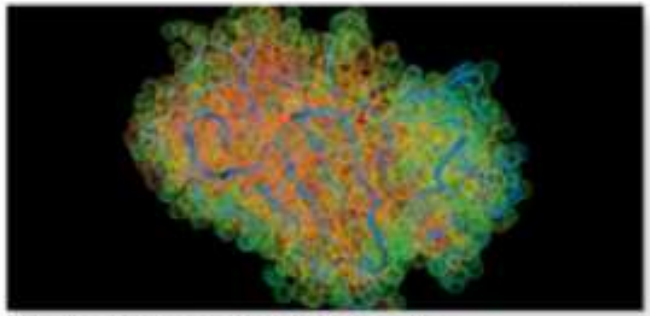
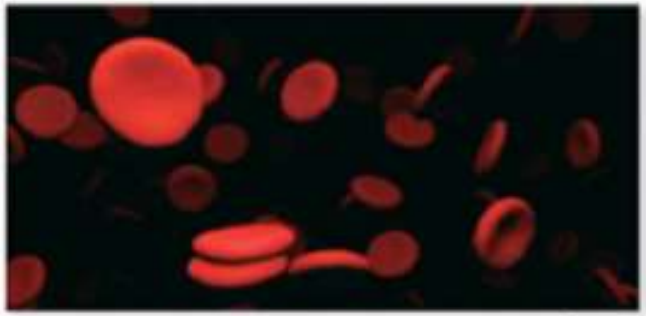
Proteins



Enzyme catalysis: space-filling model of an enzyme

Defense: venom



Transport: hemoglobin

3.3 µm

Support: keratin

Motion: actin and myosin

Regulation: insulin

Storage: calcium

Proteins

- ❖ Protein classification, its function and biological importance
- ❖ Amino acids
  - What are amino acids and their features?
- ❖ Polypeptides
  - Peptide bond formation and its features
  - How are they formed from amino acid? (Phi and Psi angles)
- ❖ Structural organization of proteins
  - Primary, secondary, tertiary and quaternary structure
- ❖ Determination of primary structure of proteins
  - Amino acid sequence determination

Proteins

-Are the most abundant organic molecules of the life.
-From *Greek Proteios: holding the first place*.
-Proteins are polymers of amino acids (Heteropolymers).
-Proteins generally contains more than 50 to several hundreds of amino acid units.

Elemental composition of Proteins:

Carbon- 50-55%
Hydrogen- 6-7.3%
Oxygen- 19-24%
Nitrogen- 13-19%
Sulphur- 0-4%
Also, contains
P, Fe, Cu, I, Mg,Mn, Zn

What are proteins and its components

- **Proteins are linear copolymers built from monomeric units called amino acids.**

- Twenty amino acids are commonly found in proteins. Among them 10 are **essential** (**body cannot synthesized them and must be obtained from the diet**).

- These amino acids contain a variety of different functional groups:
  - Alcohols (R-OH)
  - Phenols (Ph-OH)
  - Carboxylic acids (R-COOH)
  - Thiols (R-SH)
  - Amines ($R\text{-}NH_2$)
  - *and others…*

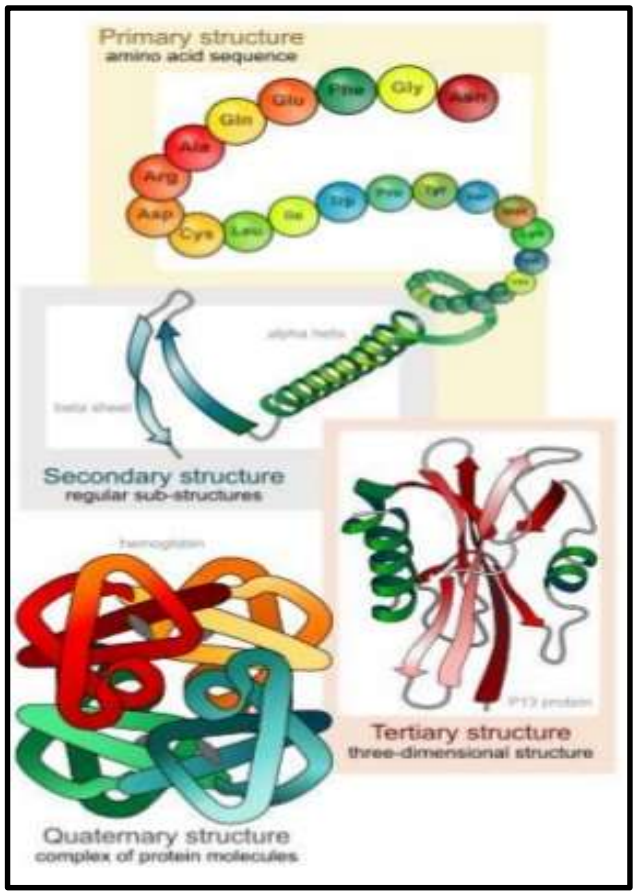
- **Protein function depends on both**
  - amino acid content, and
  - amino acid sequence.
- **Protein fold into diverse shapes to perform specific functions such as**
  - spherical
  - ellipsoidal
  - long strands, etc.
- **All information for 3-D structure is contained in the <u>linear sequence</u> of amino acids.**
- **There are four levels of structural organization of proteins:**

------Primary level (1° level)

------Secondary level (2° level)

------Tertiary level (3° level)

------Quaternary level (4° level)



Classification of protein
(Based on composition)

- **Simple protein**:*(depends on size and solubility)*
  - Fibrous protein (Ligament, Cartilage, hair, nail)
  - Globular protein
    - Albumin
    - Globulin
    - Histone
    - Gliadine

→ •The simplest
•Made of amino acid units only, joined by peptide bond
•Upon hydrolysis they yield mixture of amino acids and nothing else.

