2 CHAPTER

PROTEINS AND NUCLEIC ACIDS

Objectives

- Amino Acids
- Nucleic Acids
- Proteins
- Vitamins and Hormones

PROTEINS

2.1.1 Amino acids

Amino acids are the bifunctional organic molecules containing both amino group and carboxyl group in the same compound.

Basing on the position of amino group, the simple amino acids are classified as $\alpha-, \beta-, \gamma-, \delta-$, etc.

Proteins upon hydrolysis give α –amino acids

There are more than 700 different amino acids known to occur naturally. Out of these amino acids, 229 are α –amino acids, but a group of 20 of them are very important. When proteins are hydrolysed, only α –amino acids are obtained. Proteins may contain other functional groups also.

The general formula of α –amino acids is $H_2N{-}\underset{\displaystyle R}{\underset{|}{CH}}{-}COOH$

Examples for α –amino acids are :

$H_2N{-}\underset{\alpha}{CH_2}{-}COOH$ Glycine

$H_2N{-}\underset{\alpha}{\overset{\displaystyle CH_3}{\overset{|}{CH}}}{-}COOH$ Alanine

Examples for β –amino acids are :

$H_2N{-}\overset{\beta}{CH_2}{-}\overset{\alpha}{CH_2}{-}COOH$ β –amino propionic acid

$H_2N{-}\underset{\beta}{\overset{\displaystyle CH_3}{\overset{|}{CH}}}{-}\underset{\alpha}{CH_2}{-}COOH$ β –amino butyric acid

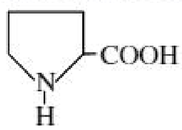
Examples for γ –amino acids are :

$H_2N{-}\overset{\gamma}{CH_2}{-}\overset{\beta}{CH_2}{-}\overset{\alpha}{CH_2}{-}COOH$ γ – amino butyric acid

$H_2N{-}\underset{\gamma}{\overset{\displaystyle CH_3}{\overset{|}{CH}}}{-}\underset{\beta}{CH_2}{-}\underset{\alpha}{CH_2}{-}COOH$ γ – amino pentanoic acid

Proline contains secondary amino group

Out of numerous amino acids, α – amino acids contain primary amino group except proline which contains secondary amino group.



(Proline)

The amino acids containing equal number of $-NH_2$ and –COOH groups are called neutral amino acids. If amino groups are more, it is basic and if carboxyl groups are more, it is acidic in nature. Twenty α – amino acids are classified into four types and are listed in Table 2.1. Structural formulae of all the twenty α – amino acids are given in Fig 2.1.

Table 2.1 List of twenty α – amino acids

Type	Name	Abbreviation	Type	Name	Abbreviation
A) With non-polar side chain	1. Glycine	Gly (or) G	B) With polar, unionised side chains	1. Asparagine	Asn (or) N
	2. Alanine	Ala (or) A		2. Glutamine	Gln (or) Q
	3. Valine*	Val (or) V		3. Serine	Ser (or) S
	4. Leucine*	Leu (or) L		4. Threonine*	Thr (or) T
	5. Isoleucine*	Ile (or) I		5. Cysteine	Cys (or) C
	6. Methionine*	Met (M)		6. Tyrosine	Tyr (or) Y
	7. Proline	Pro (or) P	D) With basic side chains	1. Lysine*	Lys (or) K
	8. Phenylalanine*	Phe (or) F		2. Arginine*	Arg (or) R
	9. Tryptophan*	Trp (or) W		3. Histidine*	His (or) H
C) With acid side chains	1. Aspartic acid	Asp (or) D	* denotes essential amino acids		
	2. Glutamic acid	Glu (or) E			

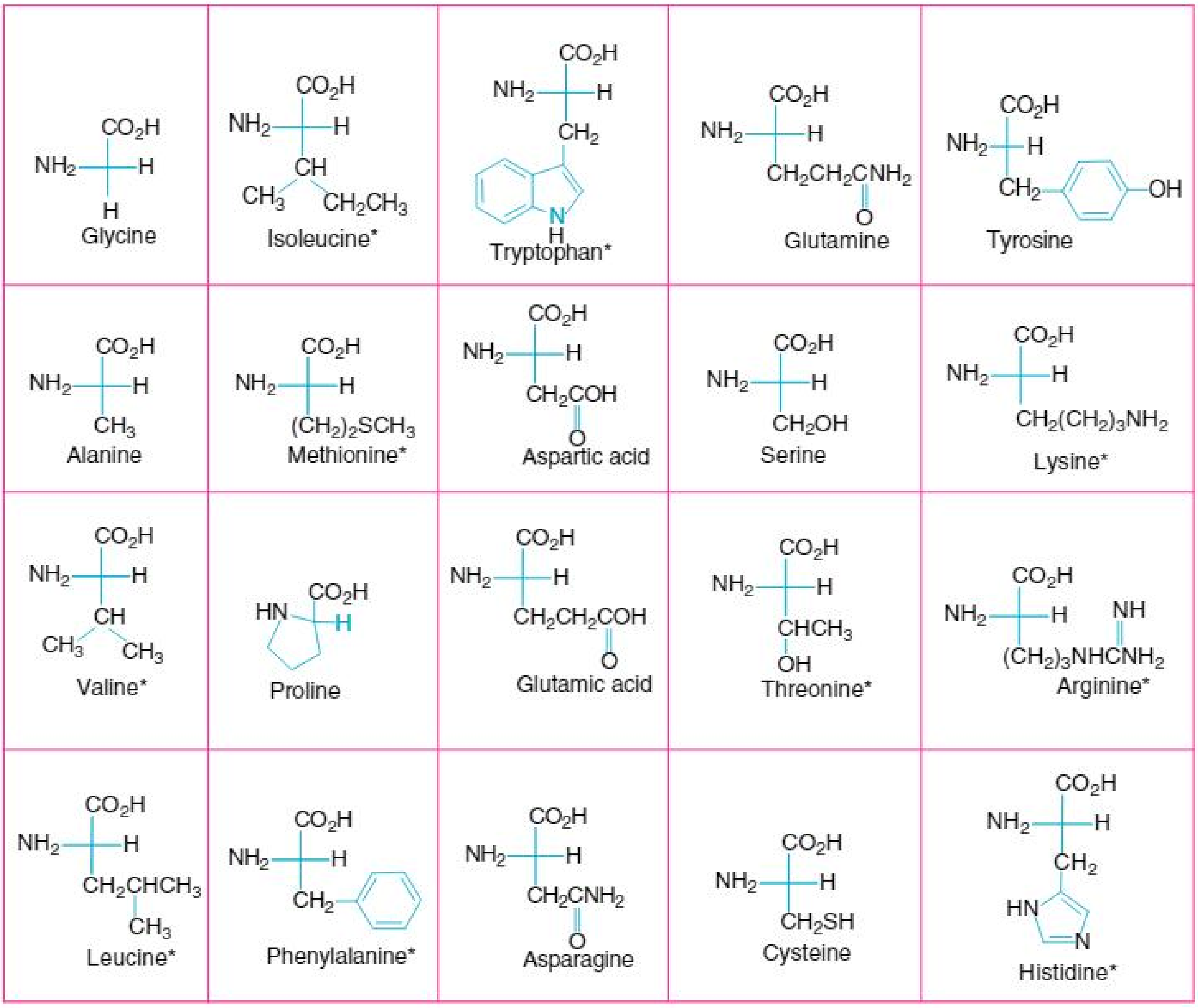


Fig 2.1 Structures of α – amino acids

The amino acids which are synthesised in the body are called non–essential amino acids. The amino acids which are not synthesised by the body but must be supplied through the food are called essential amino acids. The essential amino acids are 10 in number. They are:

1) Valine 2) Leucine 3) Isoleucine 4) Arginine
5) Lysine 6) Threonine 7) Histidine 8) Methionine
9) Phenylalanine and 10) Tryptophan

Properties of α – amino acids

The simplest amino acid is glycine. Glycine does not contain a chiral carbon. Except glycine, all other naturally occuring α – amino acids are optically active due to chiral carbon. Most of the naturally occurring amino acids have L– configuration.

