Udai Pratap (Autonomous) College, Varanasi

(Affiliated to Mahatma Gandhi Kashi Vidyapith, Varanasi)

E-Content

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Paper: **Biochemistry and Physiology**

Unit: **I**

Topic: **Amino Acids**

Sub-topic: **Structure, Classification and Physiological Significance of Amino Acids**

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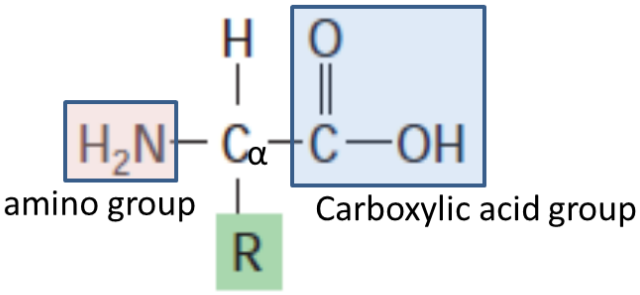
1. Amino acids:

Generally speaking, amino acids are the building blocks or monomer units of proteins. In other words, when proteins are hydrolysed, a mixture of amino acids is obtained.

Chemically, amino acids are the organic compounds having amino as well as carboxylic acids groups in the form of amino carboxylic acids. To date, in living system, nearly 300 types of amino acids have been found with biological significance. Out of 300 amino acids, some are *α-amino acids* in which amino group is attached to the alpha-carbon atom (*α-carbon is the carbon which is covalently attached to most superior functional group – carboxyl group*). Those alpha-amino acids, which are the principal constituents of proteins, are called *proteinogenic amino acids* or *standard amino acids*. In other words, protein forming *α-amino acids* are *proteinogenic amino acids* or *standard amino acids*. Proteinogenic amino acids are having corresponding codons on the m-RNA and, therefore, they take part in the translation process to synthesise protein molecules. Rest of the amino acids (including α-, β-, γ-amino acids etc) are considered *non-standard or non-proteinogenic amino acids* that are not taking part in the protein synthesis because their codons are not present in genes. Nevertheless, non-standard amino acids are also of physiological importance.

Chemistry/chemical structure of α-Amino acids: Chemically, α-amino acids are α-amino carboxylic acids in which an amino group and a carboxylic acid group are attached to a central α-carbon atom. In this way, there are four different groups are attached to central α-carbon atom of α-amino acids:

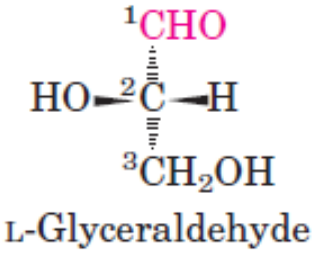
- **i.** an amino group,
- **ii.** a carboxylic acid group,
- **iii.** an R-group (variable group), and
- **iv.** a hydrogen atom



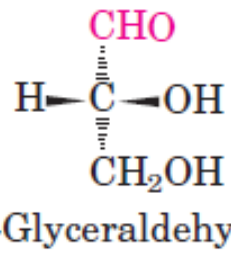
Amino acid

Out of these four groups, only R-group varies among the amino acids that determine the type/diversity, nature, properties, biochemical characteristics and biological functions of amino acids. This R-group is also known as 'side chain' or 'variable group' of amino acids.

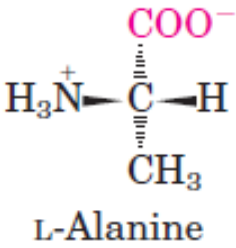
Thus the central α-carbon atom bound to four different groups is a *chiral centre (or chiral carbon atom)* in all α-amino acids (except for glycine where R = another hydrogen atom). Therefore, all amino acids (except glycine) are *optically active* in solution. Four groups around α-carbon atom can occupy two different spatial arrangements that are non-superimposable mirror images of each other. These two *enantiomers* of each amino acid are – *D-stereoisomer*, and *L-stereoisomer*.



