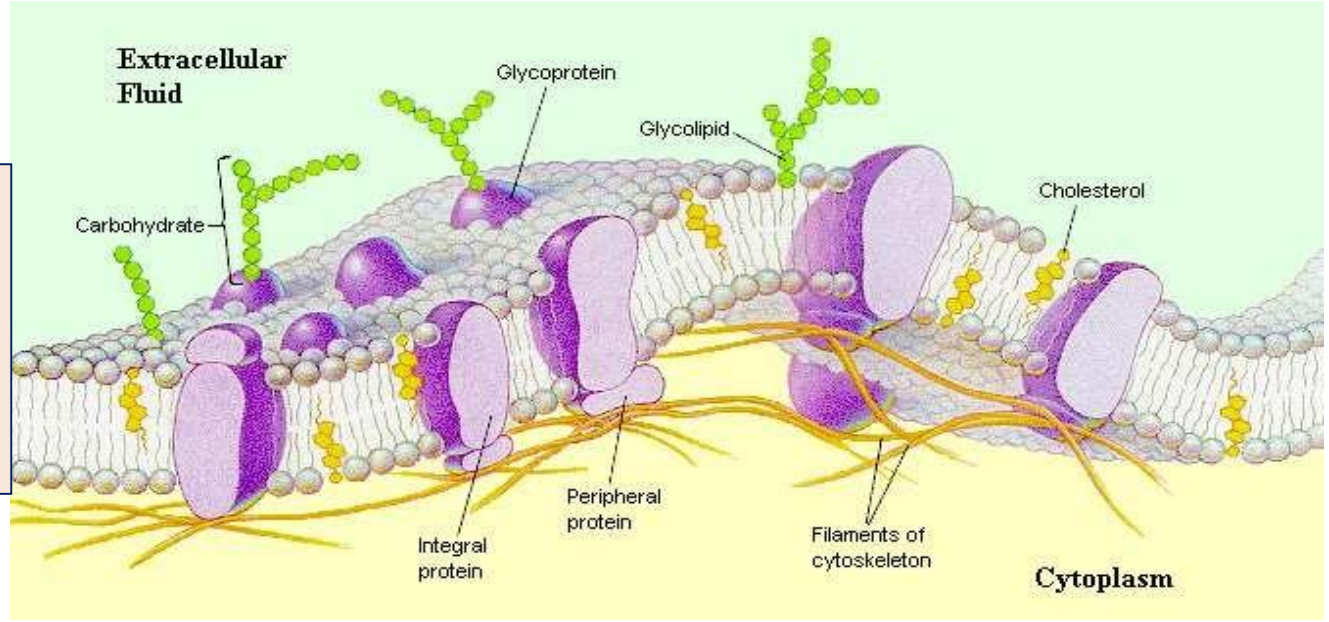
Cell membranes

Plasma membrane consists of :
cholestrol,phospholipid,sphingolipid and protein.

- The membrane is hypothesized in a model known as the fluid mosaic model. Mainly on extra cellular surface
- Components: 45% lipid, 45% protein and 10% carbohydrate
- They exist side by side without forming some other substance of intermediate nature.

This membrane is being in the membranes in the cell (structural perspective) like in lysosome and nucleus .
The difference is how this component is distributed ??
The inner mitochondrial membrane has much protein Than plasma membrane ,almost 75% protein and 25%lipid.



Phospholipids

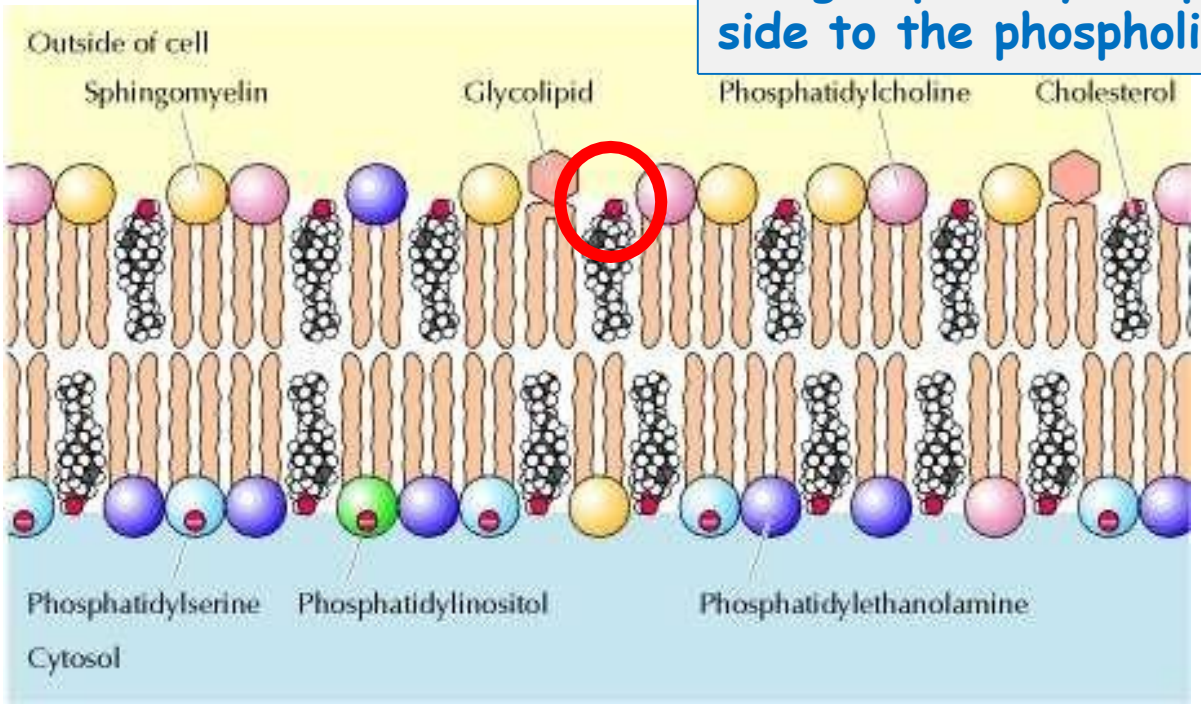
If there a lot of any component in the outer membrane that doesn't mean it not be in the inner membrane

- The outer: phosphatidylcholine, sphingomyelin, and glycolipids(cell recognition)
- The inner: phosphatidylethanolamine, phosphatidylserine, and phosphatidylinositol (signaling)

OH group always exposed outside side by side to the phospholipid head

Cholesterol is distributed in both leaflets

Animal cells vs. plant cells vs. prokaryotic cells



phosphatidylinositol is very important in signaling by producing (diacylglycerol and IP3) which transmit signals inside cell
Cholesterol has equally distribution on both surfaces (sides) of the cell membrane .

Which molecules are abundant in the outer membrane ?
Which molecules are abundant in the inner leaflet ?
(in the previous slide)

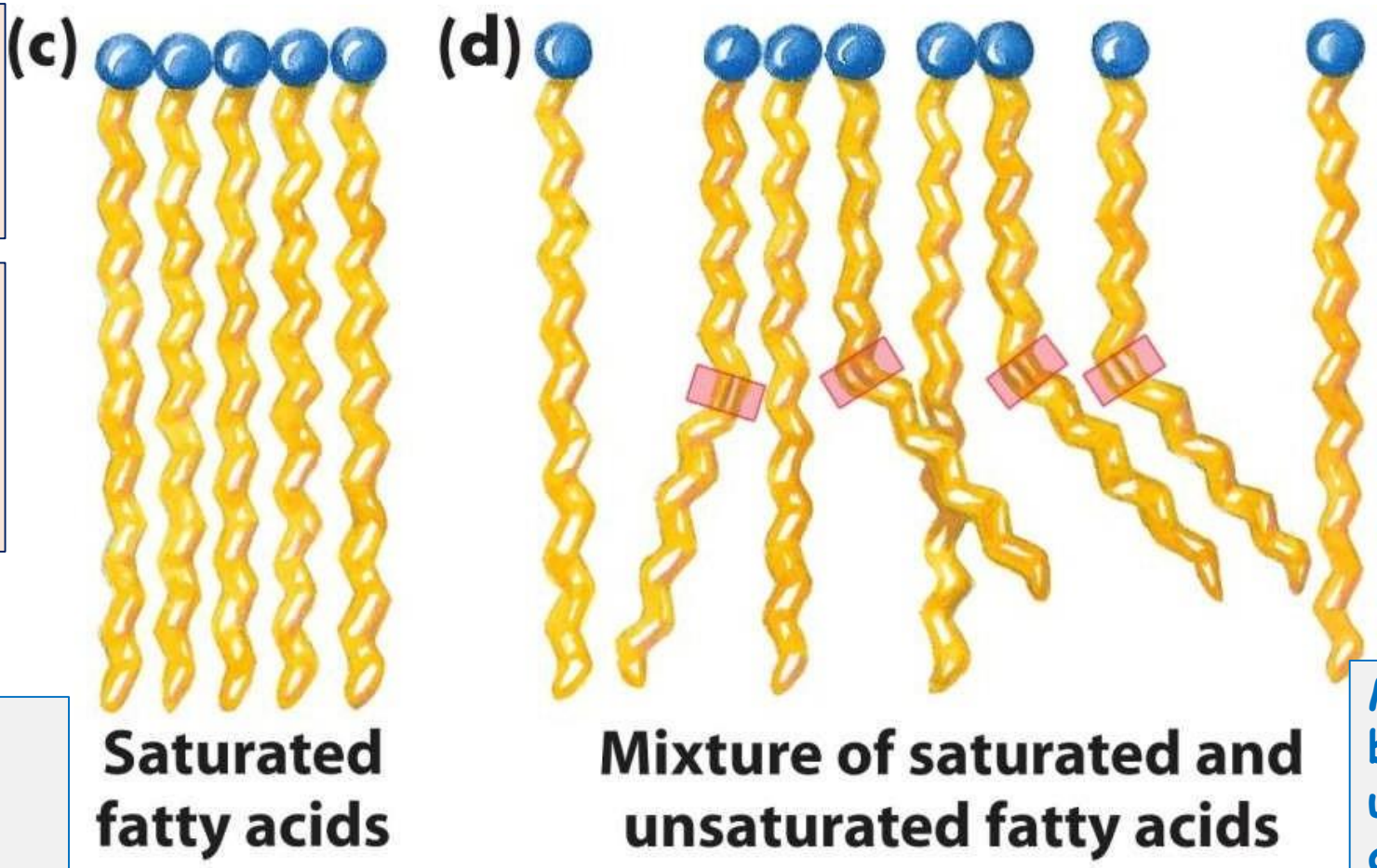
The fuction of glycolipid (in the outer) :cellular communication ,signaling and identification of the cells .

The most abundant type in the outer is :
phosphatidylcholine

Fatty acids and membrane fluidity

Sphingolipid is more Rigid than phospholipid

Saturated f.a = will be aligned ,compacted and more rigidity of membrane



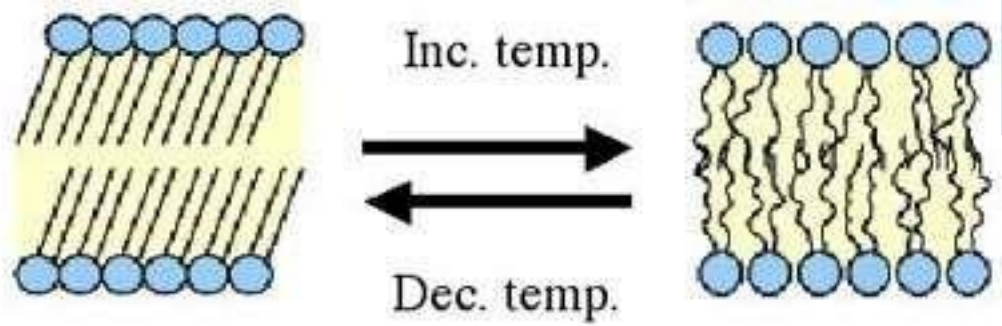
The more the dents , the more the more fluid .

Rigid because it is saturated --> no double bonds present

More fluidic membrane because it has unsaturated fatty acids which is very important for signaling molecules

Membrane fluidity and temperature

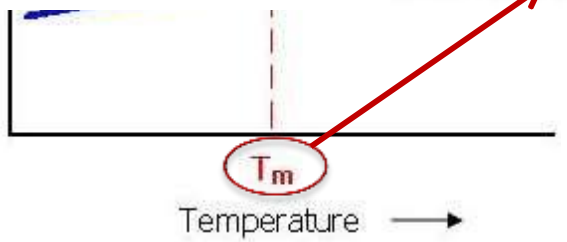
Low temperature --> more rigid membrane When we raise the temperature, the electrons will move in higher speed-- >unstable membrane



Very regular,
Ordered structure

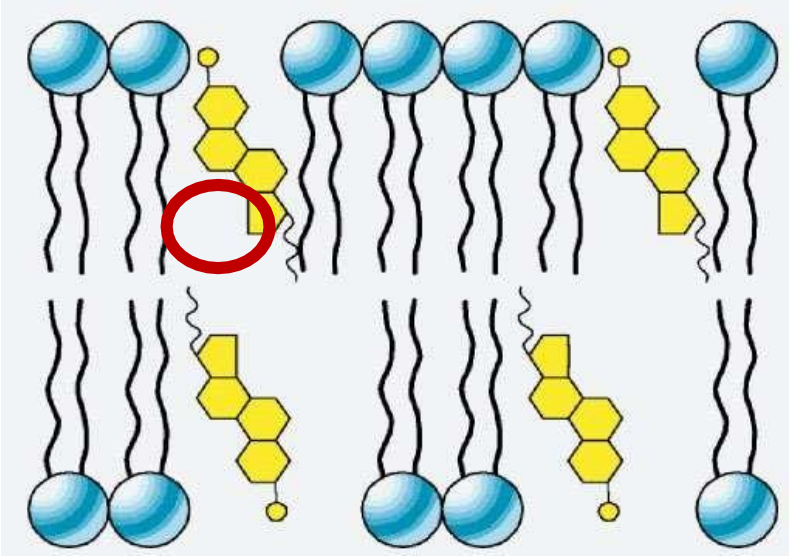
Less tightly packed,
Hydrocarbon tails
Disordered.

Increase temperature will give energy ,this energy will be converted to dinemic energy . As much as moving more , they will be more seperated and this will increase the fluidity



Cholesterol and membrane fluidity

- The presence of cholesterol and the cis unsaturated fatty acids in the membrane prevent the hydrophobic chains from packing too closely together, allowing free membrane proteins and lipid molecules to move laterally in the plane of the leaflet making the membrane a dynamic environment.
- Cholesterol can also stabilize very fluid membranes by increasing interactions between the fatty acids of phospholipids through hydrophobic interactions with the cholesterol ring structure.



