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Amino acids from marine fish and their implications in health and diseases

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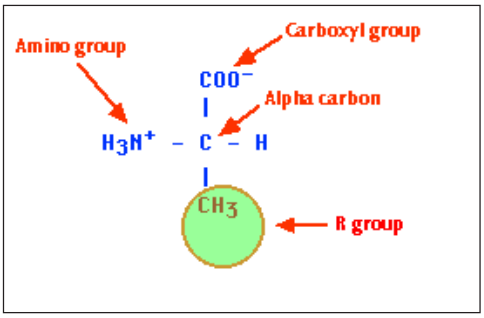
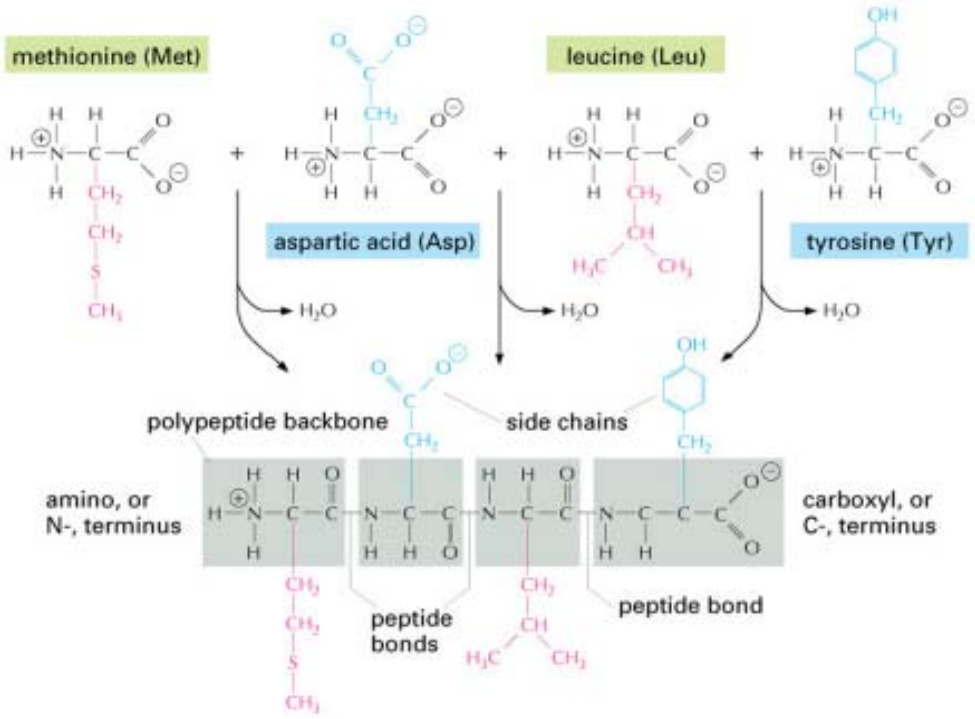
An **amino acid** is any molecule that contains both amino and carboxylic acid functional groups. Amino acid is any one of a class of simple organic compounds containing carbon, hydrogen, oxygen, nitrogen, and in certain cases sulfur. These compounds are the building blocks of proteins. Amino acids are the building blocks (monomers) of protein, and are utilized by every cell in the body for a variety of crucial functions. The shape and other properties of each protein is dictated by the precise sequence of amino acids in it. Normally, we obtain them from our food sources, particularly those high in protein; the body breaks these proteins down into their constituent parts, and then our cells use these to build the specific types of protein each of them needs. Amino acids form short polymer chains called peptides or polypeptides which in turn form structures called proteins. Each amino acid has at least one carboxyl (COOH) group, which is acidic, and one amino (NH_2) group, which is basic.

Each amino acid consists of an alpha carbon atom to which is attached

- A hydrogen atom
- An amino group (hence “amino” acid)
- A carboxyl group (-COOH). This gives up a proton and is thus an acid (hence amino “acid”)
- One of 20 different “R” groups. It is the structure of the R group that determines which of the 20 it is and its special properties. The amino acid shown here is alanine.



