Department of Medical Biochemistry, Osun State University,

BCH 201:

Amino Acid Chemistry: Structure and Classification

Introduction

- **Amino acids** are the building blocks of protein, which is one of the major biologically active compounds in the body.

- As many as 300 amino acids occur in nature. Of these, only 20—known as **standard amino acids** are repeatedly found in the structure of proteins, isolated from different forms of life— animal, plant, and microbial.

- This is because of the **universal nature of the genetic code** available for the incorporation of only 20 amino acids when the proteins are synthesized in the cells

- Amino acids are a group of **organic compounds** containing two functional groups— amino and carboxyl. The amino group (—NH2) is basic, while the carboxyl group (—COOH) is acidic in nature.

General structure of amino acids

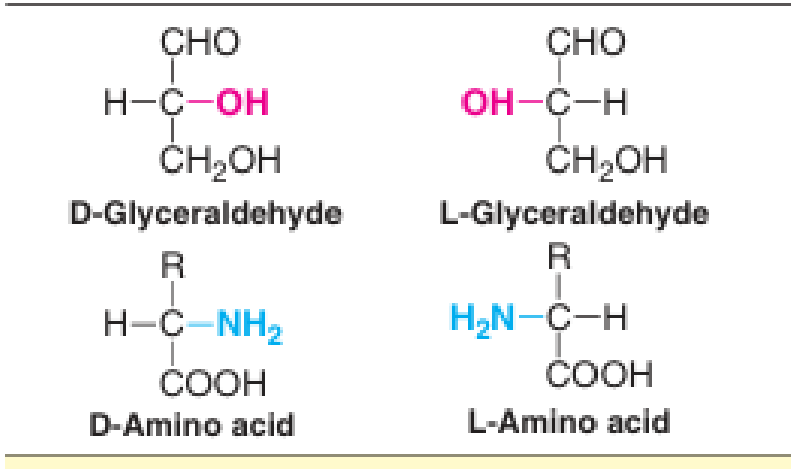
- The amino acids are termed as **α-amino acid**, if both the carboxyl and amino groups are attached to the same carbon atom, as depicted below:

- The *α-carbon atom binds to a side chain represented by R*, which is different for each of the 20 amino acids found in proteins. The amino acids ***mostly exist in the ionized form*** in the biological system (shown above)

Optical isomers of amino acids

- If a carbon atom is attached to four different groups, it is asymmetric and therefore exhibits optical isomerism. The amino acids (except glycine) possess four distinct groups (R, H, COO^-, NH_3^+) held by the α-carbon. Thus, all the amino acids (except glycine, where R = H) have optical isomers.

- The structures of L- and D-amino acids are written based on the **configuration of L- and D-glyceraldehyde**, as shown in the figure below. *The proteins are composed of L--amino acids*.



CLASSIFICATION OF AMINO ACIDS

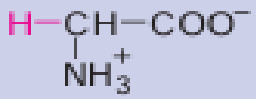
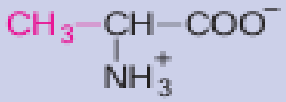
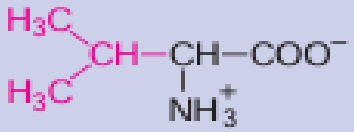
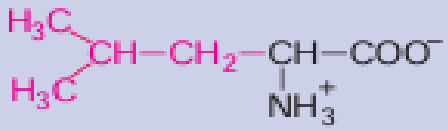
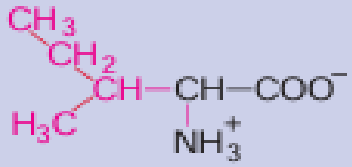
- There are different ways to classify amino acids. These include classifications based on their structure and chemical properties, nutritional requirements, metabolic fate, etc.

A. Amino acid classification based on their structure:

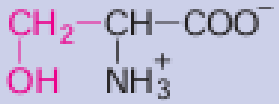
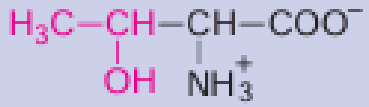
- A comprehensive classification of amino acids is based on their structure and chemical nature. Each amino acid is assigned a **3-letter** or **1-letter** symbol.

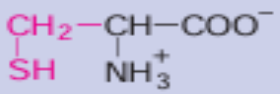
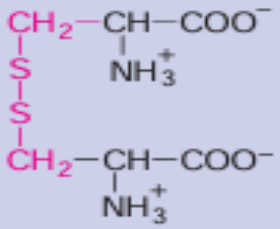
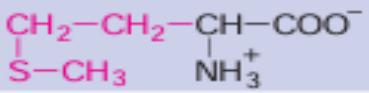
- These symbols are commonly used to represent the amino acids in protein structure. The 20 amino acids found in proteins are divided into **seven distinct groups**.

