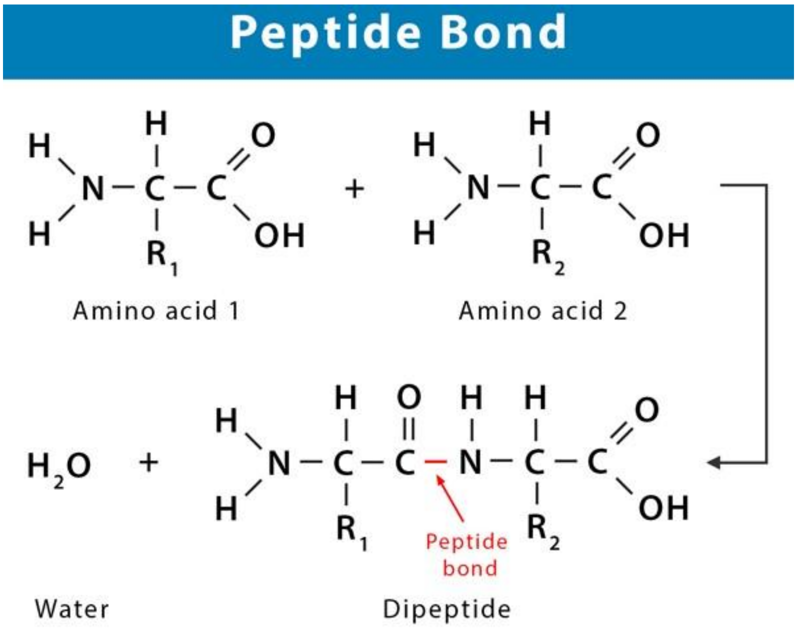
PROTEINS

Proteins are large, nitrogen-containing organic compounds made up of **amino acids** linked together by **peptide bonds**. They are essential macromolecules that perform a wide variety of structural and functional roles in living organisms.

Peptide Bond:

A **peptide bond** is a **chemical bond** that forms between the **amino group (-NH_2)** of one amino acid and the **carboxyl group (-COOH)** of another amino acid, with the **elimination of a molecule of water (H_2O)**.

A **peptide bond** is an **amide linkage** formed between the **α-carboxyl group** of one amino acid and the **α-amino group** of another, resulting in the release of a water molecule (**condensation reaction**).



STRUCTURAL LEVELS OF PROTEINS

Proteins are vital macromolecules in all living organisms, serving structural, enzymatic, transport, hormonal, and immune functions. Their function is directly dependent on their **structure**, which is organized into four hierarchical levels: **primary**, **secondary**, **tertiary**, and **quaternary** structures.

1. Primary Structure

Definition:

The **primary structure** is the **linear sequence of amino acids** in a polypeptide chain, held together by **peptide bonds**.

Formation:

- Amino acids are joined by **condensation reactions**, forming **peptide bonds** between the **carboxyl group (-COOH)** of one amino acid and the **amino group (-NH_2)** of the next.
- The sequence is genetically determined and written from the **N-terminal (amino end)** to the **C-terminal (carboxyl end)**.

Importance:

- It determines all higher levels of protein structure.
- A single change in the amino acid sequence can alter protein function (e.g., sickle cell anemia).

Example:

- **Insulin**: A hormone composed of two chains (A and B), connected by **disulfide bridges**. The exact sequence is critical for its function.
- **Sickle-cell hemoglobin**: A mutation causes valine to replace glutamic acid at the 6th position of the β-chain.

2. Secondary Structure

Definition:

The **secondary structure** refers to the **regular folding patterns** of the polypeptide chain stabilized by **hydrogen bonds** between the **backbone atoms** (not the side chains).

Types:

1. **α-Helix:**
    - Right-handed coil or spiral structure.
    - Stabilized by hydrogen bonds between every 4th amino acid.
    - R-groups extend outward from the helix.
2. **β-Pleated Sheet:**
    - Sheet-like arrangement formed by linking two or more polypeptide strands.
    - Can be **parallel** or **antiparallel**.
    - R-groups alternate above and below the plane.
3. **Turns and Loops:**
    - Provide flexibility and connect helices and sheets.

Importance:

Provides local folding and contributes to the overall shape and stability of the protein.

Examples:

- **Keratin** (hair, nails) contains mostly α-helices.
- **Silk fibroin** (from silkworms) is rich in β-sheets.

3. Tertiary Structure

Definition:

The **tertiary structure** is the **three-dimensional conformation** of a polypeptide, formed by the folding of secondary structural elements into a stable shape.

Stabilizing Interactions:

1. **Hydrogen bonds**
2. **Ionic bonds** (between oppositely charged side chains)
3. **Disulfide bridges** (covalent S-S bonds between cysteine residues)
4. **Hydrophobic interactions** (nonpolar side chains cluster away from water)
5. **Van der Waals forces**

Importance:

- Determines the **biological activity** of the protein.
- Essential for **substrate binding**, **enzyme catalysis**, and **antigen recognition**.

