32

PROTEINS

32.1 INTRODUCTION

Proteins (from greek "Proteios" meaning primary) are the major cell components of any living organism. They play most important role in all biological processes and never occur in inorganic form. In our everyday food, pulses, eggs, meat and milk are rich sources of proteins and are must for a balanced diet. In this lesson, you will learn about the composition, sources classification and several other aspects related to proteins.

32.2 OBJECTIVES:

After reding this lesson, you will be able to :

- define proteins
- write the composition of proteins.
- describe amino acids and their structures.
- list the natural sources of proteins.
- classify proteins.
- describe the structure of proteins.
- list the functions of proteins in biological systems.

32.3 WHAT ARE PROTEINS?

Proteins are linear, unbranched polymers of amino acids They are high molecular weight, nitrogen containing organic compounds with a very complex structural organization. Amino acids are referred to as the building blocks of proteins and linked together into long chains by peptide bonds.

32.4 AMINO ACIDS: THE BUILDING BLOCKS OF PROTEINS

As we have said before that the amino acids are the fundamental units of proteins Let us learn more about amino acids.

Amino acids or amino carboxylic acids are organic carboxylic acids in which at least one hydrogen atom of the hydrocarbon chain is replaced by an amino group ($-NH_2$).

The general structure of an amino acid is represented by the formula:

$$\begin{array}{c} R \\ | \\ H_2N - C - COOH \\ | \\ H \end{array}$$

Where $-NH_2$ is the amino group, $-COOH$ group is the carboxylic group and -R is the alkyl or aryl group or side chain.

There are 20 different amino acids commonly found as the building blocks of proteins in living organisms. The amino acids differ from one another only in the side chain (-R group). The carbon atom to which the -R and $-NH_2$ groups are bonded is α with respect to the -COOH group. All natural amino acids from proteins can be represented by the above formula and are called α amino acids. Chemically made β-or γ-amino acids are also known.

The first amino acid isolated from protein hydrolysate (the product of hydrolysis of a protein) was glycine, where R = H. Therefore, glycine can be written as follows by replacing R by H in the general formula given above.

$$\begin{array}{c} H \\ | \\ H_2N - C - COOH \\ | \\ H \end{array}$$

Becteria and plants are capable of synthesizing all the amino acids present in proteins, while animals including human can synthesize only 10 of the 20 or so naturally occurring amino acids from metabolic intermediates. The amino acids needed for the normal functioning of the animal body are called nutritionally "essential amino acids." These must be obtained from the diet. Those amino acids that can be synthesized from amphiphatic intermediates are called nutritionally "non essential" amino acid. Each amino acid is abbreviated by a three letter code. The essential amino acids are listed below in the Table 32.1.

Table 32.1: Essential Amino acids and their abbreviated codes:

Essential Amino Acid	Code
Arginine	Arg
Histidine	His
Isoleucine	Ile
Leucine	Leu
Lysine	Lys
Methionine	Met
Phenylalanine	Phe
Threonine	Thr
Tryptophan	Trp
Valine	Val

PEPTIDE BOND:

Peptide bond (–CO–NH–) is derived form the carboxyl group of one amino acid and the amino group of the next amino acid by the elimination of a molecule of water.

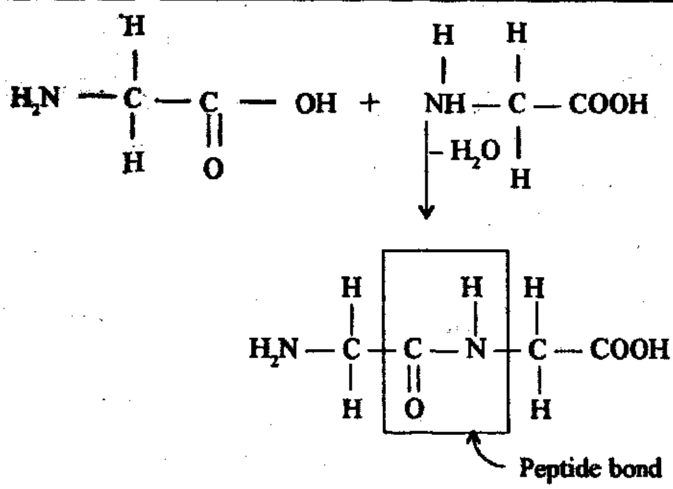


Fig. 32.1. **Glycylylycine.**

INTEXT QUESTIONS 32.1

1. What are proteins?

   ....

