University of Al-Qadisiyah

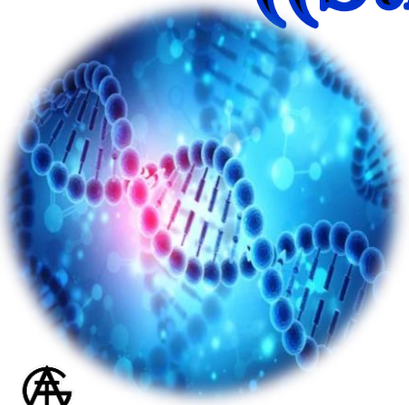
College of Medicine

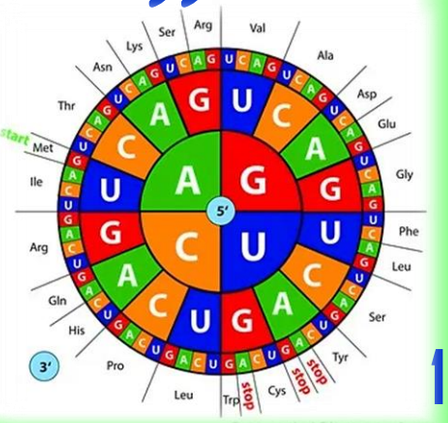
Medical Chemistry/ Part 1-Biochemistry

1st year / (2022-2023) / 1st Semester

L 4 - Amino Acids

((Structures, Classification and Genetic Code))





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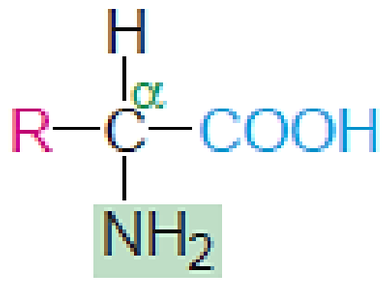
PhD. Medical Biochemistry

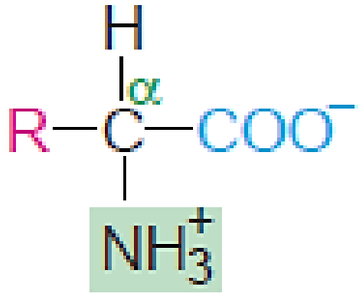
Amino acids: are a group of organic compounds containing two functional groups amino and carboxyl.

The amino group (—NH2) is basic while the carboxyl group (—COOH) is acidic in nature. More than 300 different amino acids have been described in nature, only 20 are commonly found as constituents of mammalian proteins.

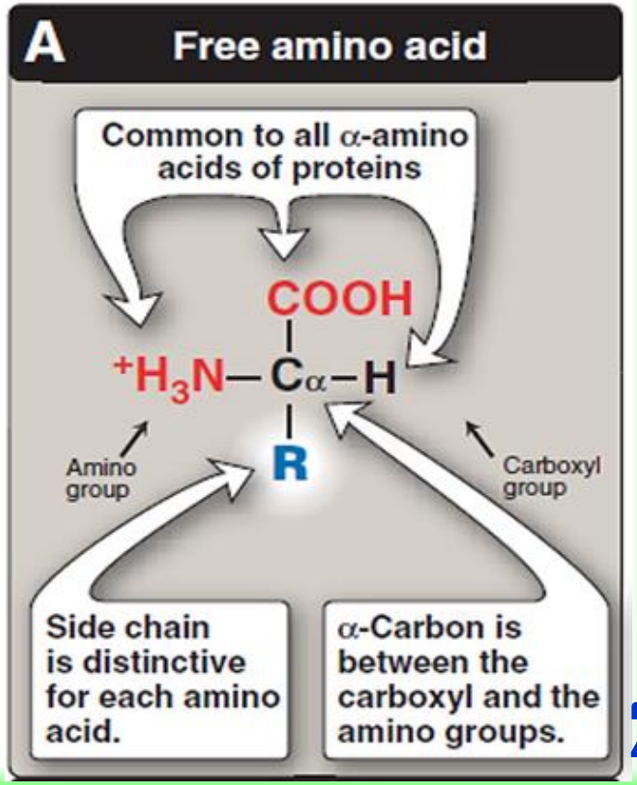
General structure of amino acids: The amino acids are termed as α-amino acids, if both the carboxyl and amino groups are attached to the same carbon atom, as depicted below:



General structure



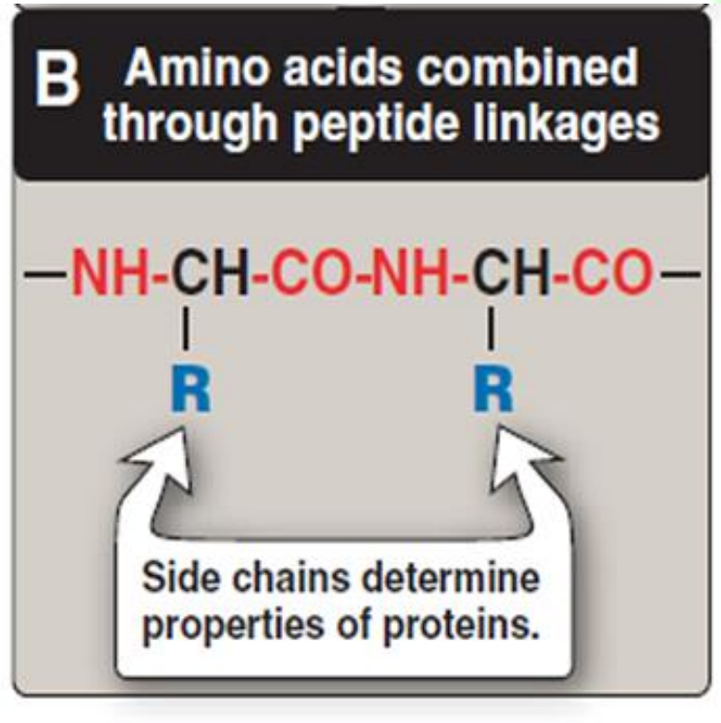
Exists as ion



The α -carbon atom binds to a side chain represented by R which is different for each of the 20 amino acids found in proteins. The amino acids mostly exist in the ionized form in the biological system.

Each amino acid a primary amino group except for proline, which has a secondary amino group. At physiologic pH (pH= 7.4), the carboxyl group is dissociated, forming the negatively charged carboxylate ion (–COO–), and the amino group is protonated (–NH3+).

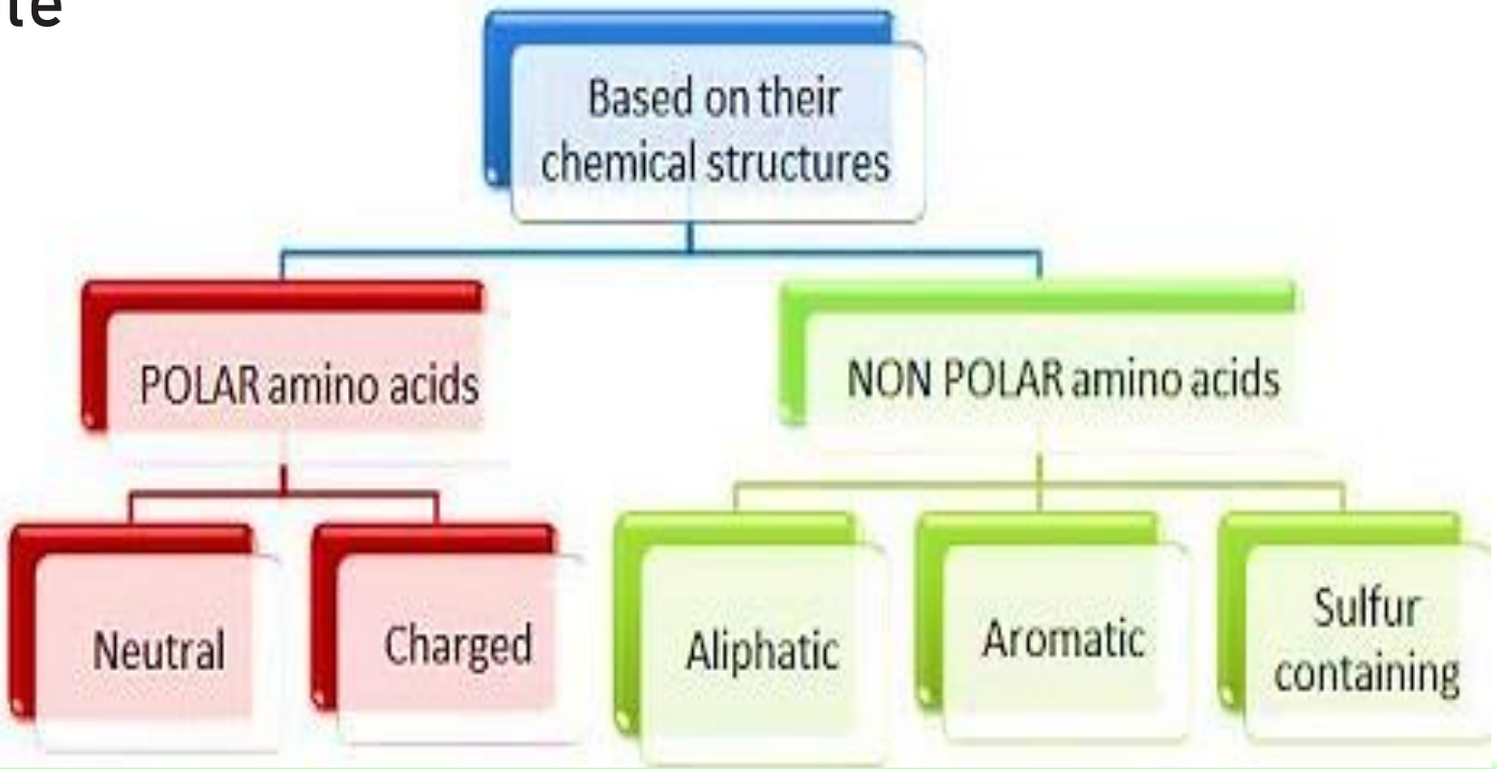
In proteins, almost all of these carboxyl and amino groups are combined through peptide linkage.



Classification of Amino Acids: The nature of the side chain (-R group) play role to classify the amino acids according to the properties of their side chains.