Cholesterol helps regulate the fluidity of a cell membrane by limiting lateral movement of the phospholipids and adds stability on plasma membrane in low ,high temperature . How?
By making more spaces between phospholipids --> more liquid state

Increasing the concentration of cholestrol ,the fluidity of membrane will decrease (the rigidity will increase).
The most of place that cholestrol concent in it :(locked rafts)

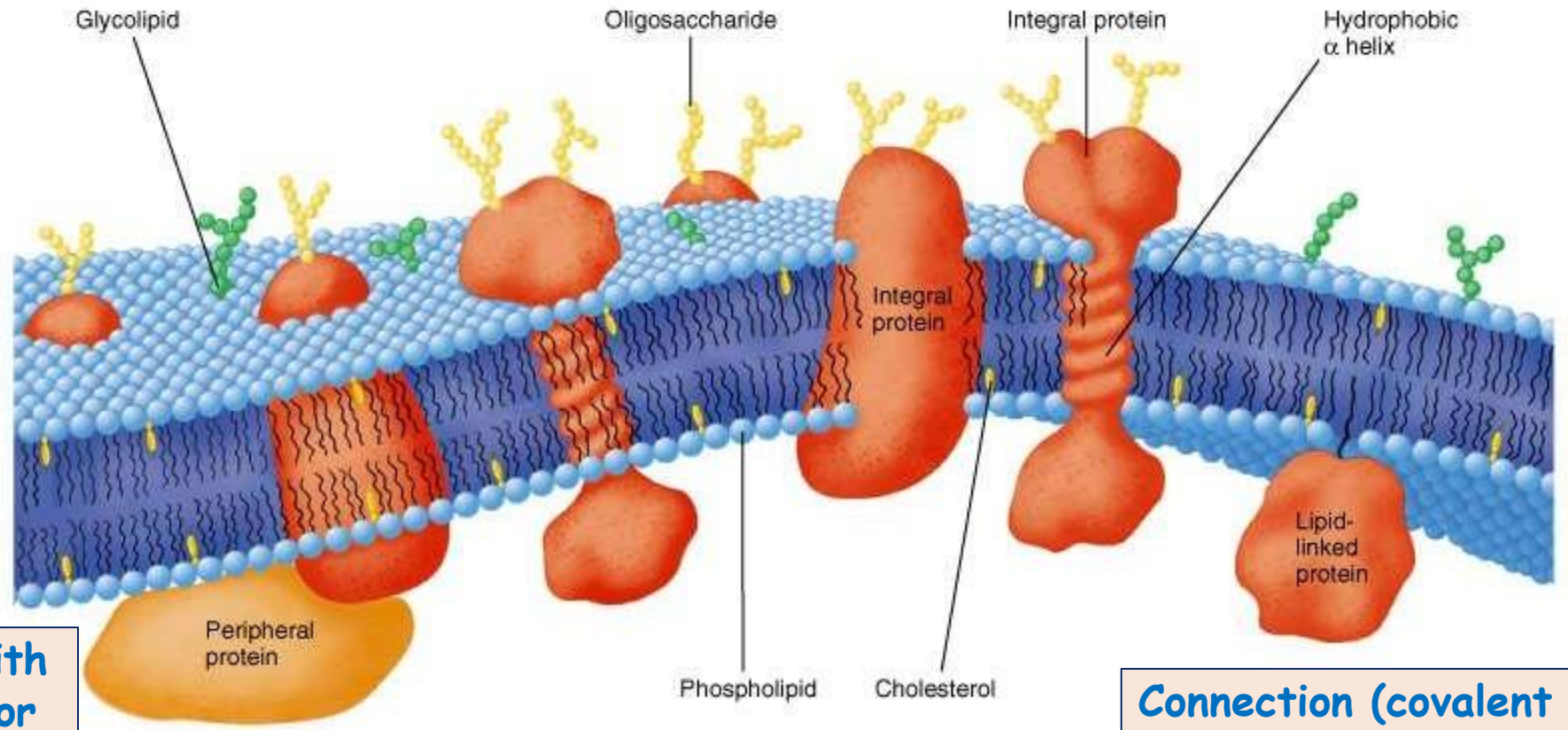
Types of membrane proteins

- Peripheral proteins:
  - are associated with Embedded with the membrane ia noncovalent interactions
- Integral membrane proteins:
  - anchored into membrane via Integrate with the membrane
- Lipid-anchored:
  - associated via a lipid group

Electrostatic or hydrogen bond

NOTE: Lipid anchors are attached to the lipid anchor to proteins via a covalent bond whereas the peripheral proteins are attached to the cytosolic domains of integral membrane proteins through non-covalent interactions.

Membrane proteins

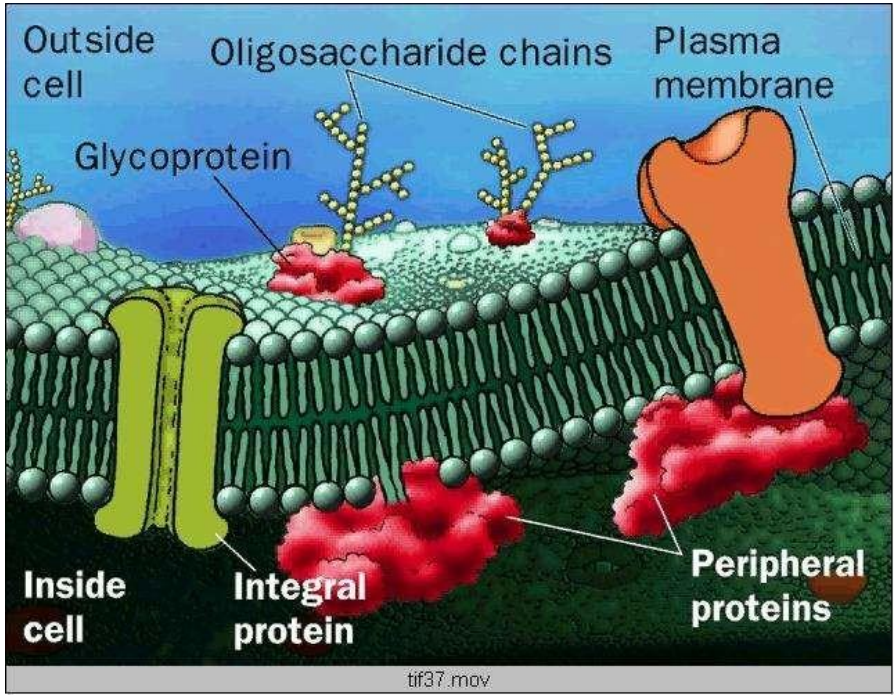


Non covalent with others protein or lipid and still attach or near the membrane

Connection (covalent)between fatty acid and and protein

Peripheral membrane proteins

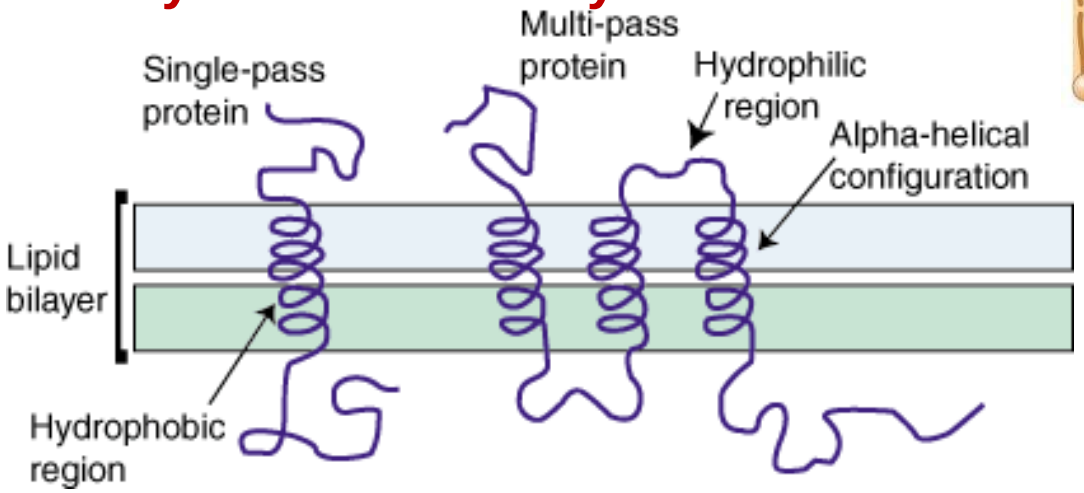
- They are associated with membranes but do not penetrate the hydrophobic core of the membrane.
  - They can be associated with integral membrane proteins.
- They are not strongly bound to the membrane and can be removed without disrupting the membrane structure.
  - Treatment with mild detergent

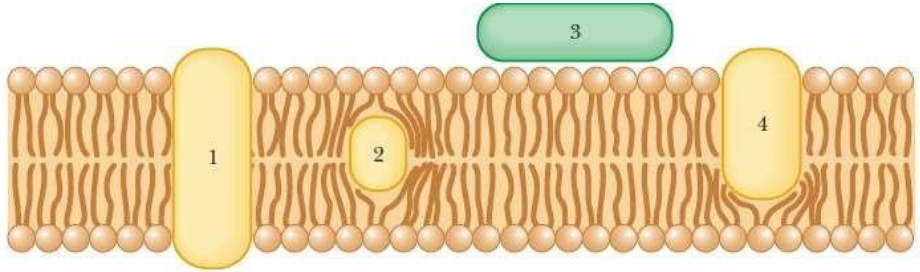


Integral membrane proteins

Inserted fully in plasma membrane they might be exposed on one or both sides of the cell membrane

The integral membrane proteins can be associated with the lipid bilayer in several ways.

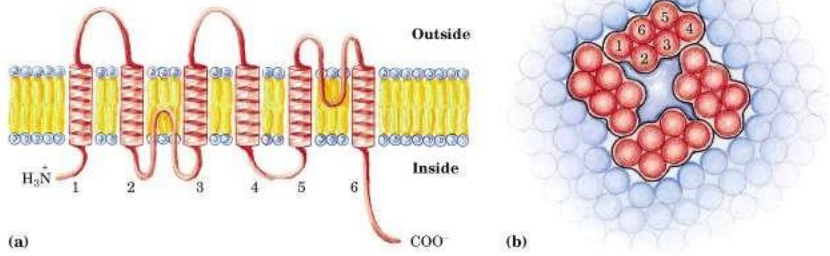




The membrane integral domains are:

1. Single or multiple

2. α-helix (human) or β-sheet (bacteria)



Some can form channels.

Very hard to study this structure so we can build a hybrid form to simulate it .

Structure-Function of Membranes (some of functions)

In both membrane protein and soluble protein .

- Transport: like channels
  - Membranes are impermeable barrier
  - Proteins can be carriers or channels
- Signaling
  - Protein receptors and small molecules (some can be lipids themselves)
- Catalysis
  - Enzyme-linked receptors

Accelerate the speed of reaction

Amino acids

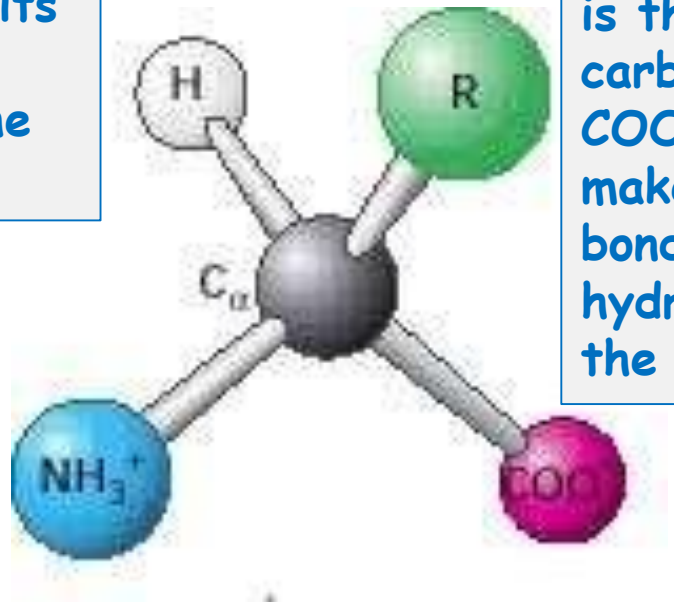
Summer 2023

Amino acid name comes from :
Amino from the amine,acid comes from the carboxylic acid

General structure

- Proteins are polymers of α-amino acids (or amino acids).
- An amino acid consists of:
  - a central carbon atom, called the α carbon, linked to four groups
  - an amino group (-NH2),
  - a carboxylic acid group (-COOH),
  - a hydrogen atom, and
  - a specific R group (the side chain)

The first 4 units are the main monomer of the protein



Alpha carbon is the first carbon after COOH and it makes bonds with hydrogen and the R group

We can distinguish the amino acids by R group (side chain)

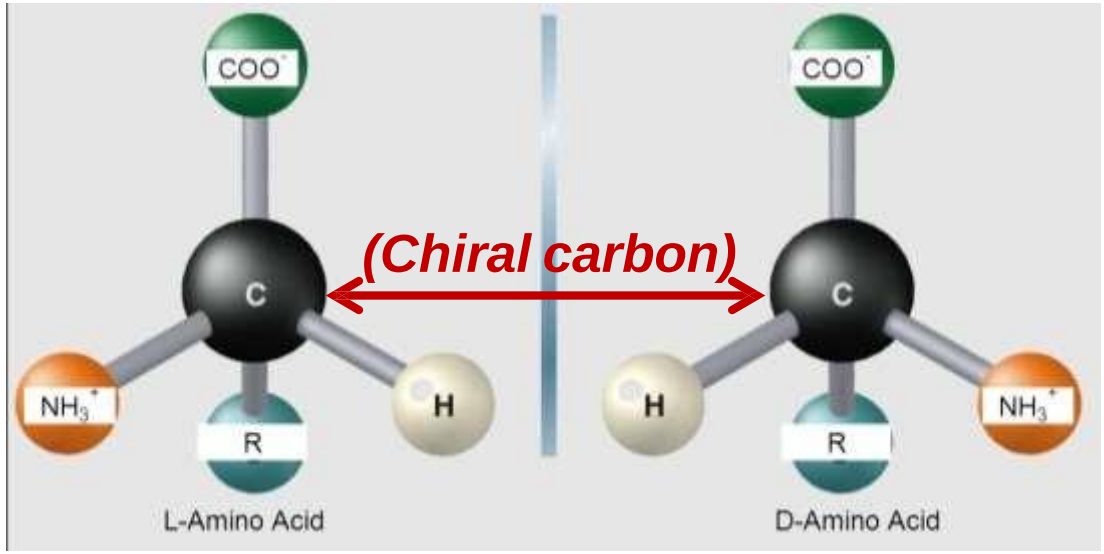
Alpha carbon is considered chiral if the R group differs from the other groups

L and D isomers

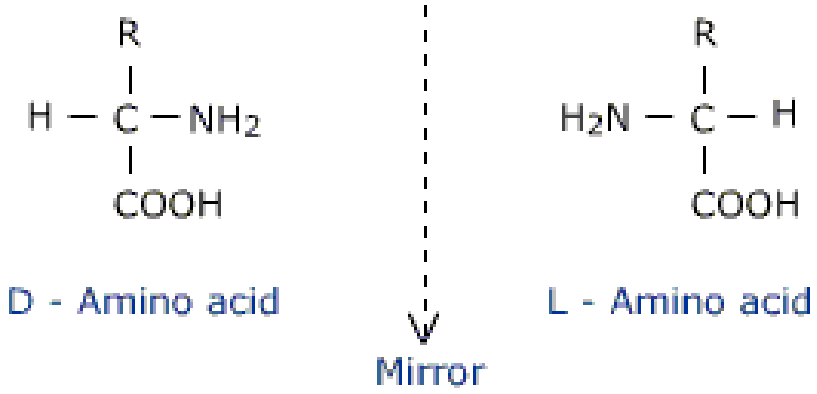
Depends on the amino groub

AMINE GROUP اذا ةدوجوم
D isomers نوكت نيميلاع
L isomer نوكت لامشلاع ةدوجوم اذا

- The α-carbon atom is chiral and, thus, amino acids can be present in two forms that are mirror-images of each other (they are enantiomers).
- The amino acids are chiral (when a central carbon is bonded to four different groups).
- They are called L isomer and D isomer.
- Only L amino acids naturally make up proteins.

