18.3: Amino Acids

Learning Objectives

- To recognize amino acids and classify them based on the characteristics of their side chains.
- Identify which amino acids are chiral.

The **proteins** in all living species, from bacteria to humans, are *polymers* constructed from the same set of 20 **amino acids**. Humans can synthesize only about half of the needed amino acids; the remainder must be obtained from the diet and are known as essential amino acids. However, two additional amino acids have been found in limited quantities in proteins: Selenocysteine was discovered in 1986, while pyrrolysine was discovered in 2002.

Amino Acid Structure

Every amino acid contains an amino group, ($–NH_2$), a carboxyl group, (–COOH), and a **side chain** or R group, which are all attached to the alpha (α-) carbon (the one directly bonded to the carboxyl functional group). Therefore, amino acids are commonly called alpha-amino (α-amino) acids. Figure 18.3.1 below shows the structure of a generic α-amino acid.

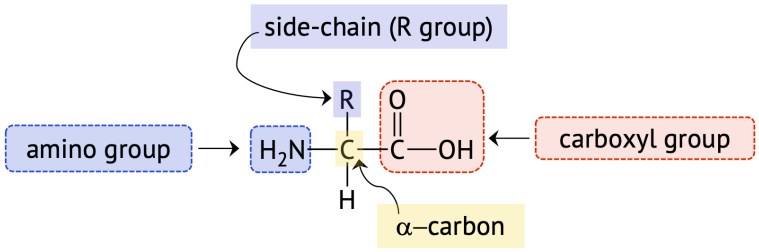


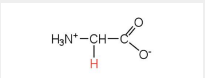
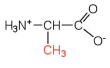
Figure 18.3.1 An α-amino acid. The three parts to an amino acid include the amino group, the carboxyl group, and the side-chain or R group all attached to the α-carbon. The R group is the part that distinguishes one amino acid from the next.

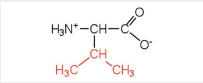
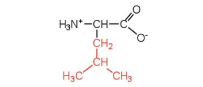
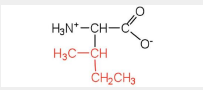
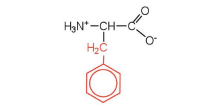
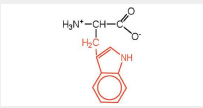
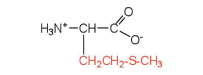
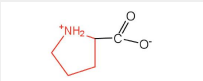
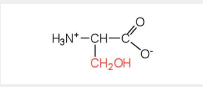
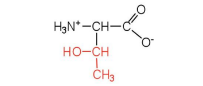
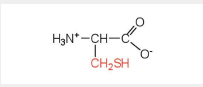
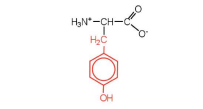
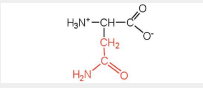
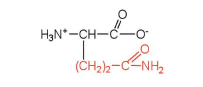
Amino Acid Side Chains

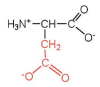
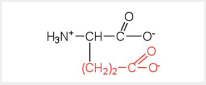
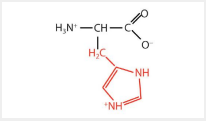
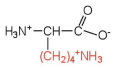
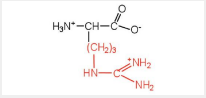
Amino acid side chains or R groups can range from a single hydrogen atom (as in glycine), to a simple hydrocarbon chain, to a hydrocarbon containing a functional group. Each R group has differences in size, shape, solubility, and ionization properties, which contributes to the unique properties of an individual amino acid, and can have an effect on the overall structure and function of a protein.

Table 18.3.1 below lists the 20 common amino acids along with their names, their three- and one-letter codes, structures, and distinctive features. The three-letter codes are generally the first three letters of the amino acid name except in a few cases, such as isoleucine (Ile) and tryptophan (Trp). Similarly, the one-letter code is usually the first letter in the amino acid name, but where the letter is not unique, a letter that is phonetically similar the amino acid name is used: F for *F*enylalanine, R for a*R*ginine, and W for t*W*iptophan. This table also groups the amino acids according to whether the side chain at neutral pH is *nonpolar*, *polar uncharged*, *positively charged*, or *negatively charged*.

Table 18.3.1: Common Amino Acids Found in Proteins. (Isoelectric points are explained in a later section.)