There are different ways of classifying the amino acids based on the structure and chemical nature, nutritional requirement (essential and nonessential), metabolic fate

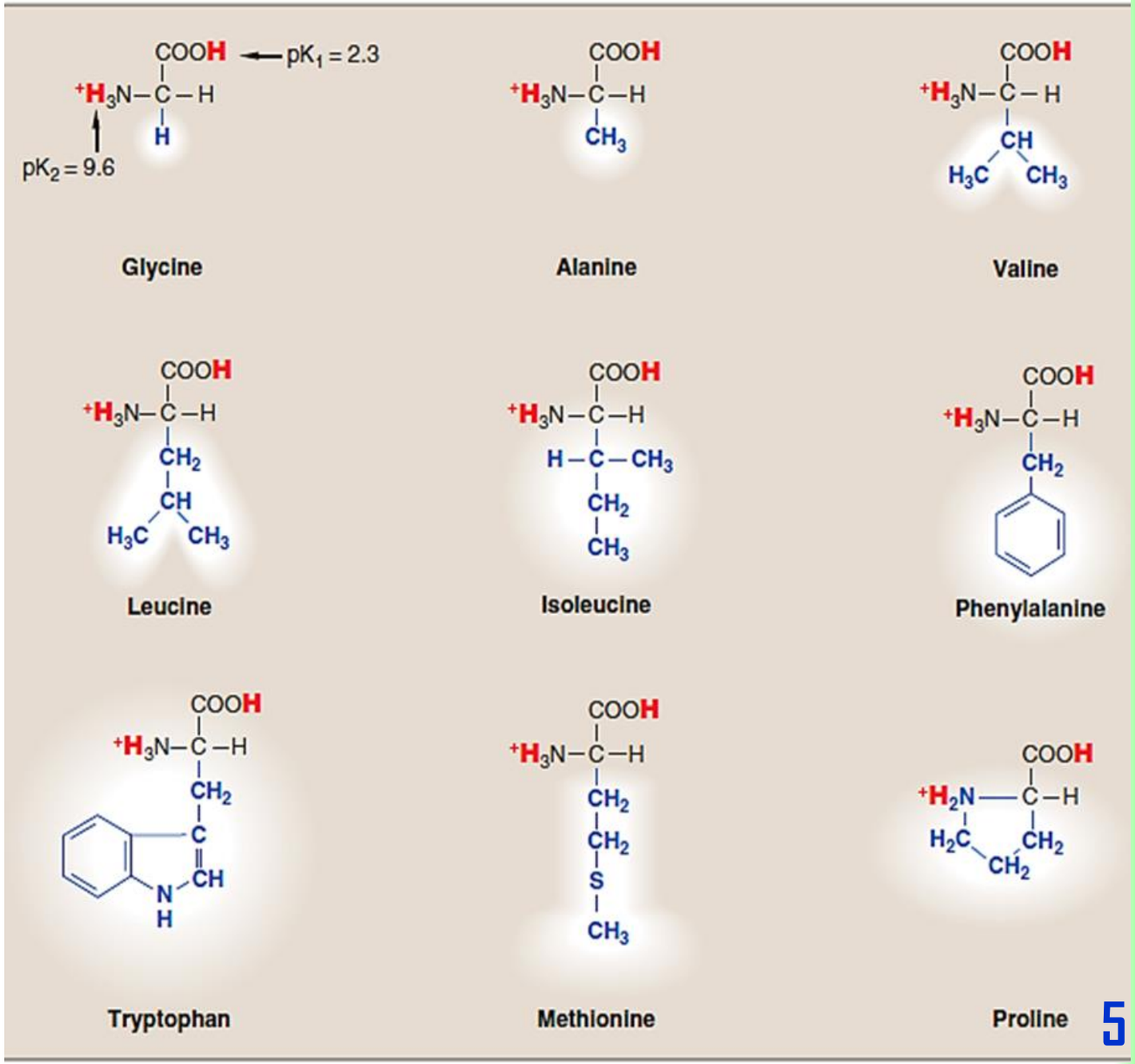
, polar and nonpolar, charged and uncharged, acidic and basic, aliphatic and aromatic side chains and contain -OH or sulfur or amide group as shown below:



1- Amino acids with nonpolar side chains:

Each of these amino acids has a nonpolar side chain that does not gain or lose protons or participate in hydrogen or ionic bonds.

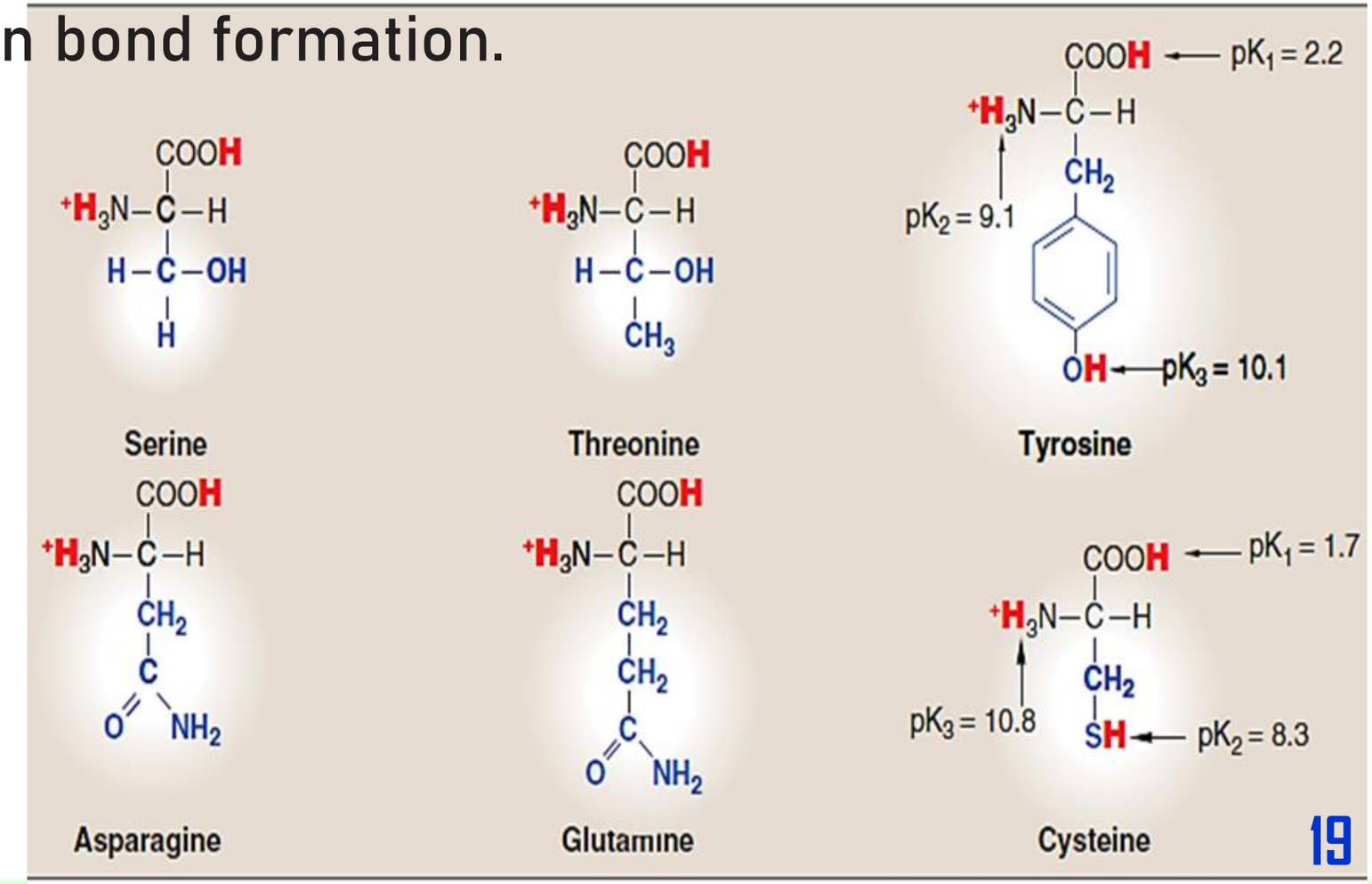
The side chains of these amino acids can be thought of as “oily” or lipid-like, a property that promotes hydrophobic interactions.



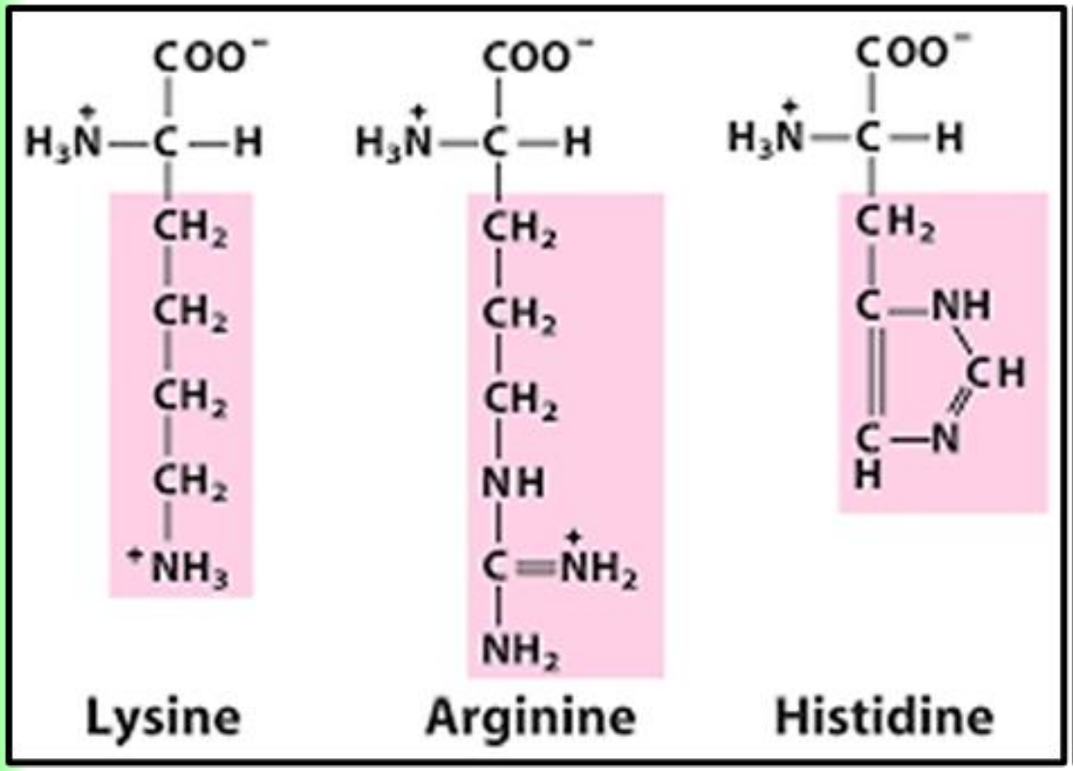
2- Amino acids with uncharged polar side chains:

