

Proteinogenic and Non-Proteinogenic Amino Acids have Biological Functions

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Short Communication

Amino acids are organic compounds that contain amino ($-NH_2$) and carboxyl ($-COOH$) functional groups, along with a side chain (R group) specific to each amino acid. The key elements of an amino acid are carbon (C), hydrogen (H), oxygen (O), and nitrogen (N), although other elements are found in the side chains of certain amino acids. About 500 naturally occurring amino acids are known as of 1983 (though only 20 appear in the genetic code) and can be classified in many ways. They can be classified according to the core structural functional groups' locations as alpha- (α -), beta- (β -), gamma- (γ -) or delta- (δ -) amino acids; other categories relate to polarity, pH level, and side chain group type (aliphatic, acyclic, aromatic, containing hydroxyl or sulfur, etc.). In the form of proteins, amino acid residues form the second-largest component (water is the largest) of human muscles and other tissues. Beyond their role as residues in proteins, amino acids participate in a number of processes such as neurotransmitter transport and biosynthesis [1].

Many important proteinogenic and non-proteinogenic amino acids have biological functions. For example, in the human brain, glutamate (standard glutamic acid) and gamma-aminobutyric acid ("GABA", nonstandard gamma-amino acid) are, respectively, the main excitatory and inhibitory neurotransmitters. Hydroxyproline, a major component of the connective tissue collagen, is synthesised from proline. Glycine is a biosynthetic precursor to porphyrins used in red blood cells. Carnitine is used in lipid transport. Nine proteinogenic amino acids are called "essential" for humans because they cannot be produced from other compounds by the human body and so must be taken in as food. Others may be conditionally essential for certain ages or medical conditions. Essential amino acids may also vary from species to species [2]. Because of their biological significance, amino acids are important in nutrition and are commonly used in nutritional supplements, fertilizers, feed, and food technology. Industrial uses include the production of drugs, biodegradable plastics, and chiral catalysts [3].

Proteinogenic Amino Acids

Protein primary structure and Posttranslational modification

Amino acids are the structural units (monomers) that make up proteins. They join together to form short polymer chains called peptides or longer chains called either polypeptides or proteins. These chains are linear and unbranched, with each amino acid residue within the chain attached to two neighbouring amino acids. The process of making proteins encoded by DNA/RNA genetic material is called translation and involves the step-by-step addition of amino acids to a growing protein chain by a ribozyme that is called a ribosome. The order in which the amino acids are added is read through the genetic code from an mRNA template, which is an RNA copy of one of the organism's genes.

Twenty-two amino acids are naturally incorporated into polypeptides and are called proteinogenic or natural amino acids. Of

these, 20 are encoded by the universal genetic code. The remaining 2, selenocysteine and pyrrolysine, are incorporated into proteins by unique synthetic mechanisms. Selenocysteine is incorporated when the mRNA being translated includes a SECIS element, which causes the UGA codon to encode selenocysteine instead of a stop codon. Pyrrolysine is used by some methanogenic archaea in enzymes that they use to produce methane. It is coded for with the codon UAG, which is normally a stop codon in other organisms. This UAG codon is followed by a PYLIS downstream sequence [1].

Several independent evolutionary studies, using different types of data, have suggested that Gly, Ala, Asp, Val, Ser, Pro, Glu, Leu, Thr (i. e. G, A, D, V, S, P, E, L, T) may belong to a group of amino acids that constituted the early genetic code, whereas Cys, Met, Tyr, Trp, His, Phe (i. e. C, M, Y, W, H, F) may belong to a group of amino acids that constituted later additions of the genetic code.

Non-Proteinogenic Amino Acids

Aside from the 22 proteinogenic amino acids, many non-proteinogenic amino acids are known. Those either are not found in proteins (for example carnitine, GABA, levodopa) or are not produced directly and in isolation by standard cellular machinery (for example, hydroxyproline and selenomethionine) [4-8].

Non-proteinogenic amino acids that are found in proteins are formed by post-translational modification, which is modification after translation during protein synthesis. These modifications are often essential for the function or regulation of a protein. For example, the carboxylation of glutamate allows for better binding of calcium cations and collagen contains hydroxyproline, generated by hydroxylation of proline. Another example is the formation of hypusine in the translation initiation factor EIF5A, through modification of a lysine residue. Such modifications can also determine the localization of the protein, e.g., the addition of long hydrophobic groups can cause a protein to bind to a phospholipid membrane.

Some non-proteinogenic amino acids are not found in proteins. Examples include 2-aminoisobutyric acid and the neurotransmitter gamma-aminobutyric acid. Non-proteinogenic amino acids often occur as intermediates in the metabolic pathways for standard amino acids - for example, ornithine and citrulline occur in the urea cycle, part of amino acid catabolism (see below). A rare exception to the

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dominance of α -amino acids in biology is the β -amino acid beta alanine (3-aminopropanoic acid), which is used in plants and microorganisms in the synthesis of pantothenic acid (vitamin B 5), a component of coenzyme A.

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