Amino acids

(Foundation Block)

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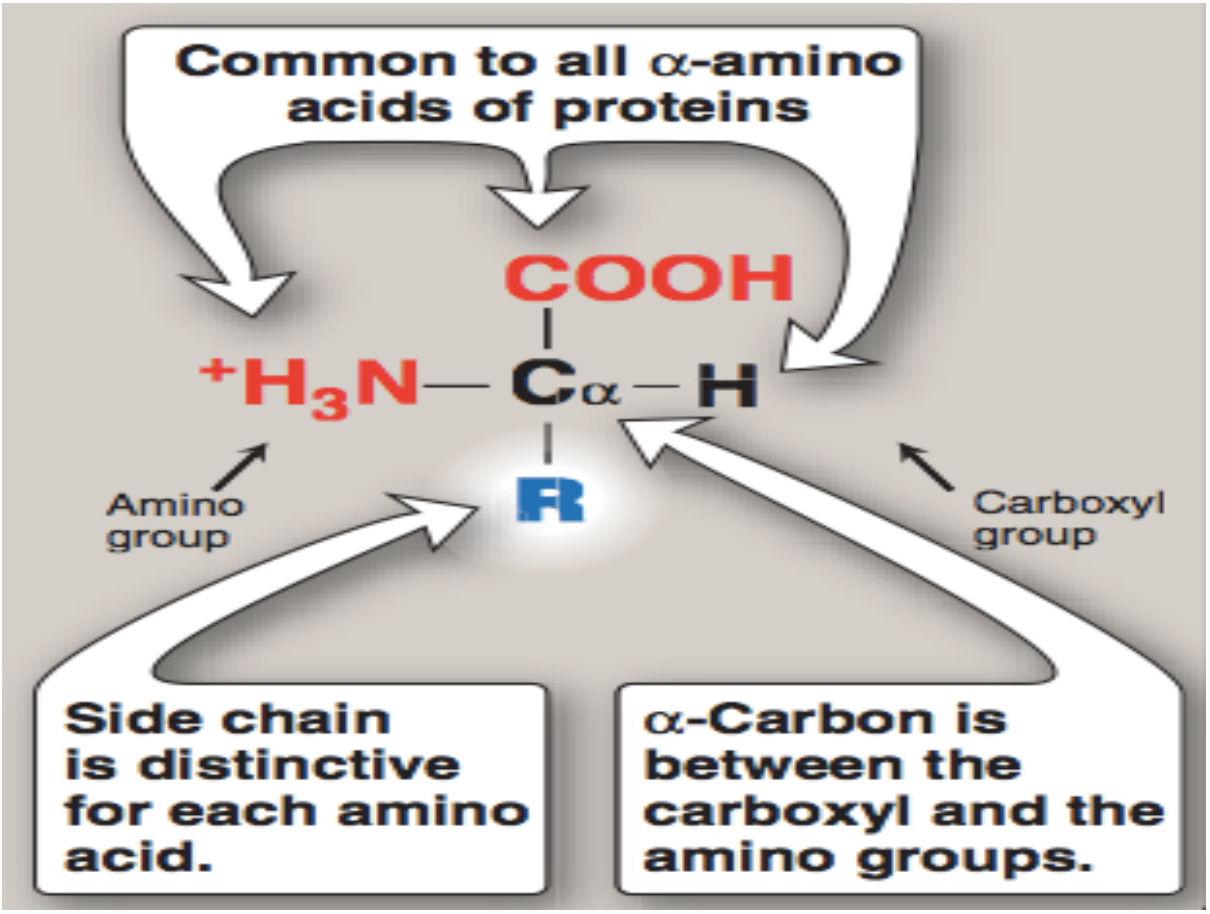
Learning outcomes

- What are the amino acids?
- General structure.
- Classification of amino acids.
- Optical properties.
- Amino acid configuration.
- Non-standard amino acids.
- Derivatives of amino acids.

