PROTEINS
(definition, structure, classification & biological role)

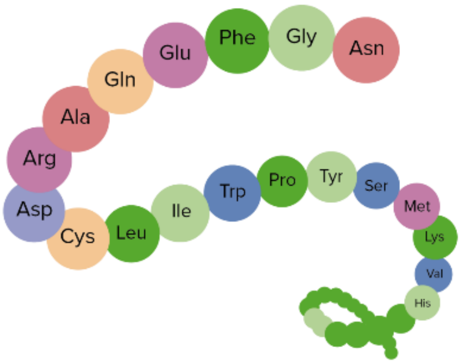
❖ Introduction

- **Definition-**proteins are the polymers of α-amino acids and they are connected to each other by peptide bond or peptide linkage. Chemically, peptide linkage is an amide formed between –COOH group and –NH2 group.
- The reaction between two molecules of amino acids, proceeds through the combination of the amino group of one molecule with the carboxyl group of the other. This results in the elimination of a water molecule and formation of a peptide bond –CO–NH–. The product of the reaction is called a dipeptide because it is made up of two amino acids. For example, when carboxyl group of glycine combines with the amino group of alanine we get a dipeptide, glycylalanine.
- If a third amino acid combines to a dipeptide, the product is called a tripeptide. A tripeptide contains three amino acids linked by two peptide linkages.
- Similarly when four, five or six amino acids are linked, the respective products are known as tetrapeptide, pentapeptide or hexapeptide, respectively.
- When the number of such amino acids is more than ten, then the products are called polypeptides.
- A polypeptide with more than hundred amino acid residues, having molecular mass higher than 10,000u is called a protein.
- However, the distinction between a polypeptide and a protein is not very sharp. Polypeptides with fewer amino acids are likely to be called proteins if they ordinarily have a well defined conformation of a protein such as insulin which contains 51 amino acids.

❖ Structure of proteins

(i) Primary structure of proteins:

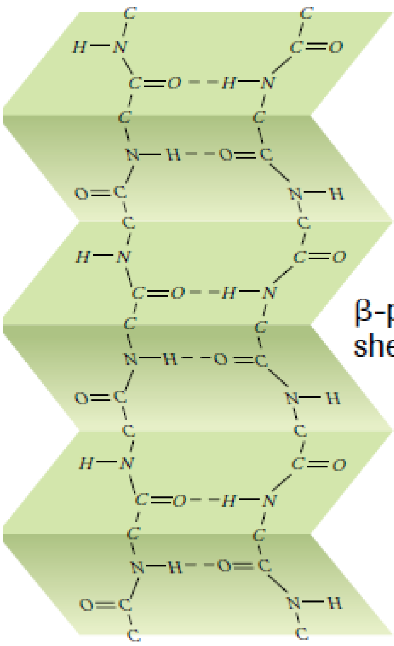
- Proteins may have one or more polypeptide chains.
- Each polypeptide in a protein has amino acids linked with each other in a specific sequence and it is this sequence of amino acids that is said to be the primary structure of that protein or we can say the order of the amino acids in the peptide chain is called primary structure
- Any change in this primary structure i.e., the sequence of amino acids creates a different protein.
- The free α-amino group, written to the left, is called the amino-terminal or N-terminal end.
- The free α-carboxyl group, written to the right, is called the carboxyl-terminal or C-terminal end.



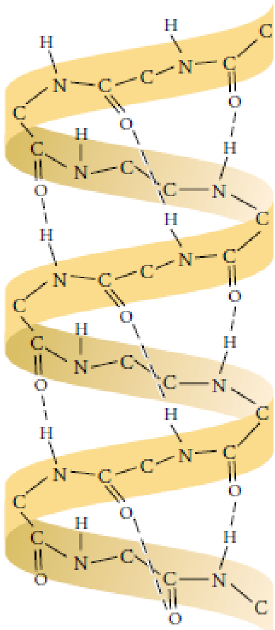
(ii) Secondary structure of proteins:

- It is the arrangement of hydrogen bonds between the peptide nitrogen and the peptide carbonyl oxygens of different amino acid residues.
- The secondary structure of protein refers to the shape in which a long polypeptide chain can exist.
- They are found to exist in two different types of structures viz. α-helix and β-pleated sheet structure.
- These structures arise due to the regular folding of the backbone of the polypeptide chain due to hydrogen bonding between $-\overset{O}{\overset{\|}{C}}-$ and –NH– groups of the peptide bond.

