

# **Amino acids**

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(Foundation Block)

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# Learning outcomes

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- 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?

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- 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<sub>2</sub>).
- 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.

**Common to all  $\alpha$ -amino acids of proteins**

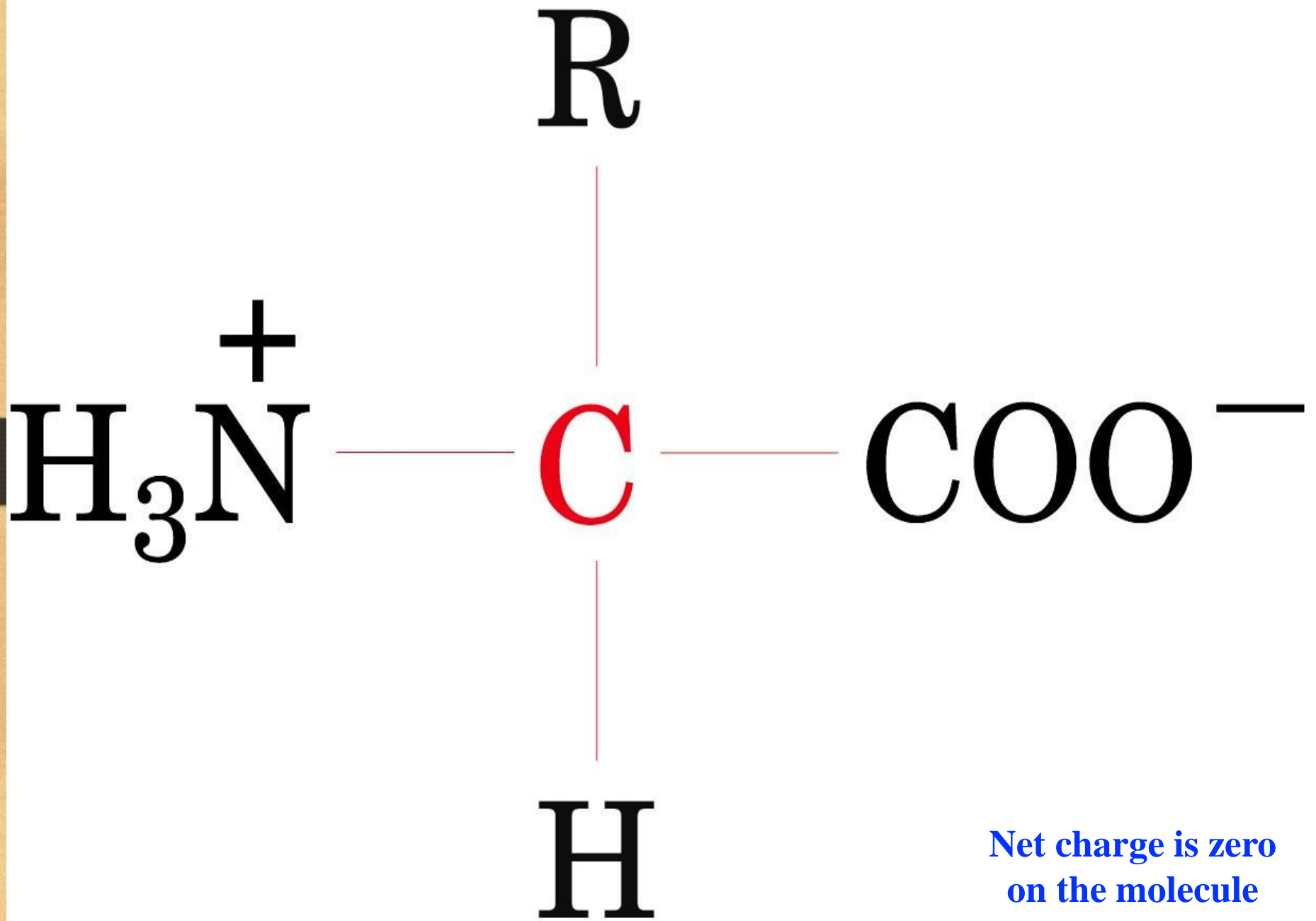


Amino group

Carboxyl group