2. Write the general structure of an amoino acid.

   ....

3. How many amino acids are there in the nature?

   ....

4. What is a peptide bond? Show a dipeptide.

   ....

32.5 COMPOSITION OF PROTEINS

Elemental composition of protein is carbon, oxygen, nitrogen, hydrogen and sulphur. Certain proteins contain phosphorous and some trace metals like copper and iron. These metals are essential for their activity. The proteins are high molecular weight compounds. Their molecular weight ranges from 5000 amu to many millions amu.

32.6 NATURAL SOURCES OF PROTEINS

Pulses, eggs, meats, fish, chicken, Sprouts, Soybeans, milk and other milk products are rich sources of protein.

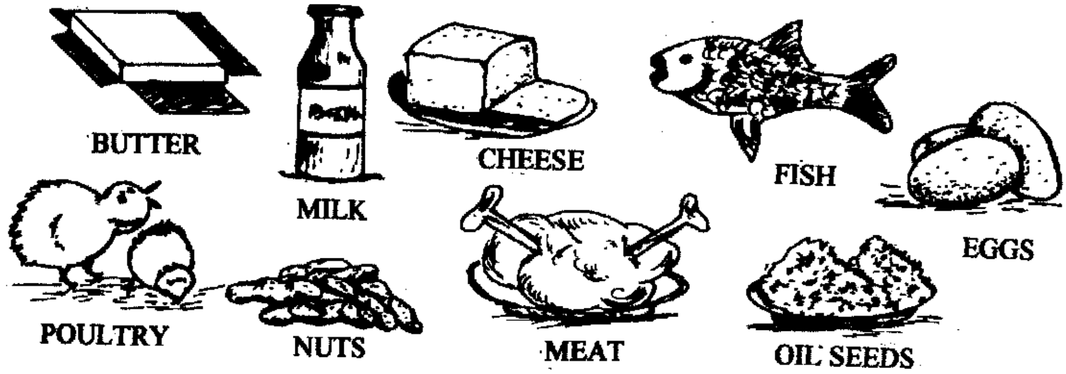


Fig. 32.2. **Natural sources of protein.**

32.7 CLASSFICATION OF PROTEINS

Based on chemical compositions, shape and solubility, proteins are classfied into three major categories namely (1) simple proteins (2) conjugated protgins and (3) derived proteins. Now let us learn about each of them in detail.

i) **Simple Proteins:** Simple proteins are those which, on hydrolysis, give only amino acids and no other major organic or inorganic hydrolysis product According to their solubility, the simple proteins are divided into two major groups fibrous and globular proteins.

Fibrous Proteins: These are insoluble animal proteins eg. Collagen (major protein of connective tissue), elastins (protein of arteries and elastic tissue), keratins (proteins of hair, wool, quills, hoof and nails) are good examples of fibrous proteins.

Globular Proteins: These proteins are generally soluble in water or aqueous salt media, acids, bases or alcohol. Some examples of globular proteins are albumin of eggs, globulin (present in serum), fibrinogen, myosin (in muscles) soy bean milk, histones (present in chromo-somes) and haemoglobin.

ii) **Conjugated proteins:** Conjugated proteins are complex proteins which on hydrolysis yield not only amino acids but also other organic or inorganic components. The non-amino acid portion of a conjugated protein is called prosthetic group.