- **Conjugated protein:**
  - Nucleoprotein (RNA,DNA)
  - Liporpotein (Lipid)
  - Glycoprotein (CHO)
  - Rhodopsin (Retinol)
  - Feritin (Iron)
  - Hemoglobin (Hb heme)

→ •Composed of simple proteins combined with a non-protein substance
•The non-proteinous substance is called **prosthetic group** or **cofactor**.

Derived proteins

•Peptones
•Peptides
•proteoses

→ •Not naturally occurring proteins
•Obtained from simple proteins by the action of enzymes and chemical agents.
•Results from hydrolysis of proteins

Classification depends on functions

- Structural protein (collagen, elastin)
- Catalytic protein (Enzyme)
- Transport protein (Alb, transferrine)
- Hormonal protein (regulation:insulin,glucagon)
- Gene regulatory (histone, protamin)
- Protective protein (prevent infection:immunoglobulin-G)
- Receptor protein (LDL receptor)
- Contractile protein (muscle contraction: actin, myosin)

BIOLOGICAL FUNCTIONS OF PROTEINS

1. **Catalytic function:**
   Nearly all chemical reactions in biological systems are catalyzed by specific enzymes.

2. **Transport and storage:**
   For example;
   - Hemoglobin transports oxygen in erythrocytes
   - Myoglobin carries & stores oxygen in muscle.
   - Albumin transports free fatty acids in blood.
   - Transferrin transports iron in blood.

3. **Coordinated motion:** Actin and myosin are contractile proteins in muscle.

BIOLOGICAL FUNCTIONS OF PROTEINS (cont.)

4. Structural and Mechanical support:

For Example; collagen, a fibrous protein in skin and bone.

5. Defense function:

For Example Clotting factors prevent loss of blood.

Immunoglobulins protects against infections.

6. Generation and transmission of nerve impulses:

For example, rhodopsin is the photoreceptor protein in retinal rod cells.

7. Control of growth and differentiation:

For Example

- growth factor proteins.
- hormones such as insulin and thyroid-stimulating hormone.

Protein deficiency diseases

A) KWASHIORKAR
B) MARASMUS
C) NUTRITIONAL EDEMA

A) KWASHIORKAR

Causes:

Occurring in children due to lack of protein in diet. Common in countries that are facing famine, political unrest, natural disasters such as earthquakes, landslides, floods, etc.

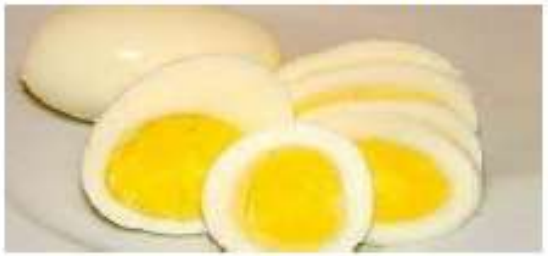
Symptoms:

Change in skin and hair colour,Fatigue, Diarrhea, Stunted physical and mental growth, Edema

Stunted physical and mental growth

Edema

Treatment: Consume Protein Rich Food



EGGS

DAIRY PRODUCTS

NUTS

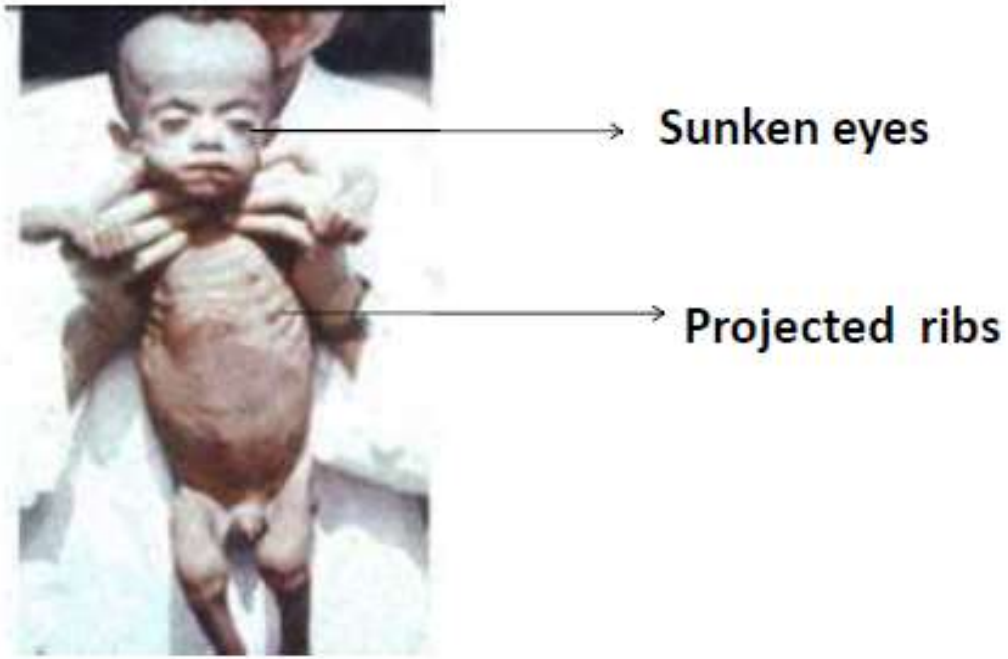
FISH &MEAT

FRUITS

B) MARASMUS

Causes: Malnutrition, Lack of energy and protein, Poverty, Contaminated water, Metabolic and anatomic changes

Symptoms: Lean body, Projected ribs, Sunken eyes, Dry skin



Treatment: Consume Protein Rich Food– eggs, fish, meat, dairy products, fruits and nuts

Building units of proteins are amino acids

What are amino acids and its features?