Proton transfer from –COOH group to $-NH_2$ group forms a zwitter ion

Amino acids are amphoteric, since they exist as cations or as anions. The proton from –COOH group transfers to $-NH_2$ group to form both anion and cation within the same molecule, which is called zwitter ion (or) dipolar ion. It is also called inner salt.

$$H_2N-\underset{\displaystyle R}{\underset{|}{C}}H-COOH \rightleftharpoons H_3\overset{+}{N}-\underset{\displaystyle R}{\underset{|}{C}}H-CO\overset{-}{O}$$

Amino acids exist as cations in acidic medium and anions in basic medium.

$$\underset{\text{Cation}}{H_3\overset{+}{N}-\underset{\displaystyle R}{\underset{|}{C}}H-COOH} \xleftarrow[\text{acid}]{H^+} \underset{\text{Zwitter ion}}{H_3\overset{+}{N}-\underset{\displaystyle R}{\underset{|}{C}}H-CO\overset{-}{O}} \xrightarrow[\text{base}]{OH^-} \underset{\text{Anion}}{H_2N-\underset{\displaystyle R}{\underset{|}{C}}H-CO\overset{-}{O}}$$

At a particular pH the zwitter ion behaves like neutral species and will not migrate towards any electrode, called as isoelectric point. Its value depends on the groups present in the side chain of α – amino acid. For the neutral amino acids, the pH range is 5.5–6.3. Generally the solubility of α – amino acids is least at isoelectric point. So they can be separated easily at this point during hydrolysis of proteins.

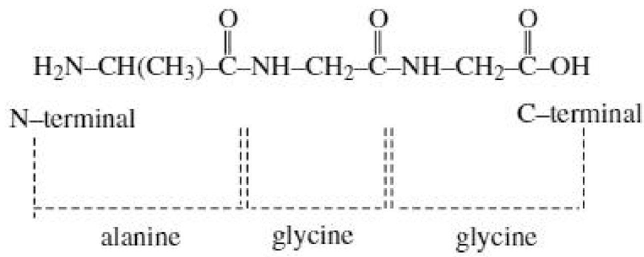
2.1.2 Proteins

Proteins are natural polypeptides

The amide bond formed between the amino group of one amino acid and the carboxylic group of another amino acid by the loss of water is called a peptide bond (–CO–NH–). Dipeptides are made from two amino acids linked by one peptide linkage. Tripeptides are made from three amino acids which may be same or different amino acids. If four to ten amino acid residues are present, the peptide is called oligopeptide. Polypeptides are called proteins.

Generally proteins are naturally occurring polypeptides containing more than 100 amino acids having molecular mass higher than 10,000u. eg: silk, hair, skin, enzymes, hormones, etc.

In writing the formula of the peptides, N–terminal amino acid containing free $-NH_2$ group must be written on the left side and the C–terminal amino acid containing free –COOH group must be written on the right side. The amino acids in a peptide chain are named from left to right by replacing –ine with –yl, except for the C– terminal amino acid. Instead of writing full name of amino acid in a polypeptide, it is most convenient to use three letter abbreviation.



The above tripeptide is named as alanylglycylglycine (or) ala–gly–gly.

The number of peptides possible for using different amino acids = x^y.

Number of tri-peptides possible for 3 amino acids is 27

Here x is number of amino acids, y is 2 for dipeptide, 3 for tripeptide, 4 for tetrapeptide, etc. For example, the number of tripeptides possible with 3 amino acids is $3^3 = 27$. A protein containing 50 amino acid units can be produced using 20 amino acids in 20^{50} ways.

Proteins can be classified into two types on the basis of their molecular shape.

Fibrous proteins : When the polypeptide chains run parallel and are held together by hydrogen and disulphide bonds, then fibre-like structure is formed. Such proteins are generally insoluble in water. Some common examples are keratin (present in hair, wool, silk) and myosin (present in muscles), etc.

Globular proteins : This structure results when the chains of polypeptides coil around to give a spherical shape. These are usually soluble in water. Insulin and albumins are the common examples of globular proteins.

Protein structure is explained with different modes of stabilisation

Protein structure can be explained by considering primary, secondary, tertiary and quaternary structures with different modes of stabilisation.

Primary structure : Each protein has one or more polypetide chains. Each polypetide in a protein has amino acid linked with each other in a specific sequence. Primary structure of protein gives this sequence of amino acids. Change in the primary structure gives a different protein.

Secondary structure : The shape in which a long polypetide chain can exist is denoted by secondary structure. Two different secondary structures of proteins are: α – helix and β – pleated sheet structure. The free rotation of peptide chain is possible only around C–C bond joining amide group to α –carbon atom.

Hydrogen bonds exist between –NH– and –CO– groups of polypetide chain. Maximum possible stability of α –helix is due to the number of hydrogen bonds in a polypetide chain. α –Helix is also known as 3.6_{13} helix. In each turn of α –helix, 3.6 amino acid residues on an average are present and a 13 membered chelate ring is formed by hydrogen bonding with L–configuration of polypeptide.

β –Pleated sheet has the peptide chains completely stretched and then put together. Hydrogen bonds are present between polypeptide chains. The stretched peptides may be arranged parallel to one another like in keratin of hair or antiparallel like in silk fibroin. α –Helix and conformations of β –pleated structures are shown in Fig 2.2 and Fig 2.3, respectively.