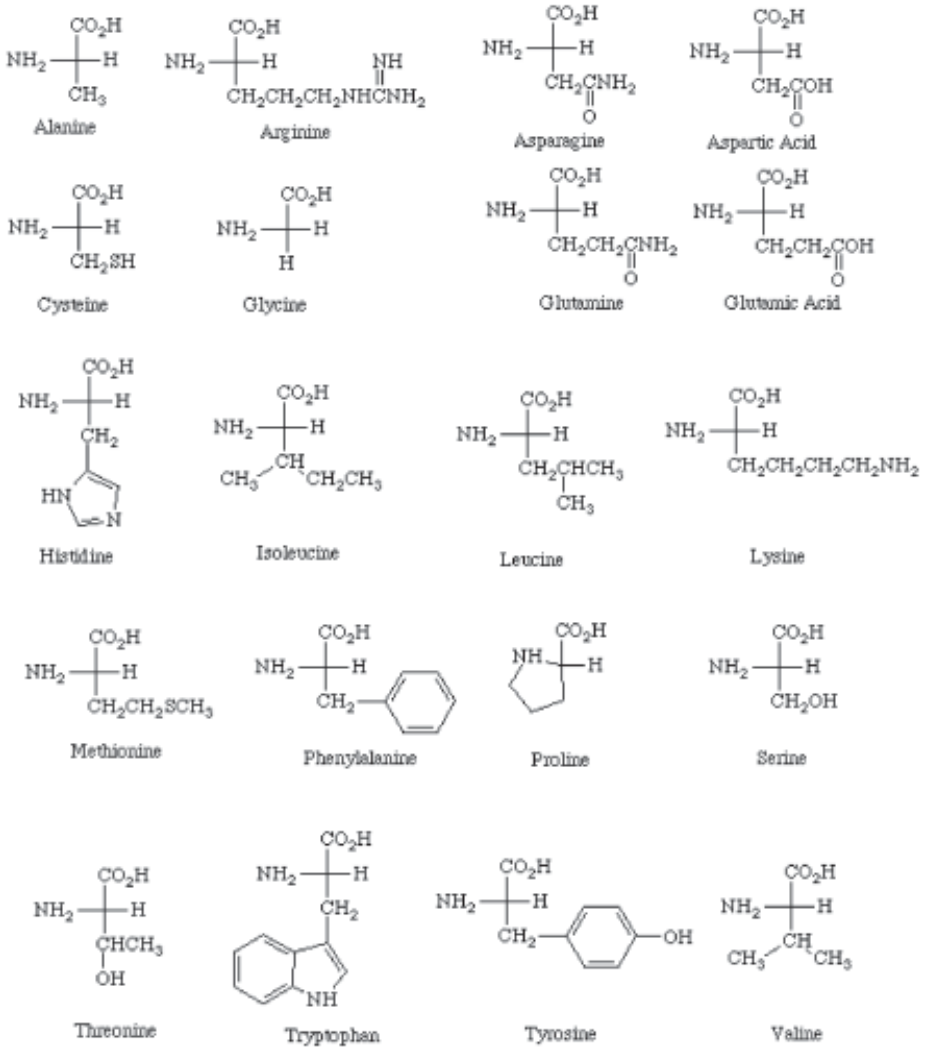
Amino acids join together in long chains, the amino group of one amino acid linking with the carboxyl group of another. The linkage is known as a peptide bond, and a chain of amino acids is known as a polypeptide. Each type of protein differs in its amino acid sequence. Thus the sequential position of the chemically distinct side chains gives each protein its individual properties. The two ends of each polypeptide chain are chemically different: the end that carries the free amino group (NH_3^+, also written NH_2) is called the amino, or N-, terminus; and the end carrying the free carboxyl group ($C00^-$, also written COOH) is the carboxyl, or C-, terminus. The amino acid sequence of a protein is always presented in the N to C direction, reading from left to right.