**Side chain is distinctive for each amino acid.**

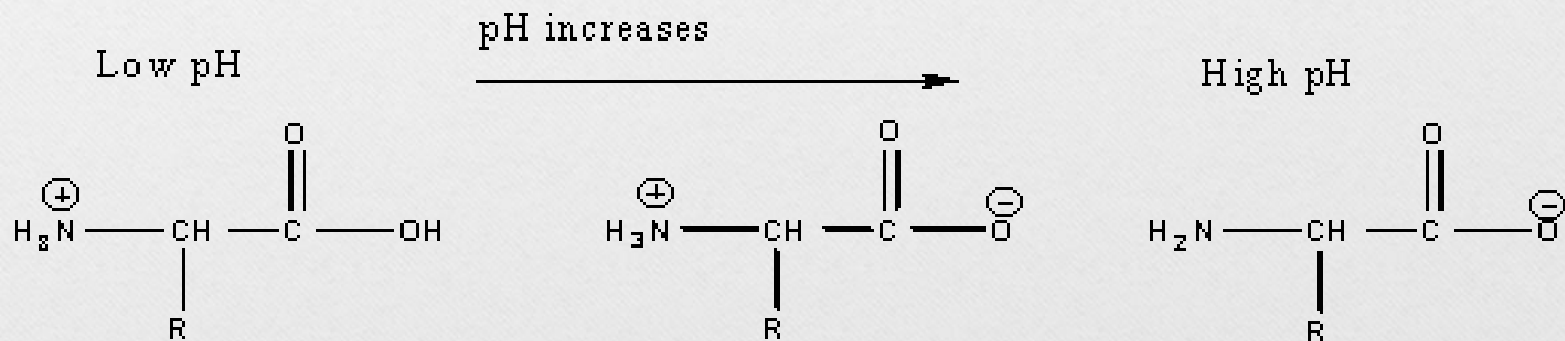
**$\alpha$ -Carbon is between the carboxyl and the amino groups.**



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.



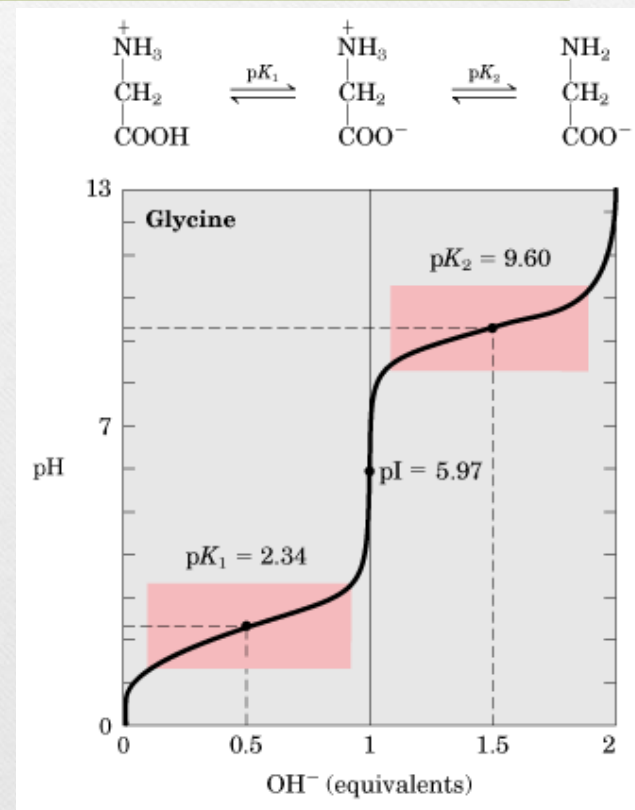
# pK Value

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

# Titration curve of glycine

- **pK<sub>1</sub>**- pH at which 50% of molecules are in cation form and 50% are in zwitterion form.
- **pK<sub>2</sub>**- 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

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- **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.

