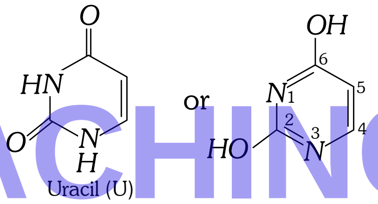
The nucleic acid was first isolated by Friedrich Miescher in 1868 from the nuclei of pus cells and was named nuclein. The term nuclein was given by Altman.

(1) **Composition : Nucleic acids like proteins and carbohydrates are polymers**. The simple units that make up the nucleic acid are called **nucleotides**. Nucleotides are themselves composed of following three simple molecules.

(i) ***Nitrogenous base* :** These are heterocyclic organic compound having two or more nitrogen atoms in ring skeleton. These are called bases because the lone pairs of electrons on the nitrogen atoms make them as Lewis bases.

Their structures are given below

(a) *Pyrimidine derivatives*



Uracil (U)
RNA

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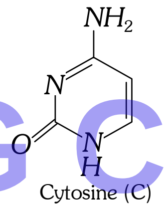
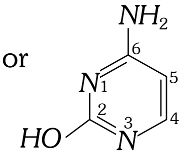


Cytosine (C)
RNA
DNA

or



Cytosine (C)

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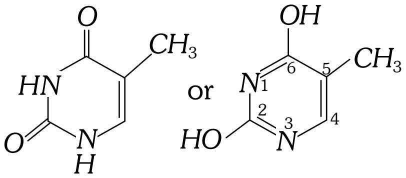
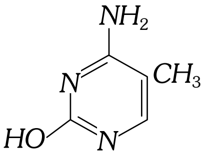
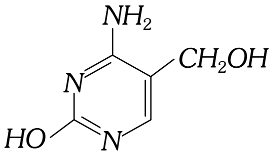


Thymine (T)
DNA



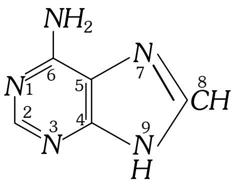
5-Methyl cytosine

;



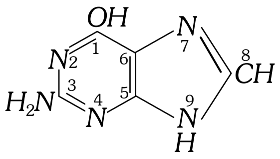
5-Hydroxy methyl
cytosine

(b) *Purine derivatives*



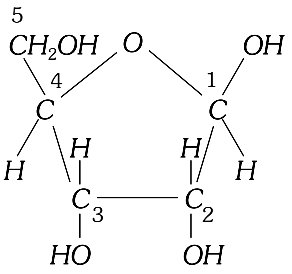
Adenine (A)
DNA
RNA

;



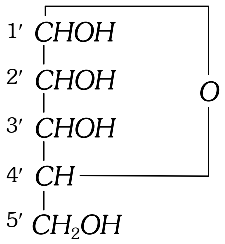
Guanine (G)
DNA
RNA

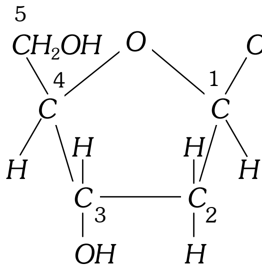
(ii) ***Five carbon sugar (Pentose)*** **:** In RNA, the sugar is ribose where as in DNA, the sugar is deoxyribose.



