

Lecture 1

Discipline: Bioorganic Chemistry

Lecturer: Associate Professor, Dr. Gulnaz Seitimova

Title: Main tasks of Bioorganic chemistry. Physiological role of biomolecules and trace elements in the body. Amino acids, their characteristics, the difference between α -, β - and γ -amino acids. Classification of natural α -amino acids, their chirality, configuration, isoelectric point, bipolar ion, chemical and biological properties.

Objective: To introduce the goals of bio-organic chemistry and show the relationship with biochemistry, biotechnology and medicine, explain physiological functions of biomolecules and trace elements, and describe structural and functional diversity of amino acids. To understand the structural features of amino acids, their characteristics, the difference between α -, β - and γ -amino acids. Classification of natural α -amino acids, their chirality, configuration, isoelectric point, bipolar ion, chemical and biological properties.

Main Questions: Definition, subject, and main tasks of bioorganic chemistry. Major classes of biomolecules and their physiological roles. Biological significance of macro- and trace elements. General structure of amino acids; differences between α -, β -, and γ -amino acids. Classification of natural α -amino acids. Chirality and configuration of amino acids. Isoelectric point (pI) and the concept of zwitterions. Chemical properties (acid-base, reactions of carboxyl and amino groups). Biological functions and metabolic roles of amino acids.

Brief Theses of the Lecture Content

Bioorganic Chemistry: Definition and Main Tasks

Bioorganic chemistry is a branch of chemistry that studies the structure, properties, reactivity, biosynthesis, and transformations of organic molecules involved in biological systems.

Its main tasks include:

- Understanding molecular mechanisms of life processes.
- Investigating how structure determines function in biomolecules.
- Studying metabolism and enzymatic catalysis at the molecular level.
- Exploring chemical pathways that sustain cellular processes.
- Applying chemical principles to biomedical, pharmaceutical, and biotechnological fields.

Physiological Role of Biomolecules

Biomolecules are compounds produced by living organisms and are essential for maintaining life.

1. Carbohydrates: Provide metabolic energy (glucose), structural functions (cellulose, chitin), participate in cell recognition (glycoproteins).
2. Lipids: Serve as long-term energy reserves, form biological membranes, act as signaling molecules (steroids, eicosanoids).
3. Proteins: Perform enzymatic, structural, transport, regulatory, immune, and contractile functions.
4. Nucleic acids: Carry genetic information (DNA), participate in protein synthesis (RNA), regulate gene expression.

5. Vitamins and cofactors: Function as enzyme activators, antioxidants, and metabolic regulators.

Physiological Role of Trace Elements

Trace elements (Fe, Zn, Cu, Mn, I, Se, Co, etc.) are required in very small amounts but are critical for:

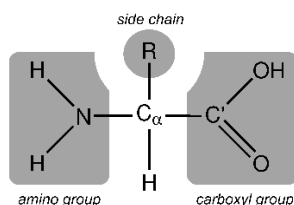
- Enzyme catalysis (Zn in carbonic anhydrase, Mg in ATP-dependent enzymes).
- Oxygen transport (Fe in hemoglobin).
- Hormone synthesis (Iodine in thyroid hormones).
- Antioxidant defense (Se in glutathione peroxidase).
- Electron transport and redox reactions (Cu, Fe, Mn).

Deficiency or excess of trace elements leads to metabolic disorders.

Amino Acids: General Structure and Types

Amino acids are organic molecules containing both an amino ($-\text{NH}_2$) and carboxyl ($-\text{COOH}$) group.

General structure of α -amino acids:



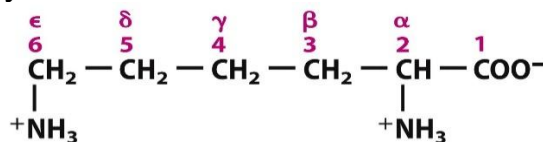
where R is a side chain determining the amino acid's properties.

Difference between α -, β -, and γ -amino acids:

- α -amino acids: amino group attached to the carbon adjacent to the carboxyl group.
- β -amino acids: $-\text{NH}_2$ attached to the second carbon.
- γ -amino acids: $-\text{NH}_2$ attached to the third carbon.

Only α -amino acids form proteins.

