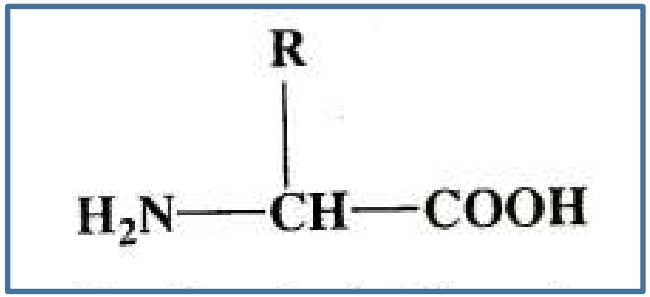
AMINO ACIDS AND PROTEINS

Structure and classification

- **Amino acids** or amino carboxylic acids are derivatives of carboxylic acids, in which at least one hydrogen atom is replaced by an amine group.
- Amino acid molecules are Heterofunctional compounds that have two functional groups, an amine group, $-NH_2$, and a carboxyl group, -COOH.

The general formula for a 2-amino(α-amino) acid is:



The biologically important amino acids have the amino group attached to the carbon atom next door to the -COOH group.

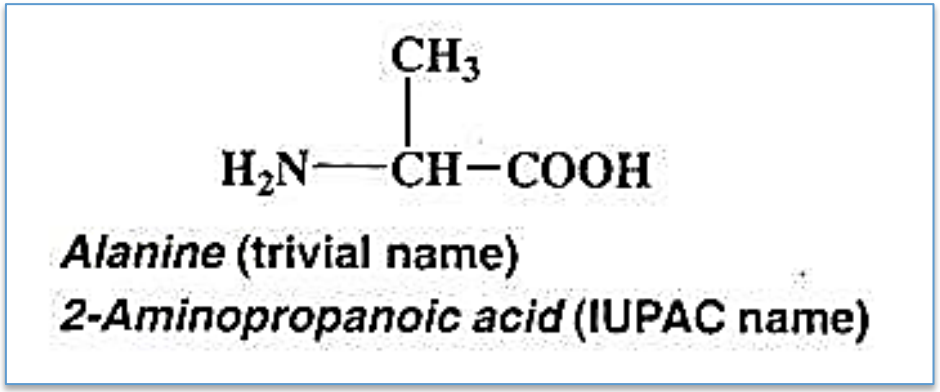
They are known as ***2-amino acids***. They are also known as ***α-amino acids***.

"R" is called a side chain

- The nature of amino acid side chain R varies considerably.
- Its structure defines the chemical properties of individual α-amino acids

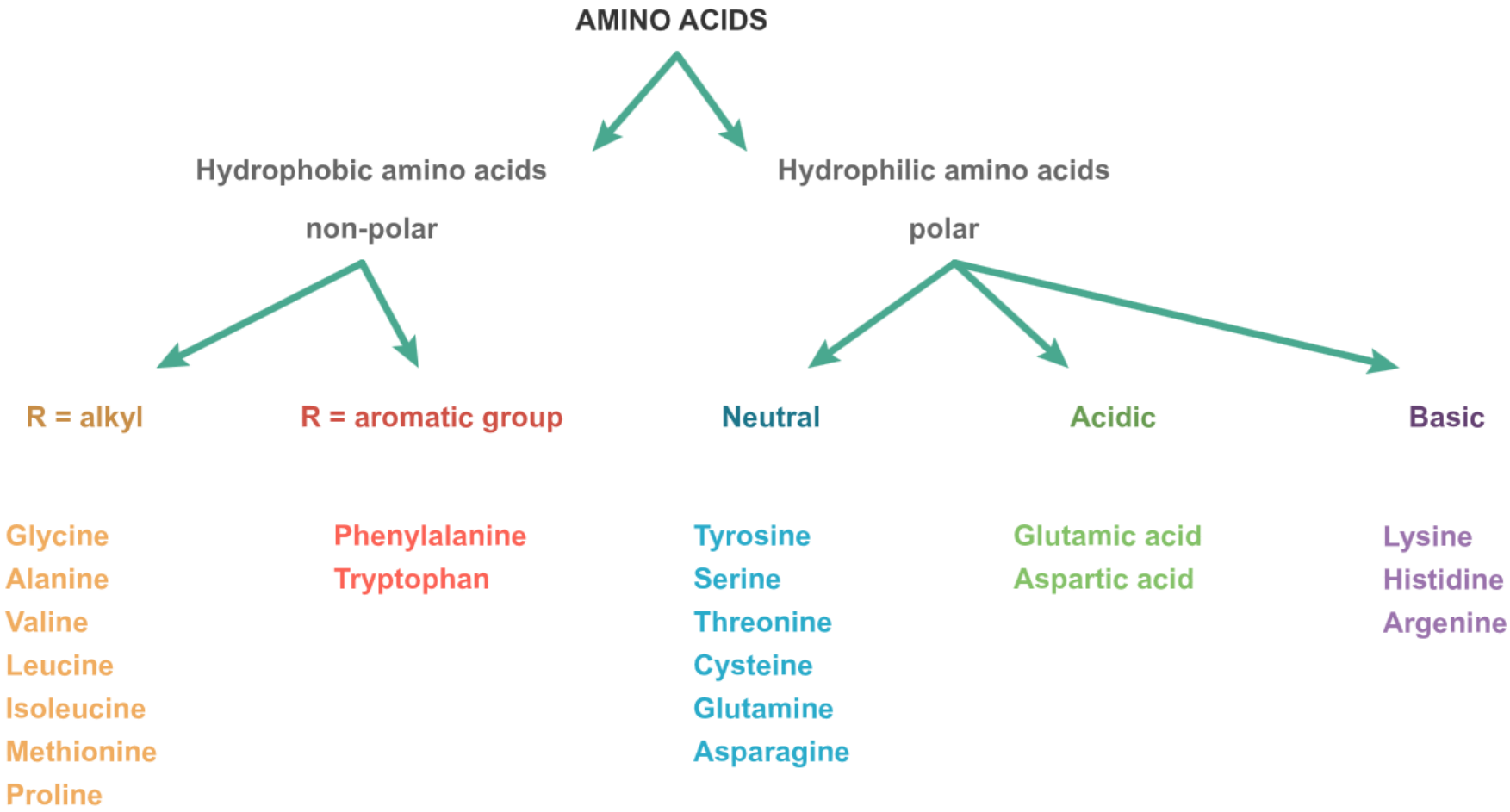
Naming proteinogenic α-amino acids

- The commonly used terms for designating proteinogenic a-amino acids are their trivial and semi-trivial names



CLASSIFICATION OF AMINO ACID

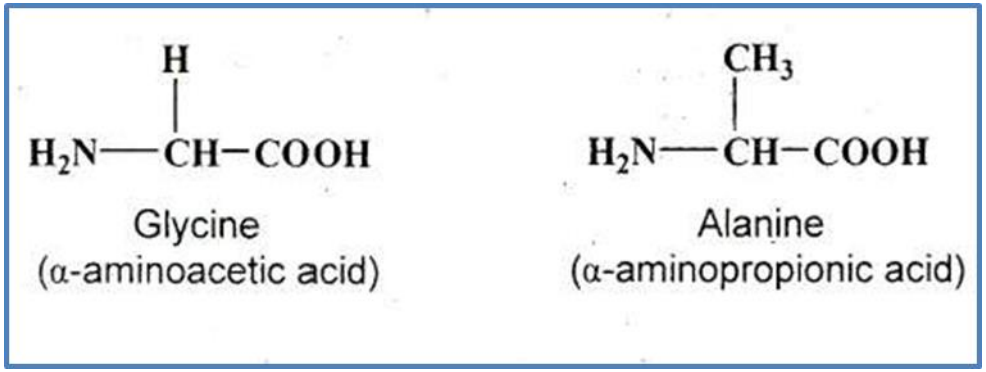
- A. Based on structure – AA with aliphatic side chains,
  AA with hydroxyl group
  AA with sulphur group
  Acidic amino acid
  Basic amino acid
  Aromatic amino acid
  Imino acid
- B. Based on polarity – Non polar amino acid
  Polar amino acid with no charge on R
  Polar amino acid with positive R charge
  Polar amino acid with negative R charge
- C. Based on nutrition – Essential amino acid
  Non essential amino acid
- D. Based on metabolic fate – Glycogenic Amino acid
  Ketogenic amino acid