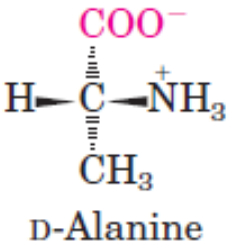
L-Glyceraldehyde



D-Glyceraldehyde



L-Alanine



D-Alanine

So, amino acids may exist in one of these two forms. But in naturally occurring proteins (of any biological system), only L-form of α-amino acids predominates and is evolutionary conserved. Therefore, it is said that proteins are the polymers of L-α-amino acids (or L-α-amino

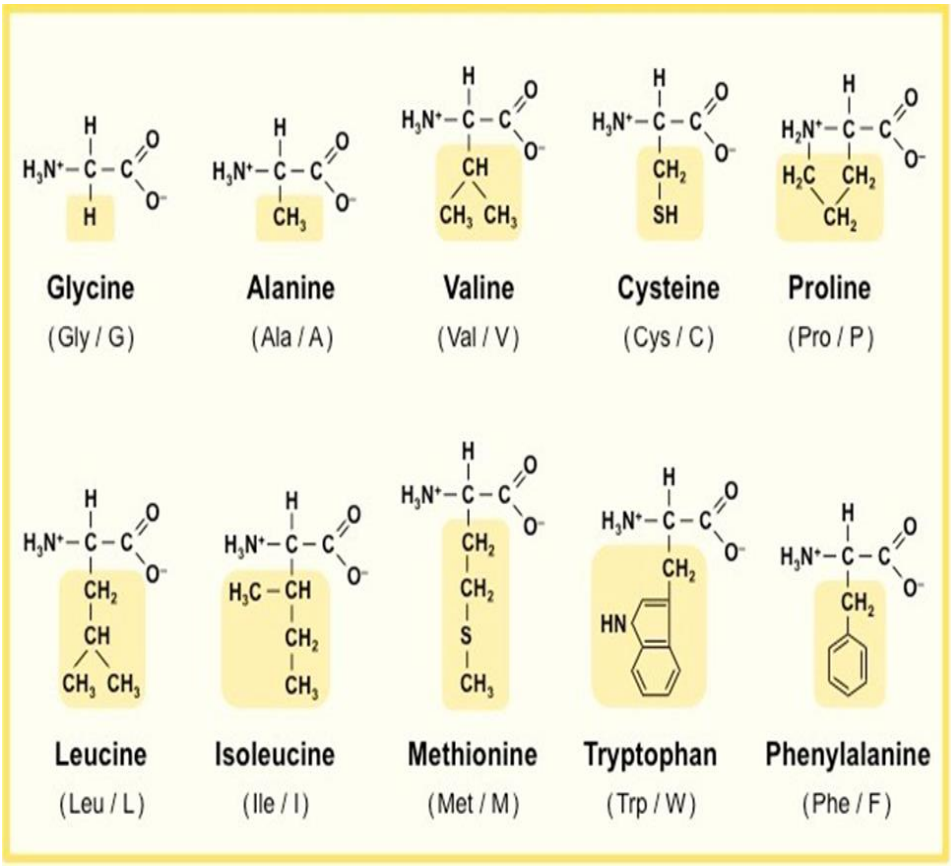
carboxylic acids). D form of α-amino acids is not the part of living system, and if provided in any culture medium, they are not utilised by cells. Cells are able to specifically synthesize and utilise L- form of amino acids because the active sites of concerned enzymes are asymmetrical, causing the reaction they catalyse to be stereo-specific.