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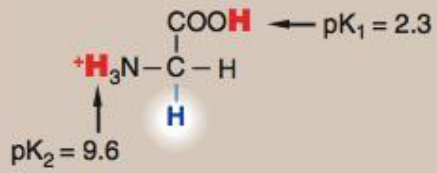
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- **According to the properties of the side chains, amino acids can also be grouped into three categories:**
  - Nonpolar amino acids.
  - Uncharged amino acids.
  - Polar amino acids.

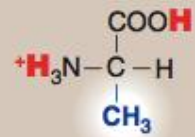
# Nonpolar amino acids

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- 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.



Glycine



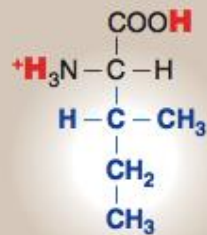
Alanine



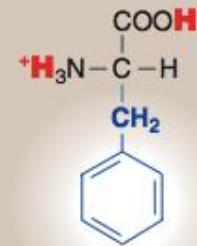
Valine



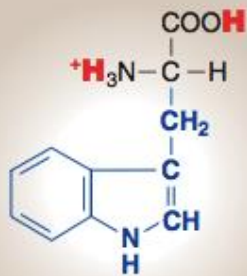
Leucine



Isoleucine



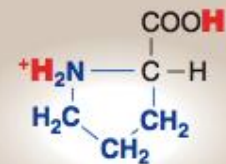
Phenylalanine



Tryptophan



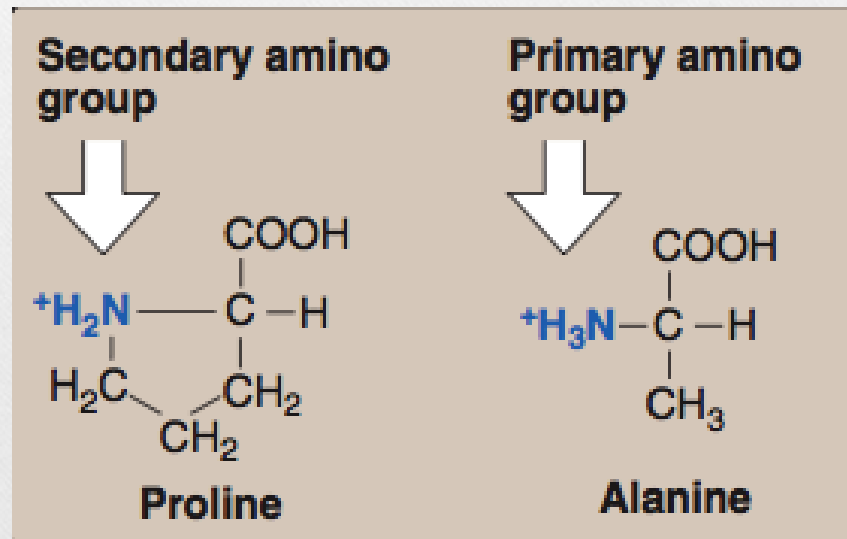
Methionine



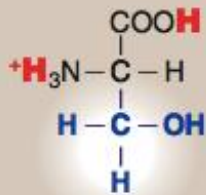
Proline

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



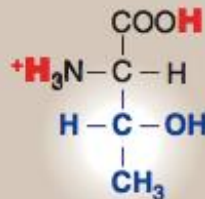
# Uncharged amino acids



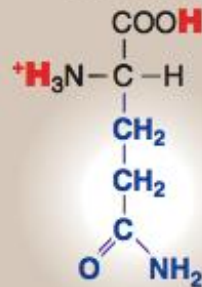
Serine



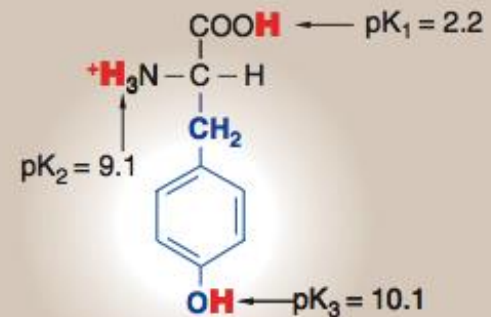
Asparagine



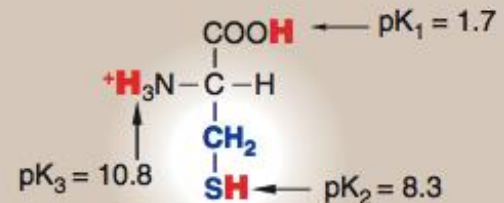
Threonine



Glutamine



Tyrosine



Cysteine

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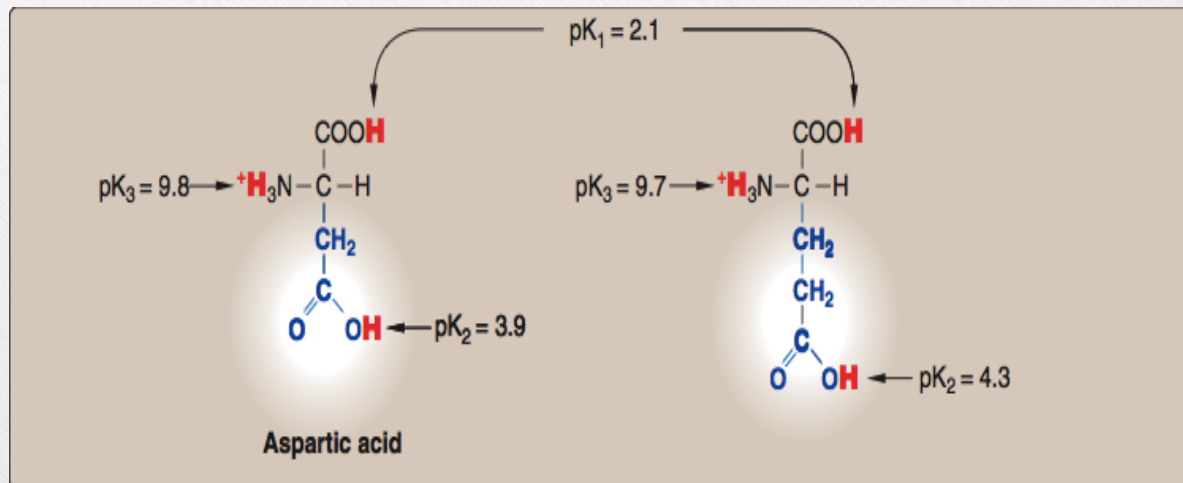
- These amino acids have zero net charge at neutral pH.

