

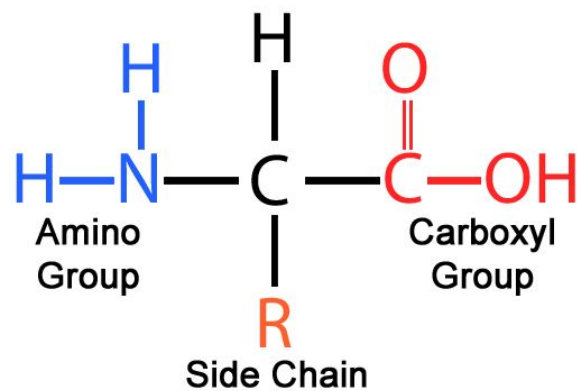
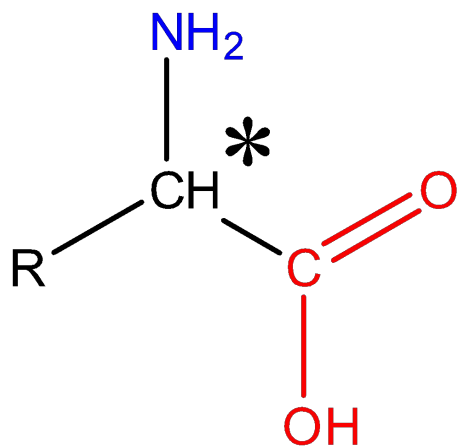


# Lecture

$\alpha$ -Aminoacids, peptides, proteins

## **$\alpha$ -Aminoacids.**

$\alpha$ -Aminoacids – class of organic compounds, which may be considered as derivatives of carboxylic acids, in which hydrogen atom in position 2 substituted by amino group.



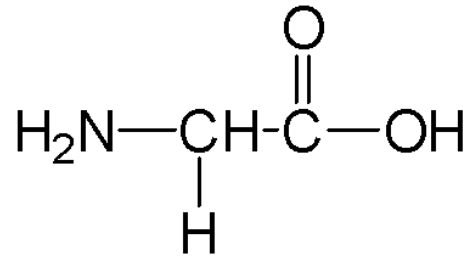
Almost all  $\alpha$ -aminoacids, except glycine (2-aminopropanoic acid) contain asymmetric carbon, it means that optical isomerism is typical for mentioned class of compounds.

# Classification

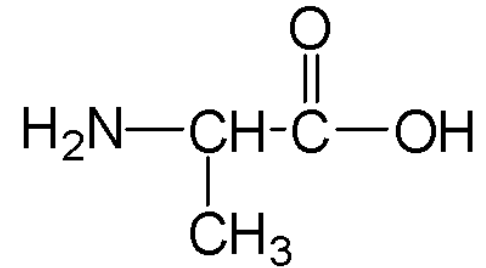
**By the one to which the carbon atom is attached an amino- (or imino-) group, the amino acids are divided into:**

- $\alpha$ -amino acids (carboxyl and amino groups are attached to the same carbon atom);
- $\beta$ -amino acids (the amino group is attached to a carbon atom adjacent to that to which the carboxyl is attached),
- $\gamma$ -amino acids (amino group attached through one carbon atom from a carboxylic acid), etc.

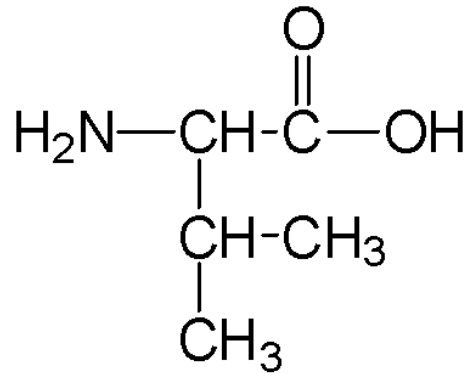
## Proteinogenic aliphatic $\alpha$ -amino acids.



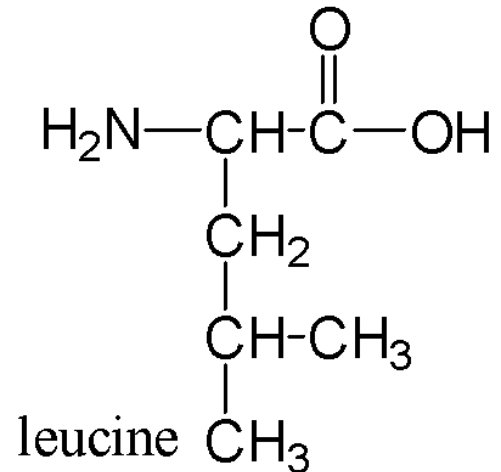
glycine



alanine

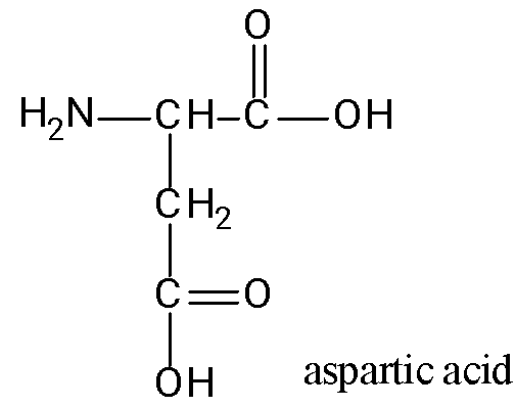
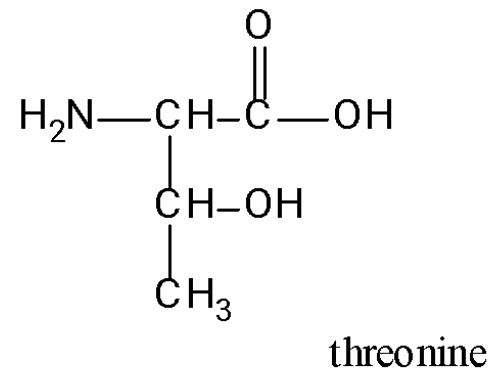
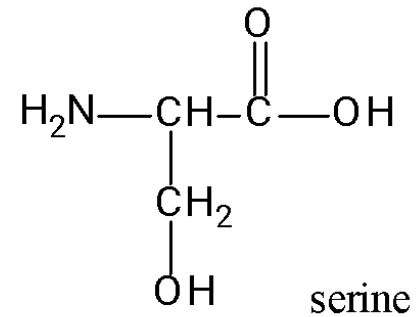
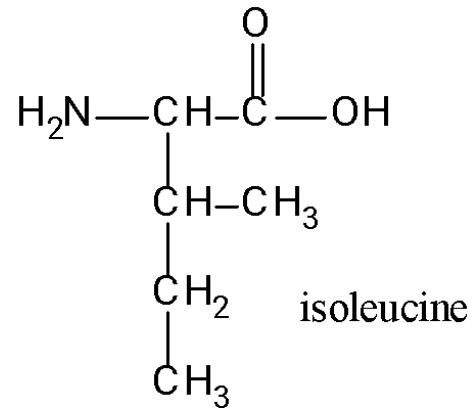


valine

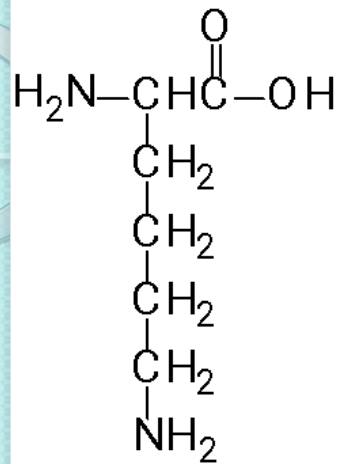


leucine

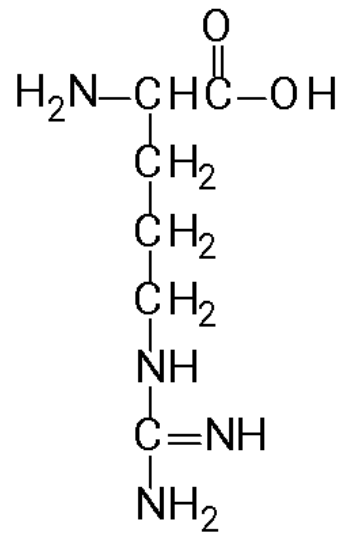
## Proteinogenic aliphatic $\alpha$ -amino acids.



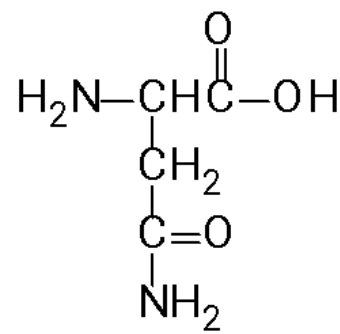
## Proteinogenic aliphatic $\alpha$ -amino acids.



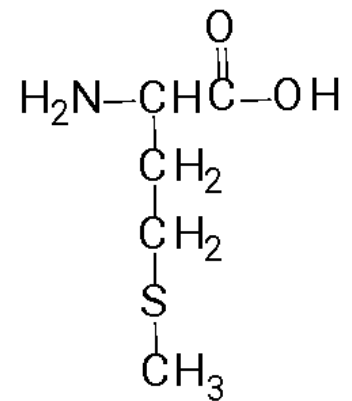
lysine



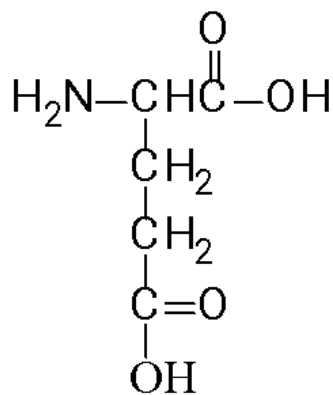
arginine



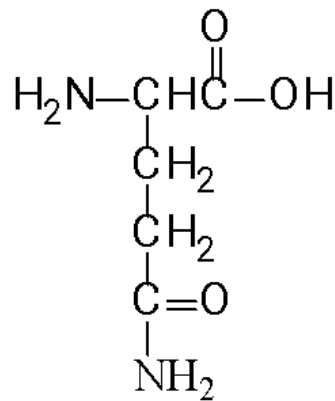
asparagine



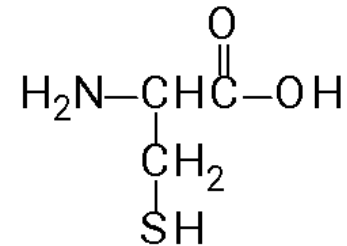
methionine



glutamic acid

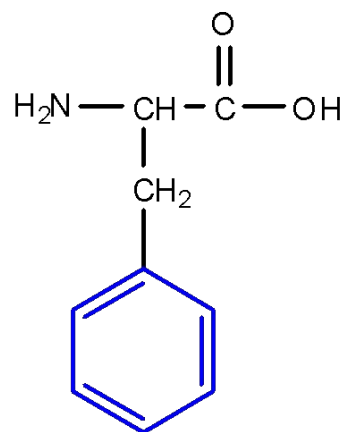


glutamine

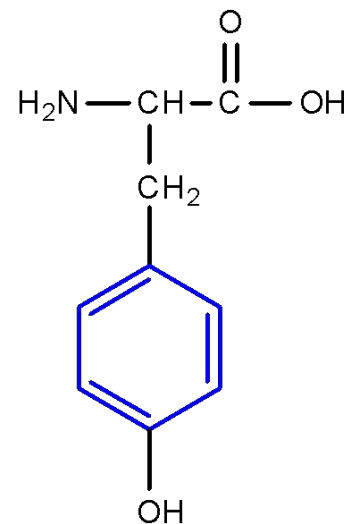


cysteine

## Proteinogenic aromatic $\alpha$ -amino acids.

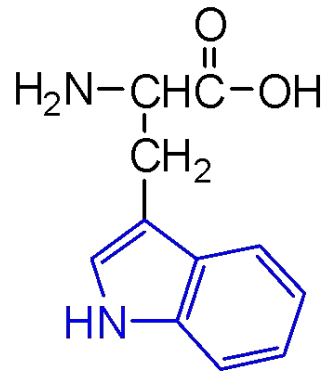


phenylalanine

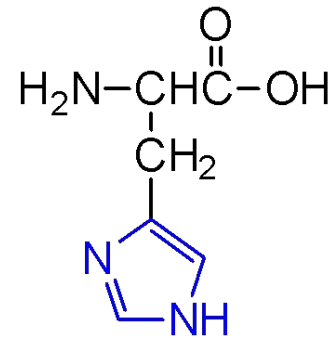


tyrosine

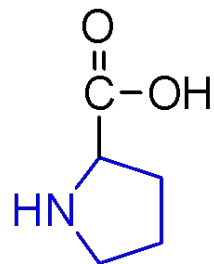
## Proteinogenic heterocyclic $\alpha$ -amino acids.