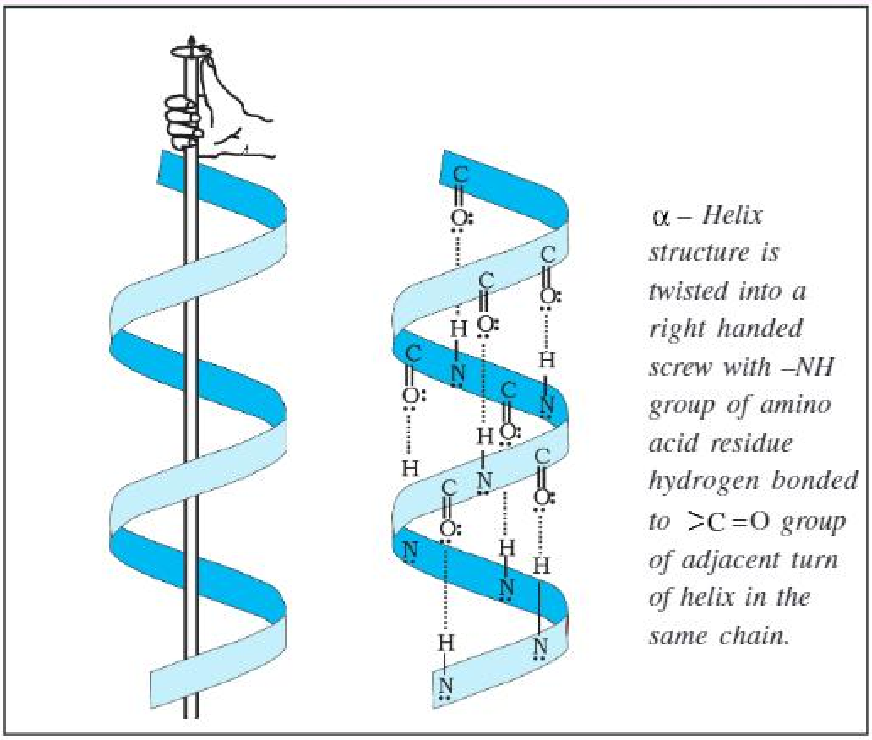


Fig 2.2 α – Helix structure of protein

α – Helix is one of the most common screw of polypeptide chain

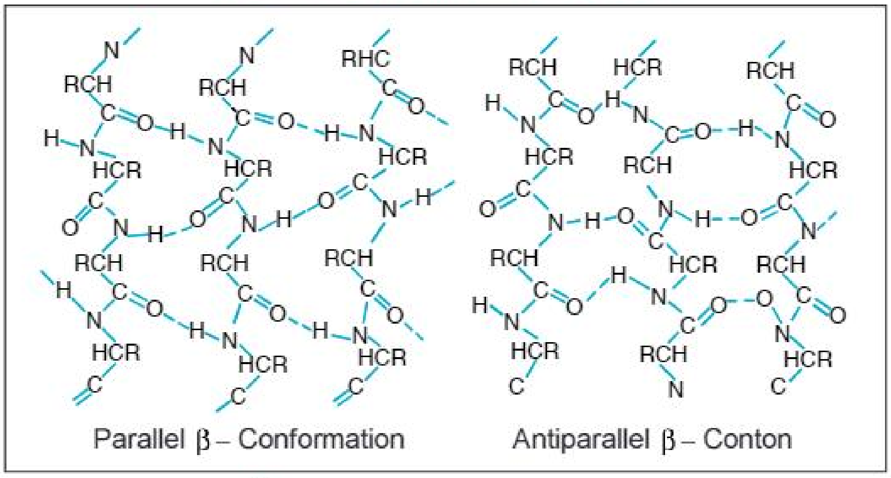


Fig 2.3 β – Pleated sheet structure of proteins

β –Pleated structure resembles the pleated folds of drapexy

Tertiary structure : The tertiary structure of proteins represents overall folding of the polypeptide chains, i.e., further folding of the secondary structure. Based on their molecular shape proteins are two types : fibrous proteins and globular proteins. Tertiary structure gives rise to these two molecular shapes. Overall folding of the polypeptide chain leads to globular structure. The extent of folding depends upon the ionic bonds, hydrogen bonds, disulphide linkages and hydrophobic interactions. Hydrophobic interactions are the attraction forces between alkyl groups of potyplides. These forces stabilise the tertiary structure of proteins. Different bonds, linkages and interactions of the tertiary structure of proteins are diagramatically represented in Fig 2.4.

Fibrous and globular are two types of tertiary

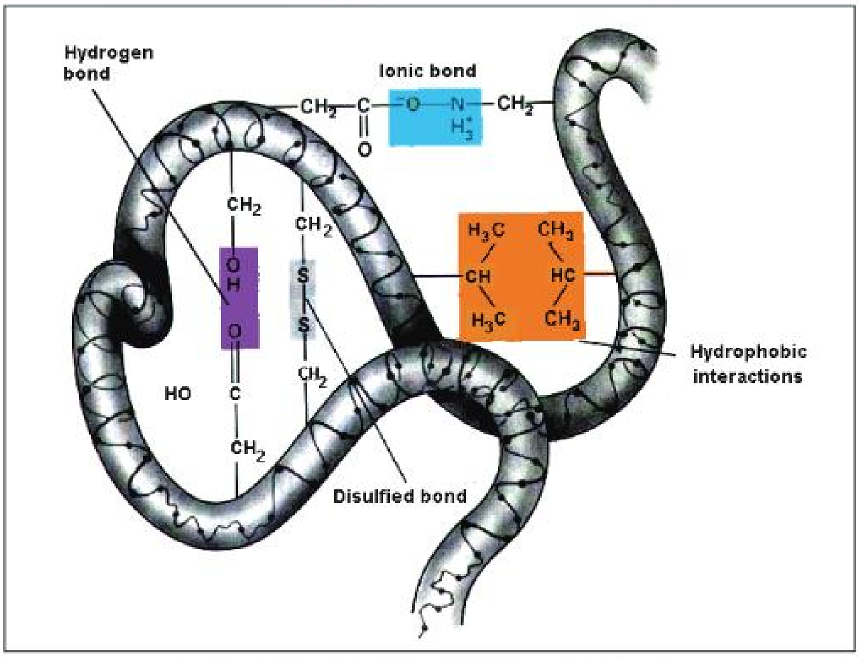


Fig 2.4 Tertiary structure stabilisation

Folding in tertiary structure is due to disulphide linkages

Oilgomers are proteins with two or more polypetide chains

Quaternary structure : Some proteins are composed of two or more polypeptide chains. These chains are called subunits and the proteins are called oligomers. These sub units form aggregates. The spatial arrangement of the sub-units relative to each other is known as quaternary structure. Two sub-units of two types in quaternary structure are shown diagrammatically in Fig 2.5.

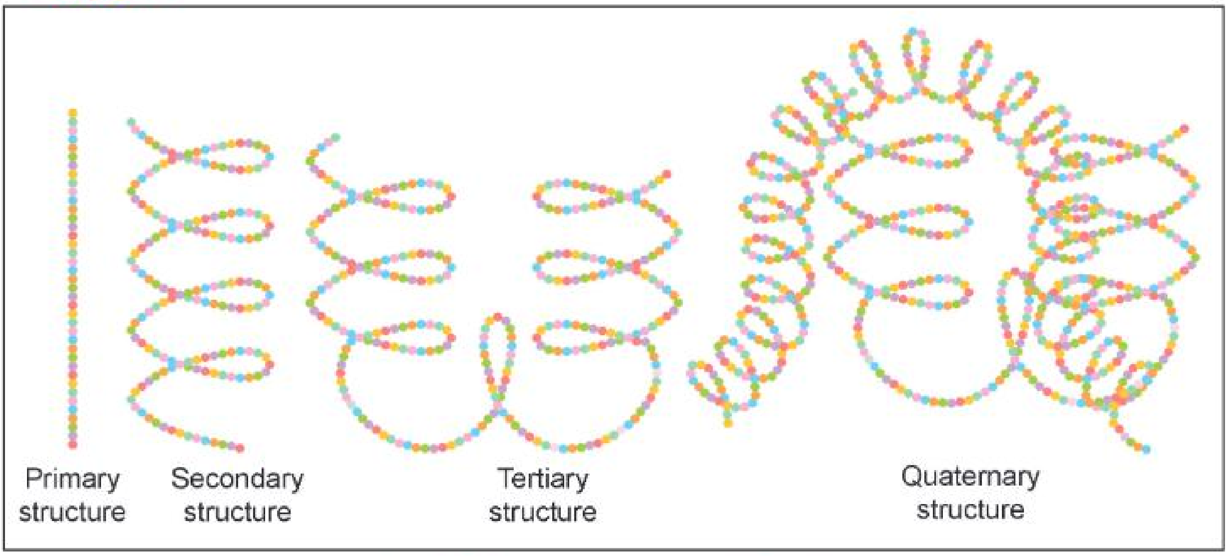


Fig 2.5 Tertiary structure stabilisation

The four structures of amino acids associated with the shape of proteins are diagramatically distinguished in Fig 2.6.

