

4. AMINO ACIDS

1. INTRODUCTION

- Amino acids serve as the monomer units in living cells from which the polypeptide chains of proteins are constructed.
- Most proteins contain, in varying proportions, of the same 20 L- α amino acids, the kinds of amino acids, the order in which they are joined together, and their mutual spatial relationship dictate the three - dimensional structures and biologic properties of simple proteins

- In addition to their roles in protein, L-amino acids and their derivatives participate in intracellular functions such as nerve transmission, cell growth, and in the biosynthesis of enzymes, porphyrins, purines, pyrimidines, and urea. L- α amino acids are present in polypeptide antibiotics synthesized by microorganisms.

- Some amino acids occur in free or combined states and fulfill important roles in metabolic processes.
- For example, citrulline, and argininosuccinate participate in the formation of urea; tyrosine in the formation of thyroid hormones, and glutamate in neurotransmitter biosynthesis.
- About 20 - D-amino acids occur in nature.
- These include the D-alanine and D-glutamate of certain bacterial cell walls and a variety of D-amino acids in antibiotics.

2. CLASSIFICATION

- **a) Hydrophobic or Hydrophilic**
- The amino acids in proteins may be classified into two broad groups on the basis of whether the R groups attached to the α - carbon atoms are polar (hydrophilic) or nonpolar (hydrophobic) (Table 4.1).

Classification of the L- α amino acids of proteins

- **Hydrophobic**

Alanine
Isoleucine
Leucine
Methionine
Phenylalanine
Proline
Tryptophan
Valine

- **Hydrophilic**

- **Uncharged**

- Asparagine
- Cysteine
- Glycine
- Glutamine
- Serine
- Threonine
- Tyrosine

- **Charged-Acidic**

- Glutamic acid
- Aspartic acid

- **Basic**

- Arginine
- Histidine
- Lysine

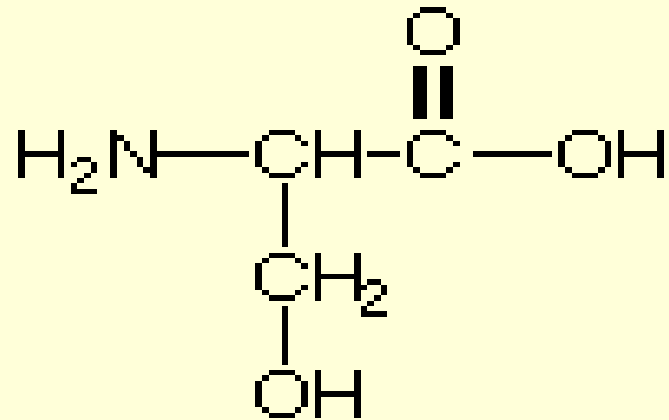
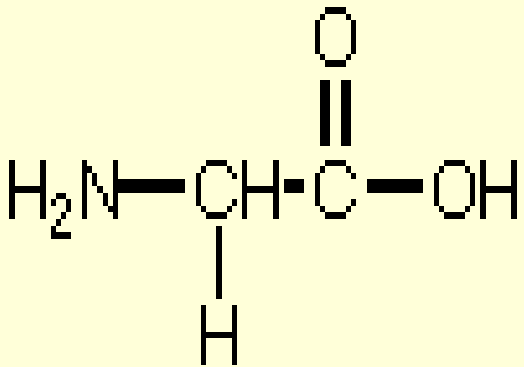
b) Based on the groups present in the side chain:

- Based on the groups present in the side chain 'R' amino acids are classified as follows

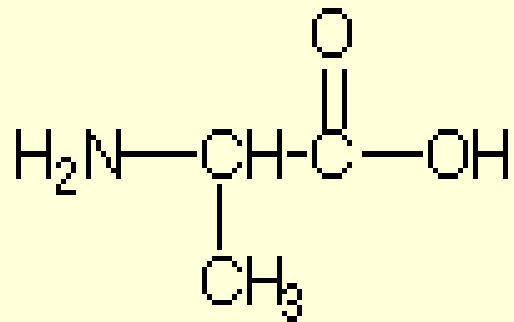
i) Amino acids with aliphatic groups in the side chain

- Glycine (Gly, G)

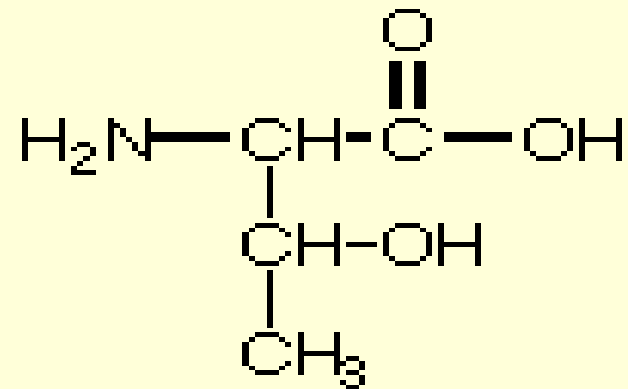
- Serine (Ser, S)