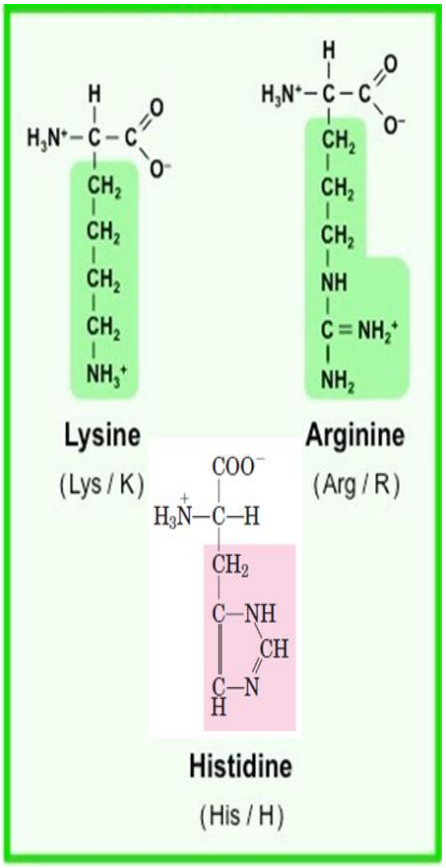
2. List of Amino Acids

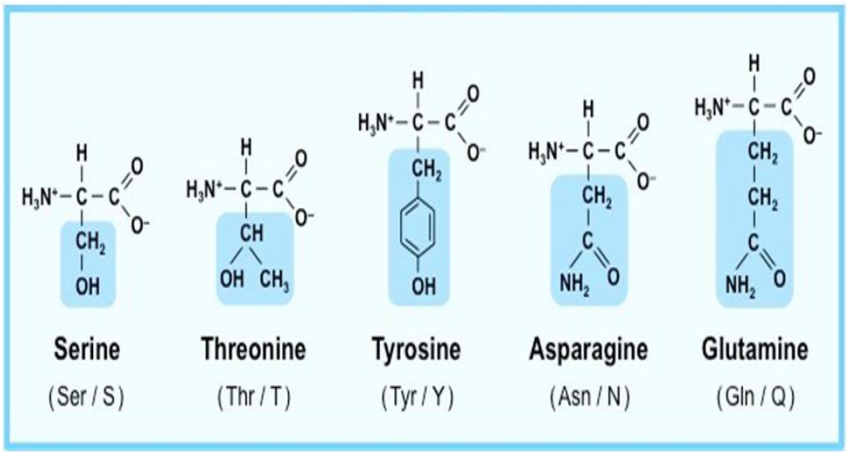
There are twenty standard or α-amino acids which can participate in protein synthesis. Each amino acid can be written as three letter code (trivial names) e.g. the amino acid glycine as 'gly', alanine as 'ala' and so on. Amino acids can also be represented as single letter (capital) code e.g. glycine as 'G', alanine as 'A' and so on. Complete list of all amino acids are listed below:

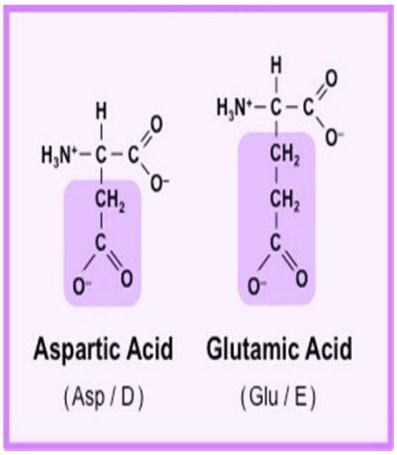
Amino acid	Three letter code	One letter code
Alanine	ala	A
Arginine	arg	R
Asparagine	asn	N
Aspartic acid	asp	D
Cysteine	cys	C
Glutamic acid	glu	E
Glutamine	gln	Q
Glycine	gly	G
Histidine*	his	H
Isoleucine*	ile	I
Leucine*	leu	L
Lysine*	lys	K
Methionine*	met	M
Phenylalanine*	phe	F
Proline	pro	P
Serine	ser	S
Threonine*	thr	T
Tryptophan*	trp	W
Tyrosine	tyr	Y
Valine*	val	V