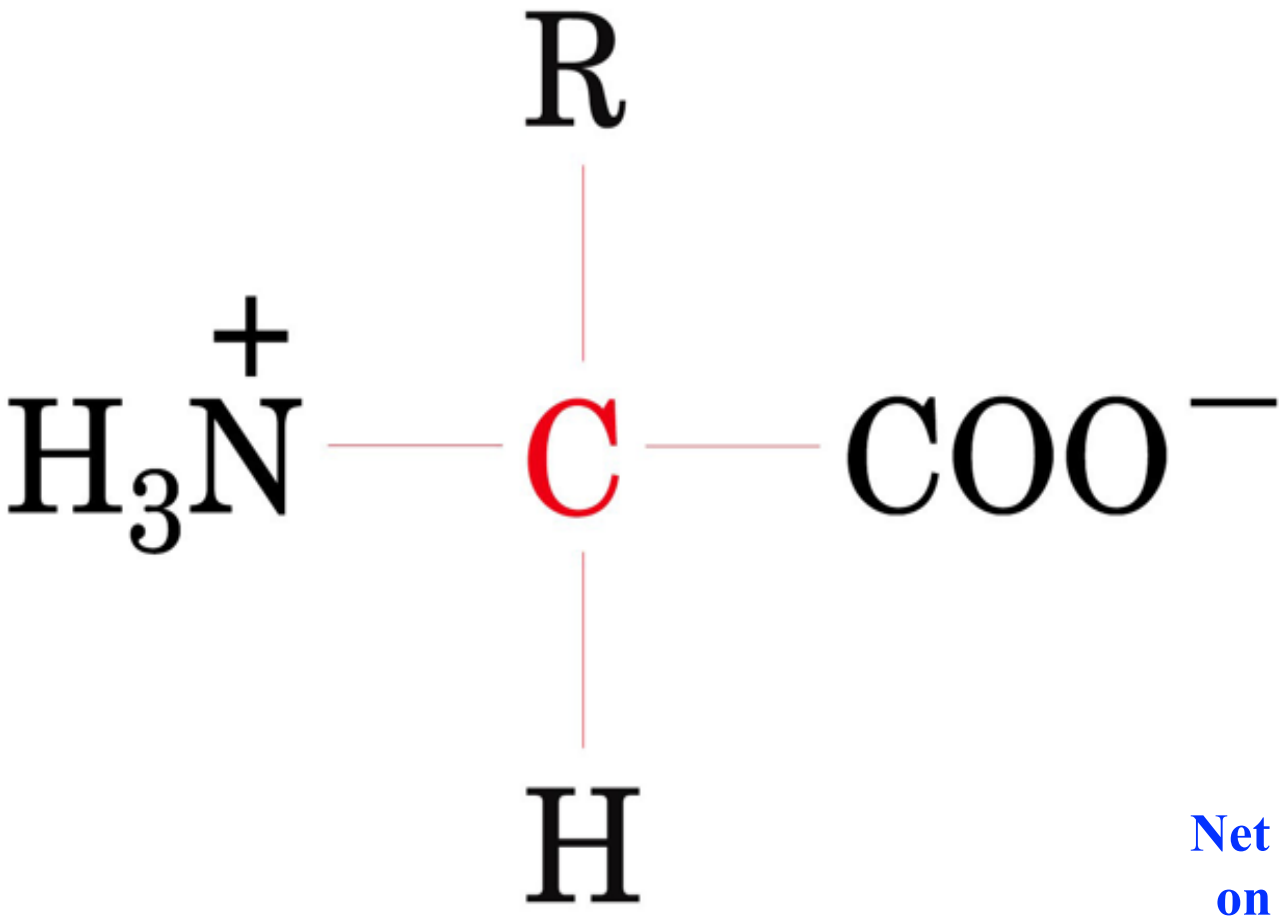
What are amino acids?

- Amino acids are the chemical units that combine to form proteins.
- Amino acids are a type of organic acid that contain both a carboxyl group (COOH) and an amino group (NH_2).
- Amino acids play central roles: as building blocks of proteins and as intermediates in metabolism.
- Humans can produce about half of amino acids. The others must be supplied in the food.
- When proteins are digested or broken down, amino acids are left.

General structure



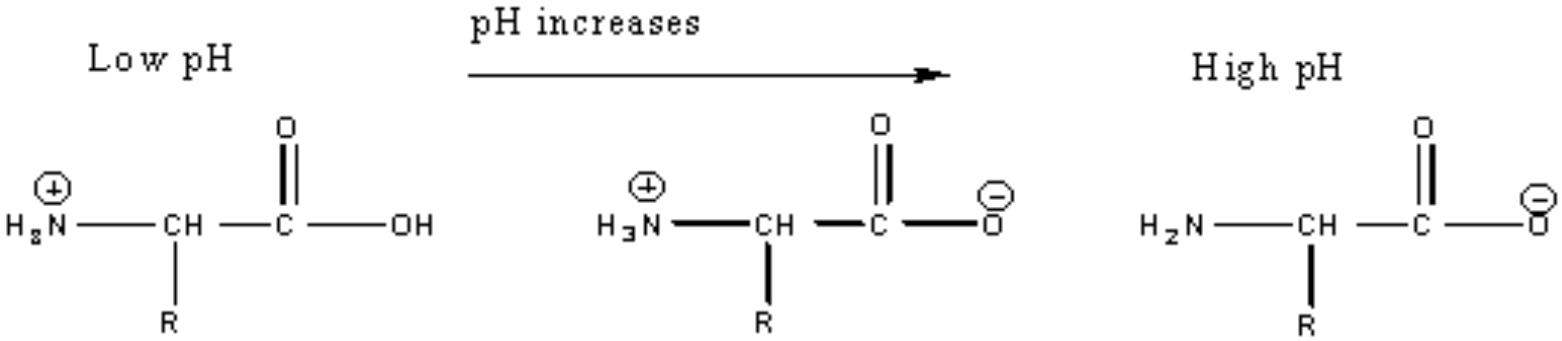
Zwitterion



Net charge is zero on the molecule

Isoelectric point

- The pH at which the molecule carries no net charge.
- In acidic solution-cationic.
- In alkaline solution- anionic.

