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Function of All Living Cells

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Abstract

Proteins are vital biomolecules crucial to numerous physiological processes and cellular functions. Comprised of amino acids, proteins form high molecular weight polymers exhibiting diverse shapes, solubility, and biological properties. They are classified based on function (catalytic, structural, regulatory), composition (simple, conjugated, derived), solubility (albumins, globulins), shape (globular, fibrous), and nutritional value (rich, incomplete, poor). The chapter delves into protein structure, detailing primary, secondary, tertiary, and quaternary structures, emphasizing peptide bonds and amino acid sequences. Protein synthesis mechanisms, including initiation, elongation, and termination, are outlined, alongside post-translational modifications. Various methods for protein analysis are discussed, from traditional techniques like electrophoresis and western blotting to modern approaches like mass spectrometry and light scattering. The importance of proteins in maintaining cellular integrity, facilitating biochemical reactions, and ensuring proper metabolic functions is underscored. This comprehensive overview highlights the indispensable role of proteins in sustaining life and their intricate relationship between structure and function, offering insights into their biochemical versatility and the critical roles they play in biological systems.

keywords: Cells, Biological, Comprehensive Etc.

Introduction-

Proteins, derived from the Greek word "proteios," are vital biomolecules in living organisms, contributing significantly to physiological processes (LaPelusa and Kaushik, 2022). Comprising a substantial portion of body weight, they are crucial for structural integrity and functional dynamics. Abnormalities in protein structure can lead to molecular diseases, impacting metabolism. Composed of Carbon, Hydrogen, Oxygen, and Nitrogen, with minor constituents like Sulfur and Phosphorus, proteins are amino acid polymers, that serve as fundamental building blocks. Their diverse structures and functions enable roles in bodybuilding, enzymatic reactions, signaling pathways, and regulation. This versatility underscores their indispensable role in sustaining life processes, emphasizing their importance in maintaining balance and proper functioning within organisms (Albertset al., 2002).

Classification of Proteins Their diverse roles can be better understood through various classification schemes. The classification of proteins is based specifically on their chemical structure, shape, and biological regulations (Table 1).

A) Classification Based on Functions

1. Catalytic Proteins: Enzymes accelerate biochemical reactions, acting on specific substrates without being consumed. They're vital for metabolism and DNA replication.
   ● Example: Enzyme lactase regulates the disintegration of lactose into glucose and galactose during digestion.
   2. Structural Proteins: These support cell structure, providing integrity and mechanical properties to tissues.

1. 3. Contractile Proteins: Essential for muscle contraction, cellular division, and movement within organisms.
● Example: Myosin interacts with actin filaments for muscle contraction via the sliding filament mechanism.
4. Transport Proteins: Facilitate the movement of molecules across cell membranes and throughout the body.
● Example: Hemoglobin transports oxygen from the lungs to tissues and carries carbon dioxide in return.
5. Regulatory Proteins: Control cellular processes like gene expression and signal transduction, ensuring coordinated responses.
● Example: Insulin regulates glucose uptake in cells to maintain blood sugar levels.
6. Signalling Proteins: Mediate communication within and between cells, initiating specific cellular responses.
Example: Receptors, like G-protein coupled receptors
7. Defensive Proteins: Protect organisms from pathogens, recognizing and neutralizing foreign invaders. Contractile Proteins Essential for muscle contraction and movement. Myosin (muscle contraction), Actin (cell movement).
Transport Proteins Carry molecules across cell membranes and in the body. Hemoglobin (oxygen transport), Myoglobin (oxygen storage).
Regulatory Proteins Control cellular processes and coordinate responses. Insulin (blood sugar regulation), Transcription Factors (gene expression).
Signaling Proteins Communicate within and between cells, initiating responses. Receptors (signal detection), Kinases (protein modification).
Defensive Proteins Protect organisms from pathogens and threats.
2. Table 1: Classification Based on Functions
B) Composition and Solubility-Based Classification
Proteins may be categorized through different methods, such as- constitution and ability to dissolve or solubility. These classifications help to understand their functions, properties, and applications in different biological and industrial contexts.
Classification Based on Composition produce amino acids or their derivatives. Examples include:
● Albumins: Water-soluble proteins found in egg whites, blood plasma, and milk.
● Globulins: not soluble in pure water but soluble in diluted solutions with salt; examples include antibodies and certain blood proteins.
● Glutelins: dissolves in diluted acids or bases; found in cereals like wheat (glutenin).
2. Conjugated ProteinsIn addition to amino acids, it includes a non-protein component known as a prosthetic group, which can be a metal ion, lipid, carbohydrate, or nucleic acid. Examples include:
● Glycoproteins: Proteins with carbohydrate groups attached, such as mucins in mucus.
● Lipoproteins: Proteins with lipid groups attached, important in cell membranes and transport of lipids in blood (e.g., HDL, LDL).
● Metalloproteins: Proteins with metal ions as prosthetic groups, likehemoglobin (iron) and cytochromes (iron and copper).
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● Metalloproteins: Proteins with metal ions as prosthetic groups, likehemoglobin (iron) and cytochromes (iron and copper).
3. Derived Proteins: These are proteins that are chemically or enzymatically changed from their original state
3. Peptones: Derived from the partial hydrolysis of proteins, used in microbiological media.
● Proteoses: Intermediates formed during the hydrolysis of proteins into amino acids.
Classification Based on Solubility
Proteins can be classified into different solvents.