Unlike simple proteins, conjugated proteins on classified on the basis of the chemical nature of their prosthetic groups. These are:

a. Nucleoproteins (protein + nucleic acid).

b. Mucoproteins and glycoproteins (protein + carbohydrates)

c. Chromoproteins (proteins + a coloured pigment)

d. Lipoproteins (proteins + lipid)

e Metalloproteins (metal binding proteins that combine with iron, copper or zinc).

f. Phosphoproteins (proteins attached with a phosphoric group).

iii) **Derived Proteins:** These proteins are not seen in nature as free proteins. Partial hydrolysis of natural proteins yield derived proteins Hydrolysis can be done by proteases (which are themselves protein-enzymes that breakdown proteins into smaller subunits). Peptones (the products of protein breakdown) are good examples of derived proteins

INTEXT QUESTIONS 32.2

1. Which elements are present in a protein molecule?

    ....

2. Name two natural sources of proteins

    ....

3. What are simple proteins? Name the groups into which simple proteins can be divided into? Give one example of each.

    ....

4. What are conjugated proteins? How have they been classified?

    ....

5. Give one example of derived proteins

    ....

32.8 STRUCTURE OF PROTEINS

Proteins are complex and very large molecules To fit into the tiny cell, each protein has to fold into a very compact structure. This folding of a protein gives each protein four basic levels of structure. These are (1) Primary (2) Secondary (3) Tertiary and (4) Quaternary

i) **Primary Structure:** Primary structure of the protein determines the other levels of structure of the protein. Primary structure of protein is the sequence of amino acids which form a chain connected by peptide bonds (recall the peptide bond between carboxyl group of an amino acid and the amino gr[illegible] of the next amino aci[illegible] in figure 32.1). This primary strucutre is the covalent backbone o[illegible] [illegible]e polypeptide chain The amino acids are linked together with the covalent bond i.e. p[illegible] [illegible]e bond.

Arg-Leu-Val [illegible] [illegible]-Arg-Trp-Phe

Fig 32.3: **Primary structure of a prot[illegible] [illegible]howing the amino acid sequence.**

This is the linear sequence of amino acid resid[illegible] [illegible] defines the primary structure

ii) **Secondary Structure:** You know that the ato[illegible] [illegible] p[illegible] molecule are held together by covalent bonds. Protein is a molecule where m[illegible] [illegible] [illegible] amino acids are linked together. Besides the covalent linkage through the peptide bonds, there are other bonds that stabilize the protein structure and give the protein a specific characteristic shape These include hydrogen bonds and van der Walls forces. When such interactions occur, the chain no longer remains linear and gets folded.

The secondary strucutre arises from interactions of neighbouring amino acids. The secondary structure consists of regularly repeating conformations (characteristic structure) of the peptide chain.

This structure results by the formation of hydrogen bonds (H-bonds) between the - C=0 group of one peptide bonds and the -NH- group of another nearbv peptide bond.

There are two types of repeating structures generally found in proteins. These are called α-helix and β-pleated sheet. These are shown in the figure 32.4.

α-helix β-pleated sheet

Fig. 32.4: **Diagrammatic representation of α-helix and β-pleated sheet.**

α-helix: α-helix develops when the hydrogen bonds form between peptide bonds in the same chain (see figure 32.5). α-helix appears to be a rod-like structure with peptide bonds coiled tightly inside and the side chains of the amino acid residues (R) protruding outside. Generally in an α-helix, each -CO is hydrogen bonded to the -NH- of a peptide bond that is four residues away.

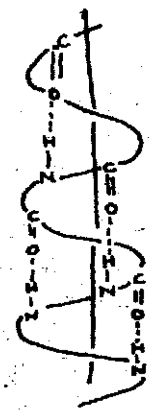


Fig. 32.5: **α-helix structure of a protein showing hydrogen bonding between peptide bonds in the same chain.**

β-pleated sheet structure: The characteristics of β-pleated sheet are :

a) β-pleated sheet structures are found in many proteins, including globular, soluble as well as some fibrous proteins.

b) They are called pleated because the C-C bond is tetrahedral and can not exist in straight line (see figure 32.6).

c) The chains lie side by side, with the hydrogen bonds forming between the -CO group of one peptide bond and the -NH group of another peptide bond in the neighbouring chain.

d) The chains may run in the same direction (that is both the chains may have $-NH_2$ terminals on the same side) when it is called parallel β-sheet or in the opposite direction (one chain has its $-NH_2$-terminal on one side and the other chain has its $-NH_2$ terminal on the other side), forming antiparallel β-sheet.