There are two types of amino acids: essential and nonessential. Essential ones are defined as those which the body cannot manufacture on its own and must obtain from food sources (or supplements); nonessential ones, on the other hand, can be produced by our own bodies from an available source of nitrogen and a carbon skeleton, but can also be consumed as supplements. The essential amino acids are isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. The nonessential amino acids are arginine, alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, proline, serine, and tyrosine. However, cysteine can partially meet the need for methionine (they both contain sulfur), and tyrosine can partially substitute for phenylalanine. Semi-essential amino acids are ones that can sometimes be made internally if conditions are right. Histidine is considered semi-essential because the body does not always require dietary sources of it. Other amino acids, such as carnitine, are used by the body in ways other than protein-building and are often used therapeutically.

The molecular structures of the major amino acids are listed below:

Leucine, isoleucine, and valine are called branched-chain amino acid (BCAAs) because human beings cannot survive unless these amino acids are present in the diet. The combination of these three amino acids makes up approximately one-third of skeletal muscle in the human body. In addition to their role in protein and enzyme synthesis, amino acids are extremely crucial for good health. Amino acids contribute significantly to the health of the nervous system, muscular structure, hormone production, vital organs and cellular structure. Some affects low levels of the essential amino acids result in hormonal imbalances, irritability, low concentration, and depression.



Essential amino acids and their importance

Isoleucine : Isoleucine belongs to a special group of amino acids called branched-chain amino acids (BCAAs), which are needed to help maintain and repair muscle tissue. Leucine and valine are other two branched-chain amino acids. Isoleucine is an essential amino acid that is not synthesized by mammalian tissues. Isoleucine is needed for hemoglobin formation and also helps to maintain regular energy levels. Isoleucine is important for stabilizing and regulating blood sugar and energy levels and is required through the diet as it cannot be produced by our bodies.

Leucine : Leucine is a member of the branched-chain amino acid family, along with valine and isoleucine. The branched-chain amino acids (BCAAs) are found in proteins of all life forms. Leucine ties glycine for the position of second most common amino acid found in proteins with a concentration of 7.5 percent on a molar basis compared to the other amino acids. Leucine is necessary for the optimal growth of infants and for the nitrogen balance in adults. It functions on balancing blood sugar level in the body. It also promotes in the development of the muscle tissue. It modulates the

level of hormone production and energy regulation. It also provides support by preventing the breakdown of muscles. Deficiency in leucine may include dizziness, irritation, headache, fatigue, etc.

Lysine : Lysine is an essential amino acid that has a net positive charge at physiological pH values making it one of the three basic (with respect to charge) amino acids. Lysine is an essential amino acid because it cannot be synthesized in the body and its breakdown is irreversible. It is an essential building block for all protein, and is needed for proper growth and bone development in children. Lysine helps the body absorb and conserve calcium and it plays an important role in the formation of collagen.

Methionine : Methionine is an important amino acid that helps to initiate translation of messenger RNA by being the first amino acid incorporated into the N-terminal position of all proteins. Methionine supplies sulfur and other compounds required by the body for normal metabolism and growth. Methionine reacts with adenosine triphosphate to form S-adenosyl methionine. S-adenosyl methionine is the principal methyl donor in the body and contributes to the synthesis of many important substances, including epinephrine and choline. It helps in breaking down of fatty acids, and hence it prevents in building up fatty elements on the artery walls. It also works significantly in the normal detoxification of liver. It is essential in promoting energy production as well as in muscle building. Methionine, one of the essential amino acids, functions like an effective anti-oxidant by supplying sulfur for inactivating free radicals.

Phenylalanine : Phenylalanine is an essential amino acid that is also one of the aromatic amino acids that exhibit ultraviolet radiation absorption properties with a large extinction coefficient. Phenylalanine is part of the composition of aspartame, a common sweetener found in prepared foods (particularly soft drinks, and gum). Phenylalanine plays a key role in the biosynthesis of other amino acids and some neurotransmitters.

Threonine : This amino acid is perfect in assisting protein balance in the body. Additionally, it helps in the development of collagen and maintaining elasticity in the skin. It also functions of liver. It functions well in reducing liver fat. In addition to other essential amino acids, threonine promotes well balancing of immune system in terms of antibody production and thymus growth.