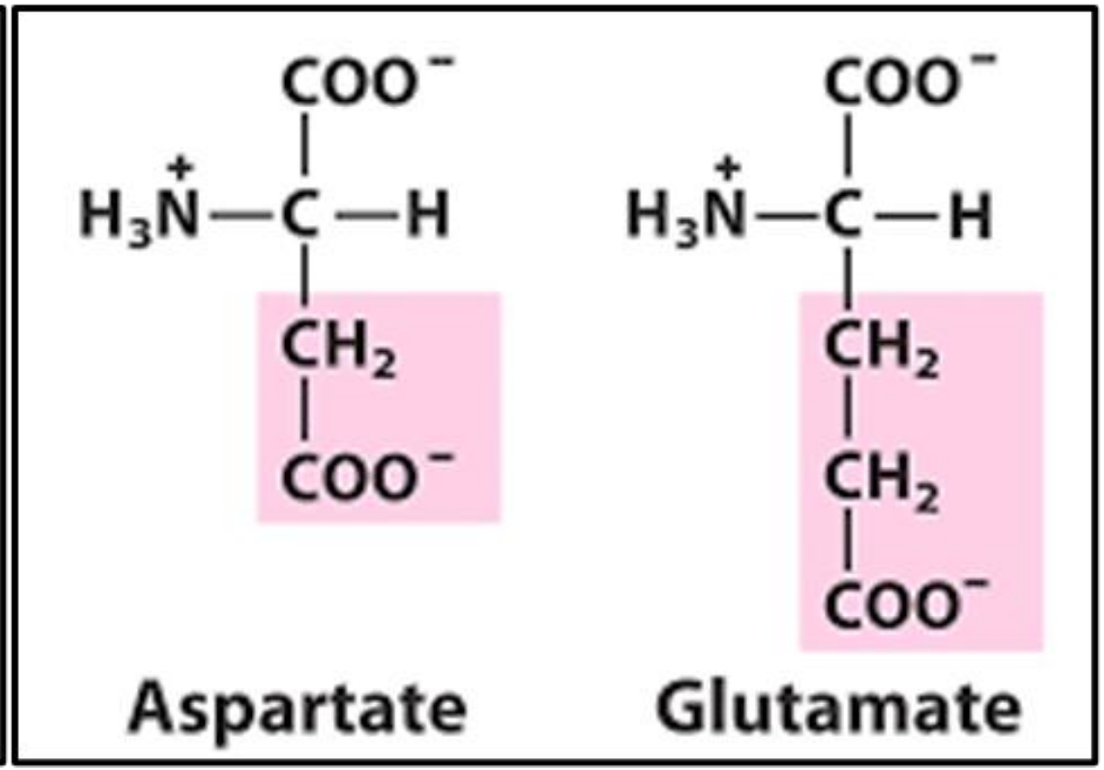
These amino acids have zero net charge at neutral pH, although the side chains of cysteine and tyrosine can lose a proton at an alkaline pH. Serine, threonine, and tyrosine each contain a polar hydroxyl group that can participate in hydrogen bond formation.

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.



3- Amino acids with charged polar side chains:

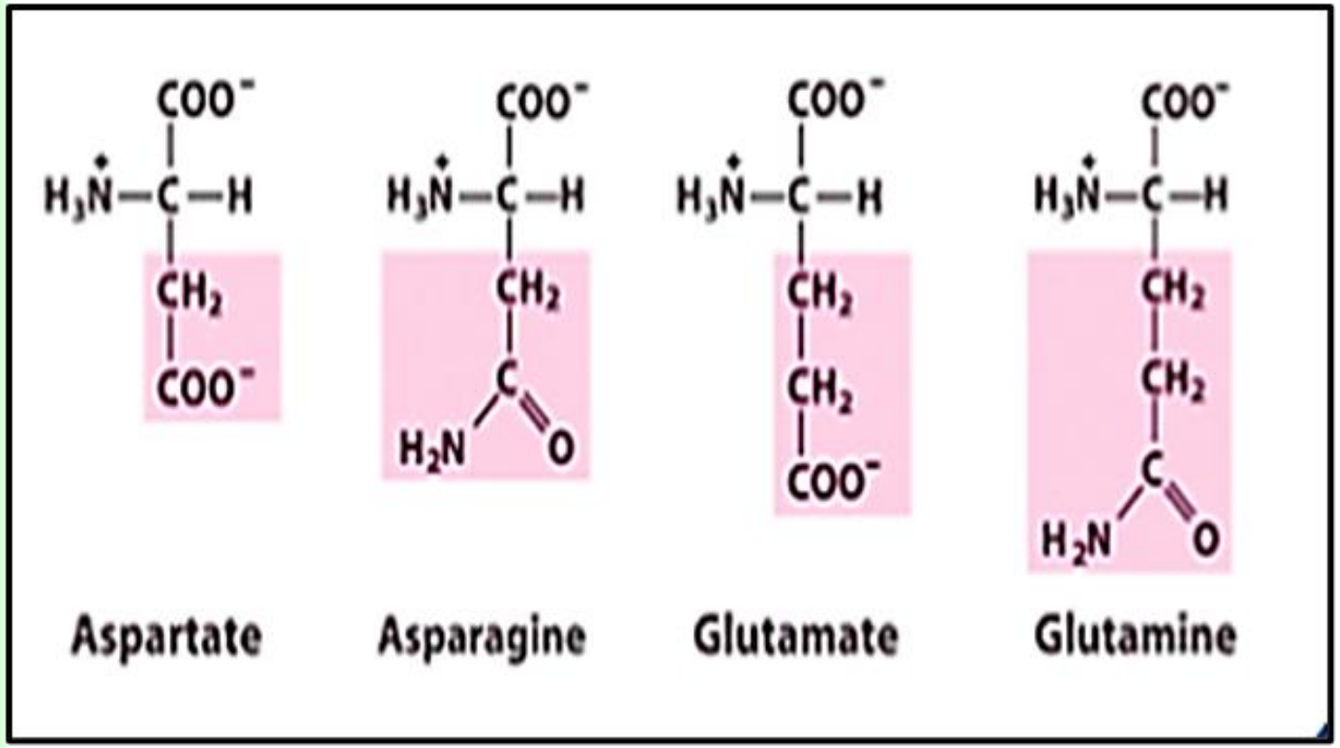


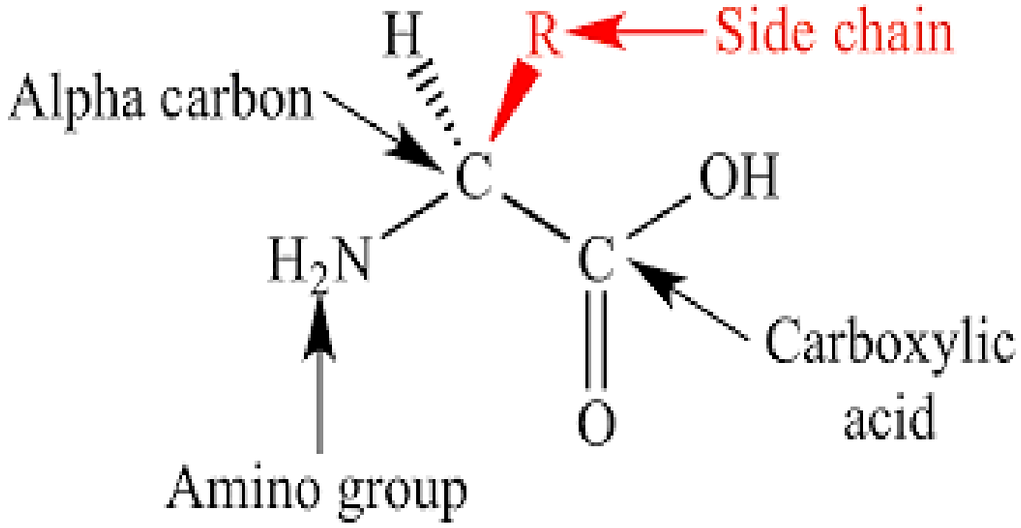


These are serine (Ser), threonine (Thr), cysteine (Cys), asparagine (Asn), glutamine (Gln), and tyrosine (Tyr). These amino acids are usually found at the surface of protein. Polar side chains contain groups that are either charged at physiological pH or groups that are able to participate in hydrogen bonding.

3- Amino acids with acidic side chains:

Aspartic acid and glutamic acids are dicarboxylic monoamino acids while asparagine and glutamine are their respective amide derivatives.

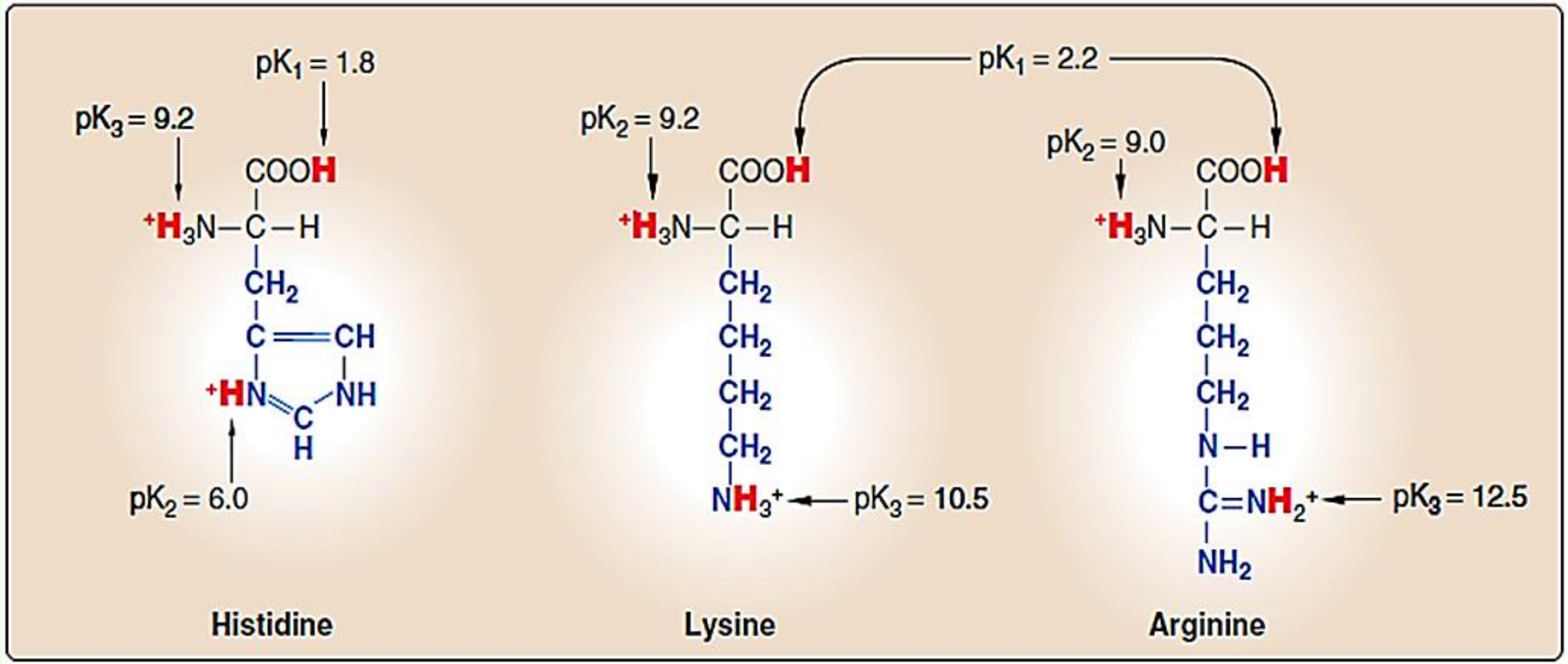




Aspartate and glutamate are the two acidic amino acids, which means that they both have a full negative charge on their side chains at the normal physiological pH.