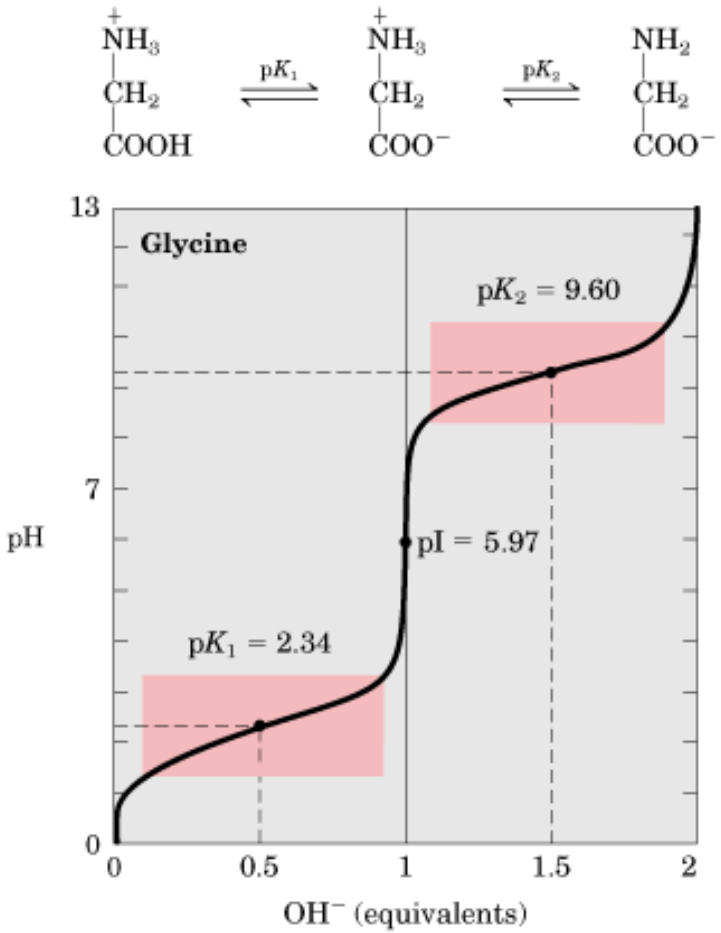


pK Value

- It is the ability of an acid to donate a proton (dissociate).
- Also known as **pKa** or acid dissociation constant.
- The pK values of α-carboxylic group is in the range of 2.2.
- The pK values of α-amino group is in the range of 9.4.

Titration curve of glycine

- pK1- pH at which 50% of molecules are in cation form and 50% are in zwitterion form.
- pK2- pH at which 50% of molecules are in anion form and 50% are in zwitterion form.
- Buffering action is maximum around pK values and minimum at pI.



Classification of amino acids

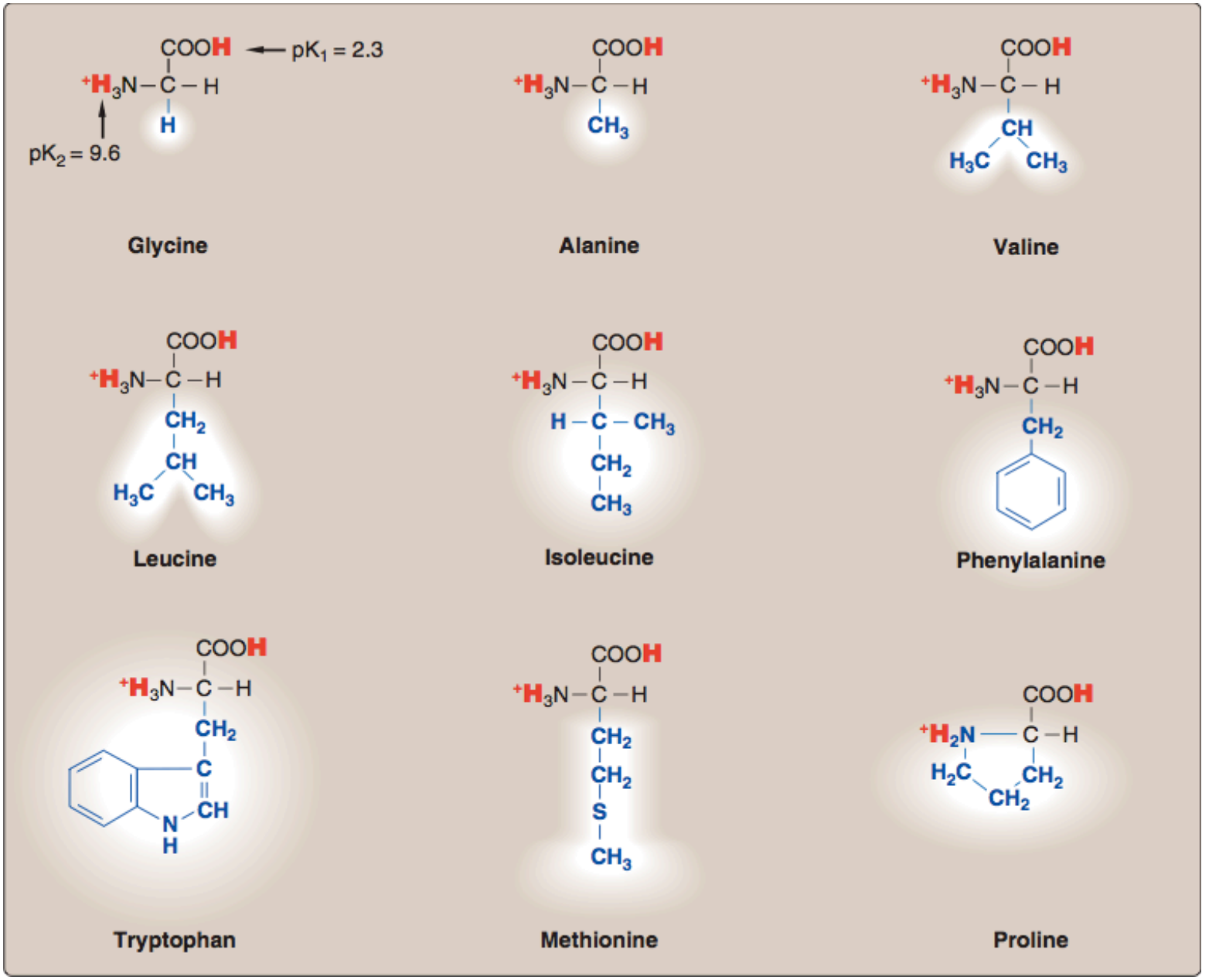
- **Based on the body requirement, amino acids can be classified into three groups:**
  - Essential amino acids: cannot be made by the body.
    e.g. histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine.
  - Nonessential amino acids: produced by the body.
    e.g. alanine, asparagine, aspartic acid, and glutamic acid.
  - Conditional amino acids: not essential, except in time of illness or stress.
    e.g. arginine, cysteine, glutamine, tyrosine, glycine, proline, and serine.