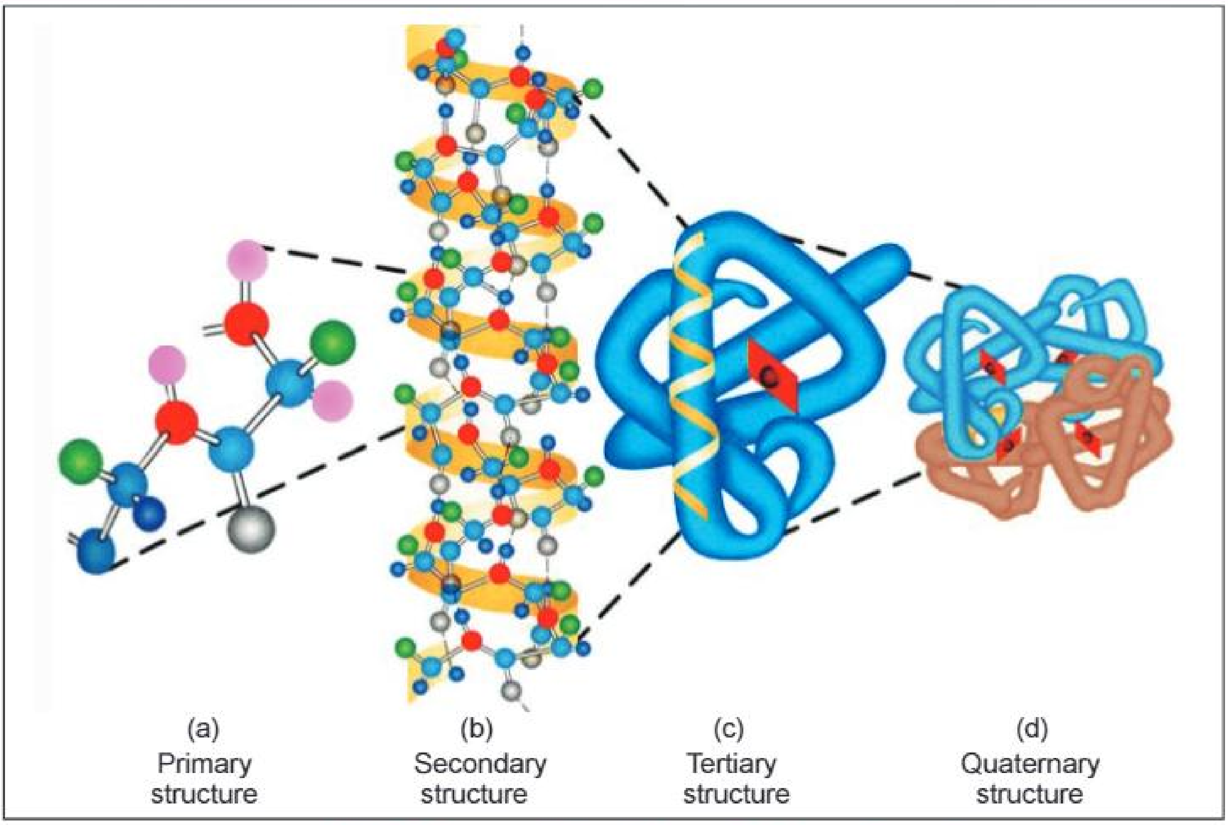


Fig 2.6 Representation of four structures of a protein

Breakdown of tertiary structure of protein is called denaturation

Denaturation of proteins : The highly organised tertiary structure of natural proteins is responsible for their biological activity. These structures are maintained by various attractive forces between different parts of the polypeptide chains. The breakdown of highly organised tertiary structure of protein and loss of its biological activity is called denaturation or unfold.

Proteins undergo denaturation most readily at its isoelectric point. During denaturation, secondary and tertiary structures are destroyed but primary structure remains intact.

Small changes in the environment can cause a chemical or conformational change resulting in denaturation. Proteins can be denaturated usually by:

a) Change in pH, which breaks down hydrogen bonds and electrostatic attractions.

b) Adding detergents which break down normal hydrophobic interactions among non–polar groups.

c) Adding reagents like urea forms stronger hydrogen bonds with proteins than the hydrogen bonds between the groups.

d) Heating or by agitation which breaks down attractive forces.

Reversal of denaturation is called refolding

Addition of organic solvents, addition of heavy metal ions and exposing to ultraviolet radiation are some other methods of protein denaturation. Denaturation may be reversible or irreversible. In irreversible denaturation the denatured protein does not return to its original shape. Cooking of an egg white gives a hard and rubbery insoluble mass due to irreversible denaturation. The reversal of denaturation is called renaturation or refolding.

2.1.3 Enzymes

Enzymes are globular conjugated proteins

All most all the enzymes are globular and are conjugated proteins. The enzymes act as specific catalysts in biological reactions. If once they are utilised in the reaction, they get deactivated in the further reaction such that they must be replaced by synthesis in the body. The mechanism of an enzyme as catalyst will be :

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

Here E is enzyme and S is substrate. They form a complex ES. ES transferms to an intermediate EI. EI changes to product EP, which finally gives the product P.

For the progress of a reaction, enzymes are needed only in small quantities. Enzymes reduce the magnitude of activation energy.

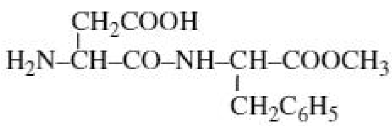
The non–protein component part associated with enzyme is called prosthetic group. The prosthetic group which is covalently bonded with enzyme is called cofactor. The enzymes which catalyse the oxidation of one substrate with simultaneous reduction of another substrate are named as oxidoreductase enzymes.

eg: The enzyme zymase converts glucose to ethyl alcohol.

Poisons : The plant venoms and most of poisonous substances in animals are proteins which are called poisons.

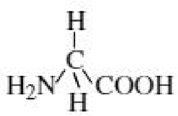
Aspartame is an ester of a dipeplide and is an artificial sweetner

Artificial sweetners : Aspartame, is a dipeptide and is 160 times sweeter than sucrose. Aspartame is named as aspartyl phenyl alanine methyl ester. Structure of aspartame is given as,



P.2.1 Glycine is optically inactive. Why?

Solution Glycine is denoted by the structural formula,



Glycine has no asymmetric carbon. Therefore it is optically inactive.

P.2.2 Melting points and water solubility of amino acids are greater than those of corresponding haloacids. Explain.

Solution Amino acids exist as linear salts. Salts have high melting point and higher solubility in water. Halo acids have only dipolar attracting.

P.2.3 Is it possible to get original egg after boiling?

Solution When an egg is boiled, the protein loses its biological activity due to disruption of hydrogen bonds among them leading to inversible denaturation.
So renaturation is impossible.

P.2.4 What is called a 3.6_{13} helix of protein?

Solution Secondary structure of proteins are two types : α – helix structure and β – pleated sheet structure.

A 3.6_{13} helix of protein is α – helical secondary structure.

Hydrogen bonds are presents within the same chain between –NH– and –CO– groups. These intramolecular hydrogen bonds stabilise the helix.

In each turn of helix, 3.6 amino acid residues are present on an average. A 13 membered chelate ring is formed due to intermolecular hydrogen bonding.

EXERCISE - 2.1.1

1. What are essential and non–essential amino acids?
2. Discuss the structure of proteins by considering different modes of stabilisation.
3. What is a peptide bond? How is the sequence of amino acids taken?
4. What is meant by denaturation and renaturation?

NUCLEIC ACIDS

2.2.1 Sugars and bases

Two kinds of nucleic acid are RNA and DNA

Chromosomes which are made up of proteins and another type of biomolecules called nucleic acids are the particles in nucleus of the cell which are responsible for heridity.

Nucleic acids are bipolymers of nucleotides with a polyphosphate ester chain. Nucleic acids combine with proteins to give nucleoproteins which are primary substances in living cells.

There are two kinds of nucleic acids : Ribonucleic acid (RNA) and deoxy ribonucleic acid (DNA).