Carbon Numbering System



Lysine

Unnumbered 3 p74
Lehninger Principles of Biochemistry, Fifth Edition
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Classification of Natural α -Amino Acids

Amino acids are classified by the nature of the side chain (R-group):

1. Non-polar (hydrophobic): Gly, Ala, Val, Leu, Ile, Met, Phe, Trp, Pro
2. Polar, uncharged: Ser, Thr, Cys, Tyr, Asn, Gln
3. Basic: Lys, Arg, His
4. Acidic: Asp, Glu

5. Aromatic: Phe, Tyr, Trp
6. Sulfur-containing: Cys, Met
7. Special-structure: Glycine (achiral), Proline (cyclic), Histidine (imidazole ring)

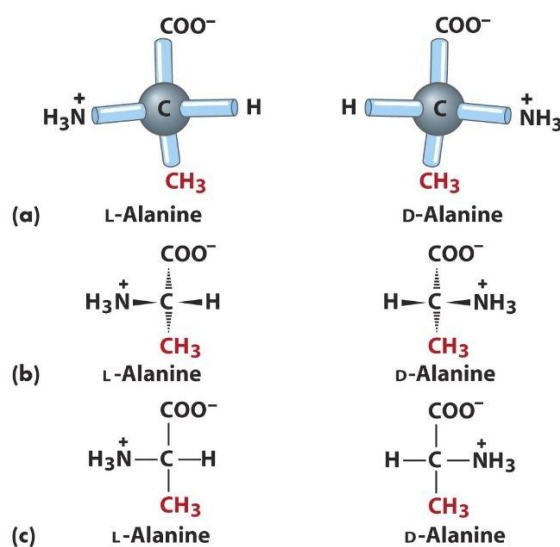
Chirality and Configuration

Most natural amino acids (except glycine) are chiral because the α -carbon is attached to four different groups.

Natural protein-forming amino acids have *L*-configuration, corresponding to the stereochemistry of *L*-glyceraldehyde.

Chirality affects:

- Folding of proteins
- Enzyme specificity
- Biological activity



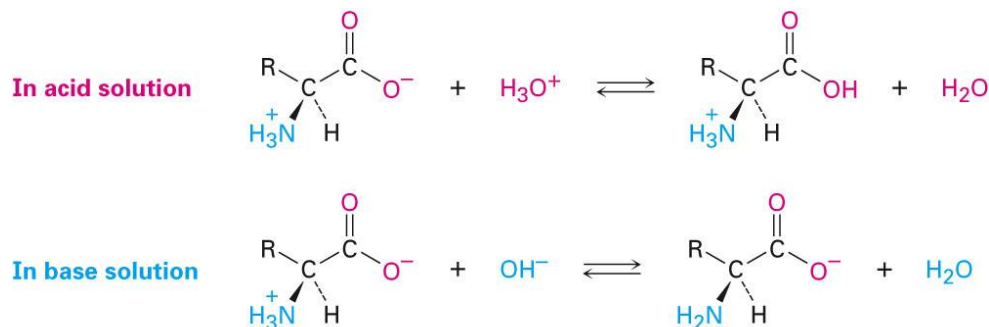
Isoelectric Point (pI) and Zwitterions

Amino acids exist in aqueous solutions as zwitterions, which contain both a positively charged ammonium group ($-\text{NH}_3^+$) and a negatively charged carboxylate group ($-\text{COO}^-$).

The isoelectric point (pI) is the pH at which the amino acid has no net charge.

- At $\text{pH} < pI \rightarrow$ amino acid is positively charged.
- At $\text{pH} > pI \rightarrow$ amino acid is negatively charged.

pI depends on whether the amino acid is acidic, neutral, or basic.



Chemical Properties of Amino Acids

1. Acid-base reactions: Amino acids act as ampholytes; they can donate or accept protons.
2. Reactions of –COOH group:
 - Esterification
 - Decarboxylation
 - Peptide bond formation (amide linkage)
3. Reactions of –NH₂ group:
 - Acylation
 - Alkylation
 - Schiff base formation with aldehydes
4. Side-chain-specific reactions:
 - Oxidation of cysteine to cystine
 - Aromatic amino acids absorb UV light ($\lambda = 280$ nm)
 - Phosphorylation of serine, threonine, tyrosine

Biological Role of Amino Acids

Amino acids participate in:

- Protein and enzyme synthesis
- Energy production (via TCA cycle intermediates)
- Synthesis of hormones (thyroxine, epinephrine)
- Neurotransmitters (GABA, serotonin)
- Detoxification and nitrogen metabolism
- Antioxidant defense (glutathione)

Some amino acids are essential (Val, Leu, Ile, Lys, Met, Phe, Trp, Thr, His), others are synthesized in the body.

Questions for Knowledge Assessment

1. What is the definition and main purpose of bioorganic chemistry?
2. List the main classes of biomolecules and their physiological functions.
3. What is the biological role of important trace elements?
4. Describe the structural difference between α -, β -, and γ -amino acids.
5. How are natural α -amino acids classified?
6. What is chirality and why is it important for amino acids?
7. Define the isoelectric point and zwitterionic form.
8. What chemical reactions are characteristic for amino acids?
9. What are essential amino acids and why are they necessary?

Recommended Literature

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