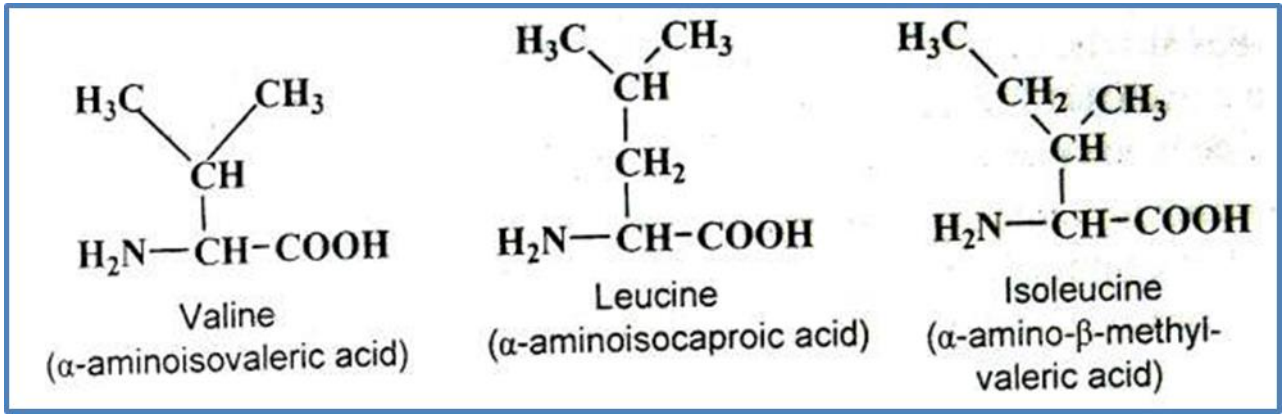

AMINO ACIDS
Hydrophobic amino acids
non-polar
Hydrophilic amino acids
polar
R = alkyl
R = aromatic group
Neutral
Acidic
Basic
Glycine
Alanine
Valine
Leucine
Isoleucine
Methionine
Proline
Phenylalanine
Tryptophan
Tyrosine
Serine
Threonine
Cysteine
Glutamine
Asparagine
Glutamic acid
Aspartic acid
Lysine
Histidine
Argenine

