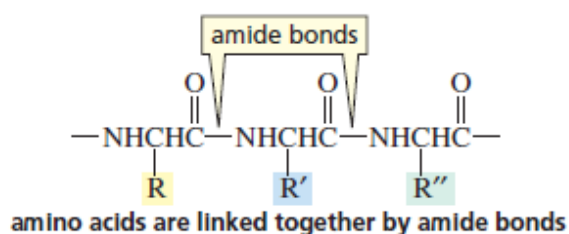


AMINO ACIDS

The three kinds of polymers that are prevalent in nature are polysaccharides, proteins, and nucleic acids. Proteins serve many functions in biological systems. Some protect organisms from their environment or impart strength to certain biological structures. Hair, horns, hooves, feathers, fur, and the tough outer layer of skin are all composed largely of a **structural protein** called keratin. Collagen, another structural protein, is a major component of bones, muscles, and tendons. Some proteins have other protective functions. Snake venoms and plant toxins, for example, protect their owners from other species, blood-clotting proteins protect the vascular system when it is injured, and antibodies and protein antibiotics protect us from disease. A group of proteins called **enzymes** catalyzes the chemical reactions that occur in living systems, and some of the hormones that regulate these reactions are peptides. Proteins are also responsible for many physiological functions, such as the transport and storage of oxygen in the body and the contraction of muscles.

Proteins are polypeptides, i.e. polymer of peptides. **Peptides** and **proteins** are polymers of **amino acids** linked together by amide bonds. The repeating units are called **amino acid residues**. Amino acid polymers can be composed of any number of monomers. A **dipeptide** contains two amino acid residues, a **tripeptide** contains three, an **oligopeptide** contains three to 10, and a **polypeptide** contains many amino acid residues. Proteins are naturally occurring polypeptides that are made up of 40 to 4000 amino acid residues.

General structure of amino acid is α -amino carboxylic acid
$$\begin{array}{c} \text{R}-\text{CH}-\text{COOH} \\ | \\ \text{NH}_2 \end{array}$$



Classification and Nomenclature of Amino Acids

The structures of the 20 most common naturally occurring amino acids and the frequency with which each occurs in proteins are shown in Table below. Other amino acids occur in nature, but only infrequently. All amino acids except proline contain a primary amino group. Proline contains a secondary amino group incorporated into a five-membered ring. The amino acids differ only in the substituent (R) attached to the α -carbon. The wide variation in these substituents (called side chains) is what gives proteins their great structural diversity and, as a consequence, their great functional diversity.

Table 23.1 The Most Common Naturally Occurring Amino Acids					
<i>The amino acids are shown in the form that predominates at physiological pH (7.3).</i>					
	Formula	Name	Abbreviations		Average relative abundance in proteins
Aliphatic side chain amino acids	$\begin{array}{c} \text{O} \\ \parallel \\ \text{H}-\text{C}-\text{CO}^- \\ \\ ^+\text{NH}_3 \end{array}$	Glycine	Gly	G	7.5%
	$\begin{array}{c} \text{O} \\ \parallel \\ \text{CH}_3-\text{C}-\text{CO}^- \\ \\ ^+\text{NH}_3 \end{array}$	Alanine	Ala	A	9.0%
	$\begin{array}{c} \text{O} \\ \parallel \\ \text{CH}_3\text{CH}-\text{C}-\text{CO}^- \\ \quad \\ \text{CH}_3 \quad ^+\text{NH}_3 \end{array}$	Valine*	Val	V	6.9%
	$\begin{array}{c} \text{O} \\ \parallel \\ \text{CH}_3\text{CHCH}_2-\text{C}-\text{CO}^- \\ \quad \\ \text{CH}_3 \quad ^+\text{NH}_3 \end{array}$	Leucine*	Leu	L	7.5%
	$\begin{array}{c} \text{O} \\ \parallel \\ \text{CH}_3\text{CH}_2\text{CH}-\text{C}-\text{CO}^- \\ \quad \\ \text{CH}_3 \quad ^+\text{NH}_3 \end{array}$	Isoleucine*	Ile	I	4.6%
Hydroxy-containing amino acids	$\begin{array}{c} \text{O} \\ \parallel \\ \text{HOCH}_2-\text{C}-\text{CO}^- \\ \\ ^+\text{NH}_3 \end{array}$	Serine	Ser	S	7.1%
	$\begin{array}{c} \text{O} \\ \parallel \\ \text{CH}_3\text{CH}-\text{C}-\text{CO}^- \\ \quad \\ \text{OH} \quad ^+\text{NH}_3 \end{array}$	Threonine*	Thr	T	6.0%