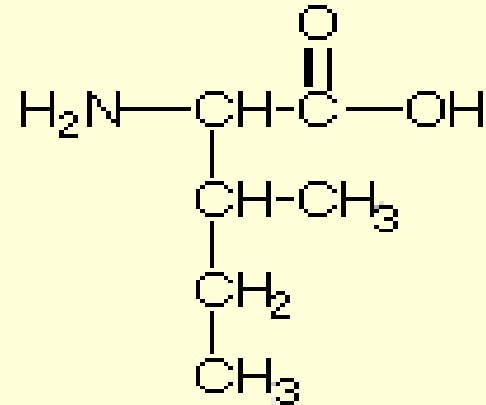
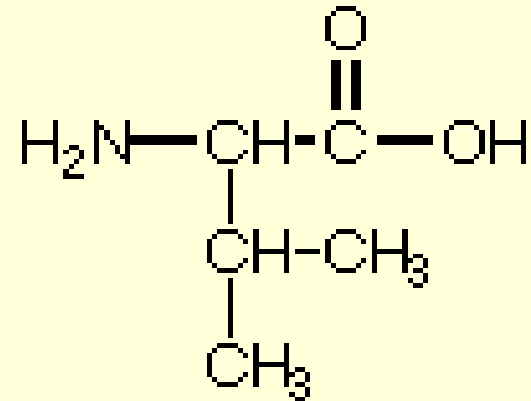
- Alanine(Ala,A)



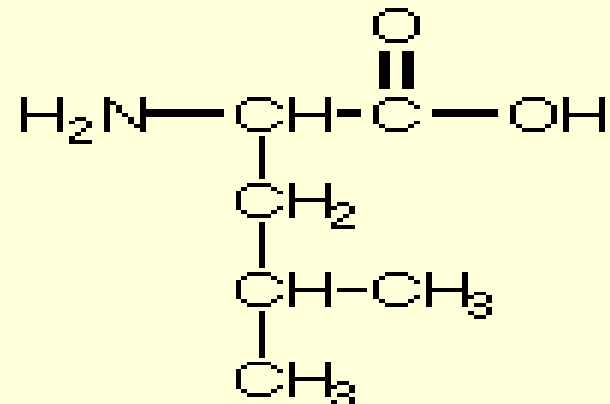
Threonine (Thr, T)



- Valine (Val, V) Isoleucine (Ile, I)

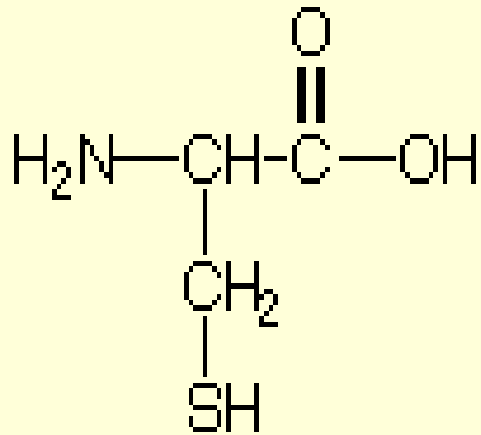


Leucine (Leu, L)

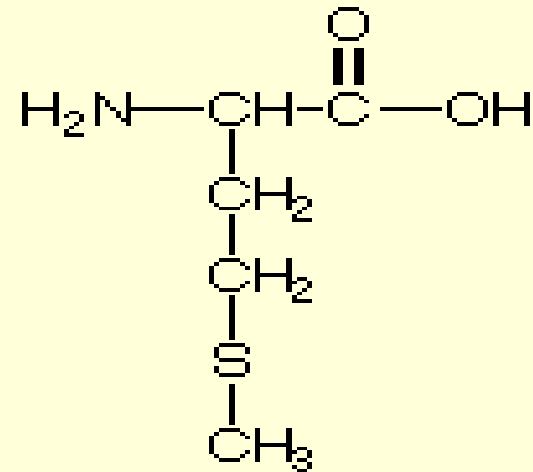


ii) Amino acids with sulphur-containing group in the side chain

Cysteine (Cys, C)

