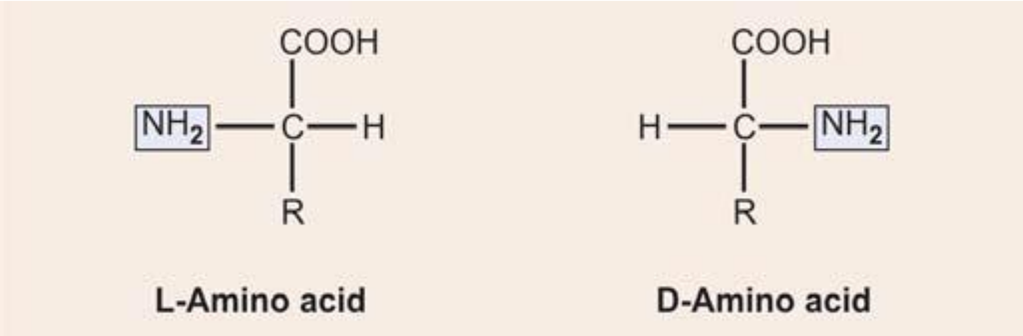
PROPERTIES OF AMINO ACIDS

A. Isomerism: **Two types** of isomerism are shown by amino acids basically ***due to the presence of an asymmetric carbon atom***(a tetravalent carbon atom bonded to four different atoms or groups of atoms) **.** ***Glycine has no asymmetric carbon atom in its structure hence is optically inactive.***

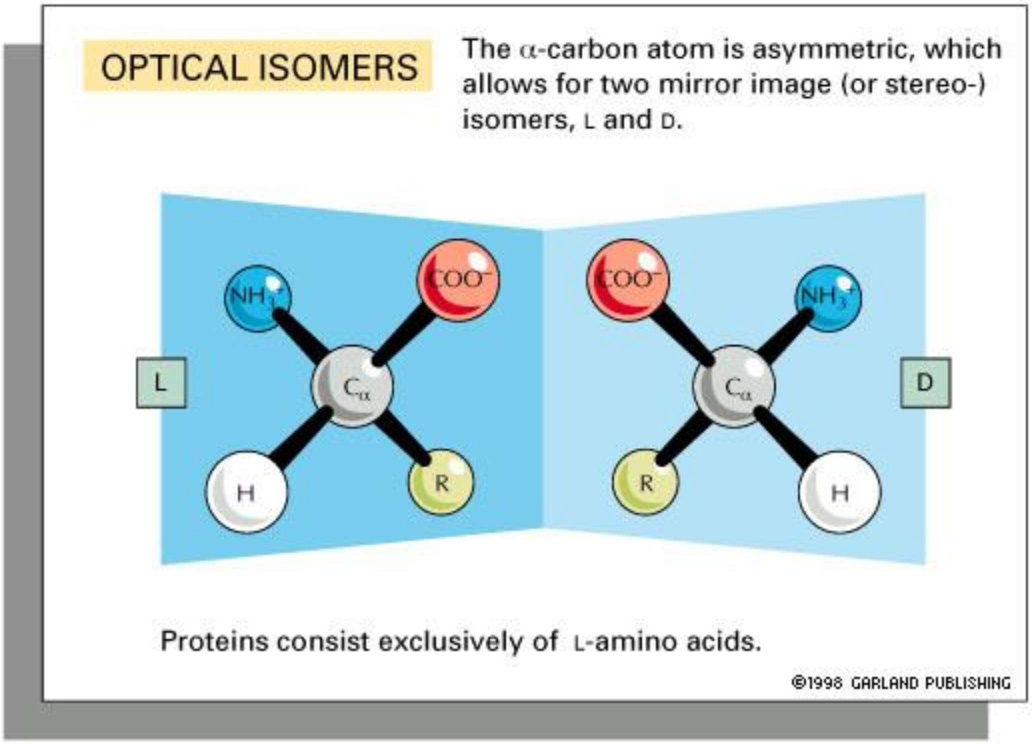
(a) Stereoisomerism: All amino acids except glycine exist in D and L isomers. In D-amino acids– NH2 group is on the right hand while in L-amino acids it is oriented to the left. It is the same orientation of –OH group of the central carbon of glyceraldehyde. Natural proteins of animals and plants generally contain L-amino acids. D-amino acids occur in bacteria.



