AMINO ACID : STRUCTURE, CLASSIFICATION AND GENERAL PROPERTIESAND PHYSIOLOGICAL IMPORTANCE OF ALPHA OR ESSENTIAL AMINO ACID

unit 3: cbcs major

DR. LUNA PHUKAN

Amino acids are organic compounds that contain amine (–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 (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.

In biochemistry, amino acids which have the amine group attached to the (alpha-) carbon atom next to the carboxyl group have particular importance.

They are known as 2-, alpha-, or α-amino acids (generic formula $H_2NCHRCOOH$ in most cases,

where R is an organic substituent known as a "side chain");often the term "amino acid" is used to refer specifically to these.

They include the 22 proteinogenic ("protein-building") amino acids, which combine into peptide chains ("polypeptides") to form the building blocks of a vast array of proteins.

These are all L-stereoisomers ("left-handed" isomers), although a few D-amino acids ("right-handed") occur in bacterial envelopes, as a neuromodulator (D-serine), and in some antibiotics.

Many important proteinogenic and non-proteinogenic amino acids have biological functions.

For example, in the human brain, glutamate (standard glutamic acid)

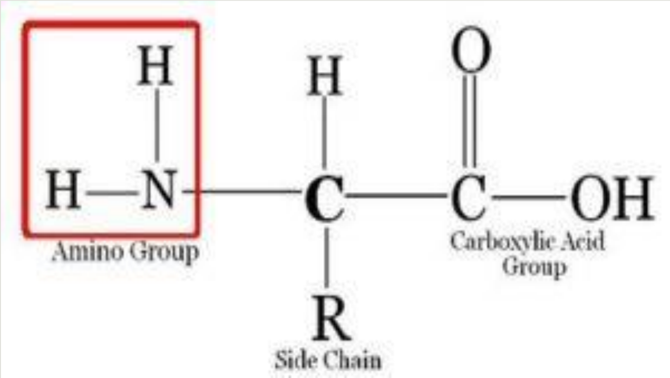
and gamma-aminobutyric acid ("GABA", nonstandard gamma-amino acid) are, respectively, the main excitatory and inhibitory neurotransmitters.

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 differ between species.

There are some 20 amino acids in the proteins that we consume. These amino acids bond together to form a larger protein molecule. Amino acid being organic compound molecules can form various different links with each other due to the versatile nature of carbon. This enables the great diversity of proteins that can be found in nature. These are an essential nutrient in our diet because of the functions they perform.

Structure of Amino Acids



(Source: Wikibooks)

There are actually thousands of amino acids occurring in nature. But only about 20 amino acids form a part of the proteins in the human body. These twenty acids will be our focus here. Although all these have varied structures, the basic structure of amino acid remains uniform.

There are some 20 amino acids in the proteins that we consume.

These amino acids bond together to form a larger protein molecule.

Amino acid being organic compound molecules can form various different links with each other due to the versatile nature of carbon.

This enables the great diversity of proteins that can be found in nature. These are an essential nutrient in our diet because of the functions they perform.

Classification of Amino Acids

Amino Acid can be classified ***based on their structure*** and the structure of their side chains i.e. the R chains. Now two basic subcategories are

1] Non-Polar Amino Acids

These are also known as hydrophobic . The R group can be either of Alkyl groups (with an alkyl chain) or Aromatic groups. The acids falling in this group are stated below. Numbers one to seven are Alkyl and the last two are aromatic

Glycine (H)

Alanine (CH_3)

Valine ($CH(CH_3)_2$)

Methionine ($CH_2CH_2SCH_3$)

Leucine ($CH_2CH(CH_3)_2$)

Isoleucine ($-CH(CH_3)CH_2CH_3$)

Proline (special structure)

Phenylalanine

Tryptophan

2] Polar Amino Acids

If the side chains of amino acid contain different polar groups like amines, alcohols or acids they are polar in nature. These are also known as Hydrophilic Acids. These are further divided into three further categories.

a) Acidic: If the side chain contains an extra element of carboxylic acid component these are acid-polar amino acids. They tend to donate their hydrogen atom. These are:

Aspartic Acid (CH2COOH)

Glutamic Acid (CH2CH2COOH)

b) Basic: These have an extra nitrogen group that tend to attract a hydrogen atom. The three basic polar amino acids are

Histidine

Lysine ($CH_2(CH_2)_2NH_2$)

Arginine

c) Neutral: These are neither acidic nor basic. They have an equal number of amino and carboxyl group. Also, they have at least one hydrogen component connected to electronegative atoms. Some of these neutral acids are

Serine (CH_2OH)

Threonine ($CH(OH)CH_3$)

Asparagine (CH_2OHNH_2)

Glutamine ($CH_2CH_2CONH_2$)

Cysteine (CH_2SH)

Tyrosine

Amino acid can also be classified on the basis of their need to the human body and their ***availability in the human body***

1] Essential Amino Acids

These are the acids that cannot be synthesized in our bodies. We must rely on food sources to obtain these amino acids. They are

Leucine

Isoleucine

Lysine

Theorine

Methionine

Phenylalanine

Valine

Tryptophan

Histidine (conditionally essential)

2] Non-Essential

These acids are synthesized in our bodies itself and we need not rely on outside sources for them. They are either produced in our bodies or obtained from protein breakdowns.