Ribose

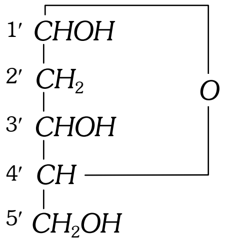
or





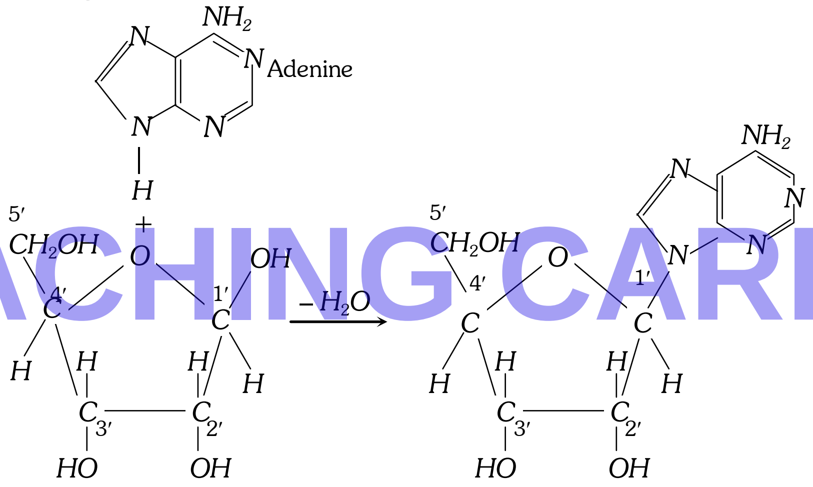
Deoxyribose

or



Both differ only at carbon atom $2'$ in the ring.

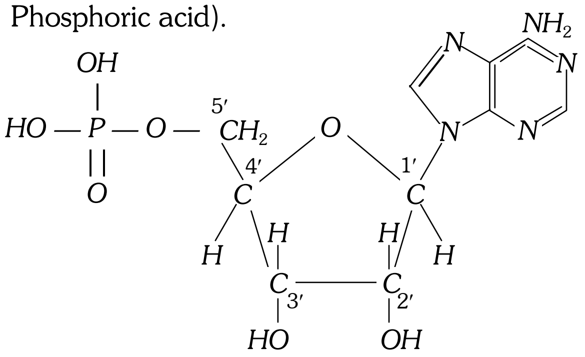
(iii) ***Phosphoric acid, H_3PO_4*** **:** Phosphoric acid forms esters to $-OH$ groups of the sugars to bind nucleotide segments together. A molecule called **nucleoside** is formed by condensing a molecules of the base with the appropriate pentose. (*i.e.*, Base + Sugar).



Ribose

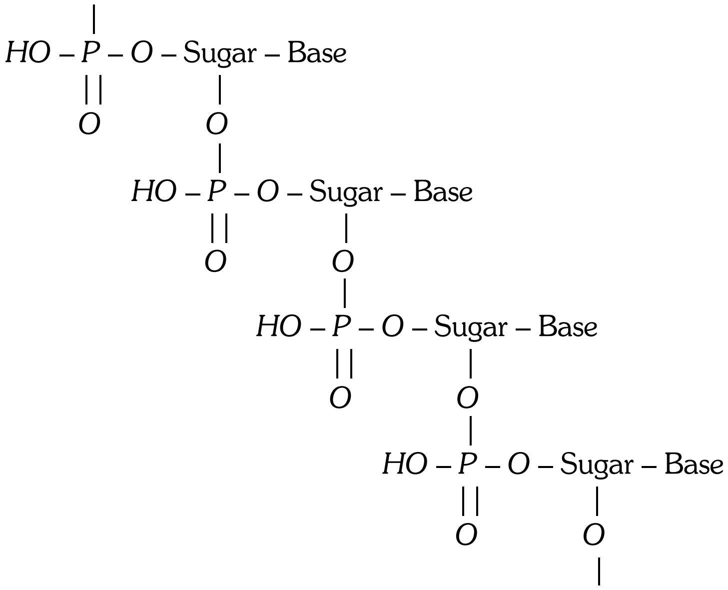
Adenosine
(nucleoside)

A **nucleotide** results when the nucleoside combined with phosphoric acid mainly at carbon 5′ of the pentose. (*i.e.*, Base + Sugar + Phosphoric acid).