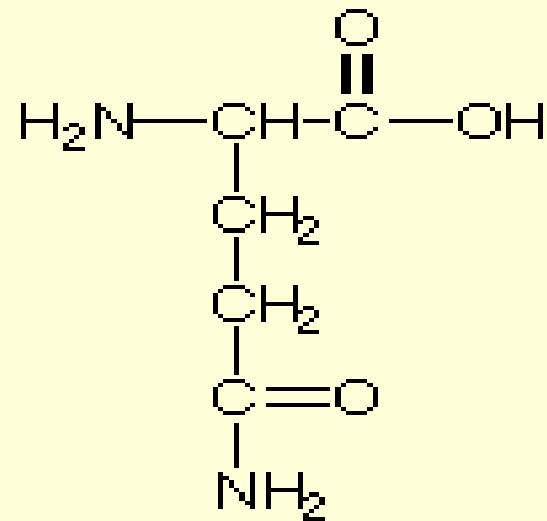
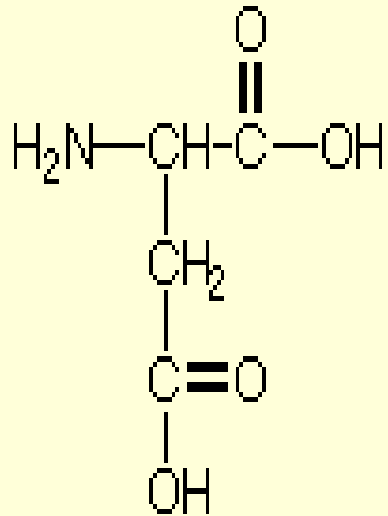


Methionine (Met, M)

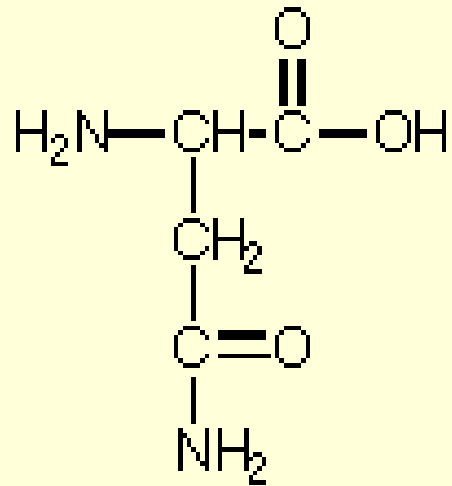


iii) Amino acids with carboxylic group in the side chain

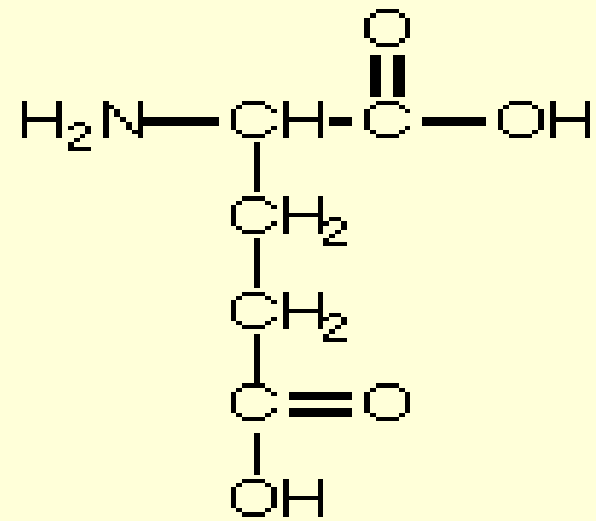
Aspartic acid (Asp, D) glutamic acid (Glu, E)



Asparagine (Asn, D)

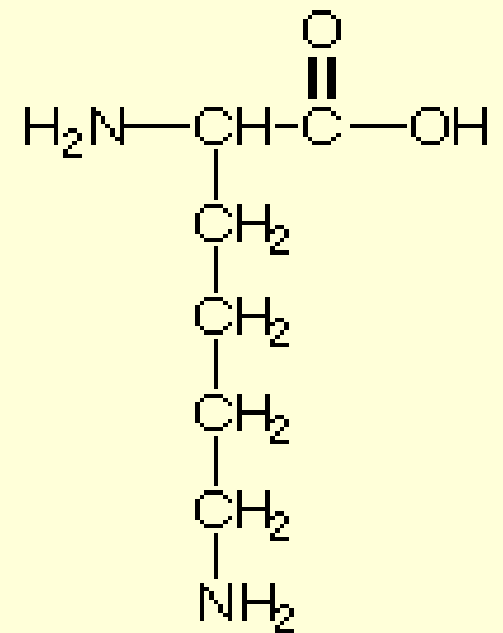
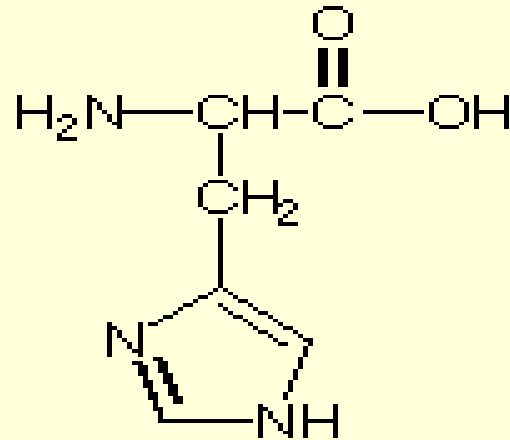
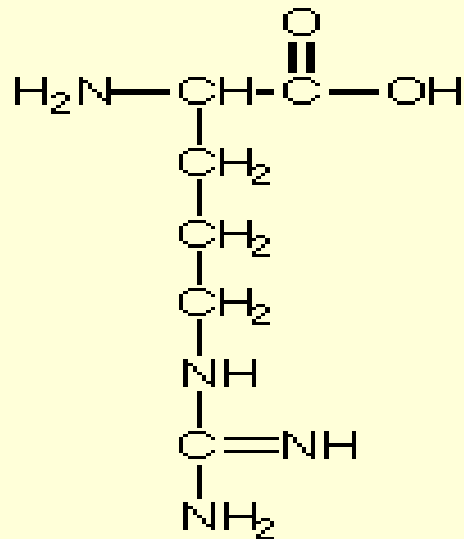