Properties of Amino Acids

Now that we have seen the structure and types of amino acids. Now from this information, we can arrive at the properties of amino acids.

Each amino acid has both an acidic and basic group as you can see from its structure. This is the reason they behave like salts.

Any amino acid in the dry state is in crystalline form. They exist as a dipolar ion. The COOH group exists as an anion. And the NH2 group exists as a cation. This dipolar ion has a special name “Zwitter ions’.

In aqueous solution, alpha amino acids exist in equilibrium between a cationic form, an anionic form and dipolar ion.

The Isoelectric point is the pH point at which the concentration of zwitter ions is the highest ad the concentration of cationic and anionic form is equal. This point is definite for every α-amino acid.

They are generally water soluble and also have high melting points

ISOMERISM

Alpha amino acids are the most common form found in nature, but only when occurring in the L-isomer. The alpha carbon is a chiral carbon atom, with the exception of glycine, which has two indistinguishable hydrogen atoms on the alpha carbon.

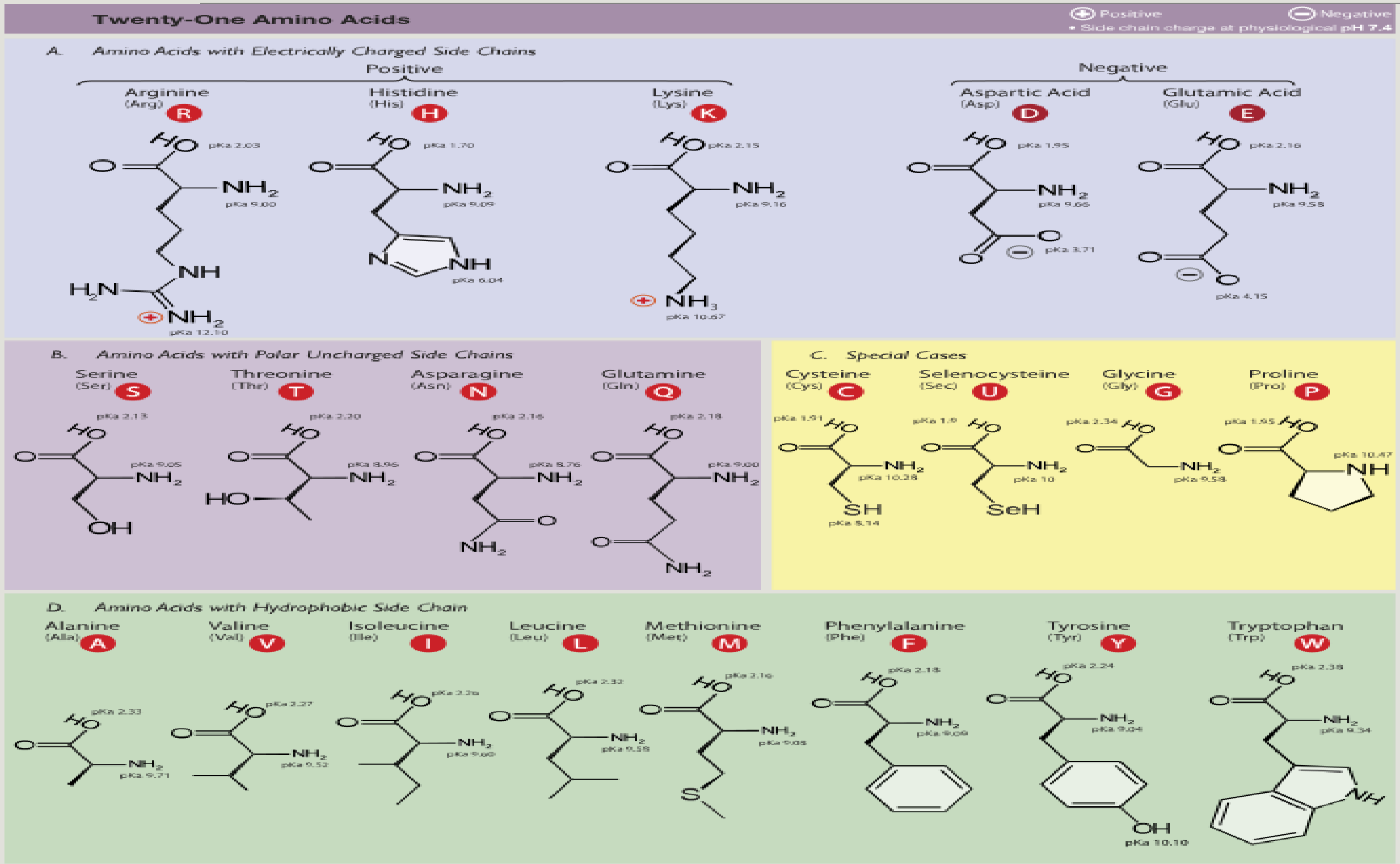
Therefore, all alpha amino acids but glycine can exist in either of two enantiomers, called L or D amino acids (relative configuration), which are mirror images of each other (see also Chirality).