Building Blocks of Proteins
Amino Acids

- Amino acids (monomers) are linked together to form proteins (polymers)
  - Each unique sequence of amino acids forms a different protein
  - All living things (even viruses) use the same 20 amino acids
- 20 different Amino Acids
  - Amino end (NH_2)
  - Carboxyl end (COOH)
  - Hydrogen
  - R group – variable component

Amino Acids

-300 amino acids occur in nature

-Out of this 20 amino acids are standard amino acids which repeatedly found in protein structure

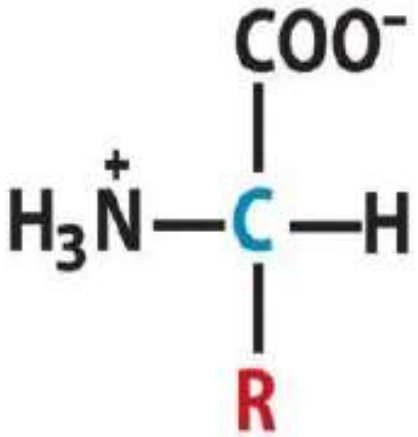
-Amino acids are a group of organic compounds containing two functional group- amino and carboxyl attached to α- carbon atom. Hence, all these are called α- amino acids.

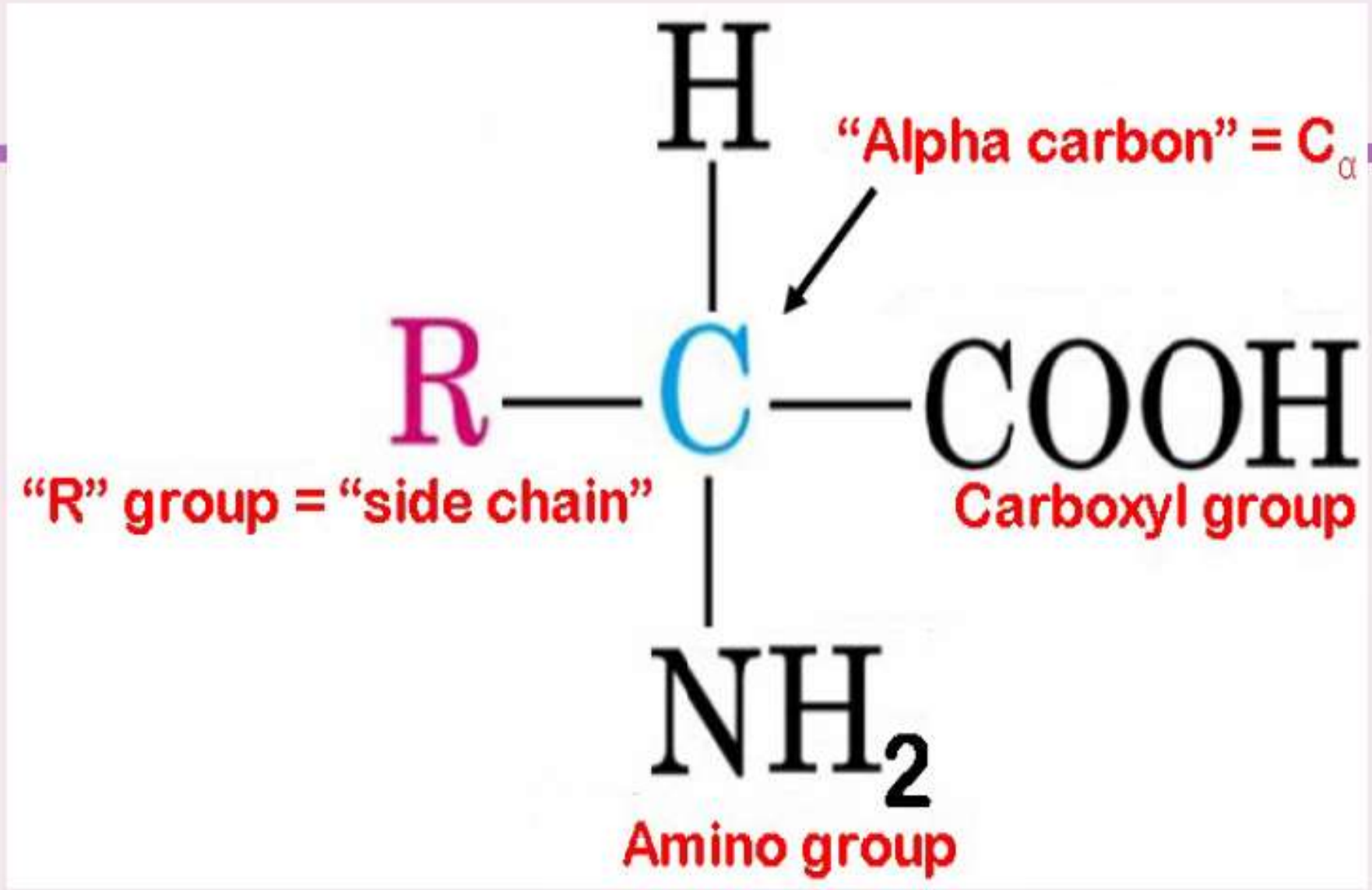
-Amino acids share many features, differing only at the R substituent

-Amino group (-NH2) is basic while the carboxyl group (-COOH) is acidic in nature

- Amino acids are obtained from proteins by hydrolysis, catalyzed by acid, base or enzymes such as pepsin, trypsin and chymotrypsin

General Structure of Amino Acid




H
"Alpha carbon" = C_α
R—C—COOH
"R" group = "side chain"
Carboxyl group
NH_2
Amino group

Each AMINO ACID

has

An amino group,

A carboxyl group,

A hydrogen atom and

a specific side chain (R group)