Glutamine (Gln, Q)



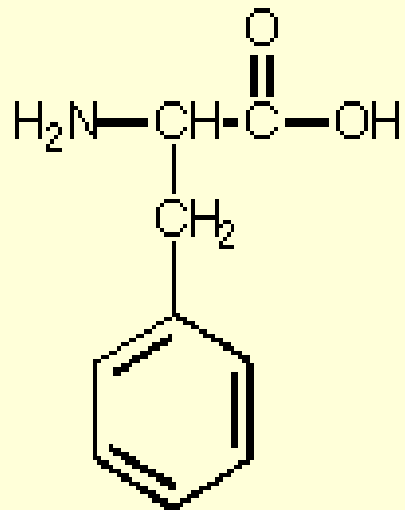
iv) Amino acids with basic group in the side chain

Arginine (Arg, R) Histidine (His, H) Lysine (Lys, K)

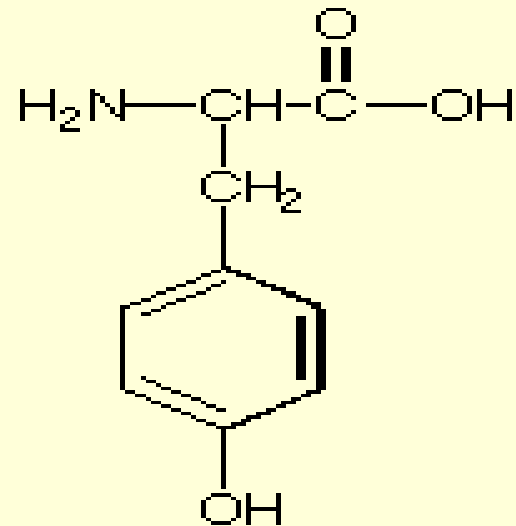


v) Amino acids with aromatic group in the side chain

Phenylalanine (Phe, F)

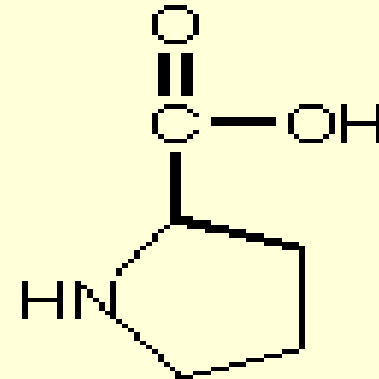
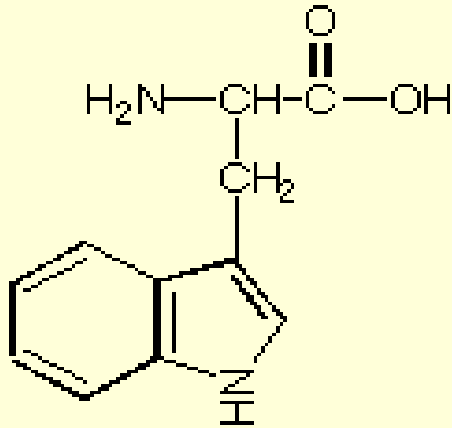


Tyrosine (Tyr, Y)



vi) Amino acids with heterocyclic group in the side chain

- Tryptophan (Try, W) Proline (Pro, P)



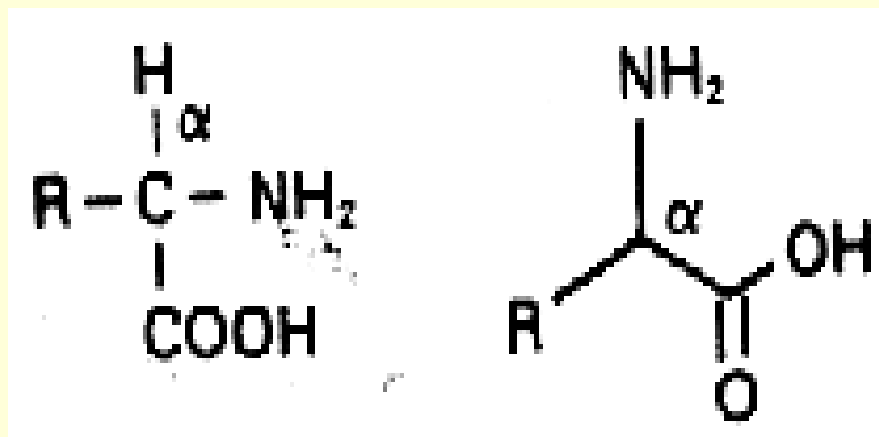
3. STRUCTURE OF AMINO ACIDS

- Amino acids consist of a central carbon atom chemically bonded to one hydrogen atom (H), one carboxylic acid group (-COOH) and one side chain R.
- The side chain gives each amino acid its identity unique to each amino acid.
- It varies from one hydrogen atom in glycine to complex ring of carbon and hydrogen in phenylalanine.

