

Science > Chemistry

CITE

Standard amino acids

↳ in **amino acid**

Michael K. Reddy Britannica Editors Mar. 2, 2026 • History

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Table of Contents

One of the most useful manners by which to classify the standard (or common) amino acids is based on the [polarity](#) (that is, the distribution of [electric charge](#)) of the *R* group (e.g., side chain).



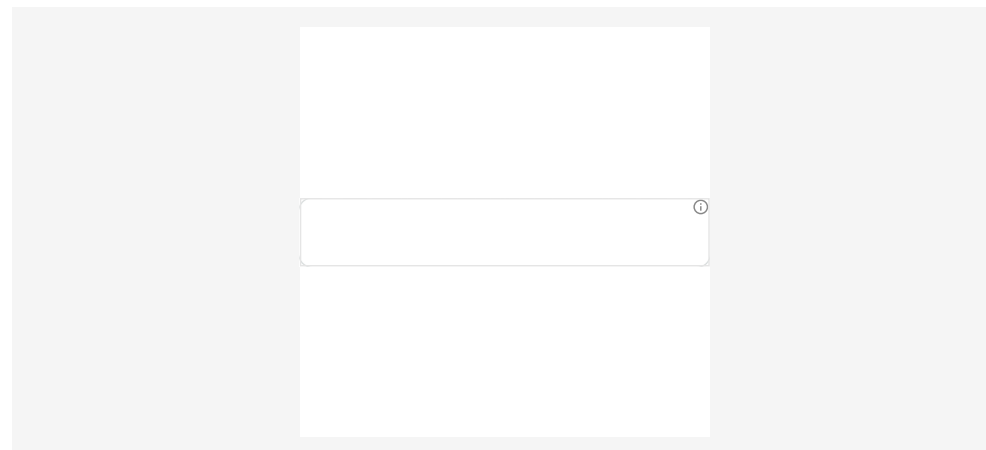
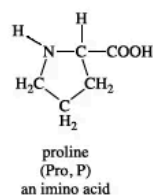
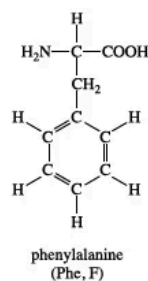
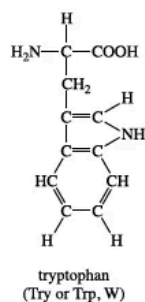
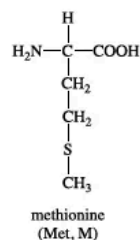
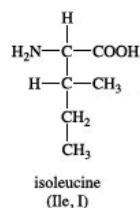
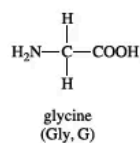
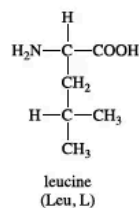
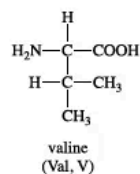
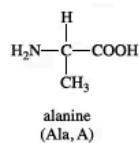
Group I: Nonpolar amino acids

Group I amino acids are [glycine](#), [alanine](#), [valine](#), [leucine](#), [isoleucine](#), [proline](#), [phenylalanine](#), [methionine](#), and [tryptophan](#). The *R* groups of these amino acids have either [aliphatic](#) or [aromatic](#) groups. This makes them hydrophobic (“water fearing”). In aqueous solutions, globular [proteins](#) will fold into a three-dimensional shape to bury these hydrophobic side chains in the [protein](#) interior. The chemical structures of Group I amino acids are:

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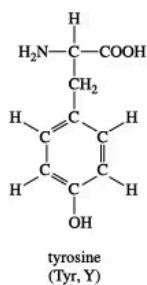
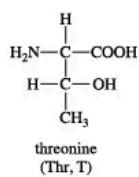
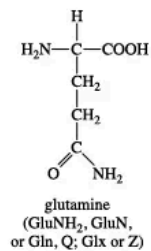
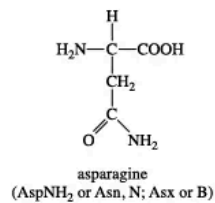
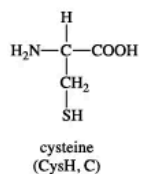
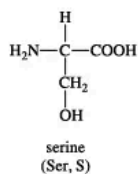


Isoleucine is an [isomer](#) of leucine, and it contains two chiral [carbon](#) atoms. Proline is [unique](#) among the standard amino acids in that it does not have both free α -amino and free α -carboxyl groups. Instead, its side chain forms a cyclic structure as the [nitrogen](#) atom of proline is linked to two carbon atoms. (Strictly speaking, this means that proline is not an amino acid but rather an α -imino acid.) Phenylalanine, as the name implies, consists of a phenyl group attached to alanine. Methionine is one of the two amino acids that possess a [sulfur](#) atom. Methionine plays a central role in protein biosynthesis ([translation](#)) as it is almost always the initiating amino acid. Methionine also provides [methyl groups](#) for [metabolism](#). Tryptophan contains an [indole](#) ring attached to the alanyl side chain.

