Amino Acids and Proteins

Introduction to Amino Acids and Protein Structure – A Complement to Chapter 18

Proteins are Biomolecules

Biomolecules:
- Proteins, carbohydrates, lipids and nucleic acids are examples of biomolecules.
- Many biomolecules are polymers containing hundreds of thousands of repeating units.
- Proteins are polymers that range in size from 10,000 g/mole to 150000 g/mole.

Topics Covered

Amino Acids and Proteins-An Introduction
- Introduction to the role of proteins
- Structure of Proteins
  - Primary, secondary, tertiary and quaternary structures
  - Importance of Protein Structure
- Properties of amino acids
  - Composition
  - Geometry-stereochemistry
  - Acid and base properties
  - Interactions between amino acids

Proteins
- Most people know that proteins are something they are supposed to eat, and some people have heard about essential amino acids and they know that these have something to do with proteins.
Proteins vs. DNA

- DNA, the instructions for our cells, gets a lot of attention, but DNA just tells an organism how to make proteins. Aside from a little bit of material that comes from our mothers, proteins are what made our bodies, and organize how our bodies function.

Protein Structure:

Proteins are the polymers of amino acids and have four levels of structure:

- Primary
- Secondary structure
- Tertiary structure
- Quaternary structure

We will deal with each one of them individually

Primary Structure

The primary structure of protein is sequence of its amino acids.
Polymers

Polymers are long chains of repeating chemical units. Though many biomolecules are polymers, polymers are also found in distinctly non-biological molecules.

This necklace is composed of beads, polymers are composed of monomers.

(propanediol (Polyoxymethylene))

Proteins—Necklaces of Amino Acids

Amino acids are the monomers that make up proteins. The subunits in all proteins are similar and are linked by the same type of chemical bond.

Two or more amino acids can be linked together by a peptide bond.

- A dipeptide results from the linkage of two amino acids.
- A tripeptide results from the linkage of three amino acids.
- A polypeptide results from joining multiple amino acids.
- A protein typically contains more than 100 amino acids linked together.

The alpha carbon is the central carbon in an amino acid to which the amine, carboxyl and side chain R groups attach.

Side chain R group, different for each amino acid.

Proline is the exception.
Amino Acid Chains

The carbon and nitrogen atoms lie along a zig-zag pattern along the backbone. Each α-carbon is tetrahedral, and each carboxyl carbon is planar.

Primary Protein Structure

- The primary structure of a protein is the sequence of its amino acids.
- The primary structure is very important. Even a single residue change in the sequence can change the biological activity. Sickle cell anemia is the result of a single amino acid change in the hemoglobin.
- In order to understand why a small change in the primary structure is so significant, it is important to consider the amino acids that make up the primary structure.

Acidic and Basic Amino Acids

- Twenty amino acids are found in naturally occurring proteins.
- The side chains (R groups) determine the characteristics of the amino acids.
- The functional groups (−COOH, −NH₂, −CH₃, −OH) on the side chains determine these characteristics.
- Amino acids are commonly grouped according to their characteristics.
Neutral And Basic Amino Acids

- The amino acids are classified as neutral, acidic and basic depending on the nature of their side chain.
- All amino acids have an amine and carboxyl group, but only some have them in the –R groups.
- The main chain amine and carboxyl groups are not considered when amino acids are classified as acids or bases.

Acidic Amino Acids

There are 2 amino acids with acidic side groups.

Basic Amino Acids

There are 3 amino acids with basic side groups.

Polar and Nonpolar Amino Acids
Polar and Nonpolar –R groups

- Side groups are also classified according to their polarity.
- There are 9 amino acids with nonpolar side chains.
- There are 6 with polar side chains that are neither acid or basic.

Polar and Nonpolar –R groups

- The nonpolar amino acid side chains do not dissolve in the water. They are called hydrophobic, water fearing.
- The polar, acidic and basic side chains dissolve in water and are called hydrophilic, water loving.
- The polarity of amino acids is key in determining the tertiary and quaternary structure of proteins.