- α-Helix is one of the most common ways in which a polypeptide chain forms all possible hydrogen bonds by twisting into a right handed screw (helix) with the –NH group of each amino acid residue hydrogen bonded to the >C=O of an adjacent turn of the helix as shown in Fig.
- In β-pleated sheet structure all peptide chains are stretched out to nearly maximum extension and then laid side by side which are held together by intermolecular hydrogen bonds. The structure resembles the pleated folds of drapery and therefore is known as β-pleated sheet.



β-pleated sheet

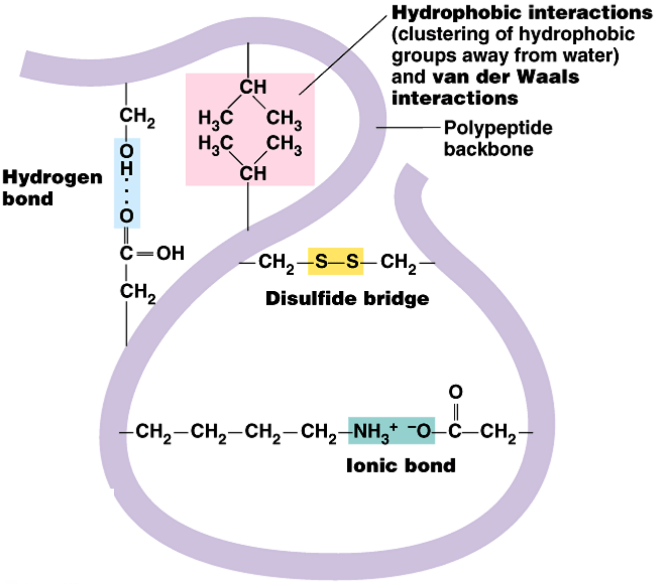


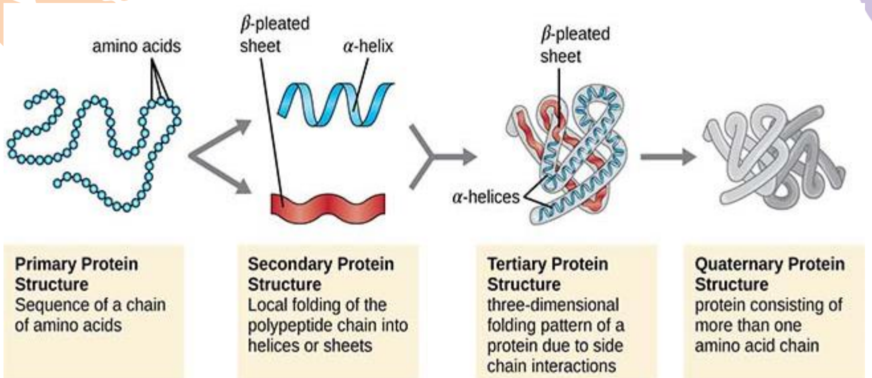
α helix

- **α-Helix** -In helical coils, the hydrogen-bonded nitrogens and oxygens are on nearby amino acid residues.
  i) The most common helical coil is a right-handed α-helix.
  ii) α-keratin from hair and nails is an α-helical protein.
  iii) Myoglobin has several α-helical regions.
  iv) Proline, glycine, and asparagine are seldom found in α-helices; they are "helix breakers."
  - **In β-sheets** (pleated sheets), the hydrogen bonds occur between residues on neighbouring peptide chains.
    i) The hydrogen bonds may be on different chains or distant regions of the same chain.
    ii) The strands may run parallel or antiparallel.
    iii) Fibroin in silk is a β-sheet protein.

(iii) Tertiary structure of proteins:

- The tertiary structure of proteins represents overall folding of the polypeptide chains i.e., further folding of the secondary structure. It gives rise to two major molecular shapes viz. fibrous and globular.
- The main forces which stabilise the 2° and 3° structures of proteins are hydrogen bonds, disulphide linkages, van der Waals and electrostatic forces of attraction.