Continued …

- **According to the properties of the side chains, amino acids can also be grouped into three categories:**
  - Nonpolar amino acids.
  - Uncharged amino acids.
  - Polar amino acids.

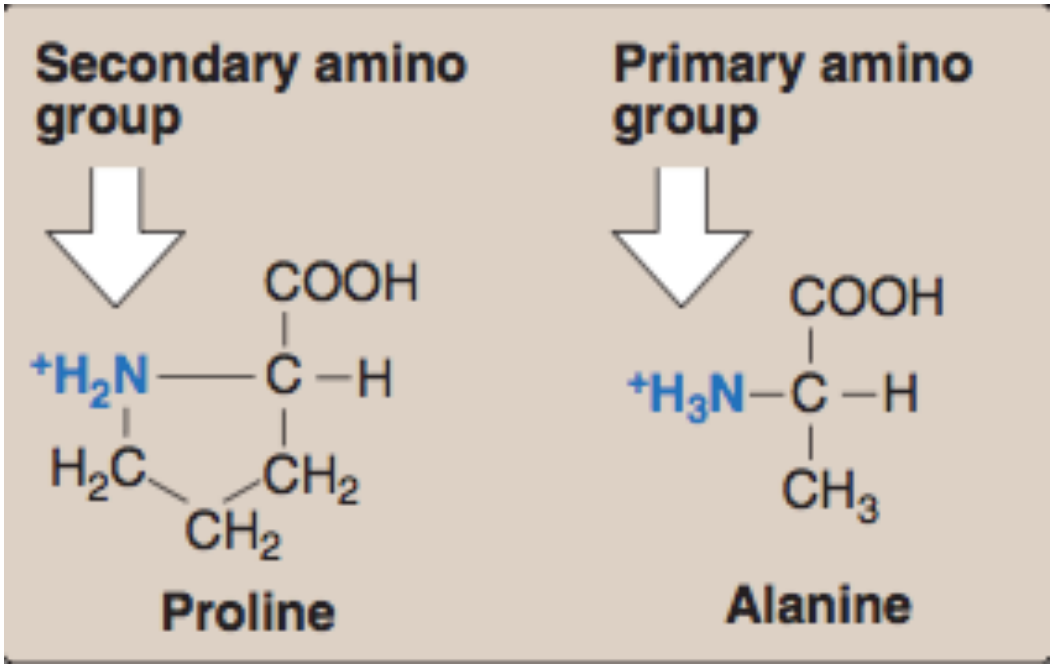
Nonpolar amino acids

- Each amino acid does not bind or give off protons or participate in hydrogen or ionic bonds.
- These amino acids promote hydrophobic interactions.
- In proteins found in aqueous solution, the side chains of the nonpolar amino acids tend to cluster together in the interior of the protein.
- The nonpolar R-group fill up the interior of the folded protein and help give it its 3D shape.
- In proteins located in hydrophobic environment, such as a membrane, the nonpolar R-groups are found on the outside surface of the protein, interacting with lipid environment to stabilize protein structure.