Group II: Polar, uncharged amino acids

Group II amino acids are [serine](#), [cysteine](#), [threonine](#), [tyrosine](#), [asparagine](#), and [glutamine](#). The side chains in this group possess a spectrum of functional groups. However, most have at least one atom ([nitrogen](#), [oxygen](#), or [sulfur](#)) with [electron](#) pairs available for [hydrogen](#)

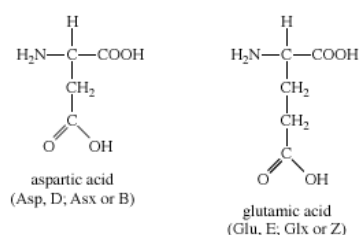
bonding to [water](#) and other molecules. The chemical structures of Group II amino acids are:



Two amino acids, serine and threonine, contain aliphatic hydroxyl groups (that is, an oxygen atom bonded to a hydrogen atom, represented as —OH). Tyrosine possesses a [hydroxyl group](#) in the aromatic ring, making it a [phenol derivative](#). The hydroxyl groups in these three amino acids are subject to an important type of posttranslational modification: [phosphorylation](#) (see below [Nonstandard amino acids](#)). Like methionine, cysteine contains a sulfur atom. Unlike methionine's sulfur atom, however, cysteine's sulfur is very chemically reactive (see below [Cysteine oxidation](#)). Asparagine, first isolated from [asparagus](#), and glutamine both contain [amide R](#) groups. The [carbonyl group](#) can function as a hydrogen bond acceptor, and the amino group (NH_2) can function as a hydrogen bond donor.

Group III: Acidic amino acids

The two amino acids in this group are [aspartic acid](#) and [glutamic acid](#). Each has a [carboxylic acid](#) on its side chain that gives it acidic ([proton](#)-donating) properties. In an aqueous solution at physiological pH, all three functional groups on these amino acids will ionize, thus giving an overall charge of -1 . In the [ionic](#) forms, the amino acids are called aspartate and glutamate. The chemical structures of Group III amino acids are

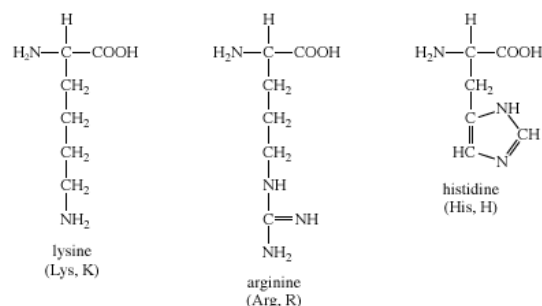


The side chains of aspartate and glutamate can form ionic bonds ("salt bridges"), and they can also function as hydrogen bond acceptors. Many proteins that bind metal [ions](#) ("metalloproteins") for structural or functional purposes possess metal-binding sites containing aspartate or glutamate side chains or both. Free glutamate and glutamine play a central role in amino acid metabolism. Glutamate is the most abundant excitatory [neurotransmitter](#) in the central [nervous system](#).

Group IV: Basic amino acids

The three amino acids in this group are [arginine](#), [histidine](#), and [lysine](#). Each side chain is basic (i.e., can accept a proton). Lysine and arginine both exist with an overall charge of $+1$ at physiological pH. The guanidino group in arginine's side chain is the most basic of all *R*

groups (a fact reflected in its pKa value of 12.5). As mentioned above for aspartate and glutamate, the side chains of arginine and lysine also form ionic bonds. The chemical structures of Group IV amino acids are



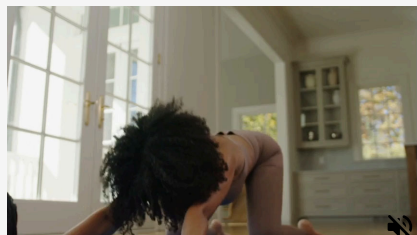
The [imidazole](#) side chain of histidine allows it to function in both [acid and base catalysis](#) near physiological pH [values](#). None of the other standard amino acids possesses this important chemical property. Therefore, histidine is an amino acid that most often makes up the active sites of protein [enzymes](#).