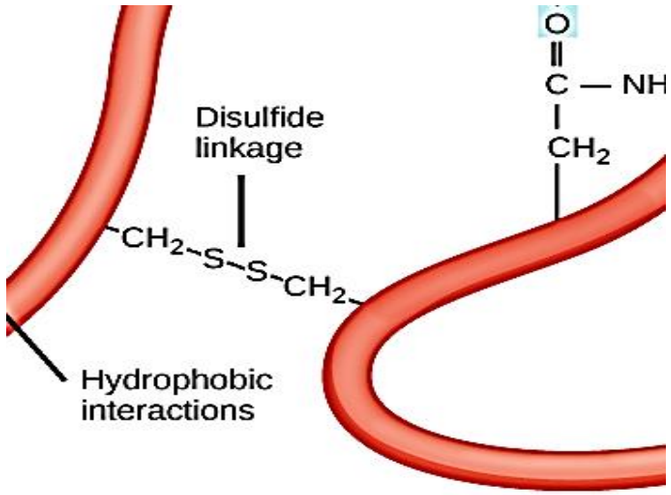
4- Amino acids with basic side chains:

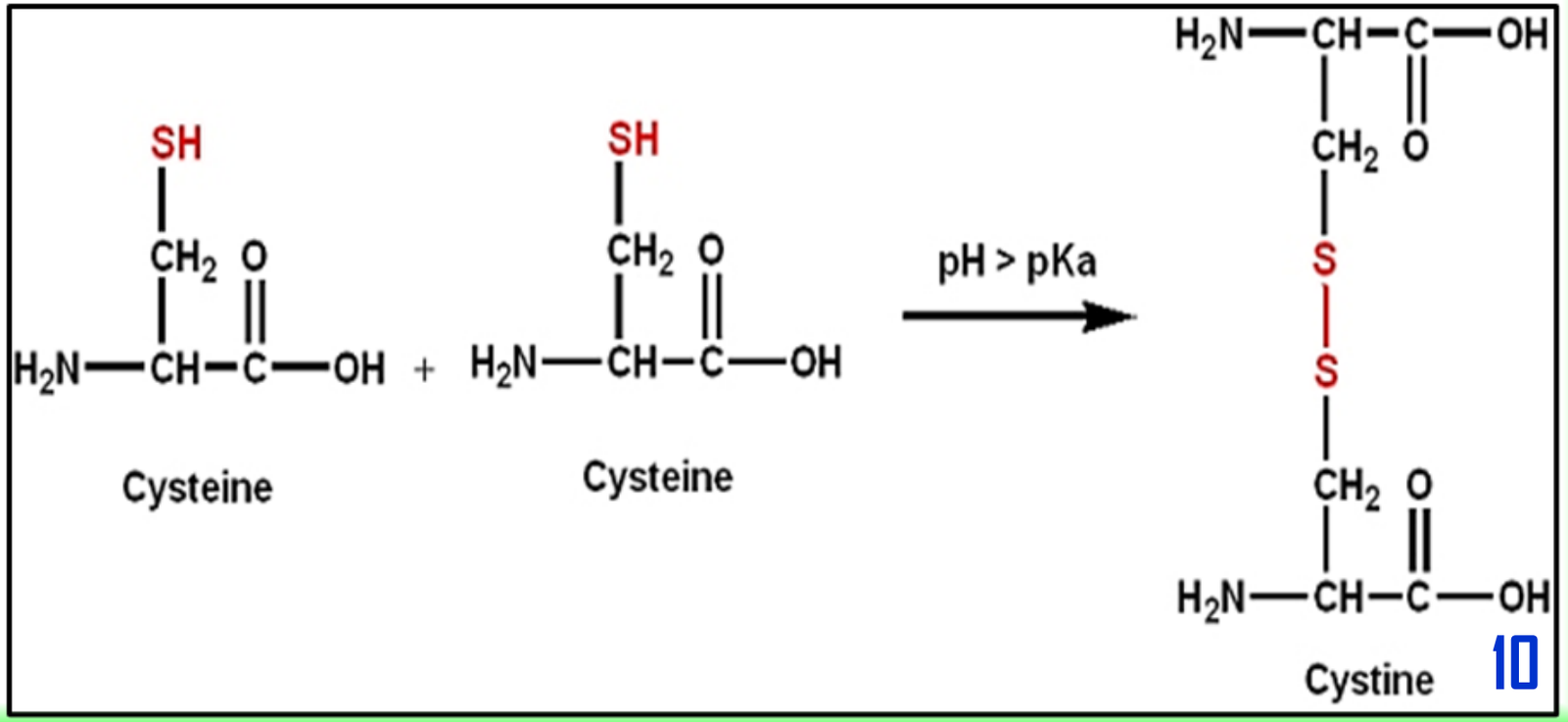
The three amino acids lysine, arginine (with guanidino group) and histidine (with imidazole ring) are dibasic monocarboxylic acids. They are highly basic in character.



5- Amino acids with disulfide bond in side chains:

The side chain of cysteine contains a sulfhydryl group (–SH), which is an important component of the active site of many enzymes. In proteins, the –SH groups of two cysteines can become oxidized to form a dimer, cystine, which contains a covalent cross-link called a disulfide bond (–S–S–).

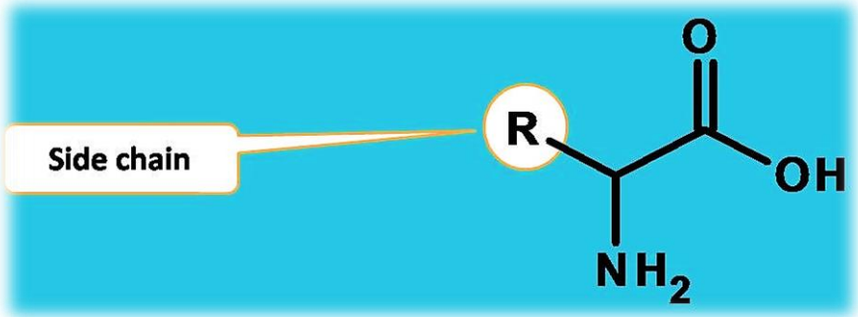


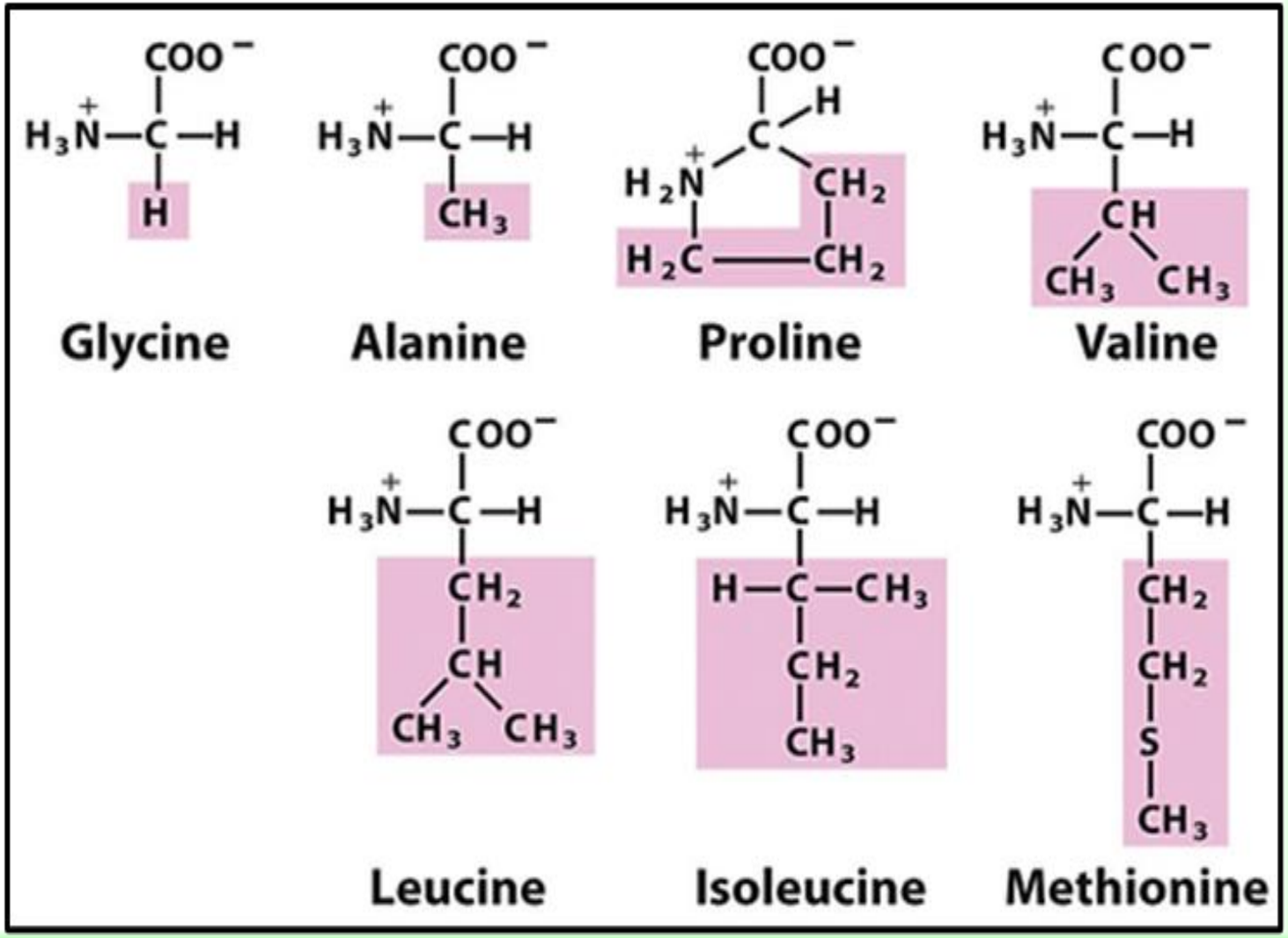


6- Amino acids with aliphatic side chains:

These are monoamino monocarboxylic acids. This group consists of the simplest amino acids—glycine, alanine, valine, leucine and isoleucine.