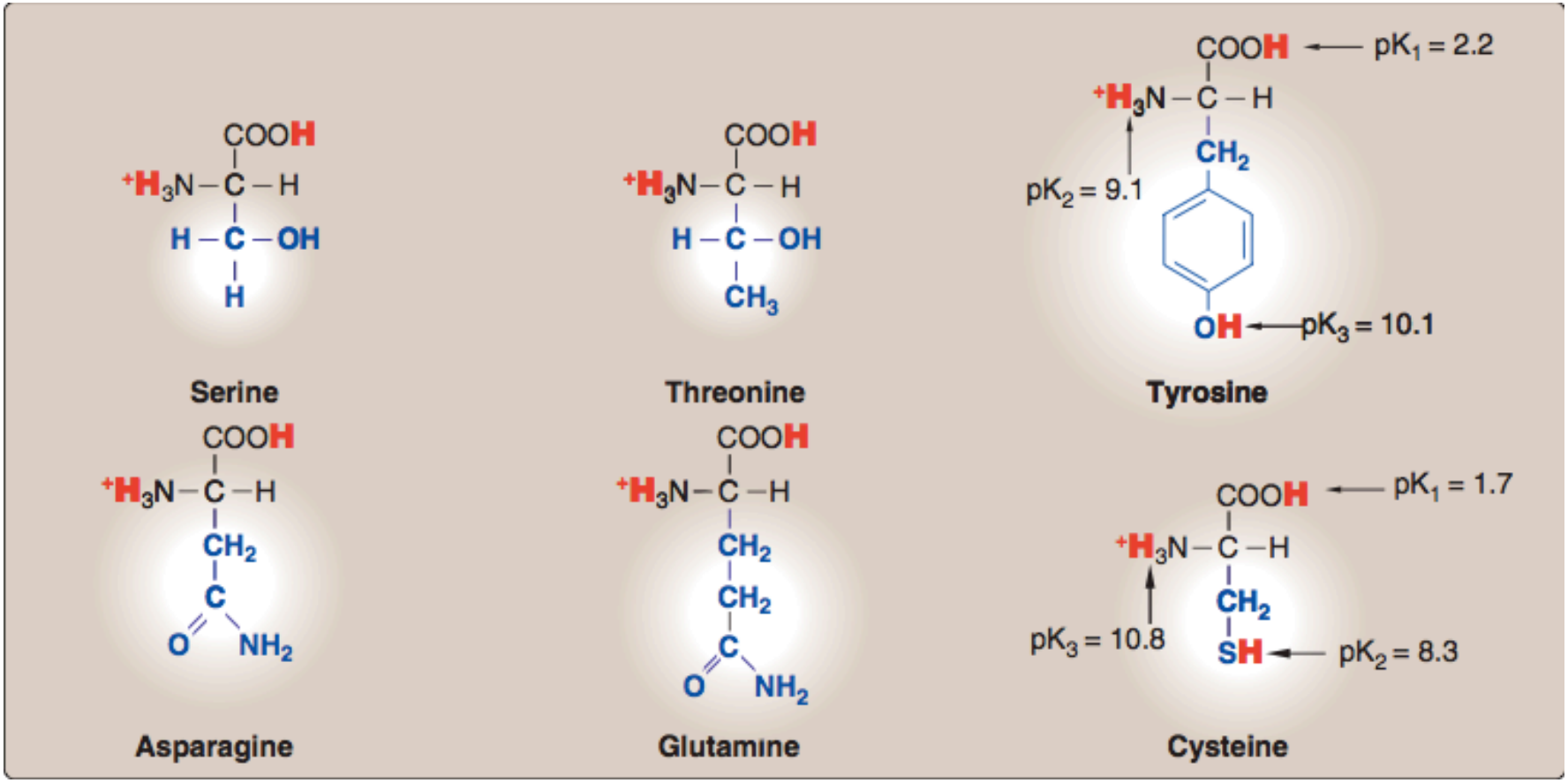

COOH
+H3N–C–H
H
pK1 = 2.3
pK2 = 9.6
Glycine
CH3
Alanine
CH
H3C
CH3
Valine
CH2
Leucine
H–C–CH3
CH2
CH3
Isoleucine
Phenylalanine
C
CH
N
H
Tryptophan
S
Methionine
+H2N
H2C
CH2
Proline

Continued …

- The structure of the proline amino acid differs from other nonpolar amino acids that the side chain of proline and its α-amino group form a ring structure (an imino group).