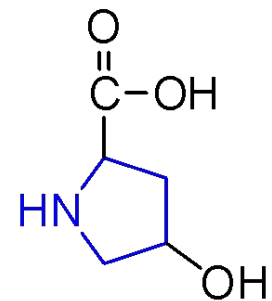
tryptophan



histidine



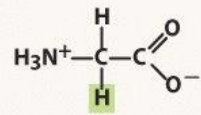
proline



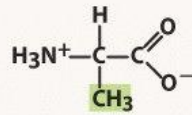
oxyproline



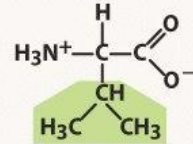
**Nonpolar side chains**



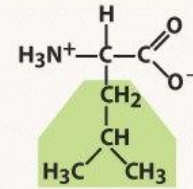
Glycine (G)  
Gly



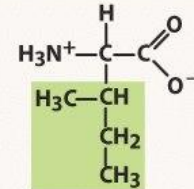
Alanine (A)  
Ala



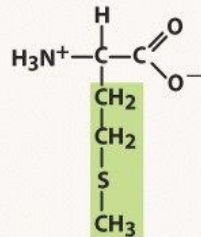
Valine (V)  
Val



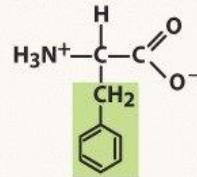
Leucine (L)  
Leu



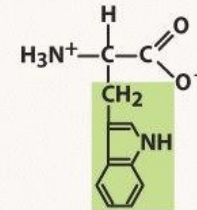
Isoleucine (I)  
Ile



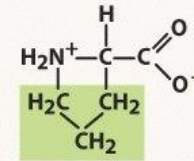
Methionine (M)  
Met



Phenylalanine (F)  
Phe

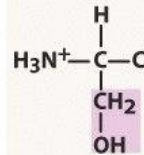


Tryptophan (W)  
Trp

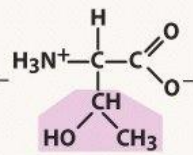


Proline (P)  
Pro

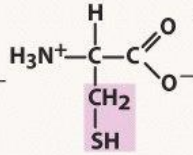
**Polar side chains**



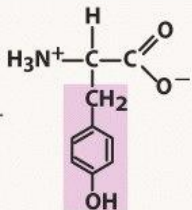
Serine (S)  
Ser



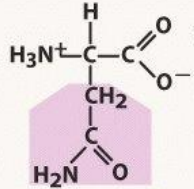
Threonine (T)  
Thr



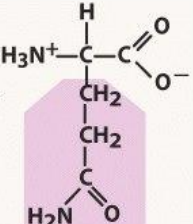
Cysteine (C)  
Cys



Tyrosine (Y)  
Tyr



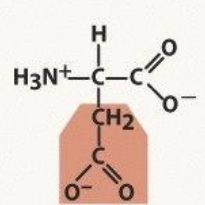
Asparagine (N)  
Asn



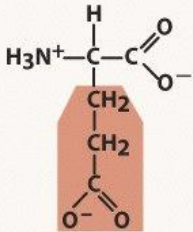
Glutamine (Q)  
Gln

**Electrically charged side chains**

**Acidic**

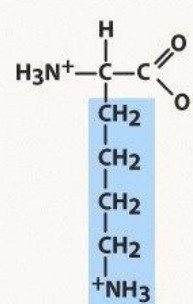


Aspartate (D)  
Asp

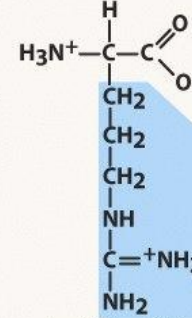


Glutamate (E)  
Glu

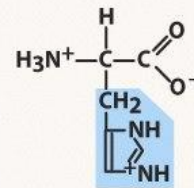
**Basic**



Lysine (K)  
Lys

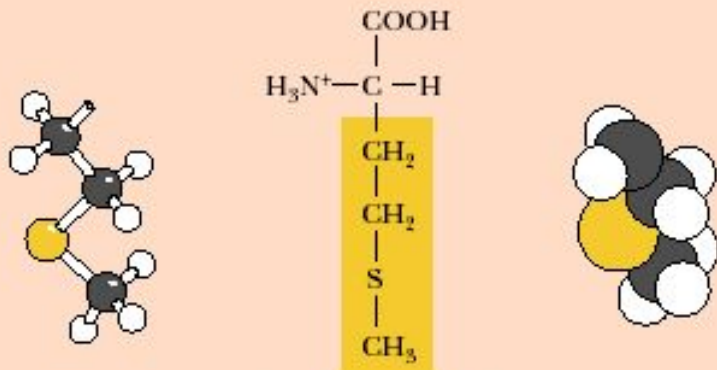


Arginine (R)  
Arg

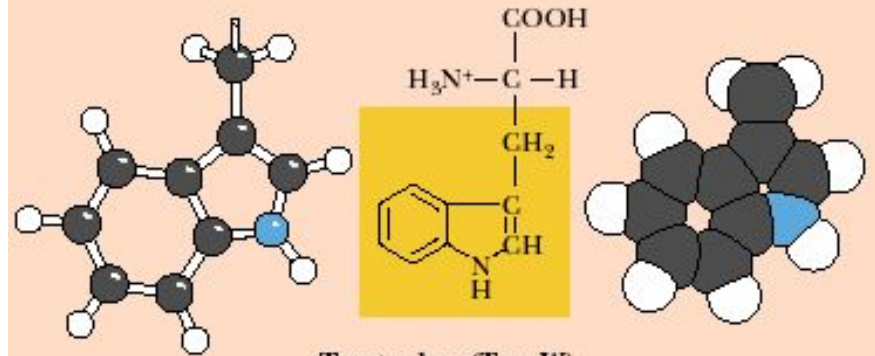


Histidine (H)  
His

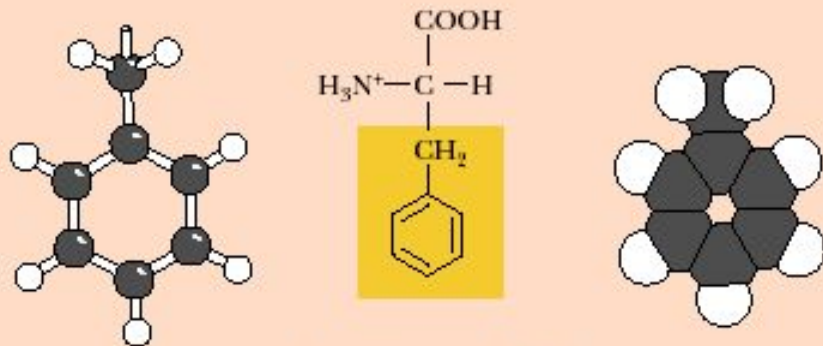
# Neutral hydrophobic amino acids



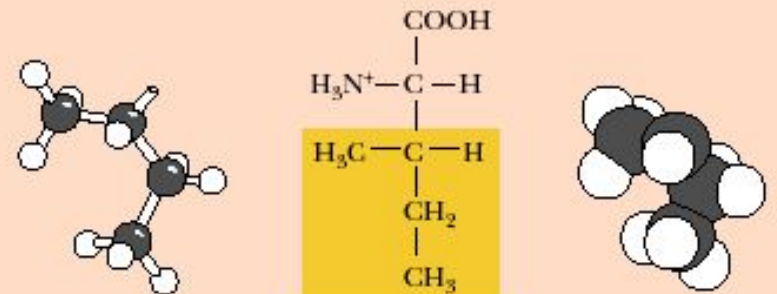
Methionine (Met, M)



Tryptophan (Trp, W)

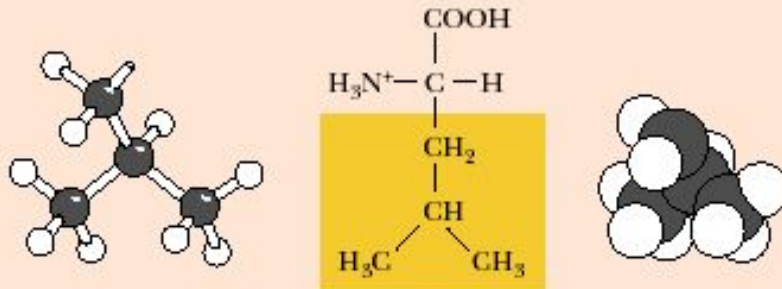


Phenylalanine (Phe, F)

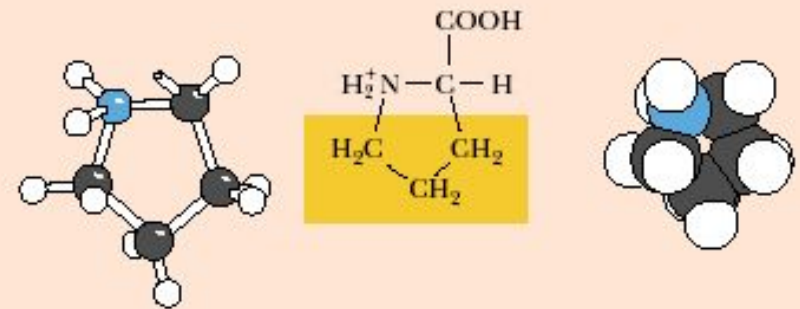


Isoleucine (Ile, I)

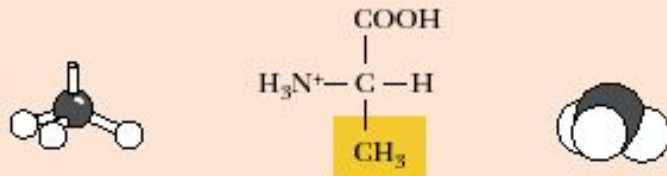
# Neutral hydrophobic amino acids



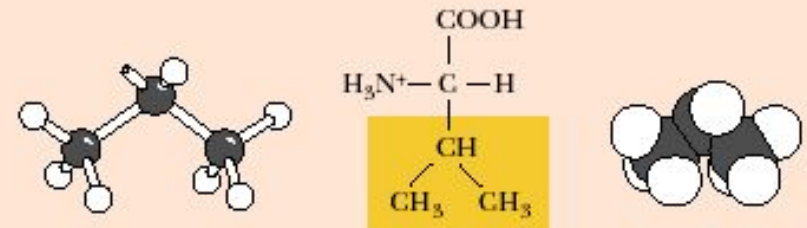
Leucine (Leu, L)



Proline (Pro, P)

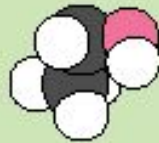
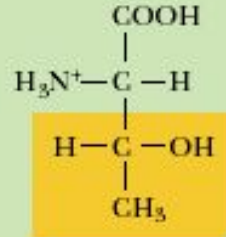
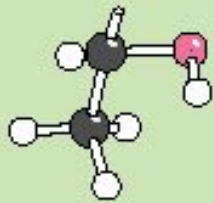


Alanine (Ala, A)

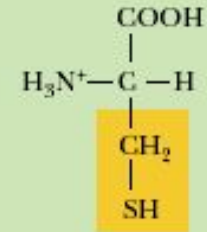


Valine (Val, V)

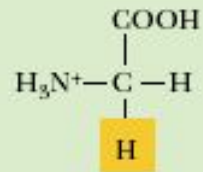
# Neutral hydrophilic amino acids



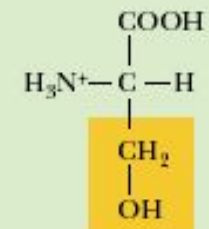
Threonine (Thr, T)



Cysteine (Cys, C)



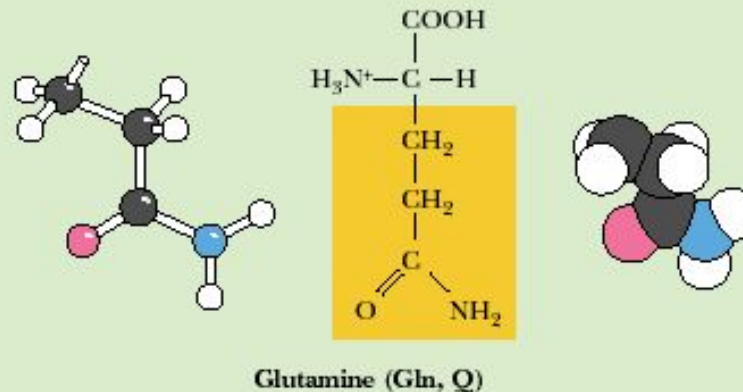
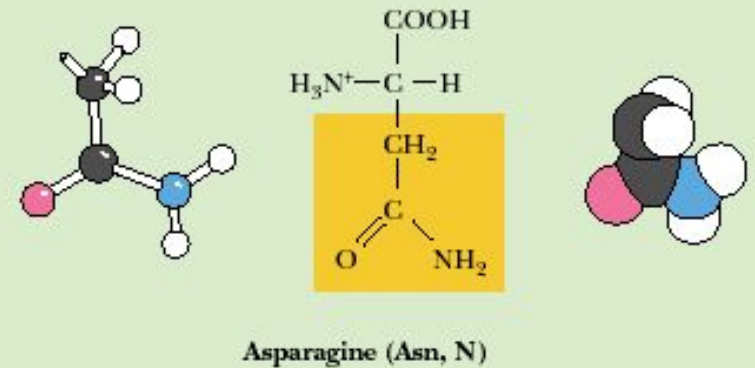
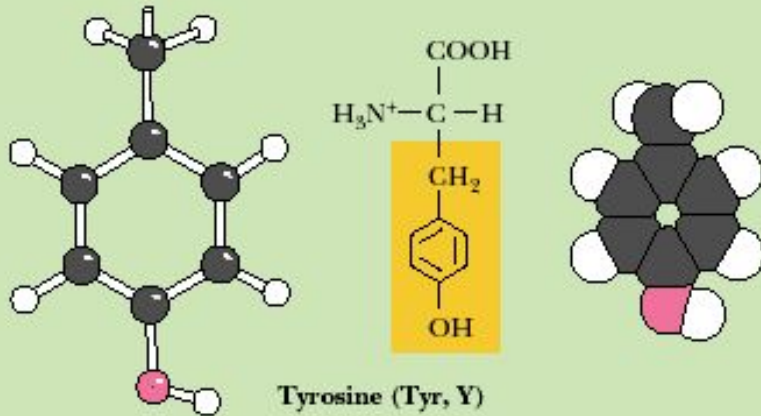
Glycine (Gly, G)