While L-amino acids represent all of the amino acids found in proteins during translation in the ribosome,

D-amino acids are found in some proteins produced by enzyme posttranslational modifications after translation and translocation to the endoplasmic reticulum, as in exotic sea-dwelling organisms such as cone snails.

Side chains

Amino acids are designated as α- when the nitrogen atom is attached to the carbon atom adjacent to the carboxyl group: in this case the compound contains the substructure N–C–CO2. Amino acids with the sub-structure N–C–C–CO2 are classified as β- amino acids. γ-Amino acids contain the substructure N–C–C–C–CO2, and so on.[41



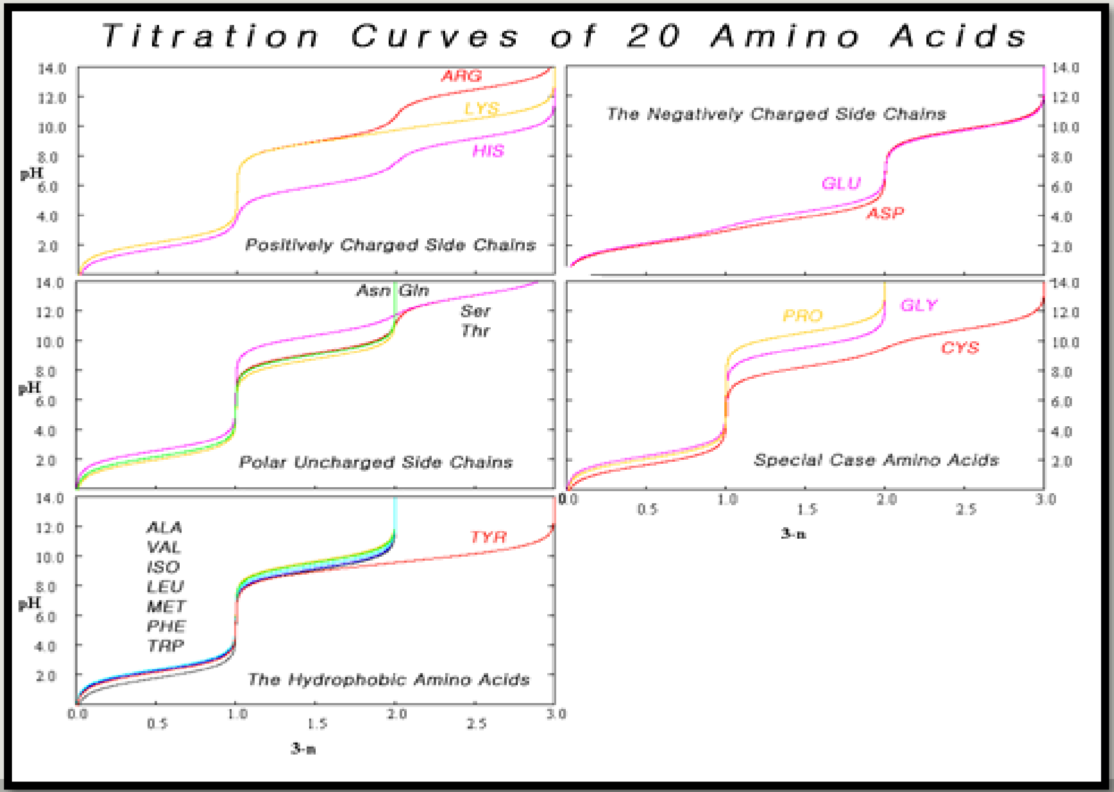
The 21 proteinogenic α-amino acids found in eukaryotes, grouped according to their side chains' pKa values and charges carried at physiological pH (7.4)

Isoelectric point

Composite of titration curves of twenty proteinogenic amino acids grouped by side chain category

At pH values between the two pKa values, the zwitterion predominates, but coexists in dynamic equilibrium with small amounts of net negative and net positive ions. At the exact midpoint between the two pKa values, the trace amount of net negative and trace of net positive ions exactly balance, so that average net charge of all forms present is zero.[46] This pH is known as the isoelectric point pI, so pI = 1/2(pKa1 + pKa2).