Tryptophan : Tryptophan is an essential amino acid formed from proteins during digestion by the action of proteolytic enzymes. Tryptophan is also a precursor for serotonin (a neurotransmitter) and melatonin (a neurohormone). This is an essential ingredient for the formation of vitamin B3. It is responsible for the production of serotonin which is exclusively important for balancing nerve and brain functioning. It is beneficial for controlling hyperactivity among children. It aids in alleviating stress. It works effectively as an appetite suppressant. It also promotes in reducing weight.

Valine : Valine is a branched-chain amino acid (BCAA) that is closely related to leucine and isoleucine both in structure and function. Valine is a constituent of fibrous protein in the body. As a branched-chain amino acid (BCAA), valine has been found useful in treatments involving muscle, mental, and emotional upsets, and for insomnia and nervousness. Valine may help treat malnutrition associated with drug addiction.

Histidine : Histidine is one of the basic (with reference to pH) amino acids due to its aromatic nitrogen-heterocyclic imidazole side chain. Histidine is the direct precursor of histamine; it is also an important source of carbon atoms in the synthesis of purines. Histidine is needed to help grow and

repair body tissues, and to maintain the myelin sheaths that protect nerve cells. It also helps manufacture red and white blood cells, and helps to protect the body from heavy metal toxicity. Histamine stimulates the secretion of the digestive enzyme gastrin.

Non-essential amino acids

Alanine : Alanine is one of the simplest of the amino acids and is involved in the energy-producing breakdown of glucose. L-alanine is created in muscle cells from glutamate in a process called transamination. Alanine comes from the breakdown of DNA or the dipeptides, anserine and carnosine, and the conversion of pyruvate, a compound in carbohydrate metabolism. Alanine is used by the body to build proteins. Alanine is vital for the production of protein, essential for proper function of the central nervous system and helps form neurotransmitters. Alanine is necessary for the promotion of proper blood glucose levels from dietary protein.

Arginine : Arginine is a complex amino acid that is often found at the active (or catalytic) site in proteins and enzymes due to its amine-containing side chain. Arginine is involved in multiple areas of human physiology and metabolism. Arginine plays an important role in cell division, the healing of wounds, removing ammonia from the body, immune function, and the release of hormones. Arginine has a number of functions in the body such as assisting in wound healing, hormone production, immune function and removal of excess ammonia.

Asparagine : Asparagine is the ß-amide of aspartic acid synthesized from aspartic acid and ATP (adenosine triphosphate). Asparagine is one of the principal and frequently the most abundant amino acids involved in the transport of nitrogen. Asparagine is very active in converting one amino acid into another (amination and transamination) when the need arises. Asparagine serves as an amino donor in liver transamination processes.

Aspartic acid : Aspartic acid is alanine with one of the â hydrogens replaced by a carboxylic acid group. Aspartic acid is a part of organic molecules containing an amino group, which can combine in linear arrays to form proteins in living organisms. Although aspartic acid is considered a non-essential amino acid, it plays a paramount role in metabolism during construction of other amino acids and biochemicals in the citric acid cycle. Among the biochemicals that are synthesized from aspartic acid are asparagine, arginine, lysine, methionine, threonine, isoleucine, and several nucleotides.

Cysteine : Cysteine is a naturally occurring hydrophobic amino acid which has a sulfhydryl group and is found in most proteins. Cysteine is one of the key components in all living things. N-acetyl cysteine (which contains cysteine) is the most frequently used form of cysteine. N-acetyl-L-cysteine (NAC) helps break down mucus and detoxify harmful substances in the body. Both cysteine and NAC have been shown to increase levels of the antioxidant glutathione.

Cystine : Cystine is the product of an oxidation between the thiol side chains of two cysteine amino acids. As such, cystine is not considered one of the 20 amino acids. This oxidation product is found in abundance in a variety of proteins such as hair keratin, insulin, the digestive enzymes chromotrypsinogen A, papain, and trypsinogen where it is heavily involved in stabilizing the tertiary structure of these macromolecules.

