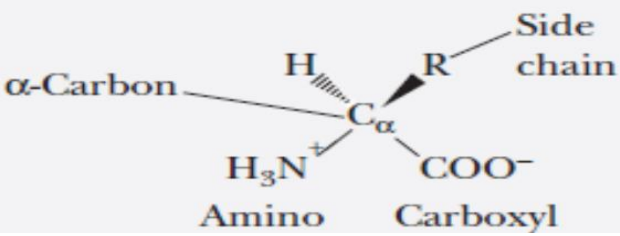
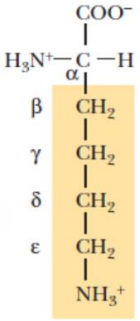
AMINO ACIDS:

GENERAL STRUCTURE:

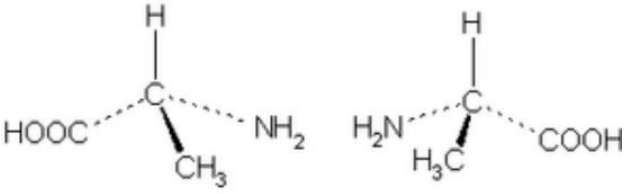


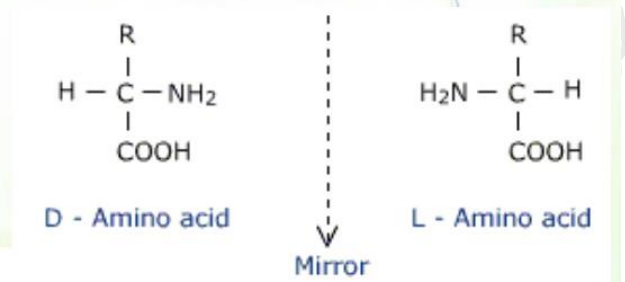
***Naming Carbons After Cα:**



If a carbon atom is terminal, it is referred to as the **ω-carbon**.

STEREOISOMERISM:





RECALL:

Latin **laevus** and **dexter**, meaning **"left"** and **"right"**, respectively. (the ability to rotate polarized light to the left or the right)

***Based on Which Group?**

Amino group

*****The amino acids in proteins are not superimposable on their mirror images (with the exception of **glycine**, because its R-group is **H**).

NOTE:

The amino acids that occur in proteins naturally are all of the **L form**.
D-amino acids occur in nature, in bacterial cell walls and in some antibiotics, but not in proteins.

TYPES OF AMINO ACIDS:

***There are 20 types of amino acids *depending on the side chains* varying in:**

- Size
- Shape
- Charge
- Hydrogen-bonding capacity
- Hydrophobic character
- Chemical reactivity

***Classification of Amino Acids *According to* Polarity and Charge of the R-Group:**

Read this NOTE After Checking the Tables:

NOTES:

-Exceptions:

- **Glycine;** achiral
- **Proline (imido acid);** the R-group is attached to the amino group. Thus, the amino group is now *secondary* instead of being *primary*

-Amino Acids that has a Functional Group within the R-Group:

Serine (OH) / Threonine (OH) /
Cysteine (SH) /
Asparagine (amide) / Glutamine (amide) /
Lysine (amine) /
Aspartate (carboxyl) /Glutamate (carboxyl)/
Phe + Trp + Tyr (arene)

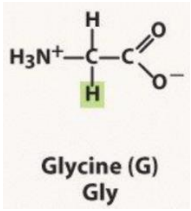
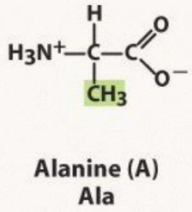
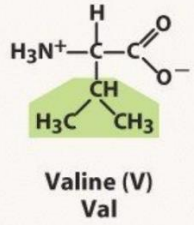
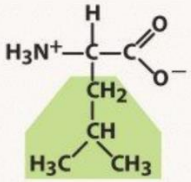
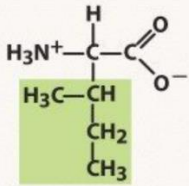
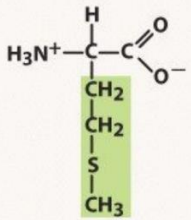
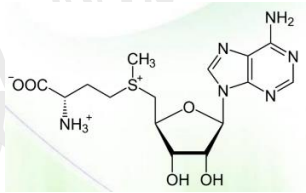
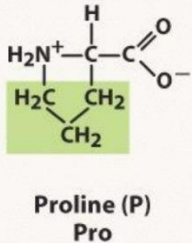
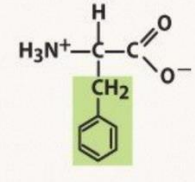
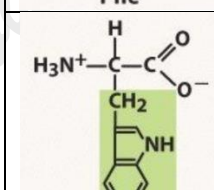
-Amino Acids that Contains Sulfur in their R-Group:

Methionine / Cysteine

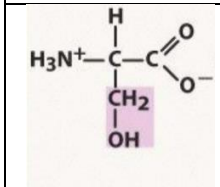
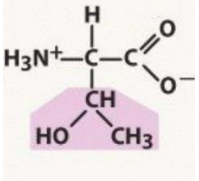
-Essential Amino Acids:

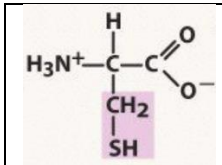
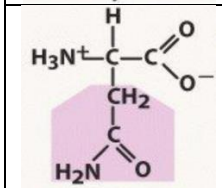
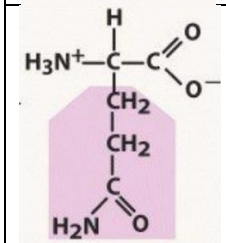
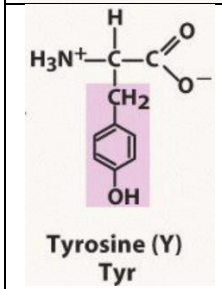
Histidine, Isoleucine, Leucine, Lysine, Methionine, Phenylalanine, Threonine, Tryptophan and Valine.

◊ Non-Polar Amino Acids:

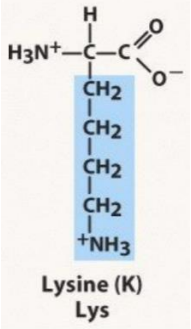
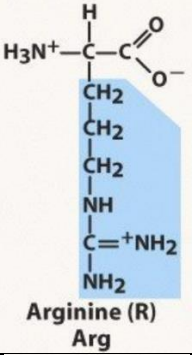
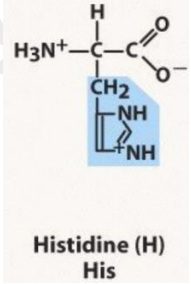
Name Abbreviation Structure	Features
 Glycine (G) Gly	• The only *achiral* amino acid • A derivative of **acetic acid** (It could be considered a derivative of **ethylamine**)
 Alanine (A) Ala	---
 Valine (V) Val	• *A branched* amino acid; an amino acid that is branched on the *a-C* • An essential amino acid in the sense that the body cannot synthesize them, so we have to obtain them from diet
 Leucine (L) Leu	[Same as **valine**] + a constitutional isomer of **isoleucine**
 Isoleucine (I) Ile	[Same as **valine**] + a constitutional isomer of **leucine**
 Methionine (M) Met	• It can react to form S-Adenosyl-L-Methionine (SAM)  which servers at a methyl donor in reactions
 Proline (P) Pro	• The R-group is attached to the amino group. Thus, the amino group is now *secondary* instead of being *primary* • Called **imido acid**
 Phenylalanine (F) Phe	• An *aromatic* amino acid • It has a **benzene** group
 Tryptophan (W) Trp	• An *aromatic* amino acid • It has an **indole** group

◊ Polar Amino Acids (Non-Charged):