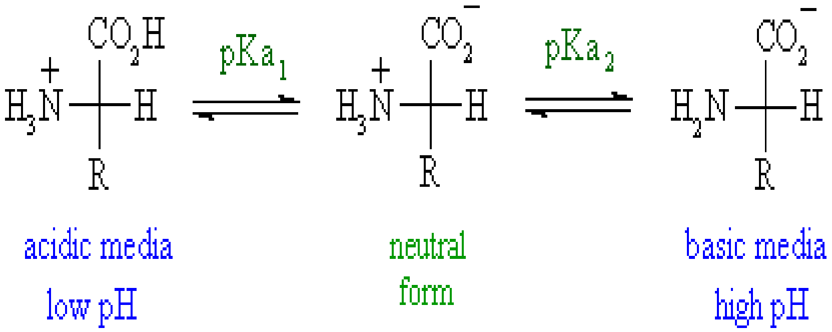
(b) Optical Isomerism: All amino acids except glycine have asymmetric carbon atom. Few amino acids like isoleucine and threonine have an additional asymmetric carbon in their structures. Consequently all but glycine exhibit 'optical' activities and can rotate plane-polarized light. and exist as dextrorotatory (d) or laevorotatory (l) isomers. Optical activity depends on the pH and side chain.

Dextrorotatory (d or +) : Rotates light to the right (clockwise)

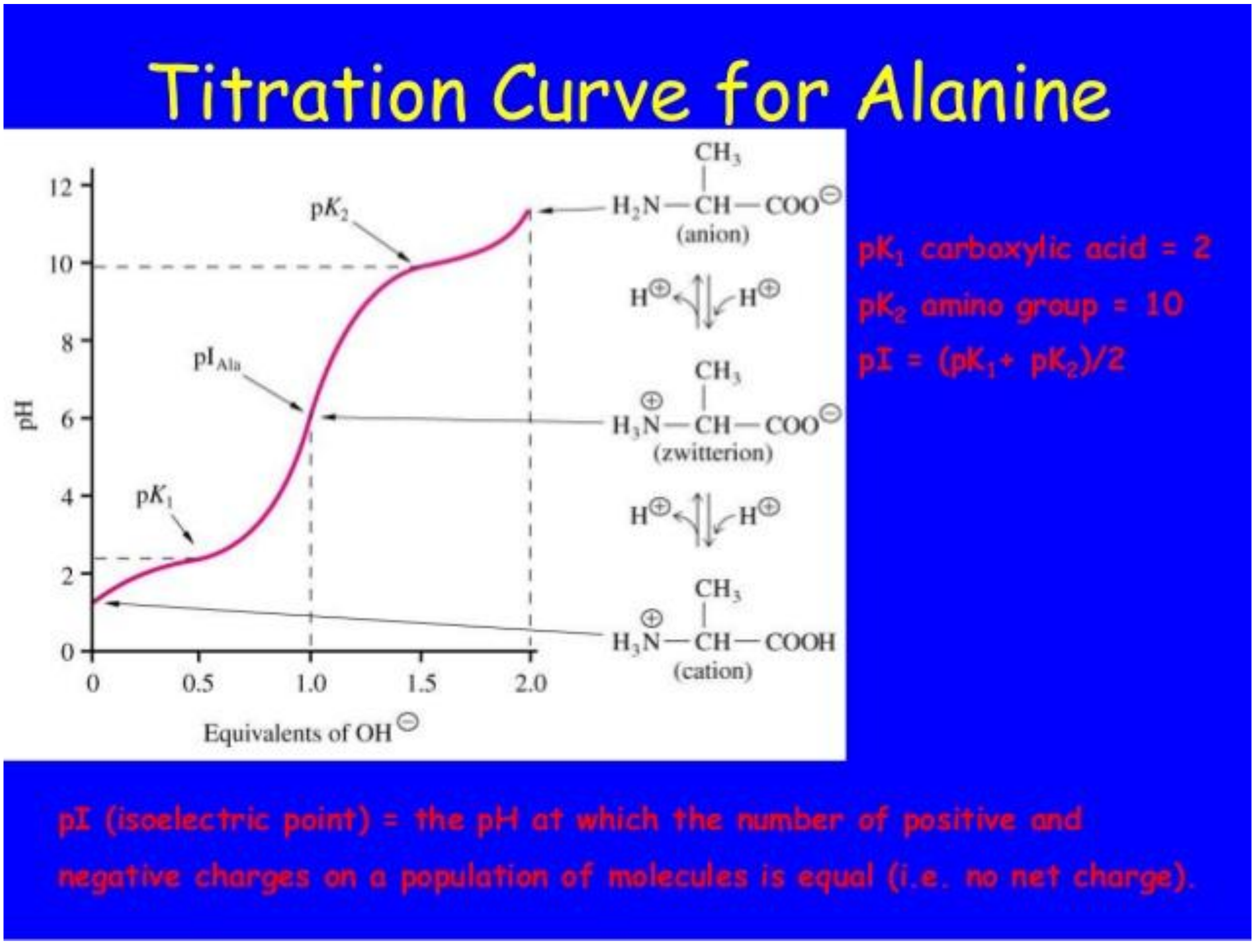
Laevorotatory (l or -) : Rotates light to the left (counterclockwise)



