Amino Acids — Structural Features, Classification and Ionization

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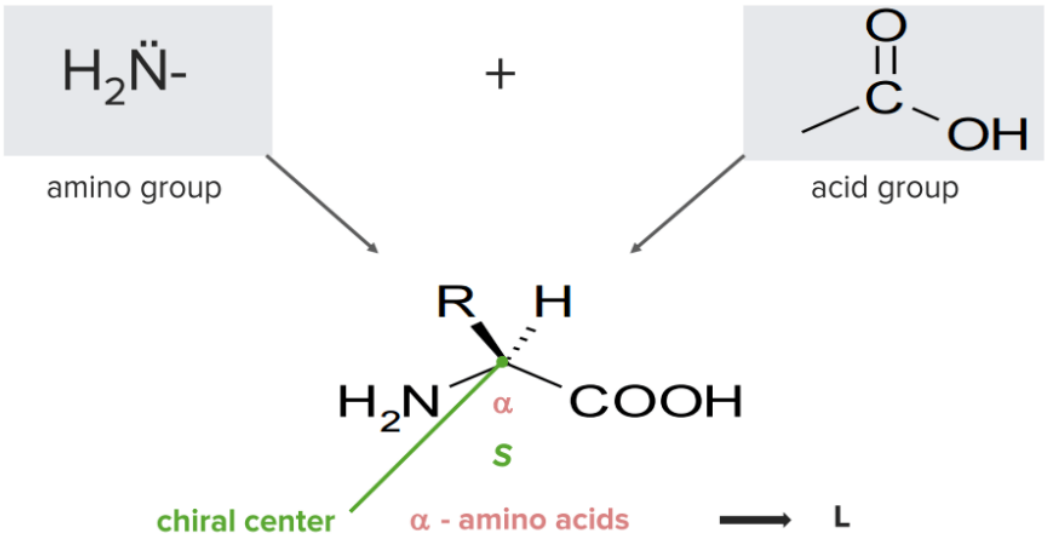
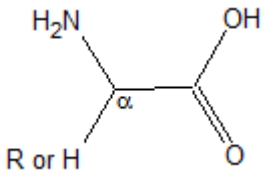
Amino acids are the simplest unit of a protein. It has distinct structural characteristics that are responsible for the different types of interaction it can make inside the body. It is important to study the structure of amino acids as the functioning of proteins is highly affected by the type of comprised amino acids. In this article, the structural features and properties of an amino acid will be discussed. Also included in this article is the classification of the amino acids based on the side chain it has. The focus is also given to the ionization of amino acids.



Amino Acids

Amino acids are the **building blocks of proteins**. Different amino acids may combine to form linear chains called polypeptides. Different polypeptides have different functions and so the **type and arrangement of amino acids that comprise them are unique**. Changes in the arrangement of the amino acids can lead to having the polypeptide not functioning well for its supposed purpose.



General Structure of Amino Acids,
prepared by Mark Xavier Bailon

Amino acids are compounds, any compound, that contains an amino and a carboxylic acid group in its structure. In the context of biomolecules, **α-amino acids are more important**. In α-amino acids, the amino group is attached to the α-carbon or the carbon adjacent to the carboxyl carbon. In this article, the general term amino acids will be used to refer to the α-amino acids.

Since all amino acids contain an amino and a carboxy group, the **structural differences of amino acids arise from the variety of R groups that can be present**. Different R groups will have varying degrees and types of interaction with the environment and other components. Understanding the chemistry of the side chains of amino acids is important in understanding properties of individual amino acids and the proteins they form.

There are 21 common α-amino acids found in all proteins or polypeptides. Humans can synthesize some of these amino acids, while the others are obtained by the diet we have. The ones we obtain from our diet are called essential amino acids. The 9 essential amino acids are the following.