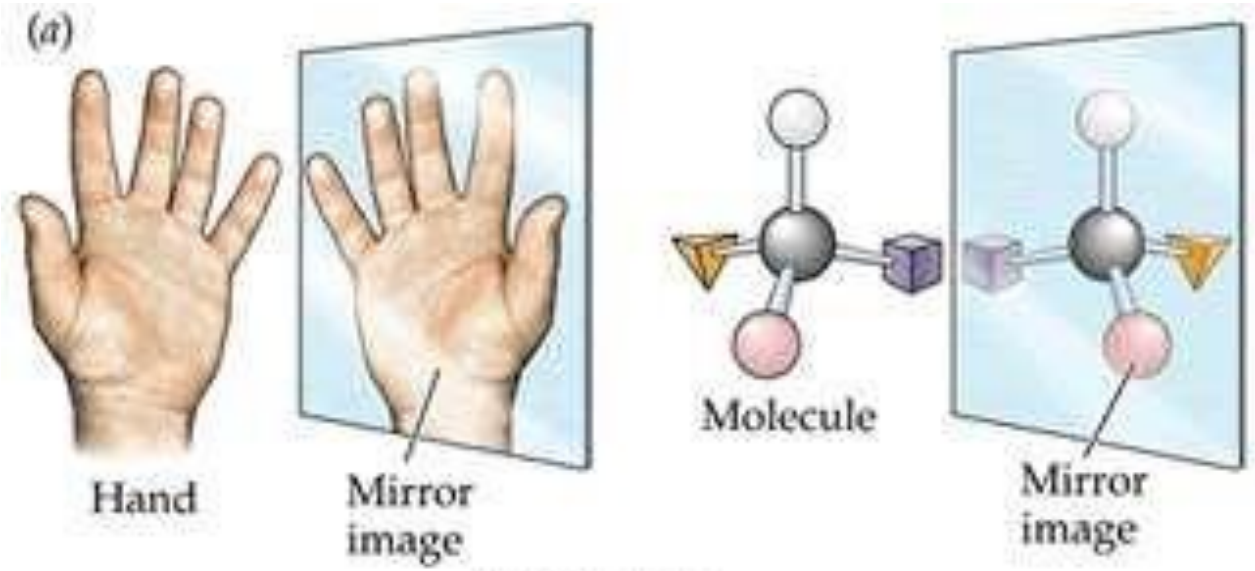


The amine group of L-amino acids occurs in the left-hand side when drawn in the Fischer projection, keeping the carboxylic acid group on bottom (or top) and the carbon chain in the top, whereas the amine group of the L-amino acids occurs in the left.



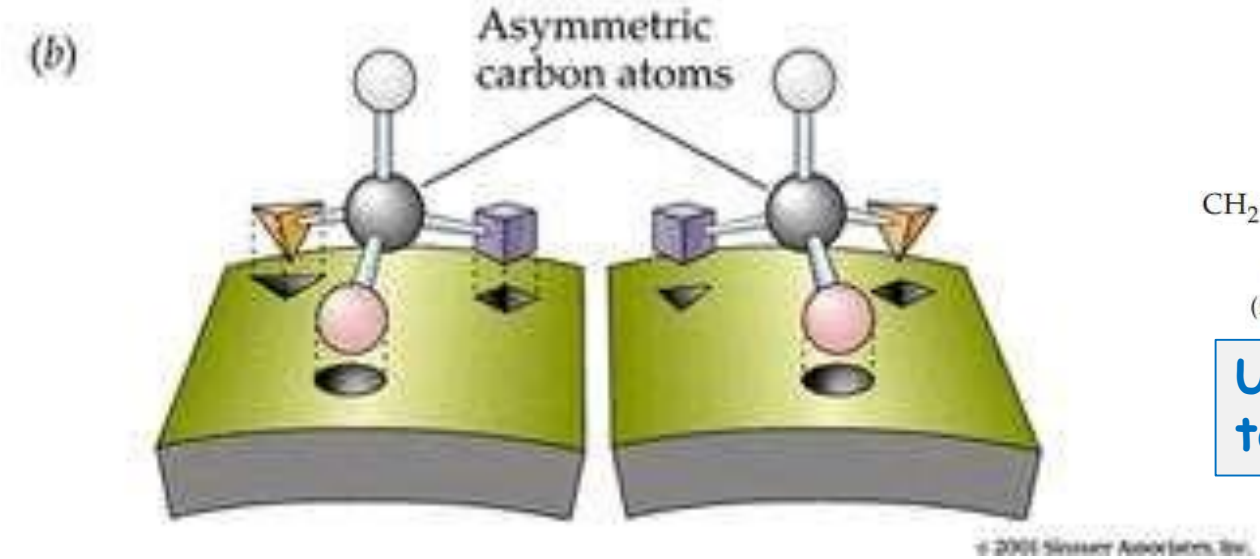
- The amino acids that exists in the human body are L isomers,but that doesn’t mean that our bodies cant deal with D isomers,no; our body can deal with it because we may take it in the drugs so our body doesn’t excret it
- There are so many amino acids in our body,but there is only 20 in our protein structure,these 20 amino acid do other functions,not just the functions they do In the protein such as their function as a Nuerotransmitters,stains,hormones and allergic mediators
- The presence of the amine group in the structure of the amino acid helps it to do these functions

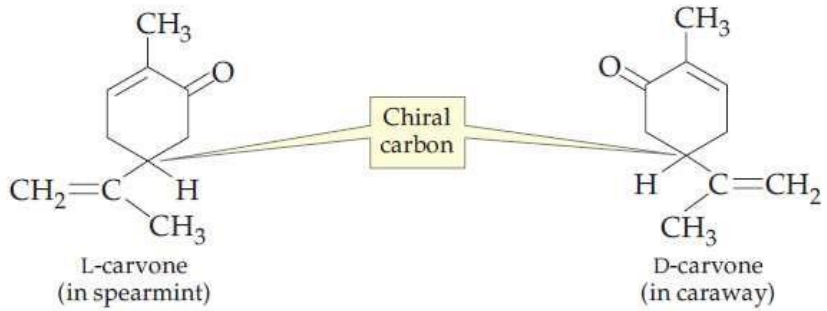
The amine groub is the back bone



There are 19 amino acids that has D and L isomers except glycine which is the simplest amino acid that doesn't has isomers

D and L isomers is very important because the diffrentiation in isomerism makes a huge changes such as carvone in the above picture





Used in the toothpaste

Types of amino acids

- There are twenty kinds of amino acids depending on the side chains varying in
  - Size
  - Shape
  - Charge
  - Hydrogen-bonding capacity
  - Hydrophobic character
  - Chemical reactivity

There are so many classifications of amino acids but the only one we will talk about in the biochemistry is THE POLARITY

Classification (according to R group)

They are both polar and charged, the positive one basic and the negative one acidic

Non-polar	Polar	Charged (positive)	Charged (negative)
Alanine	Serine	Lysine	Glutamate
Valine	Threonine	Arginine	Aspartate
Leucine	Glutamine	Histidine	
Isoleucine	Asparagine		
Methionine	Cysteine		
Tryptophan	Tyrosine		
Phenylalanine			
Proline			
Glycine			

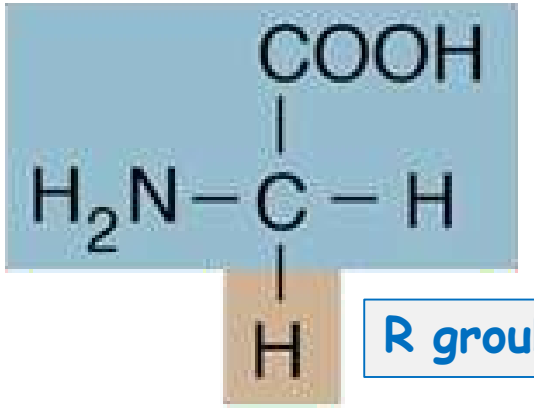
Glycine is the simplest one

- The polar amino acids could be charged or uncharged
- charged could be positive and that means that the side chain in the amino acid has accepted protons and acts as a BASE ,if it is negative that means the amino acid has lost protons and acts as a ACID
- Uncharged don’t transfer the full charge and they make dipole bond

Glycine

- Glycine is a derivative of acetic acid.
- It could be considered a derivative of aminoethane.

This is the back bone



R groub

Glycine (gly)

We abberiviate the amino acids by 3 letters

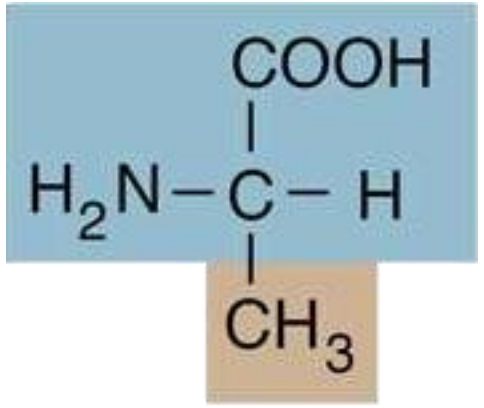
Is it chiral? no

Non-polar, aliphatic amino acids

Alanine

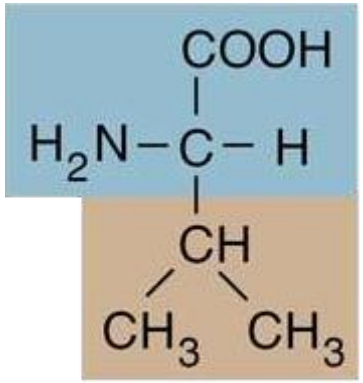
- Alanine, the next simplest amino acid, has a methyl group (-CH3) as its side chain.

The methyl group is hydrocarbon(non polar)

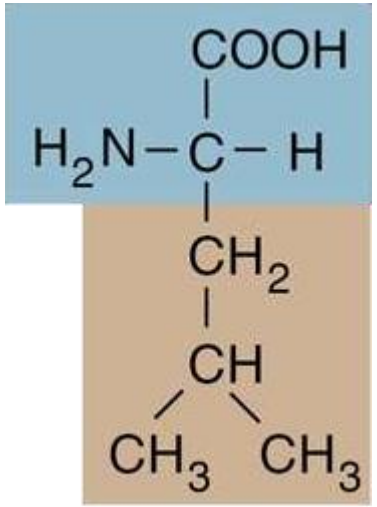


Alanine (ala)

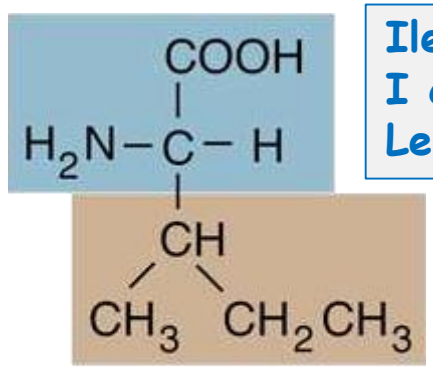
Valine, leucine, and isoleucine



Valine (val)*



Leucine (leu)*



Isoleucine (ile)*

Ile abrreviation:
I comes from iso
Le from leucine

Isoleucine and leucine are isomers

They differ in the attachment carbon

They are branched amino acids.
These are *essential amino acids in the sense that the body* cannot synthesize them.

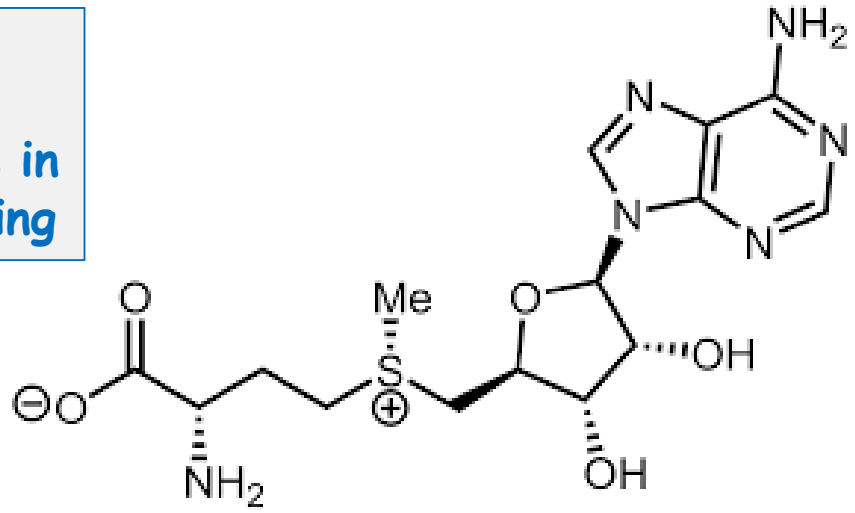
Methionine

Non polar amino acids

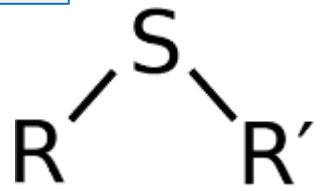
It can react to form S-Adenosyl-L-Methionine (SAM) which serves as a methyl donor in reactions.