3. Structure of All Amino Acids







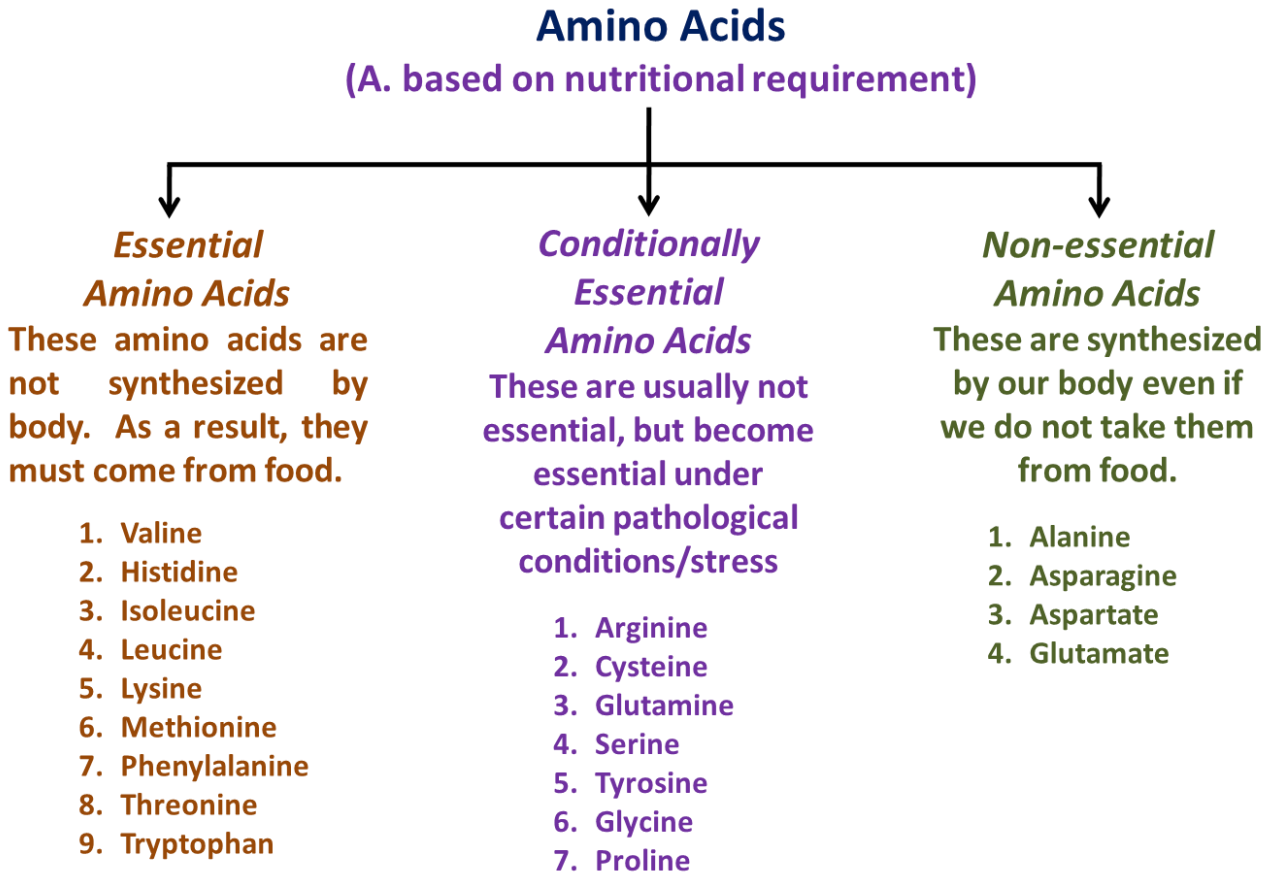


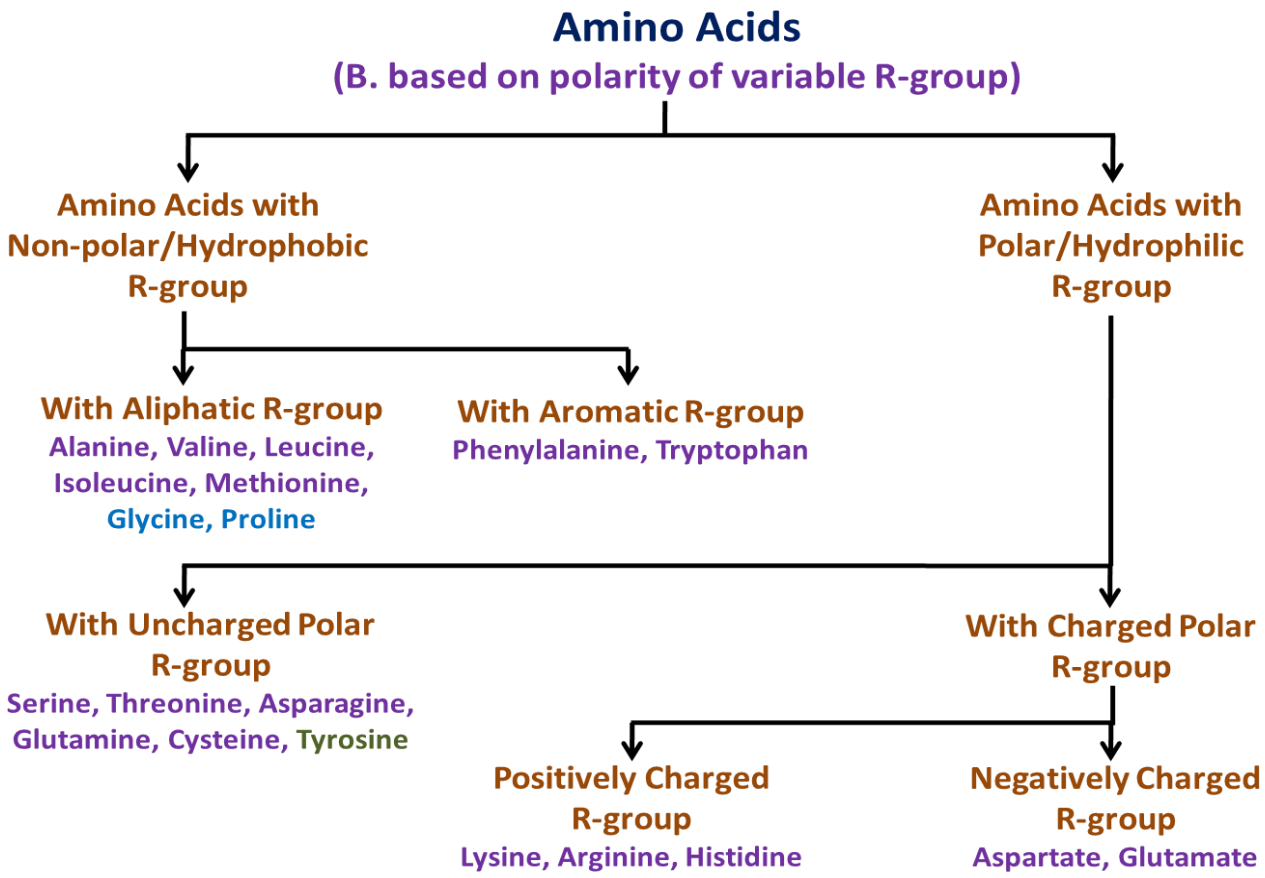
4. Classification of Amino Acids

Amino acids can be classified into different groups on different bases as follows:

A. Classification based on nutritional requirement

B. Classification based on variable R-groups (**based on polarity of R-groups**)





Amino Acids with unusual R-group – Glycine (R-group = H), Proline (NH_2 group is the part of cyclic R-group)

