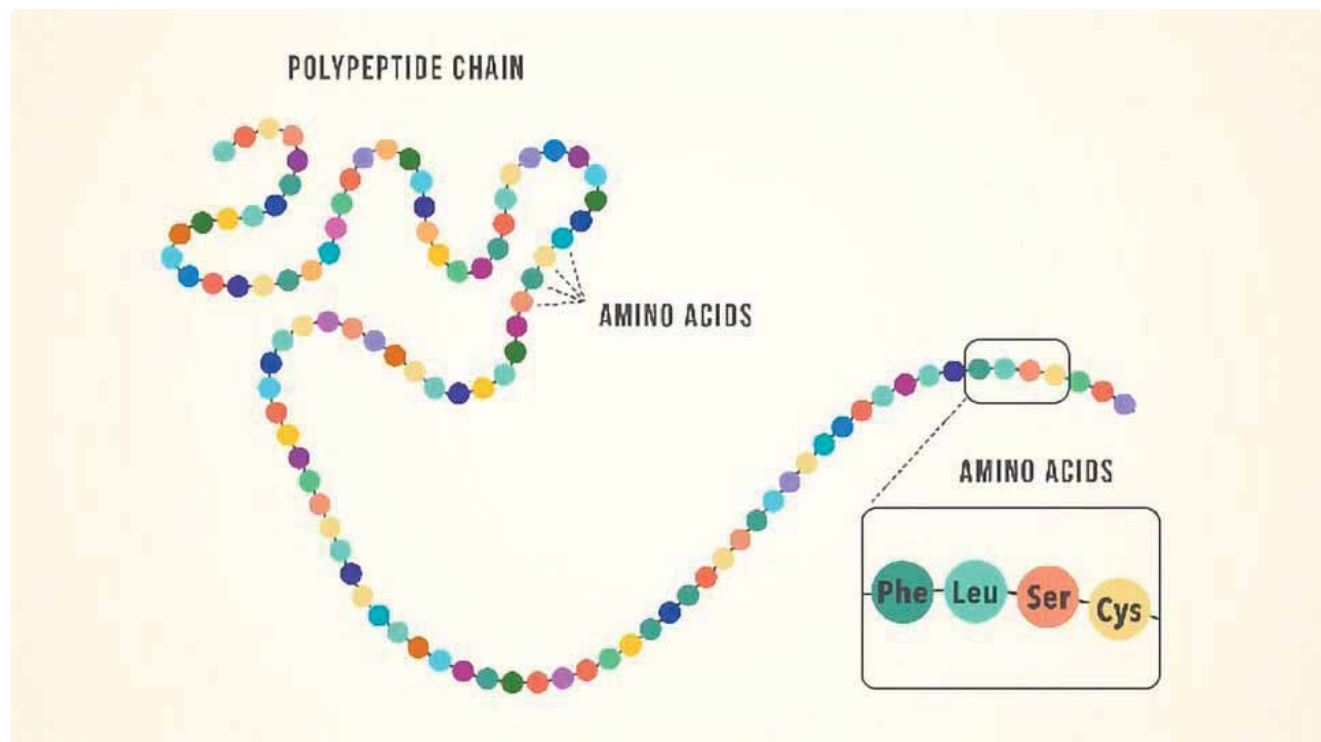


Essential Amino Acids: Chart, Abbreviations and Structure

Article Published: September 26, 2019 | [Karen Steward, PhD](#)



Credit: Technology Networks

Amino acids are the building blocks that form polypeptides and ultimately proteins. Consequently, they are fundamental components of our bodies and vital for physiological functions such as protein synthesis, tissue repair and nutrient absorption. Here we take a closer look at amino acid properties, how they are used in the body and where they come from.