During the degredation of methionone SAM is produced,which is uesd in methylation reactions that's why it serves as a methyl donor

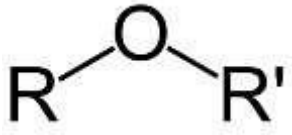
Its so important and always in the beginning



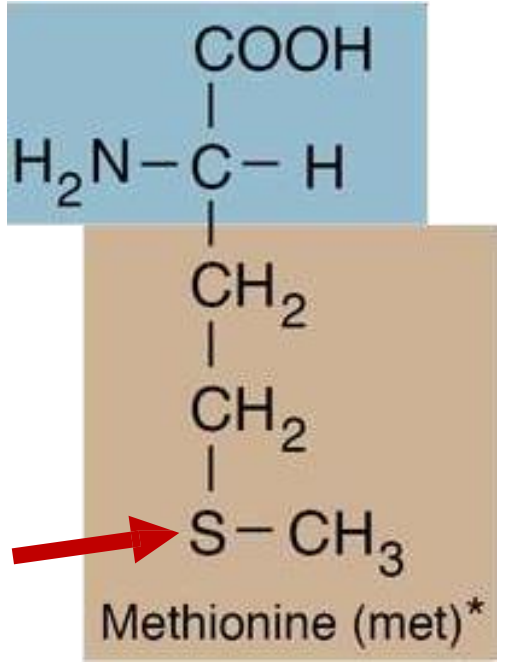
It's has a polar atom but averall its nonpolar cuz of the net charge is zero



Thioether



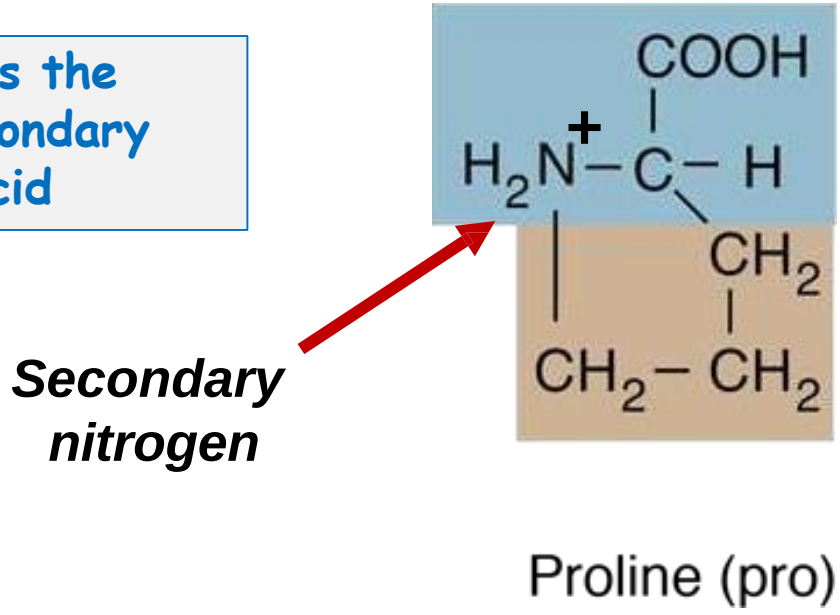
Ether



R chain is non polar

Proline (the only cyclic amino acid)

Proline is the only secondary amino acid

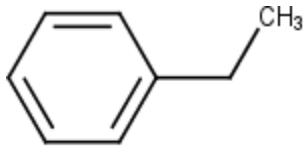


Proline is the only amino acid that makes a ring structure with the back bone, which gives the amino acid new characteristics that we will talk about later

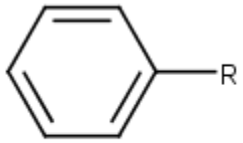
Phenylalanine and Tryptophan

Aromatic could be either polar uncharged or nonpolar and it is polar when it has a side group

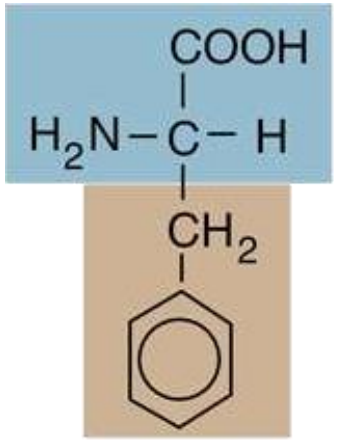
- Phenylalanine contains a phenyl ring.
- Tryptophan has an indole ring; the indole group consists of two fused rings and an NH group.



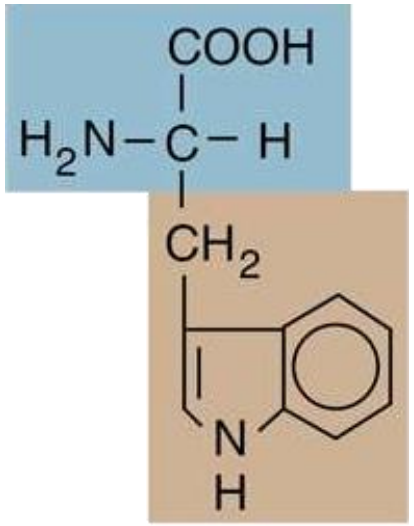
benzyl



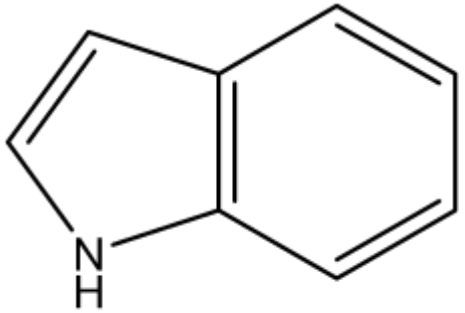
phenyl



Phenylalanine (phe)*



Tryptophan (trp)*



Indole

TRP abbreviation we use it because ther are another amino acid with TYR abbreviation so we change it to distinguish them

Benzene fused with 5 carbons ring

Positively-charged amino acids

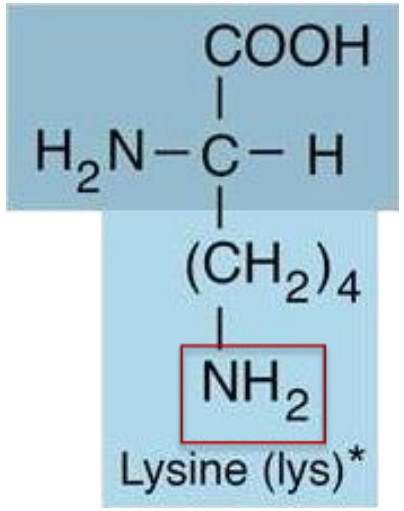
- Because the side chains on the lysine and arginine have a basic charcterstics,pka values for these bases are low
- When you compare the cojugate acid for these basic amino acids with acidic chain in amino acid you will find that the pka of the real acidic chains is higher than the conjugate acid though it is low but the conjugate acid is lower
- Pka for lysine and arginie is high,higher than the physiological pka in the body
- So you will find that these side chains are mostly protonated,because their pka is higher than 7.4,so the desired oh is acidic compared to it,so usuallu they will be having a charge

Lysine and arginine

- Lysine and arginine have relatively long side chains that terminate with groups that are positively charged at neutral pH.
- Lysine ends with a primary amino group and arginine by a guanidinium group.

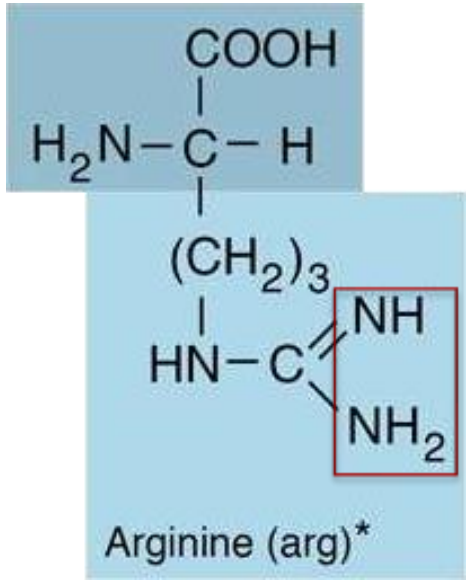
Just identify the structures

The presence of NH2 which is a base group, that makes a basic side chain



This fork shaped structure is ~~called guanidinum~~

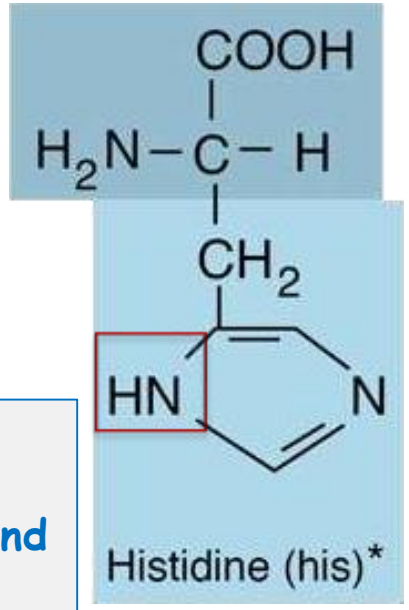
You have to identify the structure, just identify



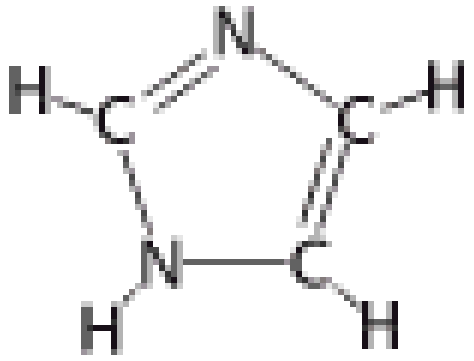
Though it has 3 nitrogen, only one c an accept proton

Histidine

- Histidine contains an imidazole group, an aromatic ring that also can be positively charged.



It has two different nitrogens,and only one of them can accept proton



Imidazole

Pka of the histidine is very close to the physiological ph

This is the nitrogen that accepts proton

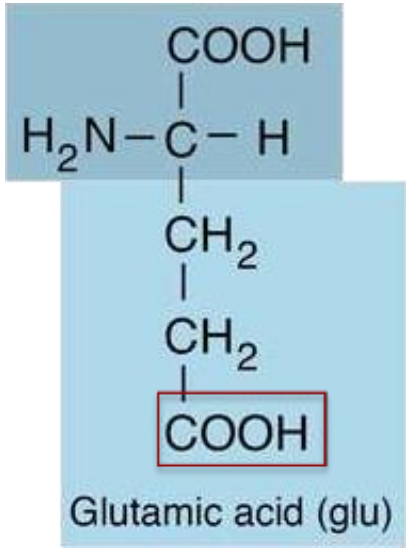
- Histidine is a basic amino,but not as lysine and arginine because they are very far from the physiological ph,but histidine ph is very close to the physiological ph
- So we are close to 1 ratio which means ph and pka are very close,which means a very small change in ph will lead to take or remove protons from histidine
- Histidine can take or lose protons more than any amino acid
- The presence of histidine in the structure of proteins,leads them to work as buffers
- Hemoglobin has 38 histidinemore than albumin that has 18 histidine,hemoglobin is a better buffer becaise it has more histidine which means more buffering capacity

Negatively-charged amino acids

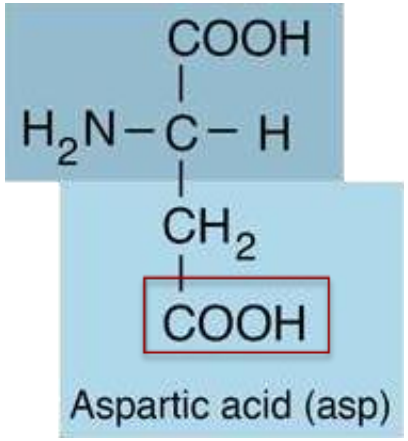
Aspartic acid and glutamic acid

Mostly they are deprotonated

- Two amino acids contain acidic side chains: aspartic acid and glutamic acid.
- These amino acids are often called aspartate and glutamate when they are charged.



Glutamic acid (glu)



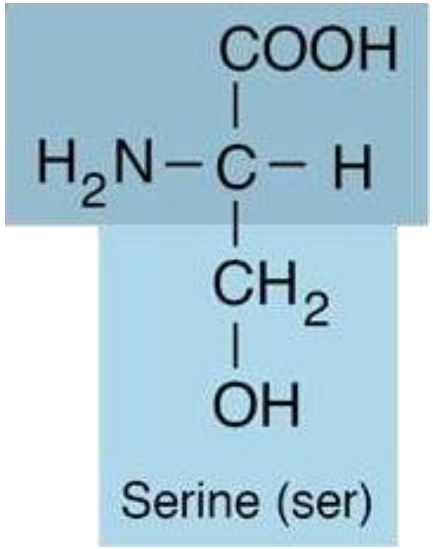
Aspartic acid (asp)

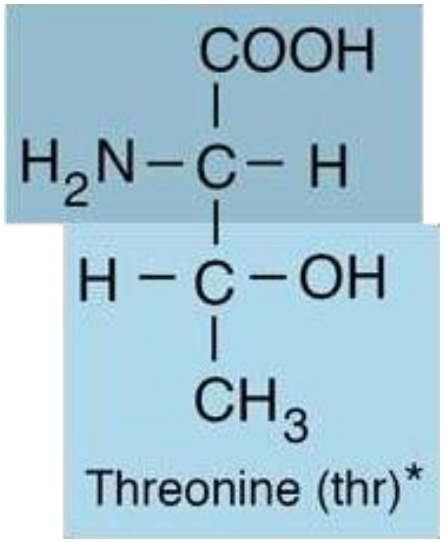
We can call them aspartate and glutamte because usually they donate the proton and pka values for their side chains are very low,lower than the physiological ph,so they are charged under the physiological conditions.

Polar, hydrophilic, neutral amino acids

Serine and threonine

- Serine and threonine, contain aliphatic hydroxyl groups.
- The hydroxyl groups on serine and threonine make them hydrophilic and reactive.

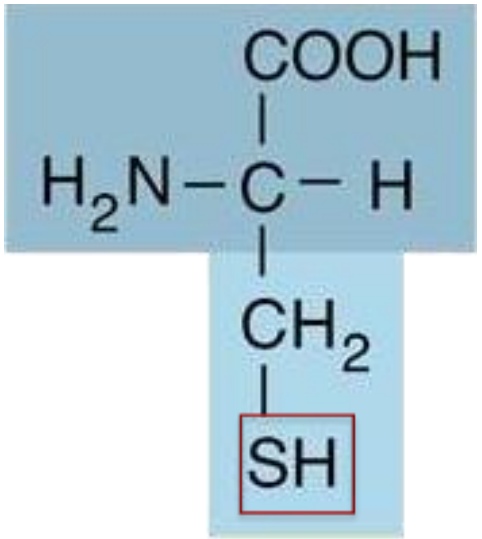




They are polar, aliphatic amino acids not charged but they contain an amino group (polar group) because of that they are considered reactive (they enter in many reactions)
both contain hydroxyl group

Cysteine (Cys)

- Cysteine contains a sulfhydryl or thiol (-SH), group.
- The sulfhydryl group is reactive.



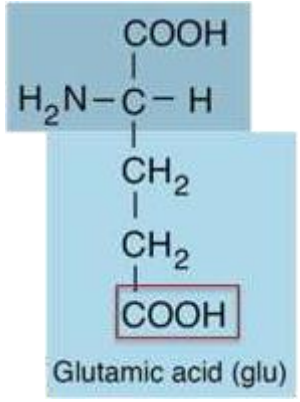
Cysteine (cys)

Sulfur is a thiol terminal group(at the end of the chain)-->it is polar because of that it is very active

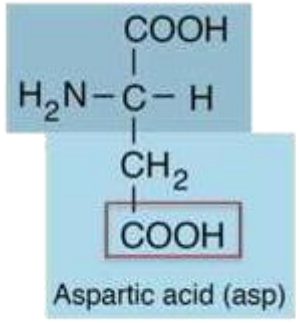
Asparagine and glutamine

Glutamate and aspartate
Instead of carboxyl group in them , we remove oh and put amino group which isn't charged but they are polar , reactive groups

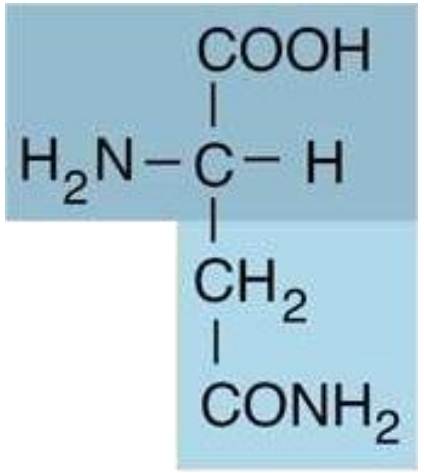
- Asparagine and glutamine are uncharged derivatives of aspartate and glutamate.
- Each contains a terminal carboxamide in place of a carboxylic acid.