Structural classification of a-amino acids

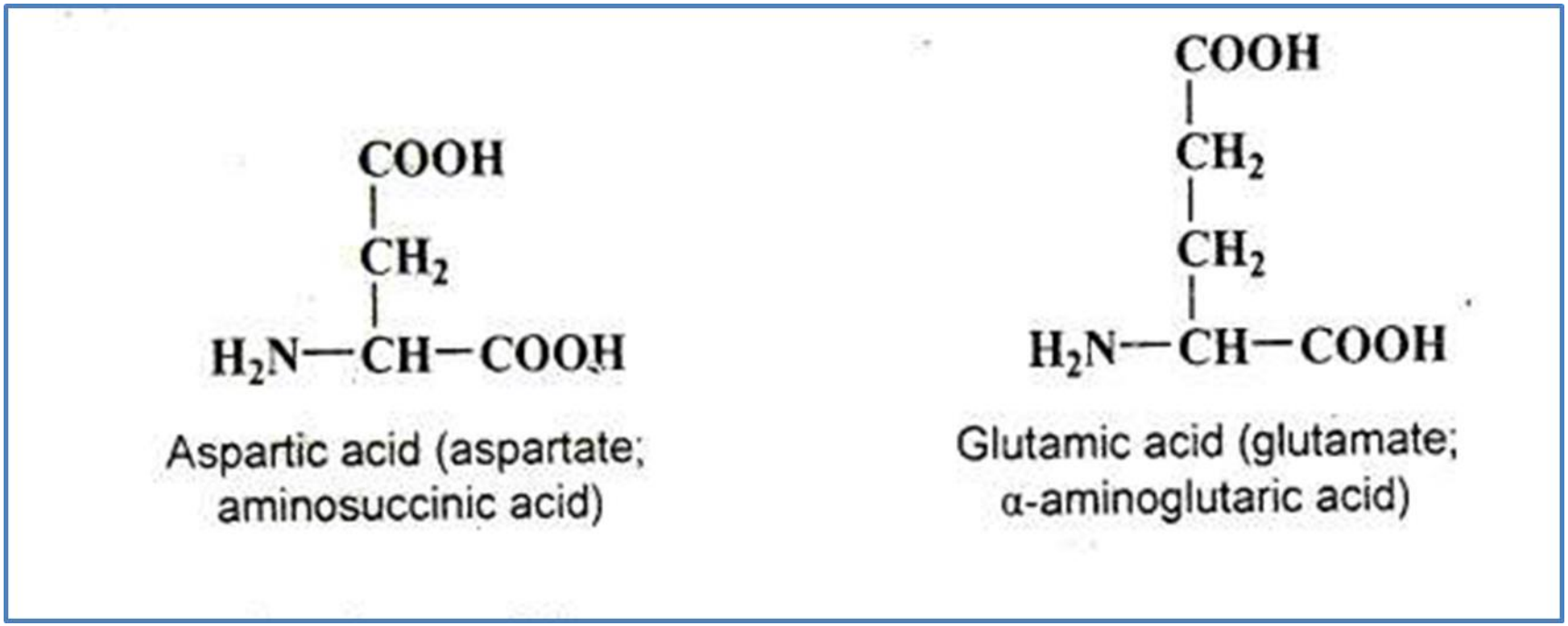
ALIPHATIC SIDE CHAINE

- ***neutral***

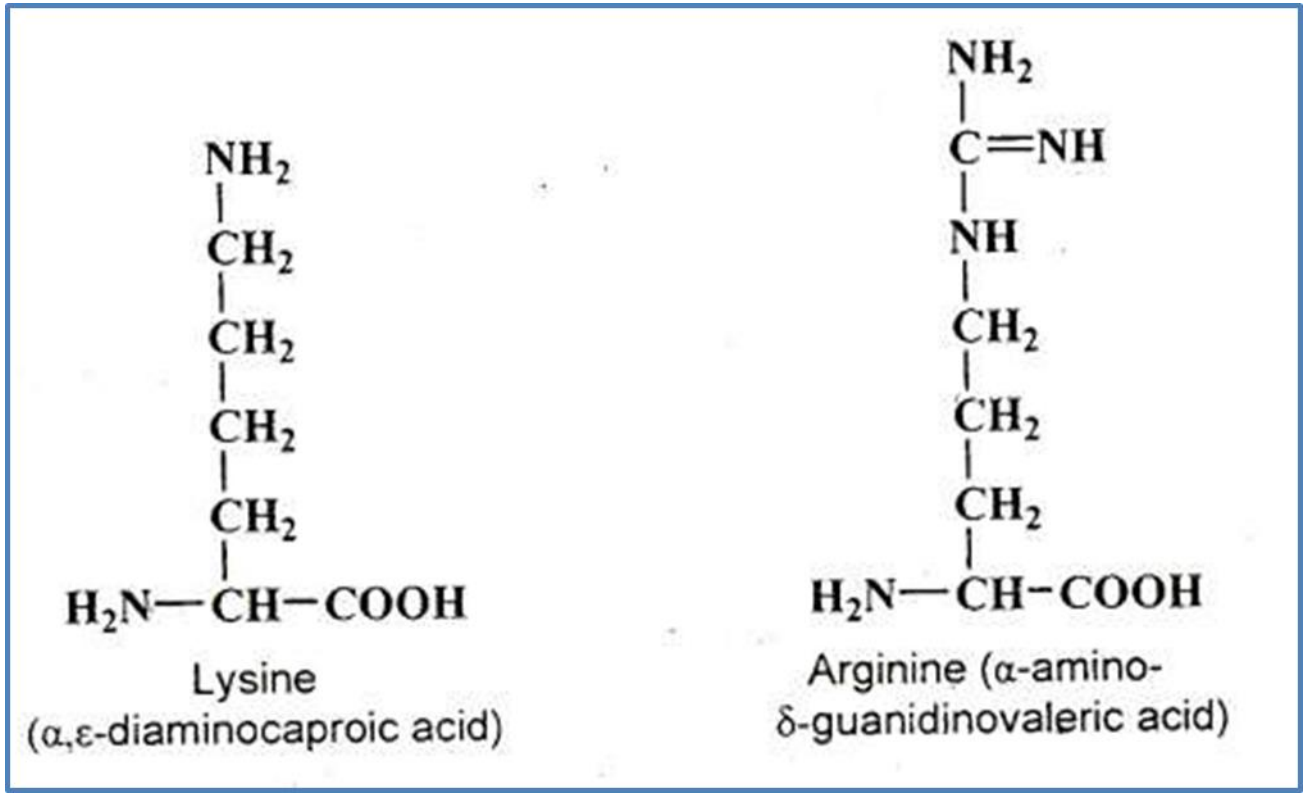




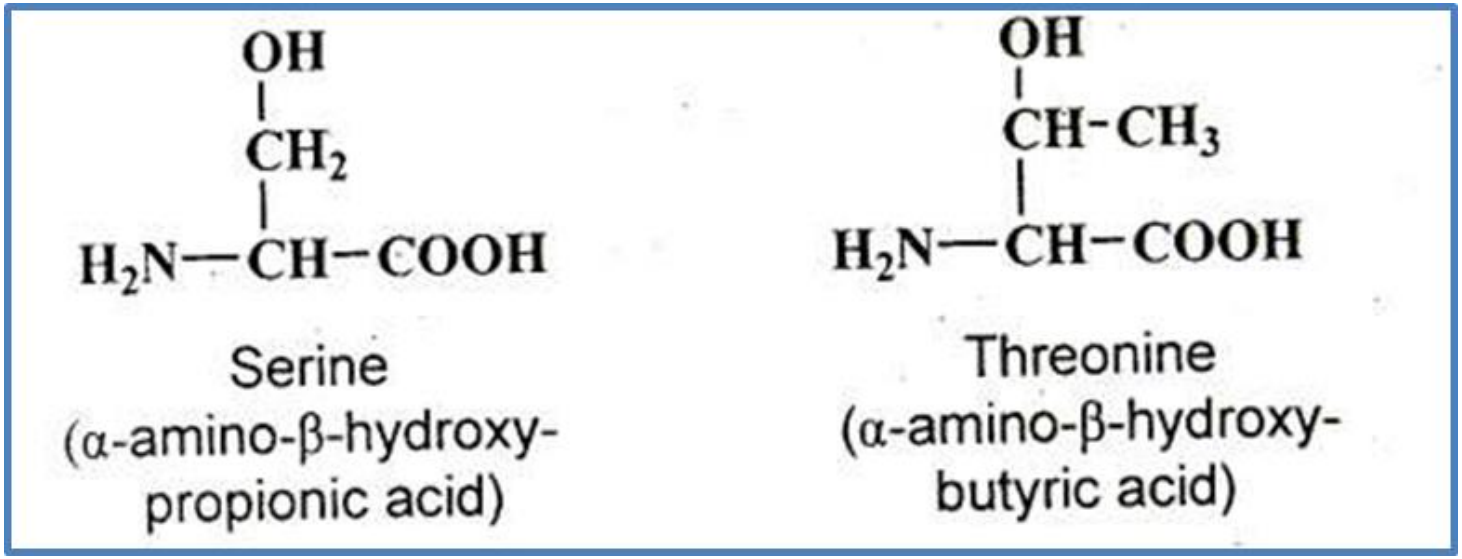
- ***acidic***


COOH
CH2
H2N—CH—COOH
Aspartic acid (aspartate; aminosuccinic acid)
COOH
CH2
CH2
H2N—CH—COOH
Glutamic acid (glutamate; α-aminoglutaric acid)

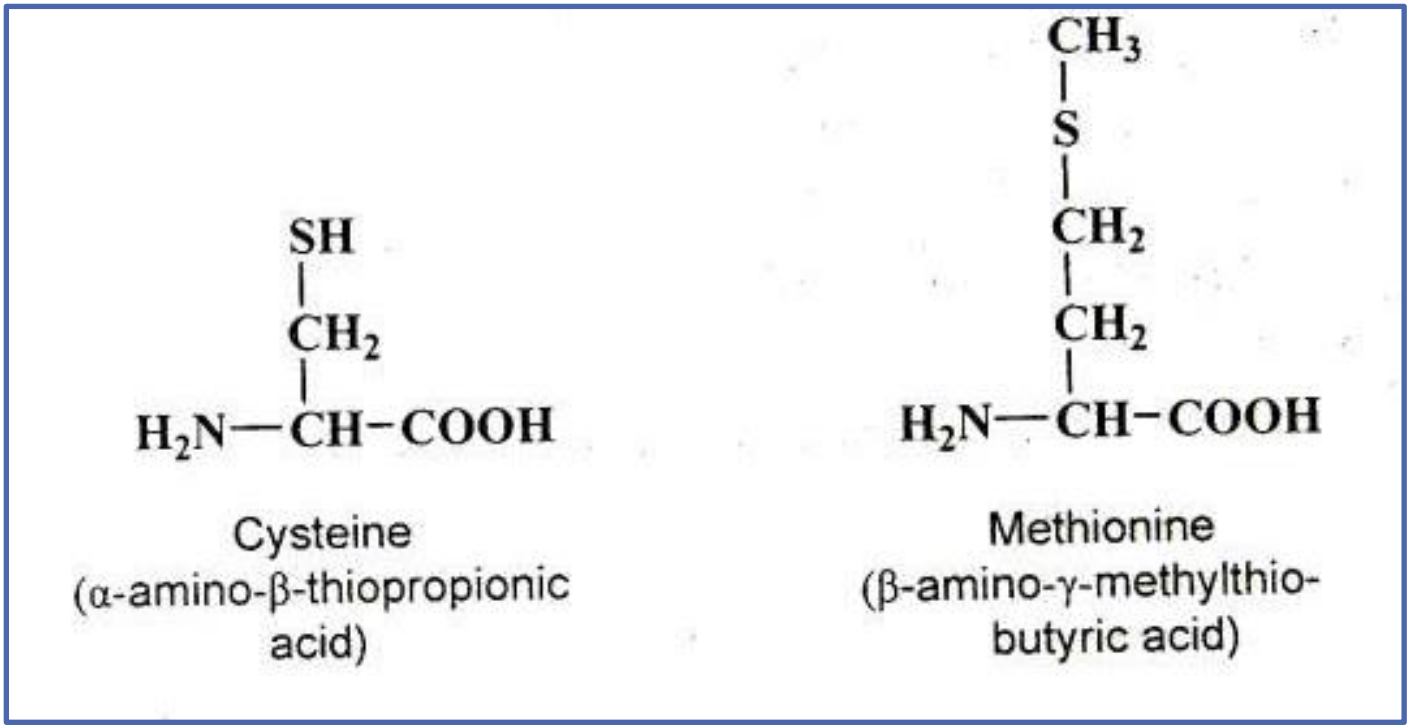
- ***basic***


NH2
CH2
CH2
CH2
CH2
H2N—CH—COOH
Lysine
(α,ε-diaminocaproic acid)
NH2
C=NH
NH
CH2
CH2
CH2
H2N—CH—COOH
Arginine (α-amino-
δ-guanidinovaleric acid)

- Hydroxyaminoacids

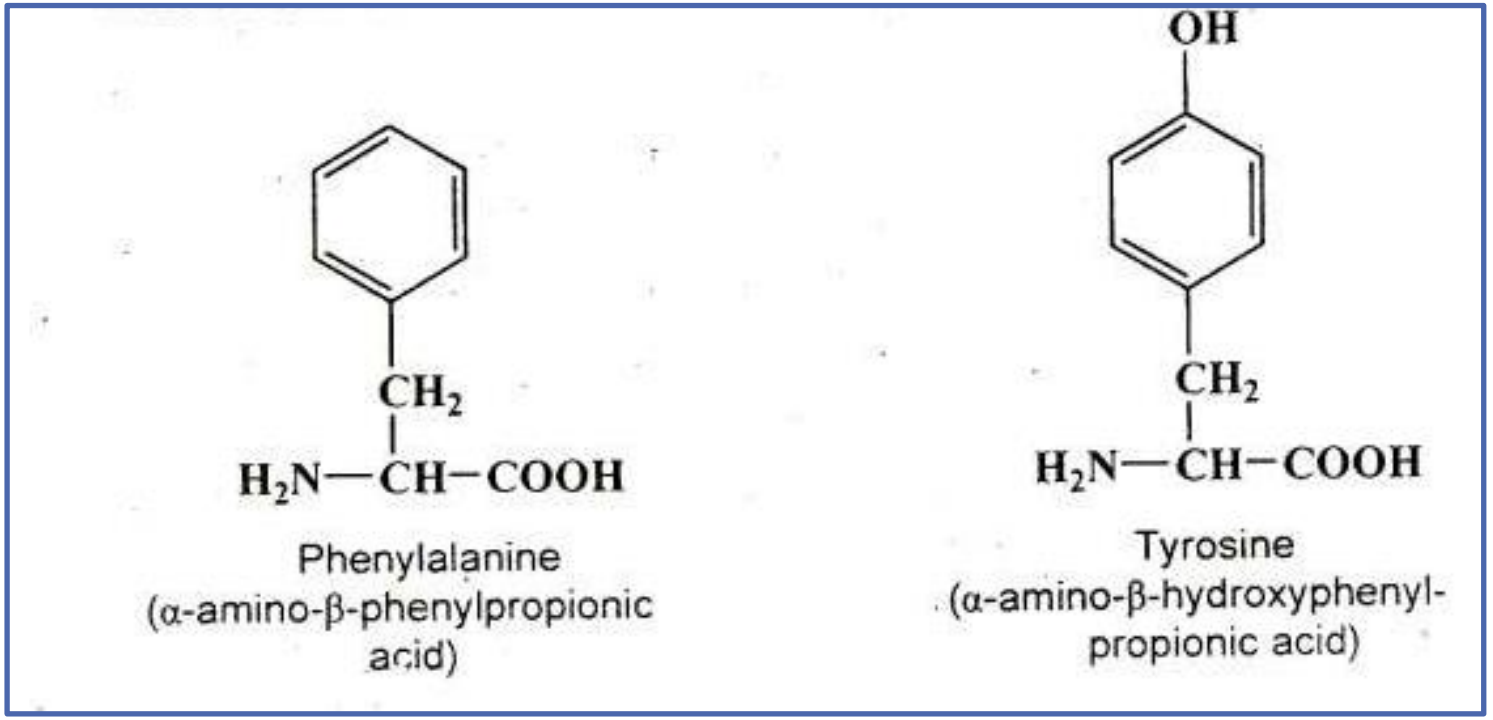


with Sulphur containing side chains:

- 

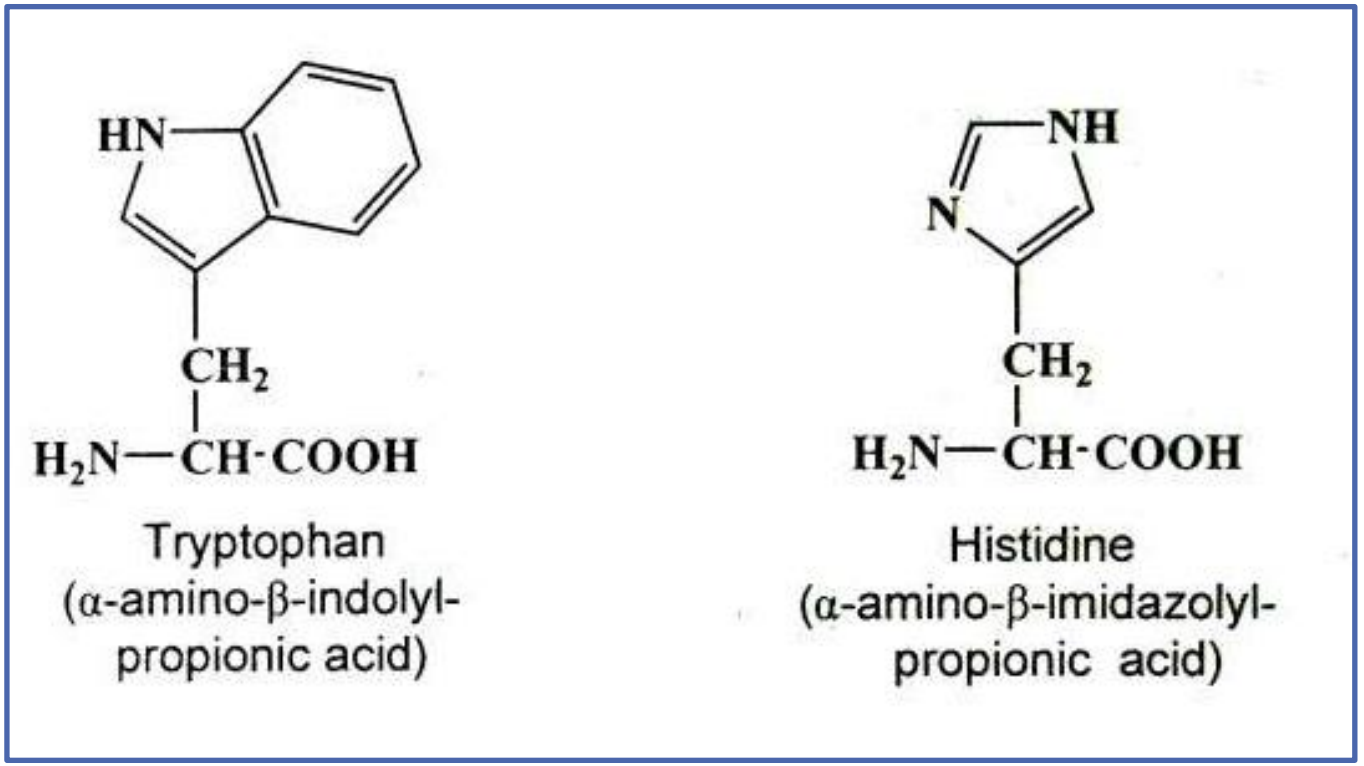
Cyclic amino acids

- *Aromatic amino acids.*
-

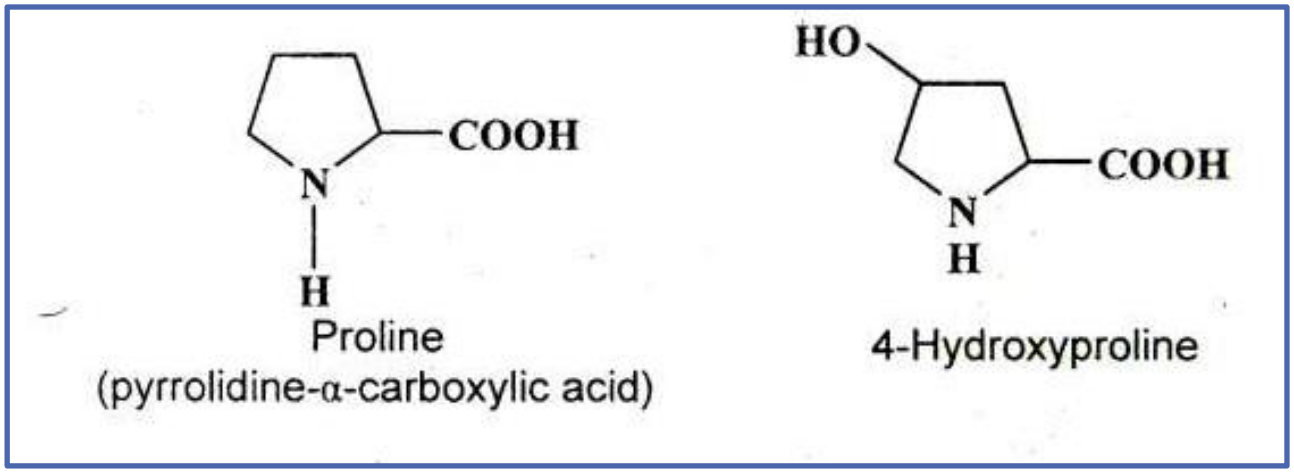


Cyclic amino acids

- ***Heterocyclic amino acids:***



Imino acids



Proline
(pyrrolidine-α-carboxylic acid)

