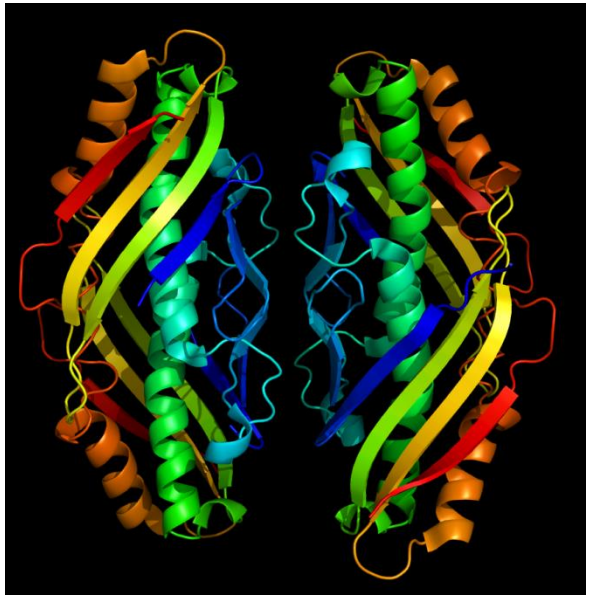
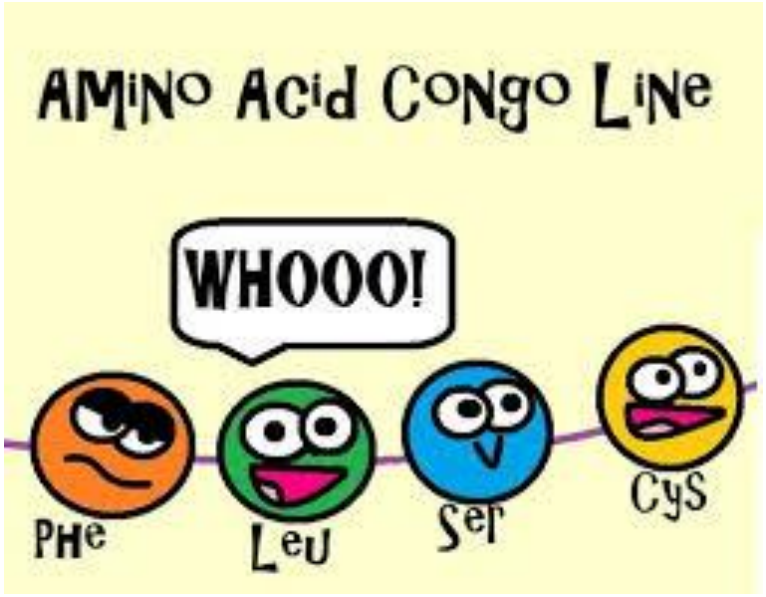
Amino Acids and Proteins

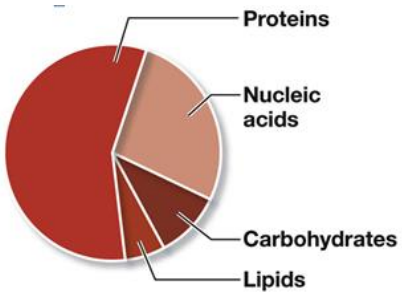




Amino Acids

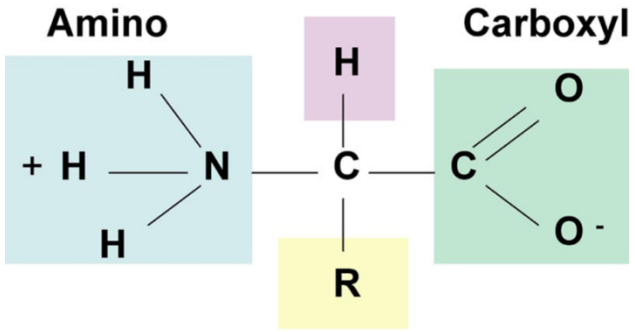
- **Amino Acids are organic compounds containing amine (-NH2) and carboxyl (-COOH) functional groups, along with a side chain (R group) specific to each amino acid. They are the building blocks of proteins, and many of them are important intermediates in metabolism.**
- **Proteins are complex organic polymers of amino acids linked together by a " peptide bond". They occur in the every part of the cell and constitute more than 50% of the cellular dry weight**

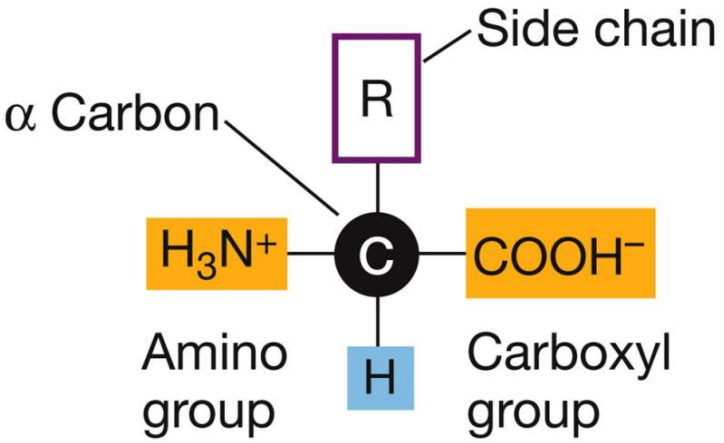
proteins are the major components of an actively growing cell



Amino Acids Structure

There are about 300 AA occur in nature. Only 20 of them are common in human proteins.





C is asymmetrical

What is an 'amino acid'?

An organic molecule possessing both carboxyl and amino groups

Functions of Proteins

- **Structural** — **Collagen**; bones, tendons, cartilage
  Keratin; hair, skin, wool, nails, feathers
- **Movement** — **Myosin & Actin**; muscle contractions
- **Transport** — **Hemoglobin**; transports O_2
  Lipoproteins; transports lipids
- **Storage** — **Casein**; in milk. **Albumin**; in eggs
- **Hormone** — **Insulin**; regulates blood glucose
  Growth hormone; regulates growth
- **Protection** — **Immunoglobulins**; stimulate immunity
  Snake venom; **plant toxins**;
- **Enzymes** — **Sucrase**; catalyzes sucrose hydrolysis
  Pepsin; catalyzes protein hydrolysis

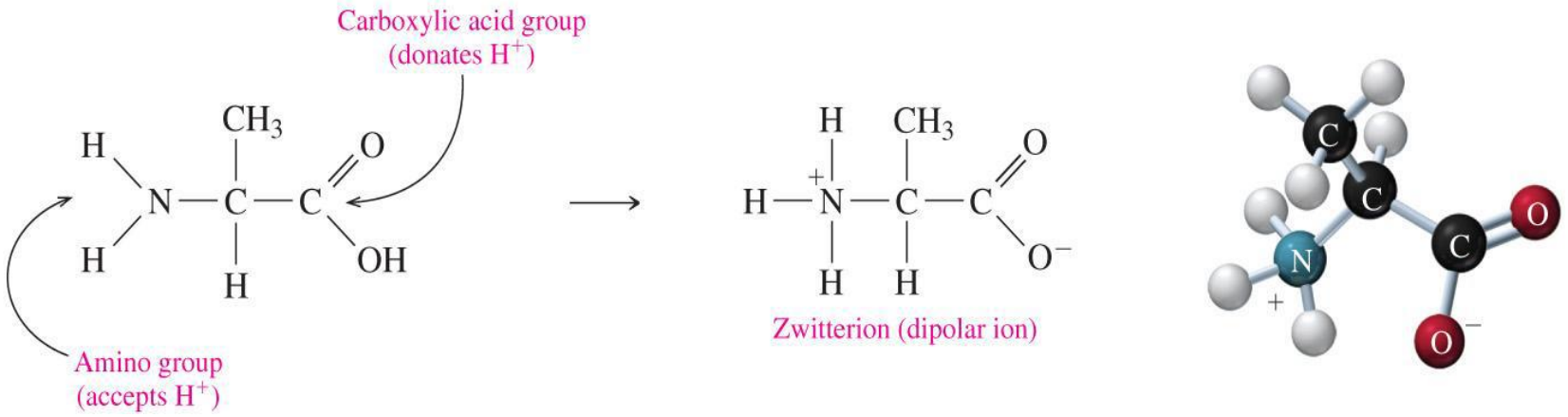
Functions of AA (cont.)

- The linear sequence of amino acid residues in a polypeptide chain determines the 3D configuration of a protein, and the structure of a protein determines its function.
- Besides synthesizing proteins, AA are used to produce nitrogen-containing compounds (e.g., purines, pyrimidines, heme, creatine, epinephrine), or are oxidized to produce energy.
- The breakdown of proteins yields **nitrogen-containing substrates and carbon skeletons**.
- AA are ionized in solutions.

