Proteins

- Proteins are the most abundant biological macromolecules, occurring in all cells.
- It is also the most versatile organic molecule of the living systems and occur in great variety; thousands of different kinds, ranging in size from relatively small peptides to large polymers.
- Proteins are the polymers of amino acids covalently linked by the peptide bonds.
- The building blocks of proteins are the twenty naturally occurring amino acids.
- Thus, proteins are the polymers of amino acids.

Proteins $\xrightarrow{\text{hydrolysis}}$ Peptides $\xrightarrow{\text{hydrolysis}}$ Amino acids

Properties of Proteins

Solubility in Water

- The relationship of proteins with water is complex.
- The secondary structure of proteins depends largely on the interaction of peptide bonds with water through hydrogen bonds.
- Hydrogen bonds are also formed between protein (alpha and beta structures) and water. The protein-rich static ball is more soluble than the helical structures.
- At the tertiary structure, water causes the orientation of the chains and hydrophilic radicals to the outside of the molecule, while the hydrophobic chains and radicals tend to react with each other within the molecule (hydrophobic effect).

Denaturation and Renaturation

- Proteins can be denatured by agents such as heat and urea that cause unfolding of polypeptide chains without causing hydrolysis of peptide bonds.
- The denaturing agents destroy secondary and tertiary structures, without affecting the primary structure.
- If a denatured protein returns to its native state after the denaturing agent is removed, the process is called renaturation.

Some of the denaturing agents include

Physical agents: Heat, radiation, pH

Chemical agents: Urea solution which forms new hydrogen bonds in the protein, organic solvents, detergents.

Coagulation

When proteins are denatured by heat, they form insoluble aggregates known as coagulum. All the proteins are not heat coagulable, only a few like the albumins, globulins are heat coagulable.

Isoelectric point

- The isoelectric point (pI) is the pH at which the number of positive charges equals the number of negative charges, and the overall charge on the amino acid is zero.
- At this point, when subjected to an electric field the proteins do not move either towards anode or cathode, hence this property is used to isolate proteins.

Molecular Weights of Proteins

- The average molecular weight of an amino acid is taken to be 110.
- The total number of amino acids in a protein multiplied by 110 gives the approximate molecular weight of that protein.
- Different proteins have different amino acid composition and hence their molecular weights differ.
- The molecular weights of proteins range from 5000 to 109 Daltons.

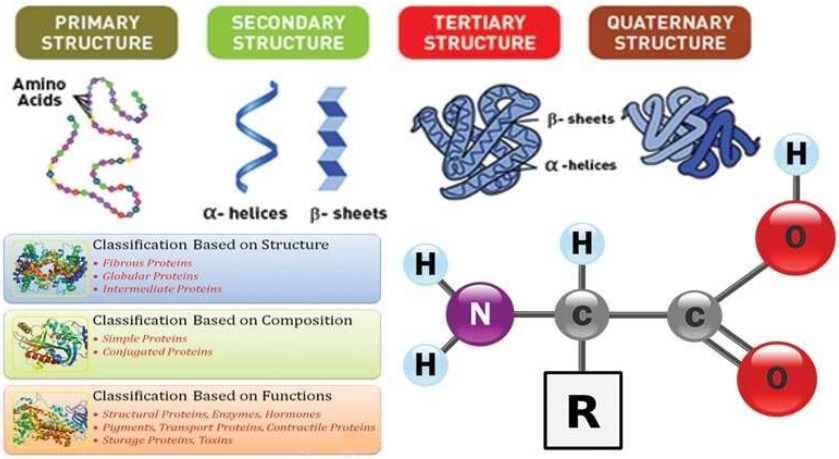
Posttranslational modifications

- It occurs after the protein has been synthesized on the ribosome.
- Phosphorylation, glycosylation, ADP ribosylation, methylation, hydroxylation, and acetylation affect the charge and the interactions between amino acid residues, altering the three-dimensional configuration and, thus, the function of the protein.

Chemical Properties

Ninhydrin test:

When 1 ml of Ninhydrin solution is added to 1 ml protein solution and heated, formation of a violet colour indicates the presence of α-amino acids.



Protein Structure

- The linear sequence of amino acid residues in a polypeptide chain determines the three-dimensional configuration of a protein, and the structure of a protein determines its function.
- All proteins contain the elements carbon, hydrogen, oxygen, nitrogen and sulfur some of these may also contain phosphorus, iodine, and traces of metals like ion, copper, zinc and manganese.
- A protein may contain 20 different kinds of amino acids. Each amino acid has an amine group at one end and an acid group at the other and a distinctive side chain.
- The backbone is the same for all amino acids while the side chain differs from one amino acid to the next.

The structure of proteins can be divided into four levels of organization:

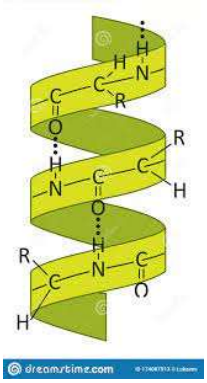
1. Primary Structure

- The primary structure of a protein consists of the amino acid sequence along the polypeptide chain.
- Amino acids are joined by peptide bonds.
- Because there are no dissociable protons in peptide bonds, the charges on a polypeptide chain are due only to the N-terminal amino group, the C-terminal carboxyl group, and the side chains on amino acid residues.
- The primary structure determines the further levels of organization of protein molecules.