- In α -amino acids, both the amino and carboxyl groups are attached to the same carbon atom.
- All the amino acids except glycine have an asymmetric carbon atom (α carbon) to which four different groups are attached (Fig. 1).
- The asymmetric carbon is a chiral center.

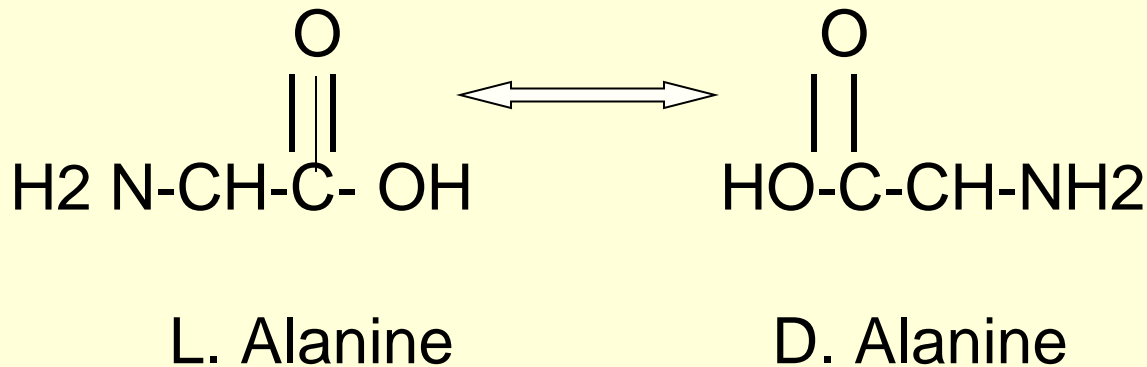
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Fig. 1 α -Amino acid).



Stereoisomerism

- Compounds with chiral center exhibit stereoisomerism and occur in two different forms.
- The stereoisomer of all chiral compounds having a configuration related to that of L glyceraldehydes are designated "L" and those related to D glyceraldehydes are designated "D"(Fig.4.1).
- The amino acids present in protein molecules are the L stereoisomer.



Optical activity

- The tetrahedral orientation of four different groups about the α carbon atom confers optical activity on amino acids.
- It is the ability to rotate the plane of plane-polarized light. Some amino acids found in proteins are dextrorotatory (+) and some levorotatory (-) at pH 7.0