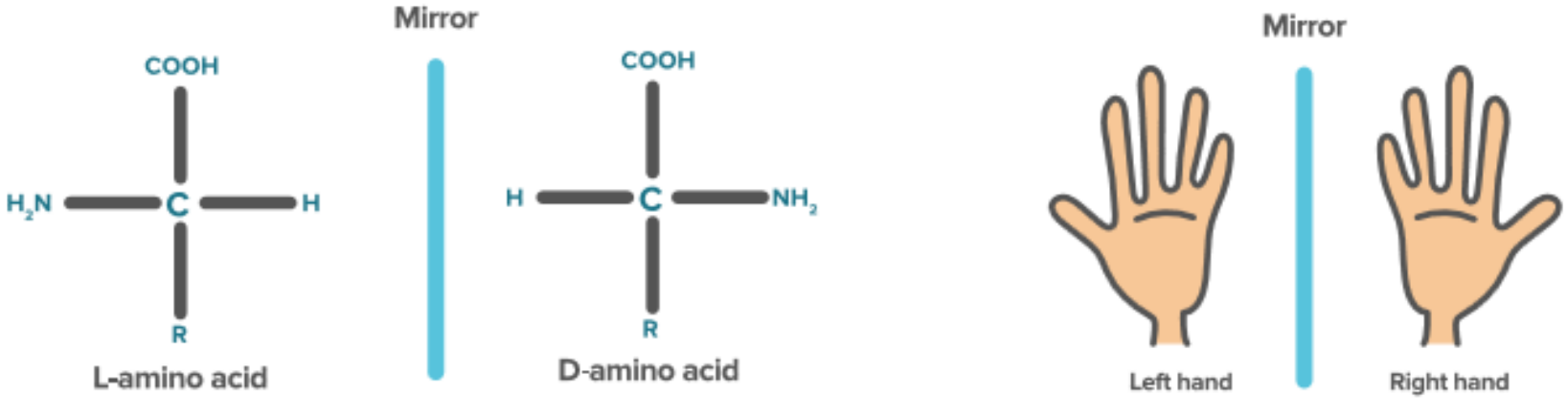
4-Hydroxyproline

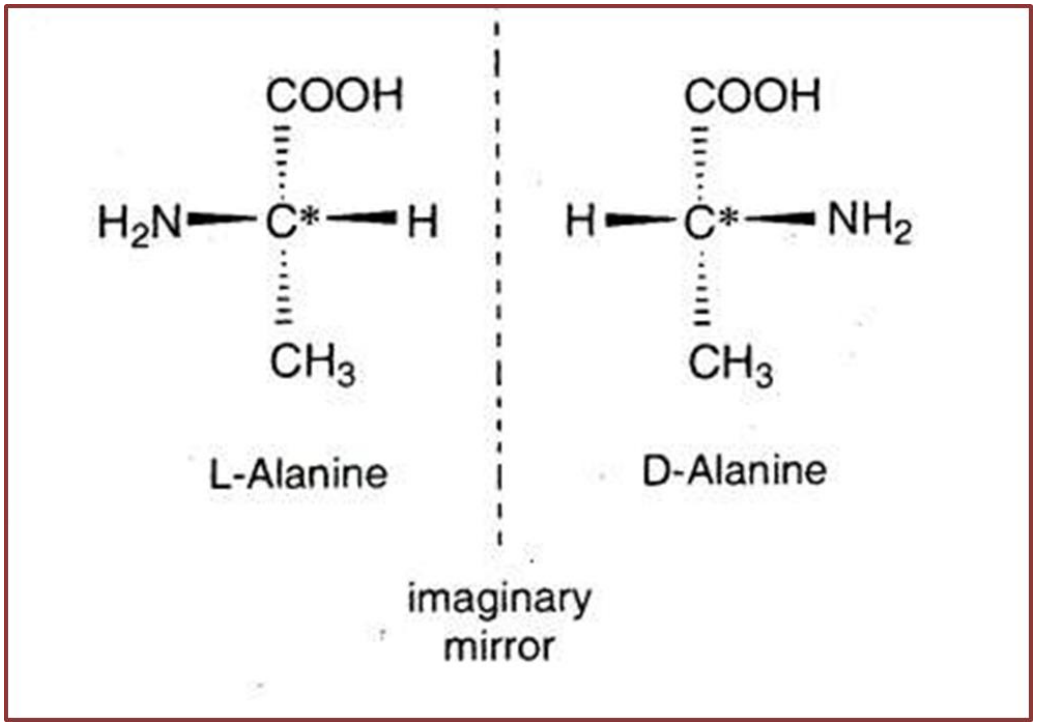
Nutritional classification

- **Essential amino acids**
- - the human body cannot synthesize them from other compounds at the level needed for normal growth, so they must be obtained from food.
- They include **valine, leucine, isoleucine, phenylalanine, threonine, tryptophan, methionine and lysine.**
- *Cysteine*, *tyrosine*, histidine and arginine are semi essential amino acids in children, because the metabolic pathways that synthesize these amino acids are not fully developed (they are not synthesized in sufficient quantity during growth).
- ***Non-essential amino acids***
- These can be synthesized by the body and may not be the requisite component of the diet.

Stereoisomerism and optical activity of a-amino acids

- the carbon atom, which is bonded to four different groups, is called *asymmetric* carbon or ***chiral*** carbon.
- In the proteinogenic amino acids, with the exception of glycine, the α-carbon atom is an asymmetric carbon. So, **the amino acids are chiral molecules.**

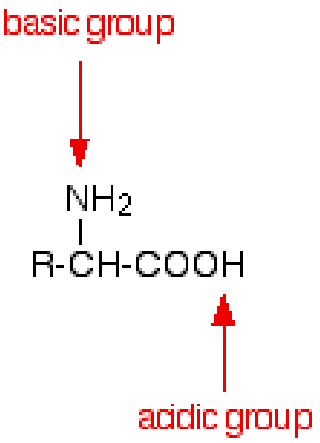

Mirror
COOH
H_2N
C
H
R
L-amino acid
COOH
H
C
NH_2
R
D-amino acid
Mirror
Left hand
Right hand


COOH
H_2N
C*
H
CH_3
L-Alanine
COOH
H
C*
NH_2
CH_3
D-Alanine
imaginary
mirror

- **The amino acids that are incorporated into natural peptides and proteins are of the L-configuration.**
- Only L-amino acids are intermediates in metabolic reactions in animal and human tissues, which is due to the chirality of biological catalysts *enzymes*

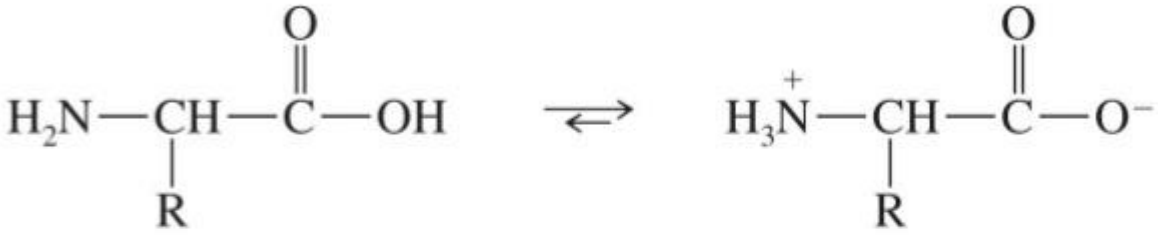
The acid-base characteristics of amino acids

- Amino acids are heterofunctional compounds. They have two different functional groups: an amine group ($—NH_2$) and a carboxyl group (-COOH).
- In water solutions the basic amine group and the acidic carboxylic acid group can react with each other.



Formation of ionic and dipolar (zwitterions) forms of amino acid

Zwitterion Formation



- Amino acid exists as a dipolar ion.
- —COOH loses H^+, —NH_2 gains H^+.
- Actual structure depends on pH.

- the substances, which are capable of exhibiting both acidic and basic properties, reacting with both bases and acids, are named ***amphoteric electrolytes*** or ***ampholytes.***
- ***amino acids*** which contain separate acidic and basic groups within one molecule, ***are the ampholytes*** too
- at low pH the carboxyl group accepts a proton and becomes uncharged, so that the overall charge on the molecule is positive ***(cationic form*** of amino acid) and the amino acid behaves as *an acid.*
- At high pH, the amine group loses its proton and becomes uncharged; thus the overall charge on the molecule is negative ***(anionic form*** of amino acid) and the amino acid becomes *a base.*

Isoelectric point of amino acids (pI)

- Is defined as the pH of a solution, at which amino acid exist as the zwitterion

Biochemical reactions of proteinogenic L-amino acids

These biochemical reactions take place under the action of the special catalysts of a protein nature named ***enzymes***.

The general ways of amino acids degradation:

- **Deamination**
- **Transamination**
- **Decarboxilation**

The major site of amino acid degradation - the liver.

Deamination of amino acids

Deamination - ***elimination of amino group from amino acid with ammonia formation.***

Four types of deamination:

- ***oxidative*** (the most important for higher animals),
- ***reduction,***
- ***hydrolytic, and***
- ***intramolecular***

Deamination of aminoacids

Reduction deamination:

$$R\text{-}CH(NH_2)\text{-}COOH + 2H^+ \rightarrow R\text{-}CH_2\text{-}COOH + NH_3$$

amino acid *fatty acid*

Hydrolytic deamination:

$$R\text{-}CH(NH_2)\text{-}COOH + H_2O \rightarrow R\text{-}CH(OH)\text{-}COOH + NH_3$$

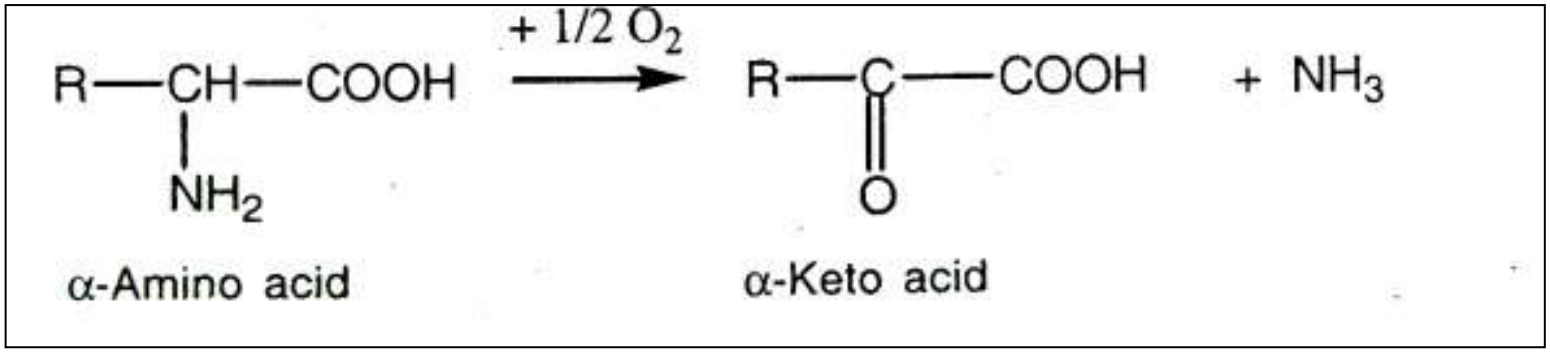
amino acid *hydroxyacid*

Intramolecular deamination:

$$R\text{-}CH(NH_2)\text{-}COOH \rightarrow R\text{-}CH\text{-}CH\text{-}COOH + NH_3$$

amino acid *unsaturated fatty acid*

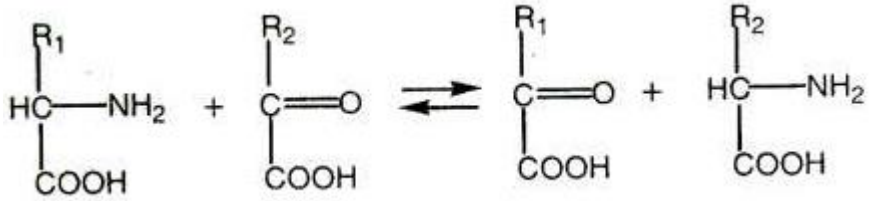
oxidative deamination:



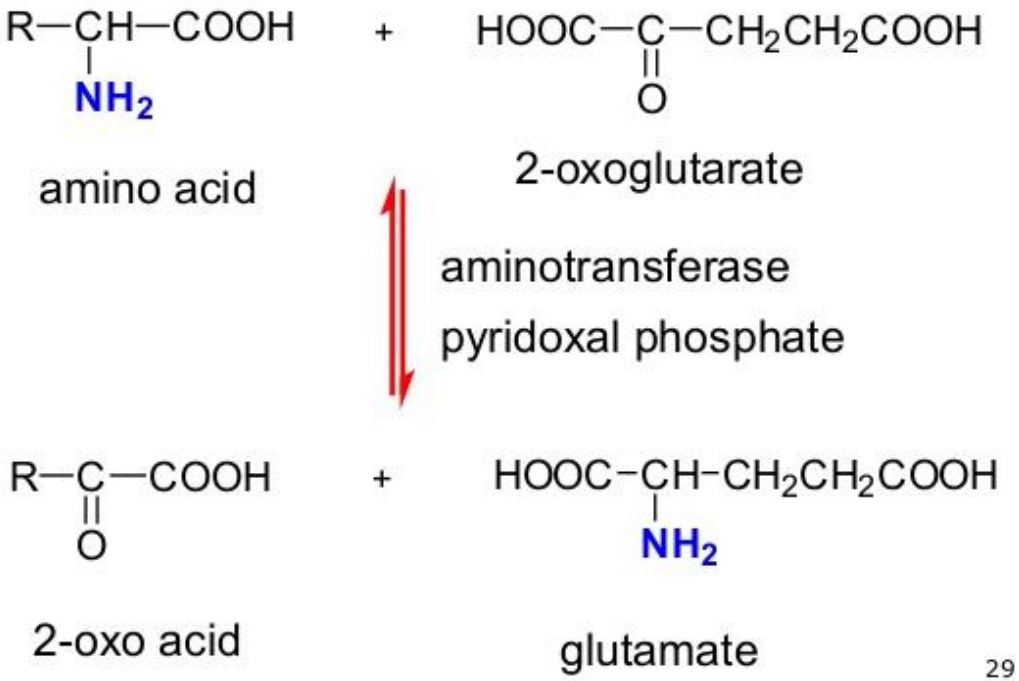
Transamination of amino acids

Transamination *transfer of an amino group from an α-amino acid to an α-keto acid (usually to α-ketoglutarate)*

Enzymes: *aminotransferases (transaminases).*

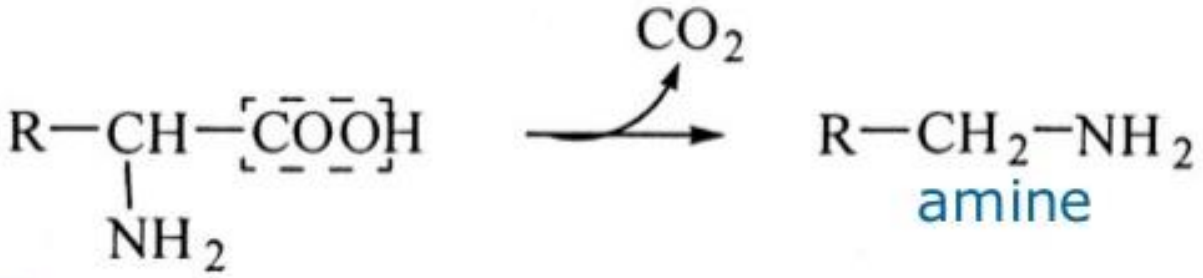


General scheme of oxydative transamination



Decarboxylation of amino acids

Decarboxylation – removal of *carbon dioxide* from amino acid with formation of *amines*.



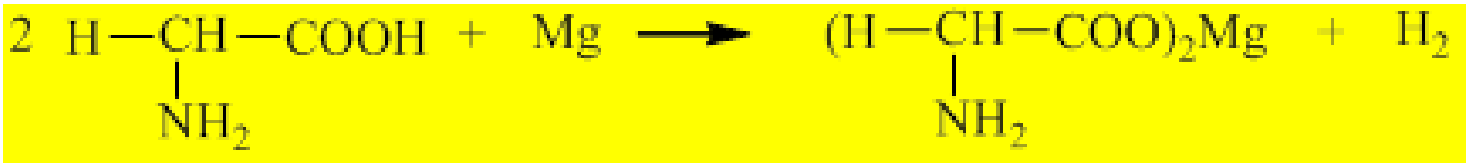
Usually amines have high physiological activity (hormones, neurotransmitters etc).