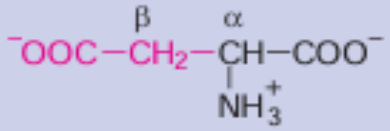
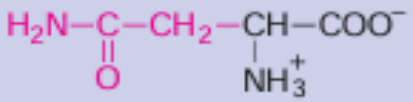
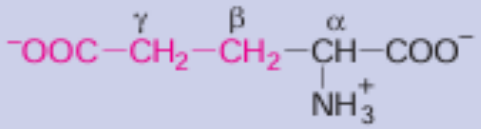
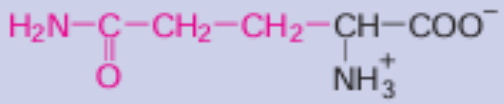
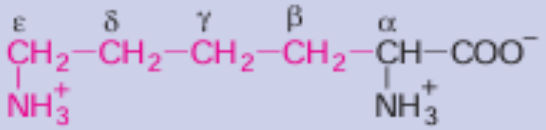
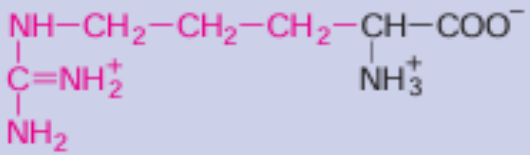
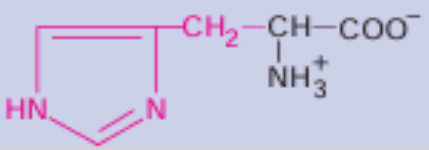
- In the tables that follow, the different groups of amino acids, their symbols, and structures are given. The salient features of different groups are described next

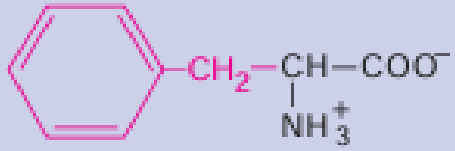
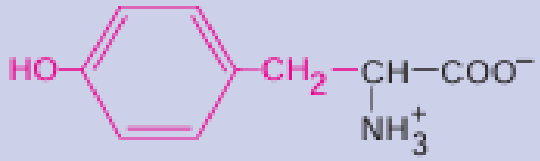
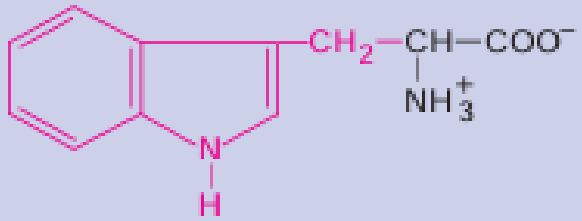
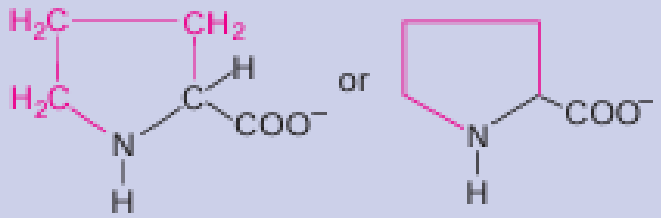
Name	Symbol		Structure	Special group present
	3 letters	1 letter		
I. Amino acids with aliphatic side chains				
1. Glycine	Gly	G		
2. Alanine	Ala	A		
3. Valine	Val	V		Branched chain
4. Leucine	Leu	L		Branched chain
5. Isoleucine	Ile	I		Branched chain

II. Amino acids containing hydroxyl (—OH) groups

6. Serine	Ser	S		Hydroxyl
7. Threonine	Thr	T		Hydroxyl
Tyrosine	Tyr	Y	See under aromatic	Hydroxyl

Name	*Symbol*		*Structure*	*Special group present*
	3 letters	*1 letter*		
III. Sulfur containing amino acids				
8. Cysteine	Cys	C		Sulfhydryl
Cystine	—	—		Disulfide
9. Methionine	Met	M		Thioether

IV. Acidic amino acids and their amides					
10.	Aspartic acid	Asp	D		β-Carboxyl
11.	Asparagine	Asn	N		Amide
12.	Glutamic acid	Glu	E		γ-Carboxyl
13.	Glutamine	Gln	Q		Amide
V. Basic amino acids					
14.	Lysine	Lys	K		ε-Amino
15.	Arginine	Arg	R		Guanidino
16.	Histidine	His	H		Imidazole

Name	Symbol		Structure	Special group present
	3 letters	1 letter		
VI. Aromatic amino acids				
17. Phenylalanine	Phe	F		Benzene or phenyl
18. Tyrosine	Tyr	Y		Phenol
19. Tryptophan	Trp	W		Indole
VII. Imino acid				
20. Proline	Pro	P		Pyrrolidine

*(**Note** : R group is shown in red)*

1. **Amino acids with aliphatic side chains**: These are monoamino monocarboxylic acids. This group consists of the simplest amino acids—**glycine, alanine, valine, leucine, and isoleucine**. The last three amino acids (Leu, Ile, Val) contain branched aliphatic side chains, hence they are referred to as **branched-chain amino acids**.