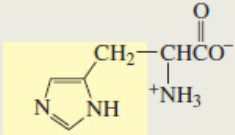
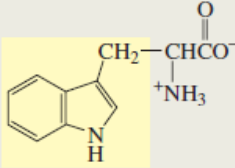
* Essential amino acids

Table 23.1 (continued)

	Formula	Name	Abbreviations	Average relative abundance in proteins
Sulfur-containing amino acids	$\text{HSCH}_2-\underset{\text{+NH}_3}{\underset{ }{\text{C}}}\overset{\text{O}}{\parallel}{\text{CO}}^-$	Cysteine	Cys C	2.8%
	$\text{CH}_3\text{SCH}_2\text{CH}_2-\underset{\text{+NH}_3}{\underset{ }{\text{C}}}\overset{\text{O}}{\parallel}{\text{CO}}^-$	Methionine*	Met M	1.7%
Acidic amino acids	$\text{^-OCCH}_2-\underset{\text{+NH}_3}{\underset{ }{\text{C}}}\overset{\text{O}}{\parallel}{\text{CO}}^-$	Aspartate (aspartic acid)	Asp D	5.5%
	$\text{^-OCCH}_2\text{CH}_2-\underset{\text{+NH}_3}{\underset{ }{\text{C}}}\overset{\text{O}}{\parallel}{\text{CO}}^-$	Glutamate (glutamic acid)	Glu E	6.2%
Amides of acidic amino acids	$\text{H}_2\text{NC(=O)CH}_2-\underset{\text{+NH}_3}{\underset{ }{\text{C}}}\overset{\text{O}}{\parallel}{\text{CO}}^-$	Asparagine	Asn N	4.4%
	$\text{H}_2\text{NC(=O)CH}_2\text{CH}_2-\underset{\text{+NH}_3}{\underset{ }{\text{C}}}\overset{\text{O}}{\parallel}{\text{CO}}^-$	Glutamine	Gln Q	3.9%
Basic amino acids	$\text{H}_3\text{N}^+\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2-\underset{\text{+NH}_3}{\underset{ }{\text{C}}}\overset{\text{O}}{\parallel}{\text{CO}}^-$	Lysine*	Lys K	7.0%
	$\text{H}_2\text{NC(=NH}_2^+\text{)CH}_2\text{CH}_2\text{CH}_2\text{CH}_2-\underset{\text{+NH}_3}{\underset{ }{\text{C}}}\overset{\text{O}}{\parallel}{\text{CO}}^-$	Arginine*	Arg R	4.7%
Benzene-containing amino acids	$\text{C}_6\text{H}_5\text{-CH}_2-\underset{\text{+NH}_3}{\underset{ }{\text{C}}}\overset{\text{O}}{\parallel}{\text{CO}}^-$	Phenylalanine*	Phe F	3.5%
	$\text{HO-C}_6\text{H}_4\text{-CH}_2-\underset{\text{+NH}_3}{\underset{ }{\text{C}}}\overset{\text{O}}{\parallel}{\text{CO}}^-$	Tyrosine	Tyr Y	3.5%
Heterocyclic amino acids	$\text{C}_5\text{H}_7\text{N}^+\text{-CO}^-$	Proline	Pro P	4.6%

* Essential amino acids

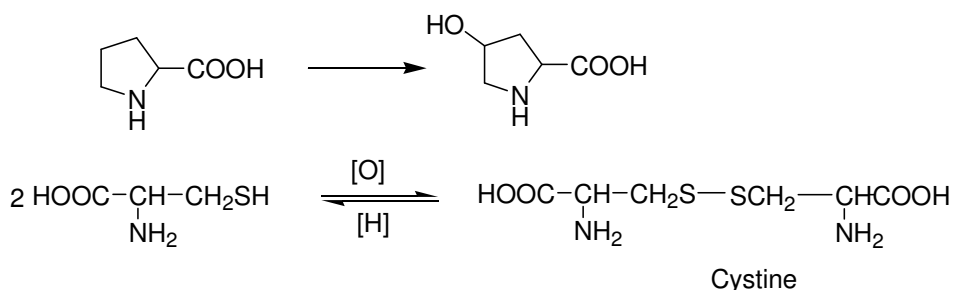
Table 23.1 (continued)

	Formula	Name	Abbreviations	Average relative abundance in proteins
Heterocyclic amino acids (continued)		Histidine*	His H	2.1%
		Tryptophan*	Trp W	1.1%

* Essential amino acids

Two amino acids are synthesized after the polyamide chain is formed (post translation modification).