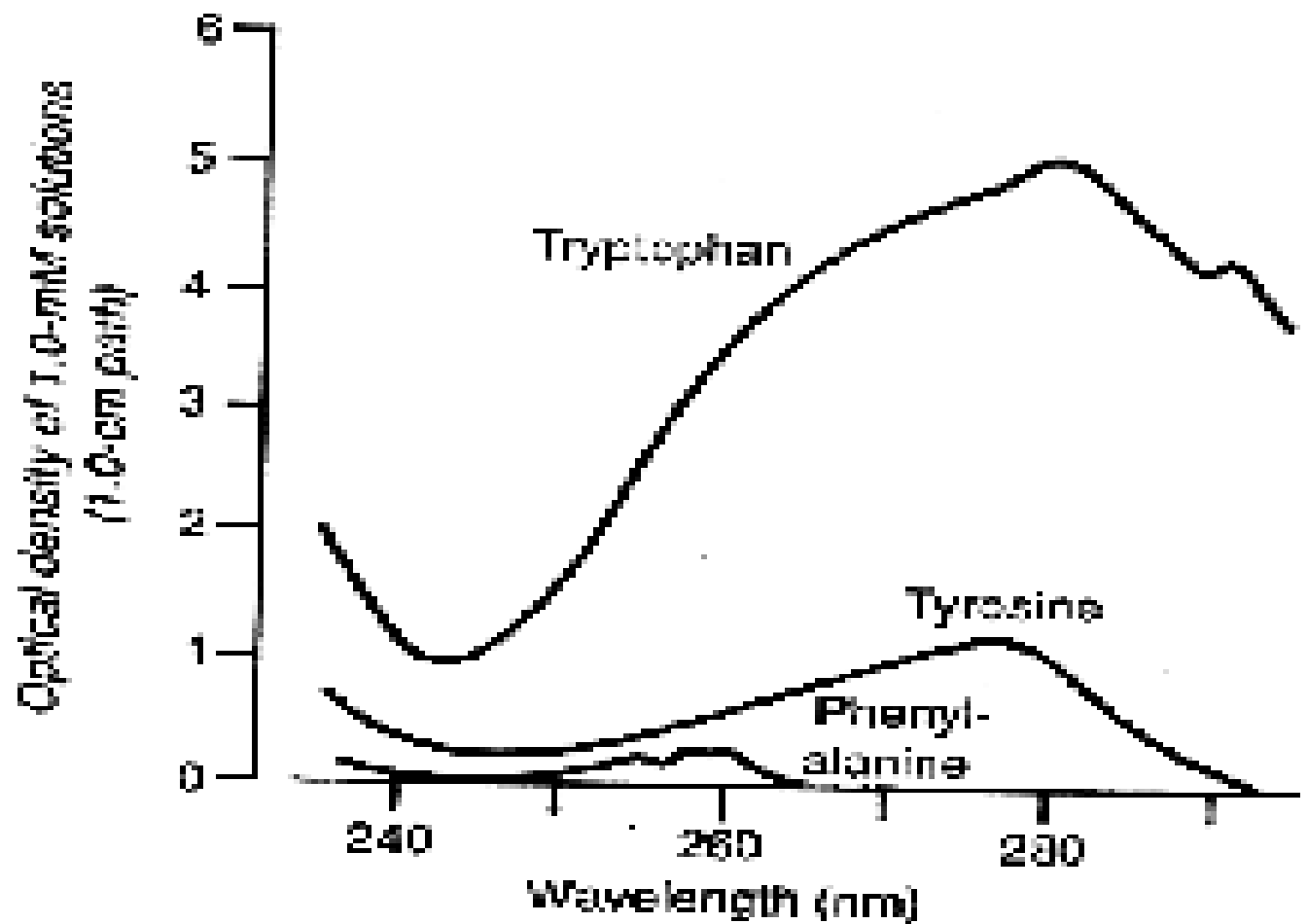
Charges

- Amino acids may have positive, negative, or zero net charge. Amino acids bear at least two ionizable weak acid groups, a -COOH and an -NH₃⁺.
- In solution, two forms of these groups, one charged and one un-charged, exist in protonic equilibrium :
 - $\text{R-COOH} \leftrightarrow \text{R-COO}^- + \text{H}^+$
 - $\text{R-NH}_3^+ \leftrightarrow \text{R-NH}_2 + \text{H}^+$

- R-COOH and R-NH_3^+ are the protonated, or acidic partners. In these the R-COO^- and R-NH_2 are the conjugate bases (proton acceptors) of the corresponding acids.
- Although both R-COOH and R-NH_3^+ are weak acids, R-COOH is a far stronger acid than is R-NH_3^+ .
- At the pH of blood plasma or the intracellular space, carboxyl groups exist almost entirely as carboxylate ions, R-COO^- .
- At these pH values, most amino groups are predominantly in the protonated form, R-NH_3^+ .