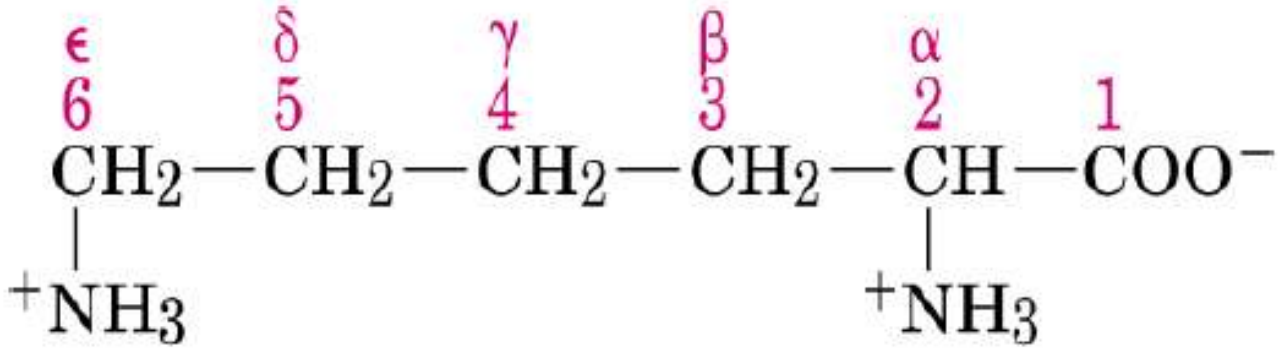
Bonded to

the α-carbon atom

Amino Acids: Atom Naming

- Organic nomenclature: start from one end
- Biochemical designation:
  - start from α-carbon and go down the R-group

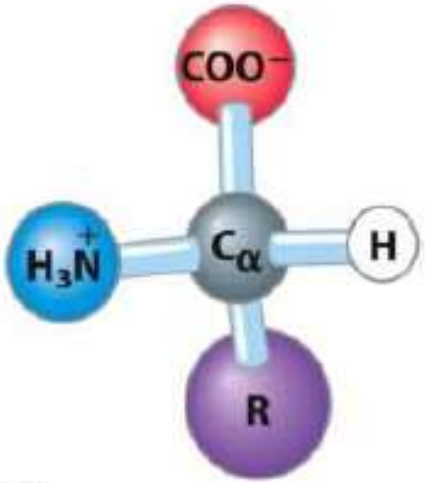
Lysine : Basic Amino Acid



Lysine

Most α–Amino Acids are Chiral

- The α-carbon has always four different substituents and is tetrahedral therefore exhibits optical isomerism
- Each amino acid has an unique fourth R-substituent
- Except In glycine, the R-substituent is also a hydrogen so it is non-chiral



Proteins only contain L amino acids

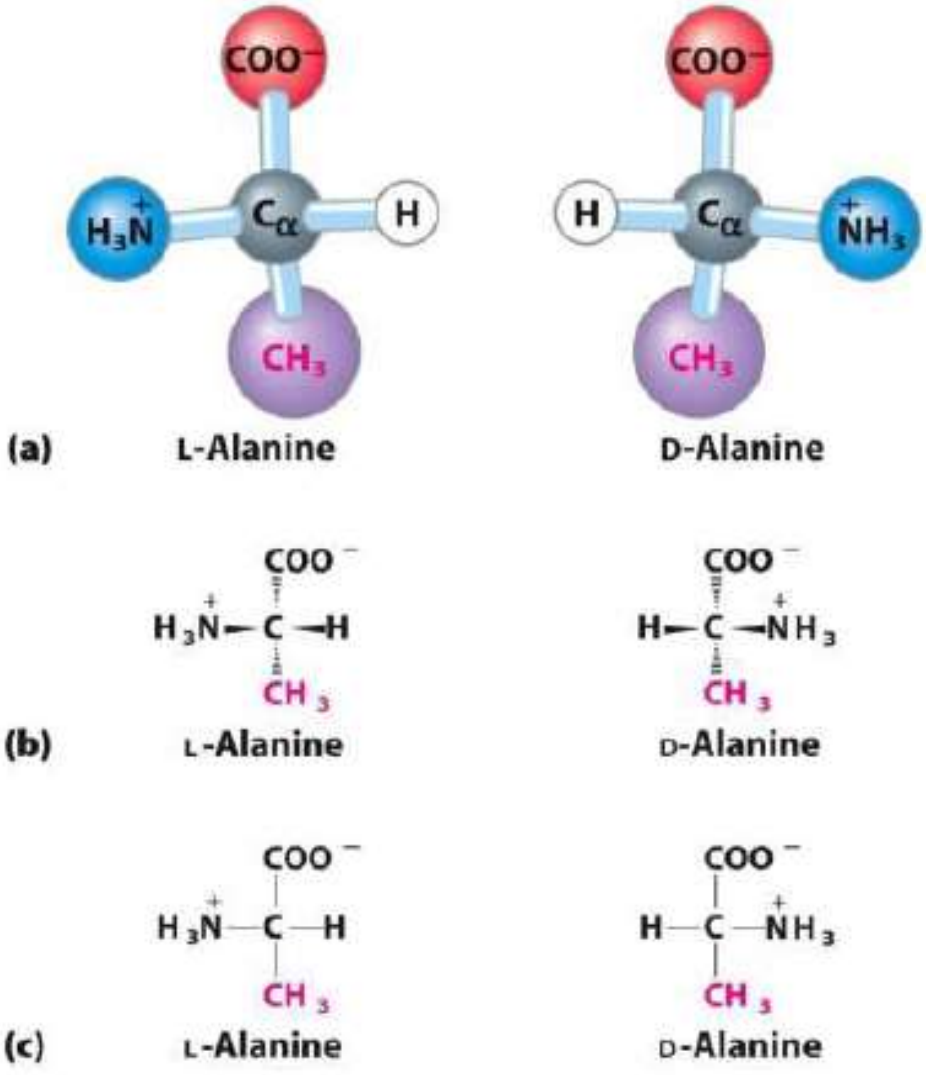


Figure 3-3
Lehninger Principles of Biochemistry, Sixth Edition

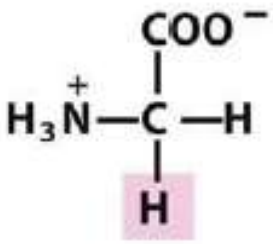
Amino Acids: Classification

A. Amino acids classification based on their structure

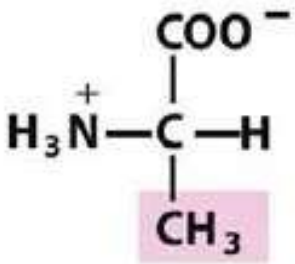
Common amino acids can be placed in seven basic groups depending on their R substituent