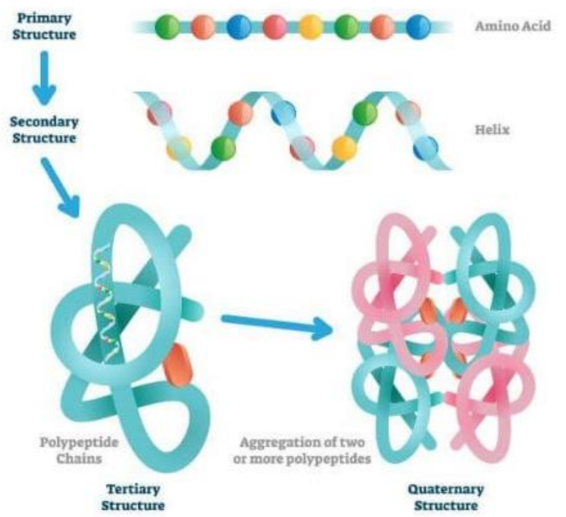




	Fibrous	Globular
Shape	Long and narrow	Round / spherical
Purpose	Structural	Functional
Acid Sequence	Repetitive amino acid sequence	Irregular amino acid sequence
Durability	Less sensitive to changes in pH, temperature, etc.	More sensitive to changes in pH, temperature, etc.
Examples	Collagen, myosin, fibrin, actin, keratin, elastin	Enzymes, haemoglobin, insulin, immunoglobulin
Solubility	(Generally) insoluble in water	(Generally) soluble in water

(iv) Quaternary structure of proteins:

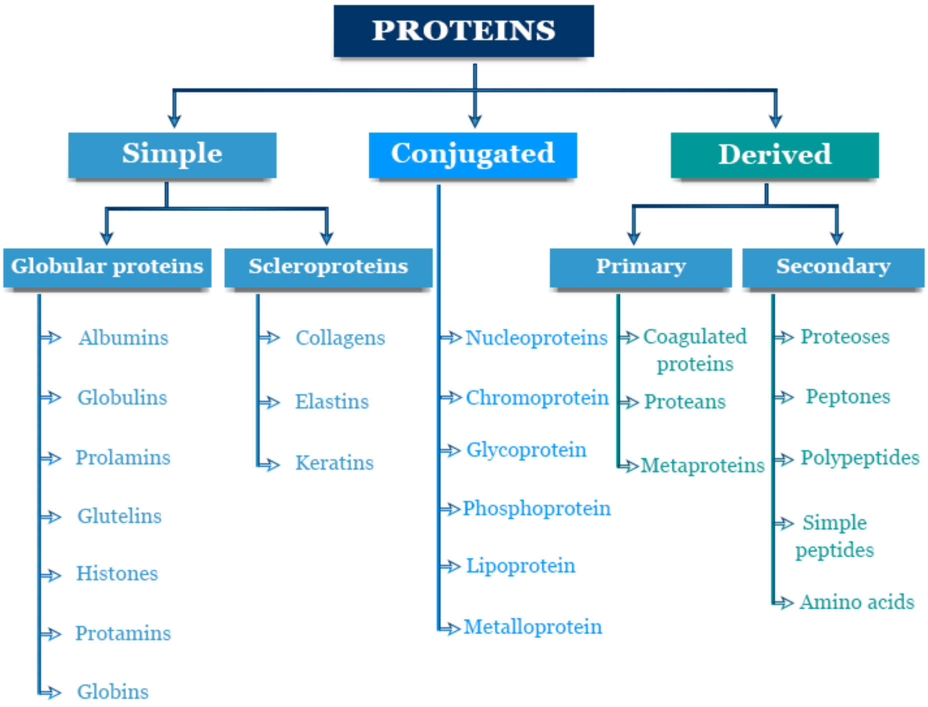
- Some of the proteins are composed of two or more polypeptide chains referred to as sub-units.
- The spatial arrangement of these subunits with respect to each other is known as quaternary structure.