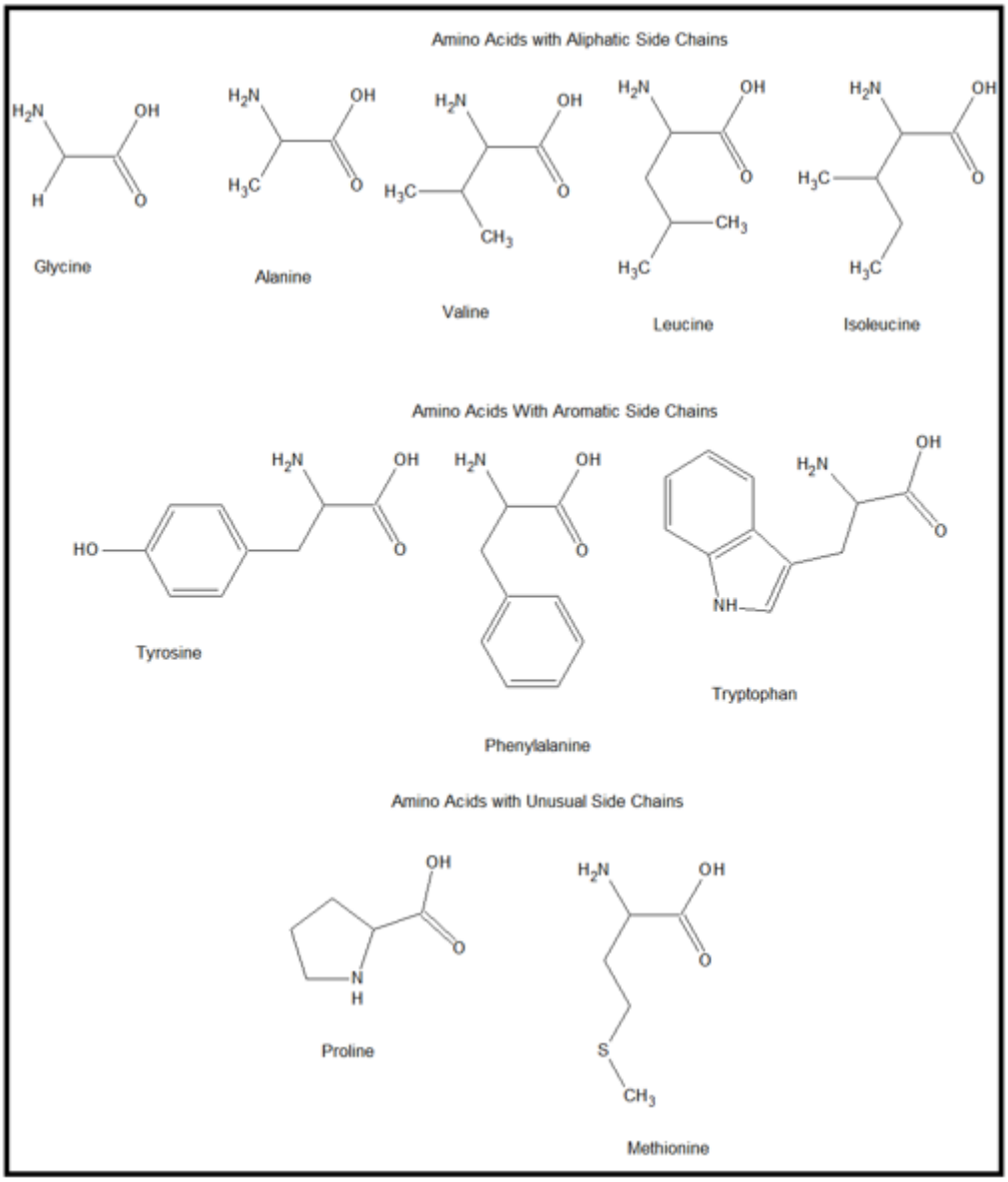
1. Histidine
2. Isoleucine
3. Leucine
4. Lysine
5. Methionine
6. Phenylalanine
7. Threonine
8. Tryptophane
9. Valine

The rest of the amino acids will be named later in the article.

Amino acids can be **classified in a variety of ways**. One common way of classification is based on their **interaction with water**. There are amino acids that are considered hydrophobic (water-fearing), hydrophilic (water-loving), and or ionic. It depends on the type of R group one can classify whether the amino acid will belong to any of the three groups.

Hydrophobic Amino Acids

Hydrophobic amino acids are those whose **side chains are considered non-polar**. Since the solvent water is a polar molecule, the non-polar side chains do not like to interact with the solvent and so in a protein structure, **these R groups are usually buried in the core of the protein**. Below are the structures of the different amino acids in this group.



Hydrophobic Amino Acids, prepared by Mark Xavier Bailon

Glycine

The **smallest amino acid** is Glycine. This is considered a hydrophobic amino acid because its **side chain is just a single hydrogen atom**. Unlike most amino acids where the α carbon is chiral (it has four different substituents around it), glycine is the only one with no chiral center.