1. Aliphatic amino acids

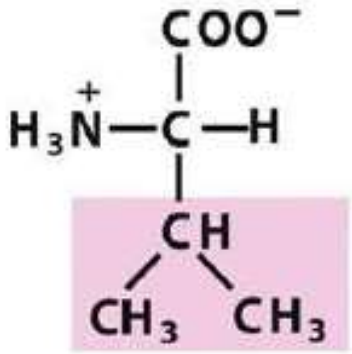
- Contains aliphatic R- chain
- these are hydrophobic and non-polar in nature
- these shows presence of simple or branched chain in R-group



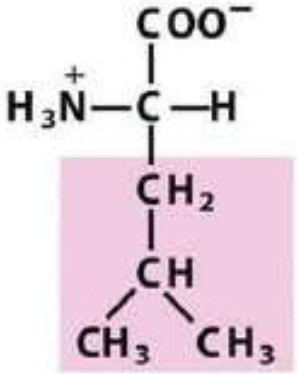
Glycine



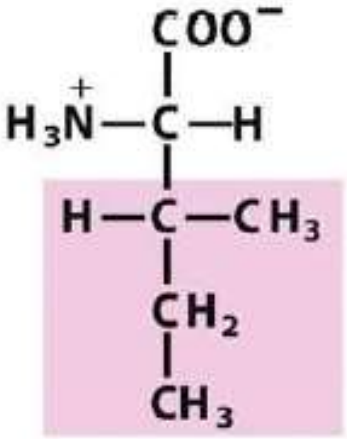
Alanine



Valine



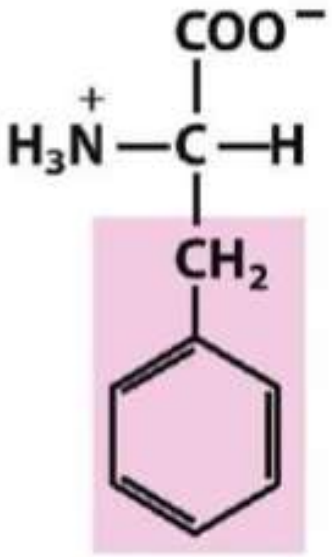