4. REACTIONS OF AMINO ACIDS

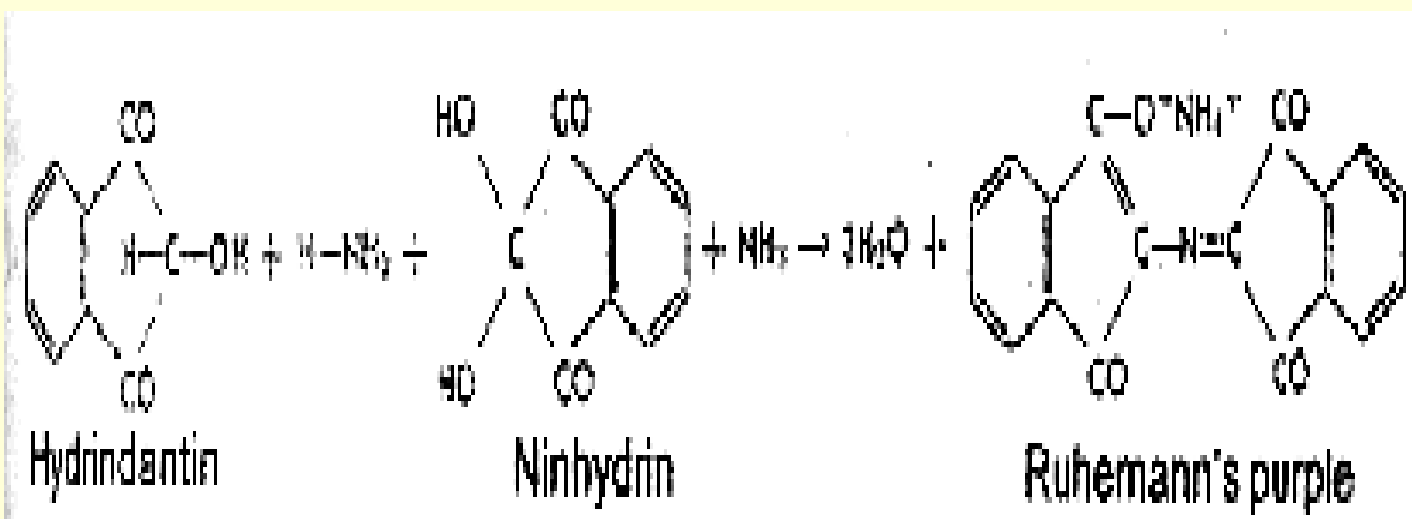
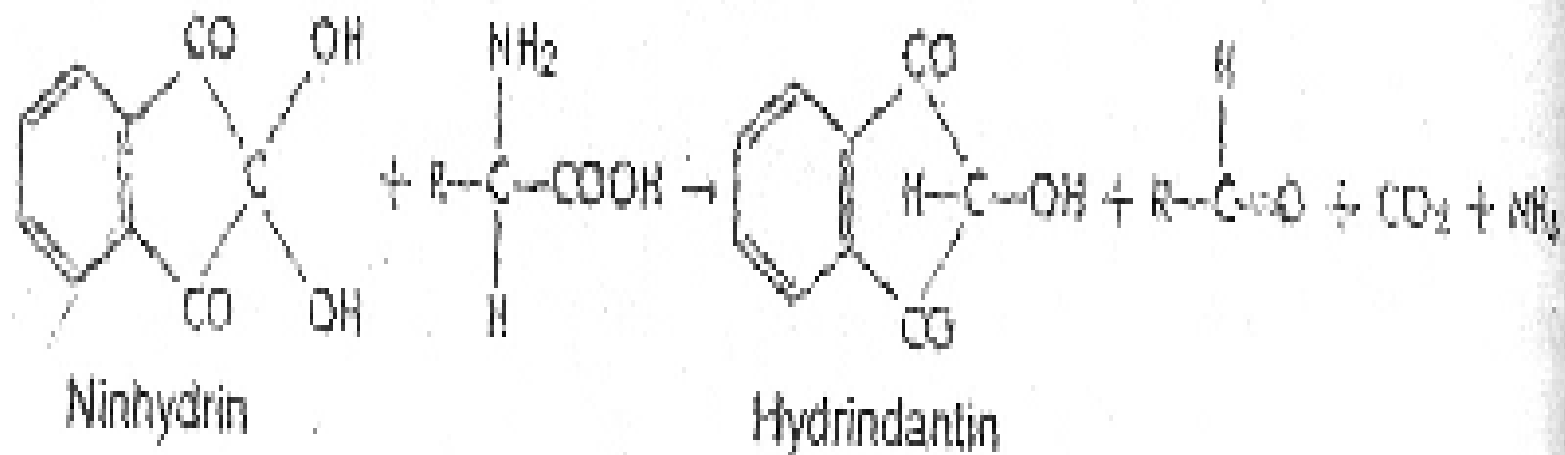
- **i) Absorption of ultraviolet light**
- Amino acids do not absorb visible light (i.e. they are colorless).
- The aromatic amino acids tryptophan, tyrosine, phenylalanine and histidine, absorb ultraviolet light of a wavelength (250-290 nm, fig.4.2).
- Tryptophan therefore makes a major contribution to the ability of most proteins to absorb light in the region of 280 nm.



ii) Reaction with Ninhydrin

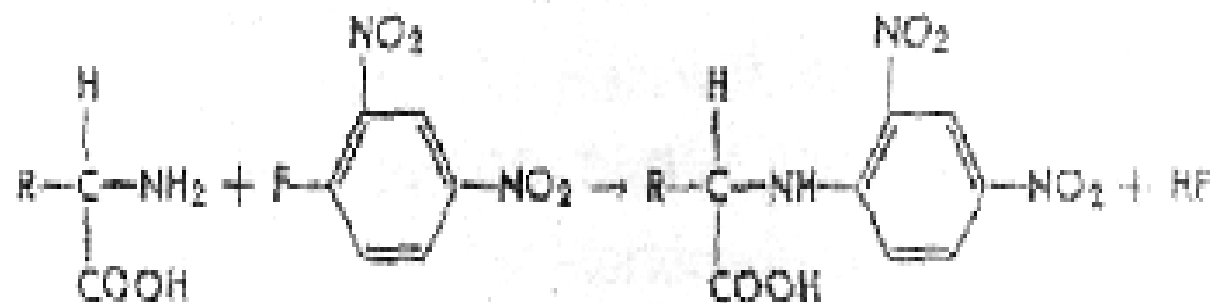
- Ninhydrin oxidatively decarboxylates α amino acids to CO_2 , NH_3 , and an aldehyde with one less carbon atom than the parent amino acid.
- The reduced compound hydrindantin reacts with another molecule of ninhydrin and the liberated ammonia, to form a purple complex (Ruhemann's purple) that maximally absorbs light of wavelength 570 nm.
- This blue color forms the basis of a quantitative test for α amino acids that can detect as little as 1 g of amino acid.