Ionization of AA

At the pH of most bodily fluids, amino acids are ionized:

- The carboxylic acid group (−COOH) donates an H+ to the amino group (−NH2) to give a carboxylate (−COO−) and ammonium group (−NH3+).
- The ionized form is called a **zwitterion**.



Zwitter ion or dipolar ion :

- **Zwitter ion is a hybrid molecule containing positive and negative ionic groups.**
- **The amino acids rarely exist in a neutral form with free carboxylic and free amino groups:**
- **In strongly acidic pH, the amino acid is positively charged (cation)**
- **In strongly alkaline pH, the amino acid is negatively charged (anion)**

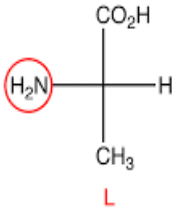
Amino Acid	3-Letters	1-Letter
Alanine	Ala	A
Arginine	Arg	R
Asparagine	Asn	N
Aspartic acid	Asp	D
Cysteine	Cys	C
Glutamic acid	Glu	E
Glutamine	Gln	Q
Glycine	Gly	G
Histidine	His	H
Isoleucine	Ile	I
Leucine	Leu	L
Lysine	Lys	K
Methionine	Met	M
Phenylalanine	Phe	F
Proline	Pro	P
Serine	Ser	S
Threonine	Thr	T
Tryptophan	Trp	W
Tyrosine	Tyr	Y
Valine	Val	V

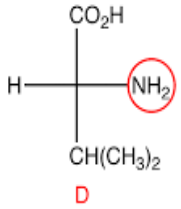
Optical isomers of amino acids

- **If a carbon atom is attached to four different groups, it is asymmetric and therefore exhibits isomerism تصاوغ.**
- **The amino acids (except glycine) possess four distinct groups (R, H, COO-, NH3+) held by a α-carbon.**
- **Thus all the amino acids have optical isomers.**
- **The proteins are composed of L- α-amino acids:**

Amino acids exist in two isomeric forms:

- **D-amino acids (*dextro*, "right")**
- **L-amino acids (*laevo*, "left")—this form is found in organisms**





In proteins, all AA are L-isomers; no D-isomers are found

Different Classification of Amino Acids

1☺ Nutritional classification:

2☺ Metabolic classification:

4☺ Classification on the basis of polarity of the side chain(R):

3☺ Chemical classification:

1-NUTRITIONAL CLASSIFICATION

Essential amino acids:

- must be taken in with the diet
- the body cannot make them (e.g. methionine, leucine, isoleucine)

Non-essential amino acids:

- can be synthesized by the body (e.g. cysteine, alanine, aspargine, aspartate)

2-Based on their metabolic fate:

Glucogenic & Ketogenic Amino Acids

Glucogenic Amino Acids

Amino acids whose catabolism yields pyruvate or one of the intermediates of citric acid cycle i.e. substrates of gluconeogenesis & therefore can give rise to GLUCOSE

Ketogenic Amino Acids

Amino Acids whose catabolism Yields acetyl CoA or acetoactyl CoA i.e. finally give rise to ketone bodies

Leucine& lysine are the only exclusively ketogenic amino acids & therefore cannot give rise to glucose

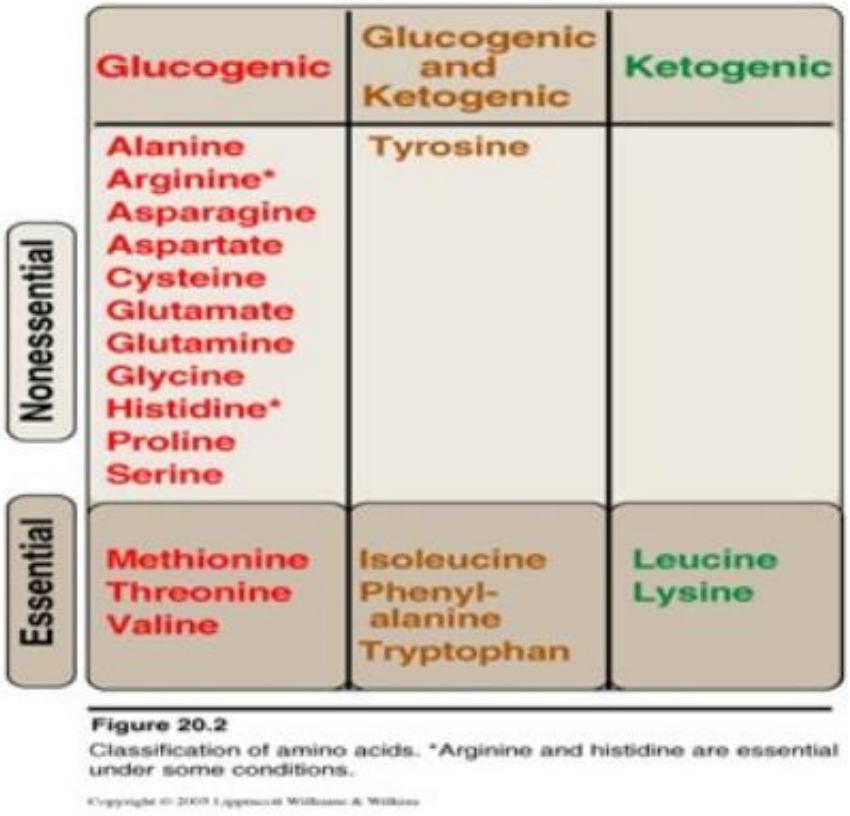


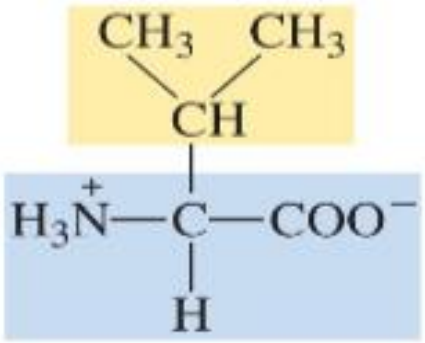
Figure 20.2
Classification of amino acids. *Arginine and histidine are essential under some conditions.

3-Based on their polarity: there are 2 Types of Amino Acids

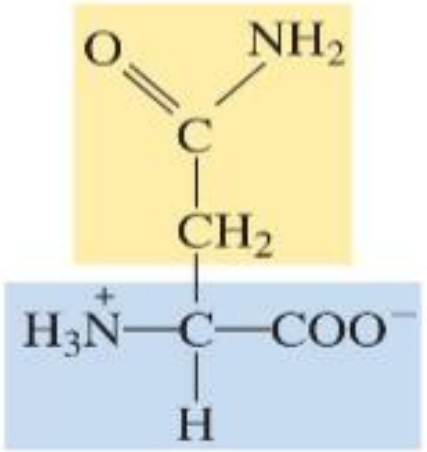
The variation in the R group allows the amino acids to be grouped based on the Polarity of their R group

Amino acids are classified as

- **nonpolar** (hydrophobic) with hydrocarbon side chains
- **polar** (hydrophilic) with polar or ionic side chains



Nonpolar
Valine



Polar
Asparagine

Amino Acid	Residue	3-letter Code	1-letter Code	R-group pK_a	Frequency (%)
Nonpolar					50.1
Glycine	Glycyl	Gly	G		7.1
Alanine	Alanyl	Ala	A		8.3
Proline	Prolyl	Pro	P		4.7
Valine	Valyl	Val	V		6.9
Leucine	Leucyl	Leu	L		9.7
Isoleucine	Isoleucyl	Ile	I		6.0
Tryptophan	Tryptophanyl	Trp	W		1.1
Phenylalanine	Phenylalanyl	Phe	F		3.9
Methionine	Methionyl	Met	M		2.4
Polar uncharged					24.0
Serine	Seryl	Ser	S		6.5
Threonine	Threonyl	Thr	T		5.3
Cysteine	Cystyl	Cys	C	8.4	1.4
Asparagine	Asparagyl	Asn	N		4.0
Glutamine	Glutaminyl	Gln	Q		3.9
Tyrosine	Tyrosyl	Tyr	Y	10.5	2.9
Polar charged					25.9
Histidine	Histidyl	His	H	6.0	2.3
Lysine	Lysyl	Lys	K	10.5	5.9
Arginine	Arginyl	Arg	R	12.5	5.5
Aspartate	Aspartyl	Asp	D	3.9	5.4
Glutamate	Glutamyl	Glu	E	4.1	6.8

CLASSIFICATION ACCORDING TO POLARITY OF SIDE CHAIN (R):

A- Polar amino acids: in which R contains polar hydrophilic group. In those amino acids, **R may contain**:

1- OH group : as in serine, threonine and tyrosine

2- SH group : as in cysteine

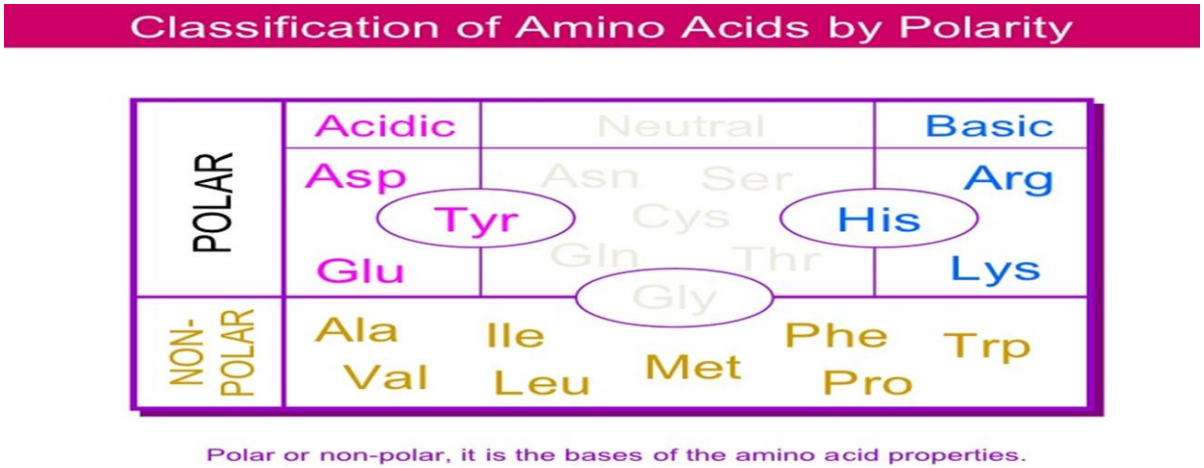
3- amide group: as in glutamine and aspargine

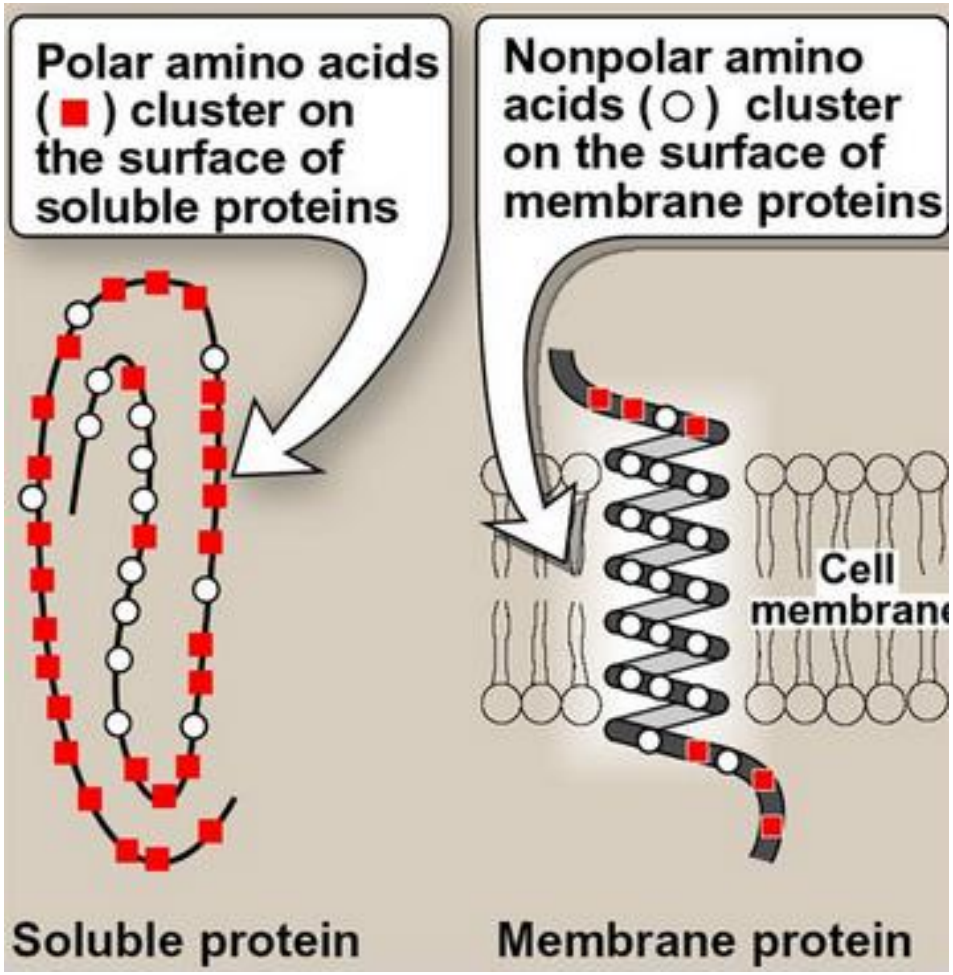
4- NH_2 group or nitrogen act as a base (basic amino acids): as lysine, arginine and histidine

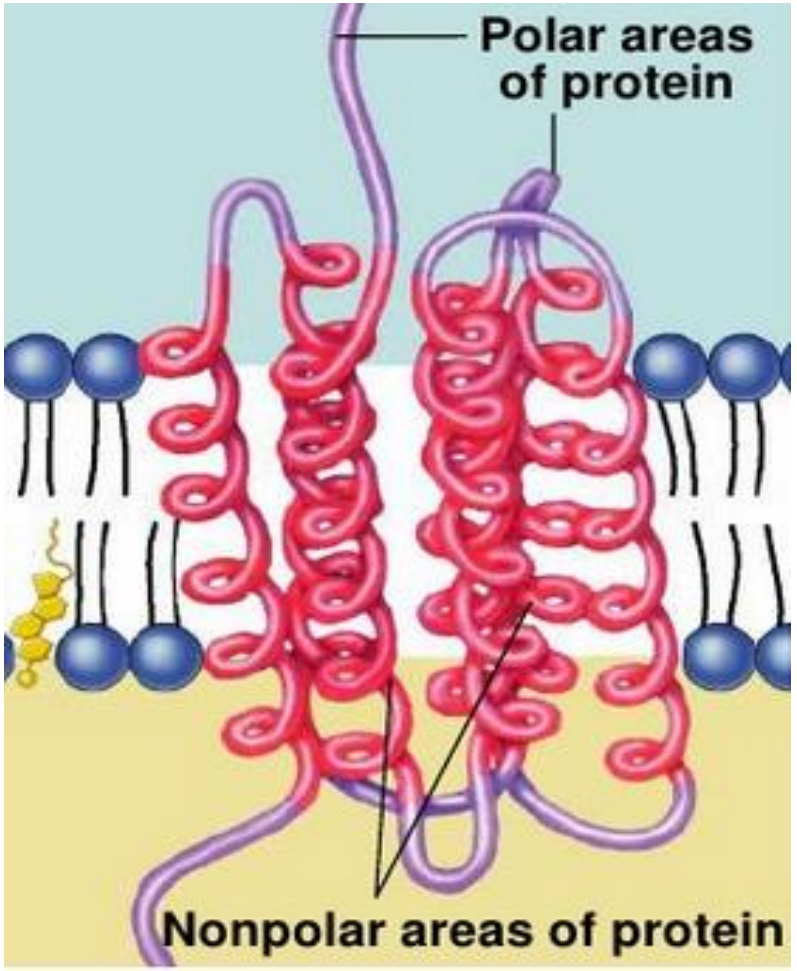
5- COOH group (acidic amino acids): as aspartic and glutamic Ac. .