B. Amphoteric Nature and Isoelectric pH: The -NH2 and -COOH groups of amino acids are ionizable groups. Further, charged polar side chains of few amino acids also ionize. Depending on the pH of the solution these groups act as proton donors (acids) or proton acceptors (bases). This property is called as amphoteric and therefore amino acids are called as ampholytes. At a specific pH the amino acid carries both the charges in equal number and exists as dipolar ion or "Zwitterion". At this point the net charge on it is zero, i.e. positive charges and negative charges on the protein/amino acid molecule equalizes. The pH at which it occurs without any charge on it is called pI or isoelectric pH. Therefore at isoelectric point, there is **no mobility in an electrical field.** Solubility and buffering capacity will be minimum at iso-electric pH. To such a solution if we add hydrochloric acid drop by drop, at a particular pH, 50% of the molecules are in cation form and 50% in zwitterion form. This pH is pK1 (with regard to COOH). If more HCl is added, more molecules become cationic in nature and solubility increases. On the other hand, if we titrate the solution from iso-electric point with NaOH, molecules acquire the anionic form. When 50% of molecules are anions, that pH is called pK2 (with respect to NH2). On the acidic side of its pI amino acids exist as a cation by accepting a proton and on alkaline as anion by donating a proton.



The iso-electric pH (pI) for mono amino mono carboxylic amino acids can be calculated :(pK1+pK2) /2
e.g. pI of glycine = (2.4 + 9.8)/2 = 6.1.



Titration Curve for Alanine

pK_1 carboxylic acid = 2

pK_2 amino group = 10

$pI = (pK_1 + pK_2)/2$

pI (isoelectric point) = the pH at which the number of positive and negative charges on a population of molecules is equal (i.e. no net charge).

In the case of amino acids having more than two ionizable groups, correspondingly there will be more pK values, e.g. Aspartic acid. It can be seen that **at physiological pH of 7.4, both carboxyl and amino groups of amino acids are completely ionized**. Thus to be very correct, zwitterion forms are to be shown as the structures of amino acids.