The last three amino acids (Leu, Ile, Val) contain branched aliphatic side chains, hence they are referred to as branched chain amino acids.

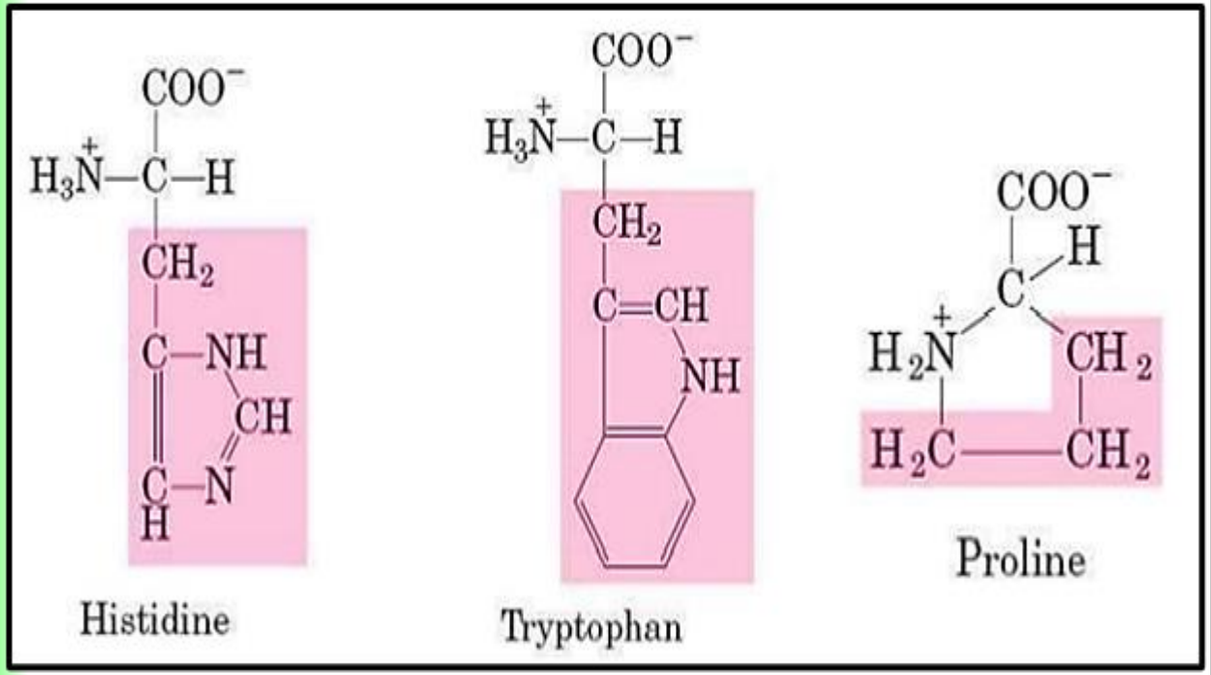


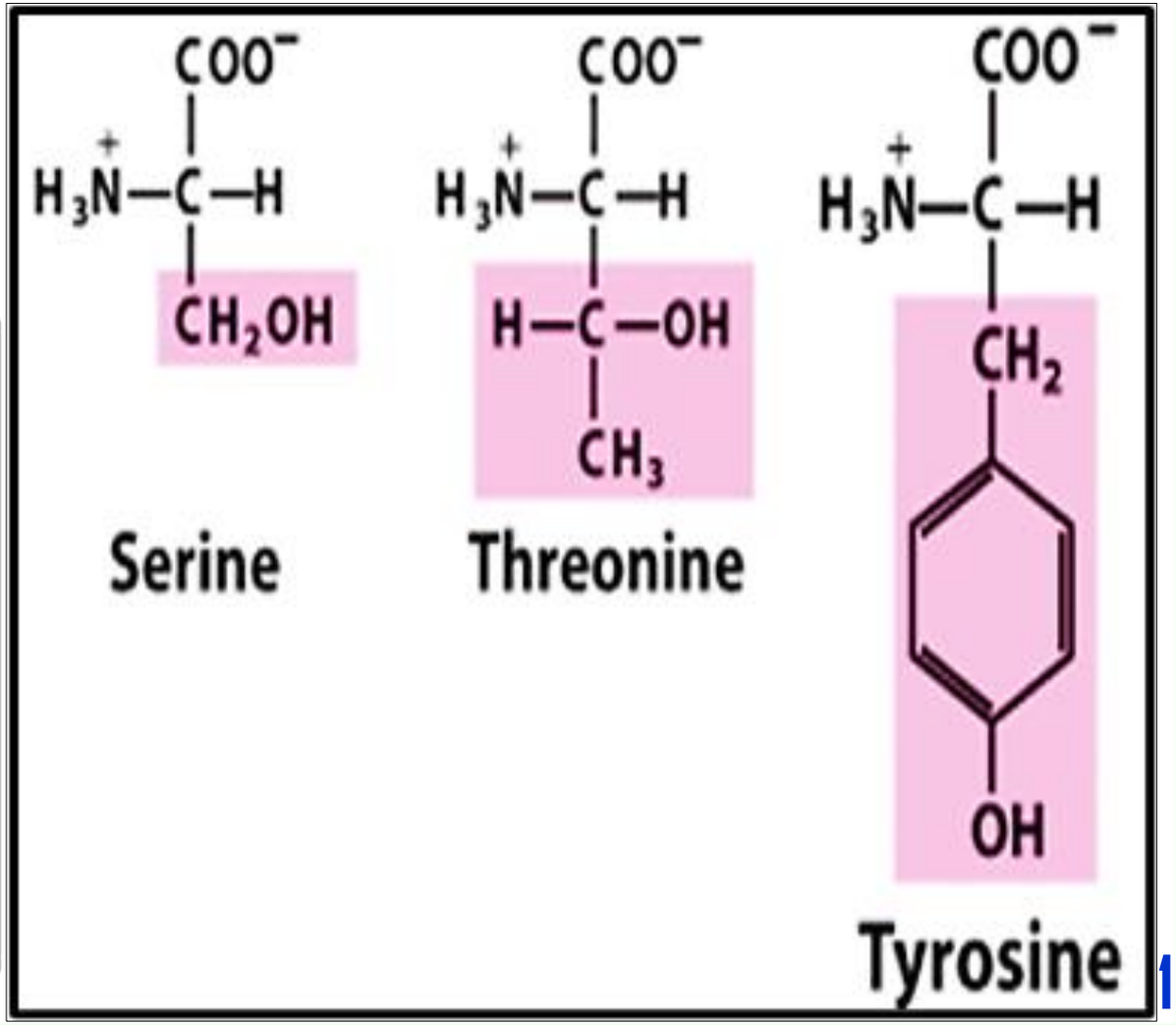


7- Amino acids with hydroxyl group side chains: Serine, threonine and tyrosine are hydroxyl group containing amino acids. Tyrosine being aromatic in nature is usually considered under aromatic amino acids.

8- Heterocyclic amino acids:

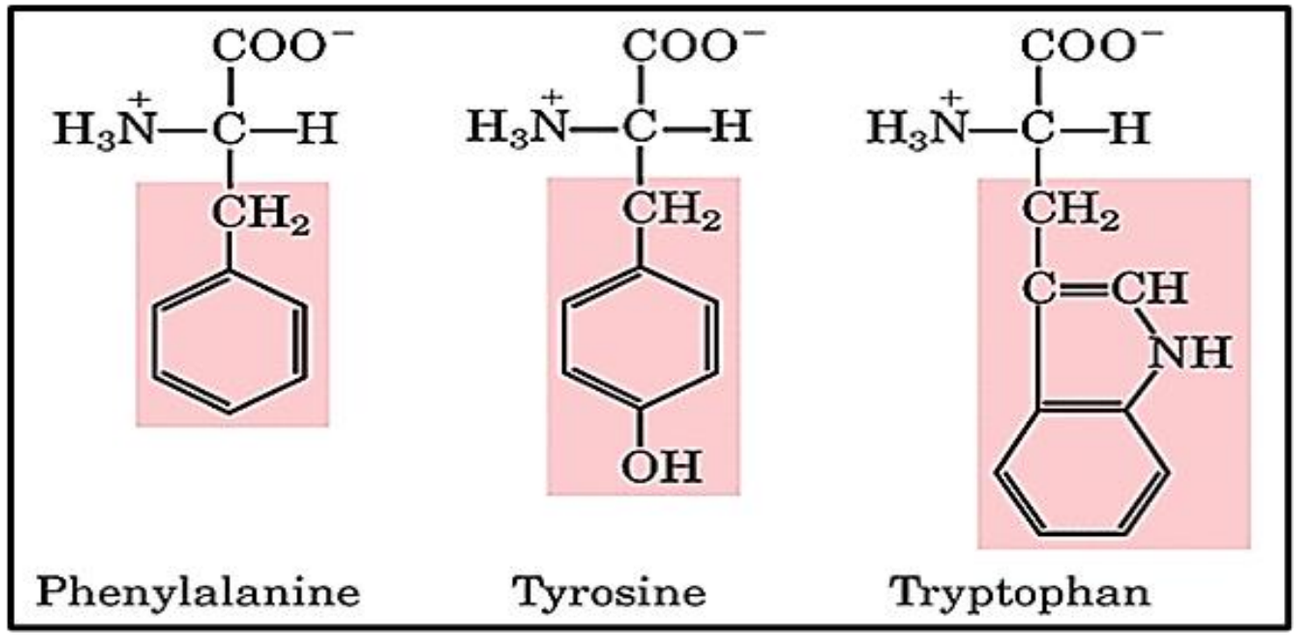
Histidine, tryptophan and proline.