The sequence of formation of nucleic acids is :

$$\text{(base)} + \text{(sugar)} \longrightarrow \text{(nucleoside)} \longrightarrow \text{(nucleotide)} \longrightarrow \text{(nucleic acid)}$$

Sugars : The two sugars present in nucleic acids are ribose and deoxyribose. These are aldopentose sugars and present in furanose form. Ribose is present in RNA and deoxyribose is present in DNA. Ribose and deoxyribose differ structurally (Fig 2.7) in terms of one oxygen atom on carbon at position-2.

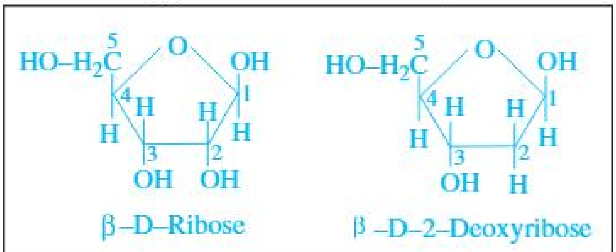


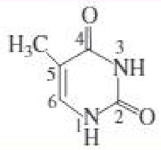
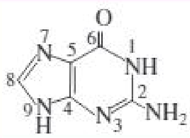
Fig 2.7 Structural difference between ribose and deoxyribose

Pyrimidine or purine bases are present in nucleic acids

Nitrogenous bases : The nitrogenous bases present in nucleic acids are the derivatives of pyrimidine or purine. The pyrimidine bases are cytosine, uracil and thymine. The purine bases are adenine and guanine. It is important to note that cytosine, adenine and guanine occur in both RNA and DNA. Uracil occurs only in RNA and thymine occurs only in DNA.

The purine bases are adenine and guanine. These bases are present both in RNA and DNA. Pyrimidine and purine bases and their structures are listed in Table 2.2.

Table 2.2 Structures and names of pyrimidine and purine bases

Base type	Name	Symbol	Structure	Systematic name of base
Pyrimidine	Cytosine	C		4–Amino–2–oxopyrimidine
Pyrimidine	Thymine	T		5–Methyl–2,4–dioxopyrimidine
Pyrimidine	Uracil	U		2,4–Dioxopyrimidine
Purine	Adenine	A		6–Aminopurine
Purine	Guanine	G		2–Amino–6–oxopurine

Nucleosides : Nucleosides are N–glycosides in which nitrogen of purine or pyrimidine is bonded to the anomeric carbon of the sugar molecule.

Nitrogenous base + sugar $\longrightarrow$ nucleoside.

In purine nucleosides, the C–1 of sugar is attached to N–9 of purines, but in pyrimidine nucleosides, the C–1 of sugar is attached to N–1 of the pyrimidines.

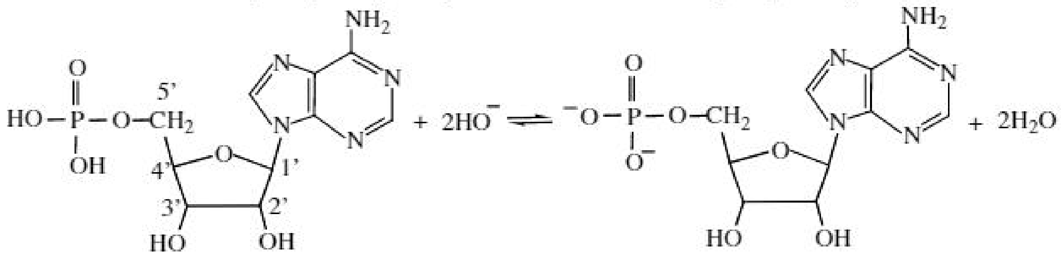
Nucleotide is phosphate of nucleoside

Nucleotides : Phosphoric acid esters of nucleosides are called nucleotides.

Nucleoside + phosphate $\longrightarrow$ Nucleotide.

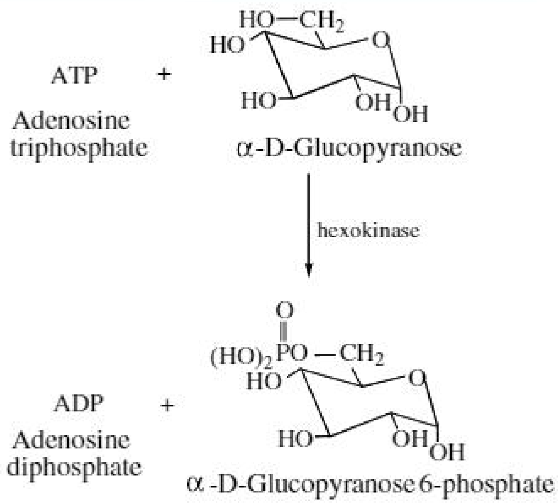
During the formation of nucleotide, the esterification takes place between –5'—OH group of sugar moiety and –OH group of phosphoric acid.

eg: Adenosine can form adenosine–5'–monophosphate (AMP), adenosine –5'– diphosphate (ADP) and adenosine –5'–triphosphate (ATP).



Adenosine 5'-monophosphate (AMP) Major species of at pH value nearly 7

ATP, ADP and AMP are natural nucleotides



The naturally occurring nucleotides are : ATP, ADP, AMP (adenosine derivatives), GTP (guanosine derivative) and UTP (uracil derivative).

2.2.2 Structures of DNA and RNA

Nucleic acids are polynucleotides. In RNA, the repeating units are ribonucleotides and in DNA, the repeating units are deoxyribonucleotides. Nucleotides are joined by phospho-diester linkage between the C–3'–oxygen of one nucleotide and the C–5'–oxygen of the next nucleotide. Always nucleotide sequences are written with the free 5'– end at the left and free 3'– end at the right. A trinucleotide sequence is written as ATG in Fig 2.8.

The structure of nucleic acids is discussed in the following two levels.

1^0 structure of nucleic acid gives the sequence of nucleotides

Primary structure : In the primary structure, the nucleotides are joined through phosphodiester bonds and should be written with free 5'–end at the left and free –3'–end at the right. It should be abbreviated by one letter code. It gives information regarding the sequence of nucleotides in the chain of a nucleic acid.

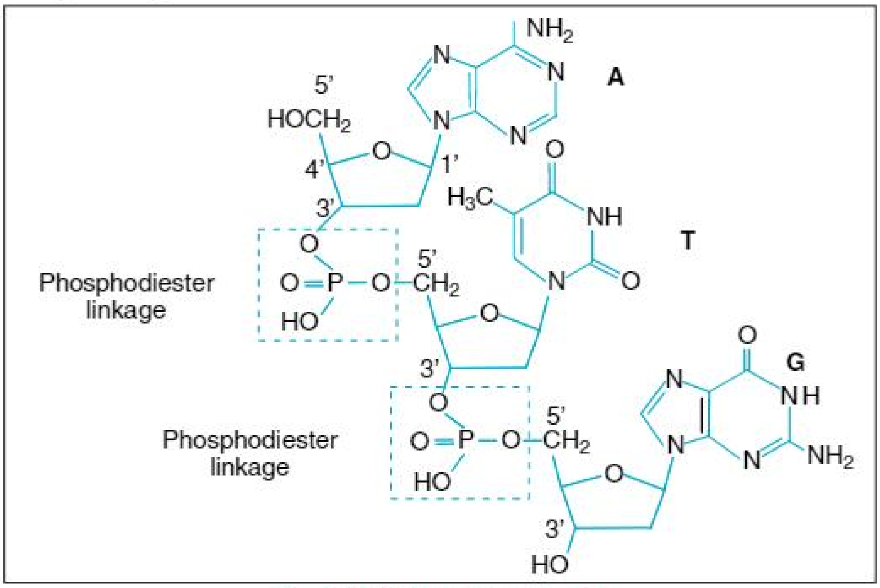


Fig 2.8 ATG, a trinucleotide

Structures of nucleic acids are usually given in two levels

Secondary structure or helical structure : In the secondary structure of RNA, it has single stranded helix (Fig 2.9), but in DNA, it has double stranded helix. RNA molecules are of three types called messenger RNA (m-RNA), ribosomal RNA (r-RNA) and transfer RNA(t-RNA).