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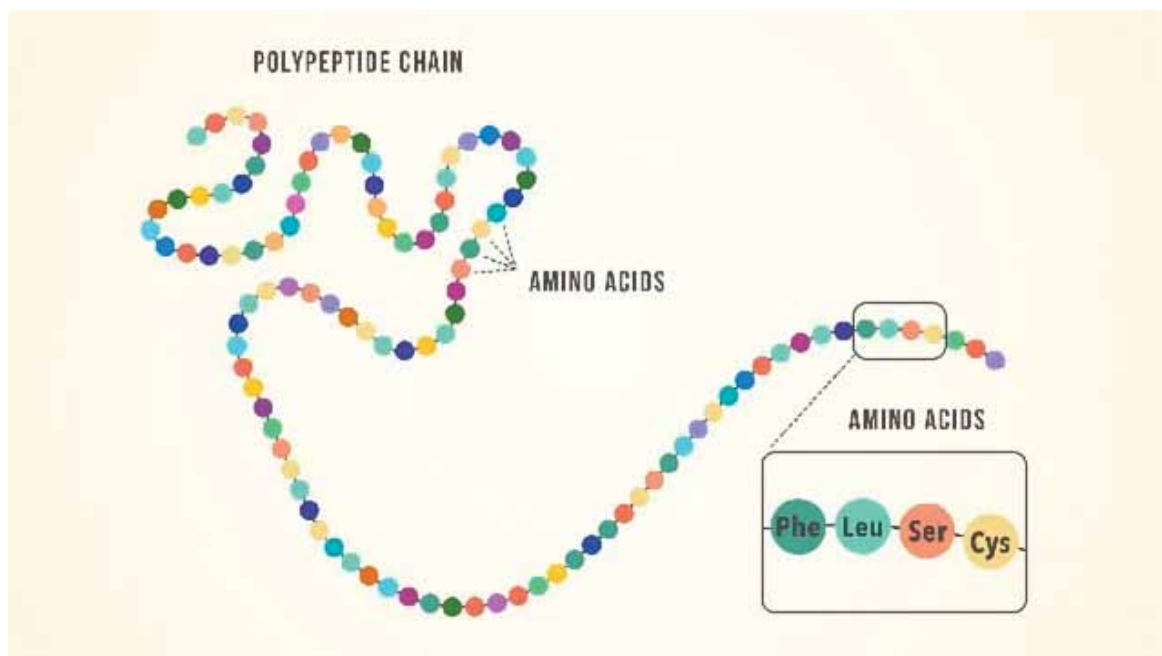
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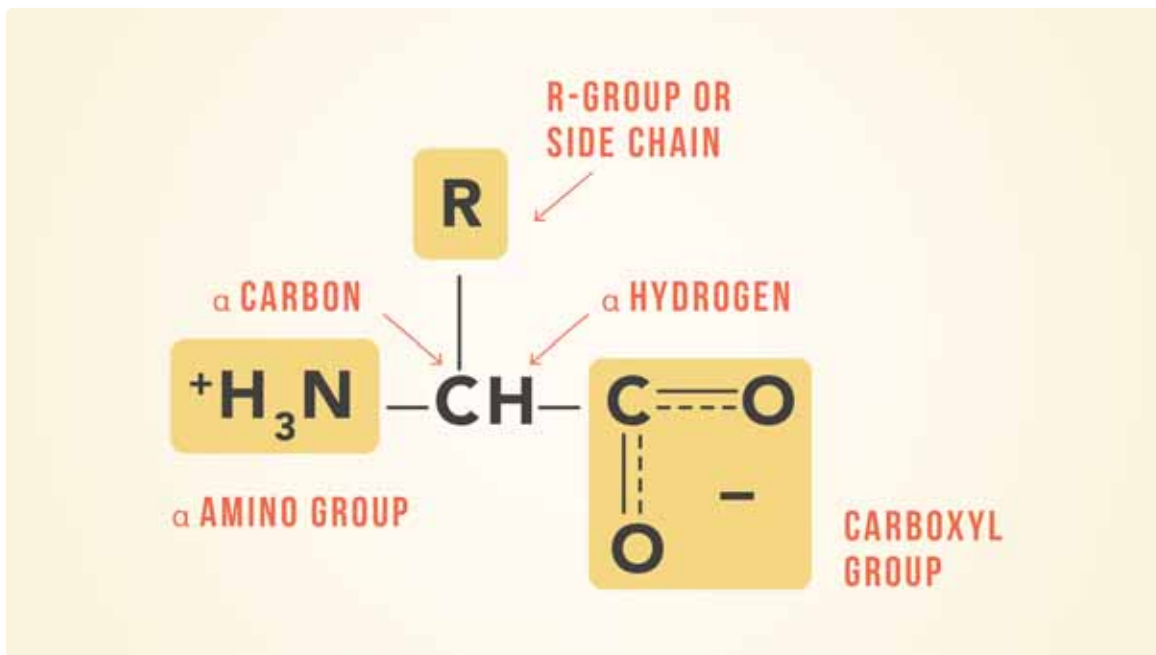
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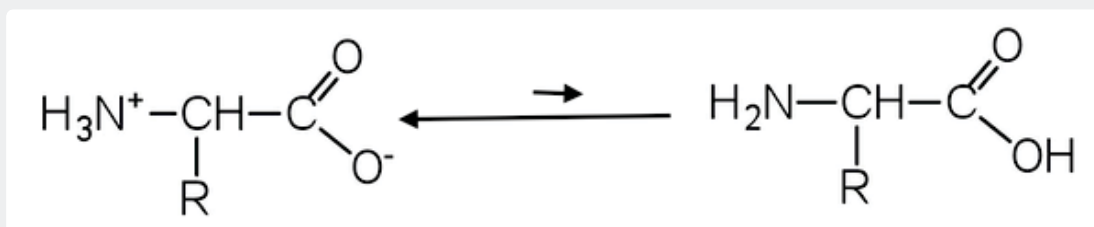
Amino acid chart