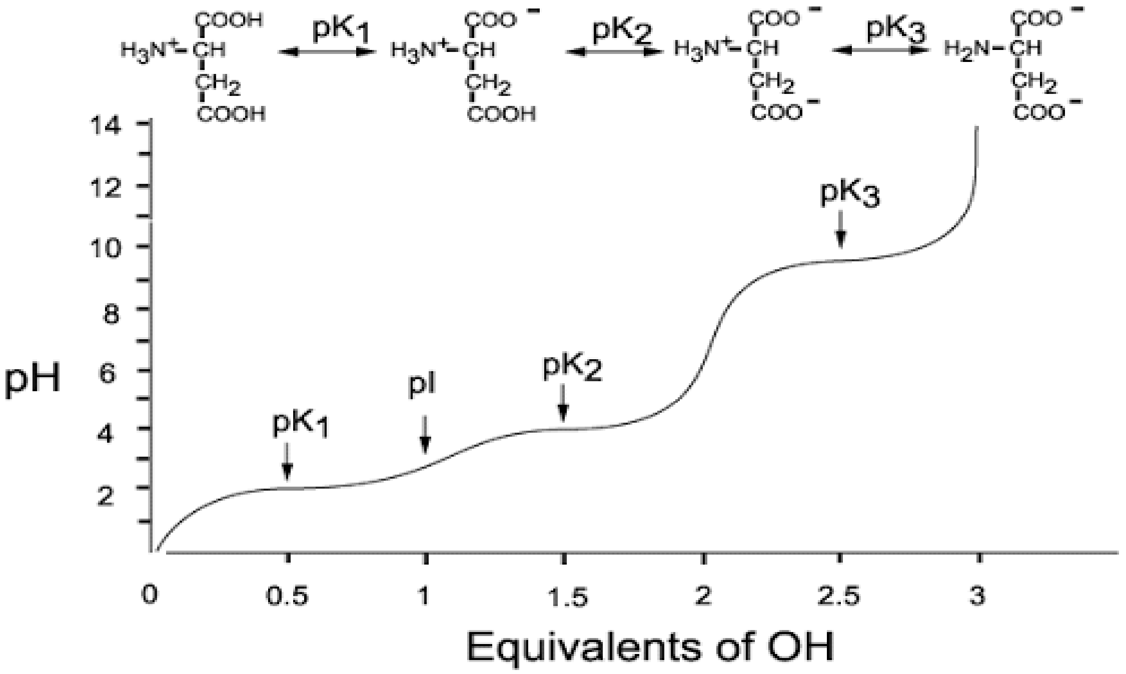


Figure: titration curve of aspartic acid with hydroxide

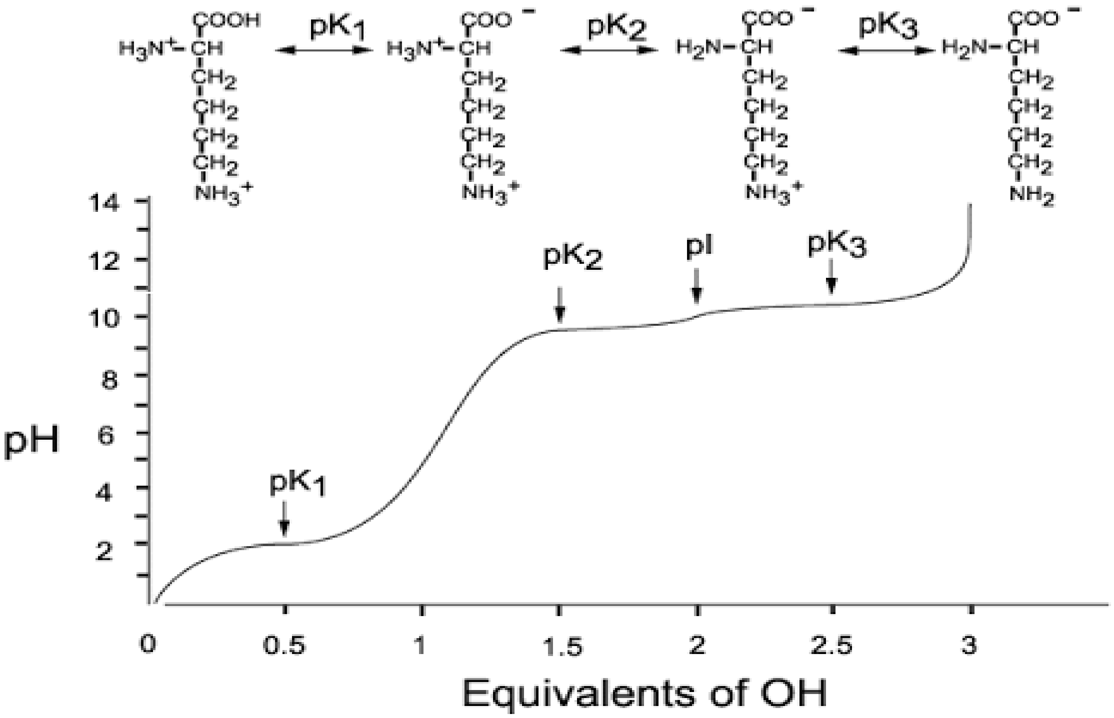


Figure: titration curve of Lysine with hydroxide

C. Physical Properties: They are colorless, crystalline substances, more soluble in water than in polar solvents. Tyrosine is soluble in hot water. They have high melting point usually more than 200°C. They have a high dielectric constant. They possess a large dipole moment.

D. Chemical Properties

I. Due to Carboxylic (—COOH) Group

1. Decarboxylation

The amino acids will undergo alpha decarboxylation to form the corresponding amine. Thus, some important amines are produced from amino acids. For example,