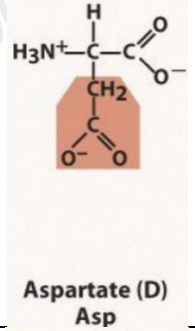
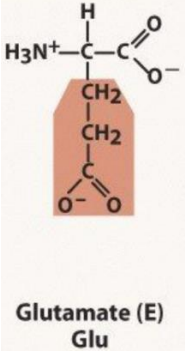
Name Abbreviation Structure	Features
 Serine (S) Ser	• It is **alanine** but with an OH group instead of one of the hydrogens in the R-group
 Threonine (T) Thr	• It is **valine** but with an OH group instead of one of the methyl groups in the R-group

 Cysteine (C) Cys	• It has a **thiol** group
 Asparagine (N) Asn	• It has an **amide** group
 Glutamine (Q) Gln	• It has an **amide** group
 Tyrosine (Y) Tyr	• An *aromatic* amino acid • It has a **phenol** group

◊ Polar Amino Acids (Positively Charged = Basic):

Name Abbreviation Structure	Features
 Lysine (K) Lys	• It has an **amine(o)** group (*in the R-group*)
 Arginine (R) Arg	• It has a **guanidine(o)** group
 Histidine (H) His	• It has an **imidazole** group • It has a buffering importance

◊ Polar Amino Acids (Negatively Charged = Acidic):

Name Abbreviation Structure	Features
 Aspartate (D) Asp	• It has a **carboxyl** group
 Glutamate (E) Glu	• It has a **carboxyl** group

AMINO ACIDS' DERIVATIVES:

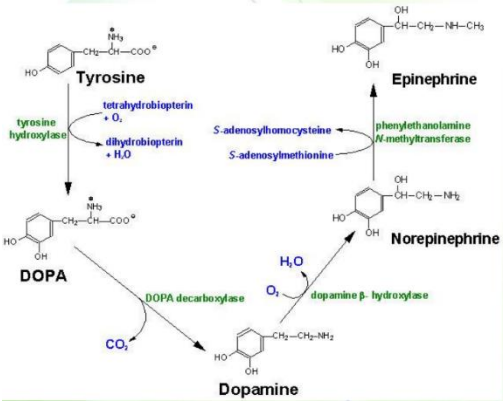
α-nitrogen atom of amino acids is a primary source for many nitrogenous compounds: Hormones/ Neurotransmitters/ Biologically active peptides

***Tyrosine Derivatives:**

◊ Catecholamine Neurotransmitters:

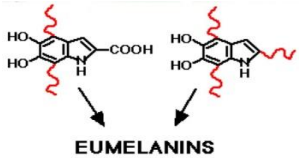
i.e. Dopamine/ Norepinephrine/ Epinephrine

Used in activating fight or flight system.

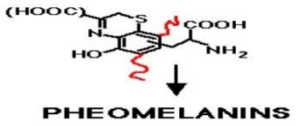


◊ Melanin:

For skin color.



For lighter or darker skin color



For red-colored hair

◊ Thyroxine Hormone (Thy = T4):

Used in:

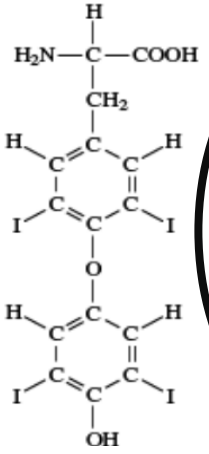
- Regulating metabolic processes inside our cells
- Playing a role in neuronal development of the fetus

Produced from the thyroid gland

How Does it Form?

A protein called **thyroglobulin** -also produced from the thyroid gland- has different amino acids including **tyrosine**.

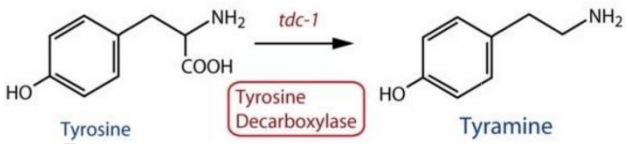
A **phenol group** is added to the **tyrosine** molecule, in addition to 4 **iodine ions**.



It is activated by the removal of one of the iodine ions to become T3

◊ Tyramine:

Cheese contain high amounts of **tyramine**, which mimics **epinephrine**. For many people a cheese omelet in the morning is a favorite way to start the day.