❖ **Denaturation of proteins**

- Protein found in a biological system with a unique three-dimensional structure and biological activity is called a native protein.
- When a protein in its native form, is subjected to physical change like change in temperature or chemical change like change in pH, the hydrogen bonds are disturbed. Due to this, globules unfold and helix get uncoiled and protein loses its biological activity. This is called denaturation of protein. During denaturation secondary and tertiary structures are destroyed but primary structure remains intact.
- The coagulation of egg white on boiling is a common example of denaturation. Another example is curdling of milk which is caused due to the formation of lactic acid by the bacteria present in milk.

❖ **Classification of proteins**



1. **Simple proteins**
   - Simple proteins yield on hydrolysis, only amino acids.
   - These proteins are further classified based on their solubility in different solvents as well as their heat coagulability as follows

A. **Globular proteins**
   - These proteins are spherical or oval shape.
   - Soluble in water and other solvents and are digestible
   - Example – Albumins, globulins, Prolamines, Glutelins, Histones, Protamines

i) **Albumins**
   - Albumins are readily soluble in water, dilute acids and alkalies.
   - Coagulated by heat.
   - Albumins may be precipitated out from solution using high salt concentration, a process called 'salting out'.
   - They are deficient in glycine.
   - Serum albumin and ovalbumin (egg white) are examples.

ii) **Globulins**
   - Globulins are insoluble or sparingly soluble in water, but their solubility is greatly increased by the addition of neutral salts such as sodium chloride.
   - These proteins are coagulated by heat.
   - They are deficient in methionine.
   - Serum globulin, fibrinogen, myosin of muscle and globulins of pulses are examples.

iii) **Prolamins**
   - Prolamins are insoluble in water but soluble in 70-80% aqueous alcohol.
   - Upon hydrolysis they yield much proline and amide nitrogen, hence the name prolamin.
   - They are deficient in lysine.
   - Gliadin of wheat and zein of corn are examples of prolamins.

iv) **Glutelins**
   - Glutelins are insoluble in water and absolute alcohol but soluble in dilute alkalis and acids.
   - They are plant proteins e.g., glutenin of wheat.

v) **Histones**
   - Histones are small and stable basic proteins.
   - They contain fairly large amounts of basic amino acid, histidine.
   - They are soluble in water, but insoluble in ammonium hydroxide.
   - They are not readily coagulated by heat. They occur in globin of haemoglobin and nucleoproteins.

vi) **Protamines**
   - Protamines are the simplest of the proteins.
   - They are soluble in water and are not coagulated by heat.
   - They are basic in nature due to the presence of large quantities of arginine.
   - Tyrosine and tryptophan are usually absent in protamines.

B. **Albuminoids(Scleroproteins or fibrous proteins)**
   - These are characterized by great stability and insolubility in water and salt solutions.
   - These are called albuminoids because they are essentially similar to albumin and globulins.
   - They are highly resistant to proteolytic enzymes.
   - They are fibrous in nature and form most of the supporting structures of animals.
   - They occur as chief constituent of exoskeleton structure such as hair, horn and nails.
   - These include Collagen, Elastin & Keratin.
     - → COLLAGEN: Present in connective tissue Occurs in skin, bone, tendons, cornea & sclera of eye.
     - → ELASTIN: Occurs in tendon and arteries.
     - → KERATIN: It occurs in animal skin, hair, nails, hoofs and feather.

2. Conjugated proteins

- These are simple proteins combined with some non-protein substances known as prosthetic groups**.**
- The nature of the non-protein or prosthetic groups is the basis for the sub classification of conjugated proteins
- Example-

i) **Nucleoproteins**

- Nucleoproteins are simple basic proteins (protamines or histones) in combination with nucleic acids(RNA or DNA) as the prosthetic group.
- They play role in genetic information

ii) **Mucoproteins**

- These proteins are composed of simple proteins in combination with carbohydrates like mucopolysaccharides, which include hyaluronic acid and chondroitin sulphates.
- The term glycoproteins is restricted to those proteins that contain small amounts of carbohydrate usually less than 4% hexosamine.