Histidine → Histamine + CO2
Tyrosine → Tyramine + CO2
Tryptophan → Tryptamine + CO2
Glutamic acid → Gamma amino butyric acid (GABA) + CO2

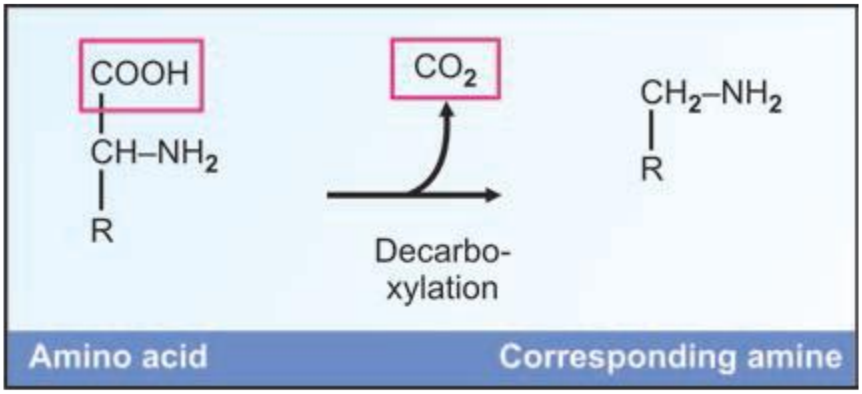


Figure: Decarboxylation of amino acid

Amide Formation

The-COOH group of dicarboxylic amino acids (other than alpha carboxyl) can combine with ammonia to form the corresponding amide. For example,
Aspartic acid + NH3 → Asparagine
Glutamic acid + NH3 → Glutamine
These amides are also components of protein structure. The amide group of glutamine serves as the source of nitrogen for nucleic acid synthesis.