Thus;

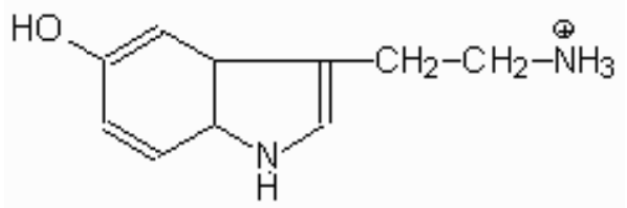
Tyramine = Decarboxylated Tyrosine

***Tryptophan Derivatives:**

A precursor for the synthesis of Neurotransmitters

◊ Serotonin (5-hydroxutryptamine):

Neurotransmitter-sedative



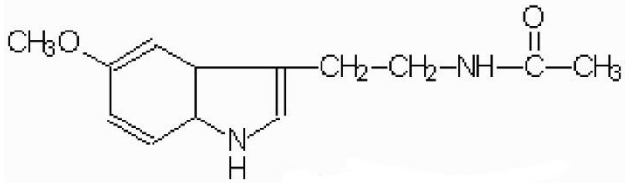
Thus;

Serotonin = Hydroxylated Decarboxylated Tryptophan

◊ Melatonin:

Produced by the pineal gland

Regulates the day-night cycle.



***Histidine Derivatives:**

◊ Histamine:

Produced by a number of cells, **i.e.** mast cells

Regulates physiological function in the gut

Acts as a vasodilator

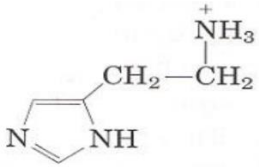
Acts as a neurotransmitter

Causes allergic symptoms (a major causes for asthma)

Contributes to inflammatory response

Causes constriction of smooth muscle

Treated by anti-histamines



→ **Histamine** = Decarboxylated Histidine

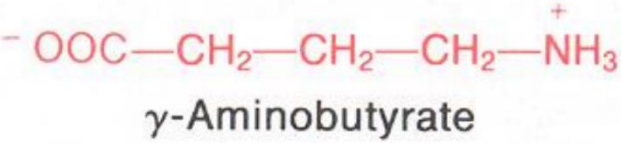
***Glutamate Derivatives:**

◊ GABA:

An inhibitory neurotransmitter (CNS) that reduces neuronal excitability.

Synthesized in brain because it does not cross the BBB.

GABA have relaxing, anti-anxiety, and anti-convulsive effects.

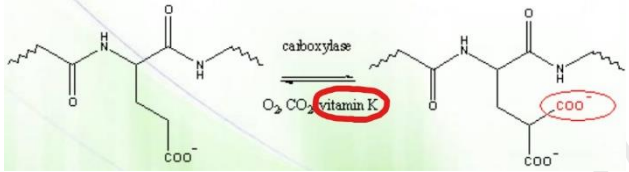


→ **GABA** = Decarboxylated Glutamate

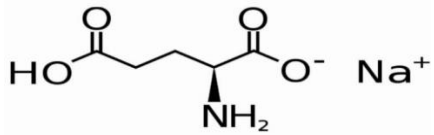
◊ γ- carboxyglutamate (Gla):

Important in blood clotting (coagulation)

[more negative charge attracts Ca^{2+}, which is essential in such process**]**



◊ Monosodium Glutamate (MSG):



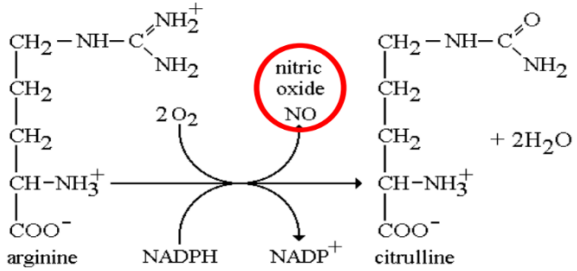
SODIUM SALT OF GLUTAMIC ACID

It is a flavor enhancer **used in** the Asian food.