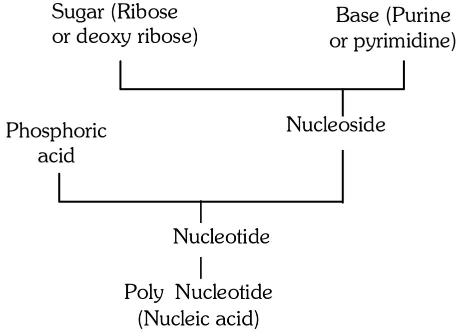


Nucleotide-adenosine 5′-phosphoric acid

This nucleotide is the building block of both DNA and RNA. The nucleic acids are condensation polymers of the nucleotide monomers and are formed by the creation of an ester linkage from phosphoric residue on one nucleotide to the hydroxy group on carbon 3′ in the pentose of the second nucleotide. The result is a very long chain possessing upto a billion or so nucleotides units in DNA.



Thus, the formation of a nucleic acid can be summarised in the following general way



RNA nucleotides

Base	+	Ribose	→	(Nucleoside)	+	Phosphoric acid	→	Nucleotide
Adenine	+	Ribose	→	(Adenosine)	+	Phosphoric acid	→	Adenylic acid
Guanine	+	Ribose	→	(Guanosine)	+	Phosphoric acid	→	Guanylic acid
Cytosine	+	Ribose	→	(Cytidine)	+	Phosphoric acid	→	Cytidylic acid
Uracil	+	Ribose	→	(Uridine)	+	Phosphoric acid	→	Uridylic acid

DNA nucleotides

Adenine	+	Deoxy ribose sugar	+	Phosphate	→	Adenosine phosphate
Guanine	+	Deoxy ribose sugar	+	Phosphate	→	Guanosine phosphate
Cytosine	+	Deoxy ribose sugar	+	Phosphate	→	Cytosine phosphate
Thymine	+	Deoxy ribose sugar	+	Phosphate	→	Thymidine phosphate

(2) **Structure :** The sequence of bases along the DNA and RNA chain establishes its primary structure which controls the specific properties of the nucleic acid. An RNA molecule is usually a single chain of ribose-containing nucleotides. DNA molecule is a long and highly complex, spirally twisted, double helix, ladder like structure. The two polynucleotide chains or strands are linked up by hydrogen bonding between the nitrogenous base molecules of their nucleotide monomers. Adenine (purine) always links with thymine (pyrimidine) with the help of two hydrogen bonds and guanine (purine) with cytosine (pyrimidine) with the help of three hydrogen bonds. Hence, the two strands extend in opposite directions, *i.e.*, are antiparallel and complimentary. The following fundamental relationship exist.

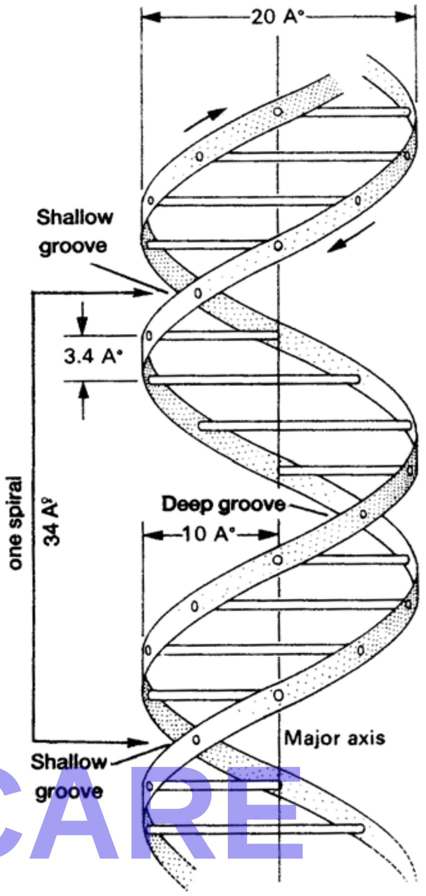


Fig : Helical structure of DNA as suggested by Watson and Crick

Note : ✹ *Thymine combines only with deoxyribose sugar and uracil only with ribose sugar. Other bases can combine with either of the two sugars.*

- *The sum of purines equals the sum of pyrimidines.*
- *The molar proportion of adenine equals to that of thymine.*
- *The molar proportion of guanine equals to that of cytosine.*