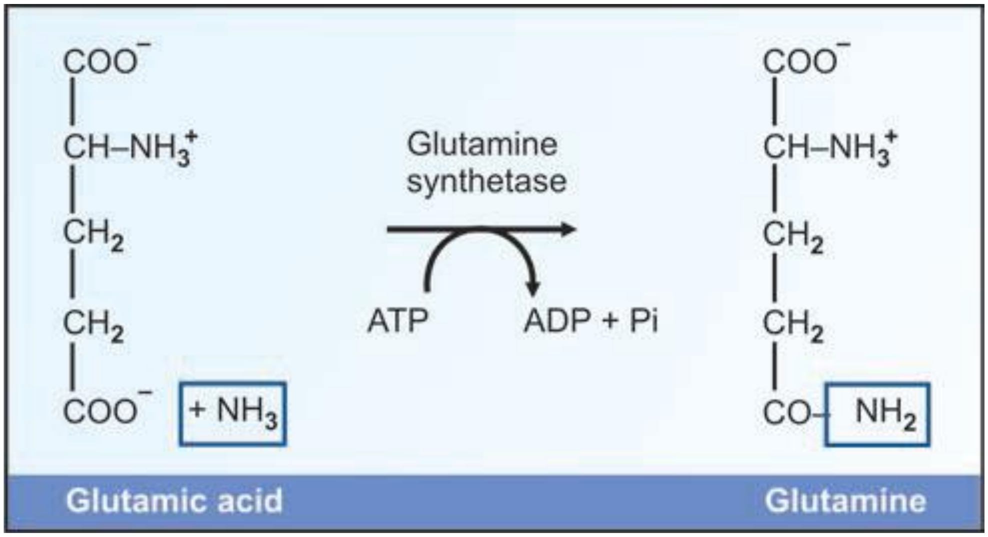
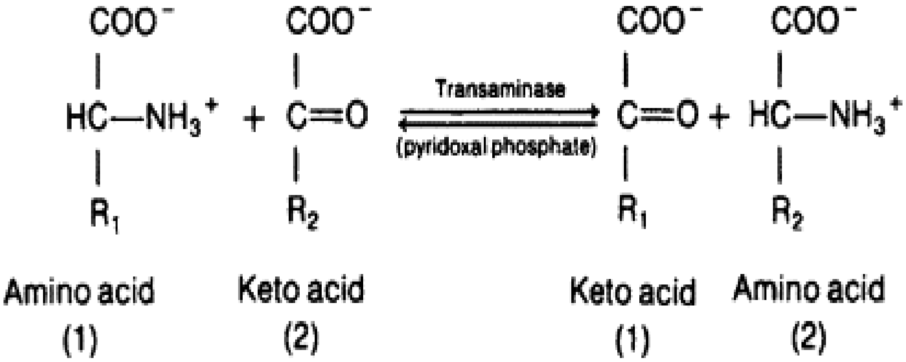


Figure: Formation of glutamine

Due to Amino Group

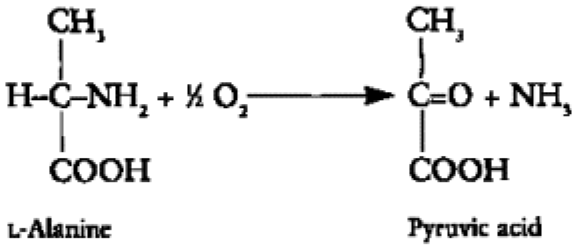
Transamination

The alpha amino group of amino acid can be transferred to alpha keto acid to form the corresponding new amino acid and alpha keto acid. This is an important reaction in the body for the interconversion of amino acids and for **synthesis of non-essential amino acids**.



Oxidative Deamination

The alpha amino group is removed from the amino acid to form the corresponding keto acid and ammonia. In the body, **Glutamic acid** is the most common amino acid to undergo oxidative deamination.