B- Non polar amino acids:

R is alkyl hydrophobic group: (glycine, alanine, valine, leucine, isoleucine, phenylalanine, tryptophan, proline and methionine)

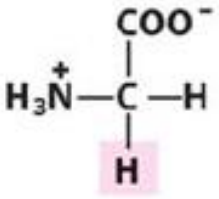



Polar amino acids (■) cluster on the surface of soluble proteins
Nonpolar amino acids (○) cluster on the surface of membrane proteins
Cell membrane
Soluble protein
Membrane protein

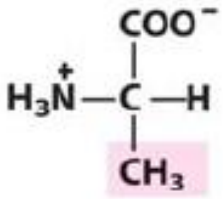

Polar areas of protein
Nonpolar areas of protein

Amino Acids

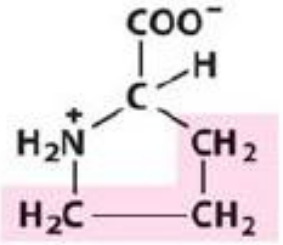
The Seven Aliphatics (Non-polar)



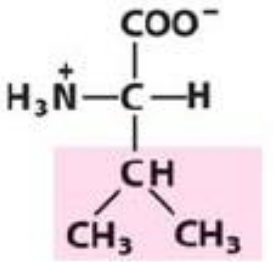
Glycine



Alanine

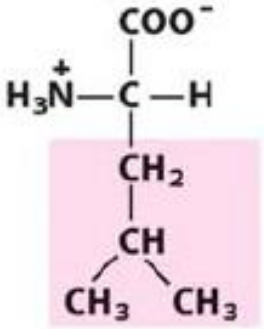


Proline

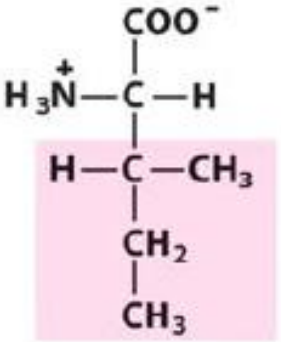


Valine

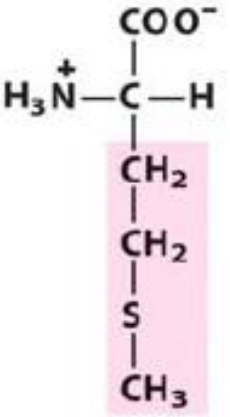
These seven amino acids tend to cluster together within proteins, stabilizing structure through hydrophobic interactions.



Leucine



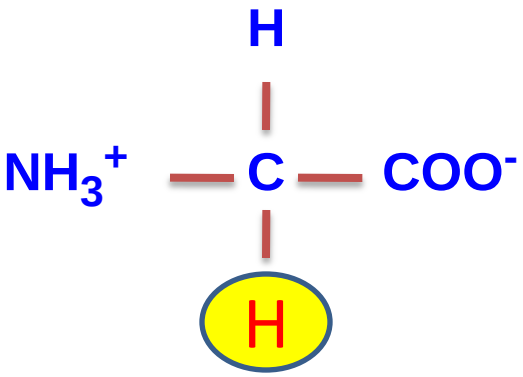
Isoleucine



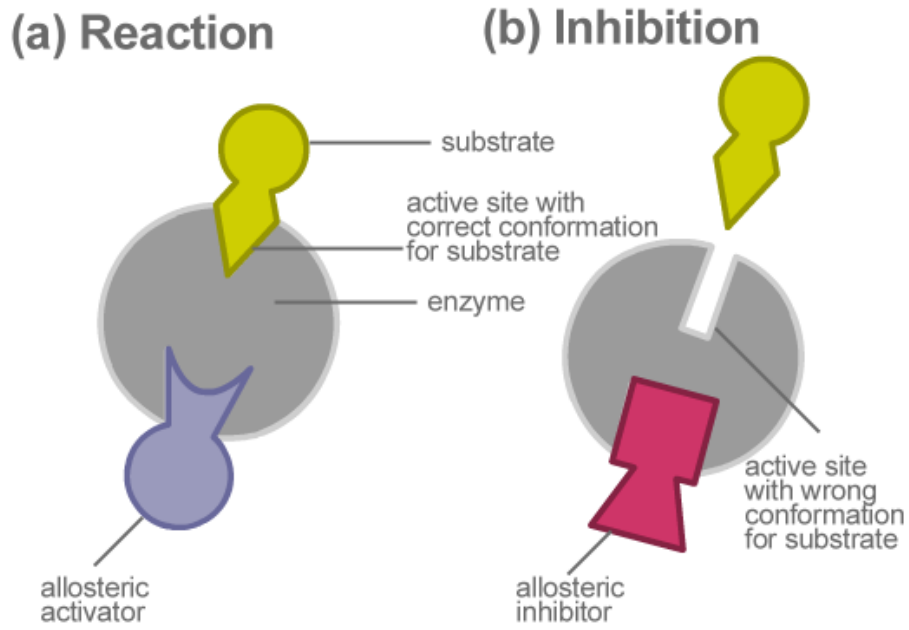
Methionine

Glycine

- **Small, simple amino acid. R – group is hydrogen**
- **It is a non essential amino acid.**
- **Glycine is allosteric inhibitor مثبط تفارغي of glutathione synthetase.**

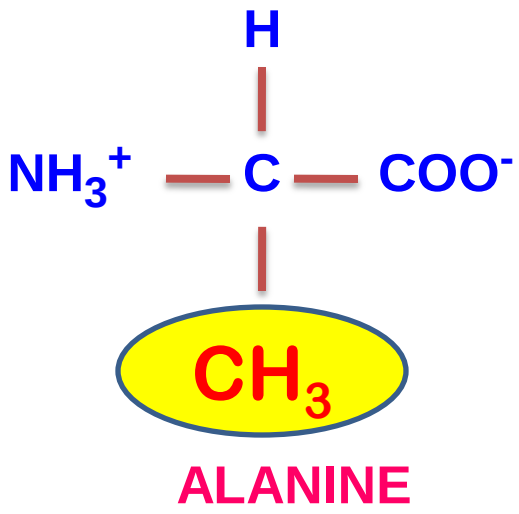


GLYCINE



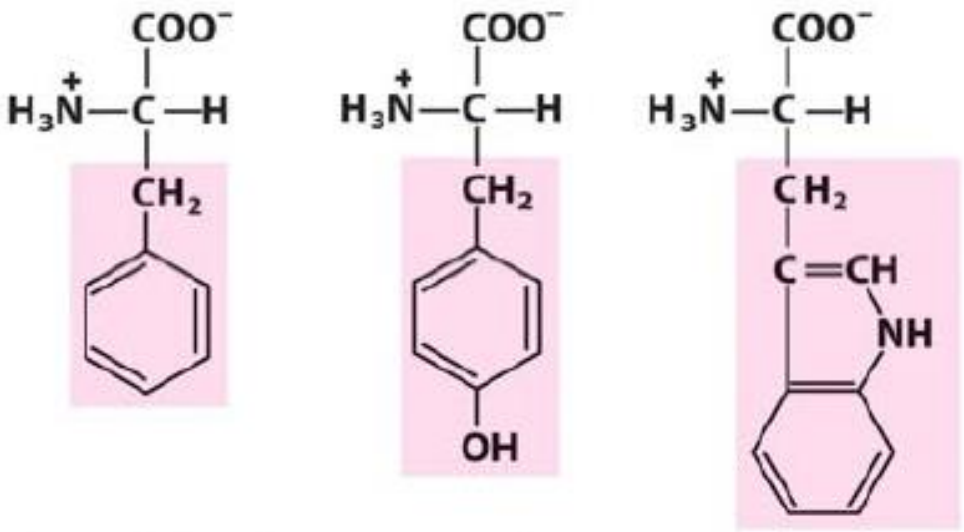
Alanine

- **It is a non essential amino acid. Alanine is allosteric inhibitor of glutathione synthetase.**
- **D-Alanine: is a component of bacterial cell wall.**



Amino Acids

The Three Aromatics

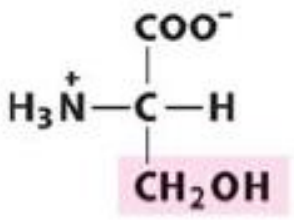


Phenylalanine **Tyrosine** **Tryptophan**

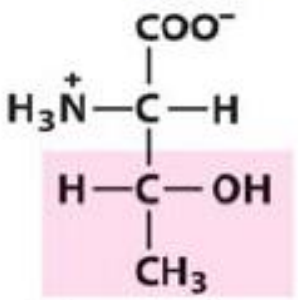
These three amino acids are relatively non-polar and all can participate in hydrophobic interactions. They all also absorb UV light due to their conjugation. The hydroxyl group of Tyr also allows this residue to form hydrogen bonds.

Amino Acids

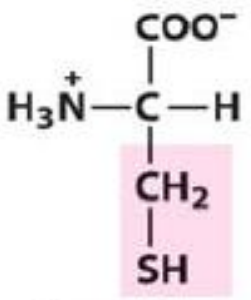
The Five Uncharged (Polar)



Serine

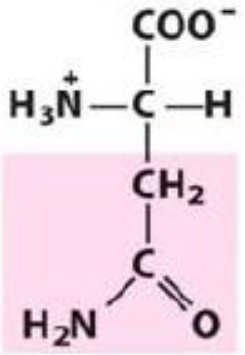


Threonine

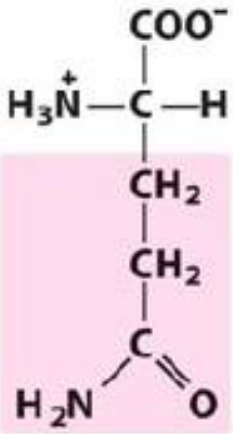


Cysteine

The R groups of these five amino acids are more soluble in water than those of the alphatic AAs due to the presence of hydroxyl, thiol and amide groups.