Glutamine : Glutamine is one of the twenty amino acids generally present in animal proteins. Glutamine is the most abundant amino acid in the body. Over 61% of skeletal muscle tissue is

glutamine. It contains two ammonia groups, one from its precursor, glutamate, and the other from free ammonia in the bloodstream. Glutamine is involved in more metabolic processes than any other amino acid. Glutamine is converted to glucose when more glucose is required by the body as an energy source. Glutamine assists in maintaining the proper acid/alkaline balance in the body, and is the basis of the building blocks for the synthesis of RNA and DNA.

Glutamic acid : Glutamic acid is biosynthesized from a number of amino acids including ornithine and arginine. When aminated, glutamic acid forms the important amino acid glutamine. Because it has a carboxylic acid moiety on the side chain, glutamic acid is one of only two amino acids (the other being aspartic acid) that has a net negative charge at physiological pH. This negative charge makes glutamic acid a very polar molecule and it is usually found on the outside of proteins and enzymes where it is free to interact with the aqueous intracellular surroundings. On a molar basis, glutamic acid is incorporated into proteins at a rate of 6.2 percent compared to the other amino acids.

Glycine : Glycine is the simplest amino acid and is the only amino acid that is not optically active (it has no stereoisomers). The body uses it to help the liver in detoxification of compounds and for helping the synthesis of bile acids. It has a sweet taste and is used for that purpose. Glycine is essential for the synthesis of nucleic acids, bile acids, proteins, peptides, purines, adenosine triphosphate (ATP), porphyrins, hemoglobin, glutathione, creatine, bile salts, one-carbon fragments, glucose, glycogen, and l-serine and other amino acids.

Proline : Proline is a non-essential amino acid that is involved in the production of collagen and in wound healing. Proline is the precursor for hydroxyproline, which the body incorporates into collagen, tendons, ligaments, and the heart muscle. Proline plays important roles in molecular recognition, particularly in intracellular signalling. Proline is an important component in certain medical wound dressings that use collagen fragments to stimulate wound healing.

Serine : The methyl side chain of serine contains a hydroxy group making this one of two amino acids that are also alcohols. Serine plays a major role in a variety of biosynthetic pathways including those involving pyrimidines, purines, creatine, and porphyrins. Serine has sugar-producing qualities, and is very reactive in the body. It is highly concentrated in all cell membranes, aiding in the production of immunoglobulins and antibodies.

Tyrosine : Tyrosine is metabolically synthesized from phenylalanine to become the para-hydroxy derivative of that important amino acid. Tyrosine is a precursor of the adrenal hormones epinephrine, norepinephrine, and the thyroid hormones, including thyroxine. L-tyrosine, through its effect on neurotransmitters, is used to treat conditions including mood enhancement, appetite suppression, and growth hormone (HGH) stimulation.

Hydroxyproline : Hydroxyproline is derived from the amino acid proline and is used almost exclusively in structural proteins including collagen, connective tissue in mammals, and in plant cell walls. An unusual feature of this amino acid is that it is not incorporated into collagen during biosynthesis at the ribosome, but is formed from proline by a posttranslational modification by an enzymatic hydroxylation reaction. Non-hydroxylated collagen is commonly termed pro-collagen.

Non protein amino acids

In humans, non-protein amino acids also have important roles as metabolic intermediates, such as in the biosynthesis of the neurotransmitter gamma-aminobutyric acid. These class of amino acids are described in detail.

Carnitine : Carnitine is a non-essential amino acid produced in the liver, brain and the kidneys from the essential amino acids methionine and lysine. Carnitine is a nutrient responsible for the transport of long-chain fatty acids into the energy-producing centers of the cells (known as the mitochondria). Carnitine is recommended as a daily supplement to help maintain blood lipid profile and promote fatty acid utilization within heart muscle.

Carnosine : Carnosine is a dipeptide composed of the covalently bonded amino acids alanine and histidine and is found in the brain, heart, skin, muscles, kidneys and stomach. Carnosine is one of the most important and potent natural antioxidant agents which act as universal antioxidants both in the lipid phase of cellular and biological membranes and in the aqueous environment protecting lipids and water-soluble molecules like proteins (including enzymes), DNA and other essential macromolecules from oxidative damage mediated by reactive oxygen species and lipid peroxides.