Formation of Carbamino Compound

Carbon dioxide adds to the alpha amino group of amino acids to form carbamino compounds. The reaction occurs at alkaline pH and serves as a mechanism for the transport of carbon dioxide from tissues to the lungs by hemoglobin

Hb—NH2 + CO2 → Hb—NH—COOH (Carbamino-Hb)

Due to Side Chains

Transmethylation

The methyl group of Methionine, after activation, may be transferred to an acceptor, which becomes methylated.
Methionine + Acceptor → Methylated Acceptor +Homocysteine

Ester Formation by the OH Group

The hydroxy amino acids can form esters with phosphoric acid. In this manner, the Serine and Threonine residues of proteins are involved in the formation of phosphoproteins. Similarly, these hydroxyl groups can form O-glycosidic bonds with carbohydrate residues to form glycoproteins.

Reaction of the Amide Group

The amide groups of Glutamine and Asparagine can form N-glycosidic bonds with carbohydrate residues to form glycoproteins.

Reactions of SH Group

Cysteine has a sulfhydryl (SH) group and it can form a disulfide (S-S) bond with another cysteine residue. The two cysteine residues can connect two polypeptide chains by the formation of interchain disulfide bonds or links. The dimer formed by two cysteine residues is sometimes called Cystine or Dicysteine.

