**THE AMINO ACID**

The general formula of an amino acid is

\[ \text{H}_2\text{N} - \text{C} - \text{COOH} \]

- **α-carbon atom**
- **amino group** \( \text{H}_2\text{N} \)
- **carboxyl group** \( \text{COOH} \)
- **side-chain group** \( \text{R} \)

**R** is commonly one of 20 different side chains. At pH 7 both the amino and carboxyl groups are ionized.

\[ \text{H}_2\text{N} - \text{C} - \text{COO}^- \]

**OPTICAL ISOMERS**

The α-carbon atom is asymmetric, which allows for two mirror image (or stereo-) isomers, **L** and **D**.

Proteins consist exclusively of **L**-amino acids.

**FAMILIES OF AMINO ACIDS**

The common amino acids are grouped according to whether their side chains are

- **acidic**
- **basic**
- **uncharged polar**
- **nonpolar**

These 20 amino acids are given both three-letter and one-letter abbreviations.

Thus: alanine = Ala = A

**BASIC SIDE CHAINS**

- **lysine**
  - (Lys, or K)
  - \[ \text{H}_2\text{N} + \text{C} = \text{C} - \text{H} - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{NH}_3^+ \]
  - This group is very basic because its positive charge is stabilized by resonance.

- **arginine**
  - (Arg, or R)
  - \[ \text{H}_2\text{N} + \text{C} = \text{C} - \text{H} - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{NH} - \text{C} = \text{C} - \text{H} - \text{CH}_2 - \text{CH}_2 - \text{NH}_3^+ \]

- **histidine**
  - (His, or H)
  - \[ \text{H}_2\text{N} + \text{C} = \text{C} - \text{H} - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{NH} + \text{C} = \text{C} - \text{H} - \text{CH}_2 - \text{CH}_2 - \text{NH}_3^+ \]

These nitrogens have a relatively weak affinity for an H⁺ and are only partly positive at neutral pH.

**PEPTIDE BONDS**

Amino acids are commonly joined together by an amide linkage, called a peptide bond.

\[ \text{H} - \text{N} - \text{C} = \text{C} - \text{O} - \text{H} + \text{H} - \text{N} - \text{C} = \text{C} - \text{O} - \text{H} \]

Peptide bond: The four atoms in each gray box form a rigid planar unit. There is no rotation around the C-N bond.

Proteins are long polymers of amino acids linked by peptide bonds, and they are always written with the N-terminus toward the left. The sequence of this tripeptide is histidine-cysteine-valine.
ACIDIC SIDE CHAINS

- Aspartic acid (Asp, or D)
  \[
  \text{H} \quad \text{O} \\
  \text{N} \quad \text{C} \quad \text{C} \\
  \text{H} \quad \text{CH}_2 \\
  \text{O} \quad \text{C} \quad \text{O}^- \\
  \]

- Glutamic acid (Glu, or E)
  \[
  \text{H} \quad \text{O} \\
  \text{N} \quad \text{C} \quad \text{C} \\
  \text{H} \quad \text{CH}_2 \\
  \text{O} \quad \text{C} \quad \text{O}^- \\
  \]

UNCHARGED POLAR SIDE CHAINS

- Asparagine (Asn, or N)
  \[
  \text{H} \quad \text{O} \\
  \text{N} \quad \text{C} \quad \text{C} \\
  \text{H} \quad \text{CH}_2 \\
  \text{O} \quad \text{C} \quad \text{O}^- \\
  \text{NH}_2 \\
  \]

- Glutamine (Gln, or Q)
  \[
  \text{H} \quad \text{O} \\
  \text{N} \quad \text{C} \quad \text{C} \\
  \text{H} \quad \text{CH}_2 \\
  \text{O} \quad \text{C} \quad \text{O}^- \\
  \text{NH}_2 \\
  \]

Although the amide N is not charged at neutral pH, it is polar.

- Serine (Ser, or S)
  \[
  \text{H} \quad \text{O} \\
  \text{N} \quad \text{C} \quad \text{C} \\
  \text{H} \quad \text{CH}_2 \\
  \text{OH} \\
  \]

- Threonine (Thr, or T)
  \[
  \text{H} \quad \text{O} \\
  \text{N} \quad \text{C} \quad \text{C} \\
  \text{H} \quad \text{CH}_2 \\
  \text{OH} \\
  \]

- Tyrosine (Tyr, or Y)
  \[
  \text{H} \quad \text{O} \\
  \text{N} \quad \text{C} \quad \text{C} \\
  \text{H} \quad \text{CH}_2 \\
  \text{CH}_3 \\
  \]

NONPOLAR SIDE CHAINS

- Alanine (Ala, or A)
  \[
  \text{H} \quad \text{O} \\
  \text{N} \quad \text{C} \quad \text{C} \\
  \text{H} \quad \text{CH}_3 \\
  \]

- Valine (Val, or V)
  \[
  \text{H} \quad \text{O} \\
  \text{N} \quad \text{C} \quad \text{C} \\
  \text{H} \quad \text{CH}_3 \\
  \text{CH}_3 \\
  \]

- Leucine (Leu, or L)
  \[
  \text{H} \quad \text{O} \\
  \text{N} \quad \text{C} \quad \text{C} \\
  \text{H} \quad \text{CH}_2 \\
  \text{CH}_3 \\
  \]

- Isoleucine (Ile, or I)
  \[
  \text{H} \quad \text{O} \\
  \text{N} \quad \text{C} \quad \text{C} \\
  \text{H} \quad \text{CH}_2 \\
  \text{CH}_3 \\
  \]

- Proline (Pro, or P)
  \[
  \text{H} \quad \text{O} \\
  \text{N} \quad \text{C} \quad \text{C} \\
  \text{H} \quad \text{CH}_2 \\
  \text{CH}_2 \text{CH}_2 \\
  \]

  (actually an imino acid)

- Phenylalanine (Phe, or F)
  \[
  \text{H} \quad \text{O} \\
  \text{N} \quad \text{C} \quad \text{C} \\
  \text{H} \quad \text{CH}_2 \\
  \text{CH}_3 \\
  \]

- Methionine (Met, or M)
  \[
  \text{H} \quad \text{O} \\
  \text{N} \quad \text{C} \quad \text{C} \\
  \text{H} \quad \text{CH}_2 \\
  \text{CH}_2 \text{CH}_3 \text{SH} \\
  \]

- Tryptophan (Trp, or W)
  \[
  \text{H} \quad \text{O} \\
  \text{N} \quad \text{C} \quad \text{C} \\
  \text{H} \quad \text{CH}_2 \\
  \text{CH}_2 \text{CH}_3 \text{N} \\
  \]

- Glycine (Gly, or G)
  \[
  \text{H} \quad \text{O} \\
  \text{N} \quad \text{C} \quad \text{C} \\
  \text{H} \quad \text{CH}_2 \\
  \text{OH} \\
  \]

- Cysteine (Cys, or C)
  \[
  \text{H} \quad \text{O} \\
  \text{N} \quad \text{C} \quad \text{C} \\
  \text{H} \quad \text{CH}_2 \\
  \text{CH}_2 \text{SH} \\
  \]

Disulfide bonds can form between two cysteine side chains in proteins.

-\text{CH}_2 \text{S-S-CH}_2-