MSG causes a physiological reaction in some people, **i.e.** chills, headaches and dizziness = *Chinese restaurant syndrome.*

***Arginine Derivatives:**

We're going to talk about **Nitric Oxide (NO)**, which is not an **arginine derivative**, but it is a by-product of the reaction that converts **arginine** to **citrulline.**

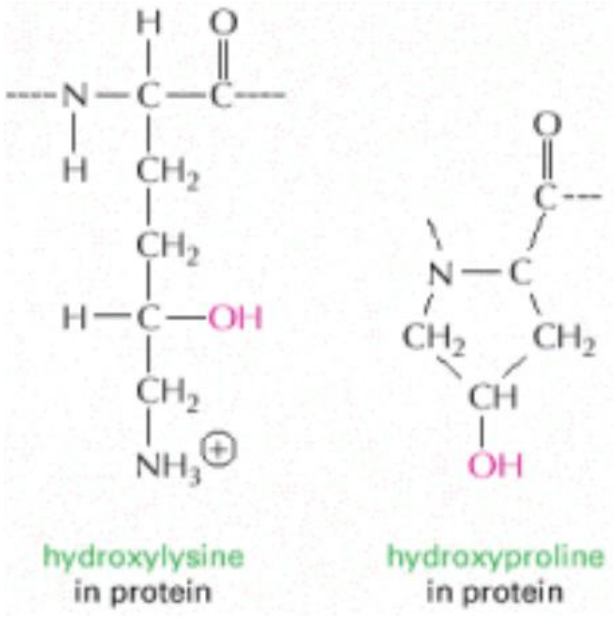


-L-arginine is the precursor of **nitric oxide (NO)**

-NO functions:

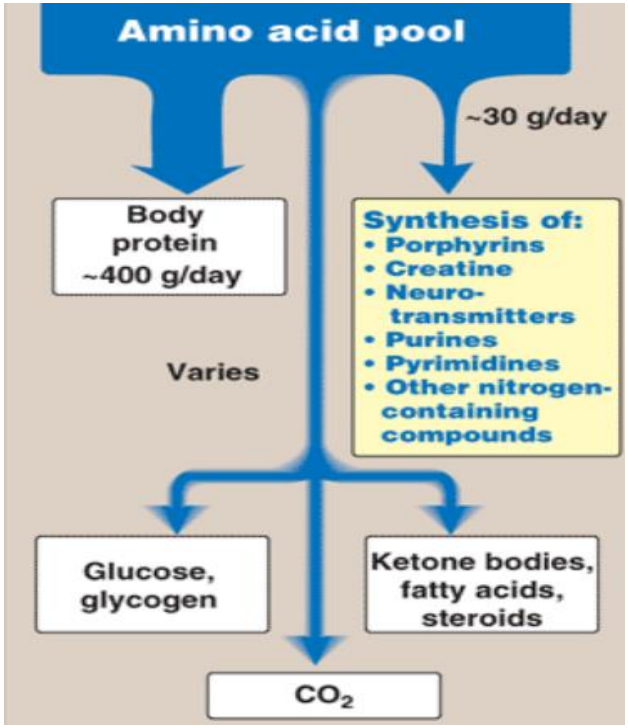
- Vasodilation
- Inhibition of platelet adhesion
- Inhibition of leukocyte adhesion
- Antiproliferative action
- Scavenging superoxide anion (anti-inflammatory)

***Lysine and Proline Derivatives:**



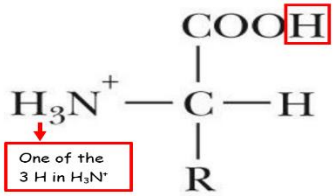
Produced by modification -*specifically* ***hydroxylation***- of the parent amino acid after protein synthesis; **posttranslational modification**.

DAILY USAGE OF AMINO ACIDS:



IONIZATION OF AMINO ACIDS:

-In the backbone of each amino acid, there are 2 protons that can be removed (Deprotonation)



Thus, each amino acid, at least, will have 2 midpoints in the titration curve.