✹*The double helix is 20 Å. It completes a spiral at every 10 nucleotide pairs at a length of 34 Å. Sequences of monomers (nucleotides) may present innumerable variations. Evidently, innumerable varities of DNA exist in the organism.*

✹***Watson, Crick and Witkins were awarded Noble prize in 1962*** *for suggesting the structure of DNA.*

Difference between DNA and RNA

DNA	RNA
It has a double helix structure.	**It has a single helix structure.**
Sugar unit is deoxyribose.	**Sugar unit is Ribose.**
Base units are adanine, guanine, thyamine and cytosine.	**It contains uracil base instead of thyamine, other bases being same as those in DNA.**
Responsible for inheritance of character.	**It is responsible for protein synthesis.**

(3) **Functions of nucleic acid :** Nucleic acid have two important functions

(i) Replication and (ii) Protein synthesis.

(i) ***Replication*** **:** The genetic information for the cell is contained in the sequence of the bases A, T, G and C (adenine, thymine, guanine and cytosine) in the DNA molecule. The sequence of bases in one chain of the double helix controls the sequence in other chain. The two chains fit together like a hand and a glove. They separate and about the hand is formed a new glove, and inside the glove is formed a new hand. Thus, the pattern is preserved in the two new molecules of DNA.

[If one strand of DNA has the sequence ATGCTTGA, then the sequence of complimentary strand will be TACGAACT].

(ii) ***Synthesis of proteins*** **:** The DNA contains the genetic code and directs protein synthesis through RNA. The double helix of DNA partially uncoils and about the individual strands are formed chains of RNA. The new chains contain ribose instead of deoxyribose and the base sequence is different which is determined by DNA, *i.e.*, opposite each adenine of DNA, there appears on RNA a uracil; opposite guanine, cytosine; opposite thymine, adenine, opposite cytosine, guanine. Thus, AATCAGTT on DNA becomes UUAGUCAA on RNA.

One kind of RNA, called messenger RNA, carries a message to the ribosome, where protein synthesis actually takes place. At the ribosome, messenger RNA calls up a series of transport RNA molecules, each of which is loaded with a particular amino acid. The order in which the transport RNA molecules are called (–the sequence in which the amino acids are arranged to form the protein chain) depends upon the sequence of bases along the messenger RNA chain. Thus GAU is the code for aspartic acid; UUU, phenyl alanine; GUG, valine. There are 64-three letter code words (codons) and only 20-odd amino acids, so that more than one codon call the same amino acid.

The relation between the nucleotide triplets and the amino acids is called Genetic code. Nirenberg, Hollay and Khorana presented the genetic code for which they were awarded Noble prize in 1968.

(4) **Mutation :** A mutation is a chemical or physical change that alters the sequence of bases in DNA molecule. Anything that causes mutation is called **mutagen**. A mutation results from ultraviolet light, ionisation radiations, chemicals or viruses. The changes in sequence of bases in DNA are repaired by special enzymes in the cell. If it is not, the protein produced has no biological activity and the cell dies.

These mutations often prove harmful and give rise to symptoms that cause diseases. Sickle-cell anaemia is one such example. Such disease is passed on from one generation to the next generation.

Lipids.

Lipids are constituents of plants and tissues which are insoluble in water but soluble in organic solvents such as chloroform, carbon tetrachloride, ether or benzene. They include a large variety of compounds of varying structures such as oils and fats; phospholipids, steroids, etc. Lipids are mainly made of carbon, hydrogen and oxygen. The number of oxygen atoms in a lipid molecule is always small as compared to the number of carbon atoms. Sometimes small amounts of phosphorus, nitrogen and sulphur are also present. They have a major portion of their structure like a hydrocarbon (aliphatic or fused carbon rings). Lipids serve as energy reserve for use in metabolism and as a major structural material in cell membranes for regulating the activities of cell and tissues.