Leucine



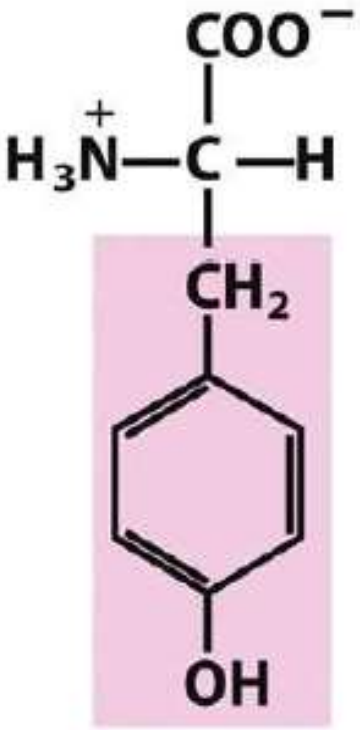
Isoleucine

2. Aromatic amino acids

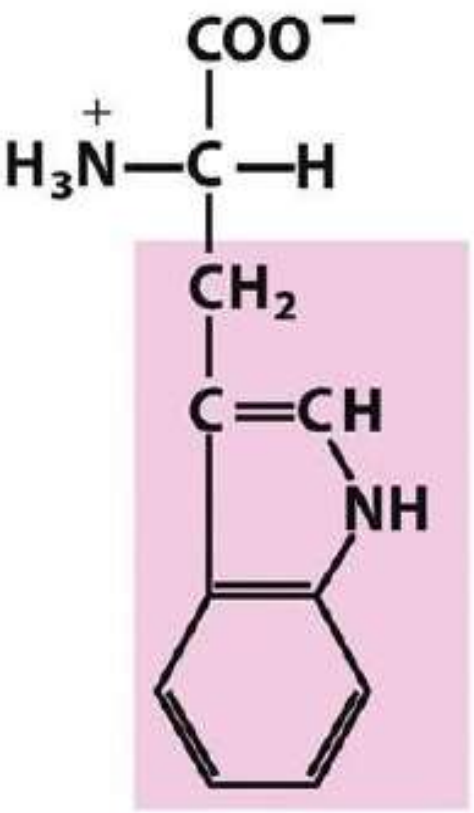
-Contains aromatic R- chain



Phenylalanine

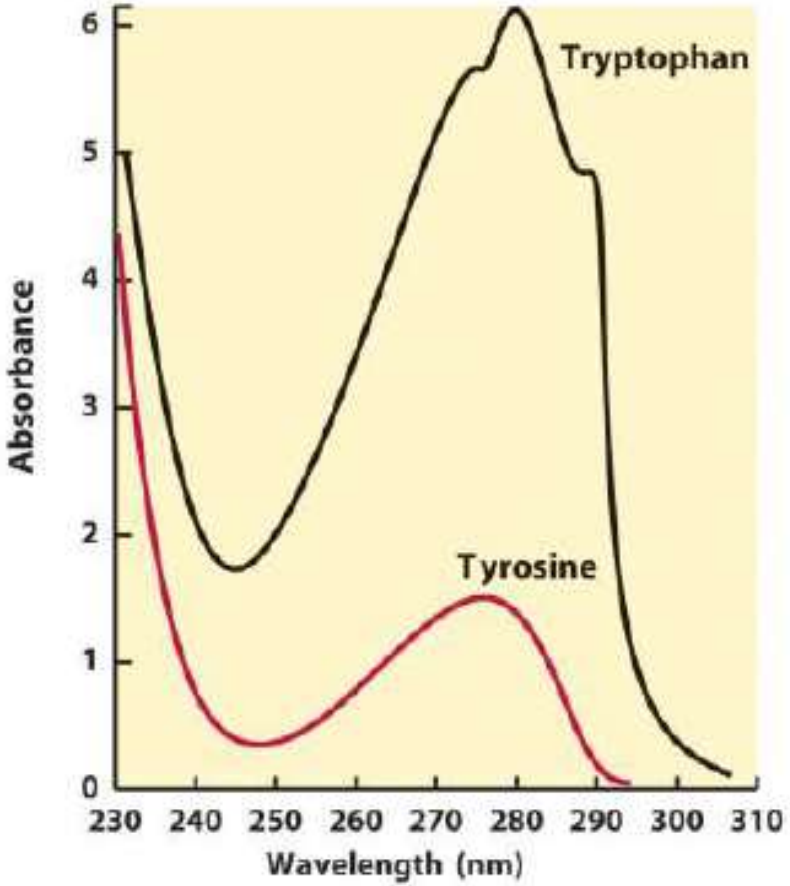


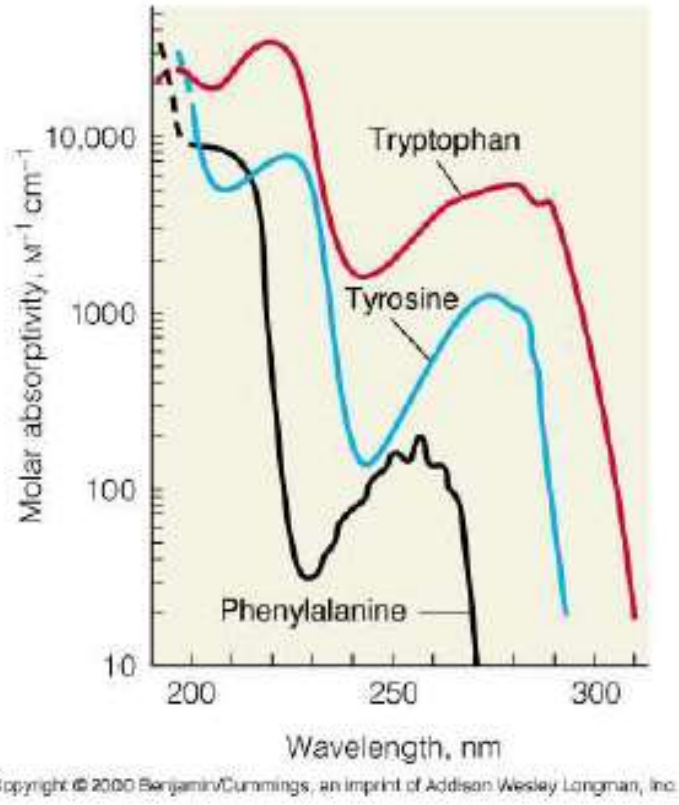
Tyrosine



Tryptophan

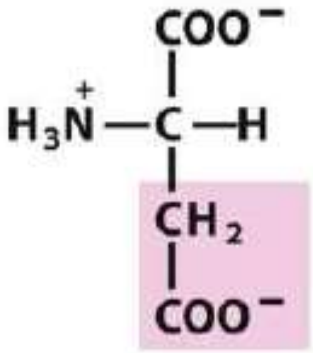
Absorption of UV Light by Aromatic Amino Acids