The majority of amino acids in Groups II, III, and IV are hydrophilic (“water loving”). As a result, they are often found clustered on the surface of globular proteins in aqueous solutions.

Amino acid reactions

Amino acids via their various chemical functionalities (carboxyls, amino, and *R* groups) can undergo numerous [chemical reactions](#). However, two reactions ([peptide](#) bond and

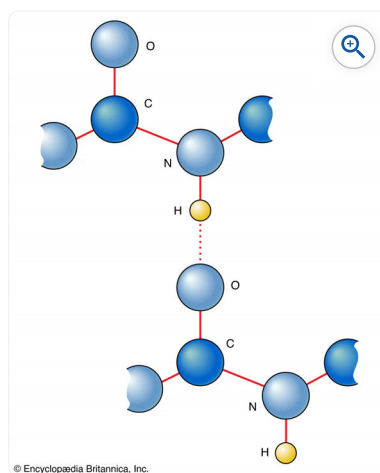
cysteine oxidation) are of particular importance because of their effect on [protein](#) structure.



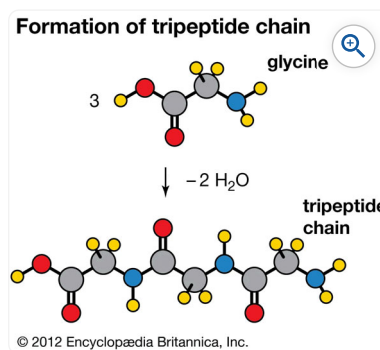
Peptide bond

Amino acids can be linked by a [condensation reaction](#) in which an —OH is lost from the carboxyl group of one amino acid along with a [hydrogen](#) from the amino group of a second, forming a molecule of [water](#) and leaving the two amino acids linked via an amide—called, in this case, a peptide bond. At the turn of the 20th century, German chemist [Emil Fischer](#) first proposed this linking together of amino acids. Note that when individual amino acids are combined to form proteins, their carboxyl and amino groups are no longer able to act as [acids](#) or [bases](#), since they have reacted to form the peptide bond. Therefore, the acid-base properties of proteins are dependent upon the overall ionization characteristics of the individual *R* groups of the component amino acids.

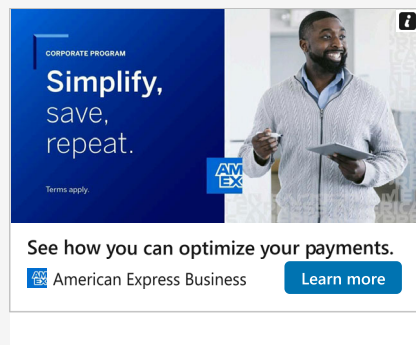
Amino acids joined by a series of peptide bonds are said to [constitute](#) a peptide. After they are incorporated into a peptide, the individual amino acids are referred to as amino acid residues. Small [polymers](#) of amino acids (fewer than 50) are called oligopeptides, while larger ones (more than 50) are referred to as polypeptides. Hence, a protein molecule is a polypeptide chain composed of many amino acid residues, with each residue joined to the next by a peptide bond. The lengths for different proteins range from a few dozen to thousands of amino acids, and each protein contains different relative proportions of the 20 standard amino acids.



peptide bond The linking of atoms in a peptide bond.



condensation reaction Condensation reaction in which three molecules of the amino acid glycine produce a tripeptide...(more)



Cysteine oxidation

The [thiol](#) (sulfur-containing) group of cysteine is highly reactive. The most common reaction of this group is a reversible oxidation that forms a disulfide. Oxidation of two molecules of cysteine forms [cystine](#), a molecule that contains a disulfide bond. When two cysteine residues in a protein form such a bond, it is referred to as a disulfide bridge. Disulfide bridges are a common mechanism used in nature to stabilize many proteins. Such disulfide bridges are often found among extracellular proteins that are [secreted](#) from [cells](#). In [eukaryotic](#) organisms, formation of disulfide bridges occurs within the organelle called the [endoplasmic reticulum](#).

