PEPTIDES AND PROTEINS

Peptides and proteins are biologically important macromolecules composed of amino acids linked together by peptide bonds. They play essential roles in structure, catalysis, transport, regulation, immunity, and signaling in living systems.

Amino Acids as Building Blocks

Amino acids are the fundamental units of peptides and proteins. Each amino acid contains:

- An amino group ($–NH_2$)
- A carboxyl group (–COOH)
- A hydrogen atom
- A variable side chain (R-group) attached to a central α-carbon

Classification of Amino Acids

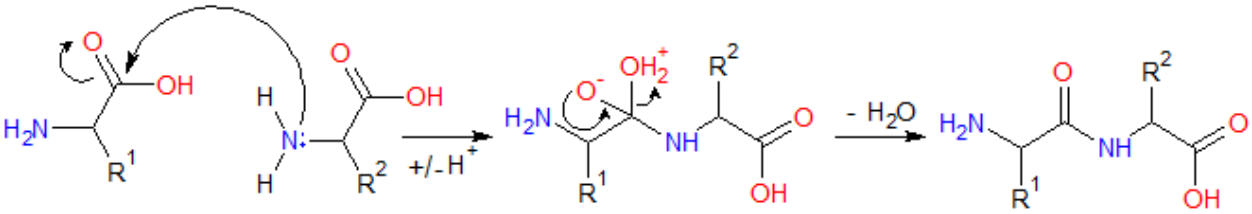
Amino acids are classified based on their R-groups:

- Non-polar (hydrophobic): e.g., glycine, alanine, valine
- Polar (uncharged): e.g., serine, threonine
- Acidic (negatively charged): e.g., aspartic acid, glutamic acid
- Basic (positively charged): e.g., lysine, arginine, histidine

Peptide Bond Formation

A peptide bond is an amide linkage formed when the carboxyl group of one amino acid reacts with the amino group of another, releasing a molecule of water (condensation reaction).

$\{–COOH\} + \{–NH_2\} \rightarrow \{–CO–NH–\} + \{H_2O\}$



he dehydration condensation of two amino acids to form a peptide bond (red) with expulsion of water (blue) with curly arrow mechanism shown

- Dipeptide: two amino acids
- Tripeptide: three amino acids
- Oligopeptide: 2–10 amino acids
- Polypeptide: more than 10 amino acids

Definition of Peptides and Proteins

- Peptides: Short chains of amino acids (usually < 50 residues)
- Proteins: Long polypeptide chains (usually > 50 residues) that fold into specific three-dimensional structures

Levels of Protein Structure

(a) Primary Structure

- The linear sequence of amino acids
- Held together by peptide bonds
- Determines all higher levels of structure

(b) Secondary Structure

- Local folding patterns stabilized by hydrogen bonds
- Common types:
- α-helix
- β-pleated sheet

(c) Tertiary Structure

- Overall three-dimensional shape of a single polypeptide
- Stabilized by:
- Hydrogen bonds
- Ionic interactions
- Hydrophobic interactions
- Disulfide bonds (–S–S–)

(d) Quaternary Structure

- Association of two or more polypeptide chains
- Example: Hemoglobin (four subunits)

Classification of Proteins

(a) Based on Shape

- Fibrous proteins: elongated, structural (e.g., collagen, keratin)
- Globular proteins: compact, functional (e.g., enzymes, hemoglobin)

(b) Based on Composition

- Simple proteins: yield only amino acids on hydrolysis (e.g., albumin)
- Conjugated proteins: contain a non-protein part (prosthetic group)
- Glycoproteins
- Lipoproteins
- Metalloproteins
- Phosphoproteins

Functions of Peptides and Proteins

- Enzymatic catalysis (e.g., amylase, pepsin)
- Structural support (e.g., collagen in connective tissues)
- Transport (e.g., hemoglobin transports oxygen)
- Hormonal regulation (e.g., insulin, glucagon)
- Immune defense (e.g., antibodies)
- Movement (e.g., actin and myosin)

Properties of Proteins

(a) Amphoteric Nature

Proteins can act as both acids and bases due to the presence of ionizable groups.

(b) Isoelectric Point (pI)

- The pH at which a protein has no net charge
- At pI, protein solubility is usually minimum

(c) Solubility

- Globular proteins are generally soluble in water
- Fibrous proteins are usually insoluble

Denaturation of Proteins

Denaturation is the loss of native structure and biological activity of a protein without breaking peptide bonds.

Causes of Denaturation

- Heat
- Extreme pH
- Organic solvents

- Heavy metals

Effects

- Loss of enzyme activity
- Changes in solubility
- Unfolding of protein structure

Biological Importance

Peptides and proteins are indispensable for life. They control metabolic processes, maintain cellular structure, regulate gene expression, and enable organisms to adapt to their environment.