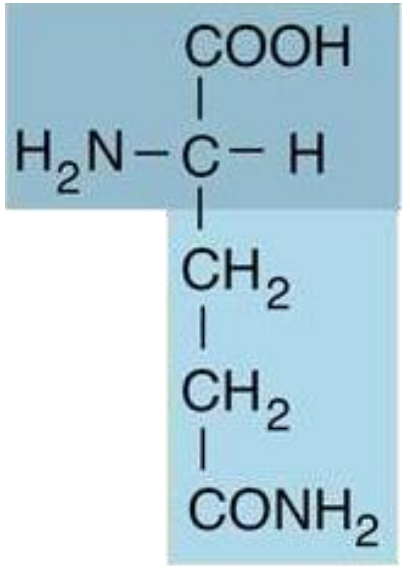
Glutamic acid (glu)



Aspartic acid (asp)



Asparagine (asn)

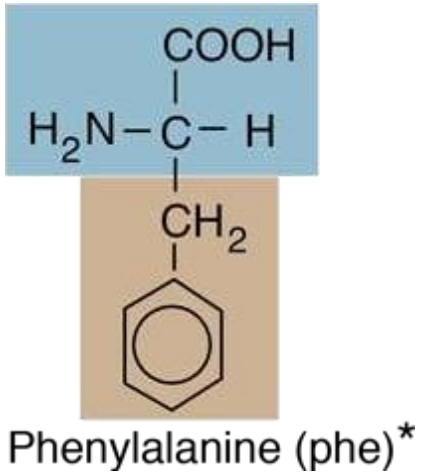


Glutamine (gln)

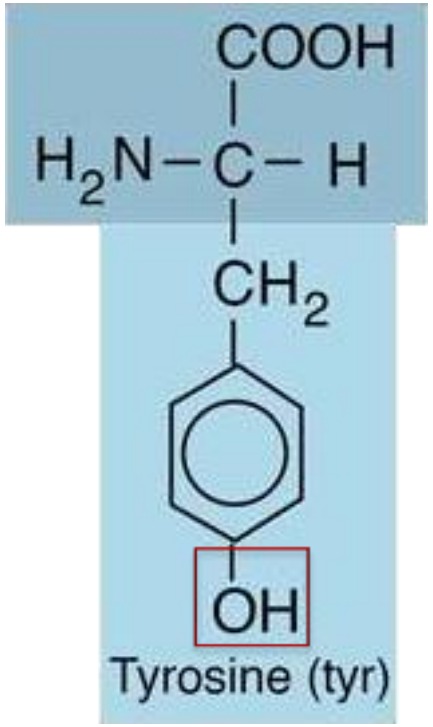
Tyrosine

Is the 3rd amino acid that contain hydroxyl group with serine and throlioline
It looks like any amino acid ? Phenylalanine but we take phenyl group and put oh group (phenol)

- The aromatic ring of tyrosine contains a hydroxyl group.
  - It is derived from phenylalanine.
- This hydroxyl group is reactive.



Phenylalanine (phe)*

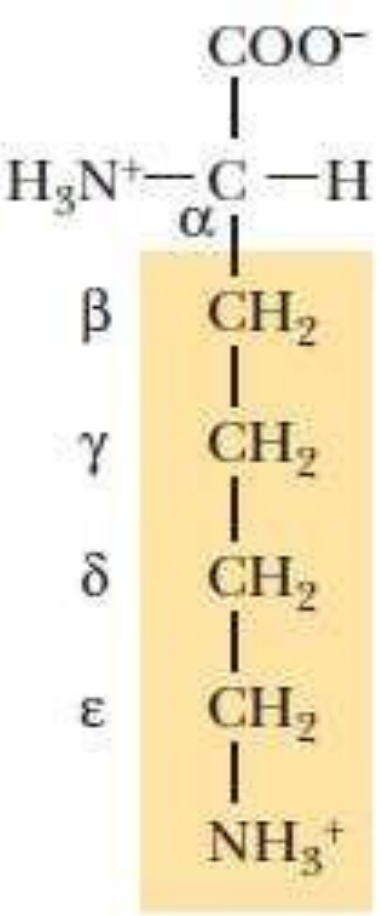


Tyrosine (tyr)

Designation of carbons

- Side-chain carbon atoms are designated with letters of the Greek alphabet, counting from the α-carbon. These carbon atoms are, in turn, the β-, γ-, δ-, and ε-carbons.
- If a carbon atom is terminal, it is referred to as the ω-carbon.

The last carbon in the chain is called (omega carbon)



Questions

- Two amino acids are negatively-charged:
- The following amino acid is achiral:
- …etc.

Specialized and uncommon amino acids

Important ;-

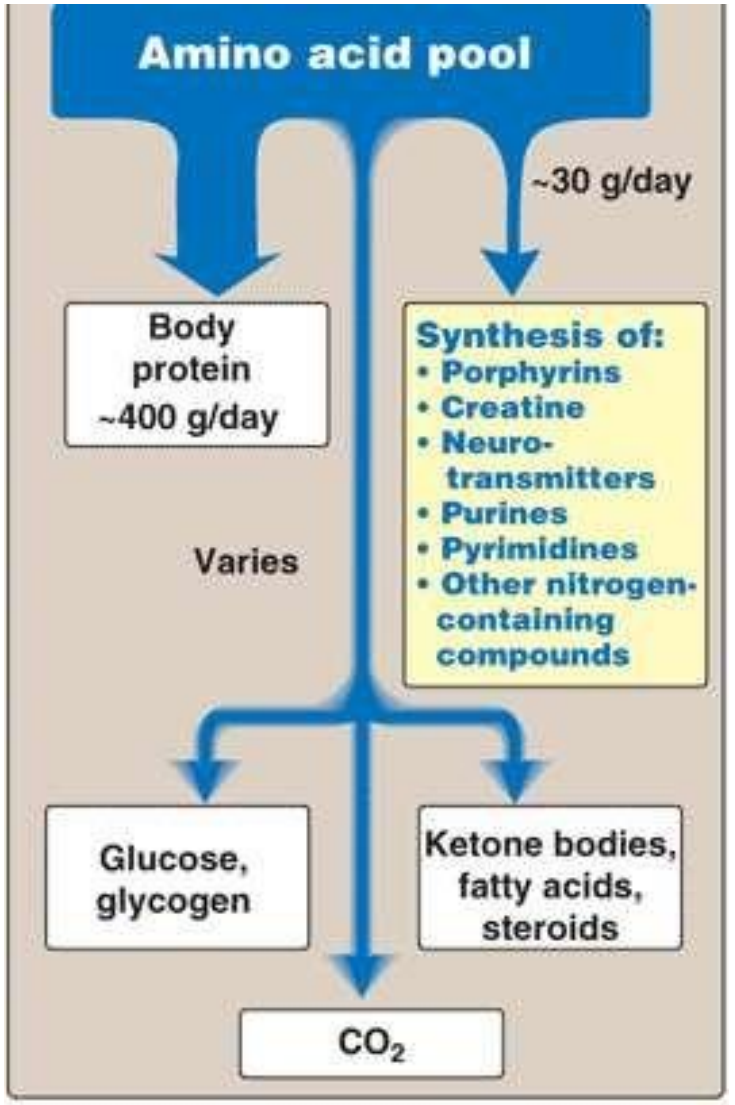
Amino acids not only produce proteins , they may do another functions like neurotransmitter, signaling molecule but some of them are converted to new structure with a specific function .

We can use them in metabolism

Amino acid--> sugar (like glucose) we will study them later ;)

Biological significance of amino acids

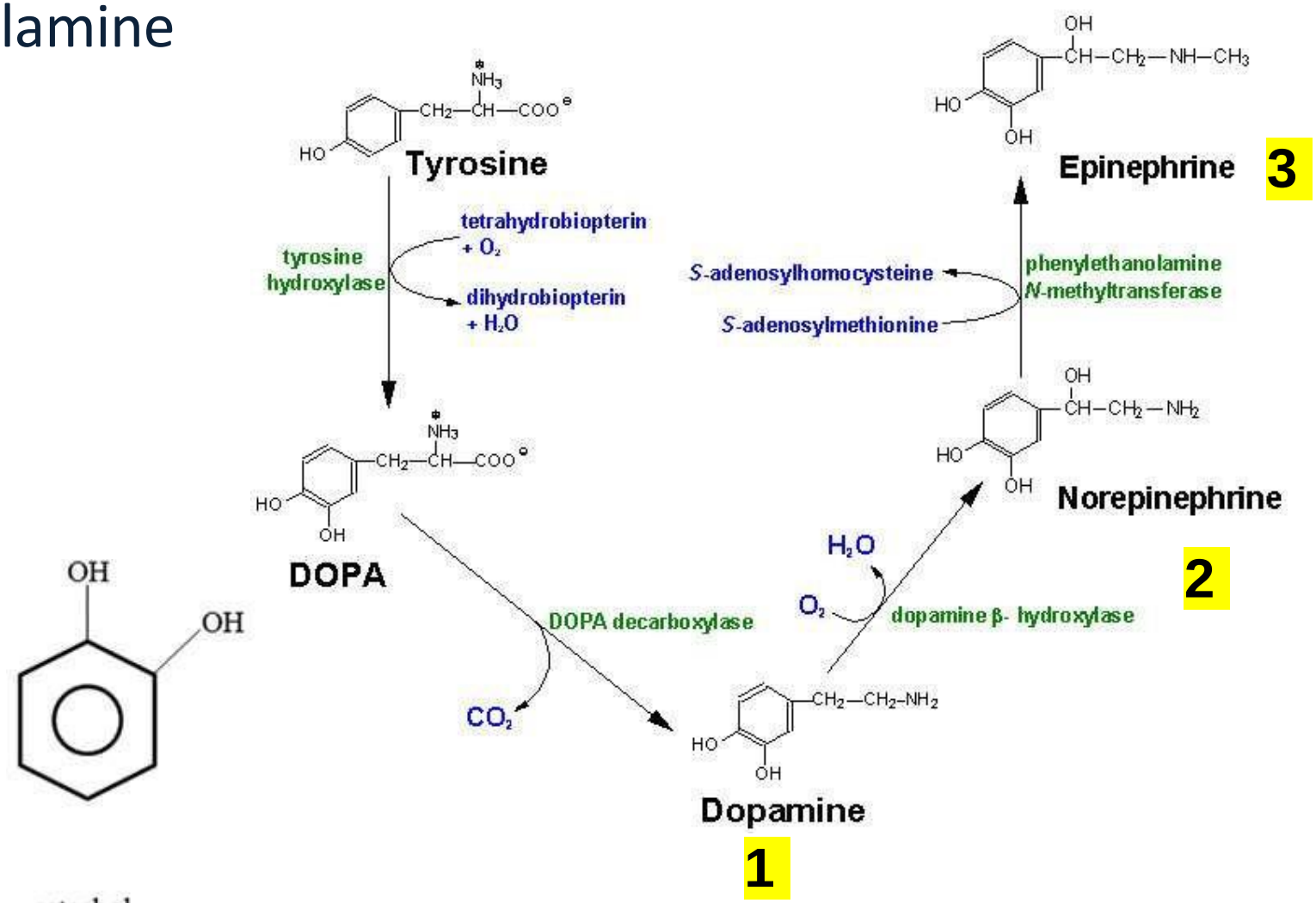
- α-nitrogen atom of amino acids is a primary source for many nitrogenous compounds:
  - Hormones
  - Neurotransmitters
  - Biologically active peptides



Tyrosine (1)

- It is converted into catecholamine neurotransmitters
  - Dopamine
  - Norepinephrine
  - Epinephrine
    - flight or fight

1+2+3 are neurotransmitters
Catecholamines because they contain catechol group (a benzene with 2 hydroxyl groups and an amino group from tyrosine)



catechol

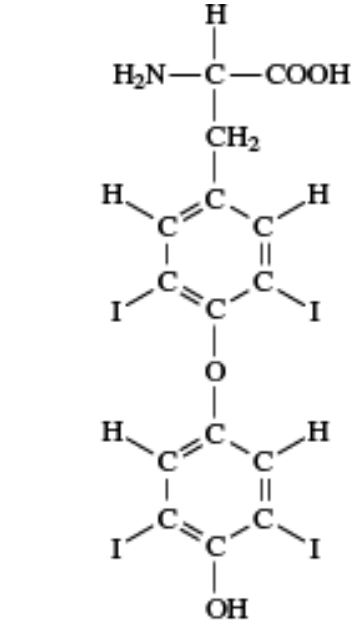
Further explanation regarding the previous slide:

You aren't required to memorize the structure or the enzyme(not important now)
#But you must now that this molecule is derived from this amnio acid and know its general function

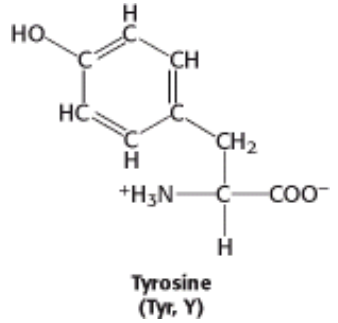
Epinephrine = adrenaline its function is production of energy as dopamine . like excitement

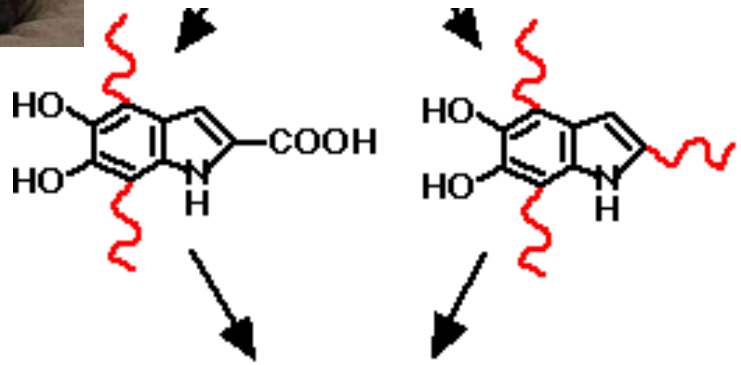
Tyrosine (2)

- Tyrosine is converted into
  - Melanin (skin colour)
  - Thyroxine (hormone) a thyroid gland hormone