[RECALL: Titration Curve]

-For Certain Amino Acids, there will be 3 midpoints:

- **The 3 Basic Amino Acids**; has an additional H_3N^+ in their side chains
- **The 2 Basic Amino Acids**; has an additional COOH in their side chains
- **Cysteine**; has a SH group in its side chain
- **Tyrosine, Serine and Threonine**; has an OH group in their side chains

***Why Do We Study Such Topic?**

This topic discusses what form of a certain amino acid is expected to be found in a certain pH.

***Important Points to Start with:**

-pK_a is the value that determines the quantity of H^+ (thus ^-OH) in a certain solution.

Higher pK_a = Lower $[H^+]$ = Higher $[^-OH]$ → less acidic

Lower pK_a = Higher $[H^+]$ = Lower $[^-OH]$ → more acidic

-Each proton that is able to be deprotonated has a certain pK_a value; a certain amount (equivalents) of ^-OH that must be added for this particular proton to be released.

Proton to be released	pK_a Required for it to be released
H from COOH of the backbone of any amino acid	2.00
One H from H_3N^+ of the backbone of any amino acid	9.00
One H from H_3N^+ of the side chain of Lysine	11.0
One H from H_3N^+ of the side chain of Arginine	12.5
One H from H_3N^+ of the side chain of Histidine	6.00
H from COOH of the side chain of Aspartate	4.00
H from COOH of the side chain of Glutamate	4.10
H from SH of the side chain of Cysteine	8.00

-The lower the pK_a of the acid, the faster the proton is released

-pH = pK_a at the midpoint in the titration curve

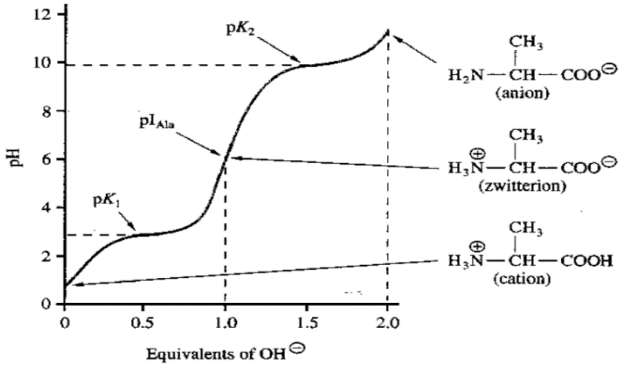
-Zwitterion: a molecule with two opposite charges and a net charge of *zero*

-Isoelectric Point (pI): The pH where the net charge of a molecules such as an amino acid or protein is zero is known as isoelectric point or pI

***Calculation of pI for:**

◊ Amino Acids with ONLY 2 Midpoints (= 2 Equivalent Points):

-From the Diagram:

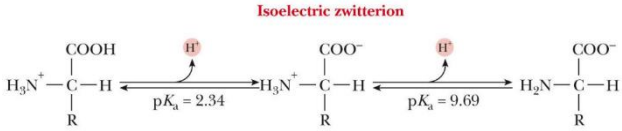


pI = $(pK_{a1} + pK_{a2}) / 2$

or

بنشوف عدد الإكويفيلانتس (= 2) و بنوخذ نصهم (= 1) و بنشوف درجة الحموضة اللي على المحور الصادي و هي نفسها نقطة تساوي الشحنات اللي بدنا إياها

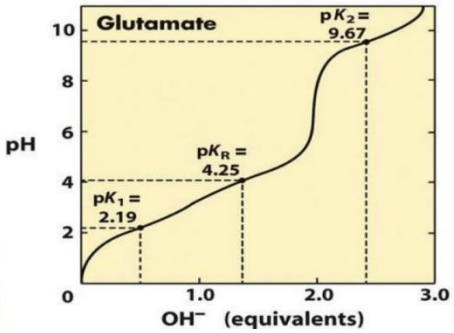
-From Numbers:



pI = $(pK_{a1} + pK_{a2}) / 2$

◊ Amino Acids with 3 Midpoints (= 3 Equivalent Points):

-From the Diagram:



pI = $(pK_{a1} + pK_{a2}) / 2$

but, which 2 pK_a(s) must considered?