Examples:

- **Myoglobin**: A single-chain globular protein that stores oxygen in muscles; its compact shape is due to hydrophobic interactions.
- **Lysozyme**: An enzyme that breaks down bacterial cell walls.

4. Quaternary Structure

Definition:

The **quaternary structure** refers to the **assembly of multiple polypeptide chains (subunits)** into a functional protein complex.

Characteristics:

- Each polypeptide chain is called a **subunit**.
- The structure is stabilized by the same types of interactions as in tertiary structure.
- Subunits may be identical or different.

Importance:

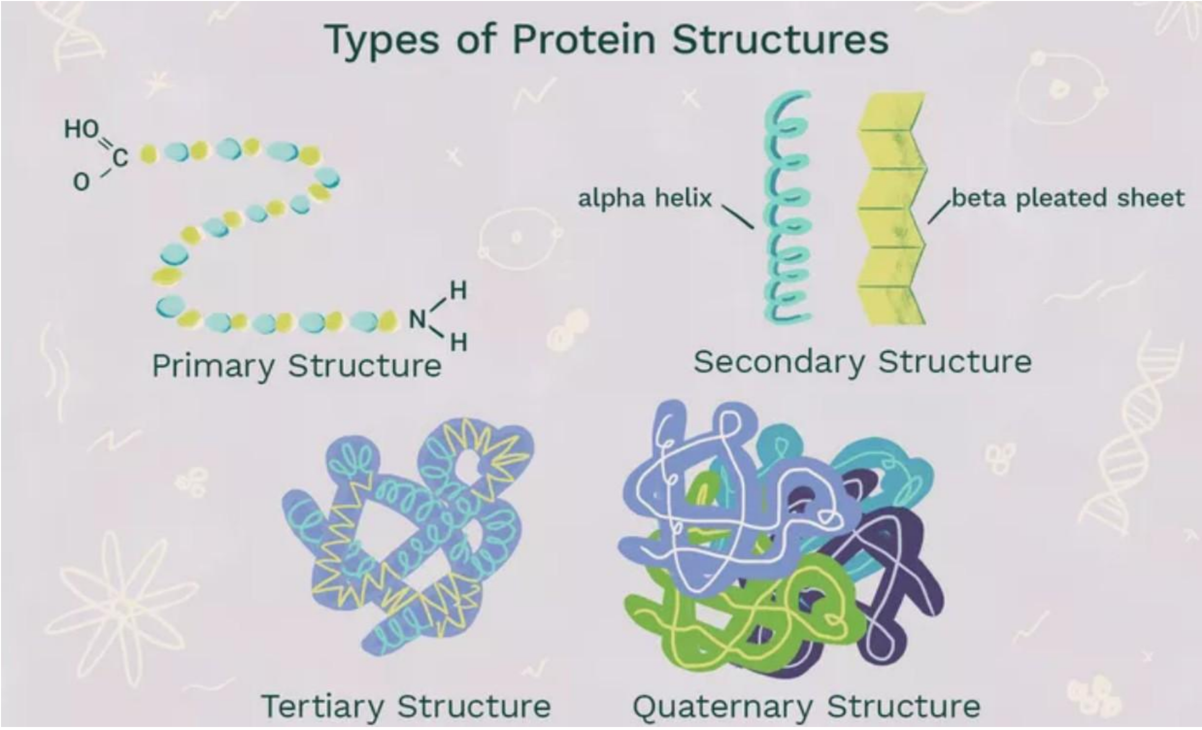
- Enables **cooperativity** and **allosteric regulation**.
- Increases protein stability and efficiency.

Examples:

- **Hemoglobin**: A tetramer composed of two α and two β chains; each subunit binds one oxygen molecule.
- **DNA polymerase**: A multi-subunit enzyme involved in DNA replication.

Table: Structural Levels of Proteins

Level	Definition	Features	Types / Bonds Involved	Examples
Primary Structure	Linear sequence of amino acids in a polypeptide chain	Determines all higher-level structures; held by peptide bonds	Peptide bonds	Insulin, Sickle-cell hemoglobin (mutation affects sequence)
Secondary Structure	Local folding of polypeptide chain into regular structures	Stabilized by hydrogen bonds between backbone atoms (not R-groups)	α-helix, β-pleated sheet, turns and loops	α-helix in keratin; β-sheet in silk fibroin
Tertiary Structure	Overall 3D shape of a single polypeptide chain	Due to interactions between R-groups; essential for biological function	Hydrogen bonds, ionic bonds, disulfide bridges, hydrophobic forces	Myoglobin, Lysozyme
Quaternary Structure	Assembly of two or more polypeptide subunits into a functional protein	Subunits can be identical or different; involved in cooperativity, regulation, complex functions	Same as tertiary (non-covalent + disulfide bridges)	Hemoglobin, DNA Polymerase, Antibodies


Types of Protein Structures
HO
C
O
N
H
H
Primary Structure
alpha helix
beta pleated sheet
Secondary Structure
Tertiary Structure
Quaternary Structure