Credit: Technology Networks

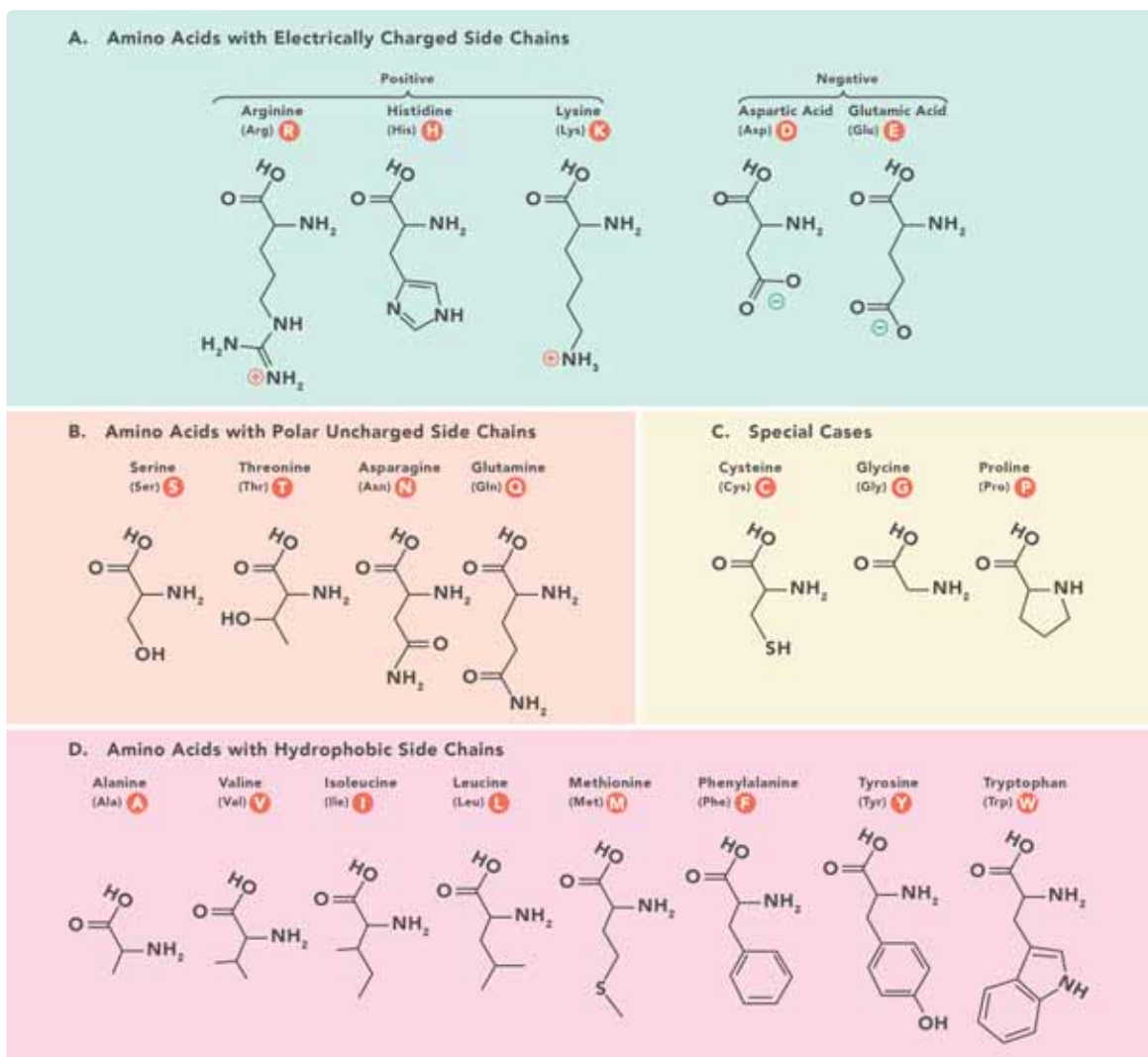
There are 20 amino acids that make up proteins and all have the same basic structure, differing only in the [R-group](#) or side chain they have.

Amino acids are in an equilibrium between two acids with the proton (H⁺) moving between the amino group and the carboxyl group as shown below.



In such an equilibrium, the weaker acid always predominates. As ammonia is a weaker acid than carboxylic acid, the equilibrium will lie to the left (on the "zwitterion" side). Although amino acids are often shown in textbooks as the right-hand structure, they actually mostly exist as the left-hand structure.