2. **Hydroxyl group-containing amino acids**: Serine, threonine, and tyrosine are hydroxyl group-containing amino acids. *Tyrosine—being aromatic in nature—is usually considered under aromatic amino acids*.

3. **Sulfur-containing amino acids**: Cysteine with a sulfhydryl group and methionine with a thioether group are the two amino acids incorporated during the course of protein synthesis. *Cystine, another important sulphur-containing amino acid, is formed by the condensation of two cysteine molecules*.

4. **Acidic amino acids and their amides**: *Aspartic acid and glutamic acids are dicarboxylic monoamino acids*, while **asparagine and glutamine are their respective amide derivatives**. All four amino acids possess distinct codons for their incorporation into proteins.

5. Basic amino acids: The three amino acids **lysine**, **arginine** (with a guanidino group), and **histidine** (with an imidazole ring) *are dibasic monocarboxylic acids*. They are highly basic in character

6. Aromatic amino acids: Phenylalanine, tyrosine, and tryptophan (with indole ring) are aromatic amino acids. Besides these, *histidine may also be considered under this category*.

7. Imino acids: Proline-containing pyrrolidine ring is a unique amino acid. It has an imino group (group (NH), instead of an amino NH2) found in other amino acids. Therefore, **proline is an α-imino acid**.

Heterocyclic amino acids: Histidine, tryptophan, and proline.

B. **Classification of amino acids based on polarity**:

1. **Non-polar amino acids**: These amino acids are *also referred to as hydrophobic* (water-hating). They have ***no charge on the 'R' group***. The amino acids included in this group are alanine, leucine, isoleucine, valine, methionine, phenylalanine, tryptophan, and proline.

2. **Polar amino acids with no charge on the 'R' group**: These amino acids, as such, carry no charge on the 'R' group. *They, however, possess groups such as hydroxyl, sulfhydryl, and amide and participate in hydrogen bonding of protein structure*. The simple amino acid glycine (where R=H) is also considered in this category. The amino acids in this group are glycine, serine, threonine, cysteine, glutamine, asparagine, and tyrosine.

3. **Polar amino acids with positive 'R' group**: The three amino acids lysine, arginine, and histidine (L.A.H) are included in this group.

4. **Polar amino acids with negative 'R' group**: The dicarboxylic monoamino acids— aspartic acid and glutamic acid (A.G) are considered in this group.

C. Nutritional classification of amino acids:

- The 20 amino acids are required for the synthesis of a variety of proteins, besides other biological functions. However, all these 20 amino acids need not be taken in the diet. Based on the nutritional requirements, amino acids are grouped into two classes: **essential** and **non-essential**

1. Essential or indispensable amino acids:

- The amino acids that cannot be synthesized by the body and, therefore, need to be supplied through the diet are called **essential amino acids**.
- They are required for the proper growth and maintenance of the individual.
- The ten amino acids listed below are essential for humans (and also rats): Arginine, Valine, Histidine, Isoleucine, Leucine, Lysine, Methionine, Phenylalanine, Threonine, Tryptophan.
- The two amino acids, namely **arginine** and **histidine, can be synthesized by adults** and **not by growing children**, hence these are considered as **semi–essential amino acids** (remember AH, to recall). **Thus, 8 amino acids are absolutely essential, while 2 are semi-essential**

2. Non-essential or dispensable amino acids:

- The body can synthesize about 10 amino acids to meet the biological needs, hence they need not be consumed in the diet.
- These are: **glycine**, **alanine**, **serine**, **cysteine**, **aspartate**, **asparagine**, **glutamate**, **glutamine**, **tyrosine,** and **proline**.

D. Amino acid classification based on their metabolic fate:

- The carbon skeleton of amino acids *can serve as a precursor for the synthesis of glucose* (glycogenic) or *fat* (ketogenic) or *both*.

- From a metabolic viewpoint, amino acids are divided into three groups:

1. **Glycogenic amino acids**: These amino acids can serve as precursors for the formation of glucose or glycogen. e.g. **alanine**, **aspartate**, **glycine**, **methionine,** etc.
2. **Ketogenic amino acids**: Fat can be synthesized from these amino acids. Two amino acids **leucine** and **lysine** (remember with **LeLy**)are exclusively ketogenic.
3. **Glycogenic and ketogenic amino acids**: The four amino acids isoleucine, phenylalanine, tryptophan, tyrosine (**PITT**) are precursors for the synthesis of glucose as well as fat.