1. **Globulins:** Pure water does not dissolve it, but diluted salt solutions do. Examples include immunoglobulins and legumins.
2. **Glutelins:** dissolves in dilute acids or bases but insoluble in neutral solvents. They are commonly found in plant seeds. Examples include glutenin and oryzenin.
3. **Prolamins:** 70%–80% ethanol-soluble and water-insoluble. The seeds of cereal plants contain them. Examples include gliadin (in wheat) and zein (in corn).
4. **Scleroproteins (Fibrous Proteins):** they are not soluble in water, dilute acids, bases, and organic solvents. They have structural and protective roles. Examples include collagen (in connective tissues).

A) Classification of Proteins Based on the Shape

Proteins can be classified into two main categories based on their shape. This classification aids in understanding their functions, structural roles, and physical properties.

Globular Proteins

Oval or spherical, and often more soluble in water. They perform various dynamic roles in biological processes. Their complex tertiary and sometimes quaternary structures allow them to be functional in diverse roles such as catalysis (enzymes), transport (hemoglobin), regulation (hormones), and defense (antibodies) (Andreeva, 2011).

Examples: **Albumins**, **globulins**, **protamines**

Fibrous Proteins

They have elongated, strand-like shapes and are less soluble in water. They primarily give support structure and strength due to their mechanical properties and resistance to digestion. Their repeating amino acid sequences frequently create stable and prolonged conformations by forming beta sheets or alpha helices, among other secondary structures.

Classification of Proteins Based on Nutritional Value

Proteins are categorized by their nutritional value into three types: nutritionally rich, incomplete, and poor proteins.

- **Nutritionally Rich Proteins contain all important amino acids in the right proportions, supporting growth and health. Example: Casein in milk.**
- **Incomplete Proteins can sustain adult health when combined with complementary proteins. Examples include pulses and cereals.**
- **Poor Proteins lack many needed amino acids and cannot support growth or health. Example: Zein in corn.**

Protein Structure and Organization

The molecules of protein have hierarchical levels of organization, each crucial for their function and stability. This chapter comprehensively examines protein structure and amino acid sequencing (Fig.1).