### **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:

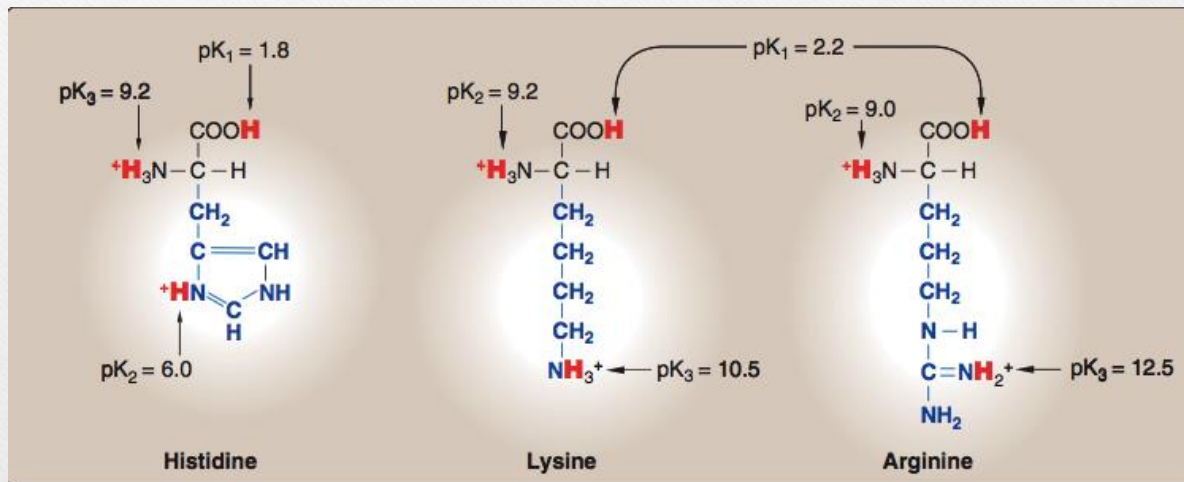


- Aspartic and glutamic acids are proton donors.
- At neutral pH, these amino acids are fully ionized (negatively charged). So, they are called aspartate and glutamate.



# Continued ...

- Amino acids with basic side chains:

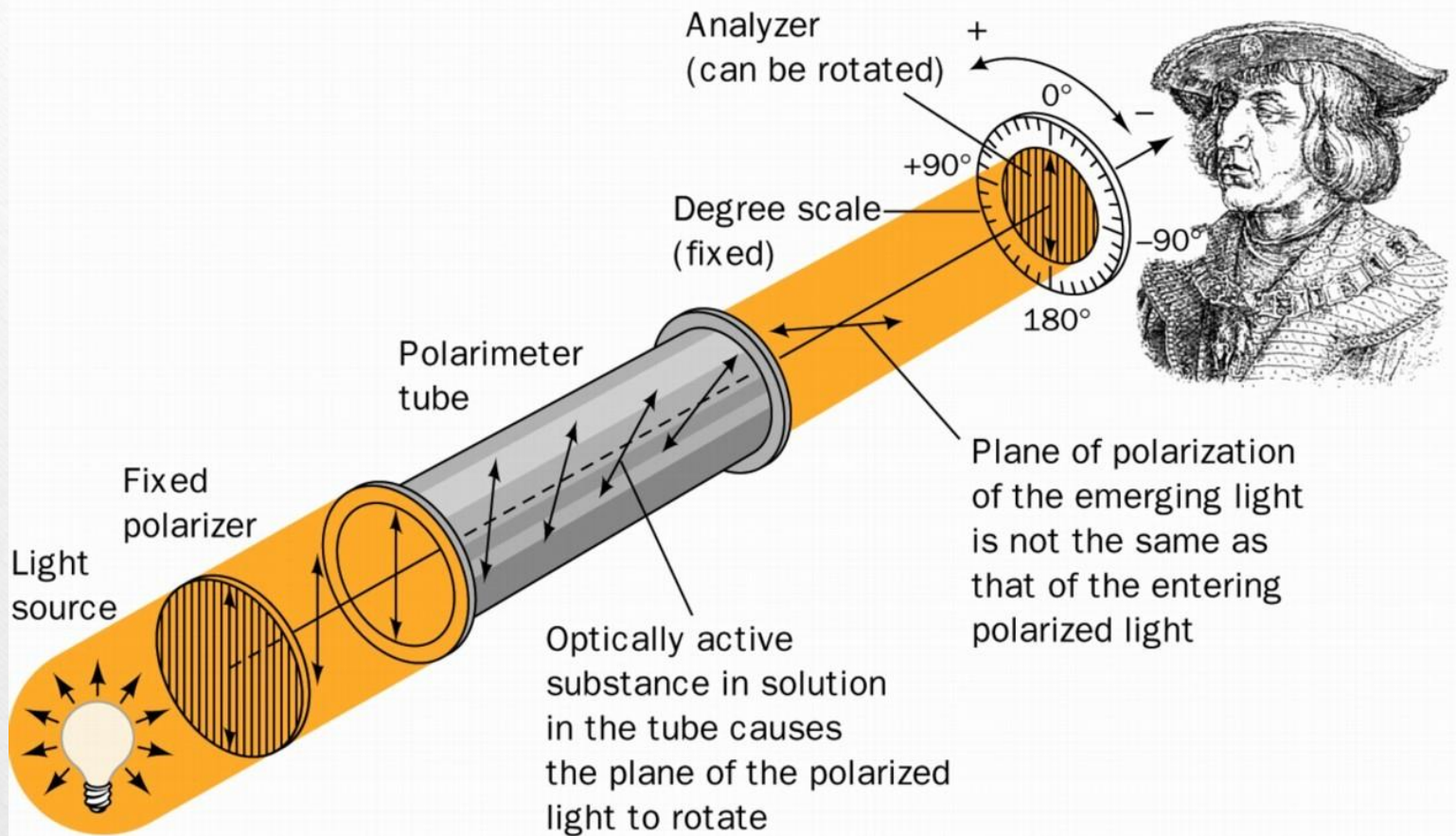


- Histidine, Lysine and Arginine are proton acceptors.
- At neutral pH, lysine and arginine are fully ionized (positively charged).

# Optical properties

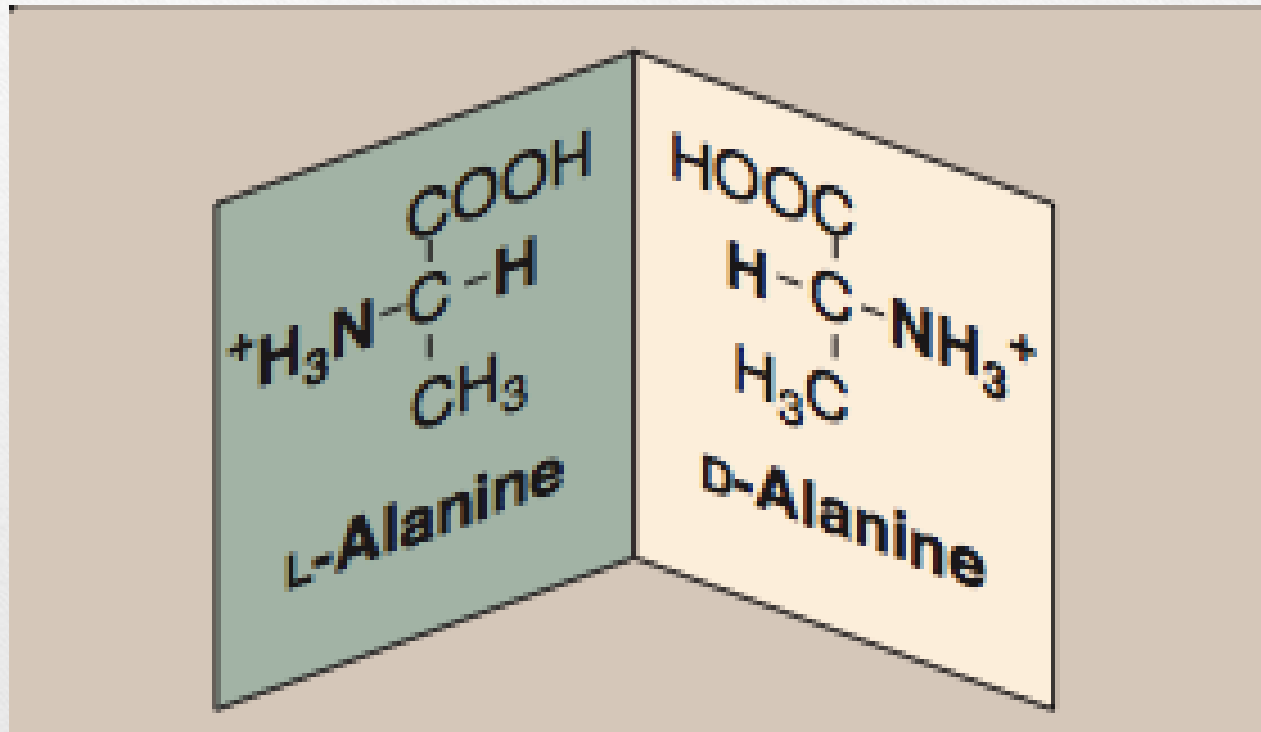
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- The  $\alpha$ -carbon of most of the amino acids is attached to four different chemical groups.
- Thus, asymmetric molecules are optically active, and symmetric molecules are optically inactive.
- All mammalian amino acids are optically active except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