Polar/Nonpolar Review

- Polar molecules can dissolve in water.
- Nonpolar molecules do not dissolve in water.
- Water is polar. That polar side chains dissolve in water is a case of like dissolves like.
- If a nonpolar molecule dissolves in water the nonpolar molecule disrupts the structure of water--hydrogen bonding and δ⁺–δ⁻ alignment.

Polar/Nonpolar Review

Differences in the electronegativity between atoms in a molecule determine if a covalent bond is polar or nonpolar.
Polar/Nonpolar Review

Nonpolar Amino Acids

Less polar
\[ \delta^+C-N\delta^- \]
Electronegativity difference:
\[ 3.0 - 2.5 = 0.5 \]

More polar
\[ \delta^+C-O\delta^- \]
Electronegativity difference:
\[ 3.5 - 2.5 = 1.0 \]

What the Ring Means

- The ring is called a phenyl functional group. It is quite nonpolar, and is flat.
  - Each corner of the ring stands for a carbon, with a bond to a hydrogen atom.
  - This shorthand is used because it is inconvenient to keep drawing the whole thing out and because this ring has special properties.
  - Phenyl side groups resemble the molecule benzene, shown on the left, except that one or more of the carbons bond to something else other than a hydrogen atom.
  - Phenyl groups are nonpolar when the atoms joined to them have an electronegativity close to that of carbon.

Background

Polar Amino Acids

- There are 6 other amino acids that are usually classified as nonpolar.
- There are 3 other polar amino acids + 5 acidic and basic amino acids that can behave as polar amino acids.
Summary of Amino Acid Polarity

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<th>3-Letter</th>
<th>Side chain polarity</th>
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<tr>
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<td>nonpolar</td>
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<tr>
<td>Asparagine</td>
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<td>polar</td>
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<tr>
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<tr>
<td>Isoleucine</td>
<td>Ile</td>
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</table>

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<tr>
<td>Valine</td>
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Acid Base Nature of Amino Acids

- All nonbonded Amino acids contain both an acidic group (-COOH) and a basic amino group (-NH₂).
- The presence of the acidic and the basic groups on the same can result in an intramolecular acid base reaction.
- The result is the transfer of the hydrogen from the –COOH group to the –NH₂ group to form a dipolar ion that has one positive charge and one negative charge and is electrically neutral. Dipolar ions are known as zwitterions.

- Because of the zwitterions nature, the amino acids have the properties of salts.
- They have high melting point, they are crystalline and are water soluble.
• **In acidic solutions** the amino acids can gain one proton. Then they have a positive charge due to the -NH$_3^+$ end.

\[
\text{NH}_3^+ \text{CH}_2\text{CH}_2\text{COOH} + \text{H}^+ \rightarrow \text{NH}_2\text{CH}_2\text{CH}_2\text{COO}^- + \text{H}_2\text{O}
\]

• **In basic solution** the acidic -NH$_3^+$ end gives the proton and leaves the negatively charged -COO$^-$ group.

\[
\text{NH}_3^+ \text{CH}_2\text{CH}_2\text{COOH} + \text{OH}^- \rightarrow \text{NH}_2\text{CH}_2\text{CH}_2\text{COO}^- + \text{H}_2\text{O}
\]

The charge on the amino acid depends on the amino acid and the pH of the medium.

**The pH at which an amino acid has equal numbers of positive and negative charges is called isoelectric point pI. At this point the overall charge on the amino acid is zero.**

**Chirality of Amino Acids**
Chiral (Ky-ral) molecules

The objects that are mirror images of each other but they cannot be superimposed on top of each other are called chiral, for example the mirror images of the hand.

Achiral Objects

- The objects whose mirror images can fit on each other are called achiral, like the images of a chair.

Can you identify the chiral and achiral objects?

Amino Acids are Chiral

- All but one amino acids is chiral.
- Left hand amino acids are used in proteins.
There Chiral Molecules in General

- There are many chiral molecules that are not biomolecules, though handedness of molecules tends to be important in biological systems.
- A carbon atom attached to four different groups is a chiral carbon atom.

Which one of the amino acids is achiral?

A  B  C  D  E  F

Summary

In this presentation the primary structure of proteins has been discussed. This discussion considered the properties of amino acids, the monomers that make up protein chains. In the presentation following this secondary, tertiary, and quaternary structure will be discussed.