In extracellular fluids (such as [blood](#)), the sulfhydryl groups of cysteine are rapidly oxidized to form cystine. In a genetic disorder known as [cystinuria](#), there is a defect that results in excessive excretion of cystine into the urine. Because cystine is the least soluble of the amino acids, crystallization of the excreted cystine results in formation of calculi—more commonly known as “[stones](#)”—in the kidney, ureter, or [urinary bladder](#). The stones may cause intense pain, infection, and blood in the urine. Medical intervention often involves the administration of D-penicillamine. Penicillamine works by forming a complex with cystine; this complex is 50 times more [water](#)-soluble than cystine alone.



In summary, it is the sequence of amino acids that determines the shape and biological function of a protein as well as its physical and chemical properties. Thus, the functional [diversity](#) of proteins arises because proteins are polymers of 20 different kinds of amino acids. For example, a “simple” protein is the [hormone insulin](#), which has 51 amino acids.

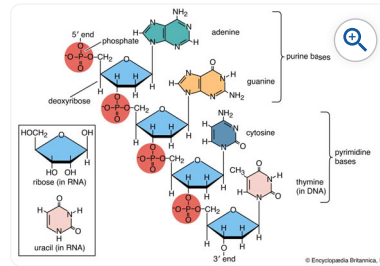
With 20 different amino acids to choose from at each of these 51 positions, a total of 20^{51} , or about 10^{66} , different proteins could theoretically be made.

Other functions

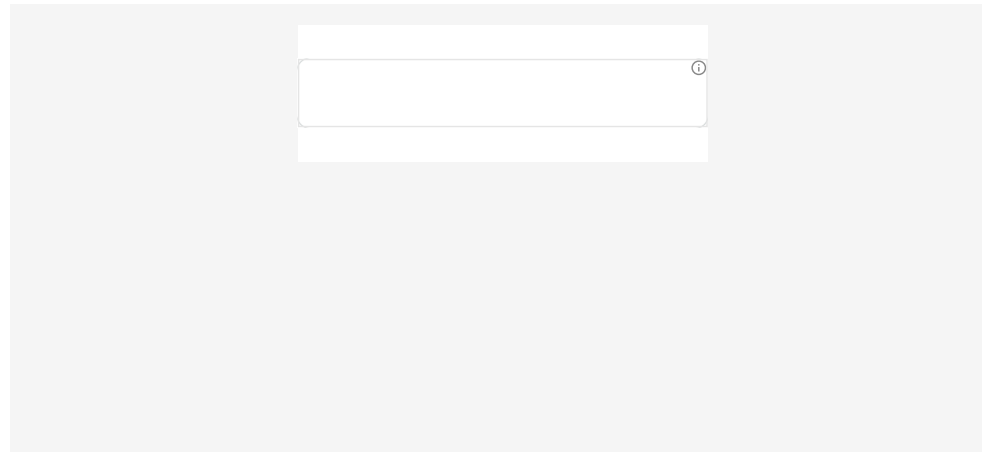
Amino acids are [precursors](#) of a variety of complex [nitrogen](#)-containing molecules. Prominent among these are the nitrogenous base components of [nucleotides](#) and the [nucleic acids](#) ([DNA](#) and [RNA](#)).

Furthermore, there are complex amino-acid derived [cofactors](#) such as heme and [chlorophyll](#).

Heme is the [iron](#)-containing organic group required for the biological activity of vitally important [proteins](#) such as the [oxygen](#)-carrying [hemoglobin](#) and the [electron](#)-transporting [cytochrome](#) c. Chlorophyll is a pigment required for [photosynthesis](#).



polynucleotide chain of deoxyribonucleic acid (DNA) Portion of polynucleotide chain of deoxyribonucleic acid (DNA). The i...(more)



Several α -amino acids (or their derivatives) act as chemical messengers. For example, γ -aminobutyric acid (gamma-aminobutyric acid, or GABA; a [derivative](#) of [glutamic acid](#)), [serotonin](#) and [melatonin](#) (derivatives of [tryptophan](#)), and [histamine](#) (synthesized from [histidine](#)) are [neurotransmitters](#). [Thyroxine](#) (a [tyrosine](#) derivative produced in the [thyroid gland](#) of animals) and [indole acetic acid](#) (a tryptophan derivative found in plants) are two examples of [hormones](#).

Several standard and nonstandard amino acids often are vital metabolic intermediates. Important examples of this are the amino acids [arginine](#), citrulline, and ornithine, which are all components of the [urea](#) cycle. The synthesis of urea is the principal mechanism for the removal of nitrogenous waste.