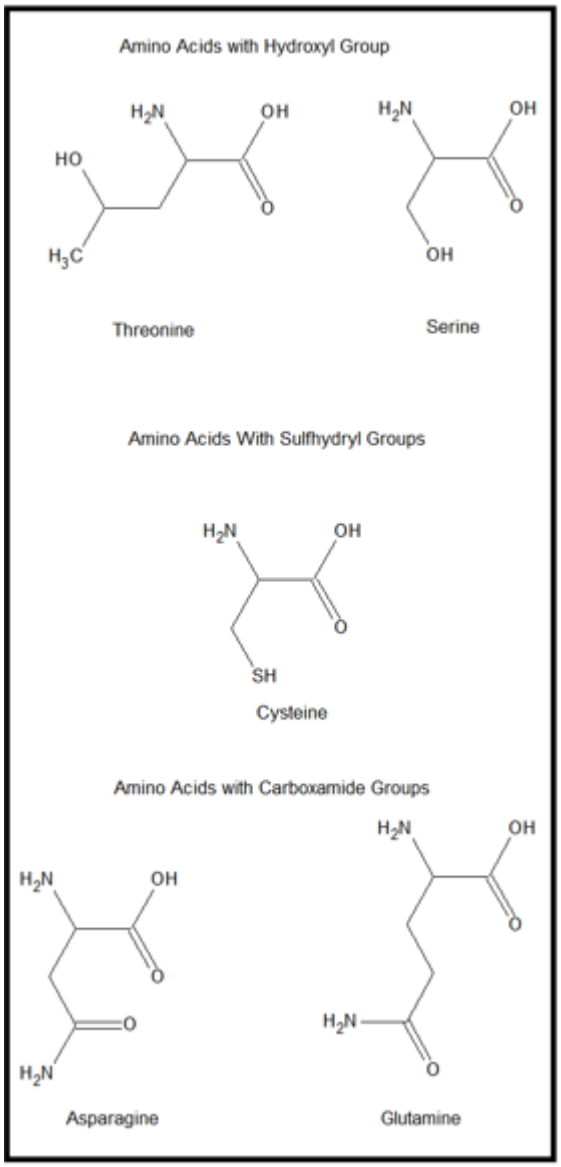
Other amino acids of this group are those with hydrocarbon side chains. These are the following.

- isoleucine
- alanine
- leucine
- valine

Hydrocarbon side chains are also considered non-polar due to the presence of only C and H atoms which have close electronegativity values. Amino acids containing aromatic side chains are also part of this group. These are Phenylalanine, tyrosine, and tryptophan. Methionine and Proline are also members of this group because of their unique structural characteristics. Methionine has a thioether group while proline contains

a cyclic structure where the amino and the α-carbons are part of the cycle.

Hydrophilic Amino Acids



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Hydrophilic amino acids are those whose **side chains are polar and not readily ionizable**. Common functional groups present in these side chains are carboxamide, sulfhydryl and hydroxyl groups. Six amino acids are members of this group.

The amino acids with carboxamide functional groups are asparagine and glutamine. They are amide derivatives of aspartate and glutamate, respectively.

Amino acids with sulfhydryl groups are cysteine. Cysteine molecules when oxidized tend to form disulfide linkages.

The amino acids with hydroxyl groups in their side chains are serine, threonine, and tyrosine.