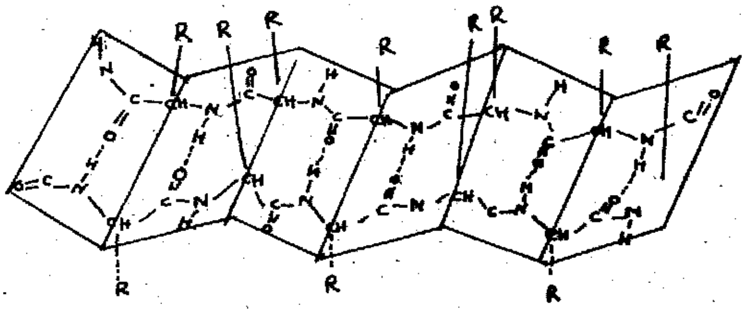


Fig. 32.6: **Anti-Parallel β-pleated sheet. Planar peptide bonds are shown with hydrogen bonds between antiparallel adjacent chains.**

iii) Tertiary Structure: Once the secondary structure is gained, different regions in a protein molecule further fold independently into domains giving a three dimensional or tertiary structure to a protein. Each protein consists of several domains that make a very long molecule compact. There is always a simple polypeptide backbone structure connecting different domains. There are several types of forces that stabilize the protein structure by folding it into tertiary structure. These are listed below:

a) **Hydrogen bonding:** Hydrogen bonds are weak bonds that forms between a covalently bonded hydrogen atom and a highly electronegative atom like oxygen or nitrogen on the same or different molecule.

b) **Ionic bonding:** Ionic bonding can take place between anionic and cationic side chains resulting side chain cross linking.

c) **Covalent bonding:** The most common form of inter-chain, covalent bonding is the disulphide bonds. These are formed between the sulphur atoms of cysteines in the protein molecule. Such disulphide covalent bond can form within a polypeptide chain (intrachain) or between poly-peptides chains (interchain).

d) **Hydrophobic bonding:** Many amino acid residues have hydrophobic side chains. Proteins in aqueous solutions fold so that most of the hydrophobic (water-hating) chains become clustered inside the folds. The polar side chains which are hydrophilic (water-loving) lie on the outside or the surface of the protein. A diagrammatic representation of these forces within a peptide chain and between two paptide chains is shown in figure 32.7.

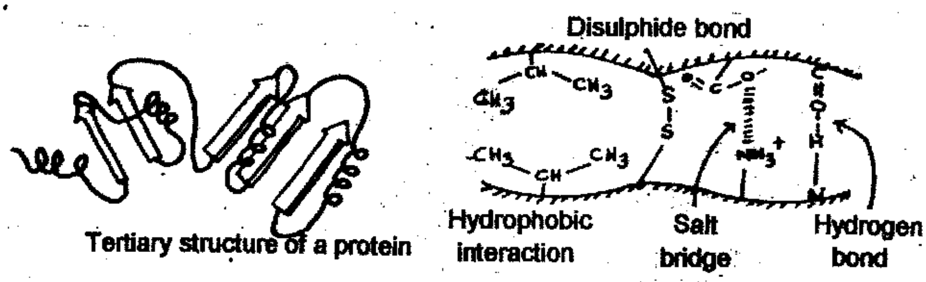


Fig. 32.7: Various forces that stabilize the protein strucutre.

iv) Quaternary structure:

You must be knowing about insulin used to treat diabetes. Diabetes is a disease in which blood glucose level increases. It is caused by the lack or insufficient amount of insulin. Insulin is a protein hormone secreted by pancreas. It is made up of two polypeptide chains held together by disulphide bonds. The two chains also fold around each other in a fashion giving is a particular three dimensional shape which is essential for its activity. This represents an example of quaternary stricture of a protein which is very important for its function. Thus assembly of quaternary structure occurs by non covalent interactions and also by covalent cross links between residues of two chains. (see fig. 32.8).