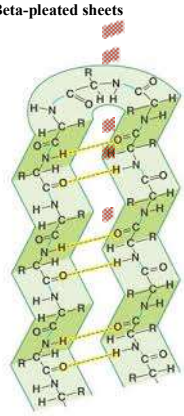
2. Secondary Structure

- The secondary structure includes various types of local conformations in which the atoms of the side chains are not involved.
- Secondary structures are formed by a regular repeating pattern of hydrogen bond formation between backbone atoms.
- The secondary structure involves α-helices, β-sheets, and other types of folding patterns that occur due to a regular repeating pattern of hydrogen bond formation.
- The secondary structure of protein could be :

1. **Alpha-helix**



2. Beta-pleated sheets



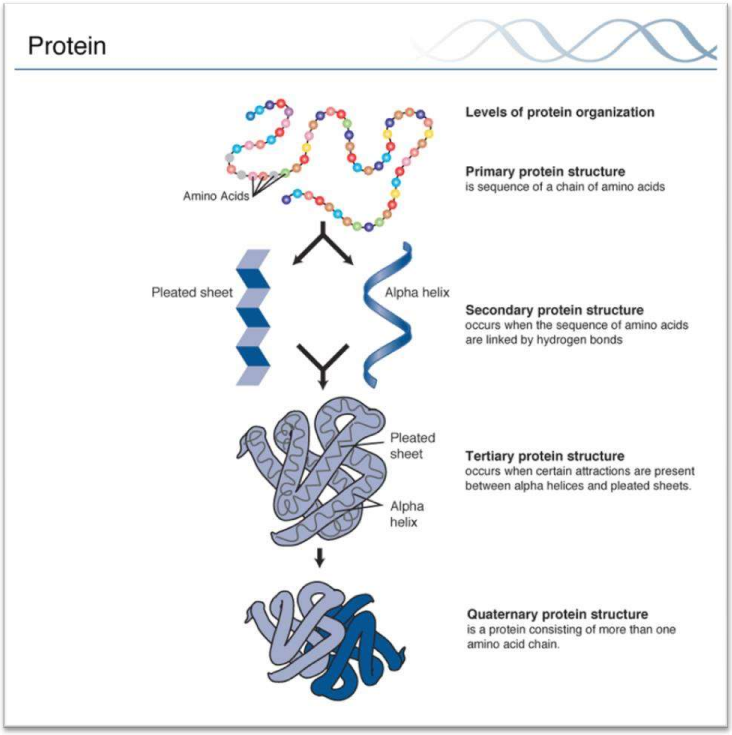
- The α-helix is a right-handed coiled strand.
- The side-chain substituents of the amino acid groups in an α-helix extend to the outside.
- Hydrogen bonds form between the oxygen of the C=O of each peptide bond in the strand and the hydrogen of the N-H group of the peptide bond four amino acids below it in the helix.
- The side-chain substituents of the amino acids fit in beside the N-H groups.
- The hydrogen bonding in a ß-sheet is between strands (inter-strand) rather than within strands (intra-strand).
- The sheet conformation consists of pairs of strands lying side-by-side.
- The carbonyl oxygens in one strand hydrogen bond with the amino hydrogens of the adjacent strand.
- The two strands can be either parallel or anti-parallel depending on whether the strand directions (N-terminus to C-terminus) are the same or opposite.
- The anti-parallel ß-sheet is more stable due to the more well-aligned hydrogen bonds.

3. Tertiary Structure

- Tertiary structure of a protein refers to its overall three-dimensional conformation.
- The types of interactions between amino acid residues that produce the three-dimensional shape of a protein include hydrophobic interactions, electrostatic interactions, and hydrogen bonds, all of which are non-covalent.
- Covalent disulfide bonds also occur.
- It is produced by interactions between amino acid residues that may be located at a considerable distance from each other in the primary sequence of the polypeptide chain.
- Hydrophobic amino acid residues tend to collect in the interior of globular proteins, where they exclude water, whereas hydrophilic residues are usually found on the surface, where they interact with water.

4. Quaternary Structure

- Quaternary structure refers to the interaction of one or more subunits to form a functional protein, using the same forces that stabilize the tertiary structure.
- It is the spatial arrangement of subunits in a protein that consists of more than one polypeptide chain.



Classification of Proteins

Based on the chemical nature, structure, shape and solubility, proteins are classified as:

1. **Simple proteins**: They are composed of only amino acid residue. On hydrolysis these proteins yield only constituent amino acids. It is further divided into:
   - Fibrous protein: Keratin, Elastin, Collagen
   - Globular protein: Albumin, Globulin, Glutelin, Histones

2. **Conjugated proteins**: They are combined with non-protein moiety. Eg. Nucleoprotein, Phosphoprotein, Lipoprotein, Metalloprotein etc.

3. **Derived proteins**: They are derivatives or degraded products of simple and conjugated proteins. They may be :
   - Primary derived protein: Proteans, Metaproteins, Coagulated proteins
   - Secondary derived proteins: Proteosesn or albunoses, peptones, peptides.

Functions of Proteins

Proteins are vital for the growth and repair, and their functions are endless. They also have enormous diversity of biological function and are the most important final products of the information pathways.

- Proteins, which are composed of amino acids, serve in many roles in the body (e.g., as enzymes, structural components, hormones, and antibodies).
- They act as structural components such as keratin of hair and nail, collagen of bone etc.
- Proteins are the molecular instruments through which genetic information is expressed.
- They execute their activities in the transport of oxygen and carbon dioxide by hemoglobin and special enzymes in the red cells.
- They function in the homostatic control of the volume of the circulating blood and that of the interstitial fluids through the plasma proteins.
- They are involved in blood clotting through thrombin, fibrinogen and other protein factors.
- They act as the defence against infections by means of protein antibodies.
- They perform hereditary transmission by nucleoproteins of the cell nucleus.
- Ovalbumine, glutelin etc. are storage proteins.
- Actin, myosin act as contractile protein important for muscle contraction.