Hydroxy proline (present mainly in collagen) from proline, *cystine* (present in most proteins) is synthesized from cysteine.

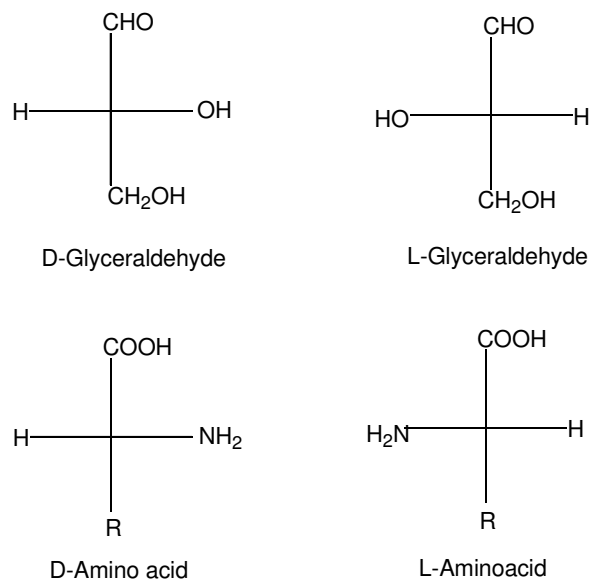


Cysteine units in a protein chain contributes to the overall structure and shape of protein.

Essential amino acids can be synthesized by all living system, plants and animals. Certain amino acids are the essential amino acids, which must be fed to young animals for proper growth is to take place. These particular amino acids evidently cannot be synthesized by the animal from the other materials in its diet.

The α -carbon of all the naturally occurring amino acids except glycine is an asymmetric carbon. Therefore, 19 of the 20 amino acids can exist as enantiomers. The D and L notation used for monosaccharides is also used for amino acids. The D and L isomers of monosaccharides and amino acids are defined in the same way. Thus, an amino acid

drawn in a Fischer projection with the carboxyl group on the top and the R group on the bottom of the vertical axis is a **D-amino acid** if the amino group is on the right and an **L-amino acid** if the amino group is on the left. Unlike monosaccharides, where the D isomer is the one found in nature, most amino acids found in nature have the L configuration. To date, D-amino acid residues have been found only in a few peptide antibiotics and in some small peptides attached to the cell walls of bacteria.

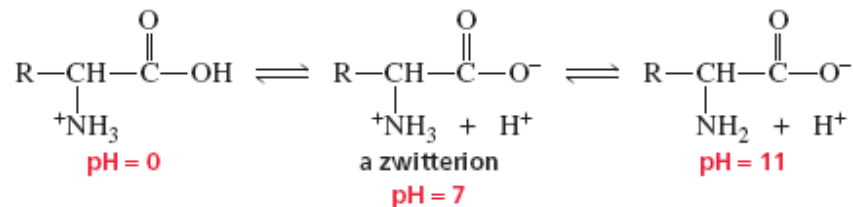


Acid base properties of amino acids: A prominent characteristic of amino acid is their amphoteric character, they can function either as acids or base.

- a) In contrast to amines and carboxylic acids the amino acids are non volatile crystalline solids which melt with decomposition at fairly high temp.
- b) They are insoluble in non polar solvents like petroleum ether, benzene or ether but are appreciably soluble in water, water solubility depends on pH of the solution
- c) Aq. Solution possess relatively high dielectric constant.
- d) Acidity and basicity constants are low for COOH and NH₂.