Watson and Crick proposed double helical structure for DNA. According to X–ray crystallographic studies, DNA is composed of two polynucleotide chains running in opposite directions such that they are held by hydrogen bonding between nitrogenous base pairs.

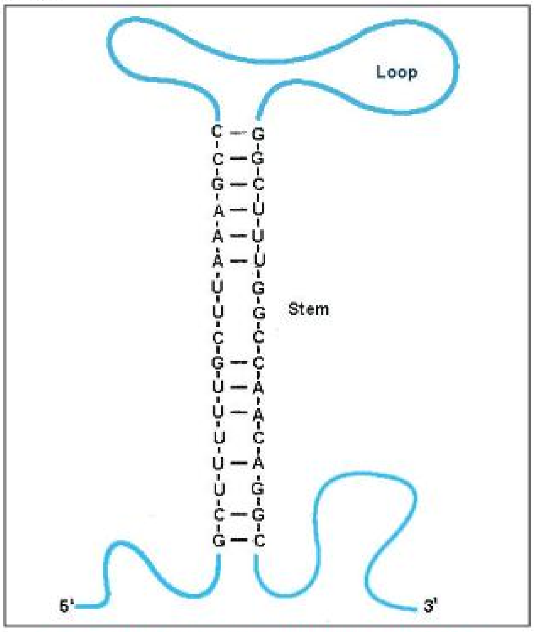


Fig 2.9 Hair pin structure of RNA

RNA has single strand

Adenine forms two hydrogen bonds with thymine but no hydrogen bond with cytosine. Guanine forms three hydrogen bonds with cytosine but only one hydrogen bond with thymine, as shown in Fig 2.10.

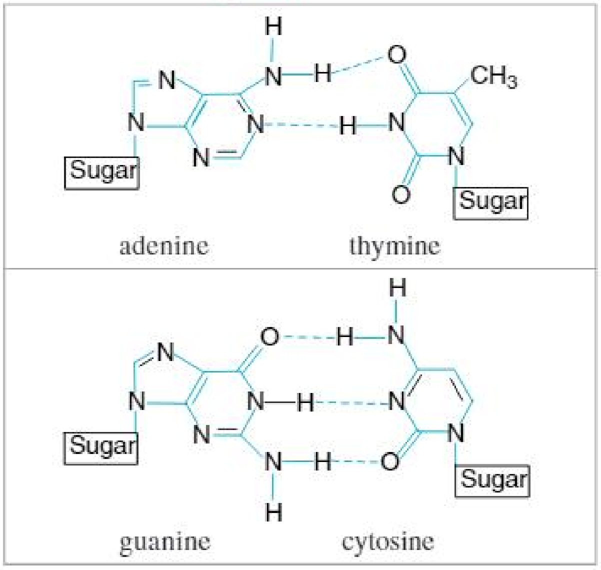


Fig 2.10 Hydrogen bonds of adenine with thymine and of guanine with cytosine

Adenine always pairs up with thymine and guanine pairs with cytosine to get maximum stability. All the hydrogen bonds are almost of same length. In DNA, the number of adenine bases is equal to that of thymine (A=T) and the number of cytosine bases is equal to that of guanine (C=G).

The total mole percent amounts of purines is equal to total amounts of pyrimidines (A + G = C + T). But $\left(\frac{A+T}{G+C}\right)$ ratio need not be always unity.

In human beings, $\frac{A+T}{G+C}$ ratio is 1.52 and in the bacteria, Escherichia coli, this ratio is only 0.93.

Base pairs are planar in DNA, though strands are twisted

The DNA strands are twisted into a helix, but base pairs are planar and parallel to each other on the inside of the helix. When the primary structure of nucleic acids tells us about the sequence of bases in the strand, the secondary structure gives the double helix. The double helix resembles a ladder with the base pairs as rungs. In addition to hydrogen bonds, other forces like hydrophobic interactions between stacked bases are also responsible for the stability of the double helix. Double helix structure of DNA is shown in Fig 2.11.

The diameter of the double helix is 2nm and the double helical structure repeats at interval of 3.4 nm (one complete turn). Though DNA helices can be both right handed and left handed, the β–conformation of DNA with right handed helices is more stable.

When DNA is heated, the strands separate out. This is called melting and the temperature where this occurs is called melting temperature which is specific for each specific sequence. Again on cooling, the strands hybridise.

DNA has double strand

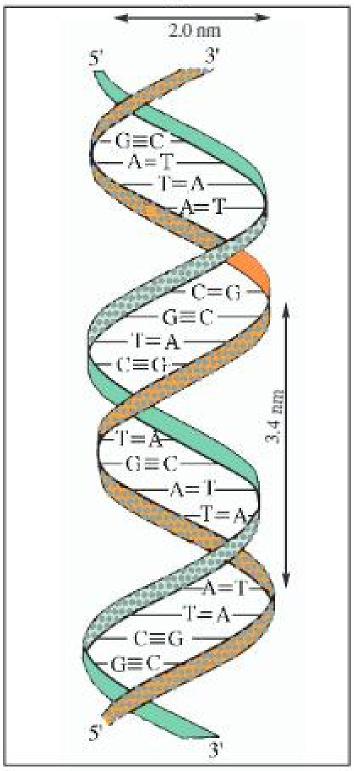


Fig 2.11 Double helix of DNA

2.2.3 Biological functions of DNA and RNA

The synthesis of identical copies of DNA is called replication or duplication of DNA. During the cell division, DNA is duplicated so that the DNA in the new cell is identical to the original DNA.

Replication of DNA is an enzyme catalysed process. In this process, the two strands of DNA starts unwinding at a particular region. Each strand of original DNA serves as template, on which a new daughter DNA is constructed due to complementary base pairing.

$$\text{DNA} \xrightarrow{\text{Replication}} \text{DNA}$$

$$\text{DNA} \underset{\text{Reverse transcription}}{\overset{\text{Transcription}}{\rightleftharpoons}} \text{m–RNA}$$

$$\text{m–RNA} \xrightarrow{\text{Translation}} \text{proteins.}$$

Three types of RNA are r–, m– and t– RNA

RNA : There are three types of ribonucleic acids.They are r-RNA, m-RNA and t-RNA. The synthesis of protein in the cell involves transcription and translation.

Transcription : Transcription is the synthesis of m–RNA from a DNA in cell nucleus. It resembles the DNA replication. DNA contains the sequences of bases called promotor sites. These promotor sites are bound to the enzyme which initiate m–RNA synthesis. The DNA at a promoter site is unwind to give single strands with bases. One of the strands is called sense strand or informational strand, but its complementary strand is called template or antisense strand. The template strand is in 3'–5' direction always.

Translation : The synthesis of a particular protein from m–RNA begining at its N–terminus in cytoplasm is called translation. A sequence of three bases, called codon specifies a particular amino acid that is to be incorporated into a protein. A codon is written with the 5'–nucleotide on the left. The amino acid specified by each three base sequence is called the genetic code.