The simplest, and smallest, amino acid is glycine for which the R-group is a hydrogen (H). They can be subdivided according to their properties, dictated by the functional groups they possess. Broadly they are divided by [charge](#), [hydrophobicity](#) and [polarity](#). These properties influence the way they interact with surrounding amino acids in polypeptides and proteins, and consequently impact protein 3D structure and properties.



Credit: Technology Networks

This chart shows the chemical structures of the 20 amino acids that make up

proteins.

Amino acid abbreviations

This table shows the abbreviations and single letter codes used for the 20 amino acids found in proteins. In addition, pyrrolysine, used in the biosynthesis of proteins in some archaea and bacteria but not present in humans, and selenocysteine, a cysteine analogue only found in some lineages, are included in blue. Finally, abbreviations used for amino acid residues with more than one potential identity, and the termination codon are shown in red to complete the alphabet of single letter abbreviations.

What is the structure of the amino acids?

An amino acid's structure consists of a central carbon atom attached to a hydrogen, an acidic carboxyl group ($-\text{COOH}$), an amino group ($-\text{NH}_2$) and an organic side chain (also called an R group). The side chain is unique in each of the 20 amino acids.

Amino acid	Abbreviation	Single letter abbreviation
Alanine	Ala	A
Arginine	Arg	R
Asparagine	Asn	N
Aspartic acid	Asp	D

Amino acid	Abbreviation	Single letter abbreviation
Cysteine	Cys	C
Glutamine	Gln	Q
Glutamic acid	Glu	E
Glycine	Gly	G
Histidine	His	H
Isoleucine	Ile	I
Leucine	Leu	L
Lysine	Lys	K
Methionine	Met	M
Phenylalanine	Phe	F
Proline	Pro	P
Serine	Ser	S
Threonine	Thr	T
Tryptophan	Trp	W
Tyrosine	Tyr	Y
Valine	Val	V
Pyrrolysine	Pyl	O
Selenocysteine	Sec	U
Aspartic acid or Asparagine	Asx	B

Amino acid	Abbreviation	Single letter abbreviation
Glutamic acid or Glutamine	Glx	Z
Any amino acid	Xaa	X
Leucine or Isoleucine	Xle	J
Termination codon	TERM	

Ala amino acid

Discovered in protein in 1875, alanine makes up 30% of the residues in silk. Its low reactivity contributes to the simple, elongated structure of silk with few cross-links which gives the fibers strength, stretch resistance and flexibility. Only the L-stereoisomer participates in the biosynthesis of proteins.

Arg amino acid

In humans, arginine is produced when proteins are digested. It can then be converted into nitric oxide by the human body, a chemical known to relax blood vessels.

Due to its vasodilatory effects, arginine has been put forward for the treatment of people with chronic heart failure, high cholesterol, compromised circulation and high blood pressure, although research on these fronts is still ongoing. Arginine can also be produced synthetically, and arginine-related compounds can be used in treating people with liver dysfunction due to its role in promoting liver regeneration. Although arginine is necessary for growth but not body maintenance, research has indicated that arginine is crucial to the wound-healing process, particularly in those with poor circulation.

Asn amino acid

In 1806, asparagine was purified from asparagus juice, making it the first amino acid to be isolated from a natural source. However, it wasn't until 1932 that scientists were able to prove that asparagine occurred in proteins. Only the L-stereoisomer participates in the biosynthesis of mammalian proteins. Asparagine is important in the removal of toxic ammonia from the body.

Asp amino acid

Discovered in proteins in 1868, aspartic acid is commonly found in animal proteins, however only the L-stereoisomer participates in the biosynthesis of proteins. The water solubility of this amino acid lends itself to the presence near the active sites of enzymes such as pepsin.

Cys amino acid

Cysteine is particularly abundant in the proteins of hair, hooves, and the keratin of the skin, having been isolated from a urinary calculus in 1810 and from horn in 1899. Subsequently, it was chemically synthesized, and the structure solved in 1903–4.

The sulfur-containing thiol group in cysteine's side chain is key to its properties, enabling the formation of disulfide bridges between two peptide chains (as with insulin) or loop formation within a single chain, impacting the final protein structure. Two cysteine molecules linked together by a disulfide linkage make up the amino acid cystine, which is sometimes listed separately in common amino acid listings. Cysteine is made in the body from serine and methionine and only present in the L-stereoisomer in mammalian proteins.

People with the genetic condition [cystinuria](#) are unable to effectively reabsorb cystine into their bloodstream. Consequently, high levels of cystine build up in their urine where it crystallizes and forms stones that block the kidneys and bladder.