Common Name	Three-letter (one-letter) Code	Systematic (IUPAC) Name	Structural Formula (*at pH 6*)	Isoelectric Point (pI)	Distinctive Feature
Amino acids with a nonpolar R group					
glycine	Gly (G)	aminoethanoic acid		6.0	the only amino acid lacking a chiral carbon
alanine	Ala (A)	2-aminopropanoic acid		6.0	a methyl group, it is the second smallest side chain

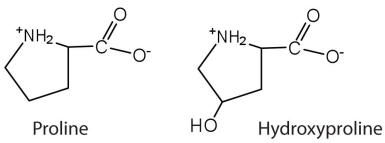
Common Name	Three-letter (one-letter) Code	Systematic (IUPAC) Name	Structural Formula (*at pH 6*)	Isoelectric Point (pI)	Distinctive Feature
valine	Val (V)	2-amino-3-methylbutanoic acid		6.0	a branched-chain amino acid
leucine	Leu (L)	2-amino-4-methylpentanoic acid		6.0	a branched-chain amino acid
isoleucine	Ile (I)	2-amino-3-methylpentanoic acid		6.0	an essential amino acid because most animals cannot synthesize branched-chain amino acids
phenylalanine	Phe (F)	2-amino-3-phenylpropanoic acid		5.5	also classified as an aromatic amino acid
tryptophan	Trp (W)	2-Amino-3-(1*H*-indol-3-yl)-propanoic acid		5.9	also classified as an aromatic amino acid
methionine	Met (M)	2-amino-4-(methylthio)butanoic acid		5.7	side chain functions as a methyl group donor
proline	Pro (P)	pyrrolidine-2-carboxylic acid		6.3	contains a secondary amine group; referred to as an *α-imino acid*
Amino acids with a polar but neutral R group					
serine	Ser (S)	2-amino-3-hydroxypropanoic acid		5.7	found at the active site of many enzymes
threonine	Thr (T)	2-amino-3-hydroxybutanoic acid		5.6	named for its similarity to the sugar threose
cysteine	Cys (C)	2-amino-3-mercaptopropanoic acid		5.0	oxidation of two cysteine molecules yields *cystine*
tyrosine	Tyr (Y)	2-amino-3-(4-hydroxyphenyl)-propanoic acid		5.7	also classified as an aromatic amino acid
asparagine	Asn (N)	2-amino-3-carbamoylpropanoic acid		5.4	the amide of aspartic acid
glutamine	Gln (Q)	2-amino-4-carbamoylbutanoic acid		5.7	the amide of glutamic acid

Common Name	Three-letter (one-letter) Code	Systematic (IUPAC) Name	Structural Formula (*at pH 6*)	Isoelectric Point (pI)	Distinctive Feature
Amino acids with a negatively charged R group					
aspartic acid	Asp (D)	2-aminobutanedioic acid		3.0	carboxyl groups are ionized at physiological pH; also known as aspartate
glutamic acid	Glu (E)	2-aminopentanedioic acid		3.2	carboxyl groups are ionized at physiological pH; also known as glutamate
Amino acids with a positively charged R group					
histidine	His (H)	2-Amino-3-(1*H*-imidazol-4-yl)-propanoic acid		7.6	the only amino acid whose R group has a pK_a (6.0) near physiological pH
lysine	Lys (K)	2,6-diaminohexanoic acid		9.7	is somewhat amphipathic due to the long hydrocarbon tail and positively charged amino group on the ϵ carbon
arginine	Arg (R)	2-amino-5-guanidinopentanoic acid		10.8	almost as strong a base as sodium hydroxide

Note: Interesting Facts About Amino Acids

The first amino acid to be isolated was asparagine in 1806. It was obtained from protein found in asparagus juice (hence the name). Glycine, the major amino acid found in gelatin, was named for its sweet taste (Greek *glykys*, meaning “sweet”). Glutamic acid is named as such because it was first isolated from gluten. The crystalline salt of glutamic acid is called monosodium glutamate (MSG), which is naturally occuring in some foods but is also added to as a savory or "umami" flavor enhancer.

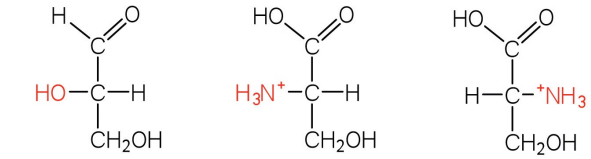
In some cases an amino acid found in a protein is actually a *derivative* of one of the common 20 amino acids (one such derivative is hydroxyproline). The modification of proline occurs *after* the amino acid has been assembled into a protein.



Chirality of Amino Acids

Notice in Table 18.3.1 that glycine is the only amino acid whose (\alpha\)-carbon is *not* chiral, in other words the molecule and the mirror-image of glycine are identical. All other amino acids have two forms that are mirror images of each other, they are

enantiomers. As you can see in the figure below, the "left-handed" form of the molecule is known as the L-amino acid and the "right-handed" form is the D-amino acid.



L–(–)–Glyceraldehyde L–Amino acid D–Amino acid

Summary

Amino acids can be classified based on the characteristics of their distinctive side chains as nonpolar, polar but uncharged, negatively charged, or positively charged. The amino acids found in proteins are L-amino acids.