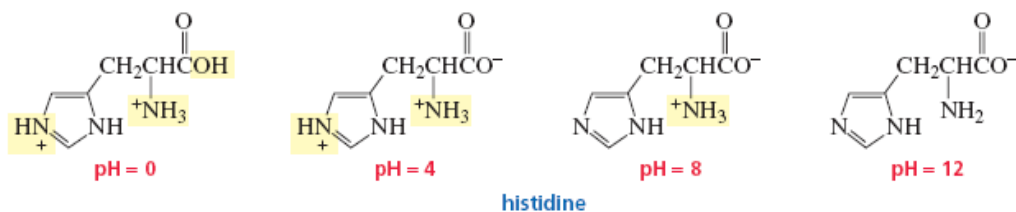
Every amino acid has a carboxyl group and an amino group, and each group can exist in an acidic form or a basic form, depending on the pH of the solution in which the amino acid is dissolved. The carboxyl groups of the amino acids have p^{Ka} values of approximately 2, and the protonated amino groups have p^{Ka} values near 9. Both groups, therefore, will be in their acidic forms in a very acidic solution pH ~ 0. At pH ~7 the pH

of the solution is greater than the p^{K_a} of the carboxyl group, but less than the p^{K_a} of the protonated amino group. The carboxyl group, therefore, will be in its basic form and the amino group will be in its acidic form. In a strongly basic solution $pH \sim 11$ both groups will be in their basic forms.



An amino acid can never exist as an uncharged compound, regardless of the pH of the solution. To be uncharged, an amino acid would have to lose a proton from an NH_3^+ group with a p^{K_a} of about 9 before it would lose a proton from a COOH group with a p^{K_a} of about 2. This clearly is impossible: A weak acid cannot be more acidic than a strong acid. Therefore, at physiological pH (7.3) an amino acid exists as a dipolar ion, called a *zwitterion*. A **zwitterion** is a compound that has a negative charge on one atom and a positive charge on a nonadjacent atom.

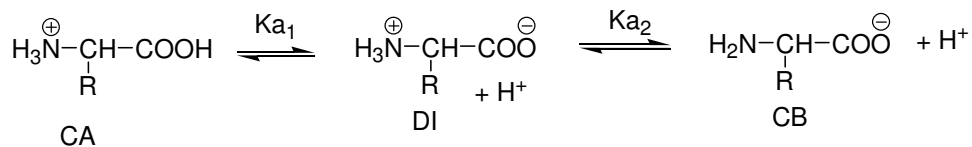
A few amino acids have side chains with ionizable hydrogens. The protonated imidazole side chain of histidine, for example, has a p^{K_a} of 6.04. Histidine, therefore, can exist in four different forms, and the form that predominates depends on the pH of the solution.



The **isoelectric point** (pI) of an amino acid is the pH at which it has no net charge. In other words, it is the pH at which the amount of positive charge on an amino acid exactly balances the amount of negative charge.

The pI of an amino acid that does *not* have an ionizable side chain—such as alanine—is midway between its two p^{K_a} values. This is because at $pH = 2.34$, half the molecules have a negatively charged carboxyl group and half have an uncharged carboxyl group, and at

pH = 9.69, half the molecules have a positively charged amino group and half have an uncharged amino group. As the pH increases from 2.34, the carboxyl group of more molecules becomes negatively charged; as the pH decreases from 9.69, the amino group of more molecules becomes positively charged. Therefore, at the average of the two p^{K_a} values, the number of negatively charged groups equals the number of positively charged groups.



$$K_{a1} = [\text{DI}] [\text{H}^+] / [\text{CA}]$$

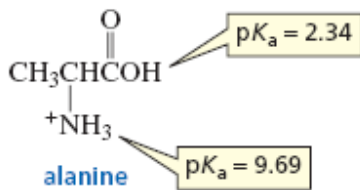
$$K_{a2} = [\text{CB}] [\text{H}^+] / [\text{DI}]$$

$$\text{Or, } [\text{CA}] = [\text{DI}] [\text{H}^+] / K_{a1}$$

$$\text{or, } [\text{CB}] = [\text{DI}] K_{a2} / [\text{H}^+]$$

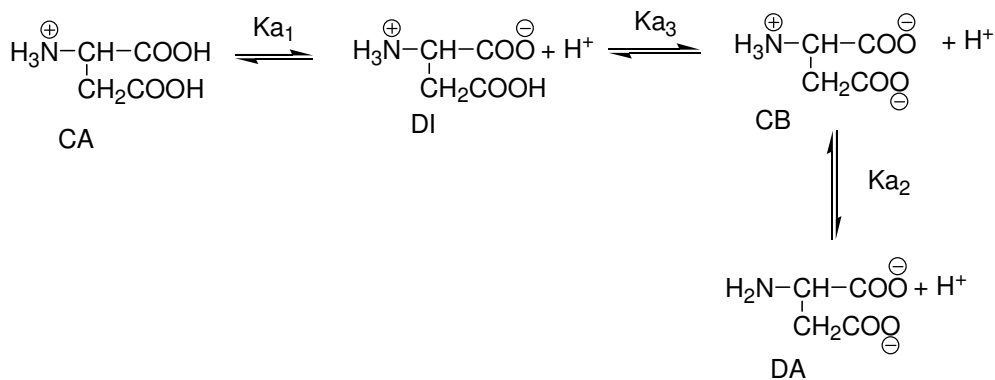
At isoelectric point, $[\text{CA}] = [\text{CB}]$