Gln amino acid

Glutamine was first isolated from beet juice in 1883, isolated from a protein in 1932 and subsequently synthesized chemically the following year. Glutamine is the most abundant amino acid in our bodies and performs several important functions. In humans, glutamine is synthesized from glutamic acid and this conversion step is vitally important in regulating the level of toxic ammonia in the body, forming urea and purines.

Glu amino acid

Glutamic acid was isolated from wheat gluten in 1866 and chemically synthesized in 1890. Commonly found in animal proteins, only the L-stereoisomer occurs in mammalian proteins, which humans are able to synthesize from the common intermediate α -ketoglutaric acid. The monosodium salt of L-glutamic acid, monosodium glutamate (MSG) is commonly used as a condiment and flavor enhancer. The carboxyl side chain of glutamic acid is able to act as a donor and acceptor of ammonia, which is toxic to the body, enabling the safe transport of ammonia to the liver where it is converted to urea and excreted by the kidneys. Free glutamic acid can also be degraded to carbon dioxide and water or transformed into sugars.

Gly amino acid

Glycine was the first amino acid to be isolated from a protein, in this case gelatin, and is the only one that is not optically active (no D- or L-stereoisomers). Structurally the simplest of the α -amino acids, it is very unreactive when incorporated into proteins. Even so, glycine is important in the biosynthesis of the amino acid serine, the coenzyme glutathione, purines and heme, a vital part of hemoglobin.

His amino acid

Histidine was isolated in 1896 and its structure was confirmed by chemical synthesis in 1911. Histidine is the direct precursor of histamine and is also an important source of carbon in purine synthesis. When incorporated into proteins, histidine's side chain can act as a proton acceptor and donor, conveying important properties when combined into enzymes such as chymotrypsin and those involved in the metabolism of carbohydrates, proteins, and nucleic acids.

For infants, histidine is considered an essential amino acid, adults are able to go for short periods without dietary intake but is still considered essential.

Ile amino acid

Isoleucine was isolated from beet sugar molasses in 1904. The hydrophobic nature of isoleucine's side chain is important in determining the tertiary structure of proteins in which it is included.

Those suffering from a rare inherited disorder called [maple syrup urine disease](#), have a faulty enzyme in the degradation pathway common to isoleucine, leucine, and valine. Without treatment, metabolites build up in patient's urine contributing the distinctive odor that gives the condition its name.

Leu amino acid

Leucine was isolated from cheese in 1819 and from muscle and wool in its crystalline state in 1820. In 1891, it was synthesized in the laboratory.

Only the L-stereoisomer appears in mammalian protein and can be degraded into simpler compounds by the enzymes of the body. Some DNA binding proteins contain regions in which leucines are arranged in configurations called leucine zippers.

Lys amino acid

Lysine was first isolated from the milk protein casein in 1889, and its structure elucidated in 1902. Lysine is important in the binding of enzymes to coenzymes and plays an important role in the way histones function.

Many cereal crops are very low in lysine which has led to deficiencies in some populations that rely heavily on these for food as well as in vegetarians and low-fat dieters. Consequently, efforts have been made to develop corn strains rich in lysine.

Met amino acid

Methionine was isolated from the milk protein casein in 1922, and its structure was solved by laboratory synthesis in 1928. Methionine is an important source of sulfur for numerous compounds in the body, including cysteine and taurine. Linked to its sulfur content, methionine helps to prevent fat accumulation in the liver, and helps to detoxify metabolic wastes and toxins.

Methionine is the only essential amino acid that is not present in significant amounts of soybeans and is therefore produced commercially and added to many soy meal products.

Phe amino acid

Phenylalanine was first isolated from a natural source (lupine sprouts) in 1879 and subsequently synthesized chemically in 1882. The human body is ordinarily able to break down phenylalanine into tyrosine, however in individuals with the inherited condition [phenylketonuria](#) (PKU), the enzyme that performs this conversion lacks activity. If left untreated, phenylalanine builds in the blood causing retarded mental development in children. On in 10,000 children are born with the condition, adopting a diet low in phenylalanine early in life can ease the effects.

Pro amino acid

In 1900, proline was chemically synthesized. The following year it was then isolated from the milk protein casein and its structure shown to be the same. Humans can synthesize proline from glutamic acid, appearing only as the L-stereoisomer in mammalian proteins. When proline is incorporated into proteins, its peculiar structure leads to sharp bends, or kinks, in the peptide chain, contributing greatly to the protein's final structure. Proline and its derivative hydroxyproline, account for 21 % of the amino-acid residues of the fibrous protein collagen, essential to connective tissue.

Ser amino acid

Serine was first isolated from silk protein in 1865, but its structure was not established until 1902. Humans can synthesize serine from other metabolites, including glycine, although only the L-stereoisomer appears in mammalian proteins. Serine is important for the biosynthesis of many metabolites and is often important to the catalytic function of enzymes in which it is incorporated, including chymotrypsin and trypsin.