Simple lipids are esters of glycerol with long chain monocarboxylic acids which can be saturated or unsaturated. These are generally called glycerides of fats and oils. Waxes are esters of fatty acids with certain alcohols, not glycerol. Fats and oils have biological importance but waxes have no value as these are not digested.

The functions of triglycerides are the following

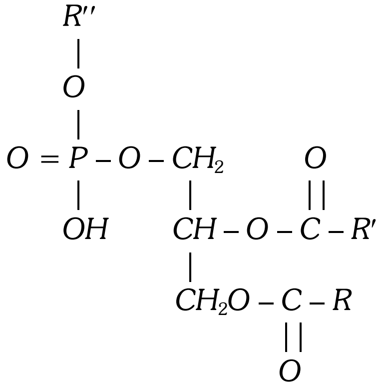
(1) They are energy reserves in the cells and tissues of living system. When digested, triglycerides are hydrolysed to fatty acids and glycerol.

(2) Catabolism of fatty acids form acetyl-coenzyme-A. Most of the energy of fatty acids is converted into ATP.

(3) Acetyl coenzyme is the starting material for the synthesis of many compounds.

(4) Fats deposited beneath the skin and around the internal organs minimise loss of body heat and also act as cushions to absorb mechanical impacts.

Another very important class of lipids are the phospholipids. These are polar lipids and like the fats, are esters of glycerol. In this case, however, only two fatty acid molecules are esterified to glycerol, at the first and second carbon atom. The remaining end position of the glycerol is esterified to a molecule of phosphoric acid, which in turn is also esterified to another alcohol. This gives a general structure.



The alcoholic compound linked to phosphoric group may be choline, ethanol, amine, serine or inositol. The phosphate groups forms a polar end, *i.e.*, hydrophilic (water-attracting) and the two fatty acid chains constitute the non-polar tail, *i.e.*, hydrophobic (water repelling). This structure gives the phospholipids good emulsifying and membrane forming properties.

Cell membranes are composed of phopholipids and proteins in about equal, proportion. The phospholipids in the membrane appear to be arranged in a double layer or bilayer in which the non-polar tails face each other, thereby exposing the polar heads to the aqueous environment on either side of the membrane. Proteins found in the membrane are embedded in the mossaic formed by the lipids. Phospholipids facilitate the transport of ions and molecules in and out of the cell and regulate the concentration of molecules and ions within the cell. They provide structural support for certain proteins.

The above mentioned lipids are mainly straight chain compounds. There is a third class of lipids which are not straight chain compounds. They are called **Sterols**. The sterols are composed of fused hydrocarbon rings and a long hydrocarbon side chain. Cholestrol is most important compound of this class and is found in animals only. It exists either free or as ester with a fatty acid. Cholestrol is also the precursor of hormones. Cholestrol and its esters are insoluble in water. So they are deposited in the arteries and veins if the blood cholestrol rises. This leads to high blood pressure and heart diseases. Cholestrol is a part of animal cell membrane and is used to synthesis steroid hormones, vitamin-*D* and bile salts.

Energy cycle or metabolism.

A cell has small molecules (micromolecules) as well as large molecules (macromolecules). The chemical reactions of a living organism can be divided into main two types

(1) *The chemical reactions by which the large molecules are constantly broken down into smaller ones* are called **catabolism**.

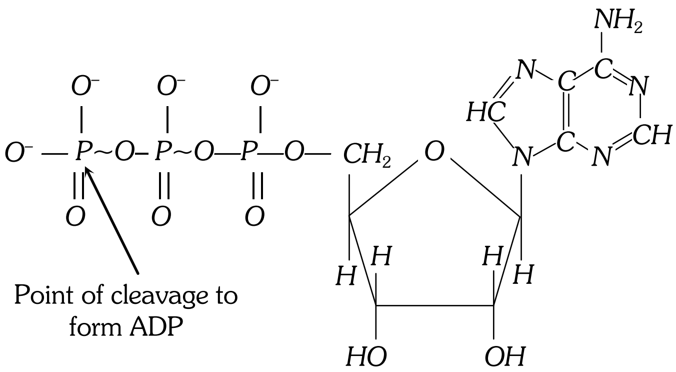
(2) *The chemical reactions by which the macromolecules are synthesised within the cell* are called **anabolism**.