The one when we have +1 net charge and the one we have -1 net charge

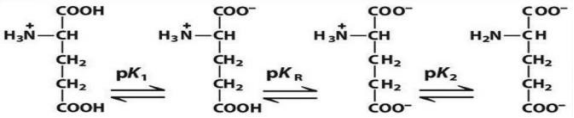
in this case;

$pK_{a1} = pK_1$ and $pK_{a2} = pK_R$

or

بنشوف عدد الإكويفيلانتس في أول ميدبوينت (= 0.5) و عدد الإكويفيلانتس في تاني ميدبوينت (= 1.5) و بنوخذ نصهم (= 1) و بنشوف درجة الحموضة اللي على المحور الصادي و هي نفسها نقطة تساوي الشحنات اللي بدنا إياها

-From Numbers:



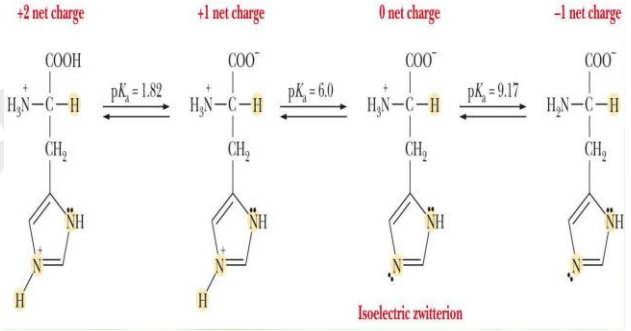
pI = $(pK_{a1} + pK_{a2}) / 2$

but, which 2 pK_a(s) must considered? نفس المبدأ

→ Check Yourself 😊:

[Answers are in the next page]

Q1: Calculate the pI of Histidine.



Q2: Draw the titration curve of histidine.

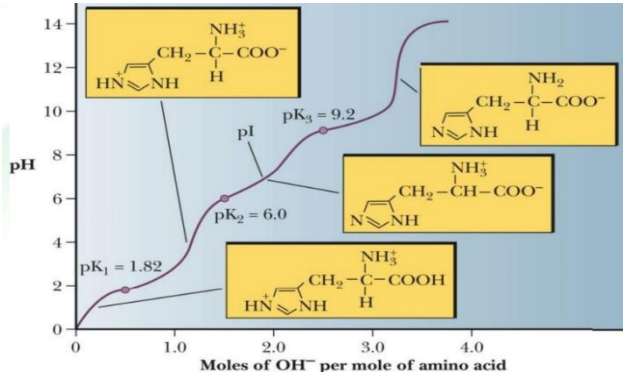
Q3: What is the ratio of the conjugate base/acid of glutamate at pH 4.5?

Q4: What is the total charge of lysine at pH 7?

→ **Answers:**

A1: pI ≈ 7.6

A2:



A3: 5: 2

pH = pK_a + log [deprotonated glutamate/ glutamate]

4.5 = 4.1 + log [deprotonated glutamate/ glutamate]

0.4 = log [deprotonated glutamate/ glutamate]

[deprotonated glutamate/ glutamate] = 2.5

[deprotonated glutamate/ glutamate] = 5:2

A4: +1

Why?

At **pH 7, lysine** has a **net charge** of very close to +1. The carboxylic acid group is fully *deprotonated* (**-1 charge**). The alpha amino group is about 99% protonated (**+1 charge**). The side chain amino group is fully protonated (**+1 charge**) → -1 + +1 + +1 = +1

Q-BANK FROM PAST PAPERS:

1) Which of the following amino acids is the precursor of NO?

A) Arginine
B) Asparagine
C) Glycine
D) Alanine
E) Glutamate

2) Aspartic acid in the pH of 5 is mostly:

A) Cationic
B) Anionic
C) Zwitterion
D) More than one of the above
E) None of the above