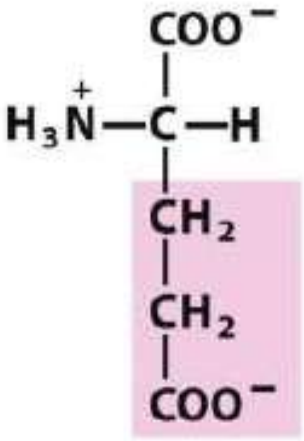


3. Acidic amino acids

i) Dicarboxylic monoamino acids– Aspartic acid and Glutamic acid

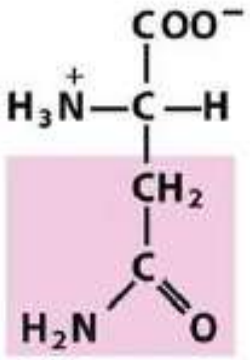


Aspartate

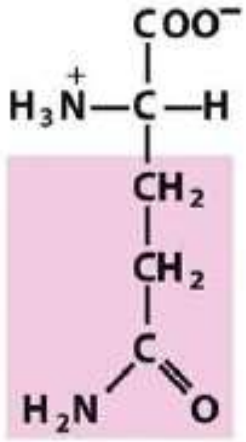


Glutamate

ii) Amides form of above acids



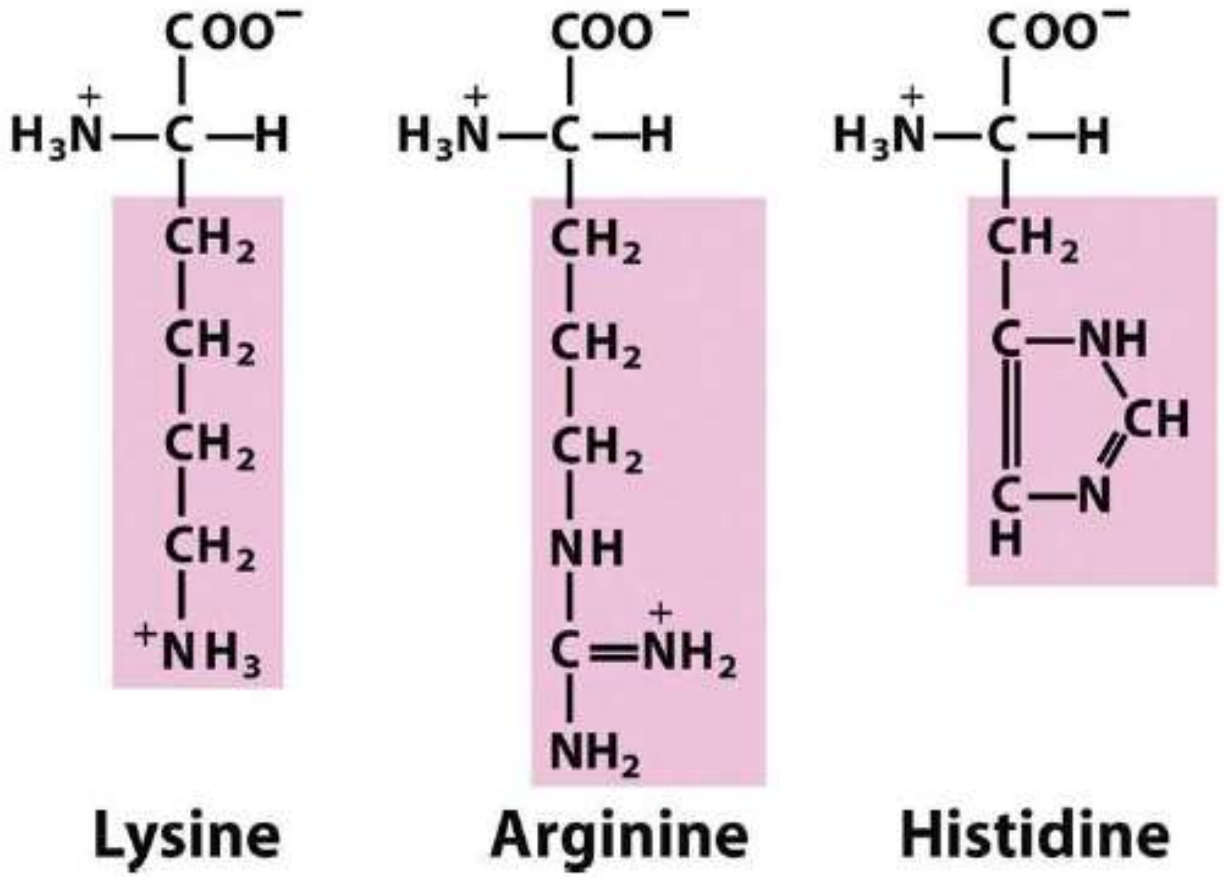
Asparagine



Glutamine

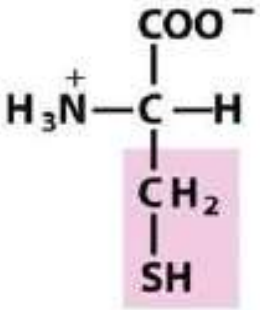
4. Basic amino acids

– These amino acids are basic in nature

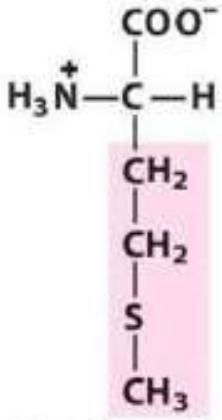


5. Sulphur containing amino acids

– These amino acids contain sulphur atom in the structure



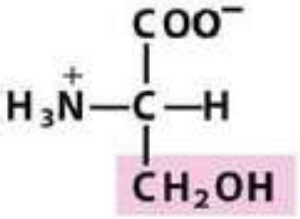
Cysteine



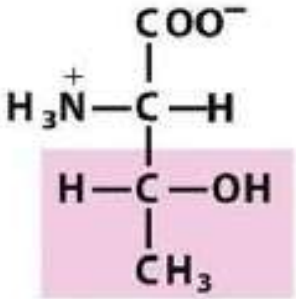
Methionine

6. Hydroxyl group containing amino acids

– These amino acids contain hydroxyl group in the structure



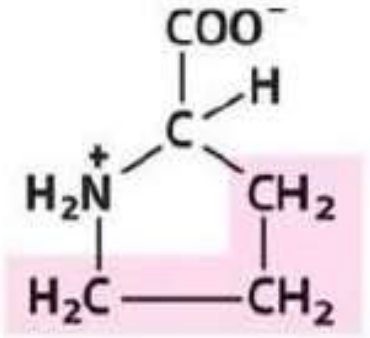
Serine



Threonine

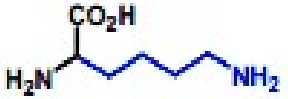
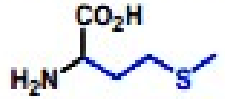
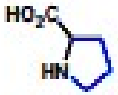
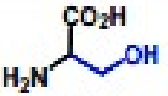
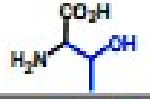
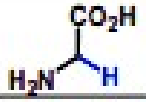
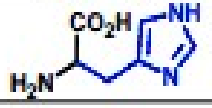
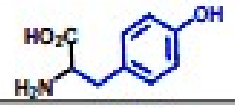
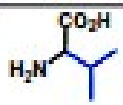
7. Imino acids

– These amino acids contain imino group(=NH) in place of amino group (–NH2) i.e. α– amino nitrogen is part of the structure



Proline

Standard Amino Acid Abbreviations

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

*Side Chain shown in Blue.

**Letters denote side chain properties: H = Hydrophobic, P = Polar, A = Acidic, B = Basic.

B. Amino acids classification based on their Nutritional requirements

1. **Essential amino acids**

   –the amino acids which can not be synthesized in the body but are required for normal functioning of body are called as essential amino acids.