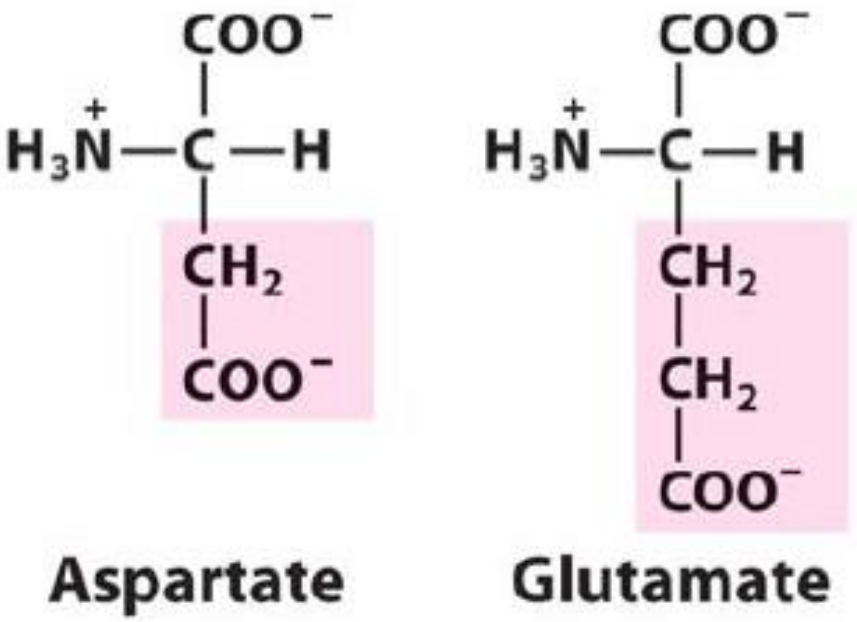
Asparagine



Glutamine

Amino Acids

The Two Acidics

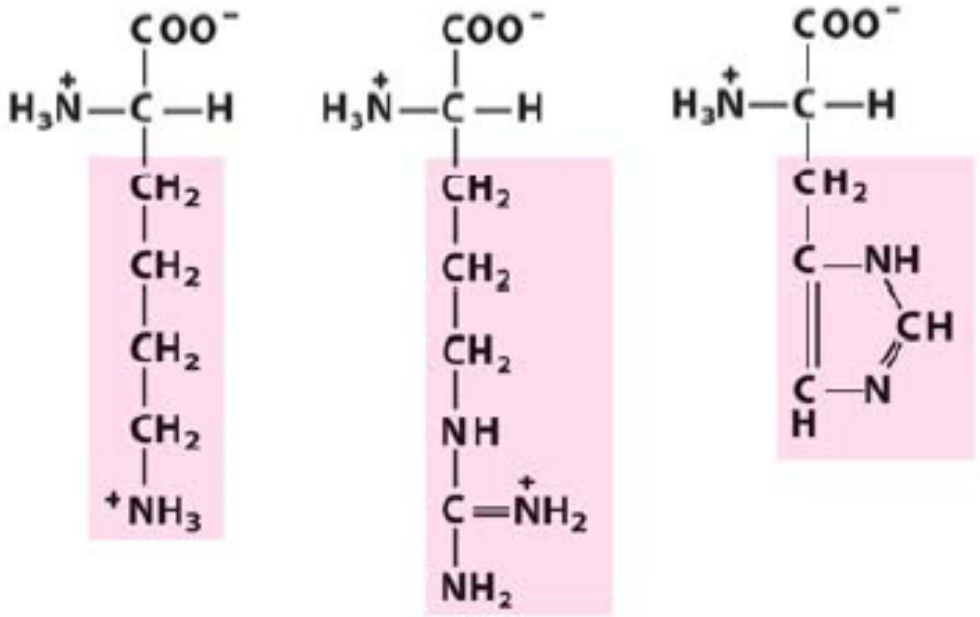


Aspartate **Glutamate**

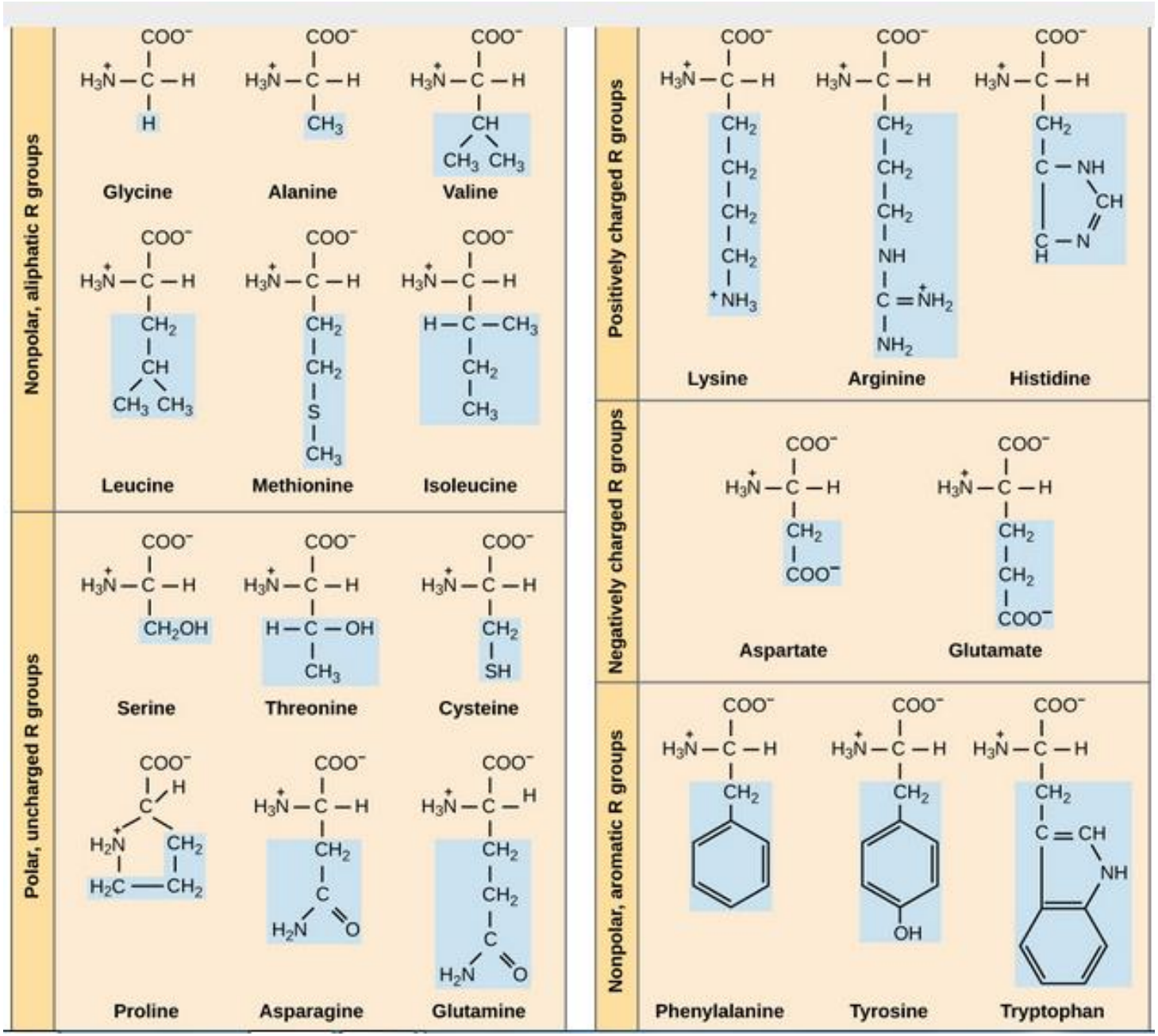
These two amino acids (along with the basic AAs) are the most hydrophilic AAs and can participate in hydrogen bonding interactions as H-bond acceptors.