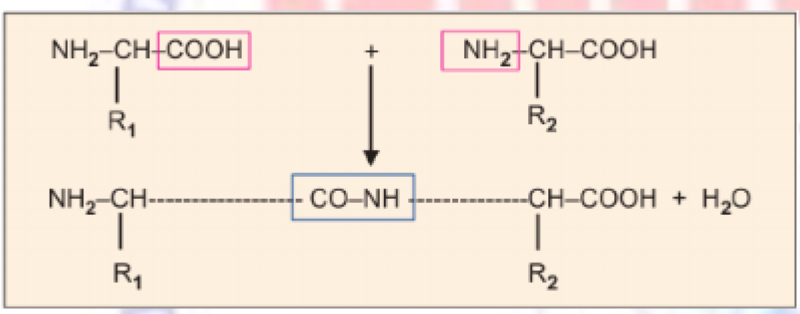

Fig. 1: Formation of peptide bonds (Vasudevan*et al*., 2016)

Primary Structure: The Blueprint of Proteins

The basic structure of a protein is the linear arrangement of amino acids inside a polypeptide chain. Every protein has a distinct primary structure encoded by specific genes. Example- the tripeptidesGly-Ala-Val and Gly-Val-Ala, while containing the same amino acids, differ in sequence, resulting in distinct peptides (Sanvictores and Farci, 2022; Vasudevan*et al*., 2016).

Peptide Bonds: The Molecular Glue

The bonds of peptides are the covalent bonds that link amino acids together in a polypeptide chain. They are characterized by their partial double-bond nature, which restricts rotation around the C-N bond axis, influencing the spatial orientation of the peptide chain. In the polypeptide, the distance between the C and N atoms is around 1.32Å, which is in between only one bond (1.49Å) as well as a double bond (1.27Å) (Vasudevan*et al*., 2016).

Characteristics of Peptide Bonds

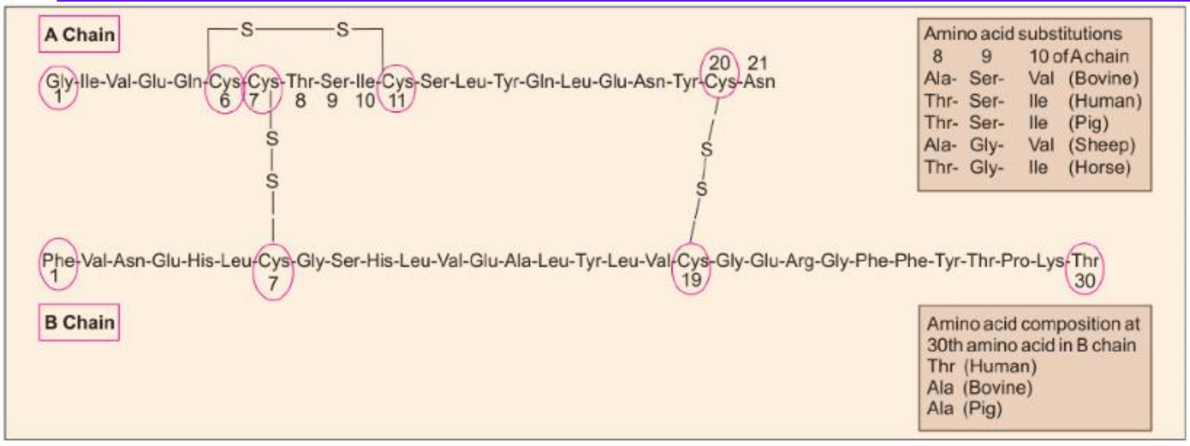

Fig. 2: structure of insulin (Vasudevan*et al*., 2016)

The Role of Primary Structure in Determining Biological Function

The primary protein structure determines its natural three-dimensional shape and biological activity. Even minor alterations can significantly impact protein function. For example, the variants of hemoglobin such as HbA (normal) and HbS (causes sickle cell anemia) demonstrate how changes in the structure of a primary protein can cause drastic physiological outcomes.

Secondary Structure of Proteins

The "secondary structure" is the local spatial arrangement of a chain of polypeptides. It describes the configurational relationships between amino acids which are typically 3-4 residues apart in the linear sequence. Noncovalent interactions include hydrogen bonds, electrostatic interactions, hydrophobic effects, and van der Waals forces stabilise this structural level.