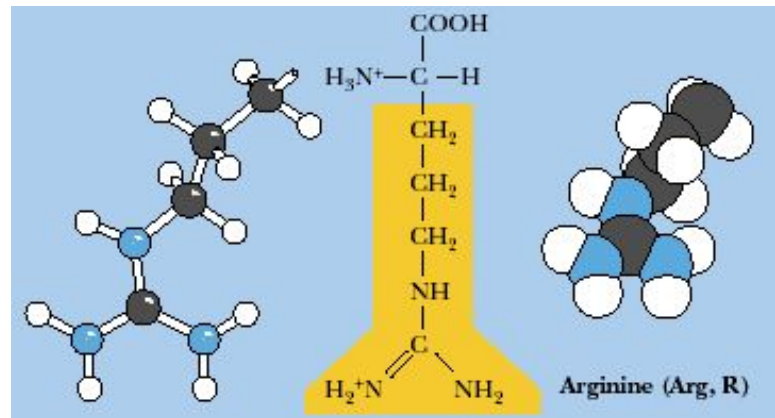
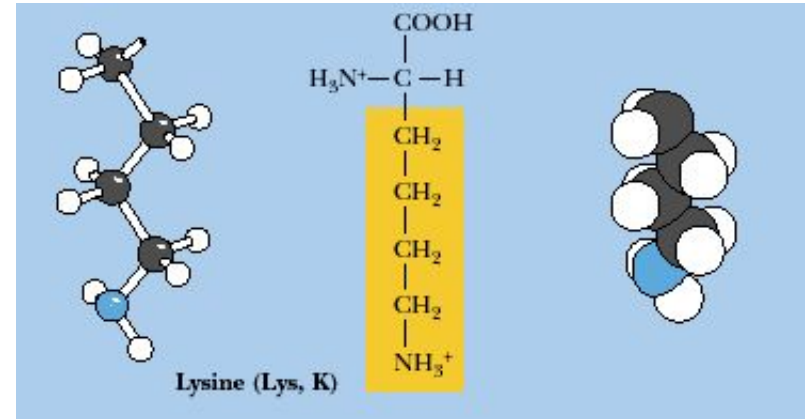
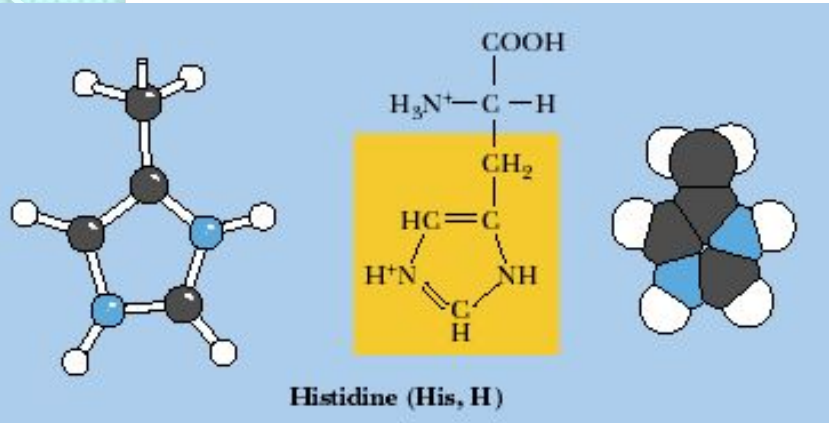
Serine (Ser, S)



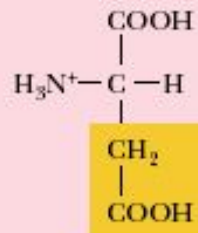
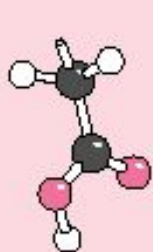
# Neutral hydrophilic amino acids



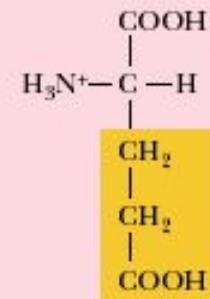
# ***Amino acids having an alkaline reaction of the solution***



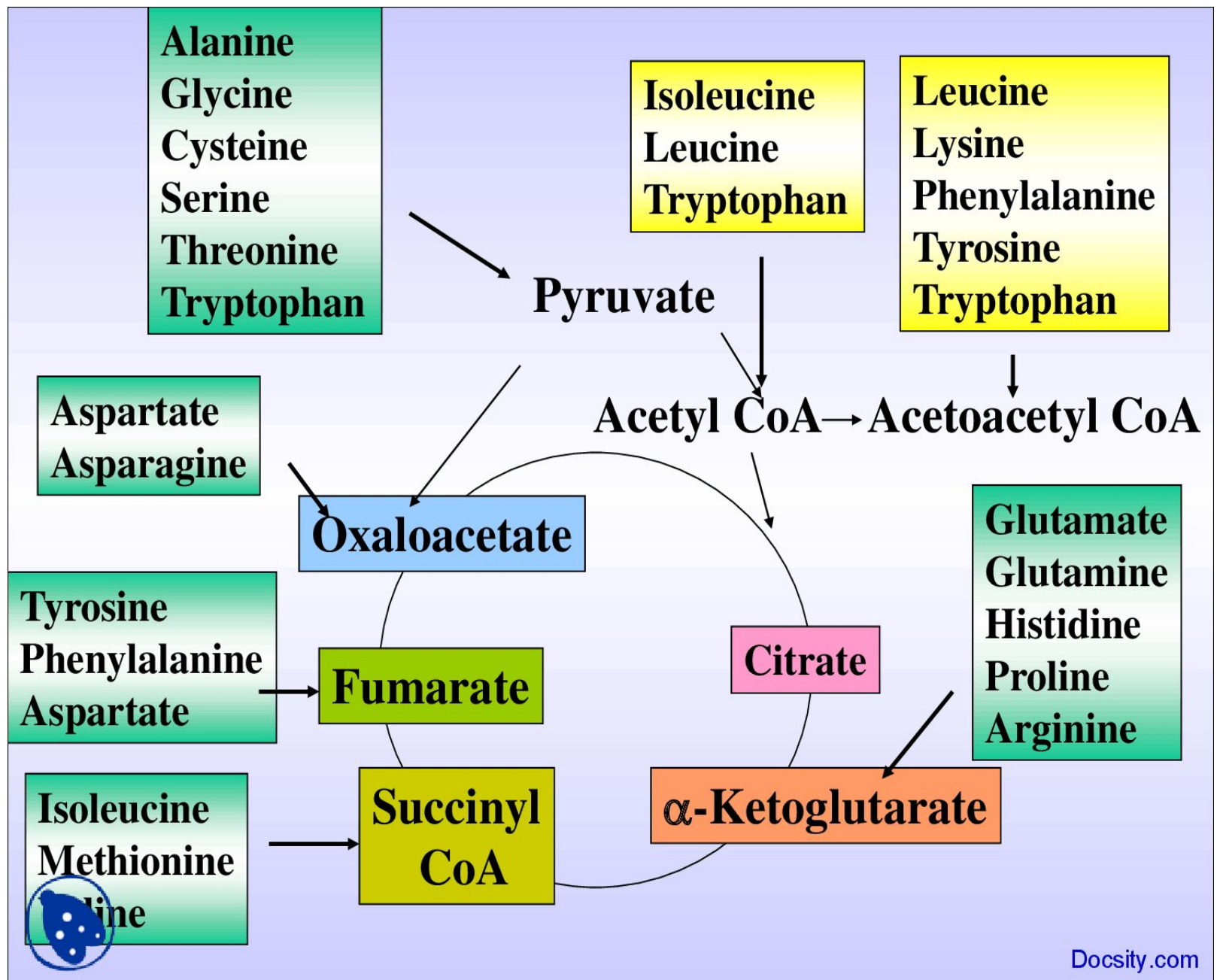
# *Amino acids having an acid reaction of the solution*



Aspartic acid (Asp, D)



Glutamic acid (Glu, E)





- ❖ **Non-essential AA:** *alanine, aspartic acid, asparagine, glutamic acid, glutamine, proline, glycine, serine.*

Enzyme systems of the human body are able to synthesize AA from other intermediate in sufficient quantity.

- ❖ **Essential AA:** *valine, leucine, isoleucine, threonine, methionine, phenylalanine, tryptophan, lysine.*

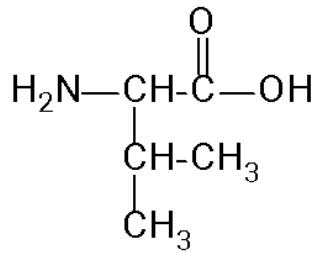
Enzyme systems of the human body are not synthesized.

- ❖ **Partially essential AA: arginine, histidine.**

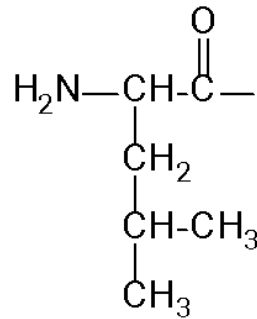
Synthesized in the body in insufficient quantities.

- ❖ The human body depends on the constant intake of these 10 AA in the food proteins - in the absence of even one of the essential amino acids, protein synthesis stops.

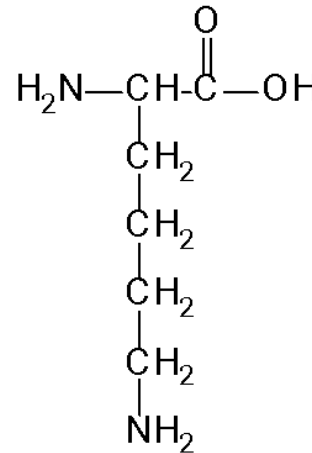
## Essential $\alpha$ -aminoacids.



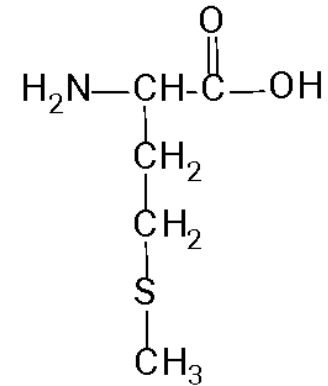
valine



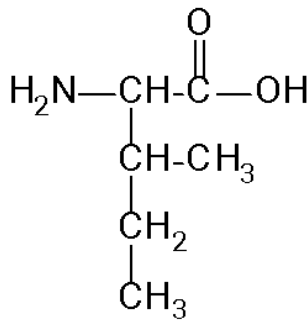
leucine



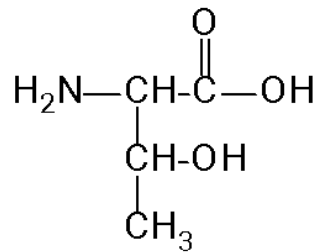
lysine



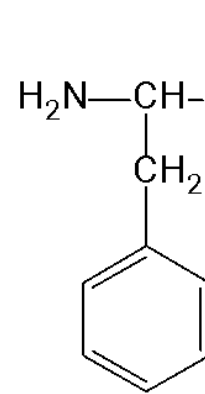
methionine



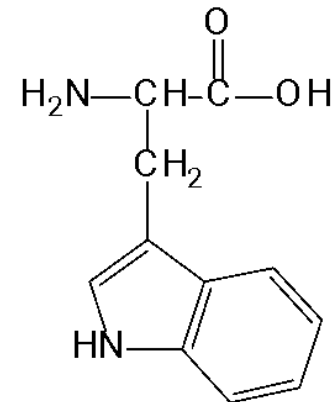
isoleucine



threonine



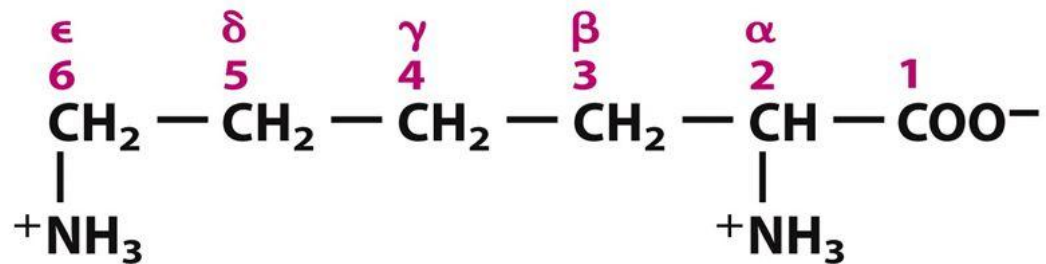
phenylalanine



tryptophan

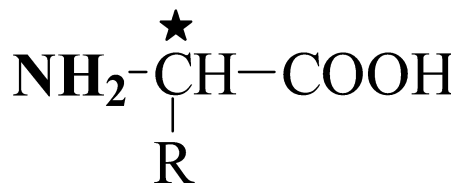
# ***Nomenclature***

1. Amino acids are referred to as carboxylic acids, indicating the position of the amino group.
2. The positions of the amino group and other substituents in the main chain are indicated by letters or numbers in order of precedence.

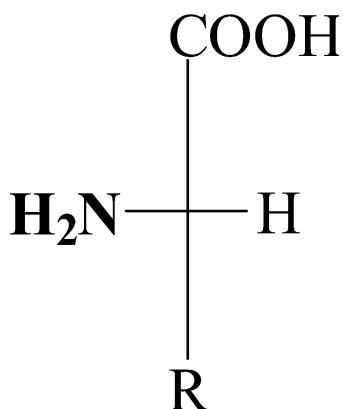


**Lysine**

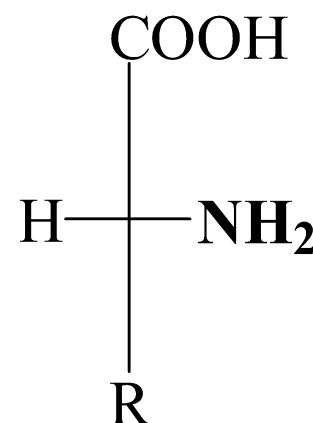
# Optical isomerism



**$\alpha$ -amino acid**



**L- $\alpha$ - amino acid**



**D- $\alpha$ - amino acid**

These isomers rotate the plane of polarization of light passing through their solution.

*The composition of proteins consists of almost only L-isomers.*

# ***Physical properties***

**Amino acids** - colorless crystalline substances with high melting temperatures.

Melting is accompanied by a decomposition of substance.