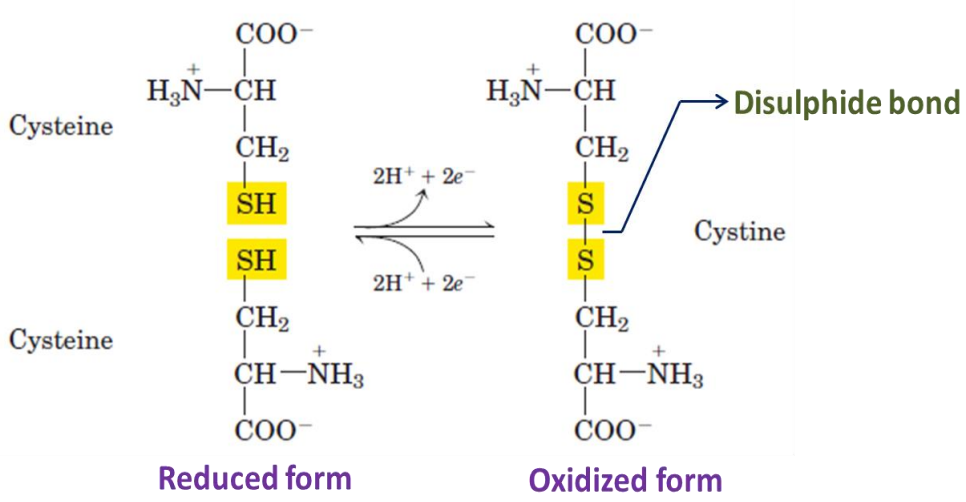
5. Important facts about Amino Acids

- Free hydroxyl (-OH) group containing amino acids: **Serine, Threonine, Tyrosine**
- Aromatic amino acids: **Phenylalanine, Tyrosine, Tryptophan**
- Sulphur containing amino acids: **Cysteine, Methionine**
- Amino Acid with free sulphhydryl (-SH) group: **Cysteine**
- Unusual amino acids: **Glycine, Proline**
- Simplest amino acid: **Glycine**
- Optically inactive amino acid: **Glycine (without chiral carbon)**
- Basic amino acid: **Arginine, Lysine, Histidine**
- Acidic amino acids: **Aspartate/aspartic acid, Glutamate/glutamic acid**
- Imino acid: **Proline (contains secondary amine attached to α-carbon)**
- Pyrrolidine ring containing amino acid: **Proline**
- Imidazole group/side chain containing amino acid: **Histidine**

- Amino acid with guanidine or 3-guanidinopropyl group**: Arginine**
- Amino Acids with heterocyclic group/side chain: **Histidine, Proline, Tryptophan**
- Branched chain amino acids (BCCAs): **Valine, Leucine, Isoleucine**
- Non-standard amino acids: **Ornithine, Citruline, L-Dopa, Homocysteine** etc.

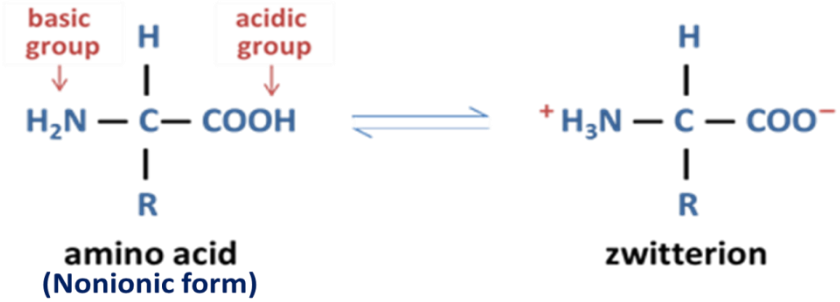
Cystine

Cystine is a dimer of two cysteine molecules joined together by disulphide bond. Therefore, cystine is oxidised dimeric form of cysteine. Free sulphhydryl (–SH) groups of two cysteine molecules are oxidized to form disulphide bond of cystine.



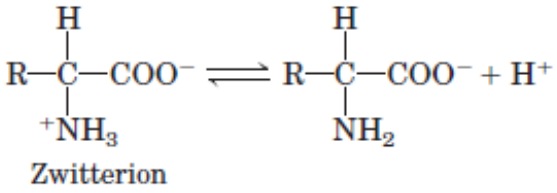
6. Ionisation of amino acids - Zwitterion

When an amino acid is dissolved in water, it exists in solution as the dipolar ion, or zwitterion, having both positive and negative charges. Amino acids exist as zwitterion in the biological system at physiological pH.



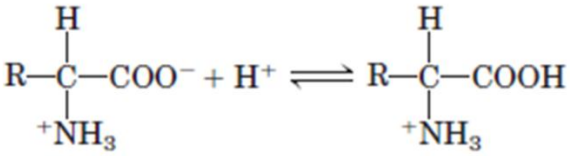
❖ The zwitterionic form of amino acids acts as acid or base to serve as buffer in the following manners:

A zwitterion can act as an acid (proton donor):



