# Chemistry 1506: Allied Health Chemistry 2

## Section 9: Proteins

### Biochemical Amides

### Outline

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Section 9.1 Protein Roles

- Structural Proteins
  - Cellular
  - Bodies
    - Tendons
    - Muscles
    - Bones

- Movement Proteins
  - Intracellular
  - Cellular
  - Bodies

- Molecular Transport Proteins
  - Within Cells
  - Across Membranes
- Catalysis Proteins
  - Digestion
  - Biochemical Pathways

- Protection Proteins
  - Antibodies

- Hormone Proteins

- Regulation of Cellular Activity Proteins

- Storage Proteins (e.g., Ca^{2+})
Section 9.2 Amino Acids

- General Structure

- 20 Commonly Occurring Amino Acids
  - $\alpha$-Amino Acids
  - 19 are chiral at $\alpha$ carbons
  - See Table in Text
Nonpolar Amino Acids

Size

Total Steric Bulk

Distance of bulk from protein backbone

- \( R = H, \text{ Glycine, Gly} \)

- \( R = \text{CH}_3, \text{ Methyl, Alanine, Ala} \)

- \( R = \text{CH(CH}_3)_2, \text{ Iso-Propyl, Valine, Val} \)
- \( R = CH_2CH(CH_3)_2 \), Iso-Butyl, Leucine, Leu

- \( R = C^*(CH_3)(CH_2CH_3) \), Sec-Butyl, Isoleucine, Ile

- \( HN\{CH_2CH_2CH_2\text{-ring}\}CH-CO_2H \), Proline, Pro
➢ R = CH$_2$-C$_6$H$_5$, Aromatic, Phenylalanine, Phe

➢ R = CH$_2$CH$_2$-S-CH$_3$, Thioether, Methionine, Met
Neutral Polar Amino Acids

- R = CH$_2$-OH, 1° Alcohol, Serine, Ser

- R = CH(CH$_3$)-OH, 2° Alcohol, Threonine, Thr

- R = CH$_2$-SH, Thiol / Thioalcohol, Cysteine, Cys

- R = CH$_2$-(1,4-C$_6$H$_4$)-OH, Phenol, Tyrosine, Tyr
➤ R = CH₂-C(=O)-NH₂, Amide, Asparagine, Asn

➤ R = CH₂-CH₂-C(=O)-NH₂, Amide, Glutamine, Gln

➤ Tryptophan, Trp, Heterocyclic

➤ Aromaticity effects on Nitrogen basicity

➤ R =

![Tryptophan structure]

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Acidic Amino Acids

Variable Chain Lengths

- $R = \text{CH}_2\text{-CO}_2\text{H}$, Aspartic Acid, Asp

- $R = \text{CH}_2\text{CH}_2\text{-CO}_2\text{H}$, Glutamic Acid, Glu
Basic Amino Acids

Variability

Base Distance

Base Strength, Lone pairs on Nitrogen

R = CH$_2$CH$_2$CH$_2$CH$_2$-NH$_2$, Lysine, Lys

R = CH$_2$CH$_2$CH$_2$NH-C(=NH)-NH$_2$, Arginine, Arg

Histidine, His

R =
Zwitterions

Molecules that contain both a positive charge and a negative charge

Intramolecular Acid-Base Chemistry

Isoelectric Point

pH at which Amino Acids are in Zwitterionic form
Cysteine

Cysteine $\Rightarrow$ Cystine

Oxidation with loss of $\text{H}_2$

Thiols $\Rightarrow$ Disulfides

Reversible Redox (Reduction reverses the reaction)
Section 9.3 Peptides and Proteins

- Peptide (Amide) Bonds
  - 6 atom unit
  - rigid
  - trans arrangement about amide linkage
  - planar
  - Dipeptide example

![Dipeptide example](image)

- Peptide Sizes
  - Dipeptide, Tripeptide, Tetrapeptide… Polypeptide….Protein

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Structures of peptides and proteins specified with 3 letter codes

- 1st start from NH$_2$ groups on the left
- Identify side chains
- Join Amino Acids by peptide bonds

Typical Exam Questions

- Example Ala-Gly-Lys
 Levels of Structure

- 1°, Primary Structure
  - Sequence of Amino Acids in protein backbone

- 2°, Secondary Structure
  - α-Helix and β-Pleated Sheets

- 3°, Tertiary Structure
  - Overall 3D shape/folding of protein chain

- 4°, Quaternary Structure
  - Multiple separate proteins clustered together
Typical Positions of Amino Acids in Proteins

- Core Amino Acid Residues
  - Nonpolar Amino Acids

- Surface Amino Acid Residues
  - Depends on protein position
    - Polar/Hydrogen Bonding/Ionic Residues where touch water
    - Nonpolar residues where in membrane

Active Site

- Acid/Basic/Etc. residues to Catalyze reactions
- Nonpolar and Polar/Hydrogen Bonding/Ionic to hold substrate in Position
How proteins keep their shapes

“Hydrophobic” vs. “Hydrophilic” Interactions

Types of Bonds Holding Proteins in their Shapes

Covalent Bonds, Directional

Disulfide linkages, Directional

Ionic Bonds, Non-directional

Hydrogen Bonds, Directional

Dipole-Dipole Interactions, Non-directional

Van der Waal’s Interactions, Non-Directional

Individually weak but strong in total
Section 9.4 Primary Structure

- Sequence

- Number of Possibilities

  - \((\text{number of Amino Acids})^n\)

  - where \(n\) is the chain length

  - Example: 20 AA in mammals ⇒

    - dipeptides have \((20)^2 = 400\) \(1\)° structures

    - tripeptides have \((20)^3 = 8,000\) \(1\)° structures

- \(1°\) Structure Determines \(2°, 3°,\) and \(4°\) Structures

- Thermodynamics

- Kinetics

- Types of Structural Variations Found in “the Same” protein

  - Between individuals in a species

  - Between sub-populations in a species

  - Between species
Effects of Structural Variations

- Depend on site and nature of substitutions
- Some changes have no observable effects
- Some changes have effects
  - On rates
  - On control
  - On specificities
- Some changes kill activity
  - These changes work by changing $2^\circ$, $3^\circ$, and $4^\circ$ structures
  and hence protein reactivity
Section 9.5 Secondary Structure

- Types of 2° structures
- See Figure in Text
  - α-Helix

- β-Pleated Sheet

- Held together by intra-structural Hydrogen Bonds
  - between backbone groups
  - N-H Hydrogen Bonds Donors
  - C=O Hydrogen Bond Acceptors

- Random coils/chains
Section 9.6 Tertiary And Quaternary Structure

➢ Bond Types same as on list above for other structural features

➢ Collagen

➢ Found in human connective tissue, very strong

➢ See Figure in Text

➢ Each Collagen molecule is a triple helix (of 3 chains)

➢ Each chain is an individual molecule made up of an \( \alpha \)-helix

➢ Twisted together like braiding

➢ Chaperones

➢ Proteins that assist folding to give thermodynamically preferred structures
Denaturation and Naturation

- Often reversible
- Can be artificially induced by heat, solvent, salts, etc.

Denaturation
- Loss of native 3D structure

Naturation
- Gain of native 3D structure

Glycoproteins
- Sugars bonded to protein surfaces
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