Uncharged amino acids



Continued …

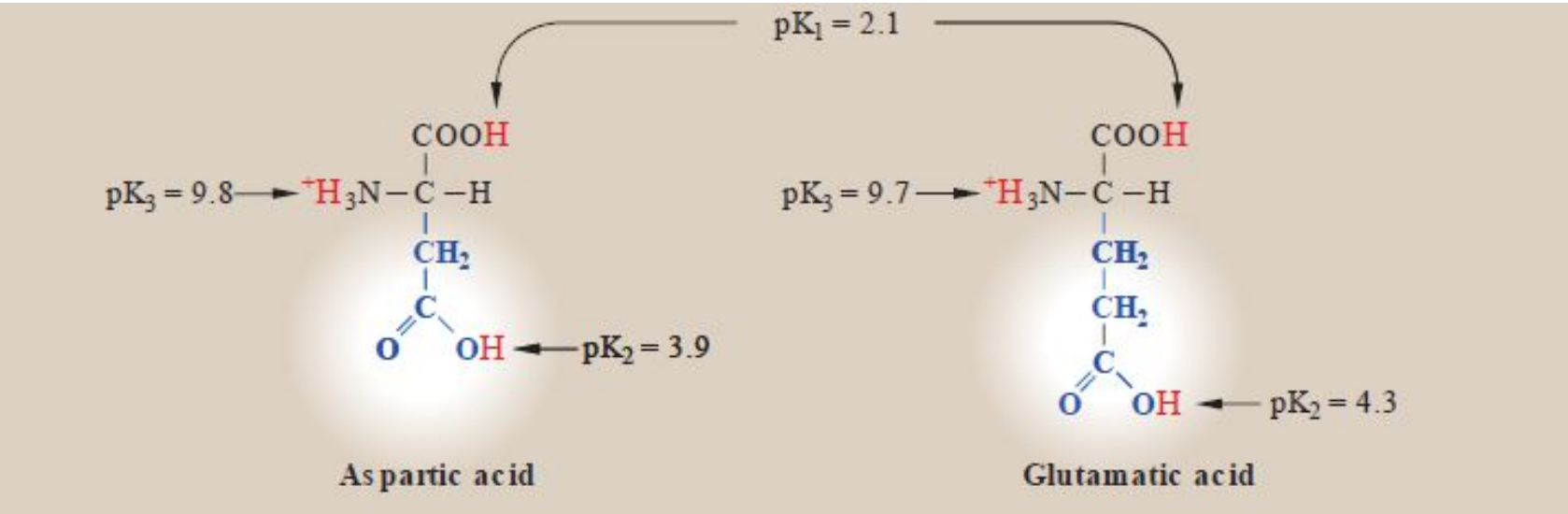
- These amino acids have zero net charge at neutral pH.

However

- The side chains of cysteine and tyrosine can lose a proton at an alkaline pH.
- Serine, Threonine and Tyrosine each contain a polar hydroxyl group that can participate in hydrogen bond formation.
- The side chains of asparagine and glutamine each contain a carbonyl group and an amide group, both of which can also participate in hydrogen bonds.

Polar amino acids

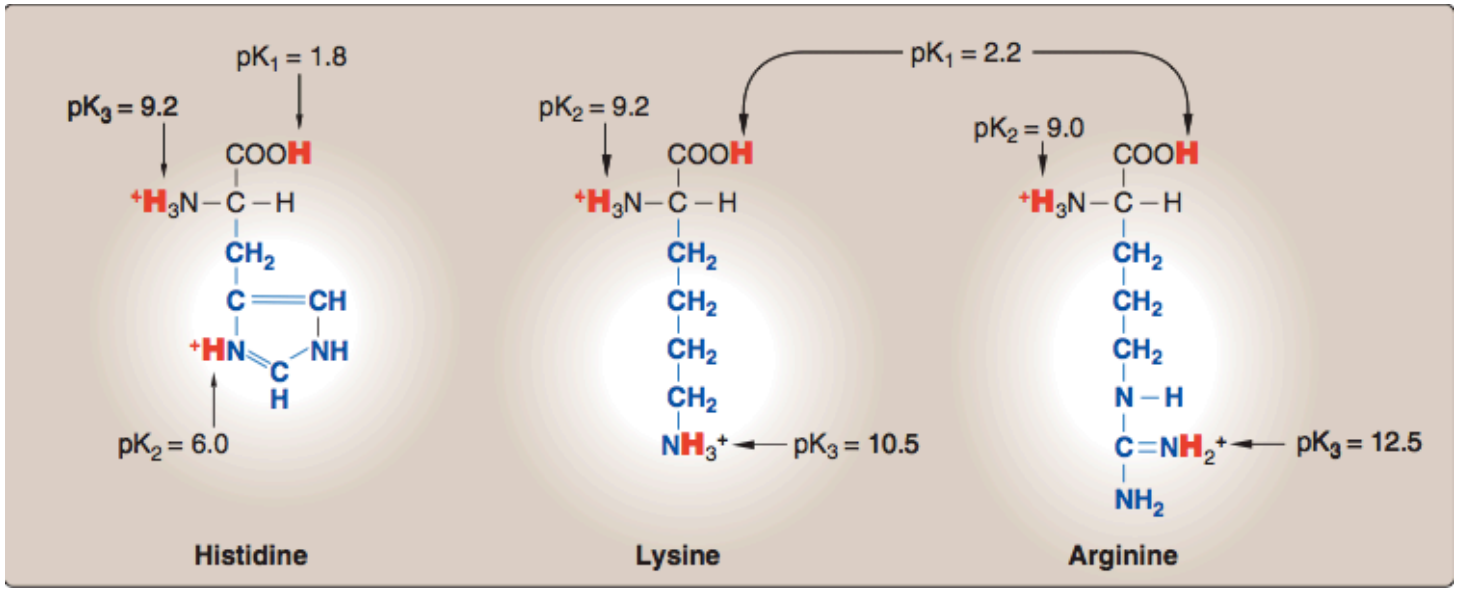
- Amino acids with acidic side chains:



- Aspartic and glutamic acids are proton donors.
- At neutral pH, these amino acids are fully ionized (negatively charged). So, they are called aspartate and glutamate.