Fig. 32.8: Two polypeptide chains held together with noncovalent and covalent bonds

This ordered folding of a polypepide chian makes it possible for a cell to contain thousands of proteins in a very compact form.

32.9 FUNCTIONS OF PROTEINS IN BIOLOGICAL SYSTEMS

1. Proteins are structural components of cells.
2. The biochemical catalysts known as enzymes are proteins.
3. The proteins known as immunoglobulins serve in the defense against infections
4. Many hormones, such as insulin, are proteins. Hormones control many cell functions from metabolism to reproduction.

5 Oxygen is absolutely essential for life A protein called haemoglobin has a unique ability to bind oxygen and serves as a carrier of oxygen from blood to different tissues

6 Proteins participate in growth and repair mechanisms

7 Proteins also participate in elimination of abnormal metabolic conditions.

8 Proteins are major components of many complex molecules specifically present in different tissues.

9 A protein called fibrinogen arrests the bleeding (hemostasis) and polymerizes as a net work (thrombosis).

INTEXT QUESTIONS 32.3

1 What is the primary structure of a protein?

....

2 What type of repeating structures could be present in secondary structure of a protein?

....

3 What type of bonding occurs in α-helix and β-pleated sheet?

....

4 Name the forces that stabilize tertiary structure of a protein.

....

5 What is the quaternary strucutre of a protein? Why quaternary structure is important

....

32.10 WHAT YOU HAVE LEARNT

- Proteins are polymers of amino acids
- Amino acids in a protein chain are linked together with a peptide bond
- Body can not synthesize all the amino acids
- Proteins are made up of carbon, nitrogen hydrogen and sulphur
- Proteins are classified into three major classes according to their compositions, shape and solubility These are simple proteins conjugated proteins and derived proteins

  Proteins obtain their final structure by ordered bonding within a polypeptide chain The final structure is stabilized by various forces
- Proteins are very important to us and perform many functions in a cell that are absolutely necessary for our survival

32.11 TERMINAL EXERCISE

1 What do you understand by essential and non-essential amino acids?

2 Classify proteins according to their strucutre.

Write short notes on the following.

Simple proteins, Conjugated proteins.

4 Write briefly about β-pleated sheet

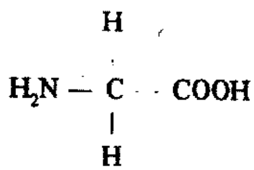
5 What are the functions of proteins in a biological system?

CHECK YOUR ANSWERS

Intext Questions 32.1

1 Refer to Section 32.3 Box.

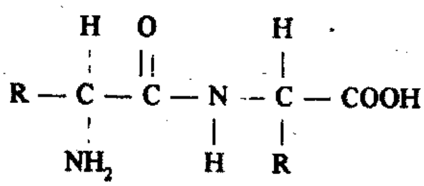
2 Proteins are made up of amino acids.

3 

Where $-NH_2$ is the amino group, -COOH is the carboxylic group and -R is the organic group or the side chain.

4. 20, Refer to Section 32 4, para 3

5. Refer to Section 32.4, Box.



Intext Questions 32.2

1. Refer to Section 32.5.
2. Refer to Section 32.6.
3. Refer to Section 32.7.
4. Refer to Section 32.7. Conjugated proteins are classified on the basis of the chemical nature of their prosthetic groups.
5. Refer to Section 32.7.

Intext Questions 32.3

Primary structure of protein is the sequence of amino acid which form a chian connected by peptide bond.

2. Refer to Section 32.8.
3. H-bonding.
4 Refer to Section 32.8
5. Non-covalent interactions or covalent cross links (Refer Sectio: 32.8.

TERMINAL EXERCISE

1. Refer to Section 32.4.
2. Proteins have been classified on the basis of chemical composition, shape and solubility into three major groups: (i) Simple proteins (ii) Conjugated proteins and (iii) Derived proteins.
3. Refer to Section 32.7.
4. Refer to Section 32.8.
5. Refer to Section 32