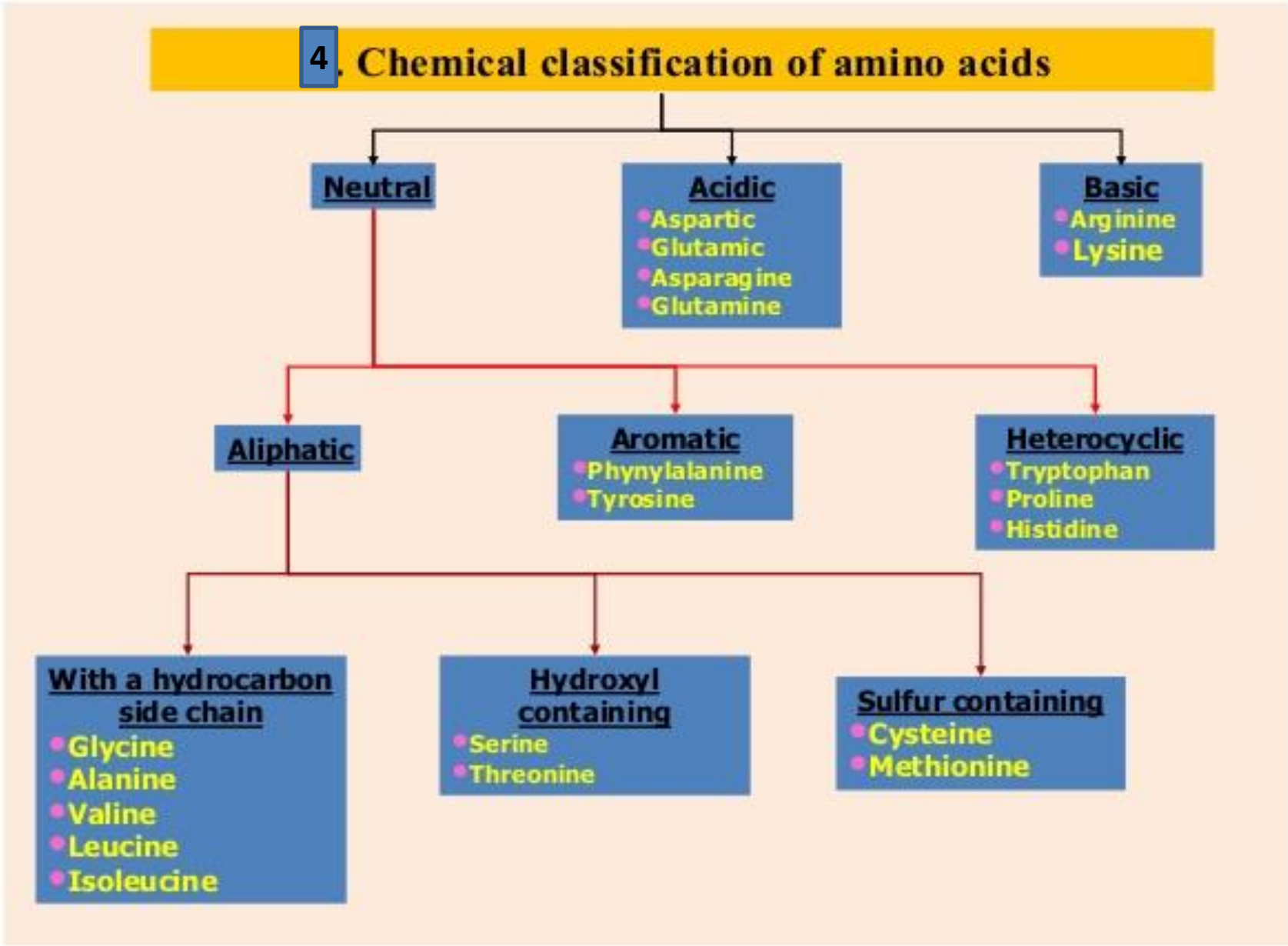
Amino Acids

The Three Basics



These three amino acids (along with the acidic AAs) are the most hydrophilic AAs and can participate in hydrogen bonding interactions as H-bond Donors.


Nonpolar, aliphatic R groups
Glycine
Alanine
Valine
Leucine
Methionine
Isoleucine
Polar, uncharged R groups
Serine
Threonine
Cysteine
Proline
Asparagine
Glutamine
Positively charged R groups
Lysine
Arginine
Histidine
Negatively charged R groups
Aspartate
Glutamate
Nonpolar, aromatic R groups
Phenylalanine
Tyrosine
Tryptophan

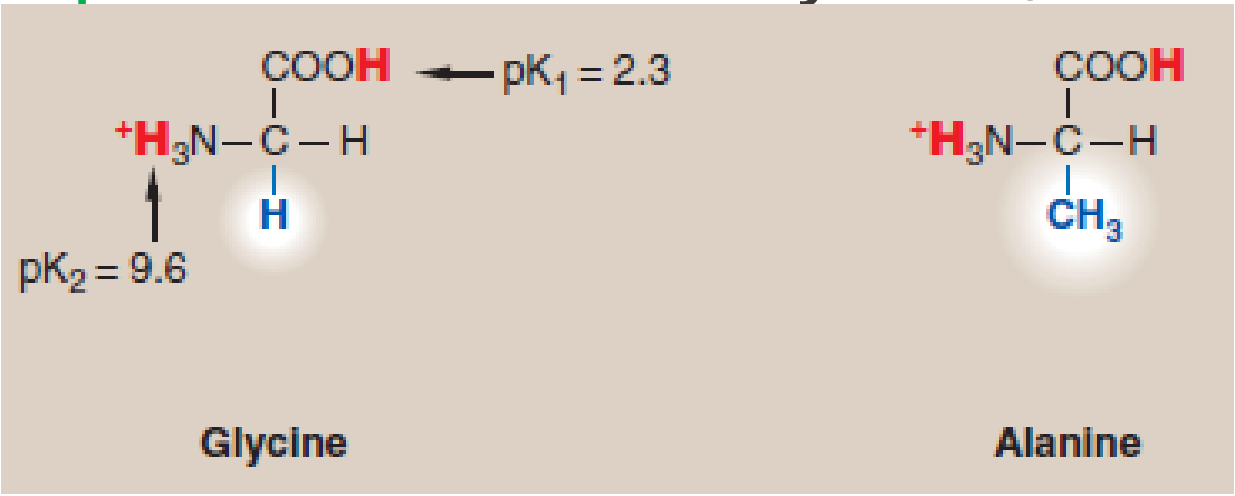

4. Chemical classification of amino acids
Neutral
Acidic
Aspartic
Glutamic
Asparagine
Glutamine
Basic
Arginine
Lysine
Aliphatic
Aromatic
Phynylalanine
Tyrosine
Heterocyclic
Tryptophan
Proline
Histidine
With a hydrocarbon side chain
Glycine
Alanine
Valine
Leucine
Isoleucine
Hydroxyl containing
Serine
Threonine
Sulfur containing
Cysteine
Methionine

4- Chemical Classification of AA

I. Aliphatic Amino Acids:

a) Mono-amino mono-carboxylic acids:

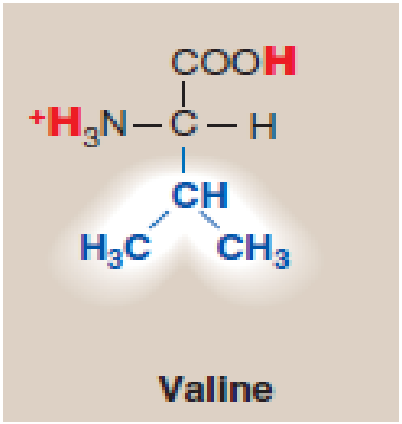
- Simple amino acids: Glycine , Alanine



I. Aliphatic Amino Acids:

a) Mono-amino mono-carboxylic acids:

- Branched chain amino acids: Valine,



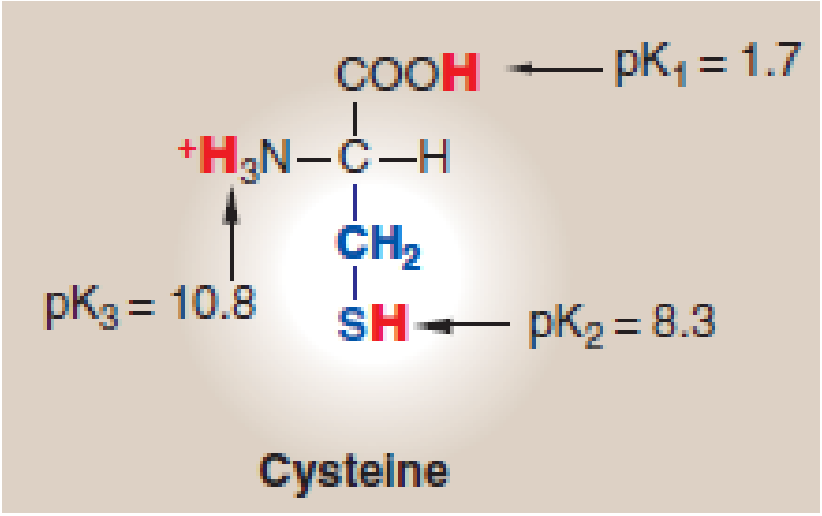
Leucine and Isoleucine

I. Aliphatic Amino Acids:

a) Mono-amino mono-carboxylic acids:

- Sulfur-containing amino acids:

Cysteine, Cystine (Formed by linking of two cysteine residues) and Methionine.