$$[\text{DI}] [\text{H}^+] / K_{a1} = [\text{DI}] K_{a2} / [\text{H}^+] \quad \text{or, } [\text{H}^+]^2 = K_{a1} K_{a2} \quad \text{or, } \text{pI} = \frac{1}{2} [\text{pK}_{a1} + \text{pK}_{a2}]$$



$$\text{pI} = \frac{2.34 + 9.69}{2} = \frac{12.03}{2} = 6.02$$

The pI of an amino acid that *has* an ionizable side chain is the average of the values of the similarly ionizing groups (a positively charged group ionizing to an uncharged group or an uncharged group ionizing to a negatively charged group). For example, the pI of lysine is the average of the p^{K_a} values of the two groups that are positively charged in their acidic form and uncharged in their basic form. The pI of glutamate, on the other hand, is the average of the p^{K_a} values of the two groups that are uncharged in their acidic form and negatively charged in their basic form.



$$K_{a1} = [\text{DI}] [\text{H}^+] / [\text{CA}]$$

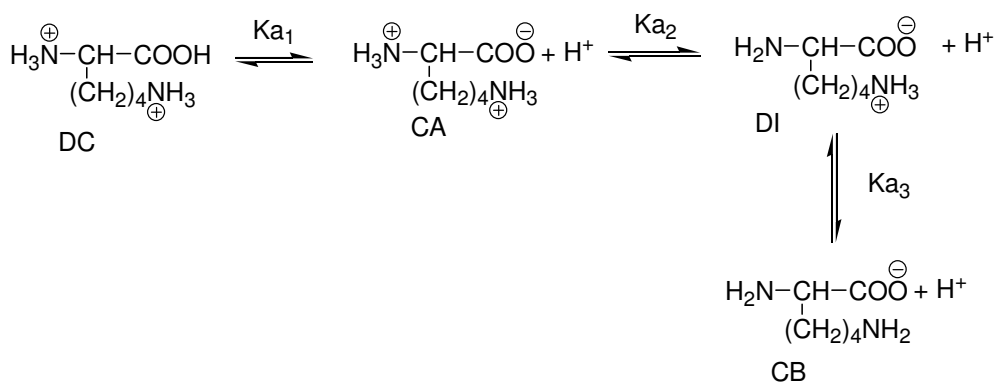
$$\text{Or, } [\text{CA}] = [\text{DI}] [\text{H}^+] / K_{a1}$$

At isoelectric point, $[\text{CA}] = [\text{CB}]$

$$[\text{DI}] [\text{H}^+] / K_{a1} = [\text{DI}] K_{a3} / [\text{H}^+] \quad \text{or, } [\text{H}^+]^2 = K_{a1} K_{a3} \quad \text{or, } \text{pI} = \frac{1}{2} [\text{pK}_{a1} + \text{pK}_{a3}]$$

$$K_{a3} = [\text{CB}] [\text{H}^+] / [\text{DI}]$$

$$\text{or, } [\text{CB}] = [\text{DI}] K_{a3} / [\text{H}^+]$$



$$K_{a2} = [\text{DI}] [\text{H}^+] / [\text{CA}]$$

$$\text{Or, } [\text{CA}] = [\text{DI}] [\text{H}^+] / K_{a2}$$

At isoelectric point, $[\text{CA}] = [\text{CB}]$

$$[\text{DI}] [\text{H}^+] / K_{a2} = [\text{DI}] K_{a3} / [\text{H}^+] \quad \text{or, } [\text{H}^+]^2 = K_{a2} K_{a3} \quad \text{or, } \text{pI} = \frac{1}{2} [\text{pK}_{a2} + \text{pK}_{a3}]$$

$$K_{a3} = [\text{CB}] [\text{H}^+] / [\text{DI}]$$

$$\text{or, } [\text{CB}] = [\text{DI}] K_{a3} / [\text{H}^+]$$