Composite of titration curves of twenty proteinogenic amino acids grouped by side chain category



Zwitterions

An amino acid in its (1) molecular and (2) zwitterionic forms

In aqueous solution amino acids exist in two forms , the molecular form and the zwitterion form in equilibrium with each other.

The two forms coexist over the pH range pK1 − 2 to pK2 + 2, which for glycine is pH 0–12.

The ratio of the concentrations of the two isomers is independent of pH. The value of this ratio cannot be determined experimentally.

Because all amino acids contain amine and carboxylic acid functional groups, they are amphiprotic. At pH = pK1 (approximately 2.2) there will be equal concentration of the species NH+

3CH(R)CO

2H and NH^+

3CH(R)CO^-

2 and at pH = pK2 (approximately 10) there will be equal concentration of the species NH+

3CH(R)CO^-

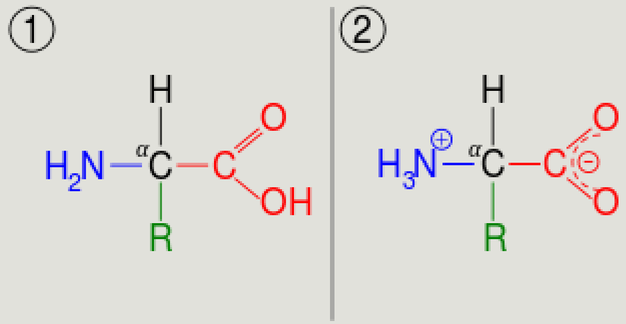
2 and NH

2CH(R)CO^-

2. It follows that the neutral molecule and the zwitterion are effectively the only species present at biological pH.

It is generally assumed that the concentration of the zwitterion is much greater than the concentration of the neutral molecule on the basis of comparisons with the known pK values of amines and carboxylic acids.

An amino acid in its (1) molecular and (2) zwitterionic forms



Physiological importance of essentials and non essential amino acids

In human nutrition

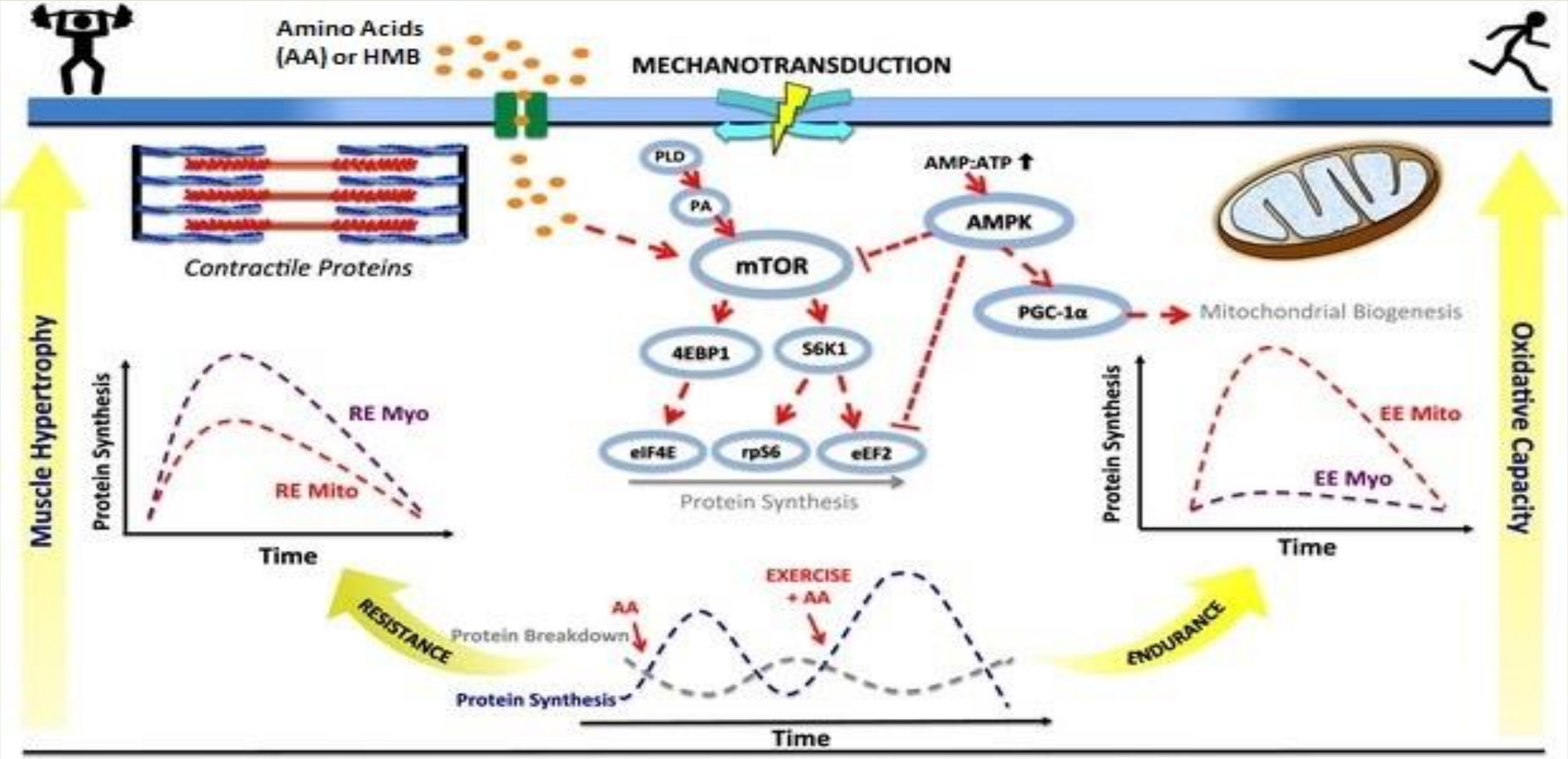
Diagram showing the relative occurrence of amino acids in blood serum as obtained from diverse diets.