iii) **Chromoproteins**

- These are proteins containing coloured prosthetic groups e.g., haemoglobin, flavoprotein and cytochrome.

iv) **Lipoproteins**

- These are proteins conjugated with *lipids such as neutral fat, phospholipids and cholesterol*

v) **Metalloproteins**

- These are metal-binding proteins.
- A β-globulin, termed transferrin is capable of combining with iron, copper and zinc. This protein constitutes 3% of the total plasma protein.
- Another example is ceruloplasmin, which contains copper

vi) **Phosphoproteins**

- These are proteins containing phosphoric acid.
- Phosphoric acid is linked to the hydroxyl group of certain amino acids like serine in the protein e.g. casein of milk

3. Derived proteins

- These are proteins derived by partial to complete hydrolysis from the simple or conjugated proteins by the action of acids, alkalis or enzymes.
- They include two types of derivatives, primary-derived proteins and secondary-derived proteins

A. **Primary-derived proteins**

- These protein derivatives are formed by processes causing only slight changes in the protein molecule and its properties
- There is little or no hydrolytic cleavage of peptide bonds.
- Example-

i) **Proteans**

- Proteans are insoluble products formed by the action of water, dilute acids and enzymes.
- These are particularly formed from globulins but are insoluble in dilute salt solutions. e.g. myosan from myosin, fibrin from fibrinogen

ii) **Metaproteins**

- These are formed by the action of acids and alkalis upon protein.
- They are insoluble in neutral solvents.
- Coagulated proteins are insoluble products formed by the action of heat or alcohol on natural proteins, e.g., cooked meat and cooked albumin

B. **Secondary-derived proteins**

- These proteins are formed in the progressive hydrolytic cleavage of the peptide bonds of protein molecule.
- They are grouped into proteoses, peptones and peptides according to average molecular weight.
- Proteoses are hydrolytic products of proteins, which are soluble in water and are not coagulated by heat.
- Peptones are hydrolytic products, which have simpler structure than proteoses. They are soluble in water and are not coagulated by heat.
- Peptides are composed of relatively few amino acids. They are water-soluble and not coagulated by heat.
- The complete hydrolytic decomposition of the natural protein molecule into amino acids generally progresses through successive stages as follows

  Protein→ Protean →Metaprotein →Proteoses → Peptones →Peptides →amino acids

❖ **Biological role of proteins**

➢ **Biological Importance of Protein**

1) Plasma membrane proteins (channel, carrier, pump proteins) regulate the transfer of many substances across the cell membrane
2) All receptors are protein in nature
3) All enzymes are proteins in nature
4) All antibodies (immuno-gobulins) are proteins in nature
5) Some hormones are proteins in nature (e.g. insulin and growth hormone).
6) Some proteins are protective e.g. Keratins (skin, hair and nails) make the skin resistant to chemicals
7) Some proteins are supportive e.g. Collagen; the most abundant protein in animals.
8) Hemoglobin is a protein carries O_2 in blood.
9) Actin and myosin are contractile proteins found in muscle cells and responsible for muscular contraction.
10) Amino acids (AA) are converted to other nitrogenous substances of great physiological importance (e.g. creatine, histamine, heme, purines and pyrimidines).

➢ **Biological functions of proteins**

1. Catalytic function: Nearly all chemical reactions in biological systems are catalyzed by specific enzymes.
2. Transport and storage:
   For example-
   i) Hemoglobin transports oxygen in blood.
   ii) Myoglobin carries and stores oxygen in muscle.
   iii) Albumin transports free fatty acids in blood.
   iv) Transferrin transports iron in blood.
3. Coordinated motion: Actin and myosin are contractile proteins in muscle.
4. Structural and mechanical support: - Collagen (a fibrous protein in skin and bone).
5. Defense function: -
   i) Clotting factors (prevent loss of blood).
   ii) Immuno-globulins (protect against infection).
6. Generation and transmission of nerve impulses: Receptor proteins (neuro-transmitters, e.g. acetyl choline), are responsible for transmitting nerve impulses.
7. Control of growth and differentiation: The activities of different cells are coordinated by hormones. Many hormones are polypeptides and proteins, such as insulin and thyroid-stimulating hormone.

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