   –These should be supplied through diet and supplements.

   –They required for proper growth and maintenance of the individual

-Valine	-Lysine
- Arginine	- Methionine
-Histidine	- Phenylalanine
- Isoleucine	- Threonine
- Leucine	- Tryptophan

2. **Non-essential amino acids**

   – these are synthesized in the body hence they need not be consumed in the diet

– Glycine	–Alanine
– Serine	– Cysteine
– Aspartic acid	– Glutamic acid
– Glutamine	– tyrosine
– Proline	– Asparagine

Some physical properties of amino acids

1. **Solubility**

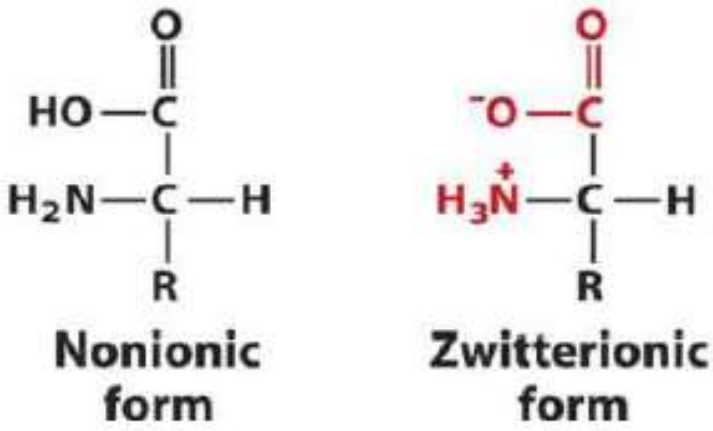
all amino acids are soluble in water, but their solubility varies to a great extent. Solubility depends on the nature of the R- group i.e. polarity of amino acids. Polar amino acids are highly soluble in water while non-polar amino acids are highly soluble in organic solvents like chloroform, ether, etc.

2. **Optical activity**

all standard amino acids except glycine have an asymmetric or chiral carbon atom. Due to this, amino acids are optically active. Also, they exist as stereo- isomers. All naturally occuring amino acids found in proteins are L- amino acids. Certain D- amino acids are found in some biological systems.

3. **Acid- base behavior**

amino acids contain the acidic carboxyl group (-COOOH) and the basic group amino (-NH2). Hence, amino acids are called as amphoteric molecules or ampholytes (i.e. amphoteric electrolyte).



Zwitterion/dipolar ionic form- Can act as acid (proton donor) and base (proton acceptor)

Amphoteric (ampholytes)- non-ionic form

Functions or Role of amino acids

Amino acids are required for the body for various reasons:

1) For synthesis of various enzymes, hormones, plasma proteins and immuno-globulins

2) For the growth and repairs of body tissues

3) Source of energy when body is having inadequate supply of carbohydrates or fats

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)**

Zwitterions

pH = 1-5

pH = 10-14

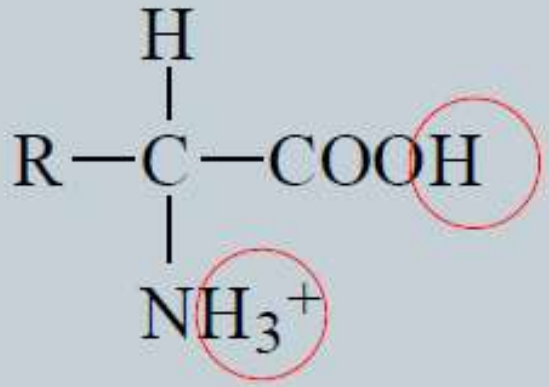
more acidic

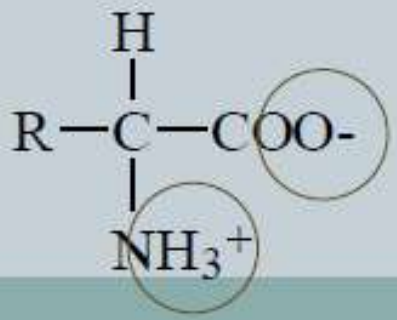
more basic

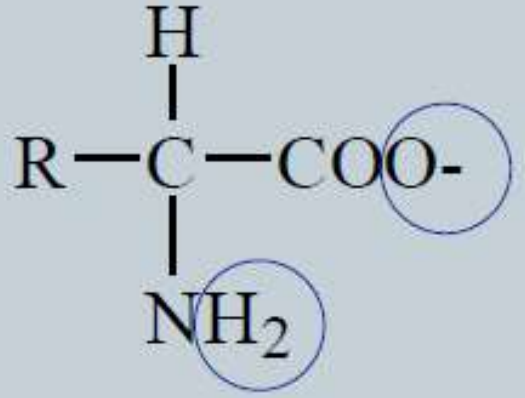
excess H^+

at pI (isoelectric point) charge = 0

excess OH^-







Non-Protein amino acids

α-Amino acids	Functions
1.Ornithine	Intermediate in the biosynthesis of urea
2.Citrulline	Intermediate in the biosynthesis of urea
3.Arginosuccinic acid	Intermediate in the biosynthesis of urea
4.Thyroxine	Thyroid hormone derived from tyrosine.
5.Triiodothyronine	Thyroid hormone derived from tyrosine
6.SAM	Methyl donor in biological system.
7.Homocysteine	Intermediate in methionine metabolism. A risk factor for coronary heart diseases.
8. 3,4-Dihydroxy phenyl alanine (DOPA)	A neurotransmitter, precursor for melanin
9.Creatinine	Derived from muscle and excreted in urine.

D-Amino acids:

- **Certain D-amino acids are also found in the antibiotics (Actinomycin-D, valinomycin, gramicidin-S).**
- **D-Glutamic acid and D-Alanine are present in bacterial cell wall.**
- **D-Serine and D-Aspartate are found in brain tissue.**