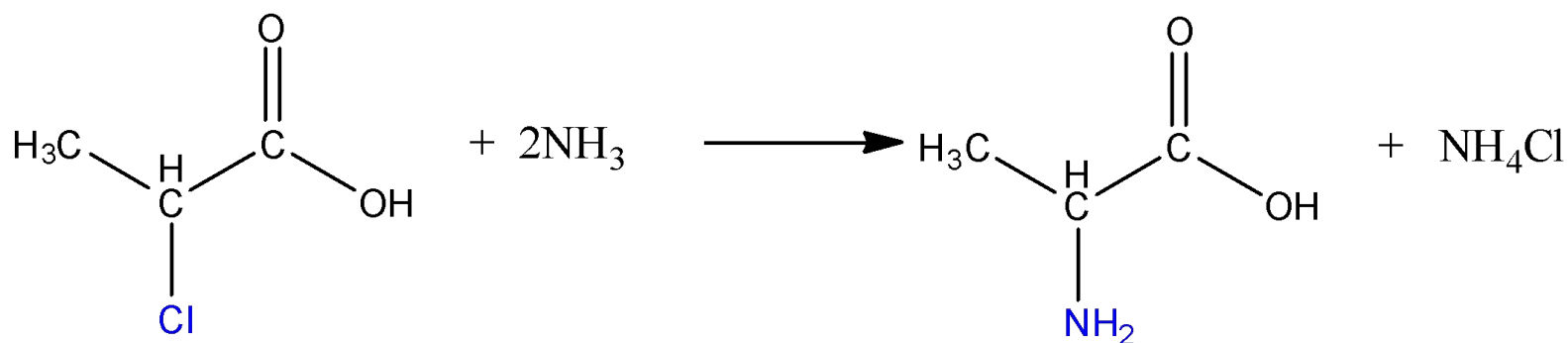
In water, amino acids dissolve well.

*Aqueous solutions of single-base amino acids almost always have a nearly neutral reaction.*

## Preparation of $\alpha$ -aminocarboxylic acids.

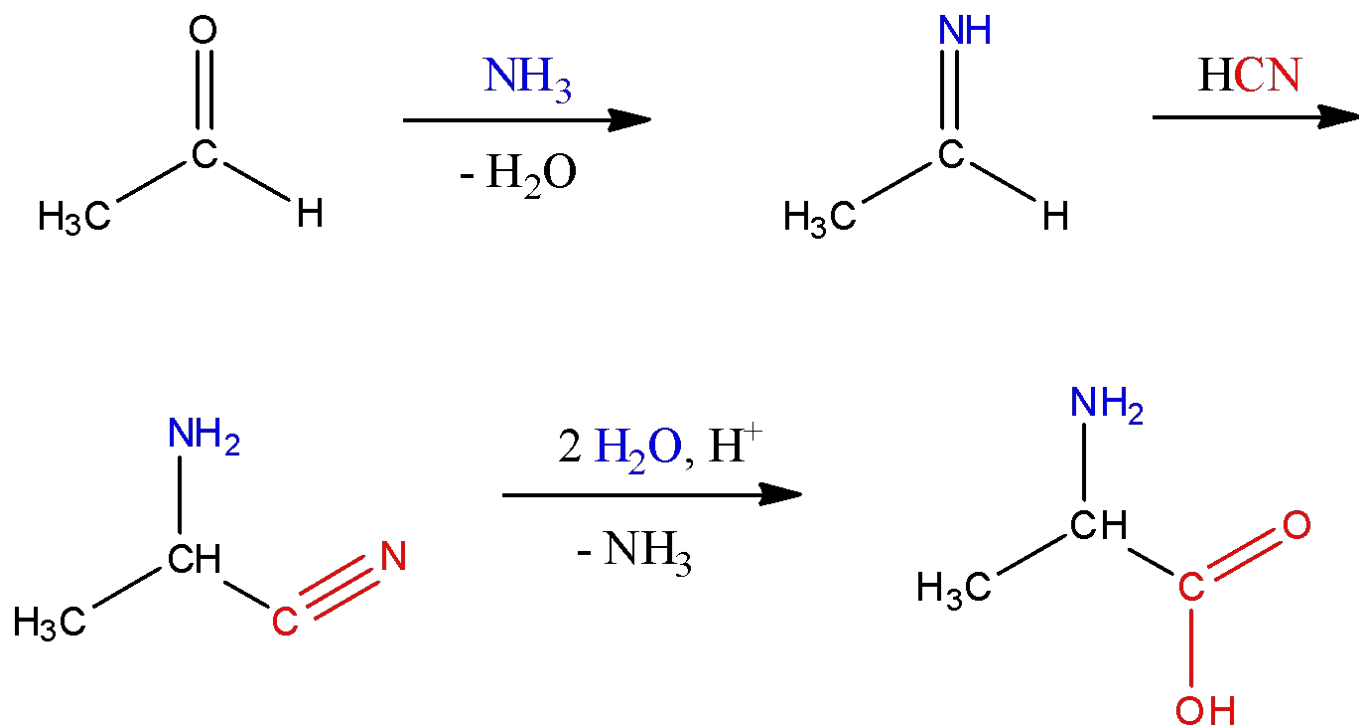
1. Isolation from native sources.

2. Aminolysis  $\alpha$ -halogencarboxylic acids



## Preparation of $\alpha$ -aminocarboxylic acids.

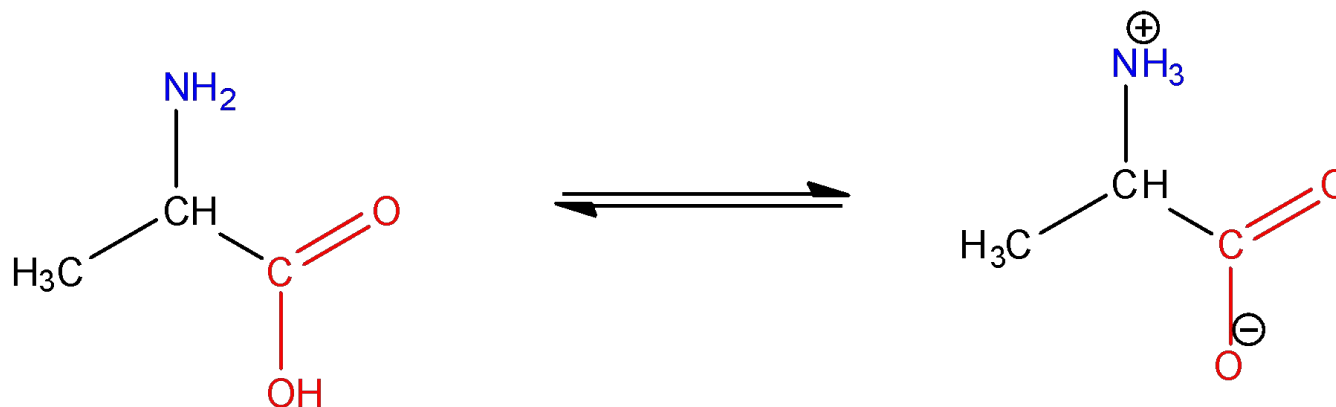
### 3. Strecker method





## Chemical properties of $\alpha$ -aminocarboxylic acids.

### Formation of intramolecular salts

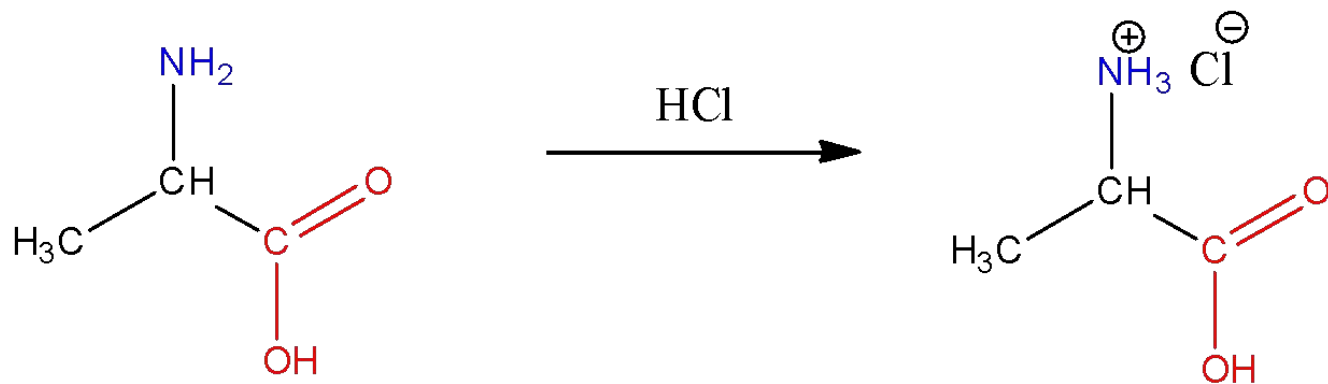
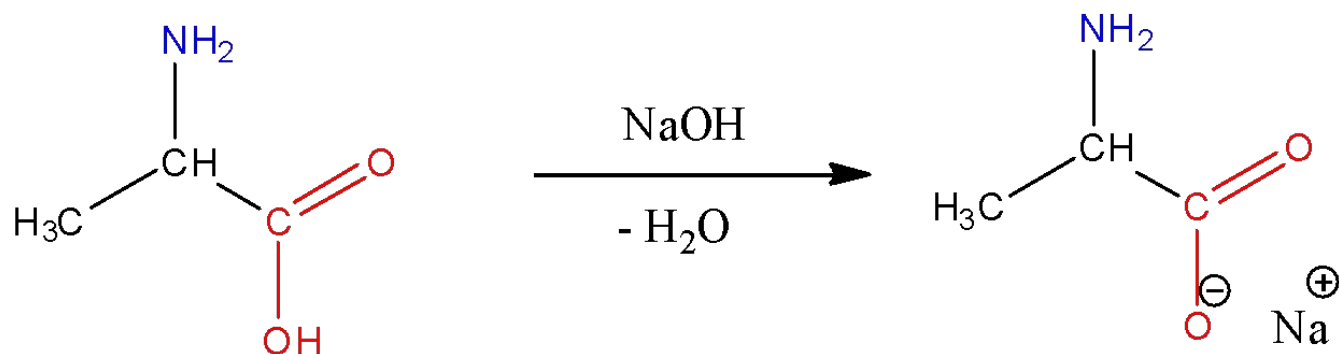


pH of aqueous solutions  $\approx 7$



## Chemical properties of $\alpha$ -aminocarboxylic acids.

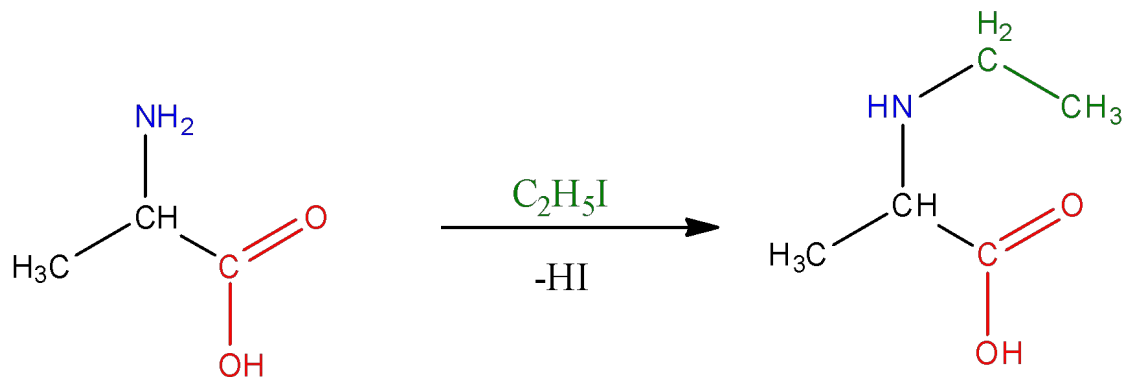
### Formation of salts.



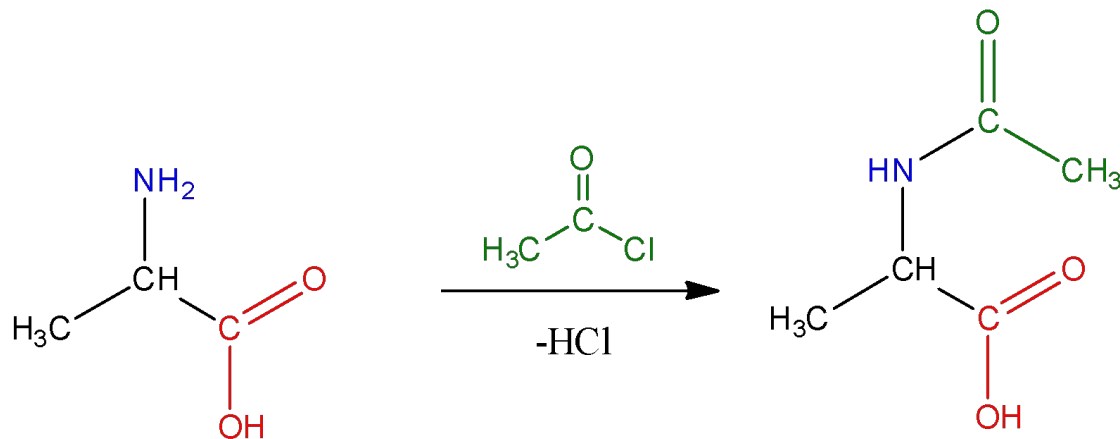
# Chemical properties of $\alpha$ -aminocarboxylic acids.