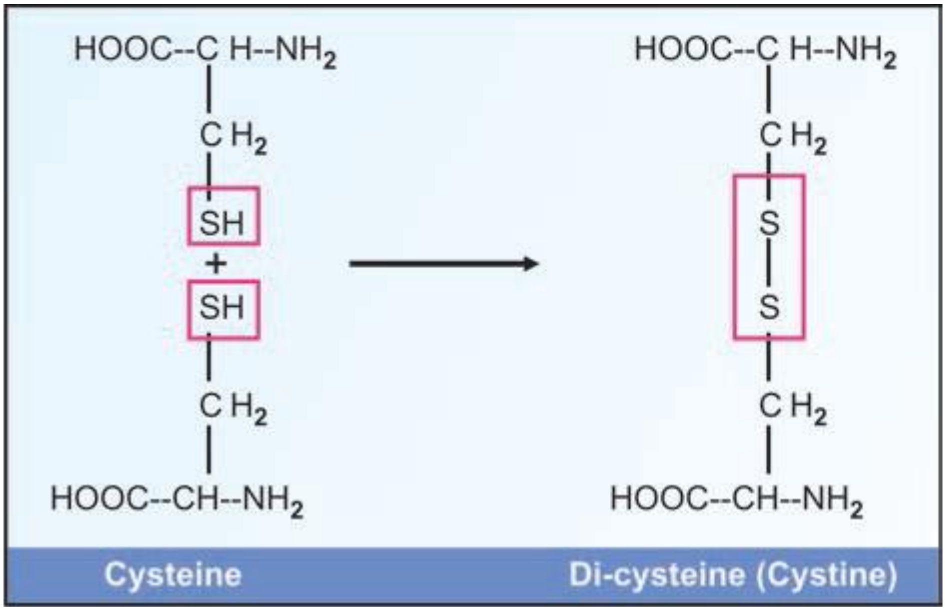
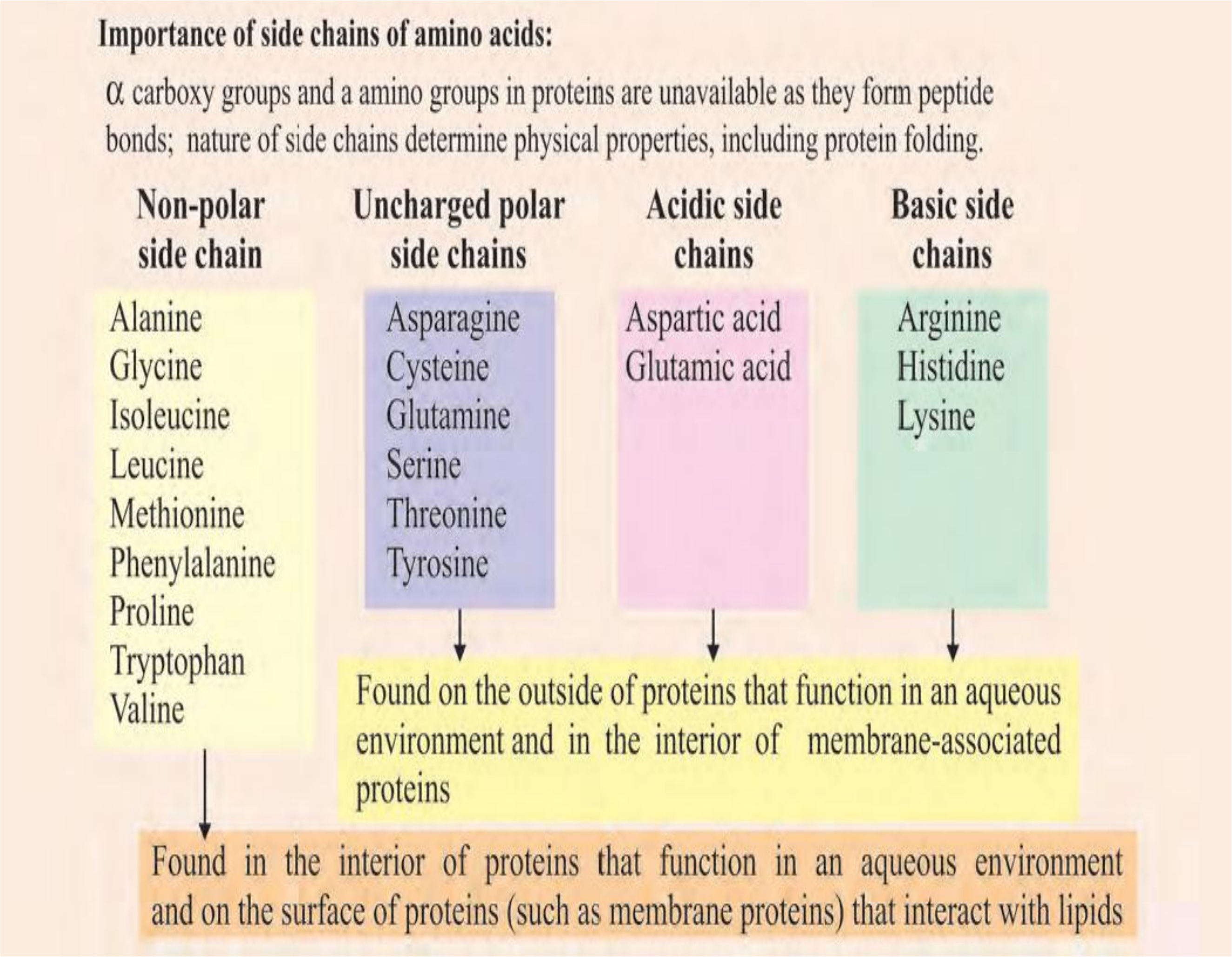


Figure: Formation of disulphide bridges

III. Properties of Amino acids Due to Both NH2 and COOH Groups

In addition to the property of reacting with both cation and anion, the amino acids form chelated, co-ordination complexes with certain heavy metals and other ions. These include Cu^{++}, Co^{++}, Mn^{++} and Ca^{++}.



Importance of side chains of amino acids:

α carboxy groups and a amino groups in proteins are unavailable as they form peptide bonds; nature of side chains determine physical properties, including protein folding.

Non-polar side chain	Uncharged polar side chains	Acidic side chains	Basic side chains
Alanine	Asparagine	Aspartic acid	Arginine
Glycine	Cysteine	Glutamic acid	Histidine
Isoleucine	Glutamine		Lysine
Leucine	Serine		
Methionine	Threonine		
Phenylalanine	Tyrosine		
Proline			
Tryptophan			
Valine			

Found on the outside of proteins that function in an aqueous environment and in the interior of membrane-associated proteins

Found in the interior of proteins that function in an aqueous environment and on the surface of proteins (such as membrane proteins) that interact with lipids