The two processes *i.e.*, degradation and synthesis are collectively called **metabolism**. Catabolism reactions are usually accompanied by *release of energy* whereas anabolism reactions require energy to occur.

The primary energy found in living cells is chemical energy, which can be easily stored, transferred and transformed. For this, the living cells contain a chemical compound called **adenosine triphosphate** (ATP). It is regarded as **energy currency** of living cells because it can trap, store and release small packets of energy with ease.

ATP consists of a purine base called **adenine** linked to a five carbon sugar named **ribose** which is further attached to **three molecules of phosphate.**

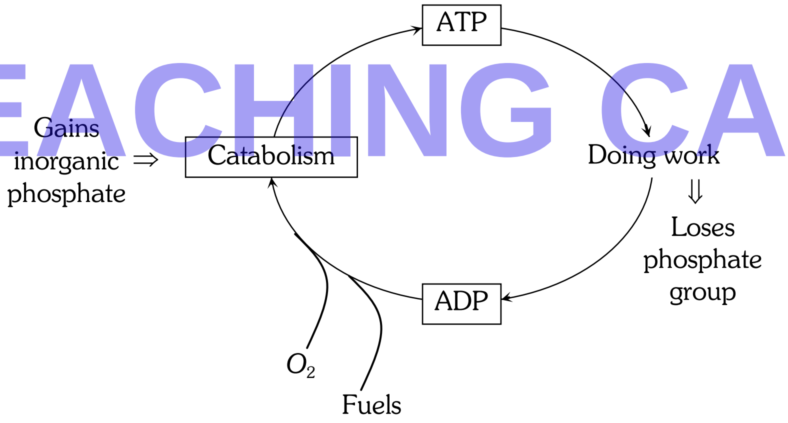
ATP is energy rich molecule, this is because of the presence of four negatively charged oxygen atom very close to each other. These four negatively charged o-atoms experience very high repulsive energy.



$$ATP \xrightarrow{\text{Hydrolysis}} \underset{\substack{\text{Adenosine}\\\text{diphosphate}}}{ADP} + Pi \qquad \Delta H = -30.93\ kJ\ mol^{-1}$$

$$ADP \xrightarrow{\text{Hydrolysis}} \underset{\substack{\text{Adenosine}\\\textit{monophosphate}}}{AMP} + 2Pi \qquad \Delta H = -28.4\ kJ\ mol^{-1}$$

ADP can change to ATP in the presence of inoraganic phosphate. This process is called **phosphorylation**.



Digestion of food.

Digestion is the process by which complex constituents of food are broken down into simple molecules by a number of enzymes in mouth, stomach and small intestine. The simple molecules thus formed are absorbed into blood stream and reach various organs.

Raw food may be taken as such or after cooking. It is chewed in the mouth and swallowed when it passes through a long passage in the body called alimentary canal. During this passage it gets mixed with various enzymes in different parts of the alimentary canal. The carbohydrates, proteins and fats are converted into simpler forms which are then carried by blood to different parts of the body for utilisation. Digestion of food can be summarised in the following form

(1) $\text{Polysaccharide} \xrightarrow[\left(\substack{\text{Saliva (mouth);}\\\text{Pancreatic juice}\\\text{(Intestine)}}\right)]{\text{Amylase}} \text{Disaccharides (maltose, etc.)} \xrightarrow[\text{(Intestine)}]{\text{Maltase}} \text{Glucose}$

(2) $\text{Proteins} \xrightarrow[\text{(Stomach)}]{\text{Pepsin}/HCl} \text{Proteases and Peptones} \xrightarrow[\left(\substack{\text{Chemotrypsin}\\\text{Pancreatic juice}\\\text{(Intestine)}}\right)]{\text{Trypsin}} \text{Peptides} \xrightarrow[\text{(Intestine)}]{\text{Peptidases}} \text{Amino acids}$

(3) $\text{Fats} \xrightarrow[\text{(From liver)}]{\text{Bile salts}} \text{Emulsified fat} \xrightarrow[\left(\substack{\text{Pancreatic and} \\ \text{intestine juice}}\right)]{\text{Lipases}} \text{Fatty acids} + \text{Glycerol}$

After digestion, there are present glucose, aminoacids, fatty acids along with vitamins and mineral salts. Undigested food and secretions are pushed forward into the rectum from where these are excreted.