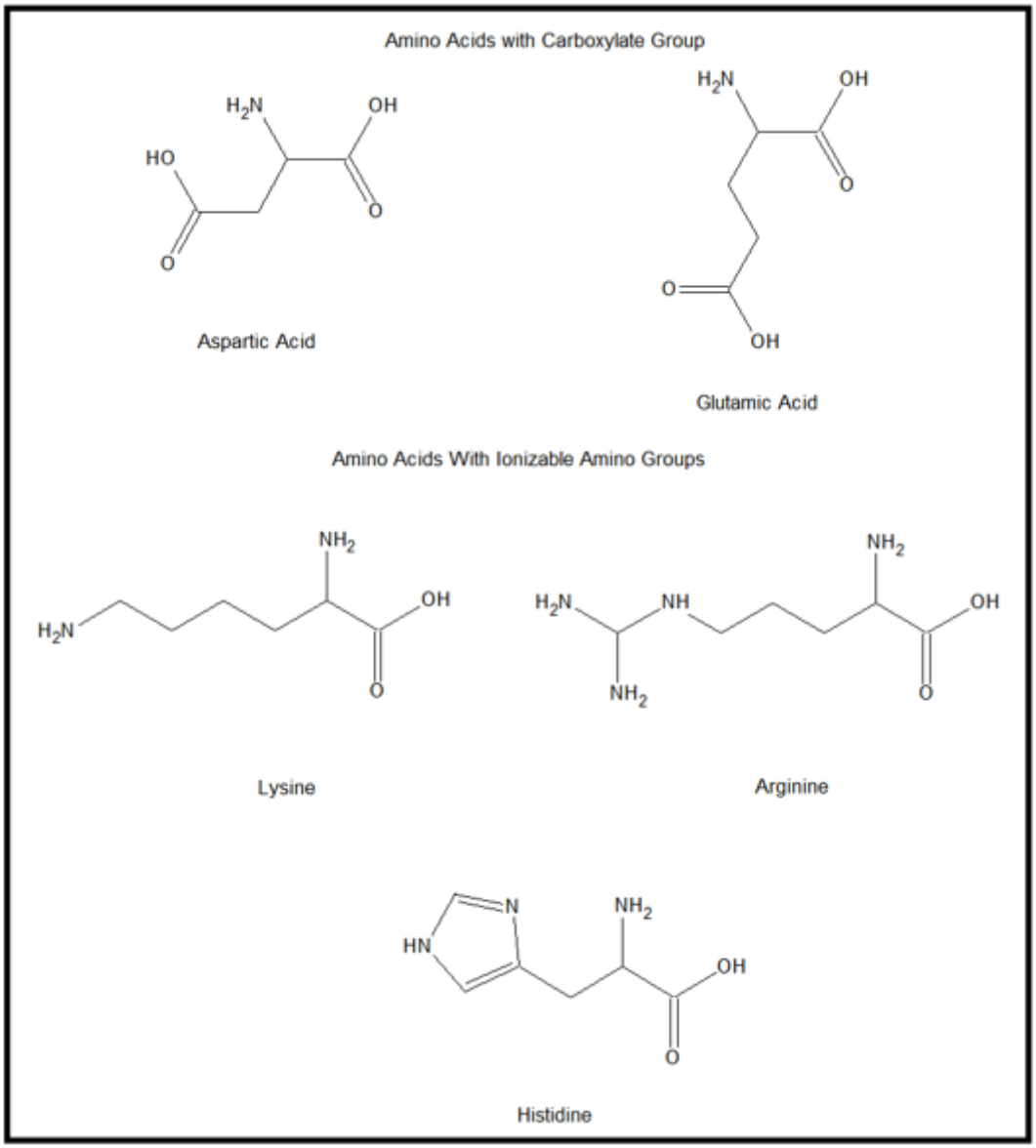
Ionic Amino Acids

The last group of amino acids is the ionic amino acids. These are the amino acids that are **ionized depending on the reaction condition**. This classification is further divided into the two following groups:

1. Basic
2. Acidic

Basic amino acids are those that contain **side chains that tend to accept protons**. They have additional amino groups in their side chains that make them more basic. Amino acids of this group include lysine, histidine, and arginine. Depending on the pH of the system, the amino groups in the side chains can be protonated.

Acidic amino acids are those whose **side chains contain additional carboxyl groups**. Depending on the pH of the solution, these side chains can be deprotonated. Amino acids of this group include aspartic acid and glutamic acid. Below are the structures of the different ionic amino acids.



Ionic Amino Acids. Prepared by Mark Xavier Bailon

Ionization

Carboxyl and amino groups have **almost the same strength of acidity and basicity**, respectively. In fact, at neutral pH of 7, the carboxy group of the amino acid is in its deprotonated form, while the amino group is in its protonated form. When this occurs, the amino acid forms a zwitterion or a dipolar ion. Because of the dipolar nature of amino acids, they tend to exhibit some uncommon properties.

Generally, amino acids have **high melting points**. They are also **more soluble in water** than in ether and dichloromethane. They have large dipole moments than normal amines and carboxylic acids. They are less acidic than normal carboxylic acid and less basic than normal amines. Because of having both a basic and acidic part in its structure, amino acids are considered also as amphoteric compounds, that is it both exhibits basic and acidic properties.

At neutral pH, both the amino and carboxylic acid groups exist in its ionic form. When you lower the pH of the solution, the $–COO^-$ tend to accept a proton to form the –COOH group. On the other hand, when you increase the pH of the solution, the $–NH_3^+$ tend to release a proton to produce $–NH_2$ group. In this way, amino acids tend to be cationic in acidic solution, and anionic in basic solution. Presence of another carboxylic acid, amino, and a hydroxyl group in the side chains also contribute in the degree of ionization in varying pH values.

Review Questions

The correct answers can be found below the references.

1. Which amino acid can form disulfide linkage when oxidized?

A. Methionine
B. Cysteine
C. Lysine
D. Arginine

2. What do you call the ionic form of an amino acid where the carboxylic acid group is deprotonated while the amino group is protonated?

A. Carboxylate
B. Amino
C. Zwitterion
D. Bipolarity

References

Voet, D., & Voet, J. G. (2011). *Biochemistry*(4th ed.). New York: J. Wiley & Sons.

Reece, J. B., Taylor, M. R., & Simon, E. J. (2012). *Campbell biology: concepts & connections*. Boston: Benjamin Cummings.

Correct answers: 1B, 2C

Notes