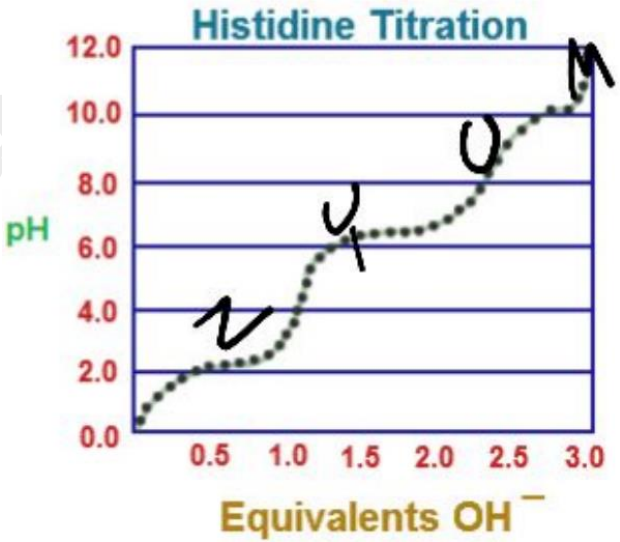
3) Which of the following amino acids can be attached to an oligosaccharides chain?

A) Lysine
B) Tyrosine
C) Threonine
D) Tryptophan
E) Proline

4) Which of the following is a positive amino acid with a guanidine group?

A) Aspartic Acid
B) Arginine
C) Glutamate
D) Proline
E) Histidine

5) According to the graph of Histidine's titration curve, in which phase is Histidine in its zwitterionic state?

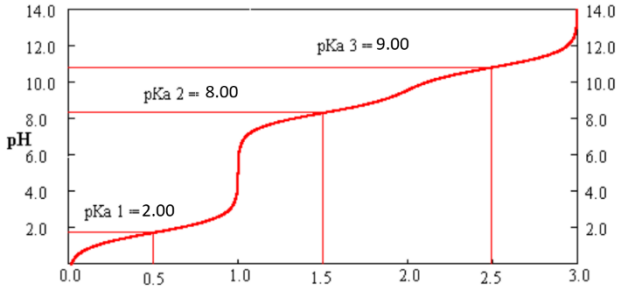


A) Phase (Z)
B) Phase (Y)
C) Phase (U)
D) Phase (M)
E) More than one of the above

6) Which of these is not a functional group in naturally occurring amino acids?

A) Thiol
B) Alkene
C) Hydroxyl
D) Amino
E) Carboxyl

7) The following graph represents the titration curve of:



A) Lysine
B) Aspartic Acid
C) Glutamic Acid
D) Cysteine
E) Histidine

8) Which of the following gives a good protein buffer system?

A) His
B) Arg
C) Asp
D) Asn
E) More than one of the above

9) Which amino acid cannot be found in human proteins?

A) Histidine
B) Ornithine
C) Serine
D) Glycine
E) Glutamic acid

10) What charged groups Glutamine has at physiological PH in the blood?

A) COO^-, H_3N^+
B) COO^-, COO^-, H_3N^+
C) COOH, COOH, H_3N^+
D) COOH, COO^-, H_3N^+
E) COOH, COO^-, H_2N

11) Which one is derived from aliphatic amino acid?

A) Dopa
B) Epinephrine
C) Aspartame
D) Norepinephrine
C) Histamine

12) Which of the following amino acids contain sulfur atom in their side chains?

A) Serine
B) Tryptophan
C) Methionine
D) A & B
E) B & C

13) Phenylalanine can be used to synthesize the following amino acid:

A) Ser
B) Trp
C) Thr
D) Tyr
E) Orn

14) The following amino acids are hydroxylated in collagen:

A) Pro and Leu
B) Pro and Ile
C) Gly and Pro
D) Pro and Lys
E) Tyr and Lys

15) One of these groups (Derivative-Precursor-Function) is correctly matched:
You can choose more than one choice

A) Histamine/ His/ Vasoconstriction
B) γ-Carboxy-glutamic acid/ Gln/ Coagulation
C) GABA/ Glu/ Relaxing inhibitory neurotransmitter
D) Serotonin/ Trp/ Sedative effects
E) Thyroxine/ Tyr/ Metabolism

→ Answers:

Q. No.	Ans.	Q. No.	Ans.
1	A	9	B
2	B	10	A
3	C	11	C
4	B	12	C
5	C	13	D
6	B	14	D
7	D	15	C+D+E
8	A		

Done by: Abdullah Al-Jaouni