Continued …

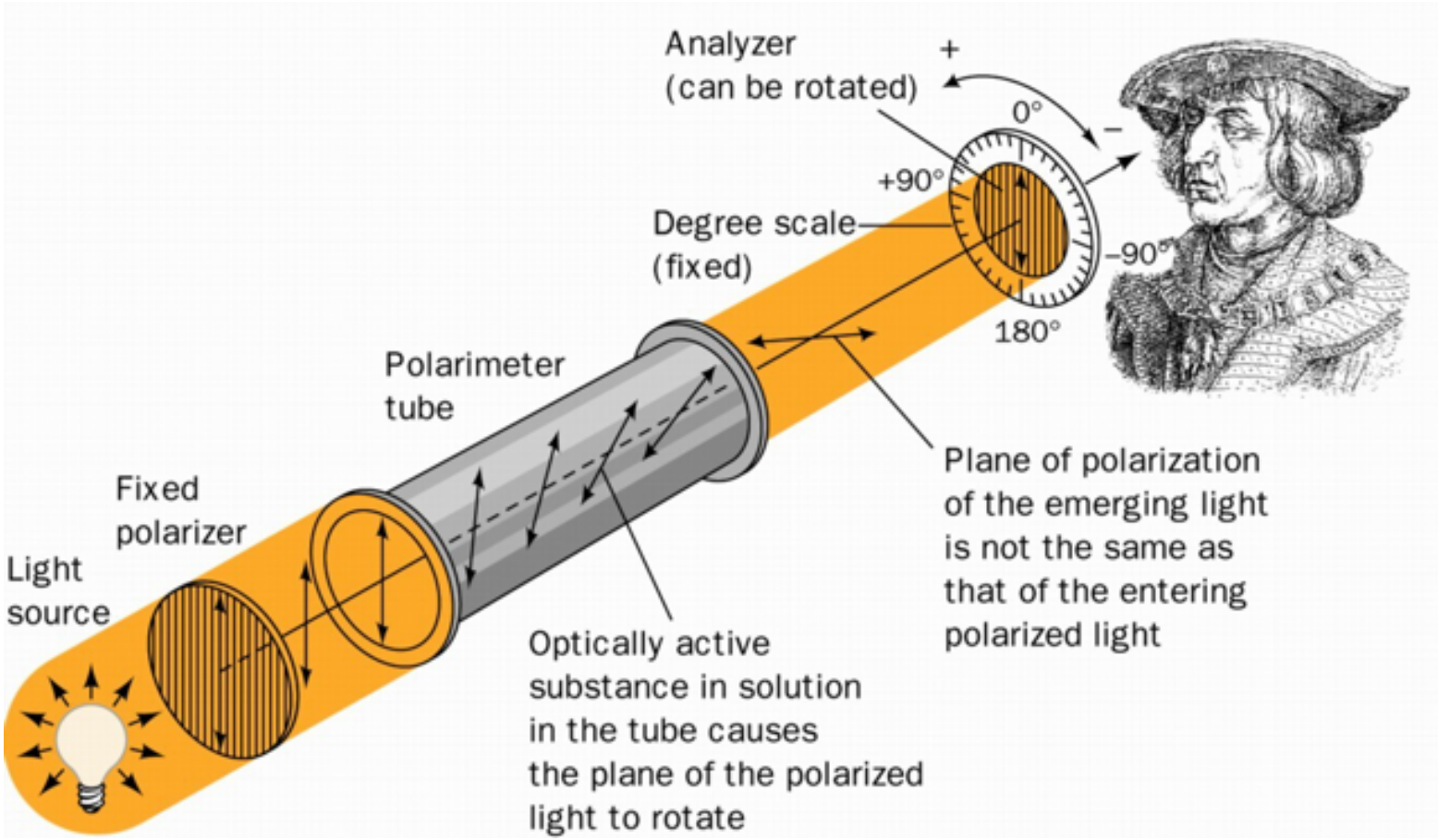
- **Amino acids with basic side chains:**



- Histidine, Lysine and Arginine are proton acceptors.
- At neutral pH, lysine and arginine are fully ionized (positively charged).

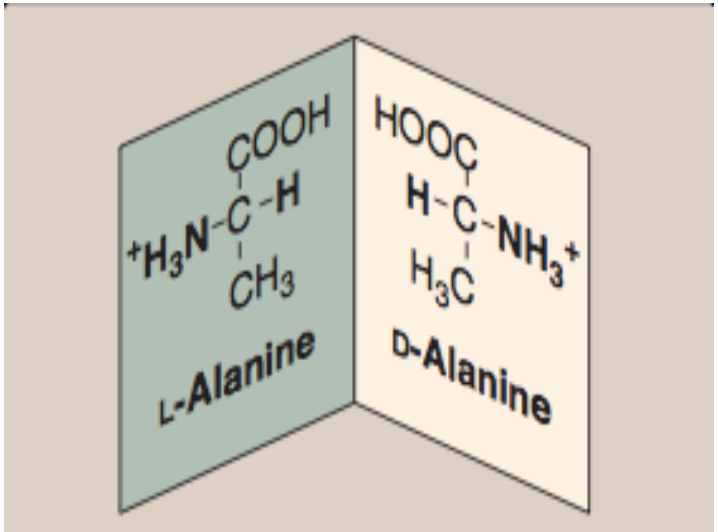
Optical properties

- The α-carbon of most of the amino acids is attached to four different chemical groups (asymmetric).
- Asymmetric molecules are optically active, and symmetric molecules are optically inactive.
- All mammalian amino acids are optically active except glycine.
  - They rotate the plane of polarized light in a polarimeter.