Share of amino acid in various human diets and the resulting mix of amino acids in human blood serum. Glutamate and glutamine are the most frequent in food at over 10%, while alanine, glutamine, and glycine are the most common in blood.

Main article: Essential amino acids

Further information: Protein (nutrient) and Amino acid synthesis

Diagram of the molecular signaling cascades that are involved in myofibrillar muscle protein synthesis and mitochondrial biogenesis in response to physical exercise and specific amino acids or their derivatives (primarily L-leucine and HMB). Many amino acids derived from food protein promote the activation of mTORC1 and increase protein synthesis by signaling through Rag GTPases.



When taken up into the human body from the diet, the 20 standard amino acids either are used to synthesize proteins, other biomolecules, or are oxidized to urea and carbon dioxide as a source of energy.

The oxidation pathway starts with the removal of the amino group by a transaminase; the amino group is then fed into the urea cycle. The other product of transamidation is a keto acid that enters the citric acid cycle.

Glucogenic amino acids can also be converted into glucose, through gluconeogenesis.

Of the 20 standard amino acids, nine (His, Ile, Leu, Lys, Met, Phe, Thr, Trp and Val) are called essential amino acids because the human body cannot synthesize them from other compounds at the level needed for normal growth, so they must be obtained from food.

In addition, cysteine, tyrosine, and arginine are considered semi essential amino acids, and taurine a semi essential aminosulfonic acid in children. The metabolic pathways that synthesize these monomers are not fully developed.

The amounts required also depend on the age and health of the individual, so it is hard to make general statements about the dietary requirement for some amino acids. Dietary exposure to the nonstandard amino acid BMAA has been linked to human neurodegenerative diseases, including ALS.

Non-protein functions

Biosynthetic pathways for catecholamines and trace amines in the human brain

Graphic of catecholamine and trace amine biosynthesis

L-Phenylalanine

L-Tyrosine

L-DOPA

Epinephrine

amino acids also have important roles as metabolic intermediates, such as in the biosynthesis of the neurotransmitter gamma-aminobutyric acid (GABA). Many amino acids are used to synthesize other molecules, for example

Tryptophan is a precursor of the neurotransmitter serotonin.

Tyrosine (and its precursor phenylalanine) are precursors of the catecholamine neurotransmitters dopamine, epinephrine and norepinephrine and various trace amines.

Phenylalanine is a precursor of phenethylamine and tyrosine in humans. In plants, it is a precursor of various phenylpropanoids, which are important in plant metabolism.

Arginine is a precursor of nitric oxide

Ornithine and S-adenosylmethionine are precursors of polyamines.

Aspartate, glycine, and glutamine are precursors of nucleotides.

However, not all of the functions of other abundant nonstandard amino acids are known.