## Properties of amino-group.

### 1. Alkylation

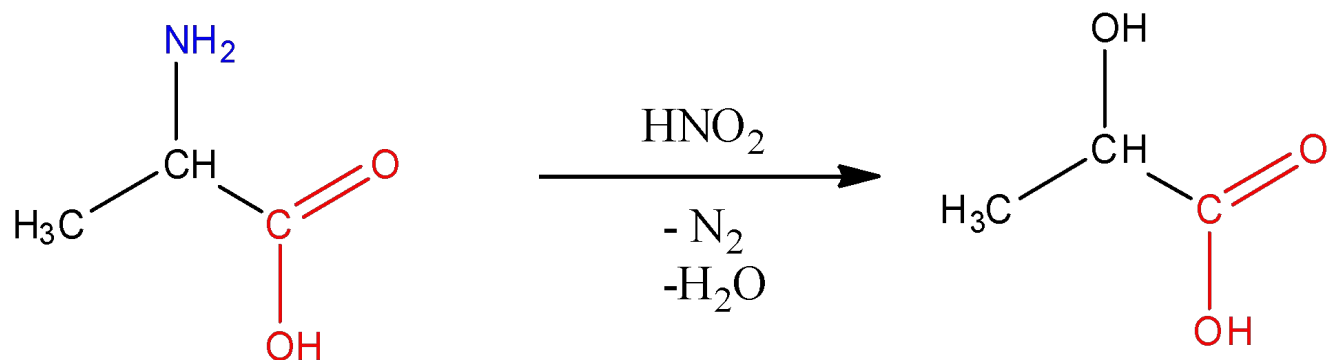


### 2. Acylation



Chemical properties of  $\alpha$ -aminocarboxylic acids.  
Properties of amino-group.

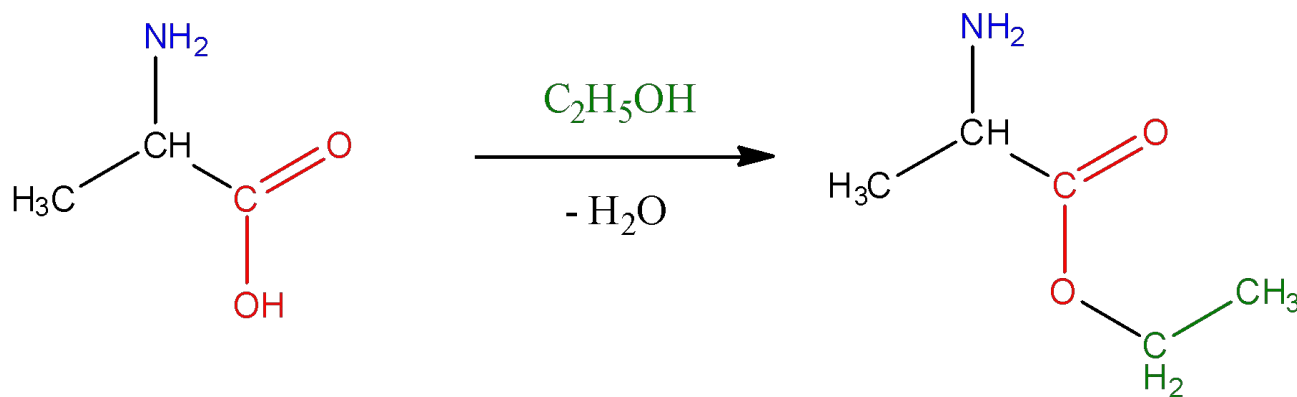
3. Reaction with nitrous acid.



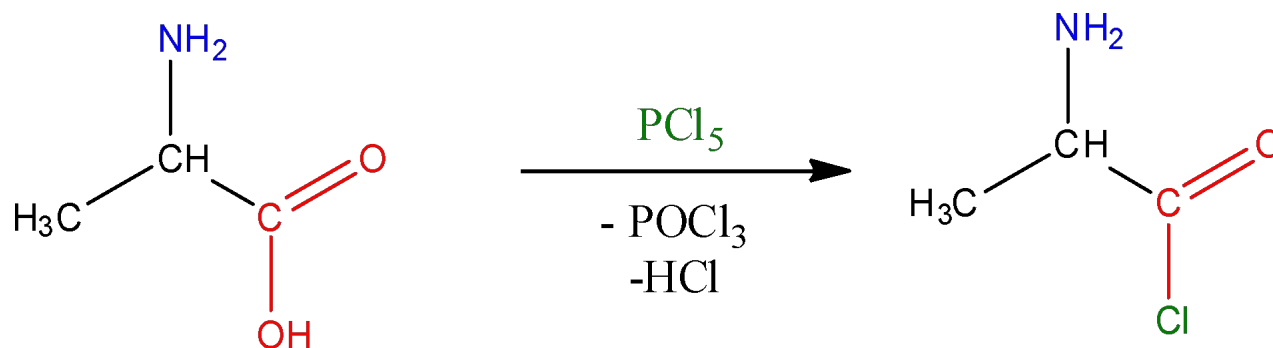
## Chemical properties of $\alpha$ -aminocarboxylic acids.

### Properties of carboxylic groups.

#### 1. Formation of esters.

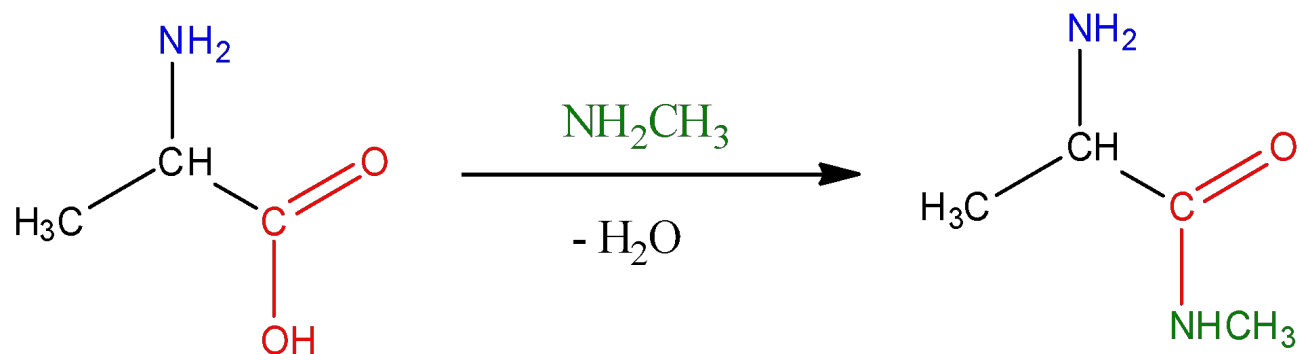


#### 2. Formation of halogenanhydrides.



Chemical properties of  $\alpha$ -aminocarboxylic acids.  
Properties of carboxylic groups.

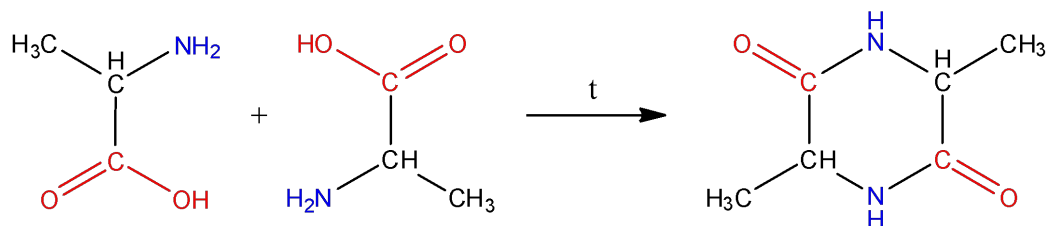
3. Formation of amides.



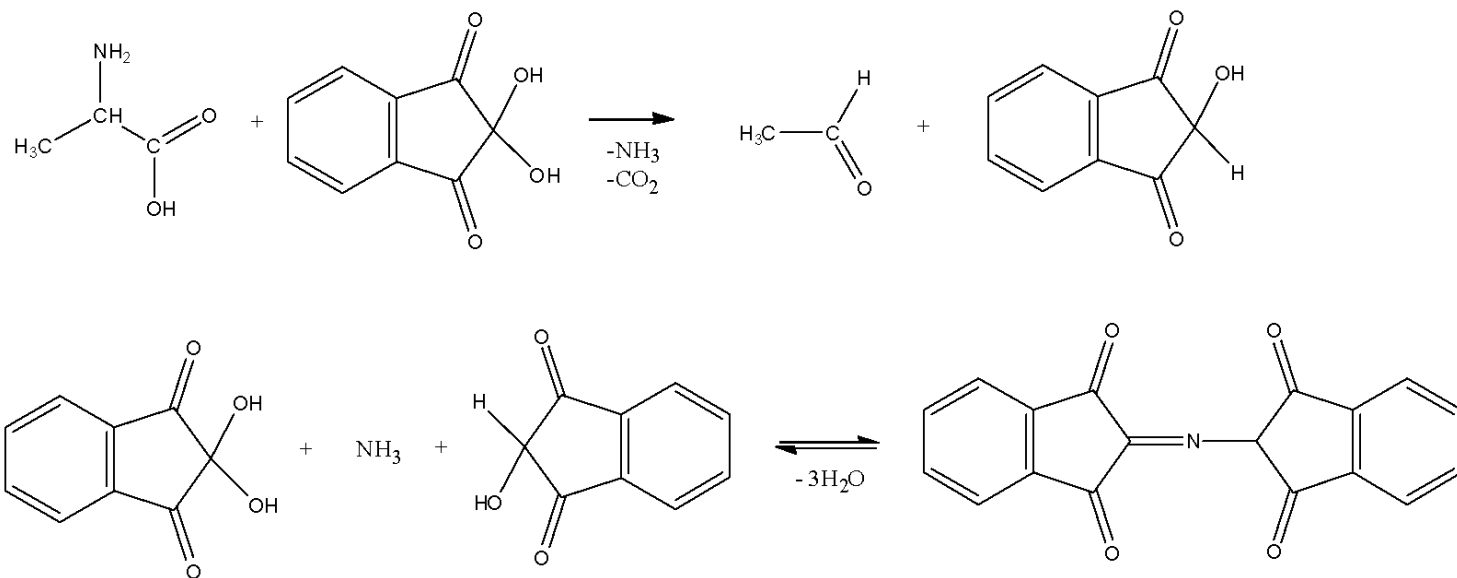
# Chemical properties of $\alpha$ -aminocarboxylic acids.