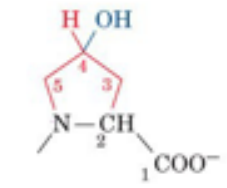

Analyzer
(can be rotated)
+
0°
–
+90°
–90°
180°
Degree scale
(fixed)
Polarimeter
tube
Fixed
polarizer
Light
source
Plane of polarization
of the emerging light
is not the same as
that of the entering
polarized light
Optically active
substance in solution
in the tube causes
the plane of the polarized
light to rotate

Amino acid configuration

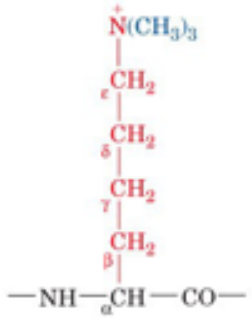
- L-Amino acids rotate polarized light to the left.
- D-Amino acids rotate polarized light to the right.
- Both L and D forms are chemically same.
- All mammalian amino acids are found in L-configuration.
- D-amino acids are found in antibiotics, plants and in the cell wall of microorganisms.



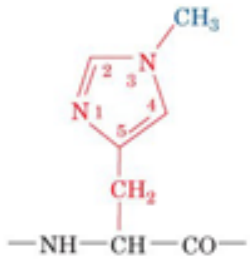
Non-standard amino acids



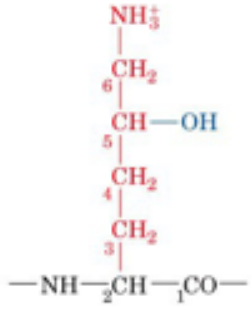
4-Hydroxyproline



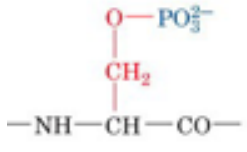
ε-*N*,*N*,*N*-Trimethyllysine



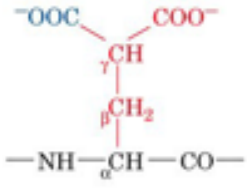
3-Methylhistidine



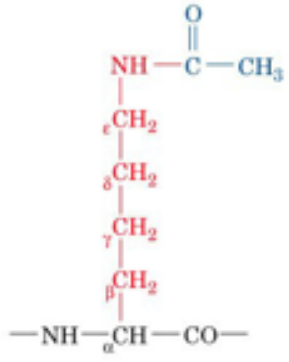
5-Hydroxylysine



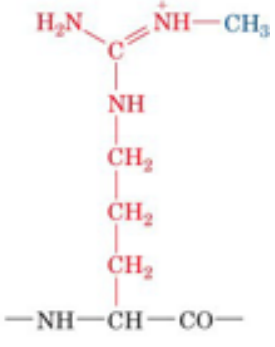
O-Phosphoserine



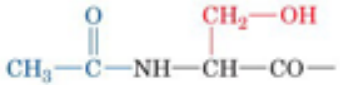
γ-Carboxyglutamate



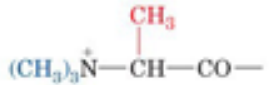
ε-*N*-Acetyllysine



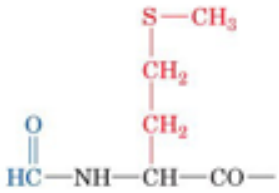
ω-*N*-Methylarginine



N-Acetylserine



N,*N*,*N*-Trimethylalanine



N-Formylmethionine

Amino acids derivatives

- **Gamma amino butyric acid** (GABA, a derivative of glutamic acid) and **dopamine** (from tyrosine) are neurotransmitters.
- **Histamine** (Histidine) is the mediator of allergic reactions.
- **Thyroxine** (Tyrosine) is an important thyroid hormone.

Take home messages

- Each amino acid has an **α**-carboxyl and a primary **α**-amino group (except for proline, which is an imino acid).
- At physiological pH., the **α**-carboxyl is dissociated and the **α**-amino group is protonated.
- Each amino acid also contains twenty distinctive side chains and the chemical nature of this side chain determines the function of the amino acid.
- All free amino acids and charged amino acids in peptide chains, can serve as buffers.
- Buffering action of proteins is maximum around pK values and minimum at isoelectric point.
- All mammalian amino acids are optically active except glycine.
- All mammalian amino acids are found in L-configuration.

Reference:

Lippincott's Illustrated reviews: Biochemistry 6th edition, Unit 1, Chapter 1, Pages 1-12.