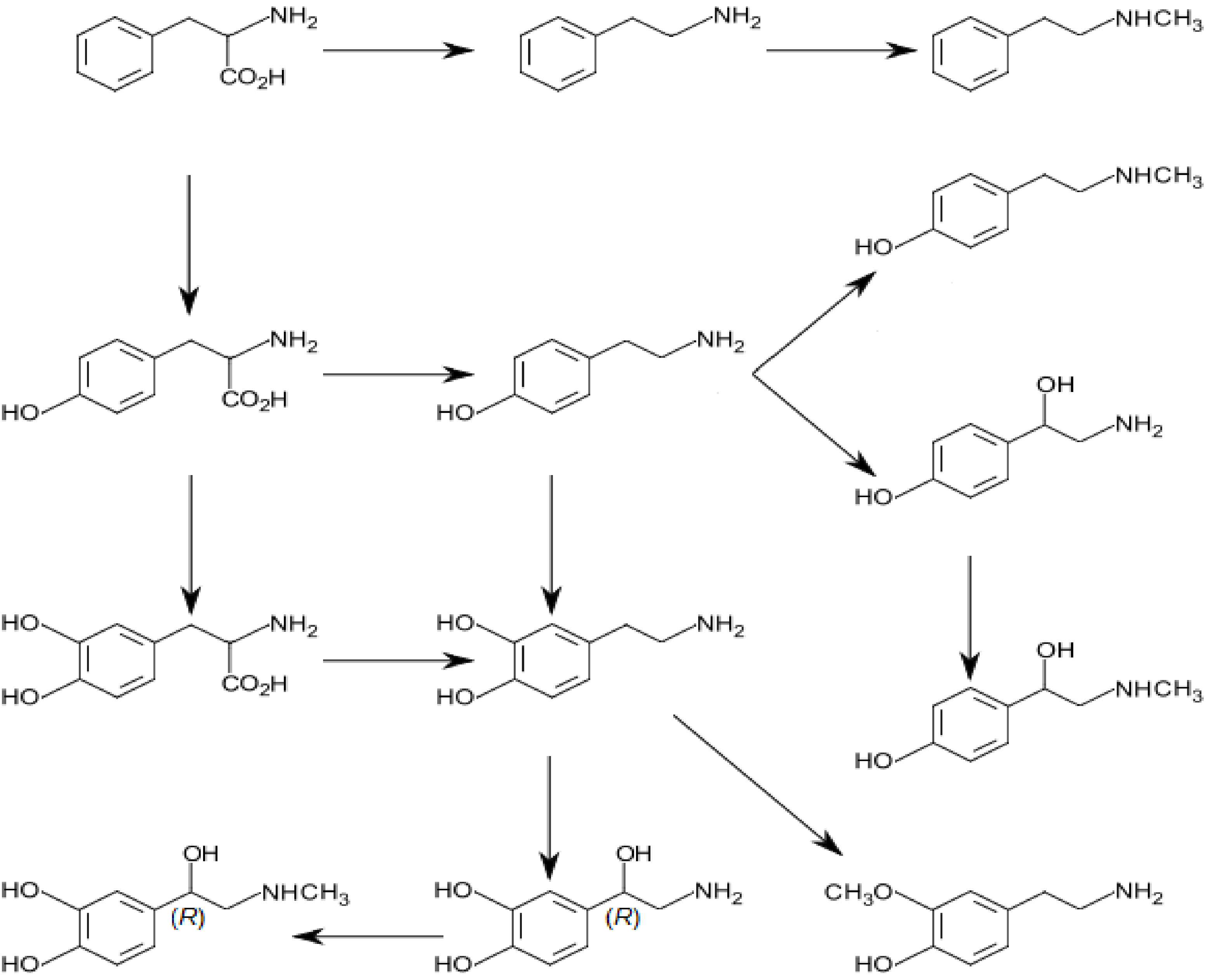
Some nonstandard amino acids are used as defenses against herbivores in plants.

For example, canavanine is an analogue of arginine that is found in many legumes,and in particularly large amounts in Canavalia gladiata (sword bean).

This amino acid protects the plants from predators such as insects and can cause illness in people if some types of legumes are eaten without processing.

The non-protein amino acid mimosine is found in other species of legume, in particular Leucaena leucocephala.

This compound is an analogue of tyrosine and can poison animals that graze on these plants.



Catecholamines and trace amines are synthesized from phenylalanine and tyrosine in humans

Expanded genetic code

Since 2001, 40 non-natural amino acids have been added into protein by creating a unique codon (recoding) and a corresponding transfer-RNA:aminoacyl – tRNA-synthetase pair to encode it with diverse physicochemical and biological properties in order to be used as a tool to exploring protein structure and function or to create novel or enhanced protein

Nullomers

Nullomers are codons that in theory code for an amino acid, however in nature there is a selective bias against using this codon in favor of another, for example bacteria prefer to use CGA instead of AGA to code for arginine.