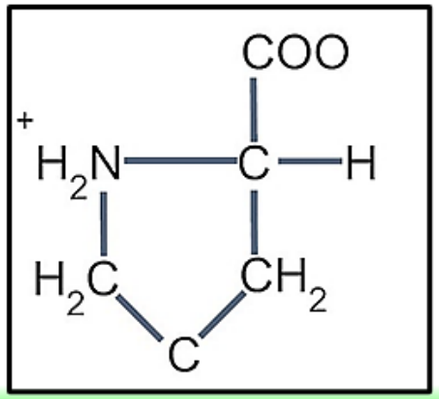
9- Amino acids with aromatic side chains:

Phenylalanine, tyrosine and tryptophan (with indole ring) are aromatic amino acids. Besides these, histidine may also be considered under this category.



10- Amino acid with imino group side chain:

Proline containing pyrrolidine ring is a unique amino acid. It has an imino group (-NH), instead of an amino group (-NH2) found in other amino acids. Therefore, proline is an α-imino acid.



The unique geometry of proline contributes to the formation of the fibrous structure of collagen and often interrupts the α-helices found in globular proteins.

11- Nutritional classification of amino acids:

The 20 amino acids are required for the synthesis of variety proteins, besides other biological functions. All these 20 AAs need not be taken in the diet. Based on the nutritional requirements, amino acids are grouped into two classes: essential and nonessential.

Essential amino acids: The amino acids which cannot be synthesized by the body and, therefore, need to be supplied through the diet.

Essential	Nonessential
Histidine	Alanine
Isoleucine	Arginine
Leucine	Asparagine
Lysine	Aspartate
Methionine	Cysteine
Phenylalanine	Glutamate
Threonine	Glutamine
Tryptophan	Glycine
Valine	Proline
	Serine
	Tyrosine

Non-essential amino acids: The body can synthesize amino acids to meet the biological needs, hence they need not be consumed in the diet.

12- Amino acid classification based on their metabolic fate:

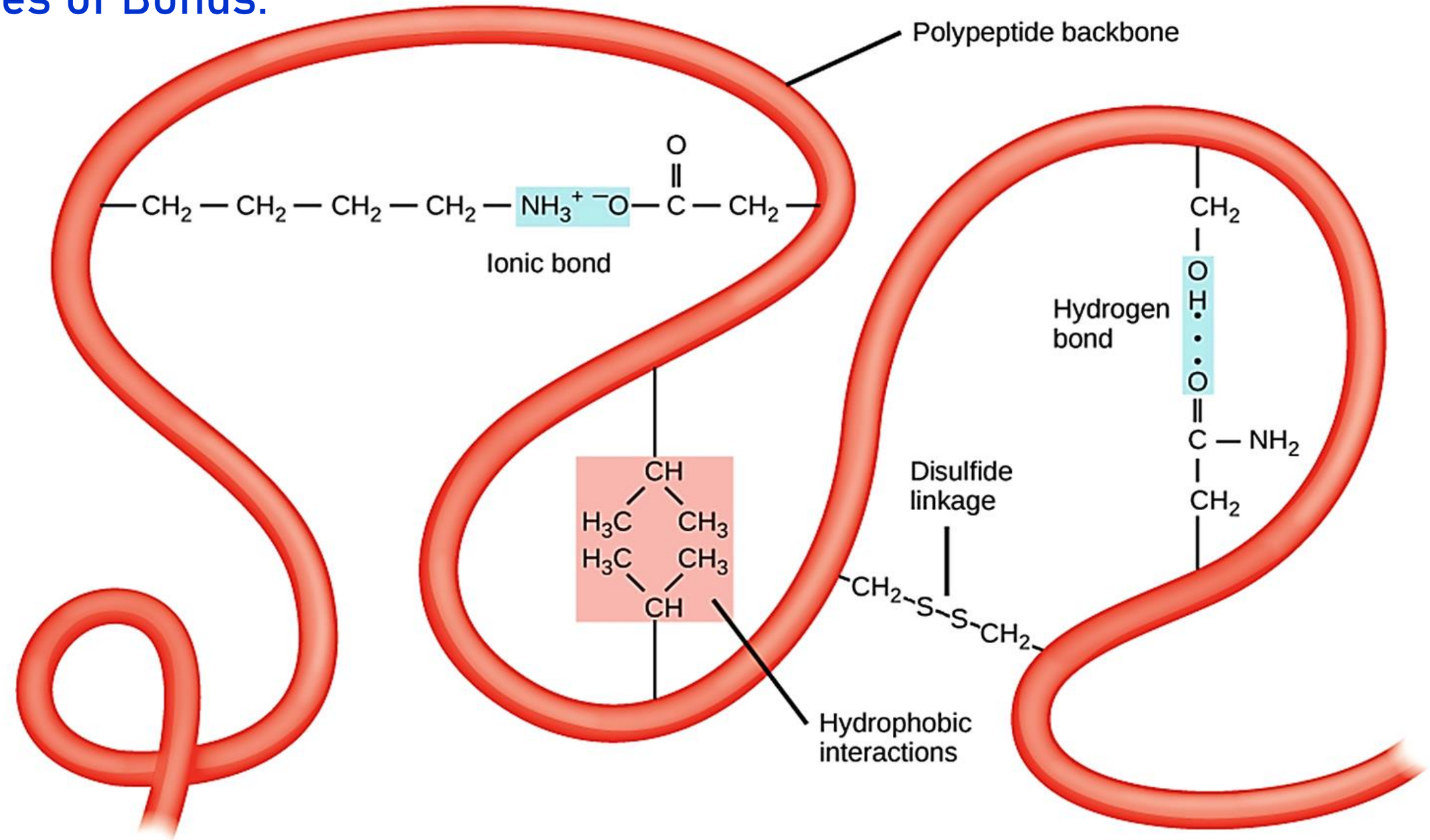
The carbon skeleton of amino acids can serve as a precursor for the synthesis of glucose (glycogenic) or fat (ketogenic) or both. From metabolic view point, amino acids are divided into three groups:

1. Glycogenic amino acids: These amino acids can serve as precursors for the formation of glucose or glycogen. e.g. alanine, aspartate, glycine, methionine.

2. Ketogenic amino acids: Fat can be synthesized from these amino acids. Two amino acids leucine and lysine are exclusively ketogenic.

3. Glycogenic and ketogenic amino acids: The four amino acids isoleucine, phenylalanine, tryptophan, tyrosine are precursors for synthesis of glucose as well as fat.

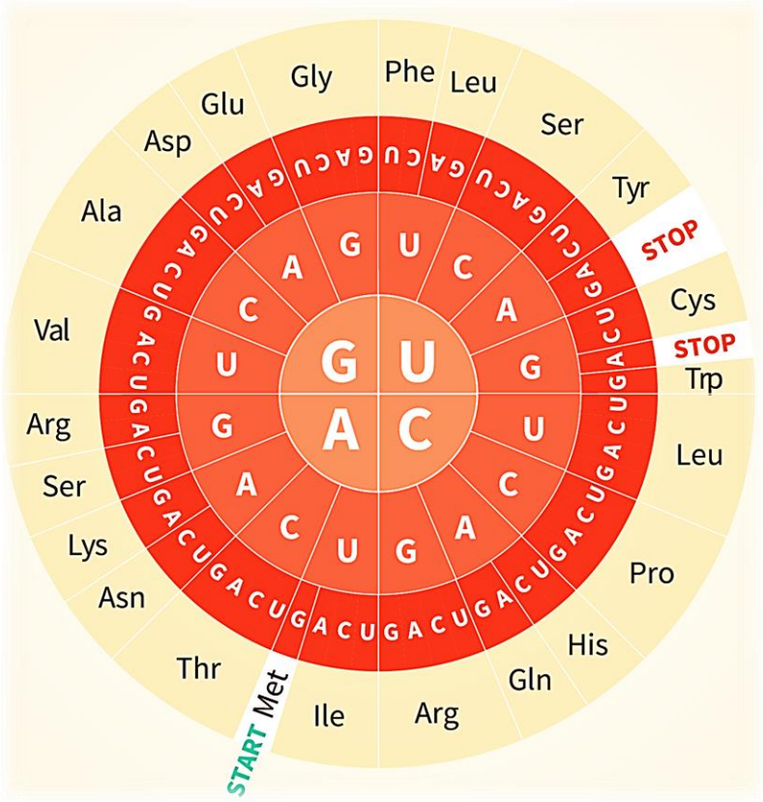
Types of Bonds:



Abbreviations and symbols of amino acids

13- Amino acid classification based on the structure: A comprehensive classification of amino acids is based on their structure and chemical nature.

Each amino acid is assigned a 3 letter or 1 letter symbol. These symbols are commonly used to represent the amino acids in protein structure.



1 Unique first letter:

Cysteine	=	Cys	=	**C**
Histidine	=	His	=	**H**
Isoleucine	=	Ile	=	**I**
Methionine	=	Met	=	**M**
Serine	=	Ser	=	**S**
Valine	=	Val	=	**V**

2 Most commonly occurring amino acids have priority:

Alanine	=	Ala	=	**A**
Glycine	=	Gly	=	**G**
Leucine	=	Leu	=	**L**
Proline	=	Pro	=	**P**
Threonine	=	Thr	=	**T**

3 Similar sounding names:

Arginine	=	Arg	=	**R** ("a**R**ginine")
Asparag**in**e	=	Asn	=	**N** (contains N)
Aspartate	=	Asp	=	**D** ("aspar**D**ic")
Glutamate	=	Glu	=	**E** ("glut**E**mate")
Glutamine	=	Gln	=	**Q** ("**Q**-tamine")
Phenylalanine	=	Phe	=	**F** ("**F**enylalanine")
Tyrosine	=	Tyr	=	**Y** ("t**Y**rosine")
Tryptophan	=	Trp	=	**W** (double ring in the molecule)

Amino Acids Reference Guide

Amino acids are the building blocks of proteins. Approximately 500 of them exist, but only 20 appear in our genetic code. Those shown below are known as standard amino acids. Use the following as a reference guide for amino acid names, abbreviations, and structures.

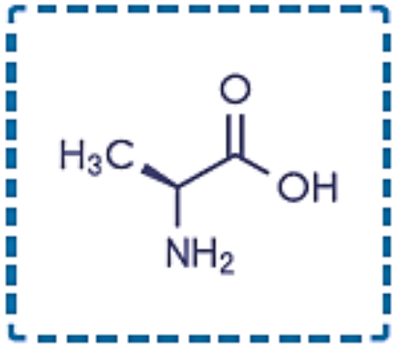
The nucleotide triplet that encodes an amino acid is called a codon. Each group of three nucleotides encodes one amino acid. Since there are 64 combinations of 4 nucleotides taken three at a time and only 20 amino acids, the code is degenerate (more than one codon per amino acid, in most cases.