- Amines, other than α amino acids also react with ninhydrin, forming a blue color, but without releasing CO₂.
- The evolution of CO₂ thus indicates an α amino acid.
- NH₃ and peptides also react, but more slowly than α amino acids.
- Proline and 4-hydroxy proline produce a yellow color with ninhydrin. (Fig.5. 3)



iii) Reaction with Sanger's reagent

- A very important reaction of the amino groups of amino acids is with 1-fluoro-2,3-dinitrobenzene, FDNB, also called "Sanger's reagent".
- The reagent condenses with free amino groups in the cold in mildly alkaline solution (bicarbonate):



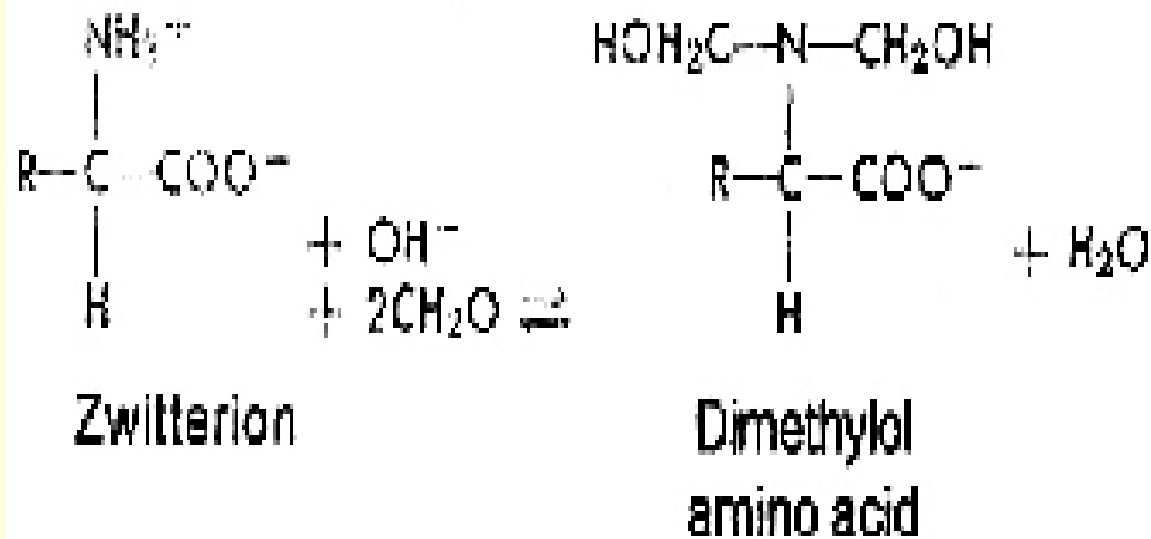
Amino acid

1-Fluoro 2,4-
dinitrobenzene

Dinitrophenyl (DNP)
amino acid

(4) Reaction of amino acids with formaldehyde (Sorensen's formal titration) :

- The carboxyl group of α -amino acids cannot be accurately titrated in water solution with alkali, because it reacts with the basic amino group to form zwitterions that are not decomposed completely at the end of alkaline indicators (phenolphthalein, thymolphthalein).
- But when formaldehyde is added to the solution of an amino acid it binds to the amino group as dimethylol and the amino acid can be titrated and estimated as an acid using the above indicators. The reactions apparently proceed as follows



5. FUNCTIONS OF AMINO ACID

- Amino acids occupy a central position in cellular metabolism since all biochemical reactions are catalysed by enzymes composed of amino acids.
- Amino acids are essential for carbohydrate and lipid metabolism, for synthesis of tissue proteins and many important compounds (i.e. Adrenalin, thyroxin, melanin, histamine, porphyrins-haemoglobin, pyrimidines and purines nucleic acids, choline, folic acid and nicotinic acid – vitamins, taurine and as a metabolic source of energy or fuel.

6. ESSENTIAL AND NONESSENTIAL AMINO ACIDS

- For nutritional purposes, amino acids may be divided into two groups essential amino acids (EAA), and the non-essential amino acids (NEAA).
- Essential amino acids
- The essential amino acids are that cannot be synthesized within the animal body or rate sufficient to meet the physiological needs of the growing animal, therefore be supplied in a ready made form in the diet.
- Non-essential amino acids
- NEAA are those acids that can be synthesized in the body from a suitable carbon source, amino groups from other amino acids or simple compounds such as diammonium citrate, and consequently do not have to be supplied in a ready made form diet.

Essential amino acids

- The 10 essential amino acids are methionine, tryptophan, threonine, valine, isoleucine, leucine, phenylalanine, lysine, arginine and histidine.
- The remaining amino acids are called non-essential or dispensable as they can be synthesized in animals from other compounds.
- They are glycine, cysteine, alanine, serine, proline, tyrosine, aspartic acid, asparagine, glutamic acid and glutamine.