This creates some sequences that do not appear in the genome. This characteristic can be taken advantage of and used to create new selective cancer-fighting drugs[and to prevent cross-contamination of DNA samples from crime-scene investigations.

Chemical building blocks

Amino acids are important as low-cost feedstocks. These compounds are used in chiral pool synthesis as enantiomerically pure building blocks.

Amino acids have been investigated as precursors chiral catalysts, such as for asymmetric hydrogenation reactions, although no commercial applications exist.

CATABOLISM

Catabolism of proteinogenic amino acids. Amino acids can be classified according to the properties of their main products as either of the following:

Glucogenic, with the products having the ability to form glucose by gluconeogenesis

Ketogenic, with the products not having the ability to form glucose. These products may still be used for ketogenesis or lipid synthesis.

Amino acids catabolized into both glucogenic and ketogenic products.

Amino acids must first pass out of organelles and cells into blood circulation via amino acid transporters, since the amine and carboxylic acid groups are typically ionized.

Degradation of an amino acid, occurring in the liver and kidneys, often involves deamination by moving its amino group to alpha-ketoglutarate, forming glutamate.

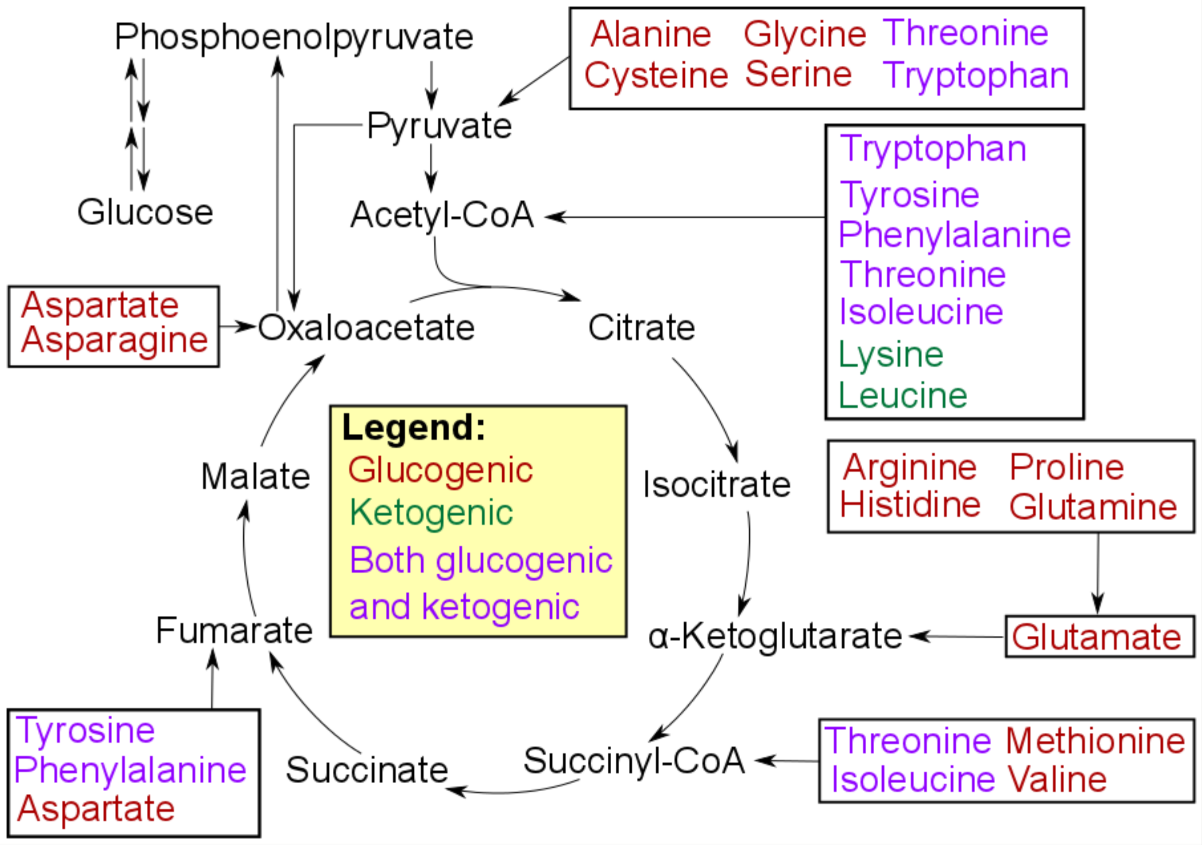
This process involves transaminases, often the same as those used in amination during synthesis. In many vertebrates, the amino group is then removed through the urea cycle and is excreted in the form of urea.

However, amino acid degradation can produce uric acid or ammonia instead. For example, serine dehydratase converts serine to pyruvate and ammonia.[81]

After removal of one or more amino groups, the remainder of the molecule can sometimes be used to synthesize new amino acids, or it can be used for energy by entering glycolysis or the citric acid cycle.