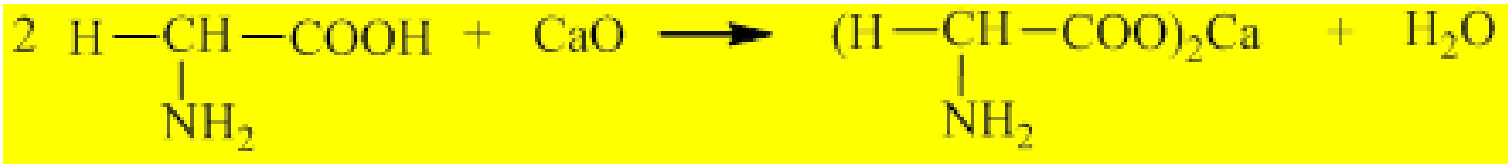
Enzyme: ***decarboxylases***

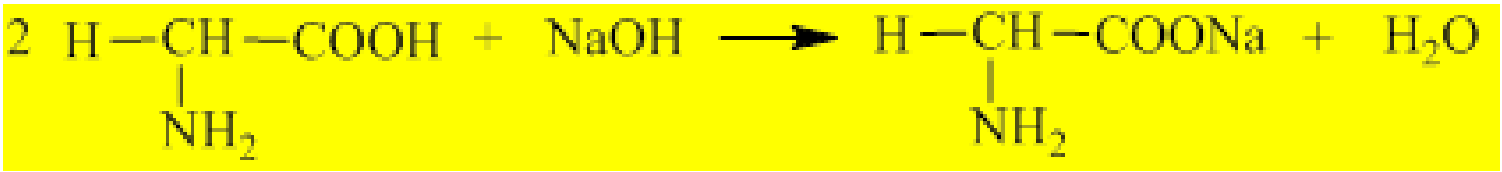
Coenzyme – **pyrydoxalphosphate**

REACTION OF ***–COOH*** GROUP

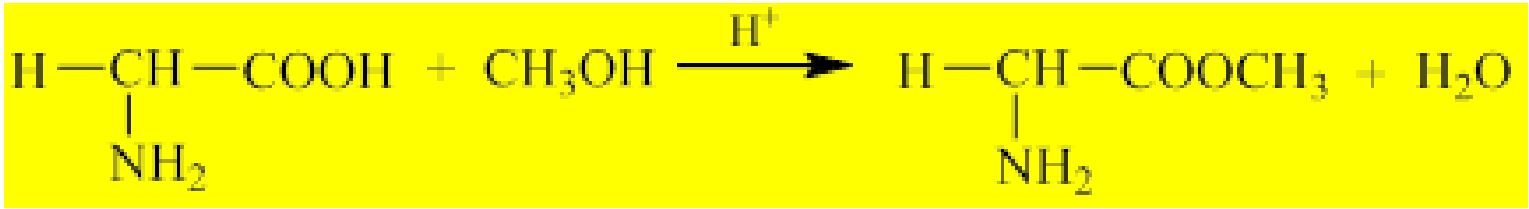
Reaction with **Mg, CaO, NaOH**







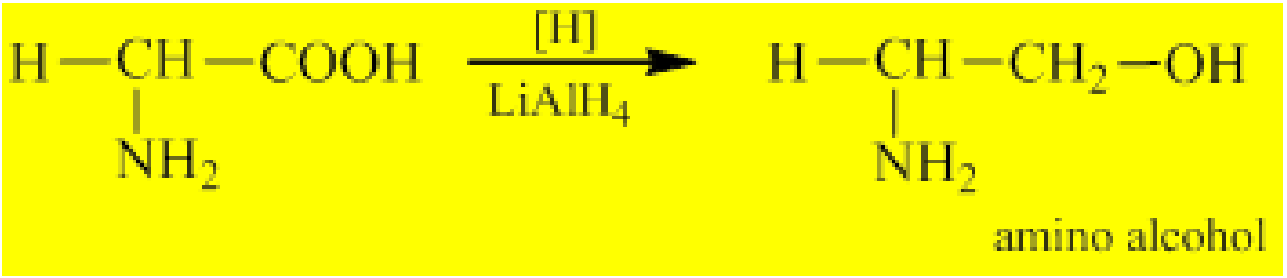
Esterification



Decarboxylation

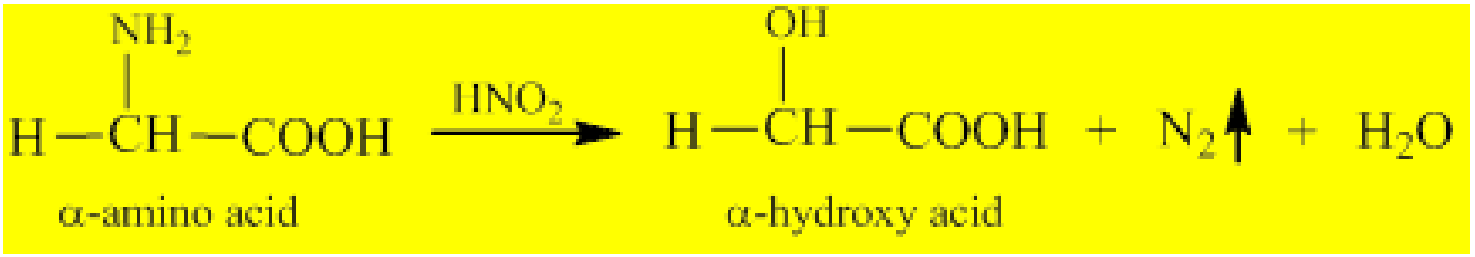
- *in vitro* $H_2N–CH_2–COOH \xrightarrow{Ba(OH)_2, t} H_2N–CH_3 + BaCO_3\downarrow + H_2O$

Reduction to amino alcohol *(in vitro):*

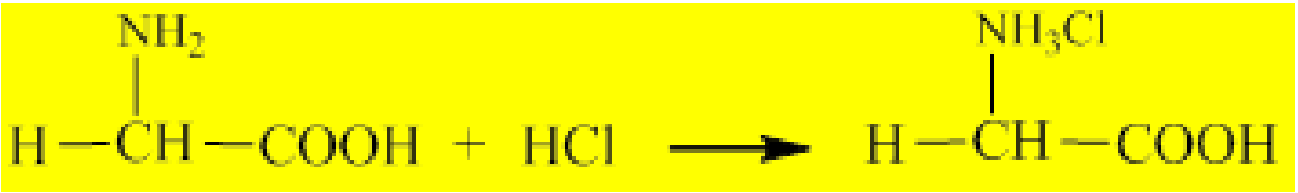


REACTION OF NH2- GROUP

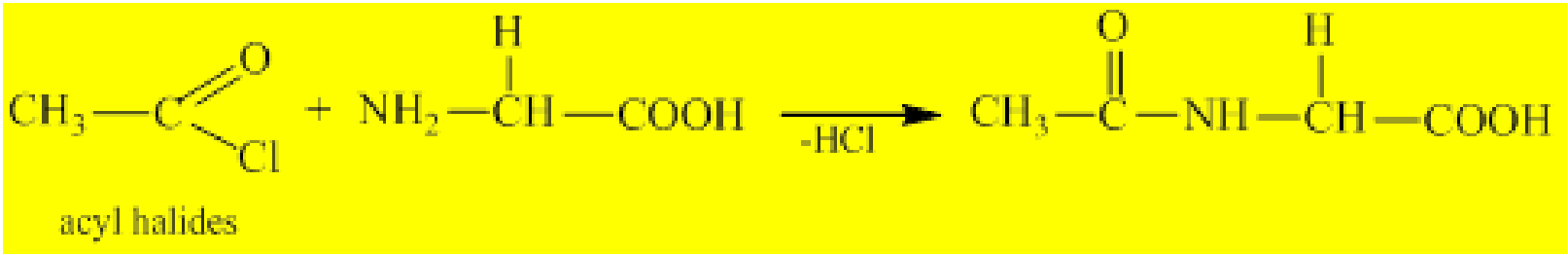
Reaction with HNO_2 (nitrous acid)



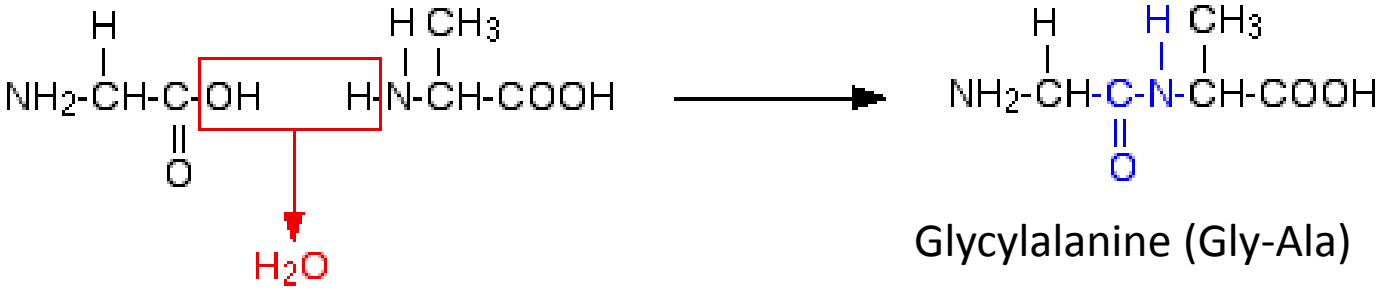
Salt formation with acids:



Acylation

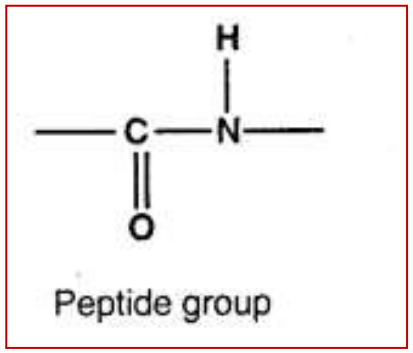


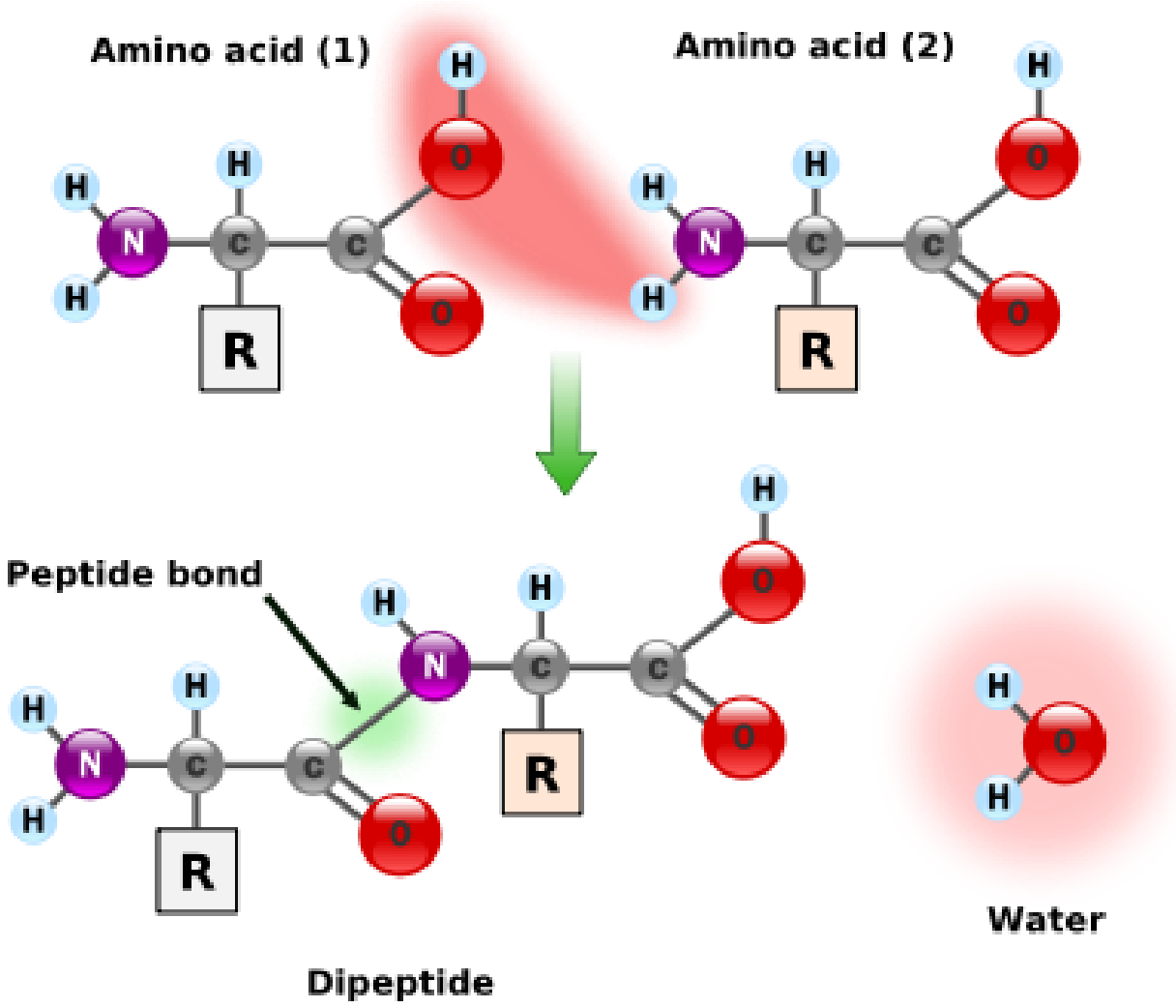
Peptide bond formation



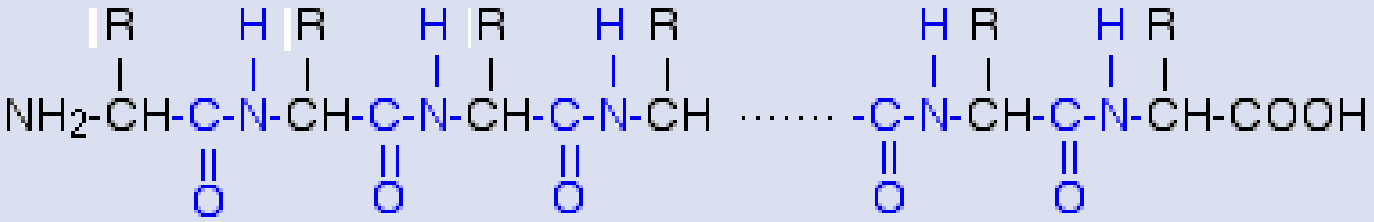
Glycylalanine (Gly-Ala)

The **peptide bond** (—**CO**—**NH**—) is the bond formed between the a-carboxyl group of one amino acid and the a-amino group of another.

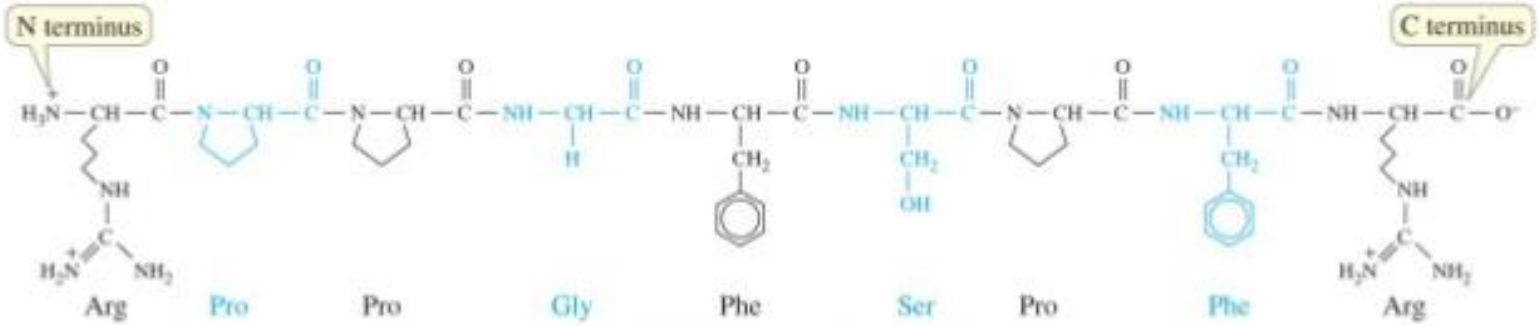



Amino acid (1)
Amino acid (2)
Peptide bond
Dipeptide
Water
H
N
C
O
R

- When joined three amino acids together, would get a tripeptide.
- When joined lots and lots together (as in a protein chain), get a ***polypeptide***.
- The end of the peptide chain with the -NH_2 group is known as the ***N-terminal***, and the end with the -COOH group is the ***C-terminal***.



Human Hormone Bradykinin



- An oligopeptide is made out of four to ten amino acids.
- Peptide structures are drawn with the N-terminal end at the left.
- Peptides are named from left to right: arginylprolylprolyl……arginine.

Proteins

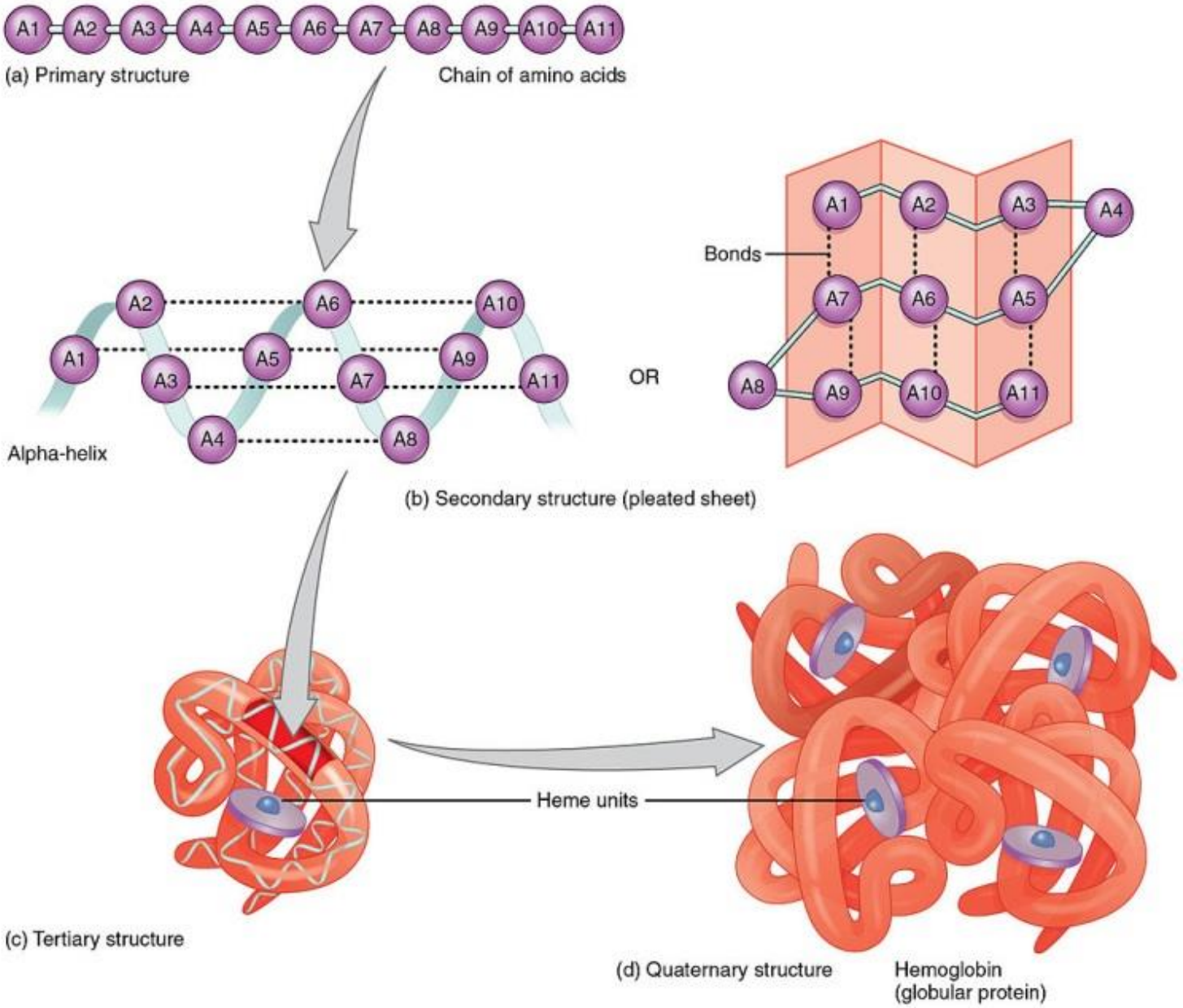
Levels of proteins structure

Proteins

- Biopolymers of α-amino acids.
- Amino acids are joined by peptide bond.
- They serve a variety of functions:
  - Structure
  - Enzymes
  - Transport
  - Protection
  - Hormones

- ***Primary structure*** is the amino acid sequence in polypeptide chain that forms a protein
- ***Secondary structure*** refers to the spatial arrangement of amino acid residues that constitute polypeptide linear sequence.
- ***Tertiary structure*** refers to the spatial arrangement of amino acids residues that are far apart in the linear sequence.
- **Quaternary structure** of a protein refers to the spatial arrangement of individual subunits and the nature of their contact.

Protein denaturation changes the solubility of individual protein molecules, entrapping solvent water into a semisolid gel structure.


A1
A2
A3
A4
A5
A6
A7
A8
A9
A10
A11
(a) Primary structure
Chain of amino acids
Alpha-helix
Bonds
OR
(b) Secondary structure (pleated sheet)
Heme units
(c) Tertiary structure
(d) Quaternary structure
Hemoglobin
(globular protein)