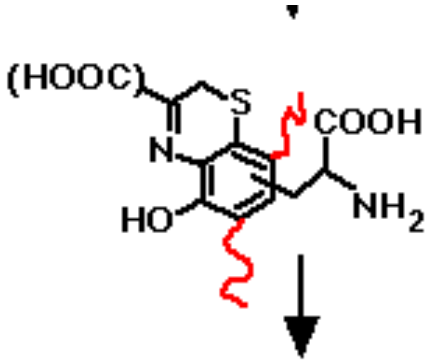
thyroxine (Thy)
occurs only in the hormone protein
thyroglobulin: I=iodine





EUMELANINS

Brownish color of the skin



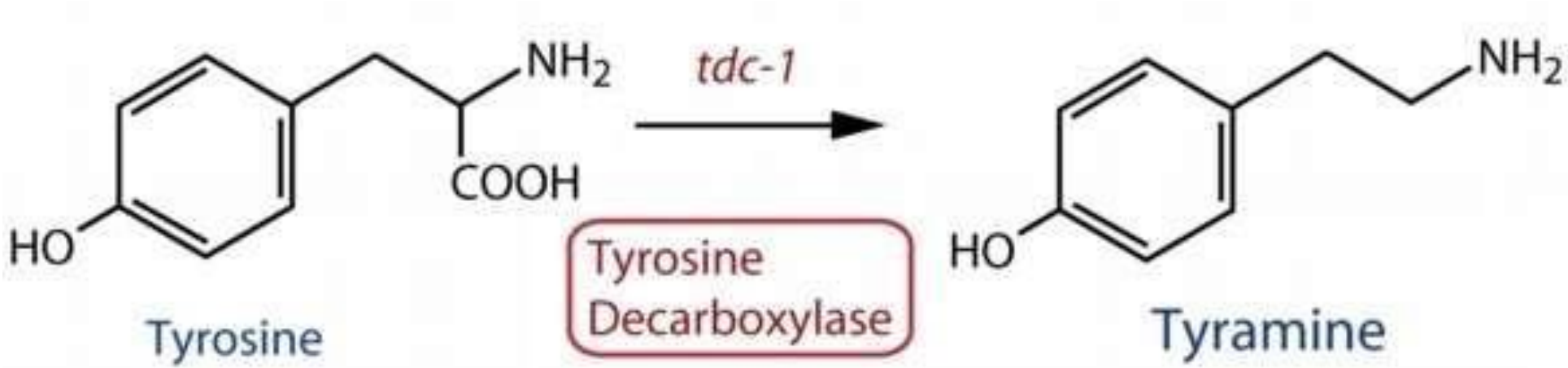
PHEOMELANINS

Red color of (skin , hair)

Tyrosine and life

Tyramine is mainly founded in our daily food like cheese
its function like epinephrine which gives energy .

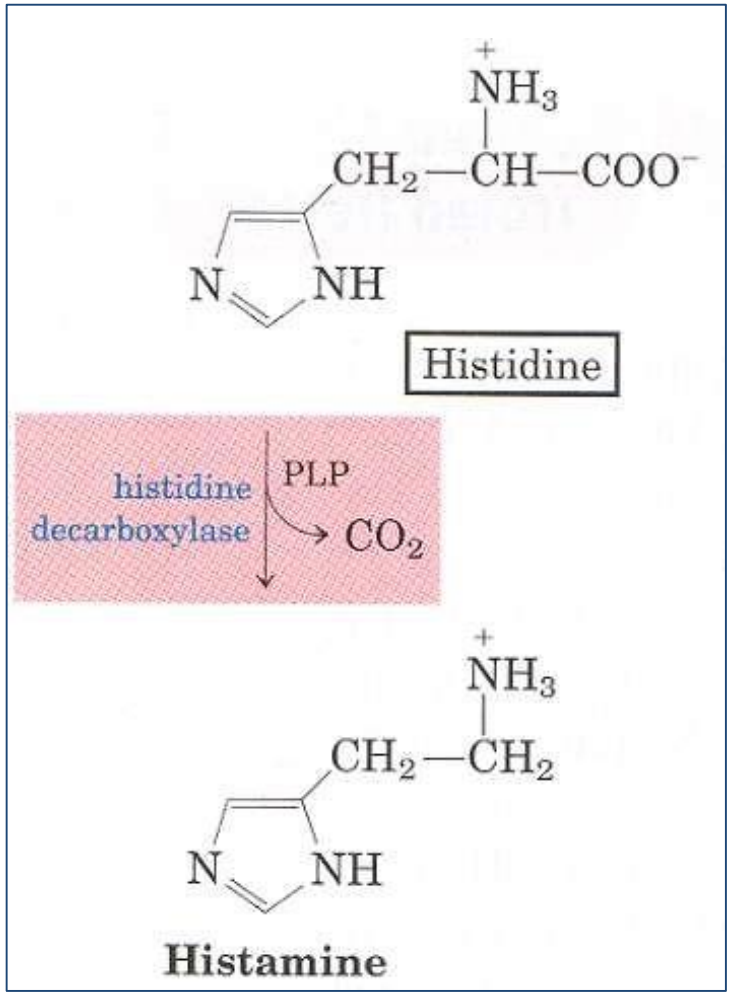
- Cheese contain high amounts of tyramine, which mimics epinephrine; for many people a cheese omelet in the morning is a favorite way to start the day.



Histamine

a chemical your immune system releases. It's mainly known for its role in causing allergy symptoms

- Regulates physiological function in the gut
- Acts as a neurotransmitter
- Causes allergic symptoms (a major causes for asthma)
- Contributes to inflammatory response
- Causes constriction of smooth muscle

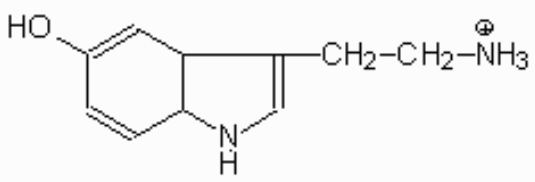


It is From histidine amino acid (His) +ve charge amino acid with an imidazole group, an aromatic ring that also can be positively charged.

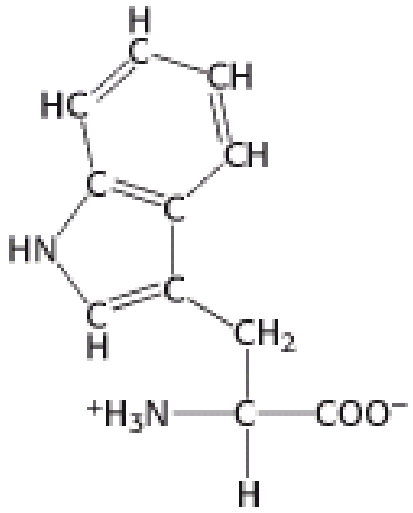
Tryptophan

Trp ; bulk , hydrophobic despite of nitrogen that is in one ring it has 2 rings

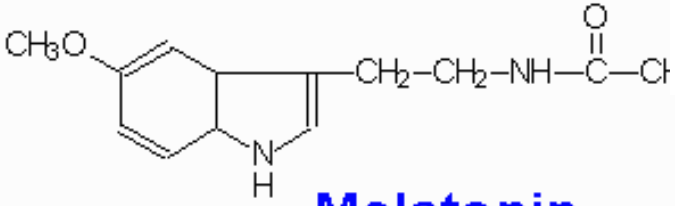
- Tryptophan serves as the precursor for the synthesis of Neurotransmitters
  - Serotonin (neurotransmitter-sedative)
  - Melatonin (day-night cycle)



Serotonin
(5-hydroxytryptamine)



Tryptophan
(Trp, W)



Melatonin

From a gland in brain

هتسلا لوصف وا مويلا ريّي روعشلا نع لوؤسملا وه

Infants have high levels of this hormone because of that they sleep for long hours not like old ages (low rate of this hormone)

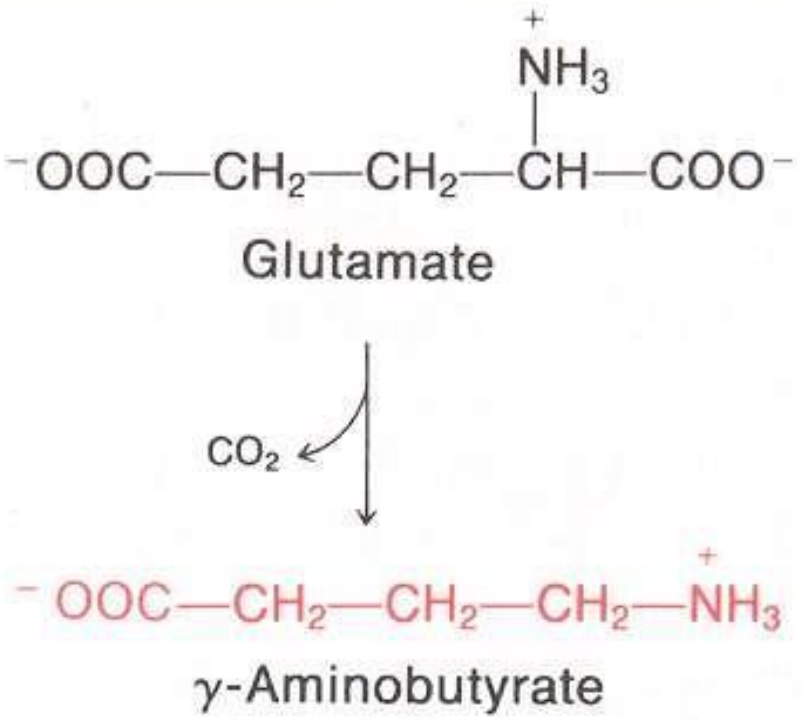
دنع مونلا ليعف هملختسا تي لضيا ملقللا مي رفسلا

عم لودلا ىدل نيوتلا فلاتخا

It is typically safe for adults to take melatonin every night for short periods of time. Several factors affect whether an individual should take melatonin every day.

Glutamate

- It is a precursor of g- aminobutyric acid (GABA) **In anxiety**
- It is an inhibitory neurotransmitter (CNS) that reduces neuronal excitability.
- It is synthesized in brain because it does not cross the BBB.
- It has relaxing, anti-anxiety, and anti-convulsive effects.



γ- carboxyglutamate (Gla)

It has a carboxyl group

- The glutamate residues of some clotting factors are carboxylated to form γ- carboxyglutamate (Gla) residues.
  - Vitamin K is essential for the process
- This carboxylation is essential for the function of the clotting factors.

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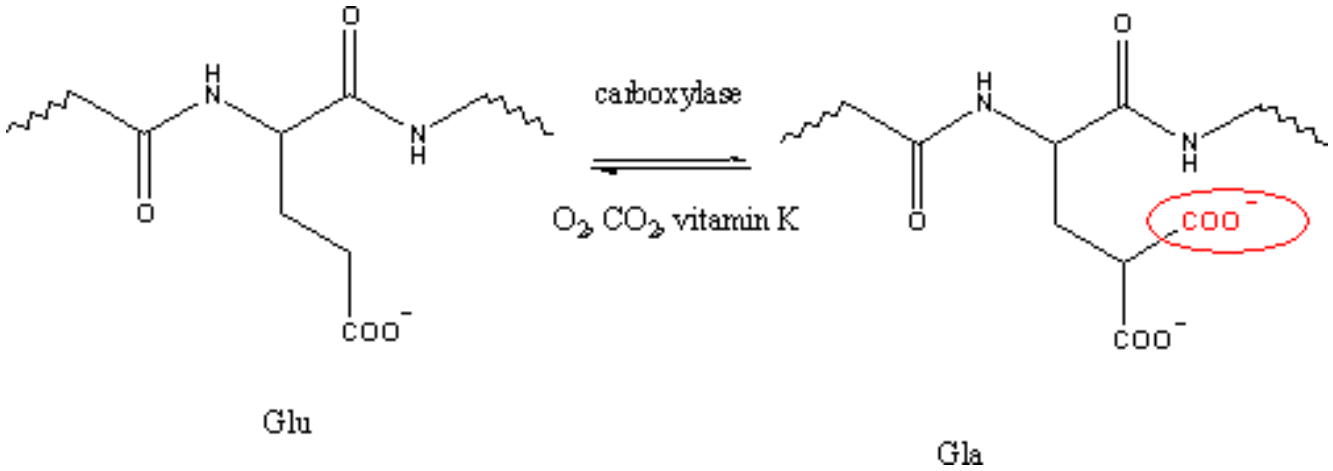
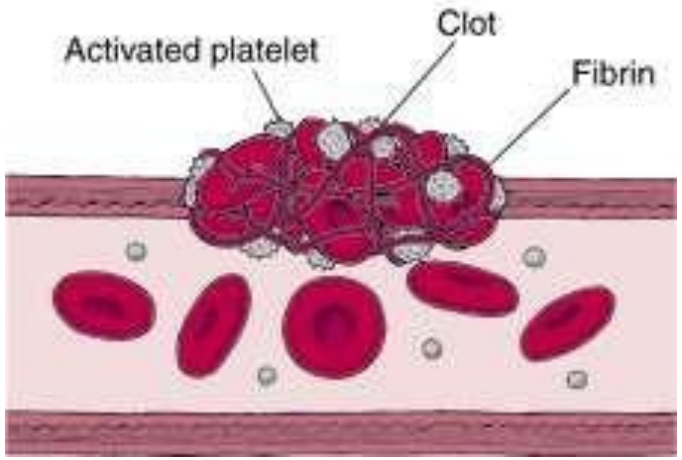
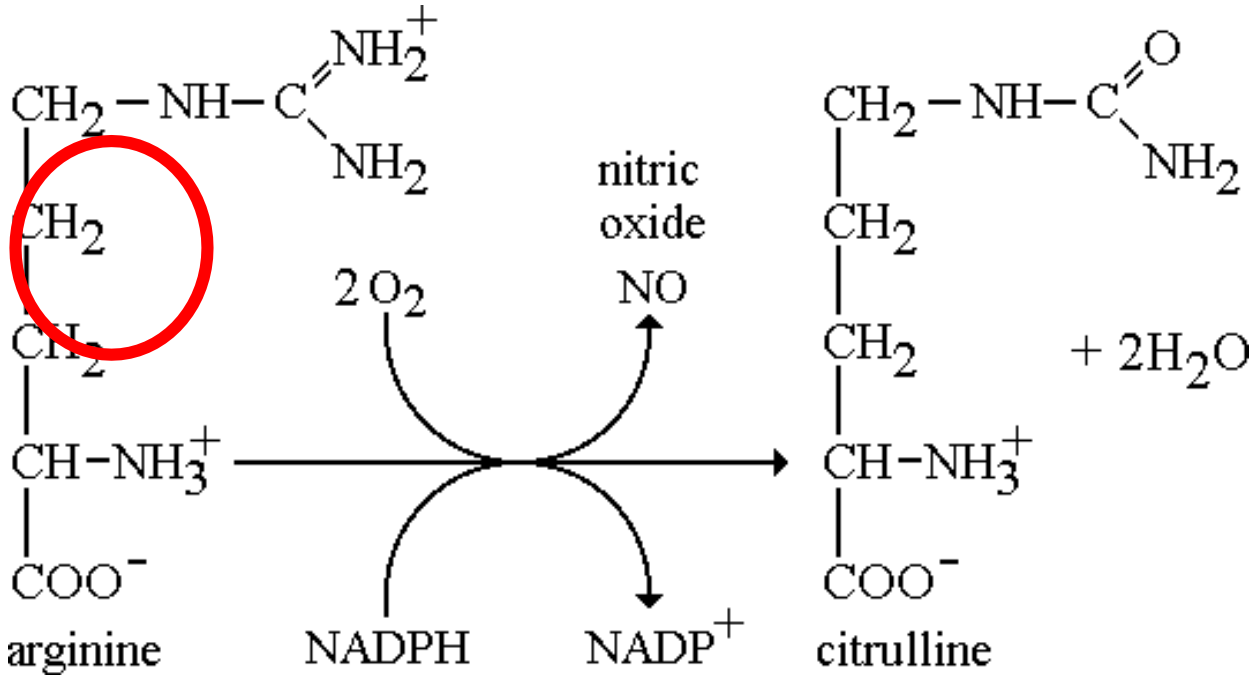