## Specific properties.

### 1. Intramolecular dehydration.

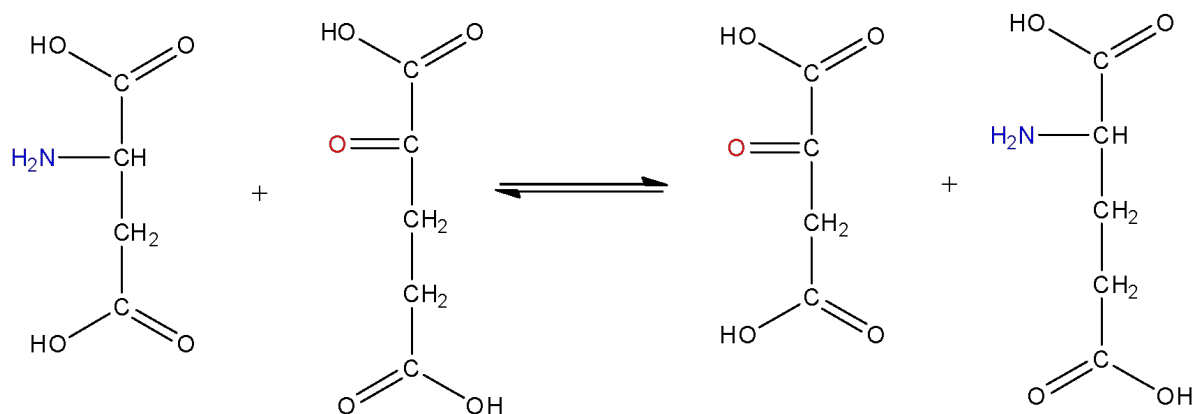


### 2. Reaction with ninhydrin.

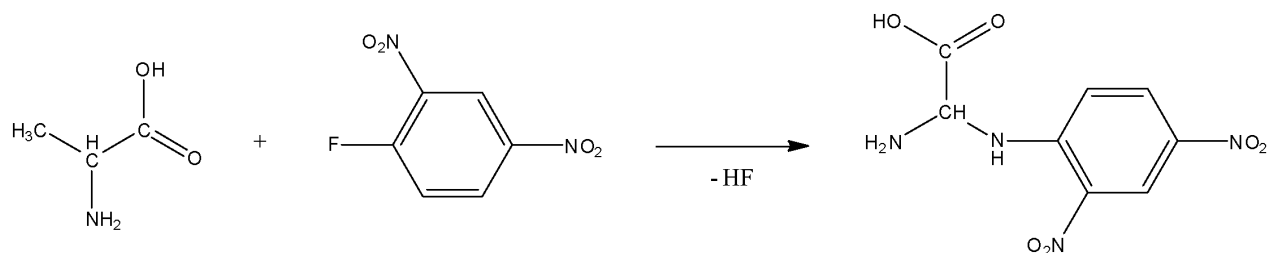


# Chemical properties of $\alpha$ -aminocarboxylic acids. Specific properties.

## 3. Transamination

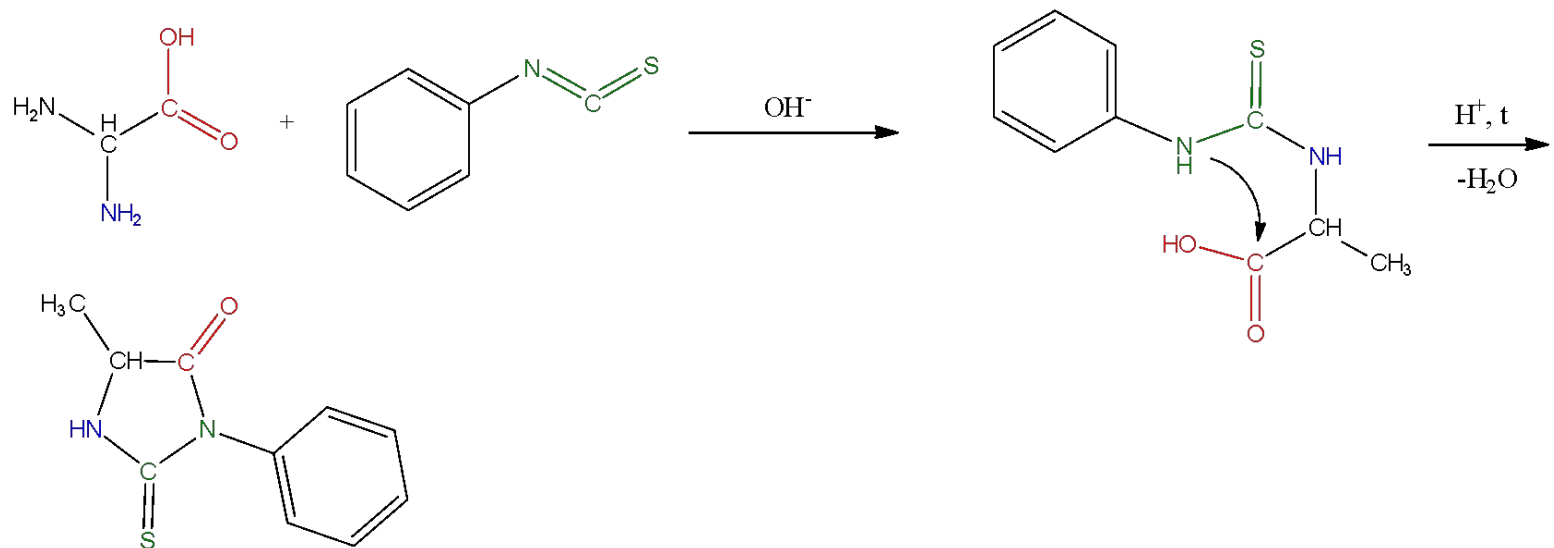


## 4. Reaction with c 2,4-dinitrofluorobenzene (Sanger reactive)



# Chemical properties of $\alpha$ -aminocarboxylic acids. Specific properties.

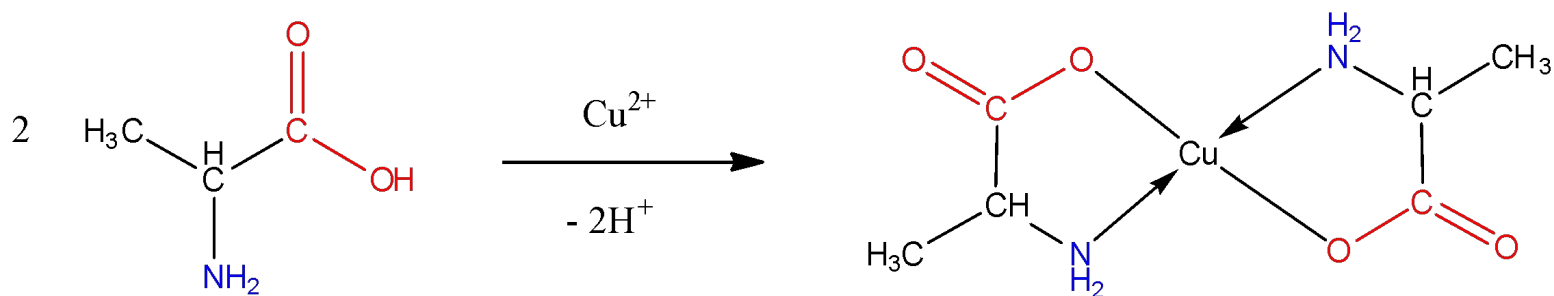
## 5. Reaction with phenylisothiocyanate (Edman reaction)



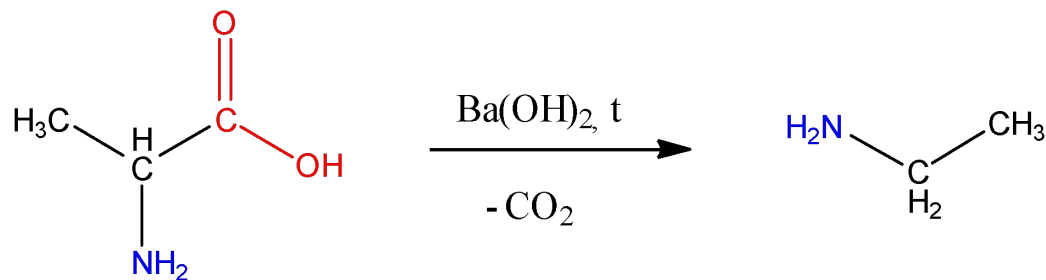


## Chemical properties of $\alpha$ -aminocarboxylic acids. Specific properties.

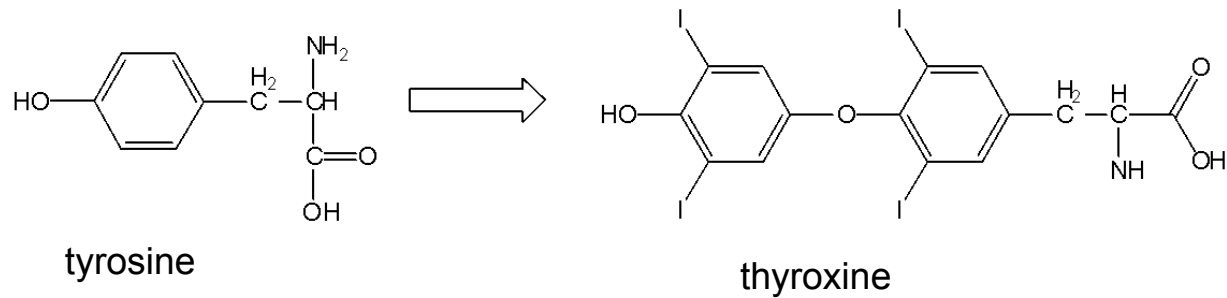
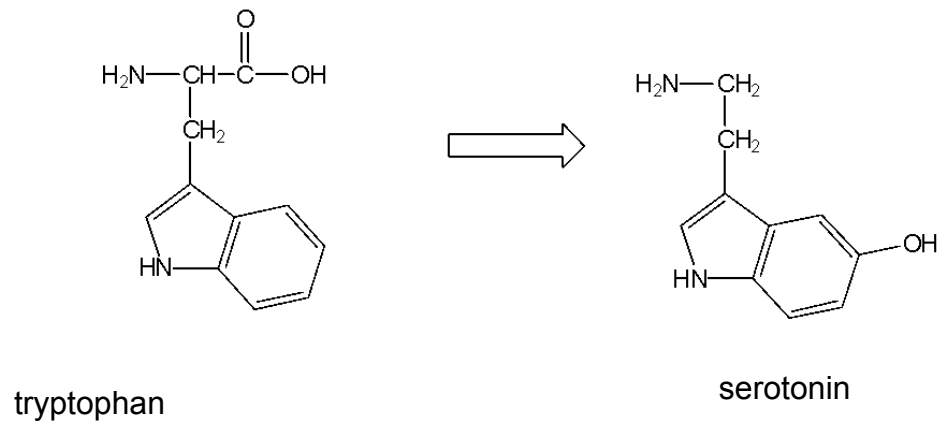
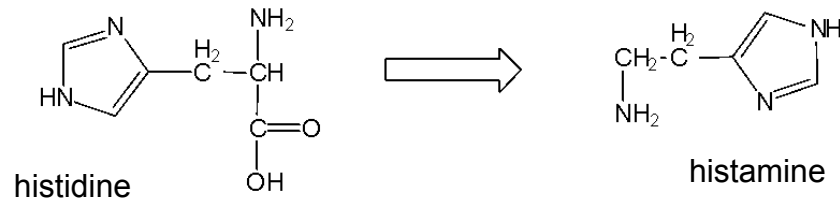
### 6. Formation of complex compound



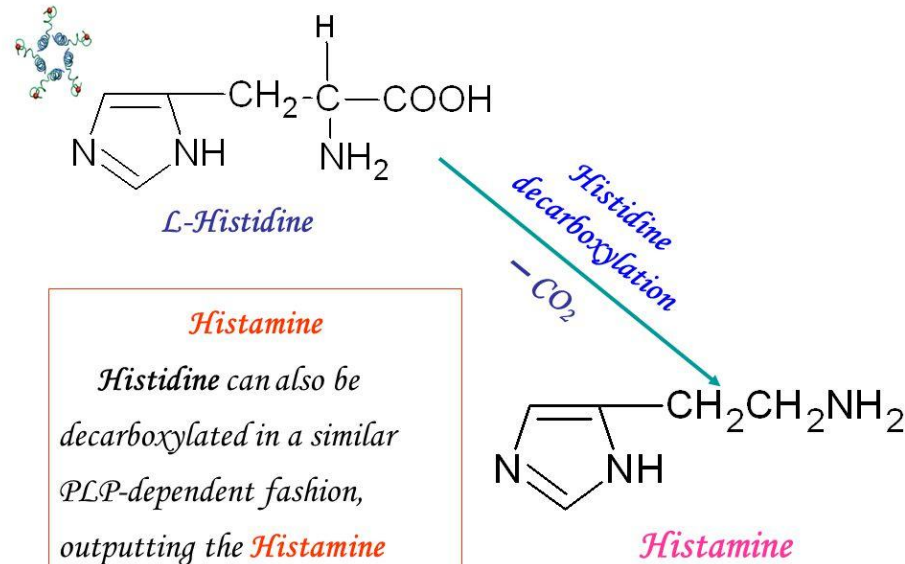
### 7. Decarboxylation



## Biologically active compounds – derivatives of $\alpha$ -aminoacids.



# Decarboxylation of histidine



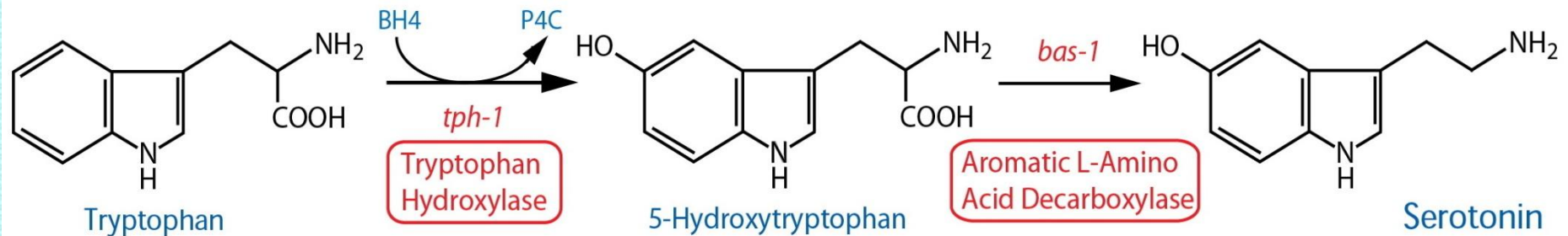
## Histamine

- H1 receptors are coupled with phosphatidyl inositol messenger system.
- H2 receptors are coupled with adenylyl cyclase messenger system.
- Histaminergic neurones of CNS, gastric mucosa cells, basophils, mast cells are the chief source of histamine.

# Functions of histamine:

- contraction of smooth muscles of gastro-intestinal tract, bronchi;
- it increases HCl secretion in stomach;
- it shows vasodilatory effect;
- it increases vasopermeability;
- it is the inflammatory process mediator;
- it is the allergic reaction mediator;
- it is the central nervous system mediator as well.

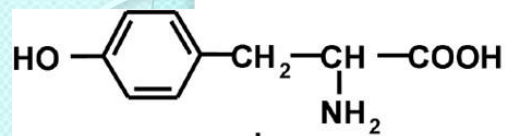
# ● Decarboxylation of tryptophan and its derivatives (5-hydroxytryptophan)



## Functions of serotonin

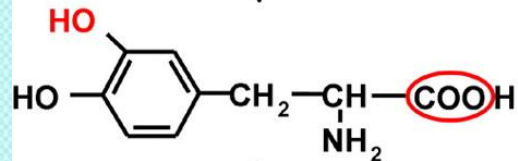
- mediator of CNS;
- potent vasoconstrictor;
- stimulator of smooth muscle contraction (of bronchi, uterus, intestine);
- mediator of inflammation;
- participates in regulation of body temperature, breathing, renal filtration;
- modulate the process of blood clotting.