Nerve gases and some insecticides act by combining with a serine residue in the active site of acetylcholine esterase, inhibiting the enzyme completely. Esterase activity is essential to breakdown the neurotransmitter acetylcholine otherwise dangerously high levels build up, rapidly leading to convulsions and death.

Thr amino acid

Threonine was isolated from fibrin in 1935 and synthesized in the same year. Only the L-stereoisomer appears in mammalian proteins where it is relatively unreactive. Although important in many reactions in bacteria, its metabolic role in higher animals, including humans, remains unclear.

Trp amino acid

Isolated from casein (milk protein) in 1901, tryptophan's structure was established in 1907, but only the L-stereoisomer appears in mammalian proteins. In the human gut, bacteria break down dietary tryptophan, releasing compounds like skatole and indole which give feces their unpleasant aroma. Tryptophan is converted to vitamin B3 (also called nicotinic acid or niacin), but not at a sufficient rate to keep us healthy. Consequently we must also ingest vitamin B3, failure to do so leading to a deficiency called [pellagra](#).

Tyr amino acid

In 1846 tyrosine was isolated from the degradation of the casein (a protein from cheese), following which it was synthesized in the laboratory and its structure determined in 1883. Only present in the L-stereoisomer in mammalian proteins, humans can synthesize tyrosine from phenylalanine. Tyrosine is an important precursor to the adrenal hormones epinephrine and norepinephrine, thyroid hormones including thyroxine and the hair and skin pigment melanin. In enzymes, tyrosine residues are often associated with active sites, alteration of which can change enzyme specificity or wipe out activity entirely.

Suffers of the serious genetic condition [phenylketonuria \(PKU\)](#) are unable to convert phenylalanine to tyrosine, whilst patients with [alkaptonuria](#) have a defective tyrosine metabolism, producing distinctive urine which darkens when exposed to the air.

Val amino acid

The structure of valine was established in 1906, after first being isolated from albumin in 1879. Only the L-stereoisomer appears in mammalian protein. Valine can be degraded into simpler compounds in the body, but in people with a rare genetic condition called [maple syrup urine disease](#), a faulty enzyme interrupts this process and can prove fatal if untreated.

Properties of the carboxyl group

- All amino acids have a [carboxyl group](#) and an [amino group](#).
- During amino acid polymerization, the carboxyl group of one amino acid is linked to the amino group of the next amino acid via a peptide bond with the loss of a water molecule.

Properties of hydrophobic amino acids

- Amino acids that fall under the classification of hydrophobic are alanine, valine, isoleucine, leucine, methionine, phenylalanine, tryptophan and tyrosine.
- As their classification suggests, the side chains tend to be repelled from water, so this impacts the positioning of these amino acids in the protein

tertiary structure.