Most of the amino acids are specified by more than one codon. As there are 64 different codons and only 20 amino acids are encoded by the DNA bases.

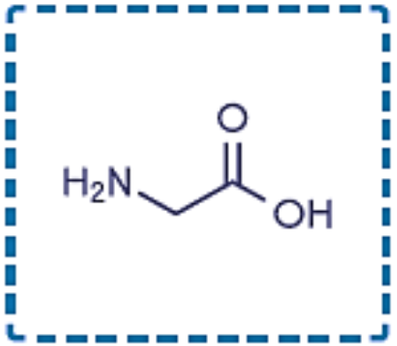
Chart Key

Alkyl | Aromatic | Neutral | Acidic | Basic | Essential | Non-Essential

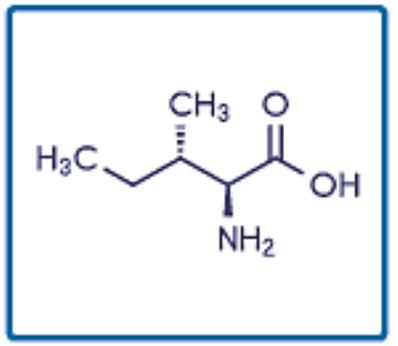
Note: The NH_2 and COOH values listed below are pK_a values.



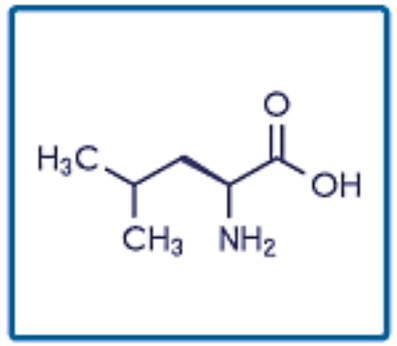
Alanine
Ala A
NH_2: 9.87 COOH: 2.35



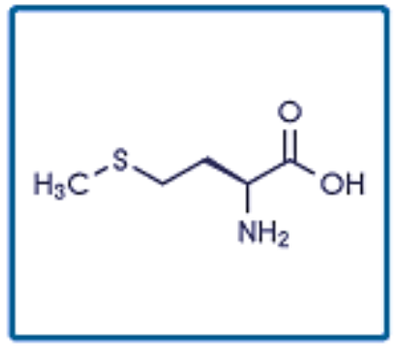
Glycine
Gly G
NH_2: 9.60 COOH: 2.34



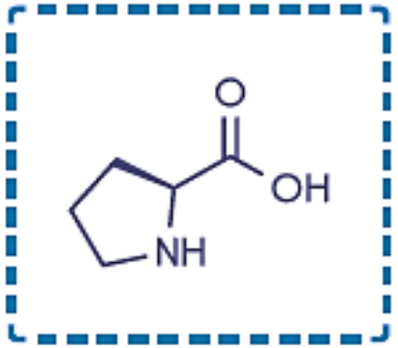
Isoleucine
Ile I
NH_2: 9.76 COOH: 2.32



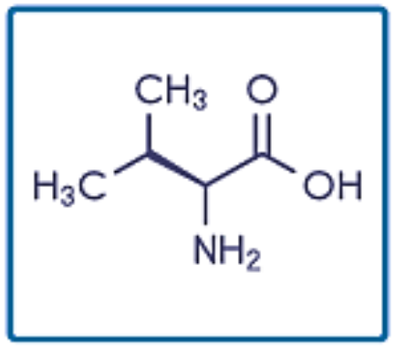
Leucine
Leu L
NH_2: 9.60 COOH: 2.36



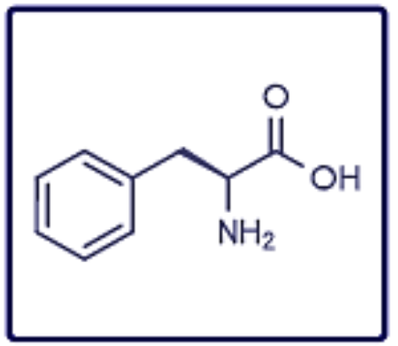
Methionine
Met M
NH_2: 9.21 COOH: 2.28



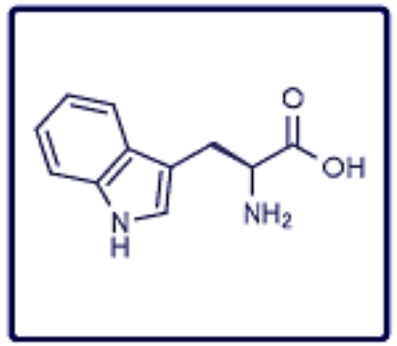
Proline
Pro P
NH_2: 10.60 COOH: 1.99



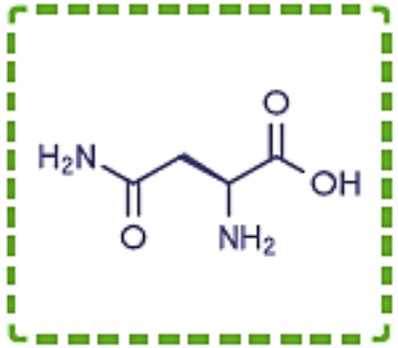
Valine
Val V
NH_2: 9.72 COOH: 2.29



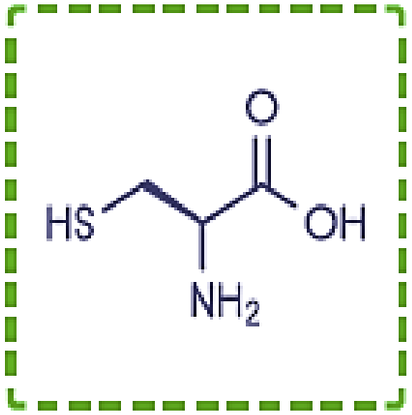
Phenylalanine
Phe F
NH_2: 9.24 COOH: 2.58



Tryptophan
Trp W
NH_2: 9.39 COOH: 2.38



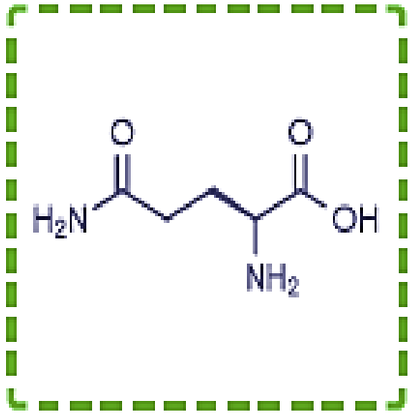
Asparagine
Asn N
NH_2: 8.80 COOH: 2.02



Cysteine

Cys C

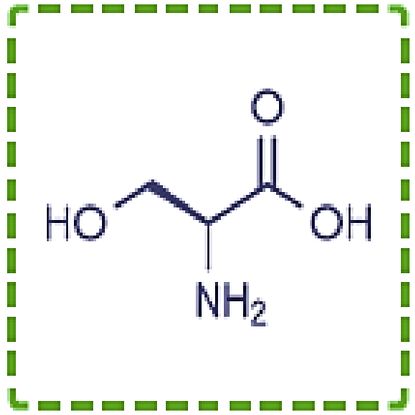
NH_2: 10.78 COOH: 1.71



Glutamine

Gln Q

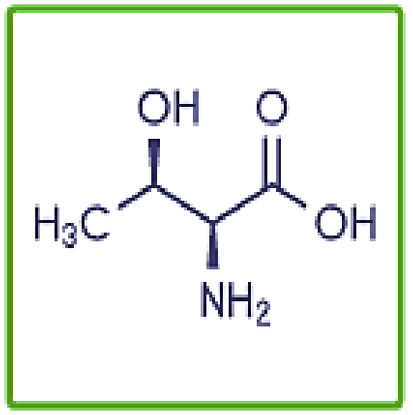
NH_2: 9.13 COOH: 2.17



Serine

Ser S

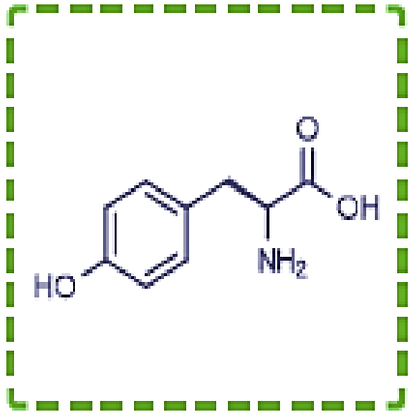
NH_2: 9.15 COOH: 2.21



Threonine

Thr T

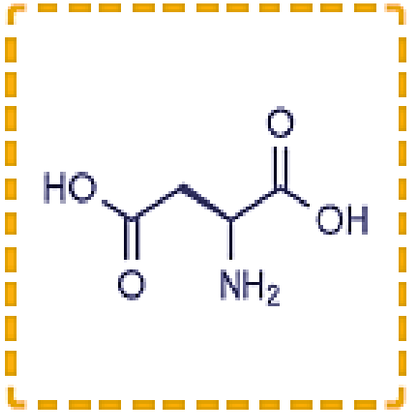
NH_2: 9.12 COOH: 2.15



Tyrosine

Tyr Y

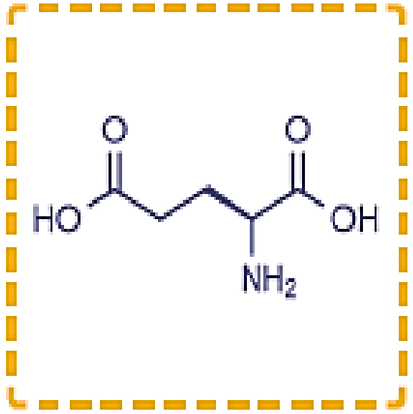
NH_2: 9.11 COOH: 2.20



Aspartic Acid

Asp D

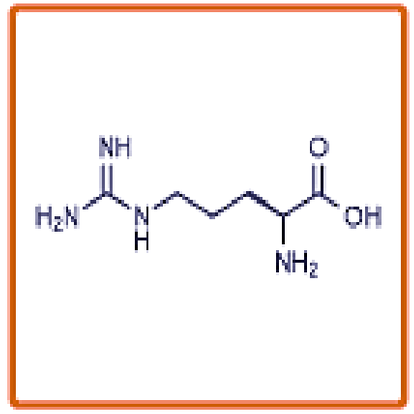
NH_2: 9.60 COOH: 1.88



Glutamic Acid

Glu E

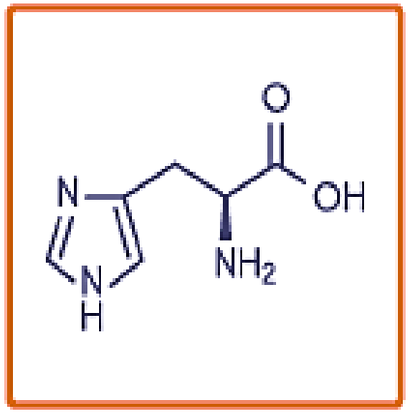
NH_2: 9.67 COOH: 2.19



Arginine

Arg R

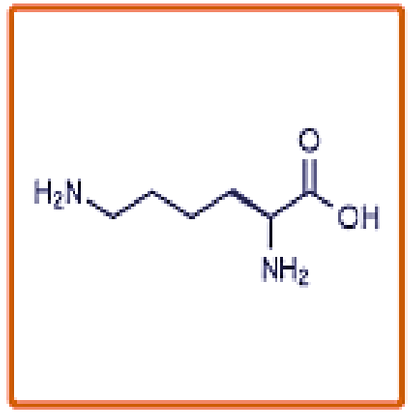
NH_2: 9.09 COOH: 2.18



Histidine

His H

NH_2: 8.97 COOH: 1.78



Lysine

Lys K

NH_2: 10.28 COOH: 8.99

Amino Acid and genetic code:

Why is thymine absent in genetic code?