Vitamins.

In addition to air, water, carbohydrates, proteins, fats and mineral salts, certain organic substances required for regulating some of the body processes and preventing certain diseases are called **vitamins**. These compounds cannot be synthesised by an organism. These vitamins are required in small amounts and deficiency of any one causes one disease or the other. Thus, vitamins are essential constituents of our diet. Several of these vitamins are known and are designated as A, B, C, D, E and so on. Many of these are now synthesised on commercial scale. On the basis of solubility, the vitamins are divided into two groups.

(1) Fat soluble; Vitamin A, D, E and K. (2) Water soluble; Vitamin B and C.

Name	***Sources***	***Functions***	***Effects of defficiency***
Water soluble vitamins			
B_1 **(Thiamine or Aneurin)** **($C_{12}H_{18}N_4SOCl_2$)**	**Rice polishings, wheat flour, oat meal, eggs, yeast, meat, liver, etc.**	**Major component of co-enzyme co-carboxylase required for carbohydrate and amino acid metabolism.**	**Beri-beri, loss of appetite and vigour, constipation, weak heart beat, muscle atrophy, even paralysis.**
B_2 or G **(Riboflavin or Lactoflavin)** **($C_{17}H_{20}N_4O_6$)**	**Cheese, eggs, yeast, tomatoes, green vegetables, liver, meat, cereals, etc.**	**Combines with phosphoric acid to form coenzyme FAD essential for oxidative metabolism.**	**Cheilosis, digestive disorders, burning sensations in skin and eyes, headache, mental depession, scaly dermatitis at angles of nares, corneal opacity, etc.**
B_3 **(Pantothenic acid)** **($C_9H_{17}O_5N$)**	**All food; more in yeast, liver, kidneys, eggs, meat, milk, sugarcane, groundnut, tomatoes.**	**Important component of Co-A required for oxidative metabolism.**	**Dermatitis, in cocks; greying of hairs, retarded body and mental growth, reproductive debility.**
B_5 or P-P **(Nicotinic acid or Niacin)** **$C_6H_5NO_2$ (C_5H_4N–COOH)**	**Fresh meat, liver, fish, cereals, milk, pulses, yeast, etc.**	**Active group in coenzyme NAD required for oxidative metabolism.**	**Pellagra, dermatitis, diarrhoea, demenia, muscle atrophy, inflammation of mucous membrane of gut.**
B_6 **(Pyridoxine or Adermin)** **($C_8H_{11}O_3N$)**	**Milk, cereals, fish, meat, liver, yeast synthesised by intestinal bacteria.**	**Important coenzyme required in protein and amino acid metabolism.**	**Dermatitis, anaemia, convulsions, nausea, insomnia, vomiting, mental disorders, depressed appetite.**
Vit. H (Biotin) **($C_{10}H_{16}N_2O_3S$)**	**Yeast, vegetables, fruits, wheat, chocolate, eggs, groundnut synthesised by**	**Essential for fat synthesis and energy production.**	**Skin lesions, loss of appetite, weakness, hairfall, paralysis.**