# Amino acid configuration

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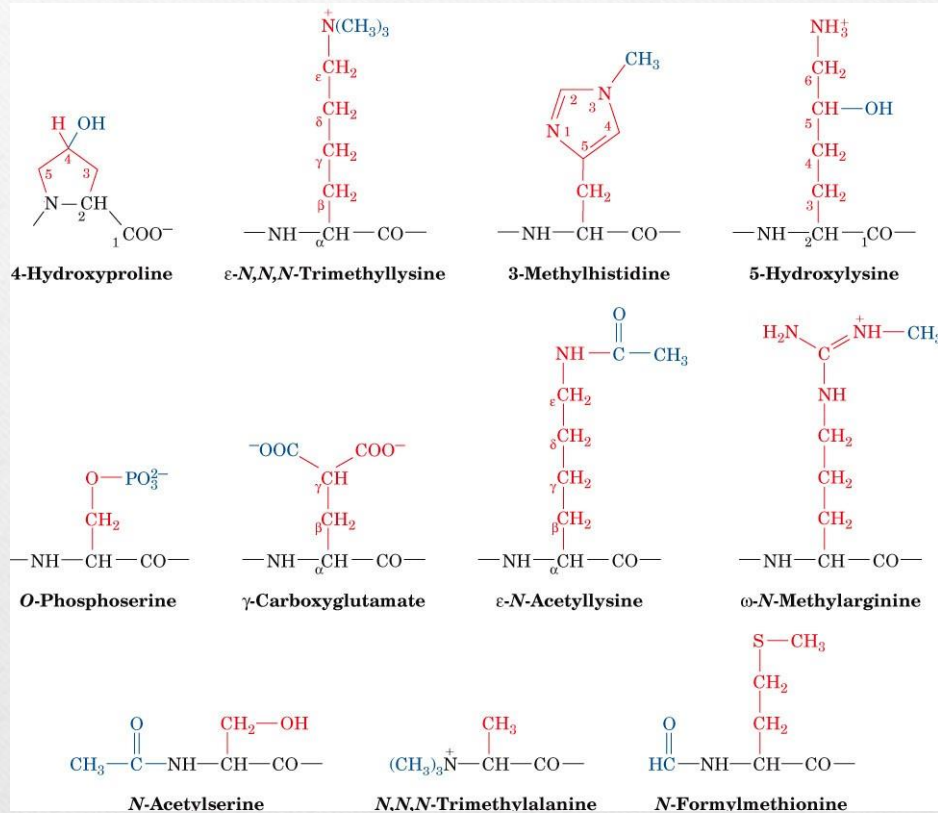


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- L-Amino acids rotate polarized light to the left.
- D-Amino acids rotate polarized light to the right.
- Both L and D forms are chemically same.
- All mammalian amino acids are found in L-configuration.
- D-amino acids are found in antibiotics, plants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

# Non-standard amino acids



# Amino acids derivatives

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- **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

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- Each amino acid has an  $\alpha$ -carboxyl and a primary  $\alpha$ -amino group (except for proline, which is an imino acid).
- At physiological pH., the  $\alpha$ -carboxyl is dissociated.
- 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.



# Take home messages

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- 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

# References

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Lippincott's Illustrated reviews: Biochemistry 4<sup>th</sup> edition, Unit 1, Chapter 1, Pages 1-12.