Heridity and genetic code : The genetic code is the message carried by m–RNA and is made up of triplets of adjacent nucleotide bases called codons. The genetic code is universal, continuous and degenerate. The third base in the codon is not always specific. Nucleic acids control the heridity at the molecular level only. The genetic information of a human living cell contains 23 pairs of chromosomes, but each chromosome contains several thousands of DNA segments. 2.9 Billion base pairs are present in the human genome.

Sequence of bases on DNA is unique for a human

DNA–finger printing : Each and every human has unique finger prints, but they can be altered by surgery. But the sequence of bases on DNA is unique for a person. It cannot be changed at all for a person. So DNA finger printing is used for: identifying criminals, identifying the dead bodies by comparing their DNA with parents or children, identifying racial groups to rewrite biological evolution, evolution of new biological species, determination of paternity of individual humans and identifying virus.

P.2.5 What is the difference between replication and transcription?

Solution Synthesis of duplicate DNA from DNA is called replication, but synthesis of m–RNA from DNA is called transcription. But both of these take place in the nucleus of cell.

P.2.6 On a strand of DNA (A + G) /(T + C) is 1.25. Find out (A + G) /(T + C) on its complementary strand.

Solution For A and G complementary bases are T and C respectively. Number of A and G on a strand are equal to number of T and C on the complementary strand. Number of T and C on a strand are equal to the number of A and G on the complementary strand.

(A + G) /(T + C) on complementary strand is reciprocal of (A + G) /(T + C) value on the first strand.

Thus, (A + G) /(T + C) on complementary strand is 1/1.25 = 0.8.

P.2.7 Give different nucleosides of RNA.

Solution
Adenine + Ribose $\longrightarrow$ Adenosine
Gaunine + Ribose $\longrightarrow$ Guanosine
Cystosine + Ribose $\longrightarrow$ Cytidine
Uracil + Ribose $\longrightarrow$ Uridine

EXERCISE - 2.1.2

1. Differentiate between nucleoside and nucleotide.
2. Write the structures of purine and pyrimidine bases.
3. Mention the sugars present in nucleic acids. Write their structures.
4. Discuss : (a) transcription, (b) translation and (c) replication.
5. What are the main differences between DNA and RNA?

VITAMINS AND HORMONES

2.3.1 Vitamins

Vitamins are organic compounds required in the diet in small amount to perform specific biological functions for normal maintenance of optimum growth and health of the organism. Plants can synthesise all vitamins.

Animals can synthesise few but not all vitamins. Human body can synthesise vitamin 'A' from carotene. Some members of vitamin B–complex and vitamin K are synthesised by microorganisms present in intestinal tract of human beings. Remaining vitamins are supplied to the organism through food.

Deficiency of vitamins cause avitaminosis

The term vitamine was introduced by Funk. Vitamins are essential dietary factors. Vitamins are not utilised in cell building or as energy source but can act as catalysts in biological processes. Their deficiency cause serious diseases known as avitaminosis.

Hence vitamins are essential constituents of our diet. They are much needed to growing children and pregnant women.

Vitamins are partly destroyed and are partly excreted. Vitamins can be stored in the body to some extent, for example, the fat-soluble vitamins are stored in the liver and subcutaneous tissue.

Vitamins can perform their work in very small quantities. Hence, the total daily requirement of vitamins is usually very small.

Vitamins are classified into water soluble vitamins and water insoluble vitamins (or) fat soluble vitamins. Vitamins soluble in water are listed in Table 2.3 and insoluble in Table 2.4.

Table 2.3 Water soluble vitamins

Vitamin	Name and formula	Important sources	Functions	Effects of deficiency
B_1	Thiamine $C_{12}H_{18}N_4\ SOCl_2$	Cereals, yeast, milk, green vegetables	Healthy nervous system, major component of coenzyme cocarboxylase, required for carbohydrate aminoacid metabolism	Beri–Beri, (loss of appetite, retarded growth), weak heart beat
B_2	Riboflavin $C_{17}H_{20}N_4O_6$	Yeast, vegetables, milk, egg white, liver, kidney	Combines with H_3PO_4 to form FAD, FMN, essential foroxidative metabolism	Cheilosis, skindiseases, dark red tongue, digestive disorders and burning sensation of the skin
B_6	Pyridoxine $C_8H_{11}O_3N$	Cereals, grams, yeast, egg yolk, meat, milk	Important coenzyme in proteins and amino acid metabolism, synthesis of fatsfrom carbohydrates	Convulsions
B_{12}	Cyanocobal amine $C_{63}H_{88}O_{14}N_{14}PCo$	Fish, meat, egg and curd	Synthesis of DNA, RNA, and fats from carbohydrates, metabolism of nervous tissues	Pernicious anaemia, hyperglycemia, RBC deficient in haemoglobin.
C	Ascorbic acid $C_6H_8O_6$	Green leafy vegetables, citrous fruits and amla	Essential for formation of collagen, bone, teeth, maintainance of redox potentials	Scurvy, break down of immunity defence system, delay in wound healing

Table 2.4 Fat soluble vitamins

Vitamin	Name and formula	Important sources	Functions	Effects of deficiency
A	Retinol $C_{20}H_{30}O$	Milk, butter, fish oil, carrot	Essential for synthesis of visual pigments, growth and division of epithelial cells, strength of bones.	Night blindness, xerophthalmia, degeneration of lacrymal glands
D	Ergocalciferol $C_{28}H_{44}O$	Synthesised in skin cells in sun light. (fish and egg yolk)	Regulates absorption of calcium andphosphorus in intestine.	Rickets in children and osteomalacia in adults, brittleness of bones
E	α,β,γ – $C_{29}H_{50}O_2$	Vegetable oils like sunflower oil, wheat germ oil	Normal muscle functioning, synthesis ofcoenzyme–Q, stores glycogen in muscle	Muscular atropy, increased fragility of RBCS
K	Phylloquinone $C_{31}H_{46}O_2$	Green leafy vegetables	Essential for blood clotting	Excessive bleading in injury, increased blood clotting time

P.2.8 How are vitamins classified based on their solubility in water?

Solution Based on the solubility in water vitamins are classified into two types.

Water soluble vitamins : vitamin B and vitamin C.

Water insoluble vitamins : vitamin A, vitamin B, vitamin E and vitamin K.

P.2.9 Who needs more vitamins, either elders or youngsters?

Solution The need of vitamins for youngsters, growing children and pregnant women is higher. It is due to their muscle growth.

P.2.10 What is meant by avitaminosis?

Solution Vitamins are essential in human diet. They are not used in cell building, but can catalyse biological processes.

Deficiency of vitamins cause diseases, known as avitaminosis.

2.3.2 Hormones

The name hormone is due to its stimulating action. Like vitamins and enzymes, hormones are also effective in minute amounts. Hormones are referred to as chemical messengers because they transfer biological information from one group of cells to distant tissues or organs. These biomolecules are secreted by the ductless (endocrine) glands and can regulate various biological processes. Hormones are carried to different parts of the body by blood stream to control metabolic reactions. These are not stored in the body like fats and carbohydrates but are continuously produced.

Hormones have several functions in the body

Hormones have several functions in the body, they help to maintain the balance of biological activities in the body. The role of insulin in keeping the blood glucose level within the limit is an example of this function. Insulin is released in response to the rapid rise in the glucose level in blood. On the other hand hormone glucagon tends to increase the glucose level in the blood. The two hormones together regulate the glucose level in the blood.

Epinephrine and norepinephrine mediate responses to external stimuli. Growth hormones and sex hormones play role in growth and development. Thyroxine produced in the thyroid gland is an iodinated derivative of amino acid tyrosine.

