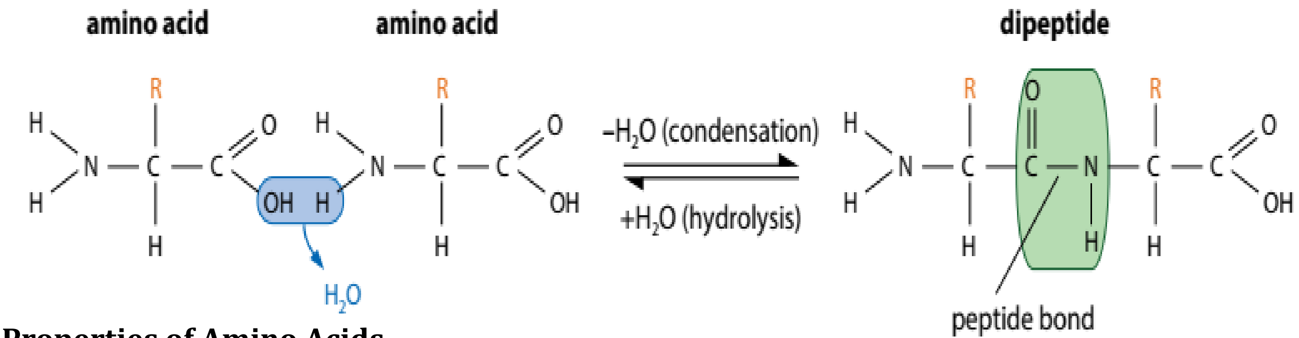
# INTRODUCTION TO AMINO ACIDS

Amino acids are the fundamental building blocks of proteins, which are crucial for almost all biological functions. Proteins act as enzymes, structural elements, and signalling molecules. The unique properties of amino acids allow proteins to adopt various structures and functions.

**General Structure**: Each amino acid consists of a central (alpha) carbon atom that is bonded to four groups:

- **Amino group (-$NH_2$)**: This group acts as a base, accepting protons.
- **Carboxyl group (-COOH)**: This acidic group can donate protons.
- **Side chain (R-group)**: This varies among different amino acids and determines their chemical properties.
- **Hydrogen atom (H)**: A single hydrogen is attached to the alpha carbon.

This general structure gives amino acids their versatile nature. The variation in the side chain (R group) makes each of the 20 standard amino acids unique, affecting how they interact in proteins and how proteins behave.




## Properties of Amino Acids

**Solubility**: Amino acids are generally soluble in water due to their polar amino and carboxyl groups, which can form hydrogen bonds with water molecules. However, the solubility of an amino acid depends on its side chain. Hydrophilic side chains (e.g., those containing polar groups) increase solubility, while hydrophobic side chains (e.g., those with nonpolar groups like alkyl chains) decrease it.

**Optical Activity**: Except for glycine (which has two hydrogen atoms attached to the alpha carbon), amino acids have a chiral center at the alpha carbon, meaning they can exist in two mirror-image forms (D and L enantiomers). In biological systems, only the L-enantiomers are commonly found. These enantiomers can rotate plane-polarized light, a property known as optical activity.

**Isoelectric Point (pI)**: The isoelectric point of an amino acid is the pH at which it carries no net electrical charge. At this pH, the amino group is protonated ($-NH_3^+$), and the carboxyl group is deprotonated ($-COO^-$), but their charges cancel out. Each amino acid has a unique pI, depending on its side chain. This property is important in techniques like isoelectric focusing, which separates proteins based on their charge.

**Reactions of Amino Acids**

1. **Reaction with Ninhydrin**:

Ninhydrin is commonly used to detect amino acids. When amino acids react with ninhydrin, they undergo deamination, releasing ammonia and forming a coloured compound. This reaction produces a deep blue or purple colour, which is useful in analytical techniques such as chromatography for identifying amino acids. Proline, however, gives a yellow colour due to its secondary amine structure.

2. **Schiff Base Formation**:

Amino acids with primary amine groups can form Schiff bases when they react with aldehydes or ketones. This reaction involves the condensation of the amino group with the carbonyl group of the aldehyde, forming an imine (Schiff base). This reaction is biologically relevant in the mechanism of enzymes like transaminases, which transfer amino groups between molecules during metabolism.

**Classification of Amino Acids**

Amino acids are classified based on the chemical nature of their side chains (R-groups), their polarity, and their role in human nutrition. These classifications help us understand the behavior of amino acids in proteins, how they interact with other molecules, and their metabolic importance.

**Classification Based on Side Chains:** Amino acids can be categorized into neutral, basic, and acidic types based on the charge of their side chains at physiological pH (around 7.4).

**Neutral Amino Acids**: Neutral amino acids have side chains that do not carry a charge at physiological pH. Most amino acids fall into this category, including those with nonpolar and polar uncharged side chains.

**Examples**:

- **Glycine (Gly)**: The simplest amino acid with just a hydrogen as its side chain.