Creatine : Creatine is a natural derivate of an amino acid and is synthesized in the liver, kidneys and pancreas out of arginine, methionine and glycine. Creatine functions to increase the availability of cellular ATP, adenosine triphosphate. Creatine works by acting on mechanisms of ATP by donating a phosphate ion to increase the availability of ATP. Creatine is stored in muscle cells as phosphocreatine and is used to help generate cellular energy for muscle contractions.

Citrulline : Citrulline is a precursor to arginine and is involved in the formation of urea in the liver. Arginine is a contributing member of the various amino acids found in the urea cycle, which is responsible for detoxifying ammonia. Citrulline supports the body in optimizing blood flow through its conversion to l-arginine and then nitric oxide (NO).

Gamma-aminobutyric acid : Gamma-aminobutyric acid (GABA) is a non-essential amino acid formed from glutamic acid with the help of vitamin B6. GABA (gamma-aminobutyric acid) is found in almost every region of brain, and is formed through the activity of the enzyme glutamic acid decarboxylase (GAD). GABA serves as a inhibitory neurotransmitter to block the transmission of an impulse from one cell to another in the central nervous system.

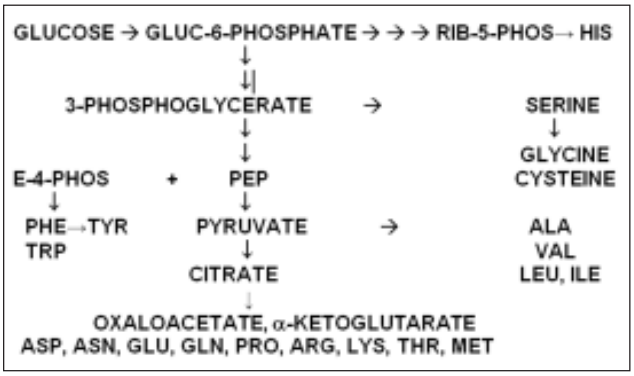
Glutathione : Glutathione (GSH) is a tripeptide composed of three different amino acids: glutamate, cysteine and glycine that have numerous important functions within cells. Glutathione plays a role in such diverse biological processes as protein synthesis, enzyme catalysis, transmembrane transport, receptor action, intermediary metabolism, and cell maturation. Glutathione acts as an antioxidant used to prevent oxidative stress in most cells and help to trap free radicals that can damage DNA and RNA.

Ornithine : Ornithine plays an important role in the urea cycle and is the precursor of the amino acids citrulline, glutamic acid, and proline. Another primary role of ornithine is being an intermediate in arginine biosynthesis, although this is due to its participation in the urea cycle (responsible for the production of urea). Ornithine is not directly incorporated into proteins and enzymes and does not have a codon in the genetic code.

Taurine - Taurine is a non-essential sulfur-containing amino acid that functions with glycine and gamma-aminobutyric acid as a neuroinhibitory transmitter. Taurine is the body's water soluble anti-oxidant, and inhibitory neurotransmitter. The major antioxidant activity of taurine derives from its ability to scavenge the reactive oxygen species hypochlorite. Taurine plays an important role in numerous physiological functions.

Metabolism of amino acids

In plants, nitrogen is first assimilated into organic compounds in the form of glutamate, formed from alpha-ketoglutarate and ammonia in the mitochondrion. In order to form other amino acids, the plant uses transaminases to move the amino group to another alpha-keto carboxylic acid. For example, aspartate aminotransferase converts glutamate and oxaloacetate to alpha-ketoglutarate and aspartate. Other organisms use transaminases for amino acid synthesis too.