Arginine

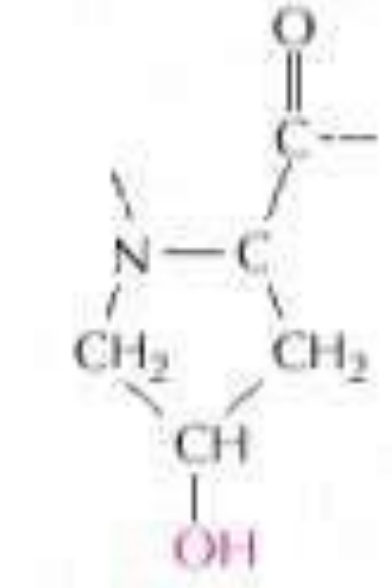
- L-arginine is the precursor of nitric oxide (NO)
- NO functions:
  - Vasodilation, inhibition of platelet adhesion, inhibition of leukocyte adhesion, antiproliferative action, scavenging superoxide anion (anti-inflammatory)

It has a +charge amino acid that contain guanidium group.
We can extract a gas from R group we take one of these 2 N and take nitrile oxide it is a gas from endothelial cells
It is a vasodilator



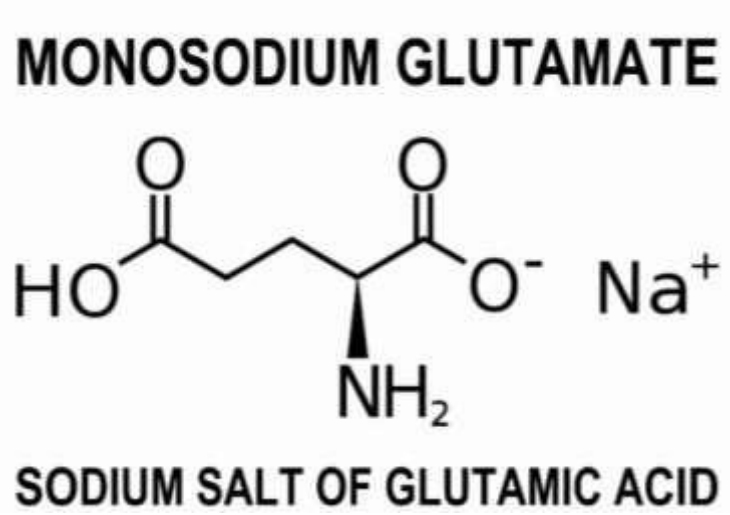
Hydroxylysine and hydroxyproline

- Both are hydroxylated and are part of collagen structure.
- Both are derived from the common amino acids.
- Both are produced by modification of the parent amino acid after protein synthesis, posttranslational modification.



They are modified lysine and proline respectively with an oh group
Lysine positive charge amino acid + oh -->Hydroxylysine
Proline non-polar cyclic and rigid amino acid R+ N group
They are presented in collagen (we will take it later)

Biochemical applications: Monosodium glutamate (MSG)



Glutamic acid derivative

Flavor enhancer, Asian food.

MSG causes a physiological reaction in some people (chills, headaches, and dizziness)

Chinese restaurant syndrome.

Monosodium glutamate (MSG);-

Is a meat tenderizer لهسي لكلاو غضملا

The goal of a meat tenderizer is to make meat softer and easier to chew(غضملا). it is used for Tough meat is difficult to chew and digest

- Amino acid and protein molecular weight. **Amino acids make the structure of protein**
- The average molecular weight of an amino acid residue is about 110.
  - The molecular weights of most proteins are between 5500 and 220,000.

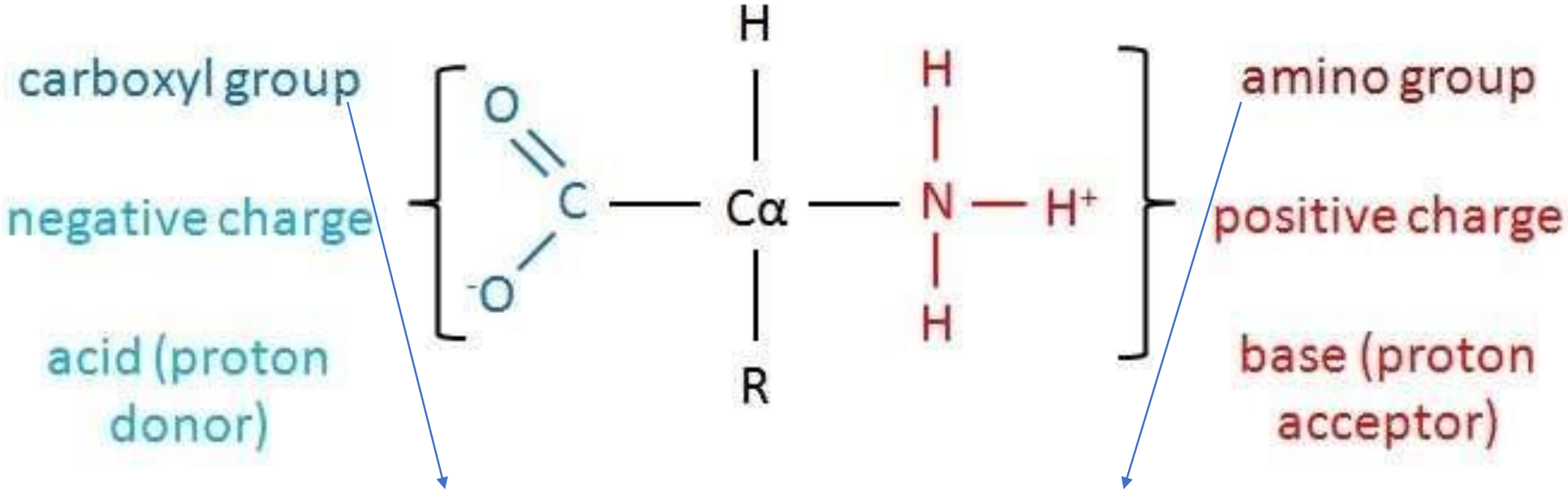
Important in the process of separating proteins in order to identify and discover them

- We refer to the mass of a polypeptide in units of Daltons.
  - A 10,000-MW protein has a mass of 10,000 Daltons (Da) or 10 kilodaltons (kDa).

Ionization of amino acids

Because we are talking about compounds that have acidic and basic functional groups, whether in side chains or backbones, we expect them to have acidic, basic and ionizing properties, so we will link them with the first topic we took, which is acids and bases

Why do amino acids get ionized?



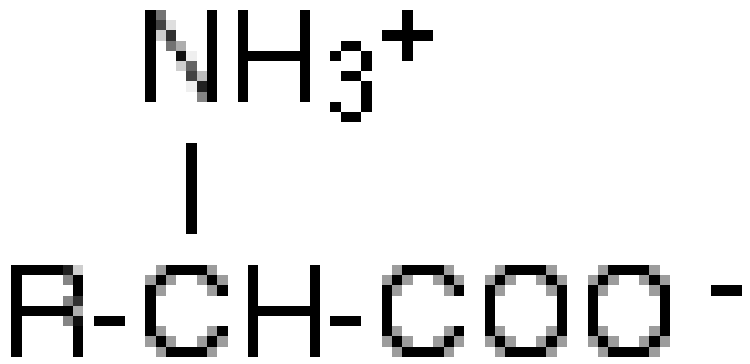
under physical conditions it loses protons (Donner proton) because the pka is low

under physical conditions, it doesn't lose protons (proton acceptor) because the pka is high

Zwitterion and isoelectric point

- At physiological pH, amino acids (without ionizable groups) are electrically neutral.
- Zwitterion: a molecule with two opposite charges and a net charge of zero.

Zwitterion: Amino acid has charges in different places but the over total charge equal zero

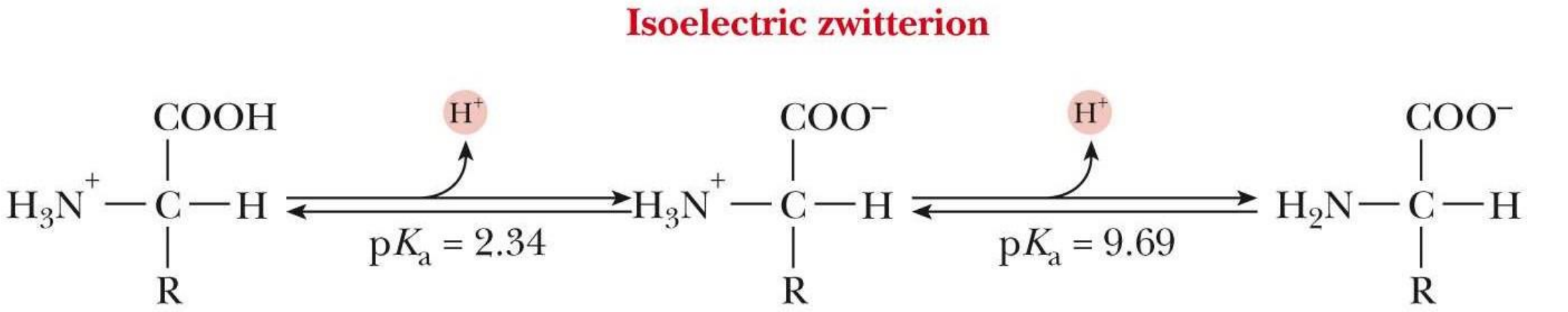


Zwitterion is formed at a point called the **isoelectric point.**
Isolectric point: the pH when the molecule is in the zwitterion form

a zwitterion

Effect of pH

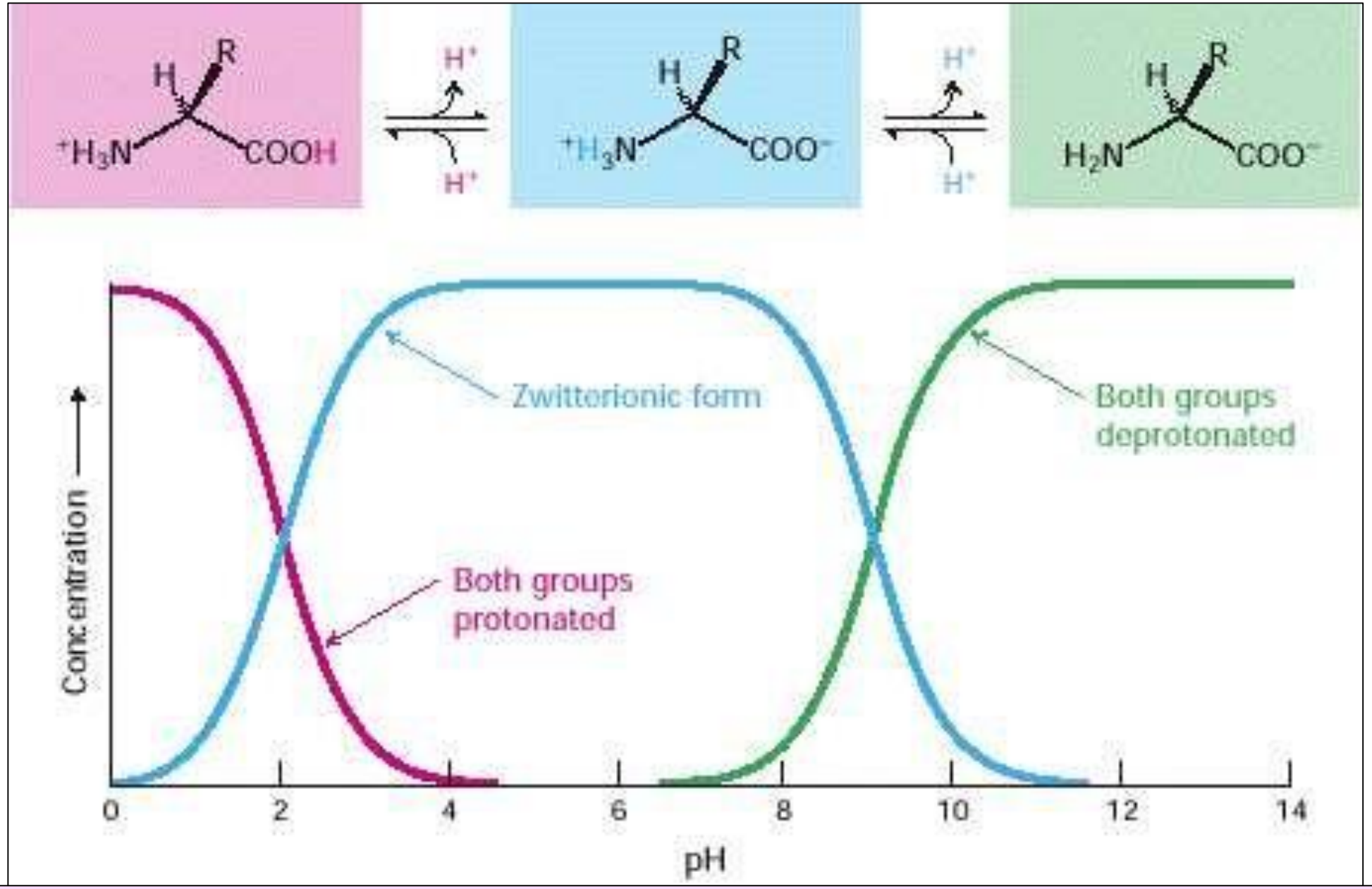
The group or the charges each unit has its own pka While when we talk about the isoelectric point here, we talk about the compound