# Decarboxylation of tyrosine



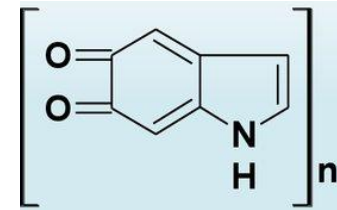
**L - TYROSINE**

***Tyrosine hydroxylase (TH)***  
(tetrahydrobiopterin,  $\text{Fe}^{2+}$ ,  $\text{O}_2$ )



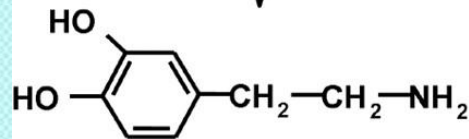
**L - DOPA**

tyrosinase



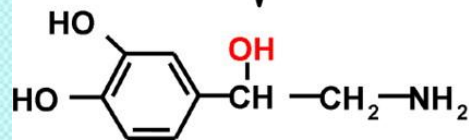
melanine

***L-Aromatic amino acid decarboxylase (AAAD)***  
(pyridoxal-phosphate)



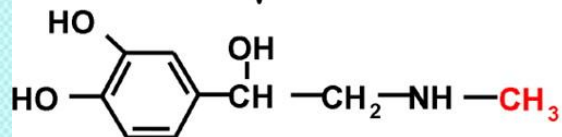
**DOPAMINE**

***Dopamine-β-hydroxylase (DBH)***  
(ascorbate,  $\text{Cu}^{2+}$ ,  $\text{O}_2$ )



**L - NORADRENALINE**

***Phenylethanolamine-N-methyltransferase (PNMT)***  
(S-adenosylmethionine)



**L - ADRENALINE**

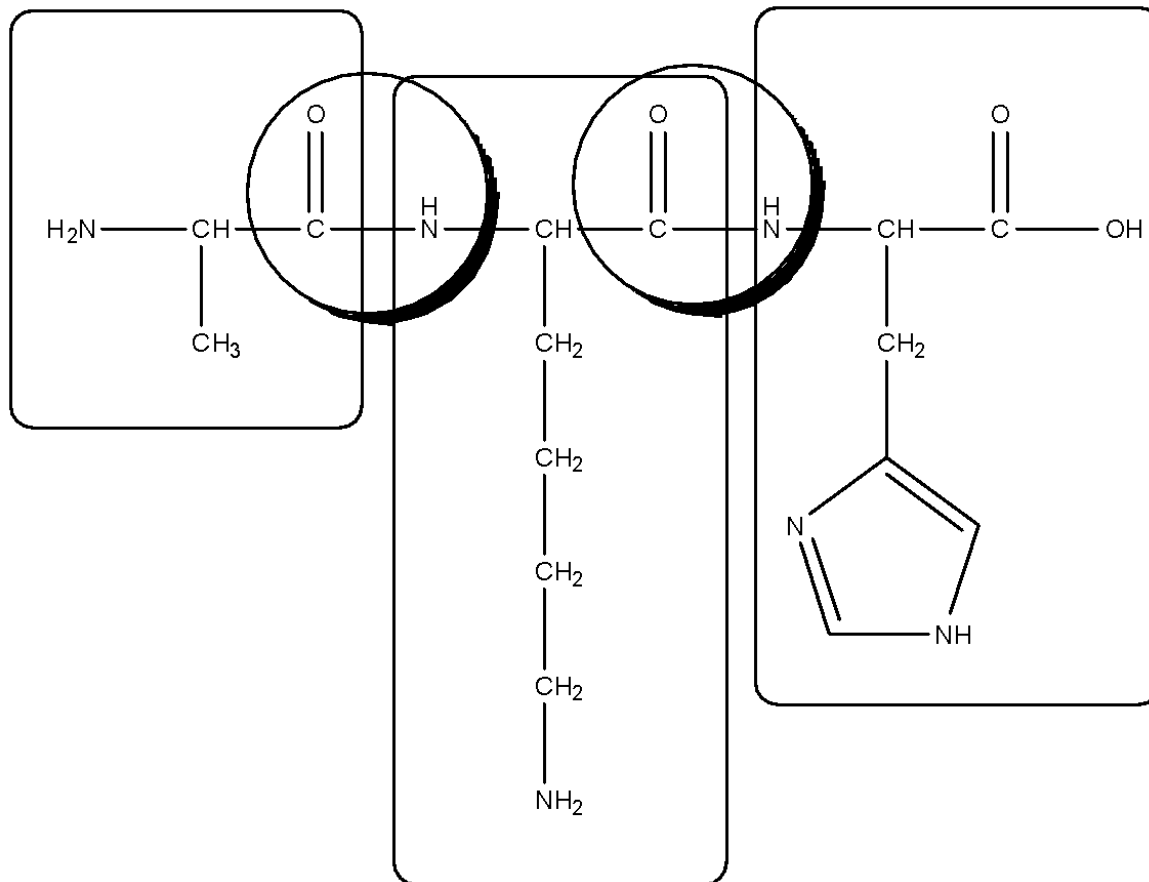


# Functions of epinephrine:

- “fight or flight”
- to increase cardiac output and to raise glucose levels in the blood.
- to increase the level of circulating free fatty acids.
- constriction in many networks of minute blood vessels but dilates the blood vessels in the skeletal muscles and the liver.

# Peptides.

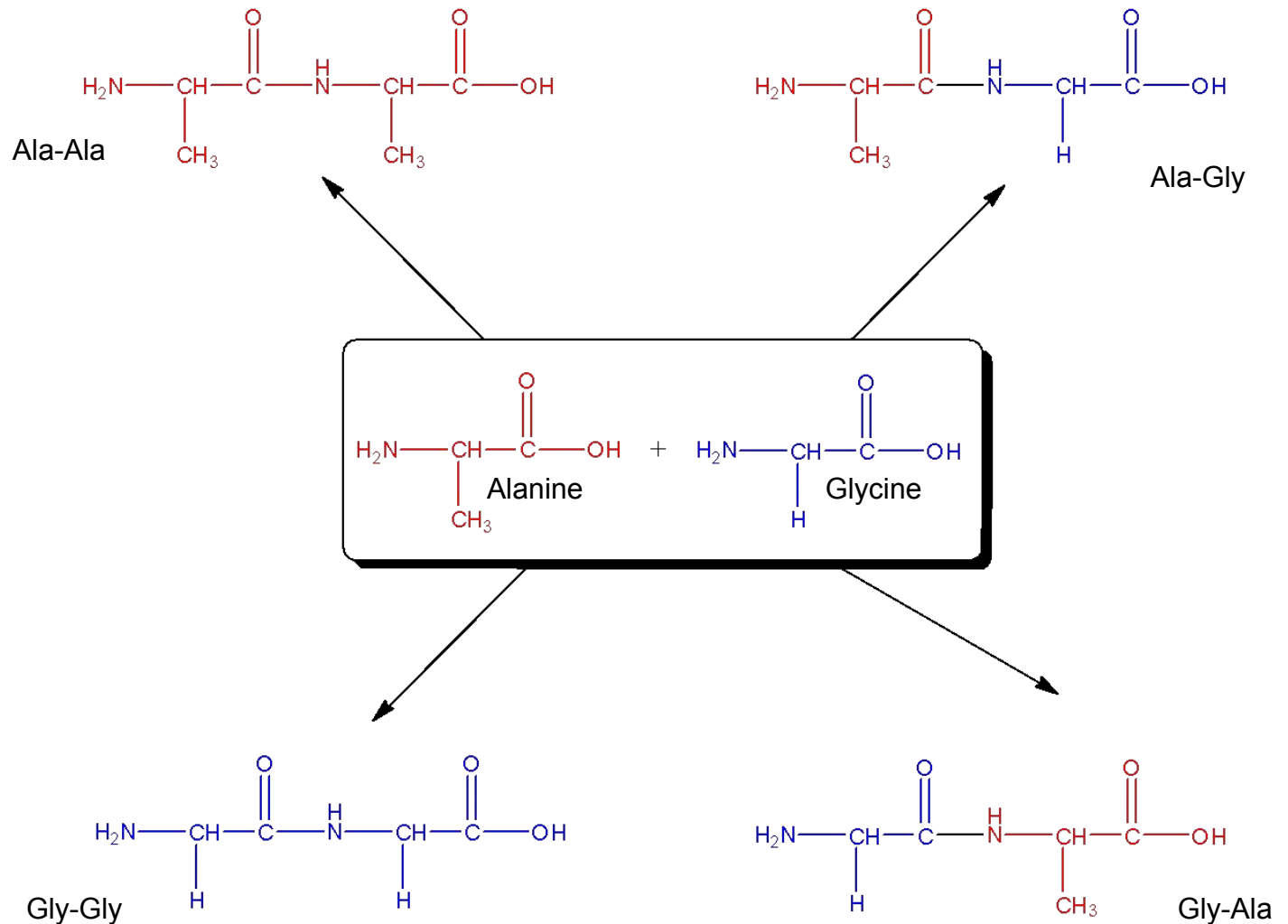
Peptides – polyamides formed by  $\alpha$ -aminoacids.



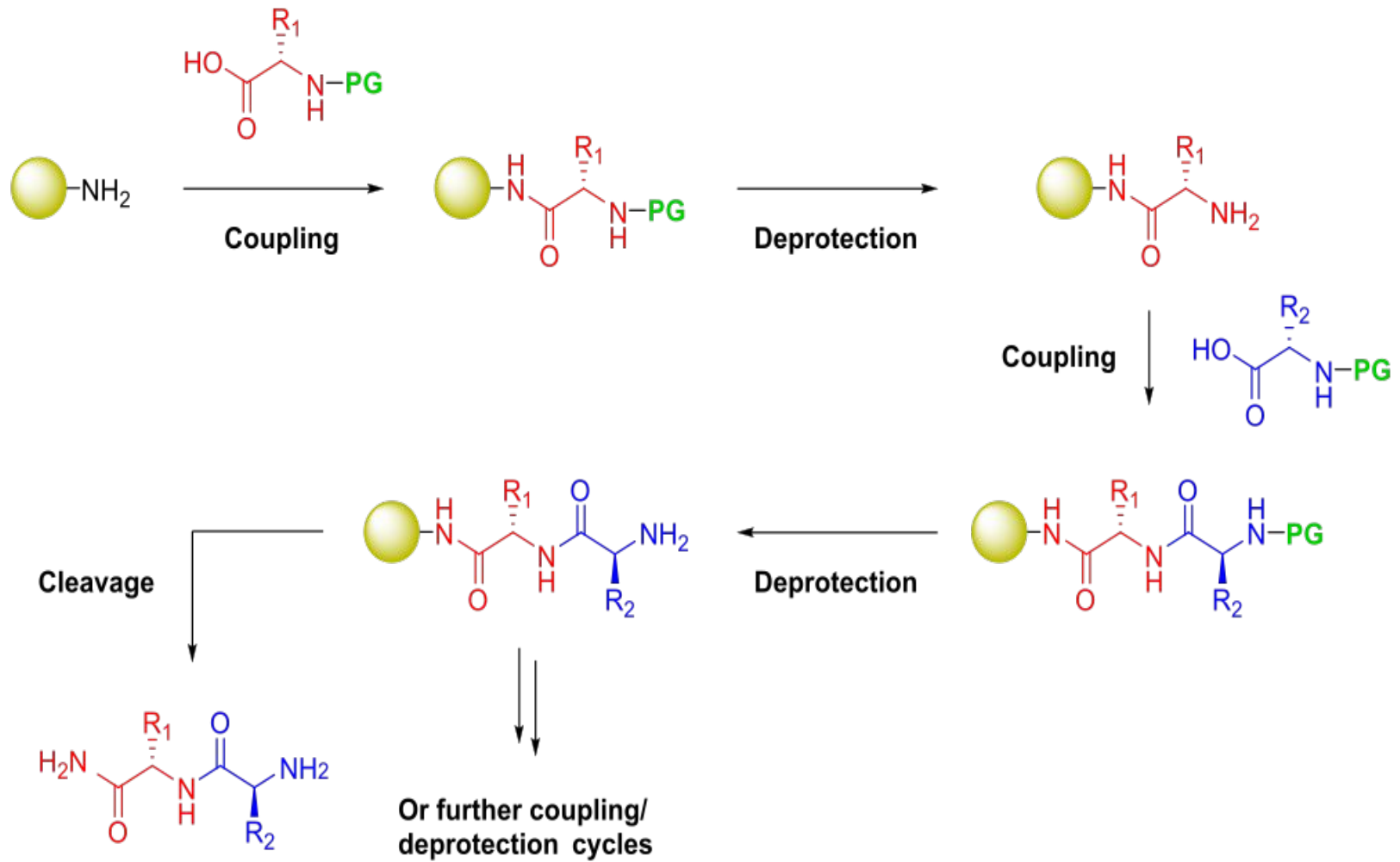


## Synthesis of peptides.

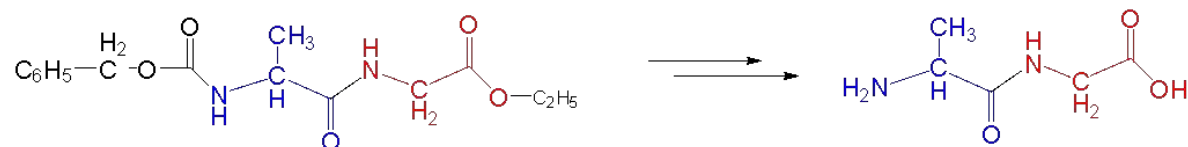
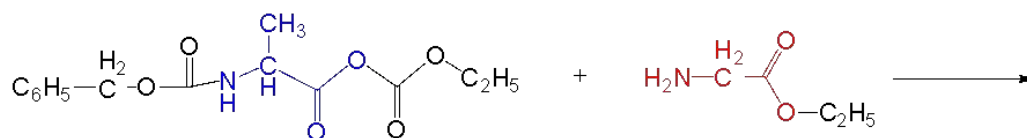
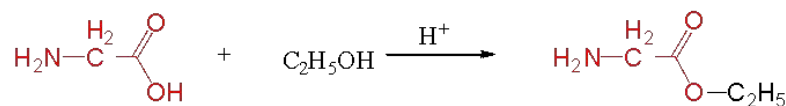
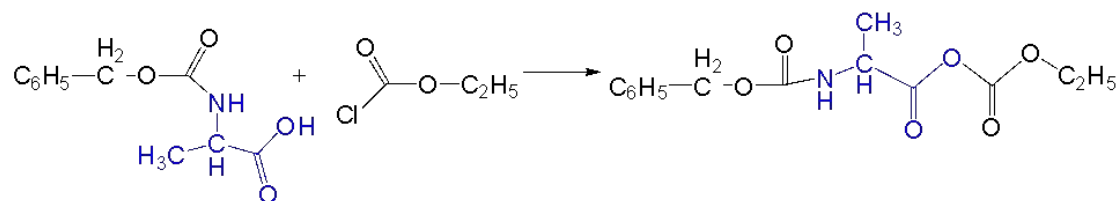
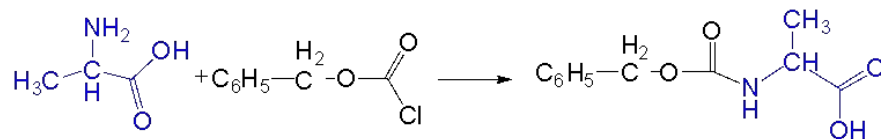
Possible products of interaction between two  $\alpha$ -aminoacids.