I. Aliphatic Amino Acids:

a) Mono-amino mono-carboxylic acids:

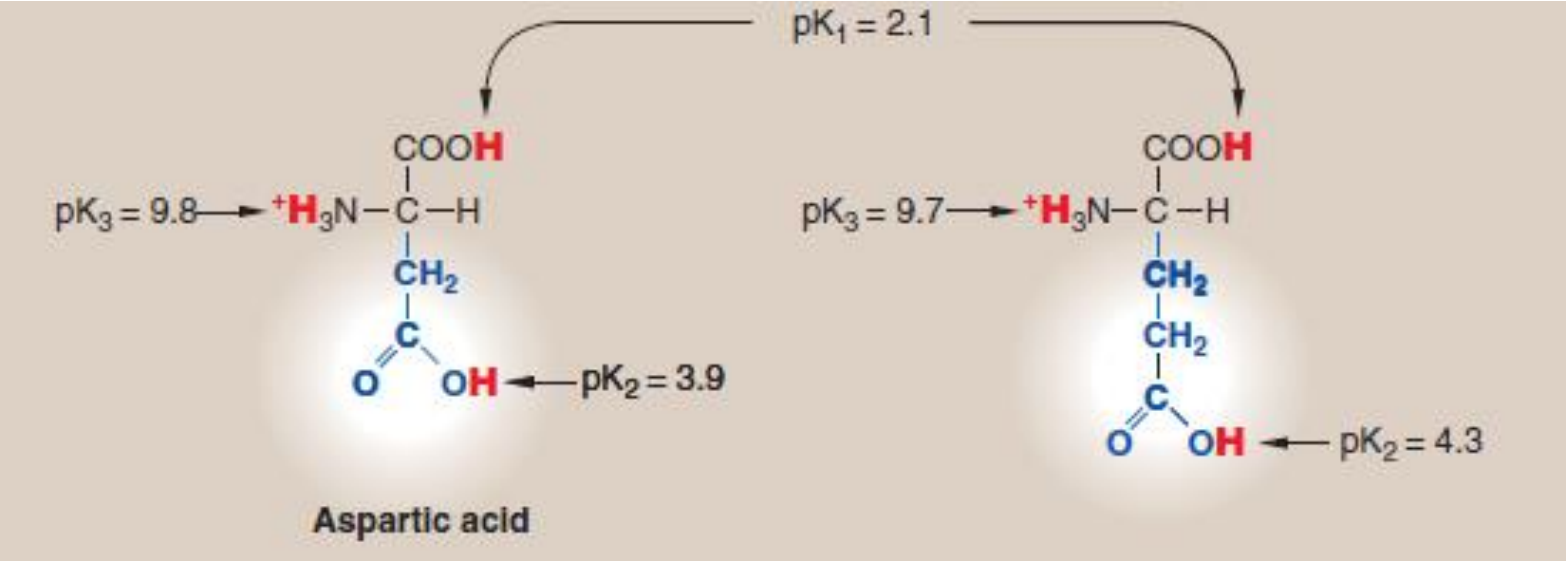
- Amide group-containing amino acids:

Glutamine and Asparagine

I. Aliphatic Amino Acids:

b) Mono-amino di-carboxylic acids:

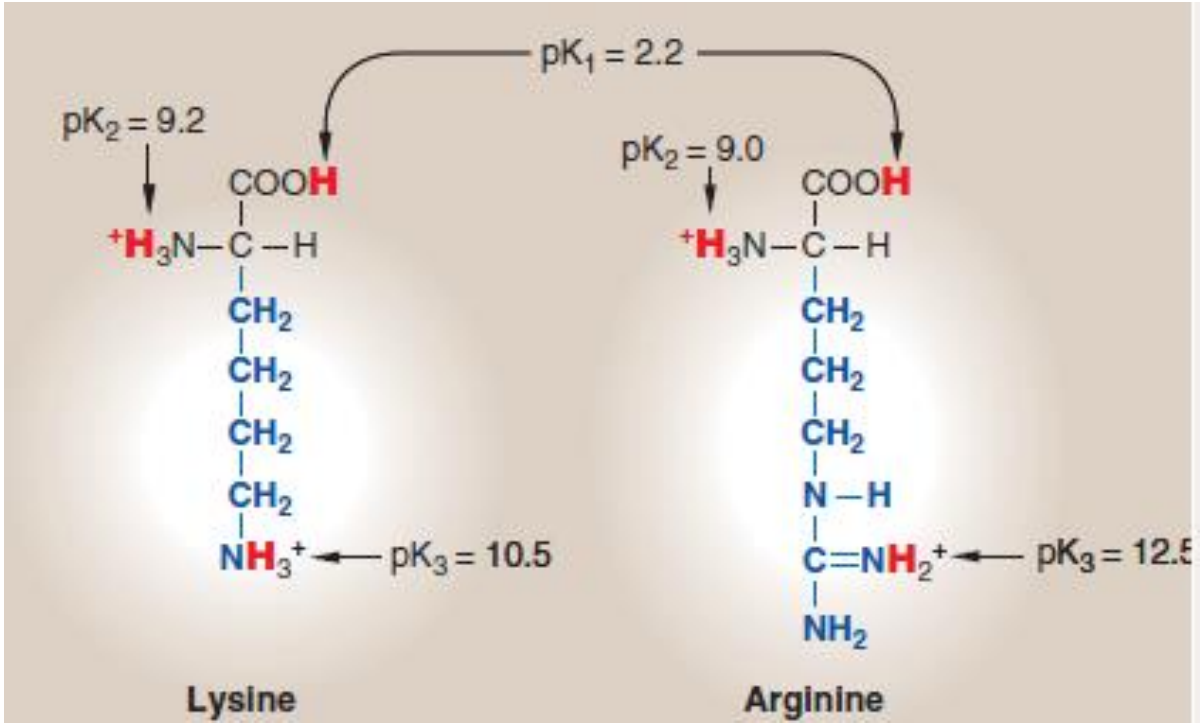
Aspartic acid and Glutamic acid



I. Aliphatic Amino Acids:

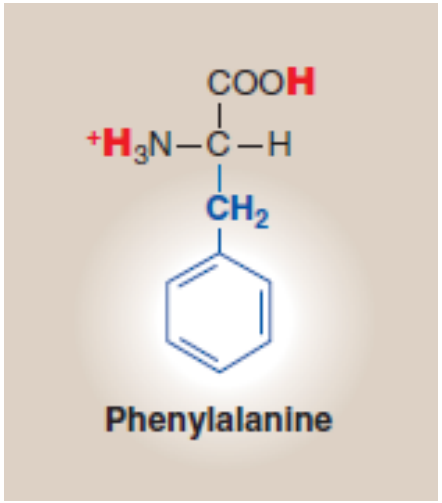
c) Di- amino mono-carboxylic acids:

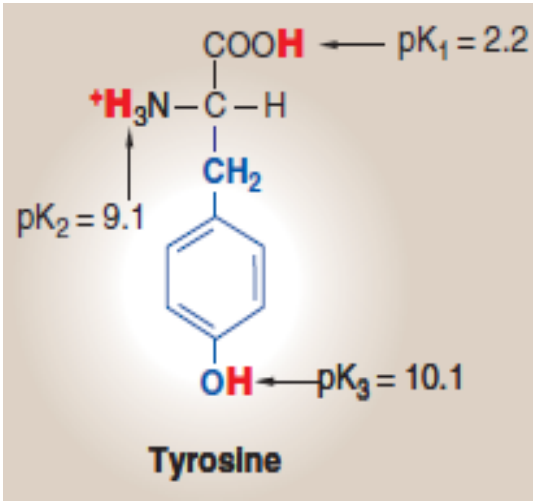
Arginine and Lysine



ii) Aromatic amino acids-

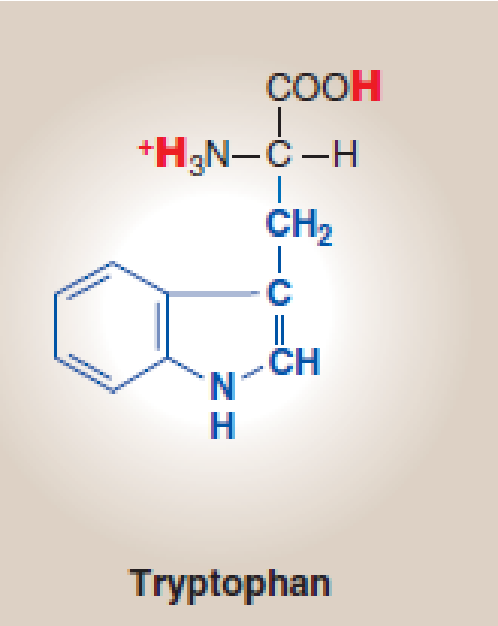
- Phenyl alanine and tyrosine



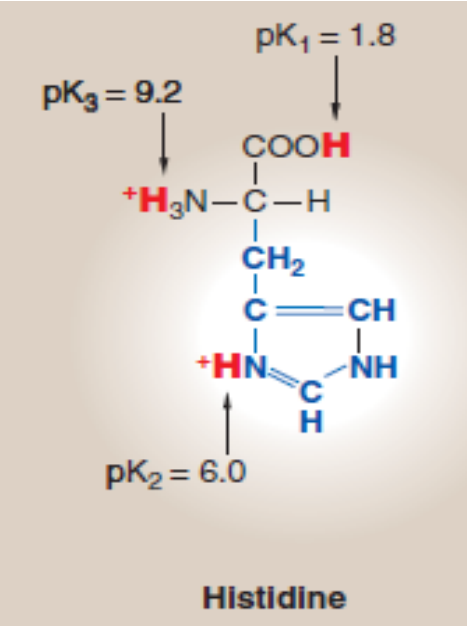


iii) Heterocyclic Amino Acids:

Tryptophan and Histidine



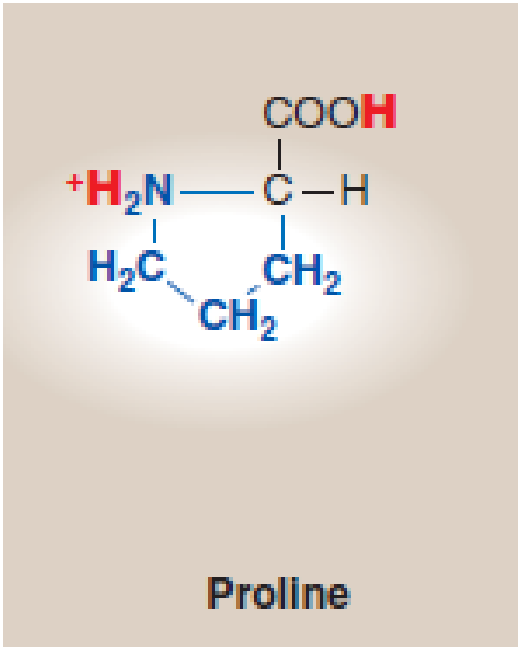
Tryptophan



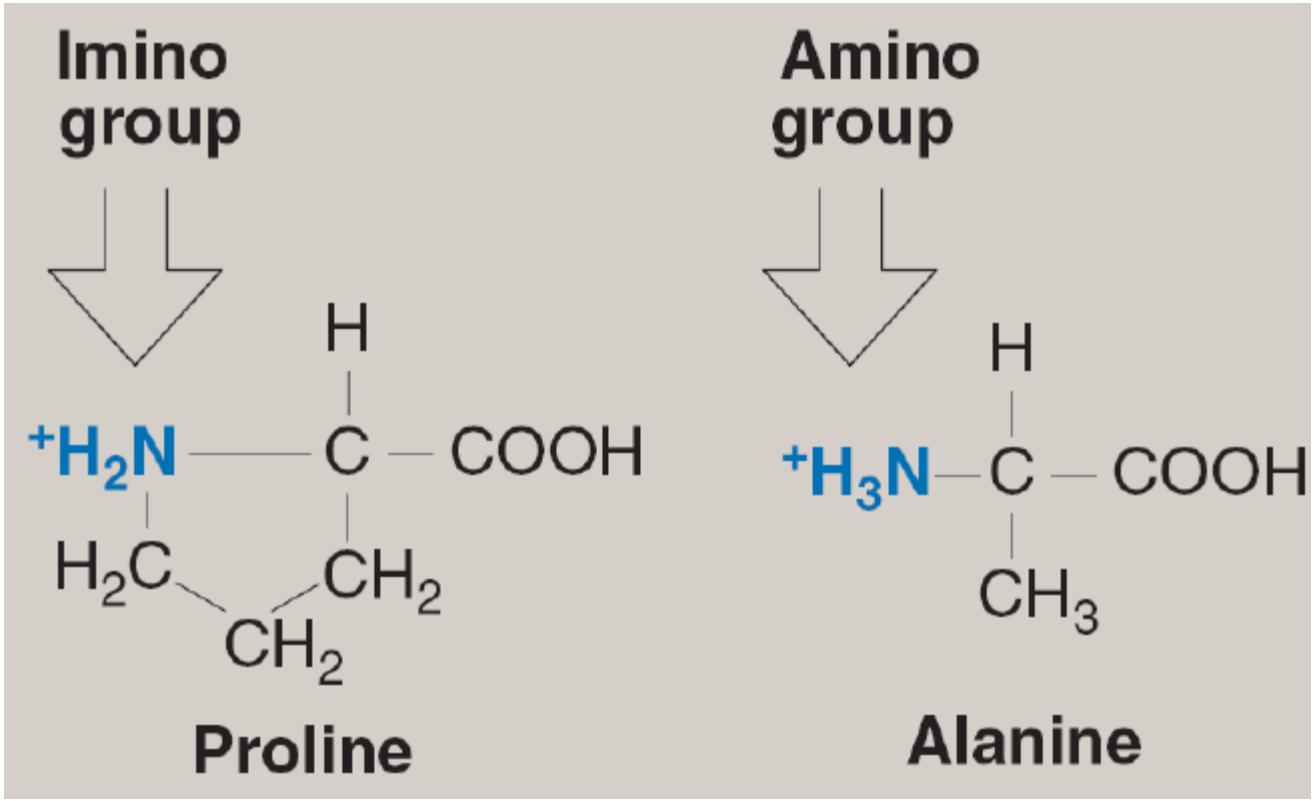
Histidine

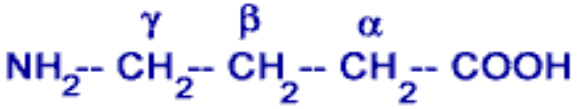
iv) Imino acid-

Proline



Proline containing pyrrolidine ring. Proline is unique amongst the amino acids – its side chain is bonded to the backbone nitrogen as well as to the a-carbon:. Threrefore, proline is an **α- imino acid.**


Imino group
Amino group
H
+H2N
C
COOH
H2C
CH2
CH2
Proline
H
+H3N
C
COOH
CH3
Alanine



V. Derived Amino Acids:

- Non-α-amino acids

e.g.: β-alanine, γ-amino butyric acid (GABA), δ-amino Levulinic acid

- Derived and Incorporated in tissue proteins:

e.g.: Hydroxy-proline, hydroxy-lysine

- Derived but not incorporated in tissue proteins:

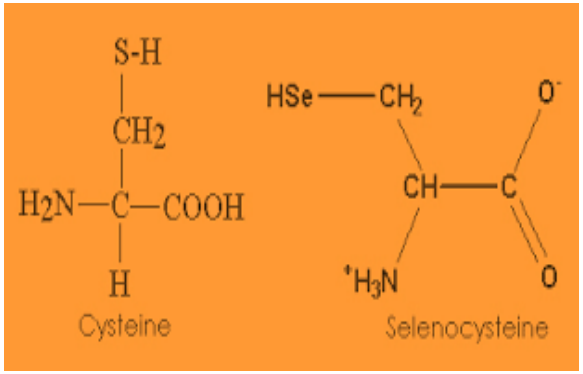
e.g.: Ornithine, Citrulline, Homocysteine, Argino succinic acid

New amino acids:

- **In addition to 20 L – amino acids that take part in protein synthesis, recently two more new amino acids are described. They are**
- **1. Selenocysteine – 21st amino acid**
- **2. Pyrrolysine – 22 nd amino acid**

Selenocysteine

Occurs at the active site of several enzymes. **E.g.,Glutathione peroxidase, and Glycine reductase**



Pyrrolysine

is an α-amino acid that is used in the biosynthesis of proteins in some archaea and bacterium; but it is not present in humans

Properties of amino acids

Physical properties:

- **Solubility:** **Most of the amino acids are soluble in water and insoluble in organic solvents.**
- **Melting points:** **Amino acids generally melt at high temperature, often above 200ºC.**
- **Taste :** **Amino acids may be sweet (Gly, Ala, Val), tasteless (Leu) or bitter (Arg).**

Monosodium glutamate is a salt of glutamic acid. It is employed as a flavoring agent in food industry to increase taste.

- **اللون:** **لاتمتص بلورات الحموض الأمينية الضوء المرئي (عديمة اللون). كما أنها لاتمتص الـ UV ذات الموجات التي يزيد طولها عن 240نم (باستثناء الحموض الأمينية الأروماتية)**

. Optical properties : **All amino acids except glycine possess optical isomers due to the presence of asymmetric carbon atom.**

. Amino acids as ampholytes : **Amino acids contain both acidic (-COOH) and basic (NH2) groups.**

They can donate a proton or accept a proton, hence amino acids are regarded as ampholytes.