Because thymine has a higher resistance to photochemical mutation and makes the genetic code more durable, DNA uses it instead of uracil.

This is required to store all the data required for life to function.

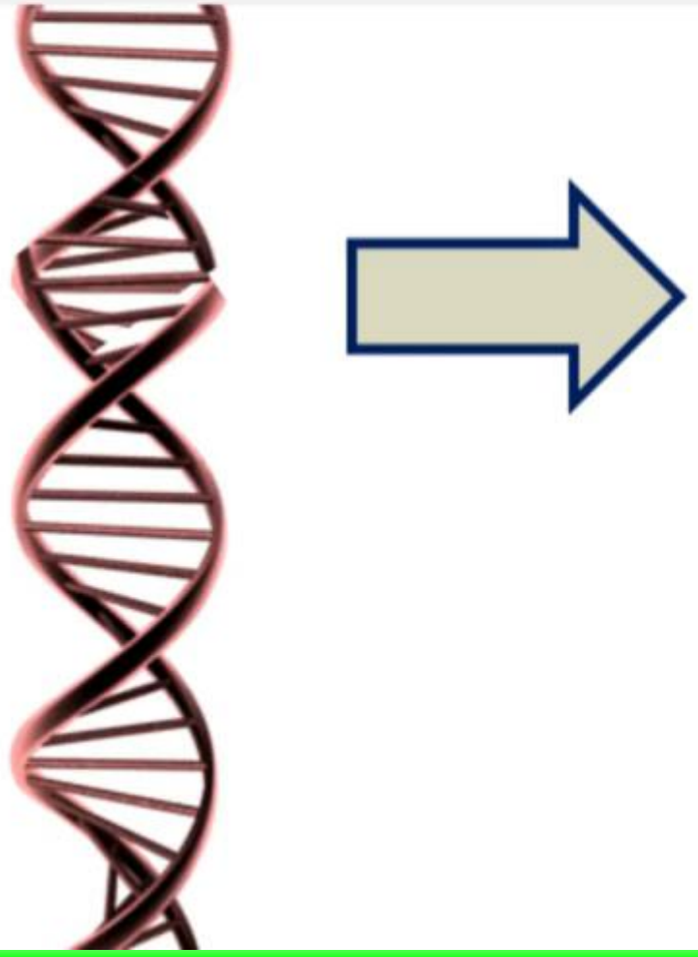
First letter	Second letter: U	Second letter: C	Second letter: A	Second letter: G	Third letter
U	UUU Phe UUC Phe UUA Leu UUG Leu	UCU Ser UCC Ser UCA Ser UCG Ser	UAU Tyr UAC Tyr UAA STOP UAG STOP	UGU Cys UGC Cys UGA STOP UGG Trp	U C A G
C	CUU Leu CUC Leu CUA Leu CUG Leu	CCU Pro CCC Pro CCA Pro CCG Pro	CAU His CAC His CAA Gln CAG Gln	CGU Arg CGC Arg CGA Arg CGG Arg	U C A G
A	AUU Ile AUC Ile AUA Ile AUG Met	ACU Thr ACC Thr ACA Thr ACG Thr	AAU Asn AAC Asn AAA Lys AAG Lys	AGU Ser AGC Ser AGA Arg AGG Arg	U C A G
G	GUU Val GUC Val GUA Val GUG Val	GCU Ala GCC Ala GCA Ala GCG Ala	GAU Asp GAC Asp GAA Glu GAG Glu	GGU Gly GGC Gly GGA Gly GGG Gly	U C A G

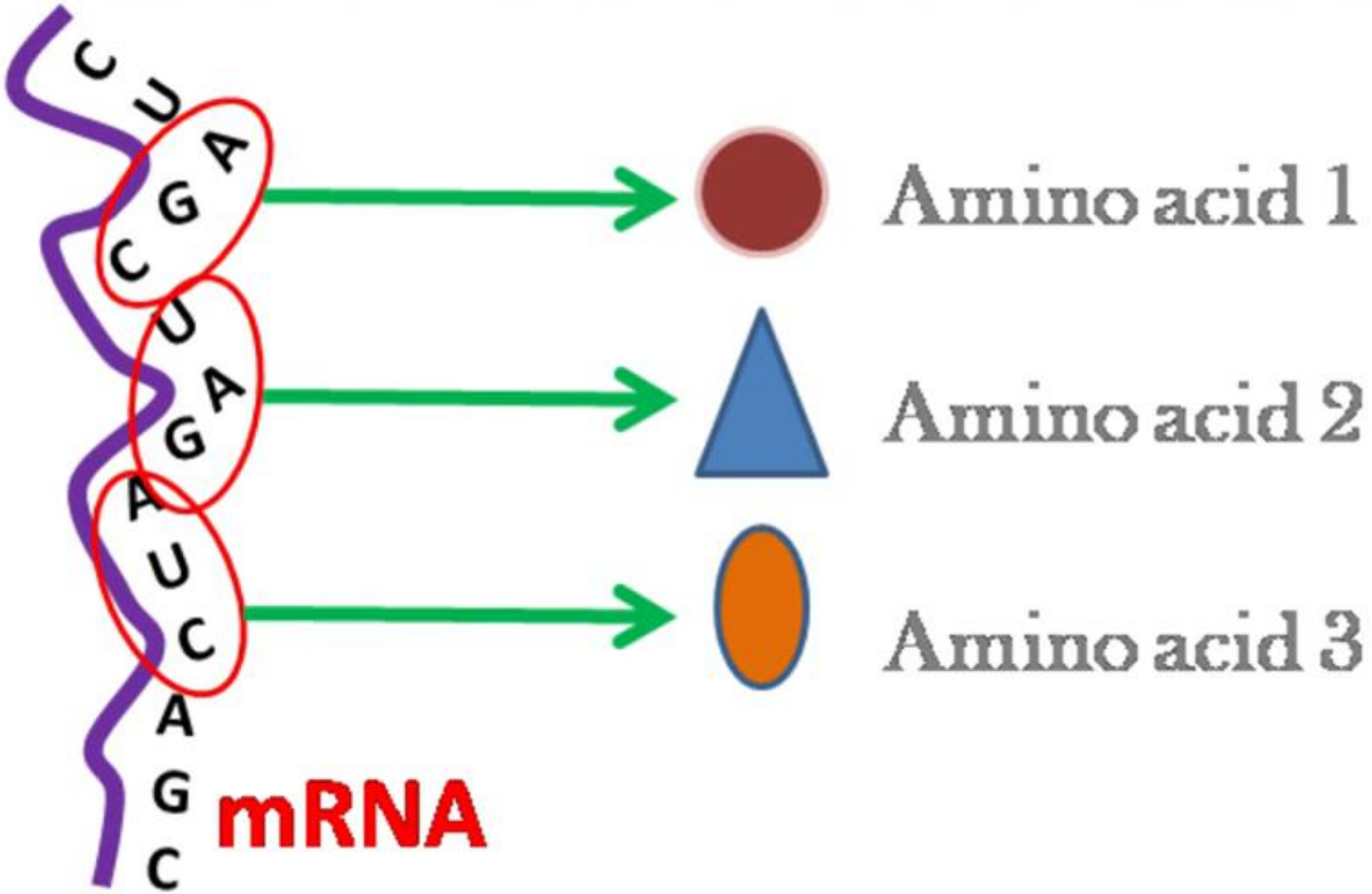
https://www.youtube.com/watch?v=gG7uCskUOrA

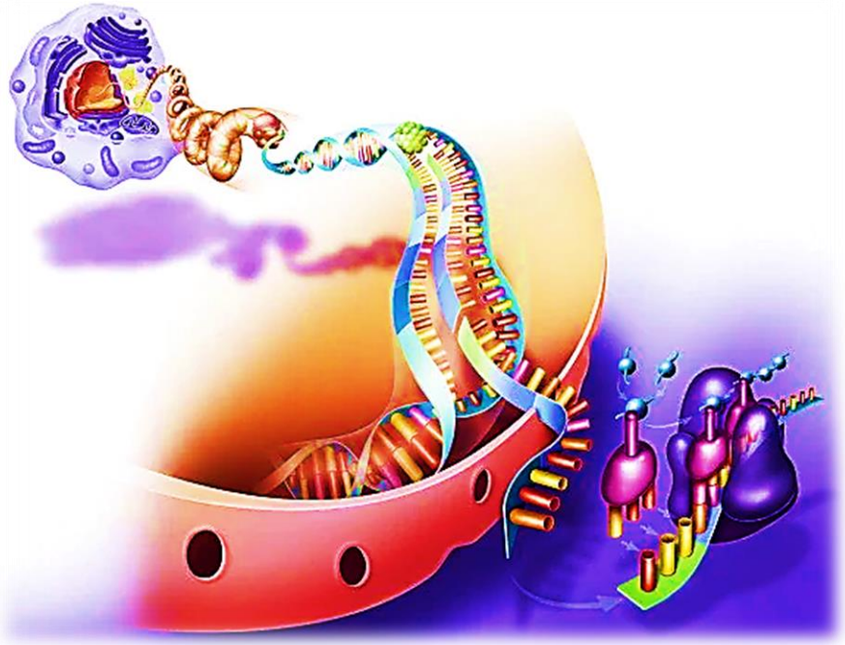
https://www.youtube.com/watch?v=ftyM-LcELSI

Quickly understand

The Genetic Code







For your listening..

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Medical Chemistry

Biochemistry