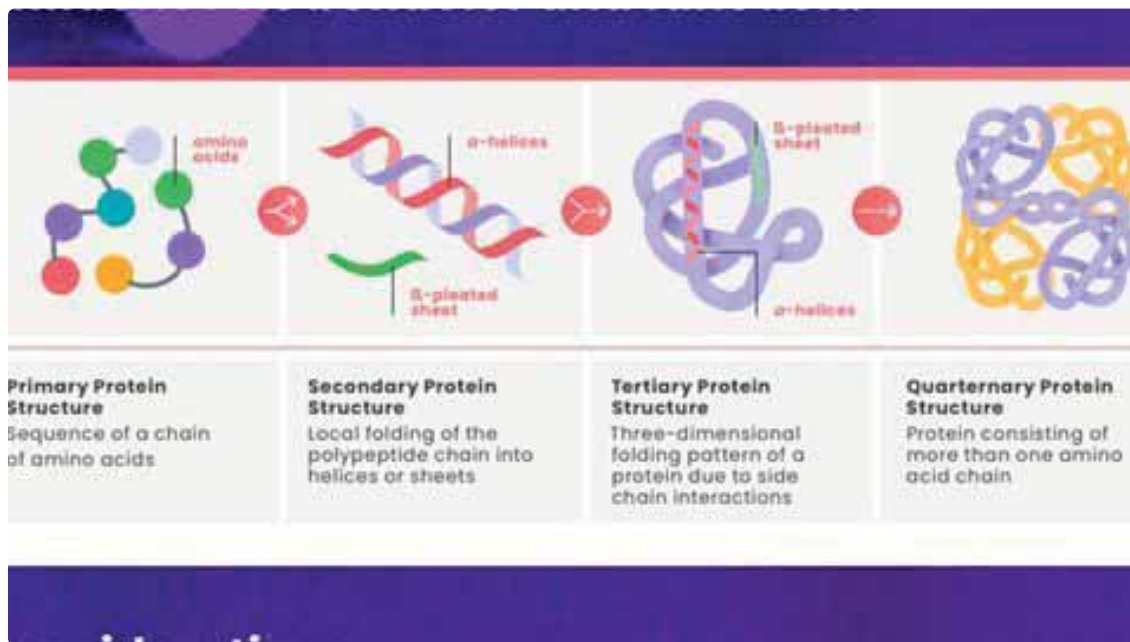
Properties of polar amino acids

- Polar amino acid residues are typically found on the outside of a protein following polymerization due to the hydrophilic properties of the side chain.
- Four amino acids are classed as polar but not charged (asparagine, glutamine, serine and threonine).

Properties of aromatic amino acids

- The aromatic amino acids (phenylalanine, tyrosine and tryptophan), whilst all falling within other classifications, possess aromatic side chains.
- Consequently, to different degrees, they all absorb ultraviolet light, with tyrosine absorbing the most and phenylalanine the least.

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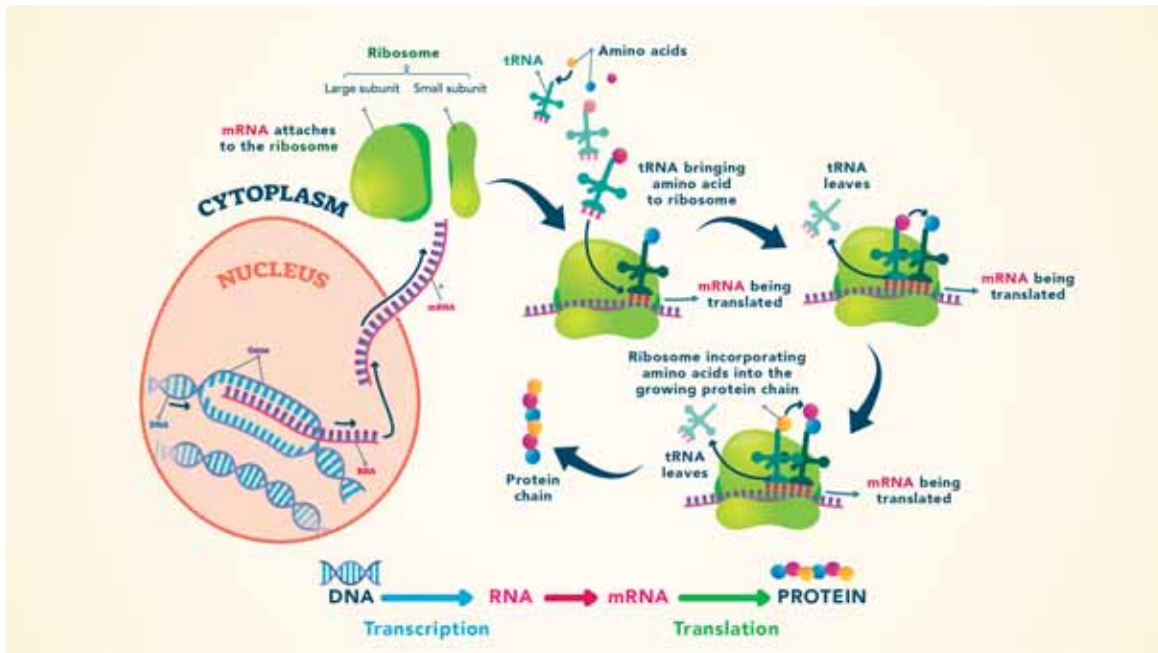
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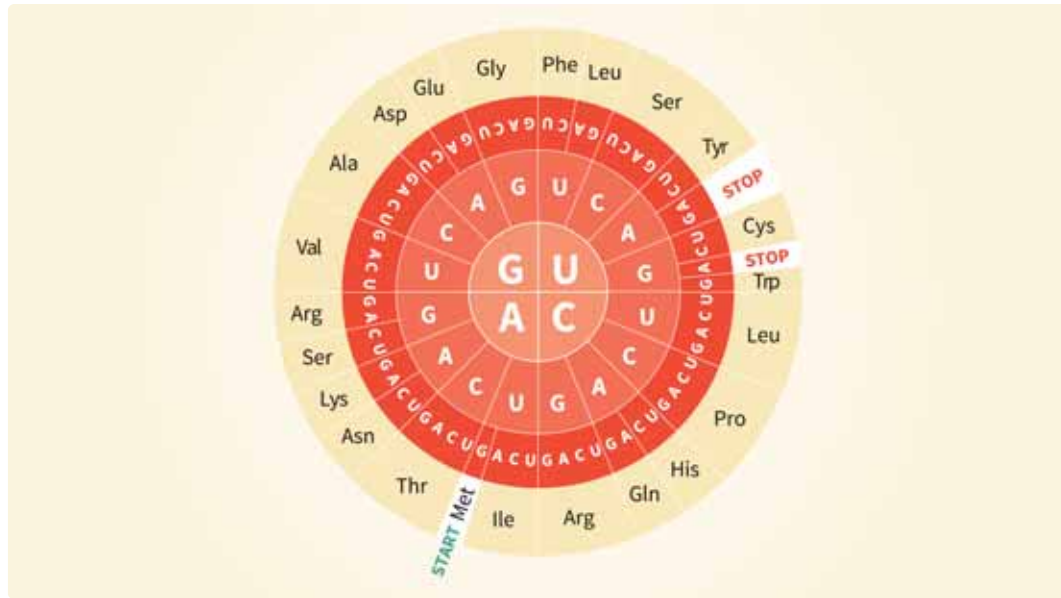
Protein synthesis definition and the amino acid code