Abnormally low level of thyroxine leads to hypothyroidism which is characterised by lethargyness and obesity. Increased level of thyroxine causes hyperthyroidism. Low level of iodine in the diet may lead to hypothyroidism which is characterised by lethagyness and obesity. Increased level of thyroxine causes hyperthyroidism. Low level of iodine in the diet may lead to hypothyroidism and enlargement of the thyroid gland. This condition is largely being controlled by adding sodium iodine to commercial table salt (iodised salt).

Steroidal hormones posses four ring network

Steroidal hormones posses four ring network. Three of these are six membered carbon rings and one is five carbon ring. Steriodal hormones are two types : sex hormones and cortico steroids.

Steroid hormones are produced by adrenal cortex and gonads (testes in males and ovaries in females). Hormones released by the adrenal cortex play very important role in the functions of the body. For example, glucocorticoids control the role in the functions of the body. For example, glucocorticoids control the carbohydrate metabolism, modulate inflammatory reactions, and are involved in reactions to stress.

The mineralocorticoids control the level of excretion of water and salt by the kidney. If adrenal cortex does not function properly then one of the results may be Addison's disease characterised by hypoglycemia, weakness and increased susceptibility to stress. The disease is fatal unless it is treated by glucocorticoids and mineralocorticoids.

Hormones released by gonads are responsible for development of secondary sex characters. Testosterone is the major sex hormone produced in males. It is responsible for development of secondary male characteristics (deep voice, facial hair, general physical constitution) and estradiol is the main female sex hormone. It is responsible for development of secondary female characteristics and participates in the control of menstrual cycle. Progesterone is responsible for preparing the uterus for implantation of fertilised egg.

Non–steroidal hormones are of two types : Peptide hormones and amino acid derivative hormones.

Peptide hormones are insulin, oxytosin, vasopressin, etc. Among them, insulin is the most important which promotes anabolic reactions and inhibits catabolic reactions.

Insulin is secreted by islets of Langerhans. It is responsible for the entry of glucose and sugars into the living cells. Its deficiency in human being causes diabetes mellitus. It maintains constant sugar level in blood.

Insulin has two chains and 51 amino acids

Insulin isolated from islets tissue of pancreas was the first hormone identified as protein. Sanger was awarded Nobel prize for determining the structure of insulin. Insulin has 51 amino acids, which are divided between two peptides chains as shown in Fig 2.12. A and B are joined by disulphide bonds between cystine residues at A–7, B–7 and A–20, B–19. One disulphide bond is present at A–6, A–11.

Amino acid hormones are thyroidal hormones like thyroxin and triiodo thyronine. Thyroxin is secreted by thyroxin gland and can control metabolism of carbohydrates, lipids and proteins.

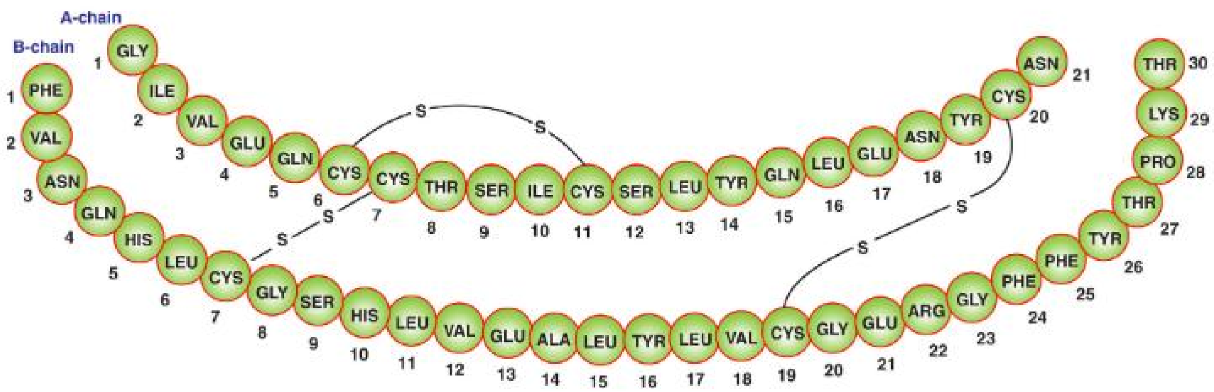


Fig 2.12 Two peptide chains in Insulin

Thimman introduced the name phytohormones for plant hormones. These are also called growth hormones, since these can regulate the growth and physiological functions in higher plants.

P.2.11 What is the difference between animal and plant hormones ?

Solution The specific glands can secrete animal hormones in the body but there are no specific glands to secrete plant hormones.

EXERCISE - 2.1.3

1. What are water soluble and fat soluble vitamins?
2. Write the effects of deficiency of vitamins B_1, B_2, B_6, B_{12} and C.
3. What are the deficiencies caused by vitamins A, D, E and K?
4. Why cannot vitamine C be stored in human body?
5. What are hormones? How are they classified?
6. Write on the linkage between two peptide chains present in insulin molecule.

SYNOPSIS

1. Ten out of twenty α – amino acids are essential. They are not synthesised in human body. Most of the naturally occurring α –amino acids are with L–configuration.
2. Amino acids are building blocks of proteins.
3. Proteins have the peptide linkage is –CO–NH–.
4. Based on the molecular shape, proteins are two types : fibrous and globular proteins.
5. Enzymes are globular and conjugated proteins.
6. Enzymes act as specific catalysts in biological reactions.
7. Nucleic acids are biopolymers of nucleotides with a polyphosphate ester chain.
8. The structure of polypetide and its shape can be examined at four different levels: primary, secondary, tertiary and quaternary structures.
9. Highly organised tertiary structure of natural proteins is responsible for their biological activity.
10. Breakdown of highly organised structure and loss of biological activity is called denaturation.
11. Nucleoside contains sugar and nitrogen base and nucleotide contains nucleoside and phosphate.
12. Cytosine, uracil and thymine are pyramidine bases.
13. Adenine and Guanine are purine basis.
14. DNA has double helix structure, but RNA has single strand.
15. Synthesis of identical copies of DNA is called replication.
16. Synthesis of protein in the cell involves transcription and translation.
17. Each and every human has unique DNA finger prints.
18. Vitamines are organic compounds required in diet in small amount to perform specific biological functions.

19.	Vitamins B and C are generally water soluble. Vitamins A, D, E and K are fat soluble.
20.	Vitamins are essential constituents in human diet. They are much needed to growing children and pregnant women
21.	Vitamins can perform their work in very small quantities.
22.	Harmones are chemical messengers and have stimulating action.
23.	Steroidal harmones posses four ring network.
24.	Insulin promotes anabolic reaction and inhibits catabotic reactions.

EXERCISE - 2.2

1. Amino acids may be acidic, basic or neutral explain.
2. Temperature and pH effect the native proteins. Explain.
3. Differentiate between nucleotide and nucleoside.
4. Name two classes of nitrogen containing bases present in nucleotides.
5. What is zwitter ion? Write the structure of zwitter ion of alamine.
6. What do you understand by the primary structure and secondary structure of proteins?
7. Mention the nitrogeneous bases present in RNA and DNA.
8. What products are formed when a nucleotide from DNA containing thymine is hydralysed?
9. What type of linkage holds together the manomers of DNA?
10. Write a note on heredity and genetic code?
11. What is meant by denaturation of proteins?
12. What are the diseases caused due to deficiency of the following substances.
    (i) Vitamin-A, (ii) Vitamin-E and (iii) Vitamin B_{12}?
13. What are the characteristics of vitamins? Write the sources of vitamins.
14. What is the quantity of vitamins required in our diet?
15. Analyse for the number of –OH, $-CH_3$ and –CO– groups in testosterone, estradiol and progesterone.
16. How progesterone helps as birth control agent?