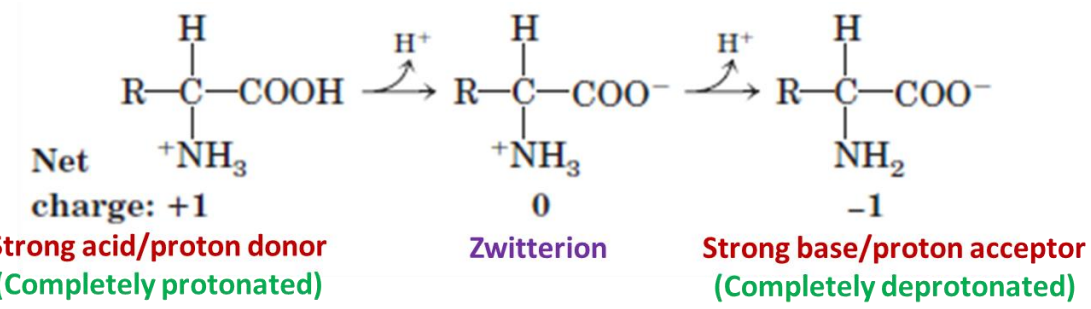
Zwitterion

A zwitterion can also act as a base (proton acceptor):



Zwitterion

- Substances having the dual nature of reacting both as an acid and as a base are amphoteric, and are called ampholytes (from "amphoteric electrolytes").
- A simple monoamino monocarboxylic α-amino acid, such as glycine or alanine, is a diprotic acid when fully protonated. At this stage, the molecule has two groups that can now donate protons: ***–COOH group*** and ***–NH_3^+ group*:**



- Therefore, reverse of the reaction will be true for the function of amino acids as base. Completely deprotonated ionic form of any amino acid can act as base (proton acceptor). Amino ($-NH_2$) group of this form can accept proton first to be converted into zwitterion which in turn can accept proton at carboxylate ($-COO^-$) group.
- Thus ionic forms of amino acids can form buffering system to maintain the constant pH of biological fluids.

7. Biological Significance of Amino Acids

In general, amino acids are organic substances that combine to form proteins, and thus they are building blocks of proteins. Apart from taking part in protein synthesis, amino acids also perform other important biological functions. Important functions are as follows:

a) Amino acids in organisms are crucial for growth, repair and good health. Therefore, nine essential amino acids must be taken through balanced diet for proper body functioning as they cannot be synthesized by our body.

b) Branched-chain amino acids (BCAAs) e.g. **valine**, **leucine** and **isoleucine** are nutritionally important as they increase the rate of protein synthesis and help promote the muscle tissue formation.

c) Some amino acids are required for synthesis of certain hormones. For example, **tyrosine** is the precursor for synthesis of thyroxin (T_3 and T_4 in thyroid gland), adrenaline, noradrenaline and dopamine. **Tryptophan** is required for melatonin biosynthesis in pineal gland.

d) Some amino acids are also crucial for the biosynthesis of certain neurotransmitter e.g. **tyrosine** for L-dopa and dopamine, **tryptophan** for serotonin, and **glutamate** for GABA (γ-Amino Butyric Acid).

e) Few amino acids act itself as neurotransmitter in various parts of nervous system, such as **glycine** and **glutamate**.

f) Nonstandard amino acids perform various functions in cellular metabolism and body physiology except protein synthesis. **Ornithine** and **citrulline** are involved in urea cycle. Dietary **L-dopa** is utilised for the biosynthesis of dopamine and also adrenalin and noradrenaline.

g) Amino acids in biological fluids also act as acid or base and, therefore, make buffer system to maintain the constancy of *milieu interieur*.

h) The amino acid – cysteine can form disulphide bonds which play important role in folding and maintenance of three dimensional structure of proteins.

i) A number of diseases are due to abnormalities in transport of amino acids that leads to excess of one or more types of amino acid in the body. Excessive amino acids are then excreted out through urine, the condition is called 'aminoaciduria.' In some cases, tryptophan deficiency causes sleep disturbances as this amino acid is crucial for synthesis of melatonin and serotonin which are important sleep-wake cycle regulators.

Suggested readings:

- Cox and Nelson: Lehninger's Principles of Biochemistry
- Murray, Granner, Mayes and Rodwell: Harper's Biochemistry
- Singh and Kumar: Animal Physiology and Biochemistry

Declaration