To [form a protein](#), amino acids are polymerized with the formation of a peptide bond, starting at the N-terminus and ending at the C-terminus.



Credit: Technology Networks

- A messenger RNA (mRNA) copied from DNA provides the instruction of which amino acid to incorporate at which position for the synthesis of a specific protein.
- At the ribosome, a transfer RNA (tRNA) binds to one end of the mRNA and carries the required amino acids at the other end.
- Additional protein factors aid in the initiation, elongation and termination of protein synthesis.
- The genetic information required to determine which amino acid needs to be incorporated at which position is encoded as a series of three bases, or triplets, in the mRNA, also called the triplet code. The 64 possible triplets and the amino acids they specify are called the genetic code or amino acid code.
- Many of the amino acids are encoded by more than one triplet code, such as arginine, which is added when CGU, CGC, CGA or CGG is encountered. In most organisms three (and sometimes two) of the triplets signal chain termination.



Credit: Technology Networks

Nine essential amino acids and amino acid supplements

The human body is able to synthesize 11 of the 20 amino acids, however the [other nine we cannot](#). This is likely as a result of gene loss or [mutation](#) over time in response to changing selective pressures, such as the abundance of particular food containing specific amino acids. These are therefore termed essential amino acids and must be acquired through our diet.

Particular animal species are able to synthesize different amino acids and, accordingly, their dietary requirements differ. Humans for example are able to synthesize arginine, but dogs and cats cannot – they must acquire it through dietary intake. Unlike humans and dogs, cats are unable to synthesize taurine. This is one of the reasons that commercial dog food is unsuitable for cats. For humans, the nine amino acids that must be acquired through diet are histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine.

Foods that contain all nine essential amino acids are referred to as "complete

proteins", and include meat, seafood, eggs, dairy products, [soy](#), quinoa and buckwheat. Other protein sources, such as nuts, seeds, grains and beans, contain some but not all essential amino acids and are therefore referred to as incomplete.

This table shows the [United States recommended daily allowances](#) per 1 kg of body weight for the nine essential amino acids.

Amino acid	Recommended daily allowances (mg/kg body weight)
Histidine	14
Isoleucine	19
Leucine	42
Lysine	38
Methionine	19
Phenylalanine	33
Threonine	20
Tryptophan	5
Valine	24

There are also guidelines for the non-essential amino acids cysteine (19 mg/kg) and tyrosine (33 mg/kg).

Let's talk supplements. All of your bodies' essential amino acid needs can be [met by having a healthy, balanced diet](#). However, there are some advocates for taking

high concentration supplements to improve factors such as mood, sleep, exercise performance, weight loss and prevent muscle loss. Look on many “health and wellbeing” pages and there are people peddling the benefits of amino acid supplements, but is there good evidence to back this up?

The essential amino acid tryptophan is required for the production of serotonin, a neurotransmitter with an important role in sleep, mood and behavior. Consequently, the effects of manipulating tryptophan levels on sleep and mood have been investigated in a number of studies. Whilst there is evidence that [depleting tryptophan](#) levels can negatively impact sleep and mood, many studies suffer from small sample sizes, lack of sufficient controls or other [failings](#). Consequently, whilst it is clearly a key component in the diet and there may be [potential](#) for supplementation to have beneficial effects, evidence to support the administration of tryptophan above and beyond what can be consumed in a healthy diet is currently lacking and further investigation is required.

Whilst there are some studies suggesting taking amino acid supplements can have [positive effects on exercise performance](#) in some groups, results vary greatly between studies, with many studies demonstrating [little or no benefit](#). A [clinical trial](#) is also looking at the consequences of taking an amino acid food supplement on skin photoaging but the results are yet to be revealed.