Transaminases are also involved in breaking down amino acids. Degrading an amino acid often involves moving its amino group to alpha-ketoglutarate, forming glutamate. In many vertebrates, the amino group is then removed through the urea cycle and is excreted in the form of urea. However, amino acid degradation can produce uric acid or ammonia instead. For example, serine dehydratase converts serine to pyruvate and ammonia. Nonstandard amino acids are usually formed through modifications to standard amino acids. For example, homocysteine is formed through the transsulfuration pathway or by the demethylation of methionine via the intermediate metabolite S-adenosyl methionine, while hydroxyproline is made by a posttranslational modification of proline. Microorganisms and plants can synthesize many uncommon amino acids. For example, some microbes make 2-aminoisobutyric acid and lanthionine, which is a sulfide-bridged derivative of alanine. Both of these amino acids are found in peptidic lantibiotics such as alamethicin. While in plants, 1-aminocyclopropane-1-carboxylic acid is a small disubstituted cyclic amino acid that is a key intermediate in the production of the plant hormone ethylene.

The health benefits of amino acids

Amino acids are needed to build the various proteins used in the growth, repair, and maintenance of body tissues. Amino acids play innumerable roles in human health and disease. Alanine is necessary for the promotion of proper blood glucose levels from dietary protein. Alanine stimulates lymphocyte production and may help people who have immune suppression. Alanine strengthens the immune system by producing antibodies. L-arginine is used by the immune system to help regulate the activity of the thymus gland, which is responsible for manufacturing T lymphocytes. The body uses arginine to produce nitric oxide. Nitric oxide is an endogenous messenger molecule involved in a variety of endothelium-dependent physiological effects in the cardiovascular system. In the central nervous system, asparagine is needed to maintain a balance, preventing over nervousness or being overly calm. Aspartic acid can help protect the liver from some drug toxicity

and the body from radiation. Carnosine is the water-soluble counterpart to vitamin E in protecting cell membranes from oxidative damage. L-carnosine supports healthy aging and cellular rejuvenation by its effects on two mechanisms: glycosylation and free radical damage. Cysteine strengthens the protective lining of the stomach and intestines, which may help prevent damage caused by aspirin and similar drugs. The health benefits of glutamine include immune system regulation, nitrogen shuttling, oxidative stress, muscle preservation, intestinal health, injuries, and much more. Glycine is an inhibitory amino acid with important functions centrally and peripherally. Glycine may be indicated to help alleviate the symptoms of spasticity. Histidine is known to be vital in the maintenance of the myelin sheaths surrounding nerves, particularly the auditory nerve and is used to treat some forms of hearing disability. Isoleucine is necessary for the optimal growth of infants and for nitrogen balance in adults. Leucine is used as a source for the synthesis of blood sugar in the liver during starvation, stress, and infection to aid in healing. Lysine is used in managing and preventing painful and unsightly herpes sores caused by the herpes simplex virus (HSV). Methionine is both an antioxidant and lipotrope, meaning it helps remove fat from the liver. Phenylalanine is used to treated depression, rheumatoid arthritis and osteoarthritis, menstrual cramps, Parkinson's disease, vitiligo, and cancer. Proline is an important component in certain medical wound dressings that use collagen fragments to stimulate wound healing. Serine is needed for the metabolism of fats and fatty acids, muscle growth, and a healthy immune system. Taurine helps regulate the contraction and pumping action of the heart muscle and it helps regulate blood pressure and platelet aggregation. Threonine may enhance immunity by assisting in the production of agents that fight viral infections. L-theanine reduces stress and anxiety without the tranquilizing effects found in many other calming supplements. Tryptophan is important for the production of serotonin. Increasing tryptophan may help to normalize sleep patterns. Tyrosine may act as an adaptogen, helping the body adapt to and cope with the effects of physical or psychological stress by minimizing the symptoms brought on by stress. As a branched-chain amino acid (BCAA), valine has been found useful in treatments involving muscle, mental, and emotional upsets, and for insomnia and nervousness. Creatine supplements fuels and enhances short bursts of high-energy exercise. Creatine prevents the body from relying solely on the process of glycolysis. Citrulline supports the body in optimizing blood flow through its conversion to l-arginine and then nitric oxide (NO). GABA has been used in the treatment of depression, manic-depressive (bipolar) disorder, seizures, premenstrual dysphoric (feeling depressed) disorder, and anxiety. Glutathione are necessary for supporting the immune system, glutathione is required for replication of the lymphocyte immune cells.

Suggested Reading

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