- **Serine (Ser)** and **Threonine (Thr)**: Contain hydroxyl (-OH) groups that are polar but uncharged.
- **Alanine (Ala)**: Has a simple nonpolar methyl group (-$CH_3$) as its side chain.

Neutral amino acids contribute to the overall structure of proteins, often forming alpha-helices and beta-sheets. Their lack of charge allows them to be flexible in both hydrophilic and hydrophobic environments.

2. **Basic Amino Acids**: These amino acids have side chains that are positively charged at physiological pH. Their side chains contain amino groups that can accept protons, making them basic.

**Examples**:

- **Lysine (Lys)**: Has an aliphatic side chain with a terminal amino group that can carry a positive charge.
- **Arginine (Arg)**: Contains a guanidinium group, making it highly basic.
- **Histidine (His)**: Contains an imidazole group that can be protonated or deprotonated depending on the pH, giving it a buffering capacity in proteins.

Basic amino acids often play critical roles in binding negatively charged molecules, such as DNA (due to its phosphate backbone). They are also found in enzyme active sites, where they help in catalysis by donating or accepting protons.

3. **Acidic Amino Acids**: Acidic amino acids have side chains with carboxyl groups that are negatively charged at physiological pH. They are good proton donors, making them acidic.

**Examples**:

- **Aspartic acid (Asp)**: Has a carboxyl group in its side chain that can lose a proton, resulting in a negative charge.
- **Glutamic acid (Glu)**: Similar to aspartic acid but with a longer side chain.

Acidic amino acids are commonly involved in protein-protein interactions and binding to metal ions. They also help maintain the solubility of proteins and are important in energy metabolism, such as in the citric acid cycle (where glutamate plays a role).

**Classification Based on Polarity**

Amino acids can also be classified as polar or non-polar depending on whether their side chains can interact with water (hydrophilic) or not (hydrophobic). This classification affects how amino acids are distributed within proteins, influencing protein structure and function.

**Non-polar (Hydrophobic) Amino Acids**: Non-polar amino acids have side chains that do not form hydrogen bonds with water, making them hydrophobic. These amino acids tend to be located in the interior of proteins, away from aqueous environments, where they help stabilize protein structures through hydrophobic interactions.

**Examples**:

- **Valine (Val)**, **Leucine (Leu)**, and **Isoleucine (Ile)**: Have branched aliphatic side chains.
- **Phenylalanine (Phe)**: Contains a benzyl side chain.
- **Methionine (Met)**: Has a sulfur-containing nonpolar thioether group.

Non-polar amino acids are crucial for the formation of transmembrane domains in membrane proteins, allowing proteins to embed in the hydrophobic lipid bilayer. They also promote the folding of proteins into compact, stable structures by minimizing exposure to water.

2. **Polar (Hydrophilic) Amino Acids**:

Polar amino acids have side chains that can form hydrogen bonds with water, making them hydrophilic. These amino acids are usually found on the exterior of proteins, where they can interact with the aqueous environment.

**Examples**:

- **Serine (Ser)** and **Threonine (Thr)**: Contain hydroxyl groups that can form hydrogen bonds.
- **Asparagine (Asn)** and **Glutamine (Gln)**: Have amide groups that also form hydrogen bonds.
- **Cysteine (Cys)**: Contains a thiol group (-SH), which can form disulfide bonds, stabilizing protein structure.

Polar amino acids are essential in the active sites of enzymes where they participate in catalytic mechanisms, often by stabilizing transition states or intermediates. They are also involved in molecular recognition processes such as antigen-antibody interactions.

**Classification Based on Nutritional Requirements:**

Amino acids can be classified into **essential** and **non-essential** based on whether they can be synthesized by the human body or need to be obtained through the diet.

1. **Essential Amino Acids**:

These amino acids cannot be synthesized by the human body and must be obtained through the diet. They are crucial for growth, tissue repair, and overall health. A deficiency in any of these amino acids can lead to health problems, such as muscle wasting and immune dysfunction.

**Examples**:

- **Valine (Val)**, **Leucine (Leu)**, and **Isoleucine (Ile)**: Branched-chain amino acids important for muscle metabolism.
- **Lysine (Lys)**: Essential for protein synthesis and the production of carnitine, a molecule involved in fatty acid metabolism.
- **Methionine (Met)**: Serves as a precursor to S-adenosylmethionine (SAM), a major methyl donor in biochemical reactions.
- **Phenylalanine (Phe)**: A precursor to neurotransmitters like dopamine and norepinephrine.
- **Threonine (Thr)**, **Tryptophan (Trp)**, **Histidine (His)**: Essential for protein synthesis and various metabolic functions.

The body's inability to synthesize essential amino acids underscores the importance of a balanced diet containing sufficient amounts of these amino acids. A complete source of protein (e.g., eggs, meat, dairy) provides all essential amino acids, whereas plant-based sources may require combination to meet dietary needs (e.g., combining rice and beans).