	intestinal bacteria.		
Folic acid group	**Green vegetables, soyabean, yeast, kidneys, liver, synthesised by intestinal bacteria.**	**Essential for synthesis of DNA and maturation of blood corpuscles.**	**Retarded growth, anaemia.**
B_{12} (Cyanocobalamine) ($C_{63}H_{88}O_{14}N_{14}PCo$)	**Meat, fish, liver, eggs, milk synthesised by intestinal bacteria.**	**Required for chromosome duplication and formation of blood corpuscles.**	**Retarded growth, pernicious anaemia**
Vit. C (Ascorbic acid) (CH_8O_6)	**Lemon, orange and other cirtus fruits, tomatoes, green vegetables, potatoes, carrots, pepper, etc.**	**Essential for formation of collagen, cartilage, bone, teeth, connective tissue and RBCs and for iron metabolism.**	**Wound-healing and growth retarded, scurvy, breakdown of immune defence system, spongy and bleeding gums, fragile blood vessels and bones, exhaustion, nervous breakdown, high fever.**
Fat soluble vitamins			
Vit. A (Retinol or Axerophthol) ($C_{20}H_{30}O$)	**Synthesised in cells of liver and intestinal mucous membrane from carotenoid pigments found in milk, butter, kidneys, egg yolk, liver, fish oil, etc.**	**Essential for synthesis of visual pigments; growth and division of epithelial cells.**	**Xerophthalmia-keratinized conjunctive and opaque and soft cornea. Stratification and keratinization in epithelia of skin, respiratory passages, urinary bladder, ureters and intestinal mucosa, night-blindness, impaired growth, glandular secretion and reproduction.**
Vit. D (Ergocalciferol), (Sun shine vitamin) $C_{28}H_{44}O$ and cholecalciferol	**Synthesised in skin cells in sunlight from 7-dehydro-cholesterol also found in butter, liver, kidneys, egg yolk, fish oil, etc.**	**Regulates absorption of calcium and phosphorus in intestine, mineral deposition in bones and teeth.**	**Rickets with osteomalacia; soft and fragile teeth.**
Vit. E group Tocopherols (α, β, γ) ($C_{29}G_{50}O_2$)	**Green vegetables, oil, egg yolk, wheat, animal tissues.**	**Essential for proper spermatogenesis, pregnancy, lactation and muscular function.**	**Sterility (impotency) and muscular atrophy.**
Vit. K (Phylloquinone) ($C_{31}H_{46}O_2$)	**Carrots, lettuce, cabbage, tomatoes, liver, egg yolk, cheese; synthesized by colon bacteria.**	**Essential for synthesis of prothrombin in liver, which is required for blood clotting.**	**Haemorrhages, excessive bleeding in injury, poor coagulation of blood.**

Hormones.

Harmones are the chemical substances secreated by duetless glands, which influence and control biological reactions. Some important harmones alongwith their source and function are being given below.

Hormone	*Source*	*Functions*
Steroid hormones		
Testosterone (Androgens)	**Testis**	**Regulates development of reproductive male organs.**
Estrogene and progesterons	**Ovary (Uterus)**	**Female sex hormones : control normal functioning of female sex organs.**
Cortisone and related hormones	**Adrenal cortex**	**Regulates the metabolism of fats, proteins, carbohydrates and mineral salts.**
Amine hormones		
Adrenalino (Epinephrine)	**Adrenal medulla**	**Increase the pulse rate and blood pressure : reduces glucose from glycogen and fatty acids from fats.**
Thyroxine	**Thyroid**	**Stimulates rate of oxidative metabolism and regulates general growth and development.**
Peptide hormones		
Oxytocino	**Posterior pituitary**	**Causes contraction of some smooth muscle. Also causes contraction of uterus during child birth.**
Vasopressin	**Posterior pituitary**	**Inhibits excretion of water from the body by way of urine.**
Insulin	**Pancreas**	**Decrease blood glucose level.**
Glucogen	**Pancreas**	**Elevates blood glucose level.**

Product	*Applications*
Human insulin hormone	**Treatment of diabetes**
Interferon	**Antiviral agent**
Growth hormones	**Treatment of abnormal growth related diseases**
Tissue plasminogen factor	**Dissolving unwanted blood clots**
Blood clotting factor VIII	**Treatment of haemophilias**
Vaccines	**Against various infective diseases**