Alpha Helix

It was first identified by Linus Pauling and Robert Corey in 1951 and is one of the most prevalent and stable secondary structures in proteins (Fig. 3). In this configuration, the polypeptide chain forms a right-handed spiral stabilized by hydrogen bonds between NH and C=O groups of the backbone, with each helical turn consisting of about 3.6 amino acids and a translation distance of 1.5 Å between adjacent residues. The alpha helix is essentially absent from some proteins, such as chymotrypsin, although it is present in proteins like haemoglobin and myoglobin. Proline and hydroxyproline residues typically interrupt the association of an alpha helix due to their unique structural properties. ***Beta-Pleated Sheet***

Polypeptide chains in the beta-pleated sheet are nearly completely stretched, and hydrogen bonds between NH and C=O groups bind neighbouring chains together. These sheets can be parallel, with strands running parallel, or anti-parallel. In a beta-strand, the spacing between neighbouring amino acids is 3.5 Å. Important structural motifs seen in proteins such as carbonic anhydrase (both), flavodoxin (parallel),and silk fibroin (anti-parallel) are beta-pleated sheets. Any bend, or sarp

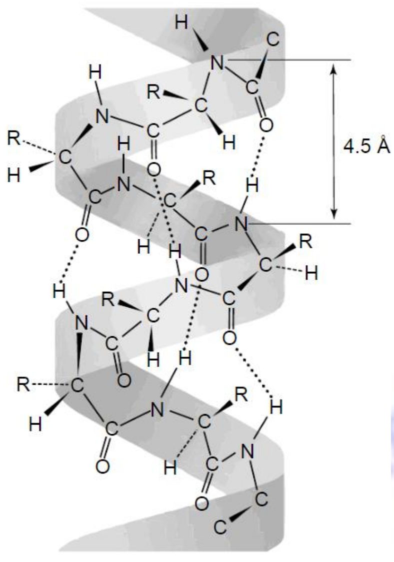

Fig. 3: structure of alpha helix (Georgiev and Glazebrook, 2020)

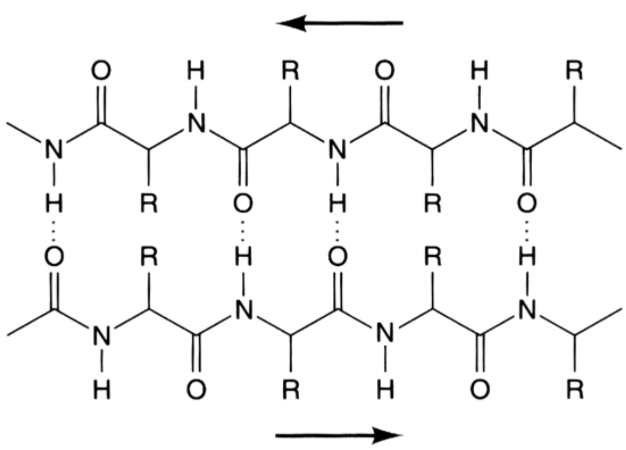

Fig – 4

Stabilizing Interactions in Tertiary Structure

1. **Hydrogen Bonds**: These bonds, which connect various segments of the polypeptide chain, occur between polar side chains and support the stability of the protein's tertiary structure.

2. **Hydrophobic Interactions**: The folded structure of proteins is stabilised when nonpolar side chains group together inside the protein, away from the aqueous environment.

3. **Disulfide Bridges**: Covalent bondsamong the sulfur atoms of cysteine residues form disulfide bridges, which provide significant stability by linking various segments of the protein chain or various polypeptide chains.
4. **Ionic Bonds (Electrostatic Interactions)**: Positively and negatively charged side chains interact with one another in these interactions, which add to the protein's overall stability.
5. **Van der Waals Forces**: Weak interactions between closely positioned atoms help fine-tune the structure by providing additional stabilization.

Conclusion-

Proteins often fold into distinct regions called domains, which are independently stable and functional units in the protein. Each domain can be associated with a specific role, and proteins may contain one or multiple domains. Structural motifs, like helix-turn-helix or zinc finger motifs, are common arrangements of secondary structures that perform specific roles within the proteinThe process by which a tertiary protein attains its tertiary structure is known as protein folding. This complex process involves the progressive stabilization of intermediate structures, guided by the characteristics of the amino acid sequence (primary structure) and assisted by molecular chaperones. Proper folding is essential for the functional conformation of the protein structure.

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