Catabolism of proteinogenic amino acids. Amino acids can be classified according to the properties of their main products as either of the following:[121]

* Glucogenic, with the products having the ability to form glucose by gluconeogenesis
* Ketogenic, with the products not having the ability to form glucose. These products may still be used for ketogenesis or lipid synthesis.
* Amino acids catabolized into both glucogenic and ketogenic products.



Peptide bond formation

Peptide bond formation

See also: Peptide synthesis and Peptide bond

Two amino acids are shown next to each other. One loses a hydrogen and oxygen from its carboxyl group (COOH) and the other loses a hydrogen from its amino group (NH2). This reaction produces a molecule of water (H2O) and two amino acids joined by a peptide bond (–CO–NH–). The two joined amino acids are called a dipeptide.

The condensation of two amino acids to form a dipeptide through a peptide bond

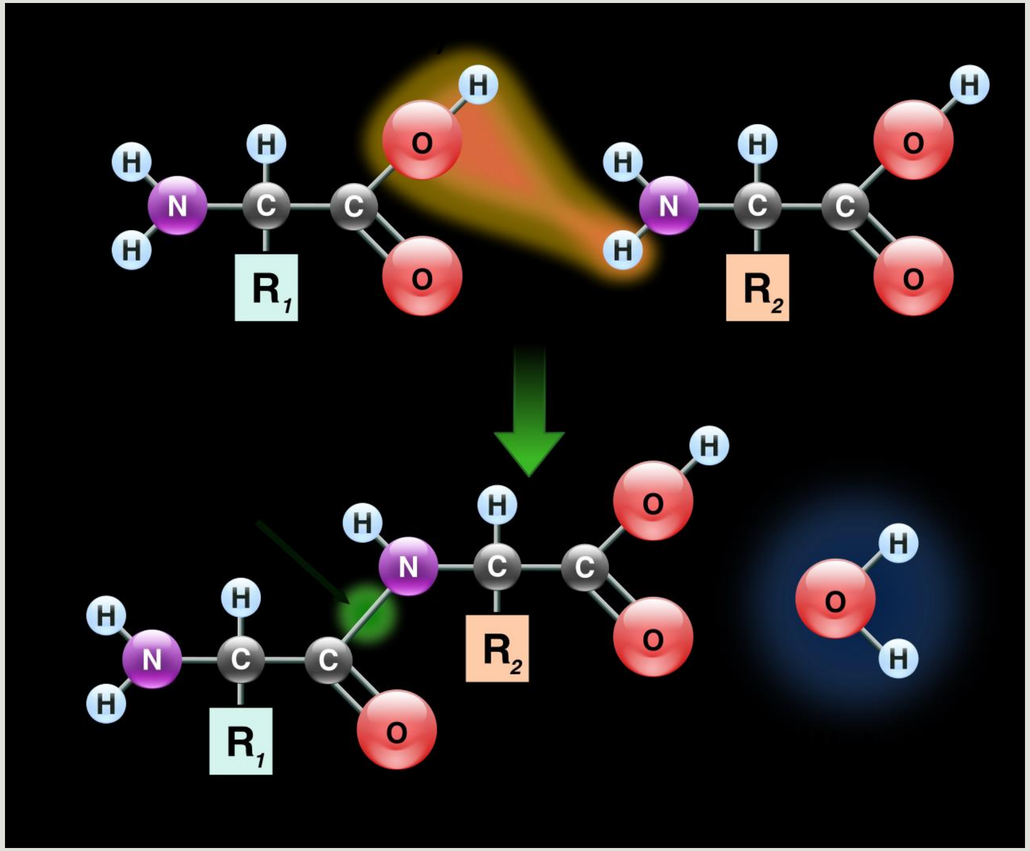
As both the amine and carboxylic acid groups of amino acids can react to form amide bonds, one amino acid molecule can react with another and become joined through an amide linkage. This polymerization of amino acids is what creates proteins.

This condensation reaction yields the newly formed peptide bond and a molecule of water. In cells, this reaction does not occur directly; instead, the amino acid is first activated by attachment to a transfer RNA molecule through an ester bond. This aminoacyl-tRNA is produced in an ATP-dependent reaction carried out by an aminoacyl tRNA synthetase.

This aminoacyl-tRNA is then a substrate for the ribosome, which catalyzes the attack of the amino group of the elongating protein chain on the ester bond.

As a result of this mechanism, all proteins made by ribosomes are synthesized starting at their N-terminus and moving toward their C-terminus

The condensation of two amino acids to form a dipeptide through a peptide bond



THANK YOU