Over total charges equal +1

Over total charges equal zero

Over total charges equal -1

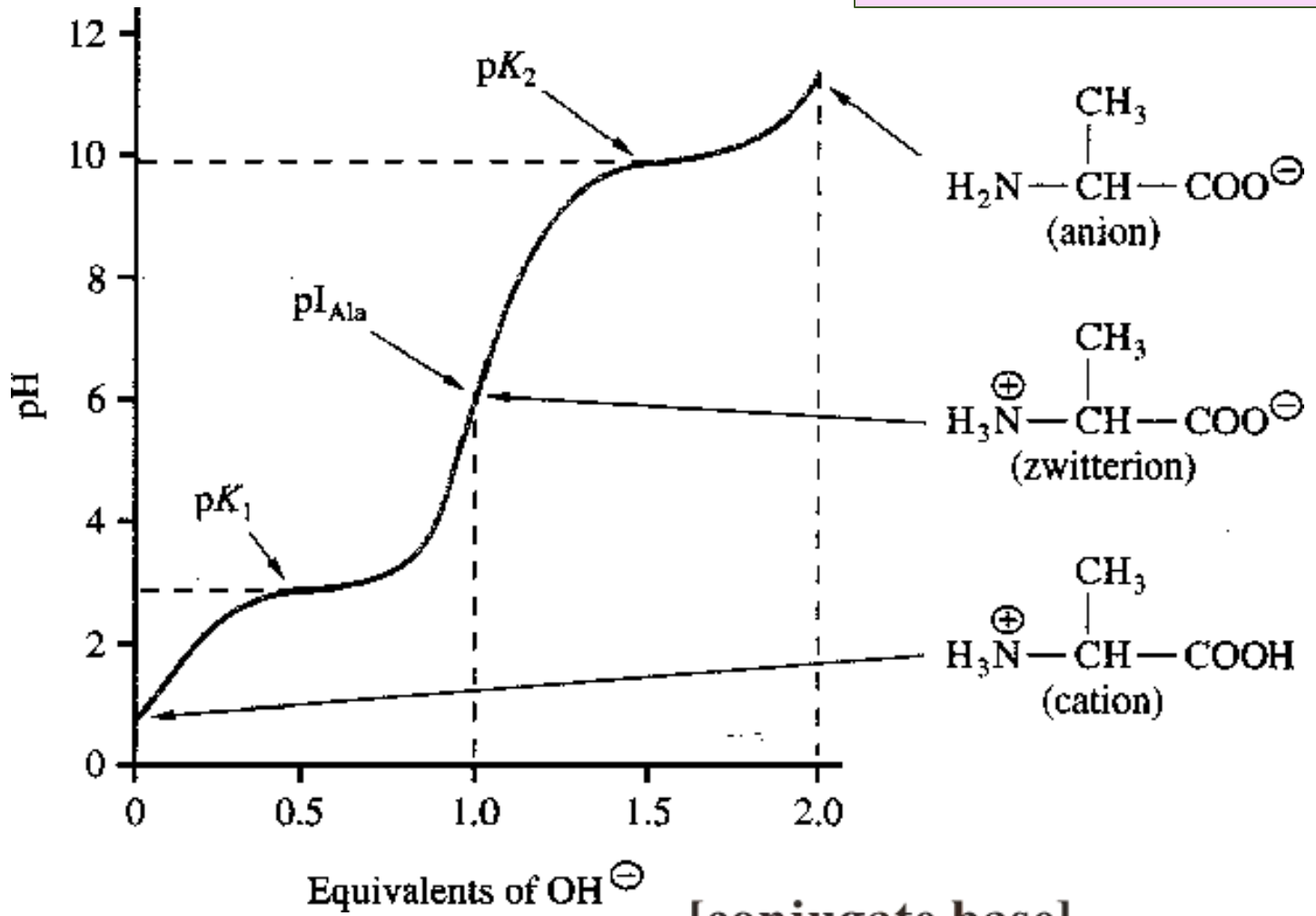


When the pH is below the pka (constant) the group will be protonated

ام ً امت سكعلاو

Example 1 (alanine)

ةروتكد حرشبكن عجرن حار ياه ةديلاسلا
ياجلا بيفيوملاب اهلا نومأم روتكدو لايد



$$pH = pK_a + \log \frac{[\text{conjugate base}]}{[\text{weak acid}]}$$

Isoelectric Point

The isoelectric point of an amino acid is the point at which the amino acid has no net electrical charge

- 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.
- For the nonpolar and polar amino acids with two pKa's, the isoelectric point is calculated by taking the numerical average of the carboxyl group pKa and the a-amino group pKa.

$$\mathrm{pI} = \frac{\mathrm{p}K_{\mathrm{a1}} + \mathrm{p}K_{\mathrm{a2}}}{2}$$

Ionization of side chains

- Nine of the 20 amino acids have ionizable side chains.
- These amino acids are tyrosine, cysteine, arginine, lysine, histidine, serine, threonine, and aspartic and glutamic acids.
- Each side chain has its own pKa values for ionization of the side chains.

Extra information (it wasn't mentioned) :-
Seven amino acid side chains contain groups that ionize between pH 1 and 14. For Asp, Glu, Tyr, and Cys, the ionizable groups are uncharged below their pK and negatively charged above their pK. For His, Lys, and Arg, the ionizable groups are positively charged below their pK and uncharged above their pK.

pH of amino acids

Isoelectric Point

Amino Acid	Side Chain pK_a [3]	pI
Arginine	12.5	10.8
Aspartic Acid	4.0	3.0
Cysteine	8.0	5.0
Glutamic Acid	4.1	3.2
Histidine	6.0	7.5
Lysine	11.0	10

Aspartic & Glutamic Acids are much lower than physiological PH (more acidic) so they must be deprotonated

Histidine is close to physiological PH

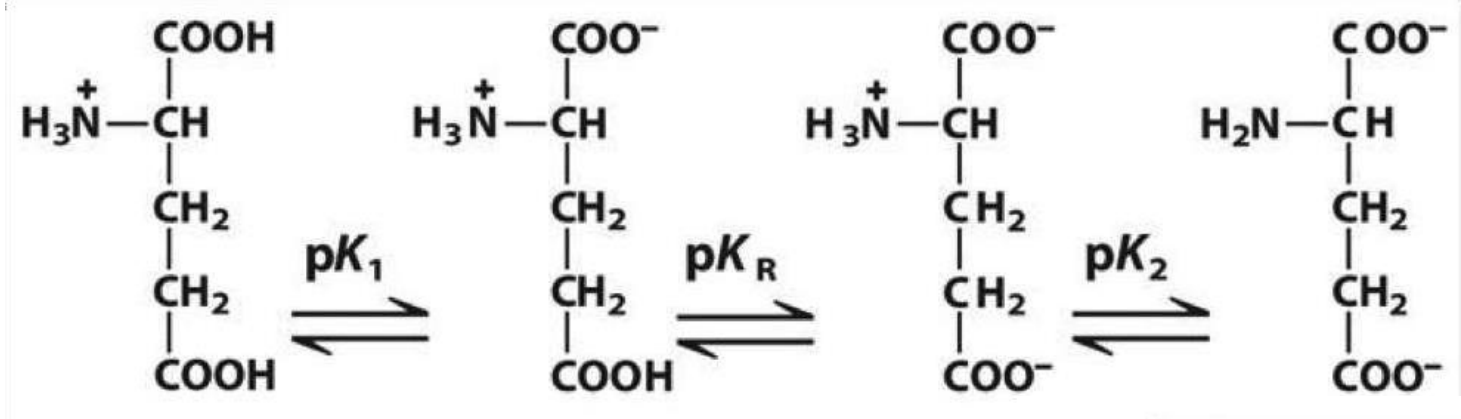
Let's consider pKa of -NH_2 = 9 and pKa of –COOH = 2 for all amino acids

Calculation of pI of amino acids with ionizable R groups

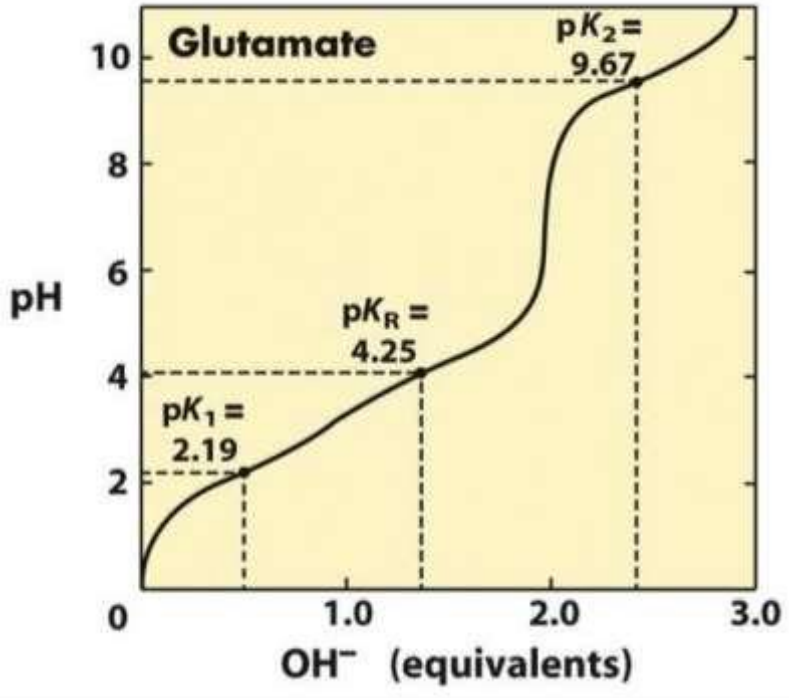
- The isoelectric point for these amino acids is calculated by taking the average of the pKa's of the groups with same charge when ionized
- In this case, the total charge on the groups with like charge must equal one (1) so that it can be balanced by the one (1) opposite charge present on the molecule

Example: Glutamate

It is like example 1 , slide 46 :-
It will be explained in more details in the next modified



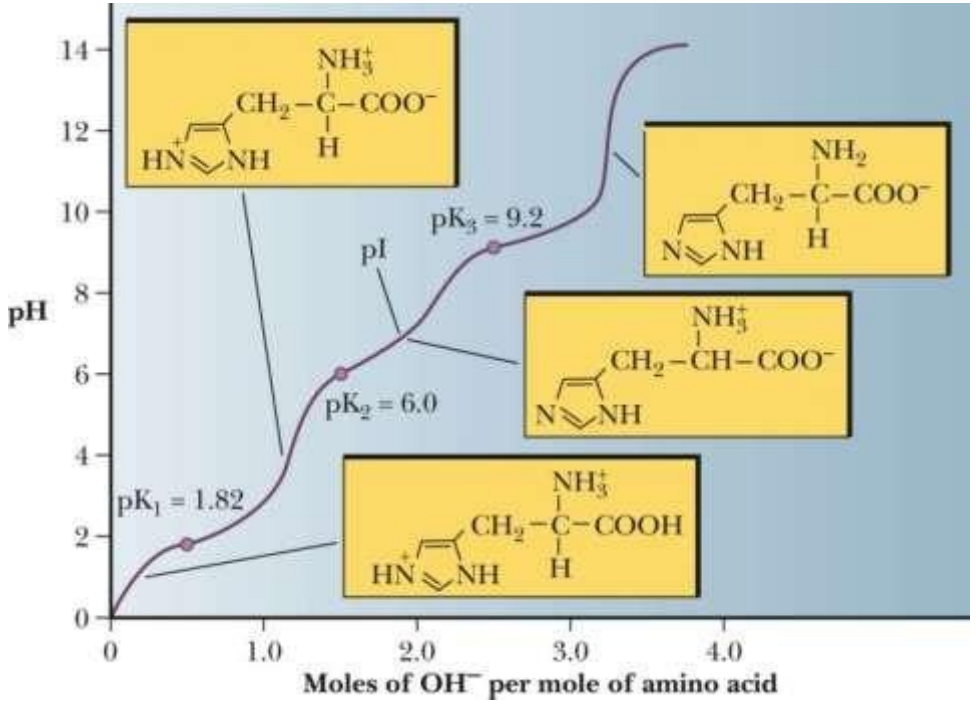
- To calculate the isoelectric point of Glu, the pKa's of the two carboxyl groups are averaged.

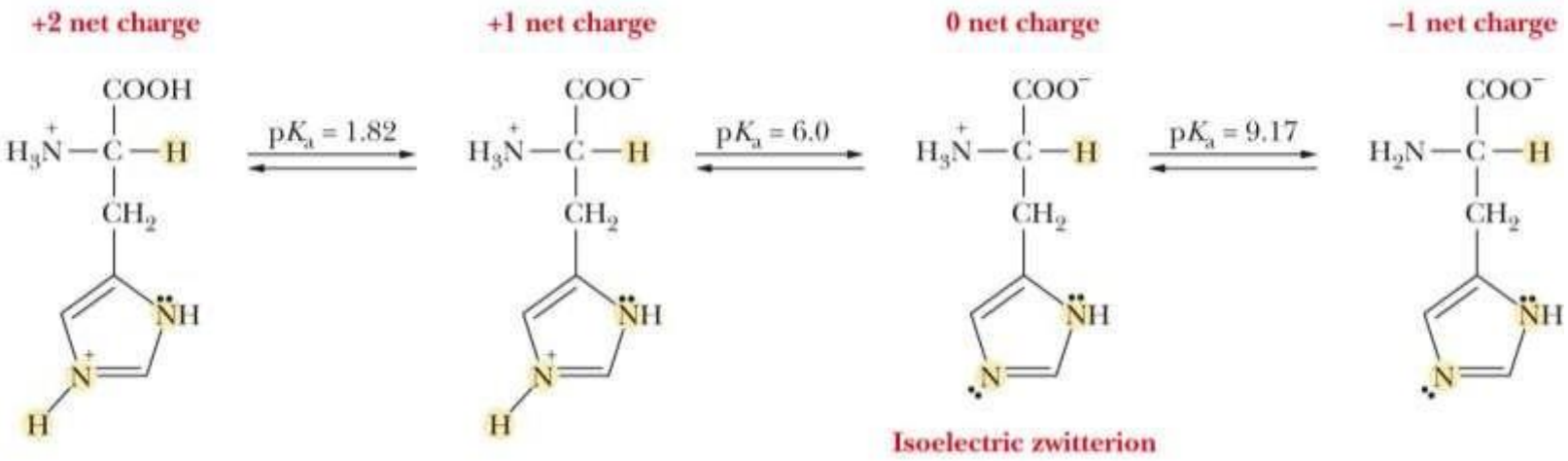


Histidine

A basic amino acid

- PH = ~7.5 (The imidazole group can be uncharged or positively charged near neutral pH).





Further explanation in next slide:-

Explanation to the previous slide:-

R groups for histidine play an important role (buffering) because it is around physiological PH value.
Its Pk=6 in an individual histamine.
If histamine was a part of a large molecule (like large protein) histamine's R group will be affected by the environment (like hydrogen , electrostatic bond , van der Waals by taking or giving electrons to histidine R group)
So, when histamine is apart from protein its pka will not stay 6, it will change to 7.3.
If this protein is in cell ,blood ,cell surface, it is going to accept or donate protons and it can regulate a physiological ph.
Albumin is a plasma protein (which is the most abundant protein in blood 60%) contains 16 histamine residues or (16 R group) which plays an important role in buffering.

Questions

- Draw the titration curve of histidine.
- What is the ratio of conjugate base/acid of glutamate at pH 4.5?
- What is the total charge of lysine at pH 7?