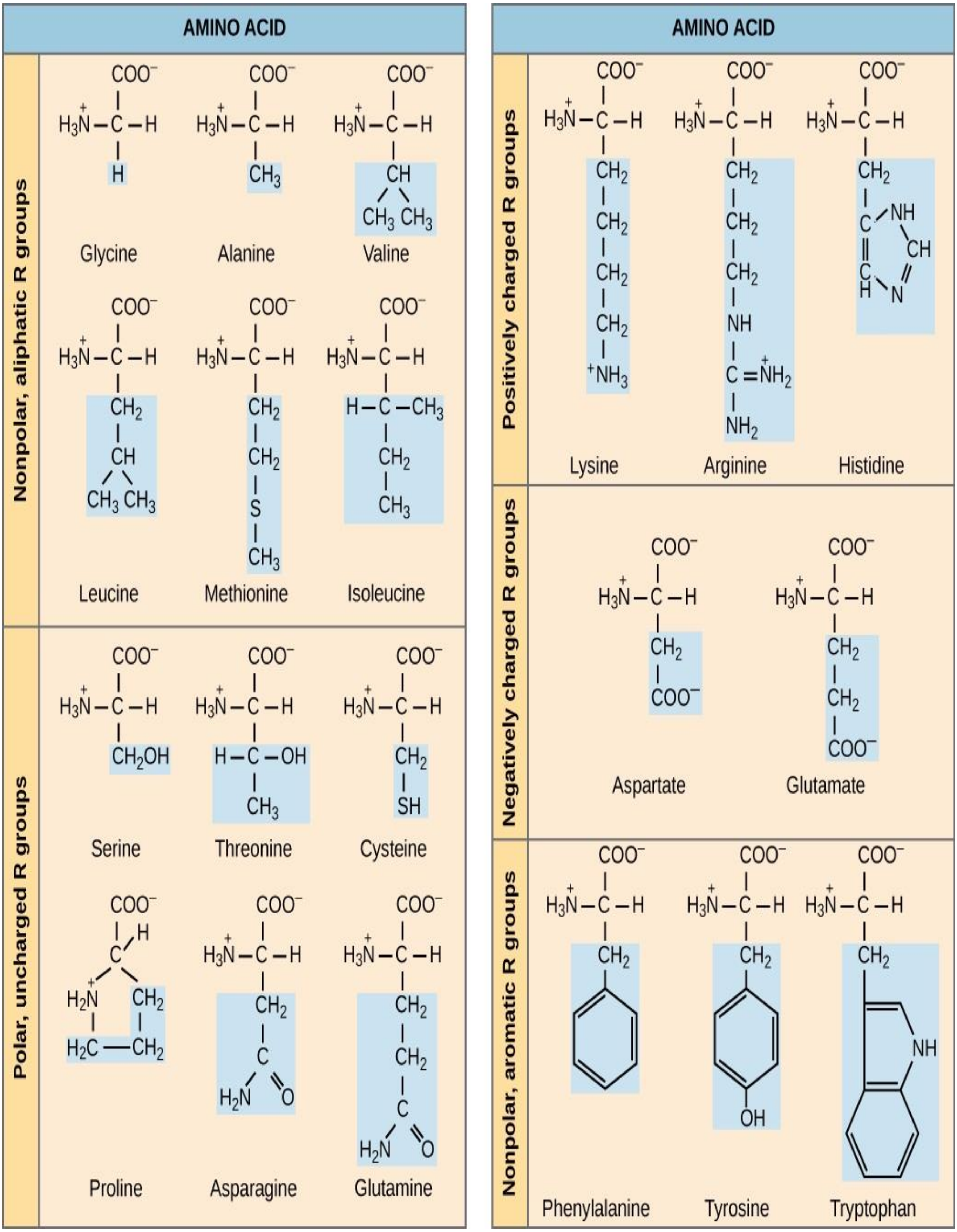
2. **Non-essential Amino Acids**:

Non-essential amino acids can be synthesized by the body, usually from intermediates in the citric acid cycle or from other amino acids. Though not required in the diet, they are still vital for overall health and proper functioning.

- **Examples**:

- **Alanine (Ala)**: Synthesized from pyruvate and involved in glucose-alanine cycle.
- **Asparagine (Asn)** and **Glutamine (Gln)**: Derived from aspartate and glutamate, respectively, and involved in nitrogen transport.
- **Proline (Pro)**: Involved in collagen formation, synthesized from glutamate.
- **Cysteine (Cys)**: Can be synthesized from methionine in a process requiring sulfur.

Non-essential amino acids are important for maintaining cellular metabolism, tissue repair, and nitrogen balance. In conditions of stress or illness, some non-essential amino acids, such as glutamine and arginine, may become conditionally essential because the body's demand exceeds its ability to produce them.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