# Synthesis of peptides.

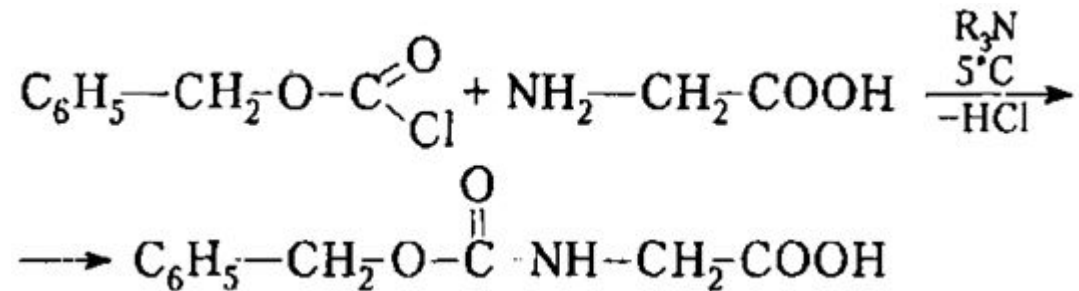


## Synthesis of peptides.

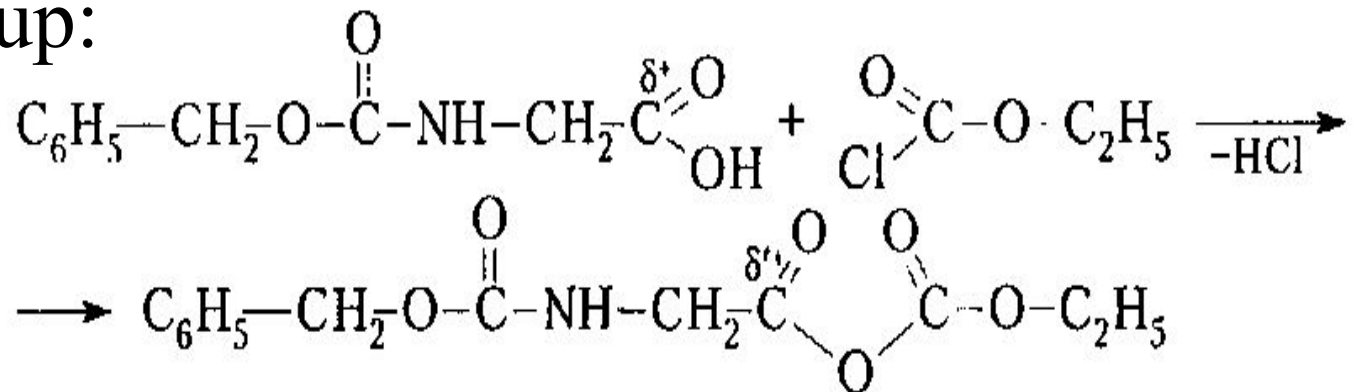


# The main steps outlined in the synthesis of dipeptide from glycine and alanine.

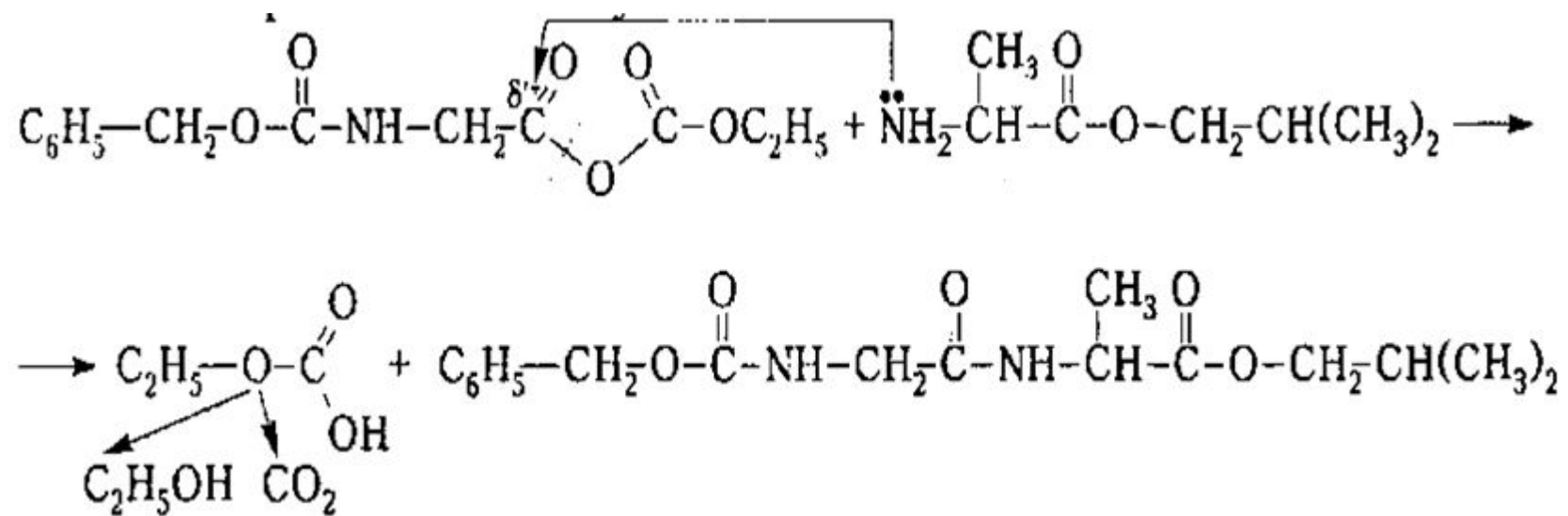
## 1. Protection of NH<sub>2</sub> groups:



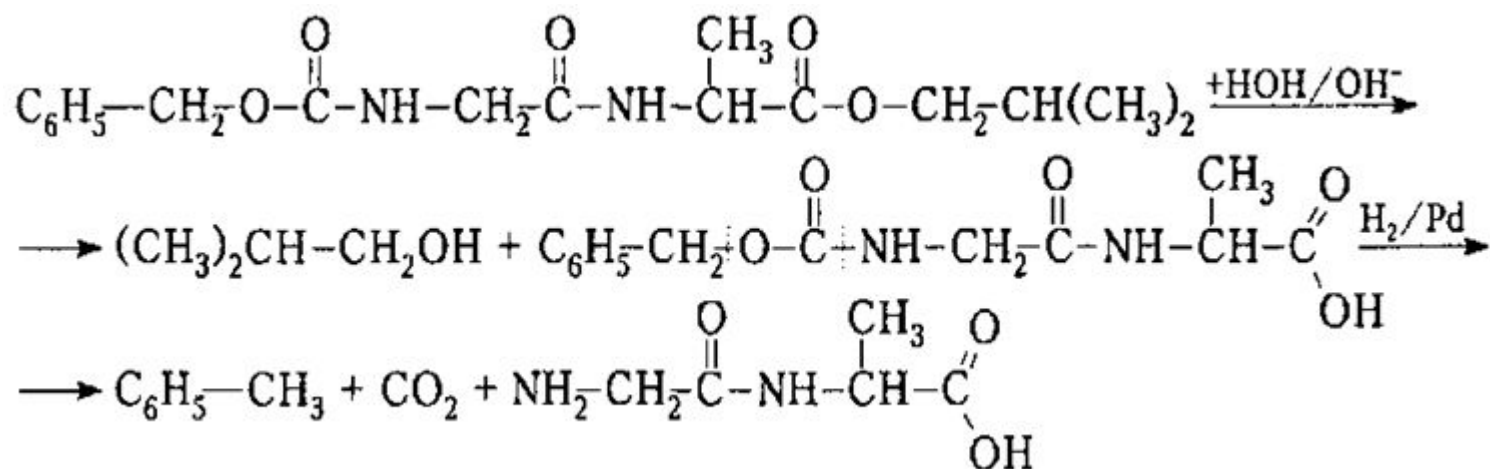
Protection and activation of the -COOH group:



## 2. Formation of a dipeptide:



### 3. Deletion of protection groups (removal of protection):



*The above sequence of reactions can be repeated with other amino acids further down to the formation of a tripeptide, a tetrapeptide, etc.*



# Proteins.

**Proteins** – macromolecular compounds, polypeptides with molecular weight more than 10000.

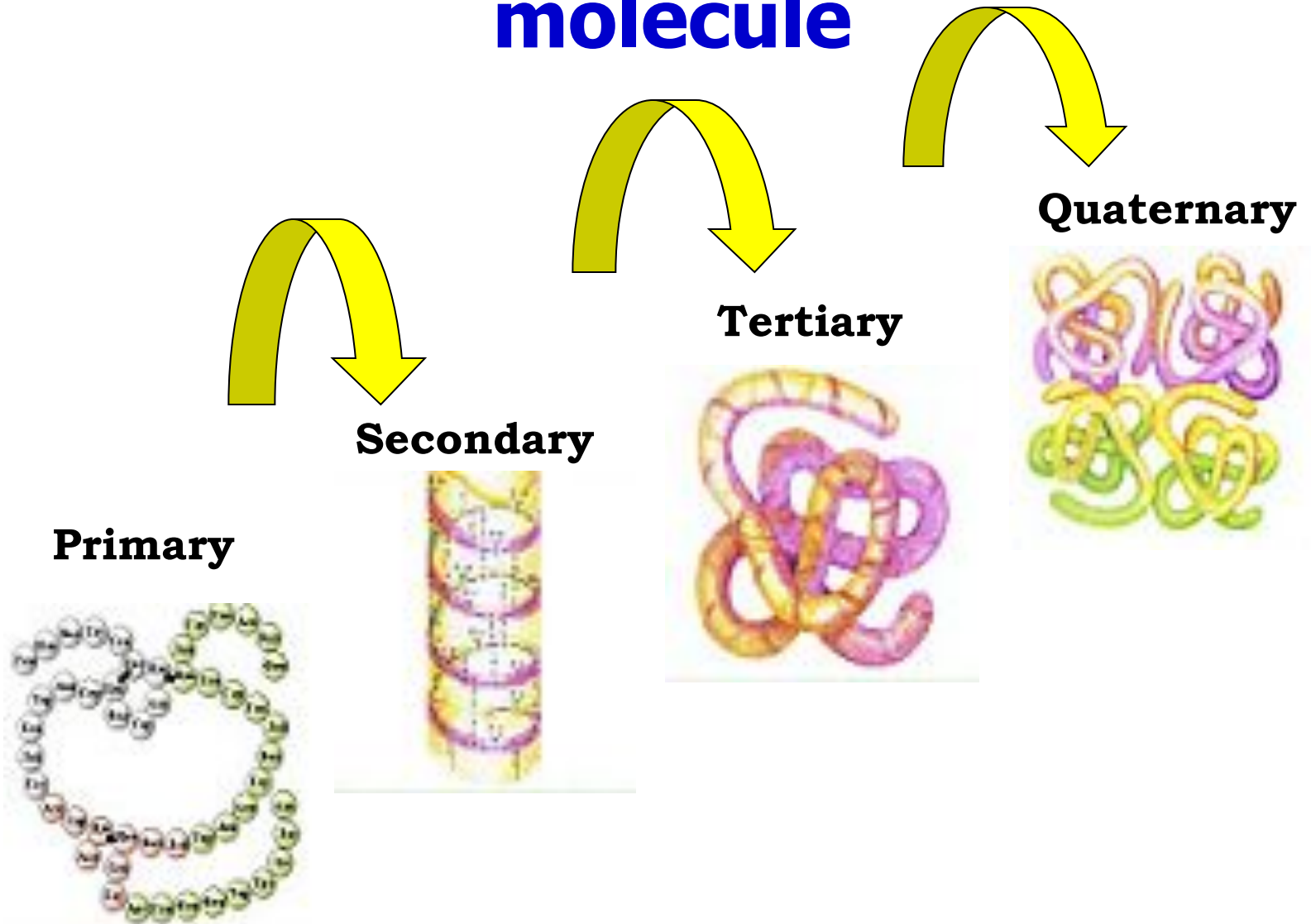
**Primary structure** – caused by amino acids sequence.

**Secondary structure** - regularly repeating local structures stabilized by hydrogen bonds.

**Tertiary structure** - the spatial relationship of the secondary structures to one another.

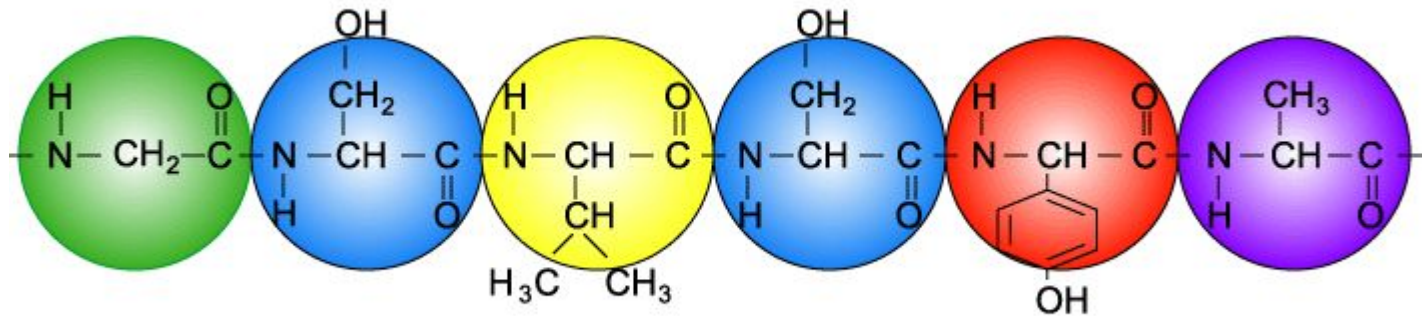
**Quaternary structure** - the structure formed by several protein molecules bonded by non-covalent bonds.

# The structure of the protein molecule

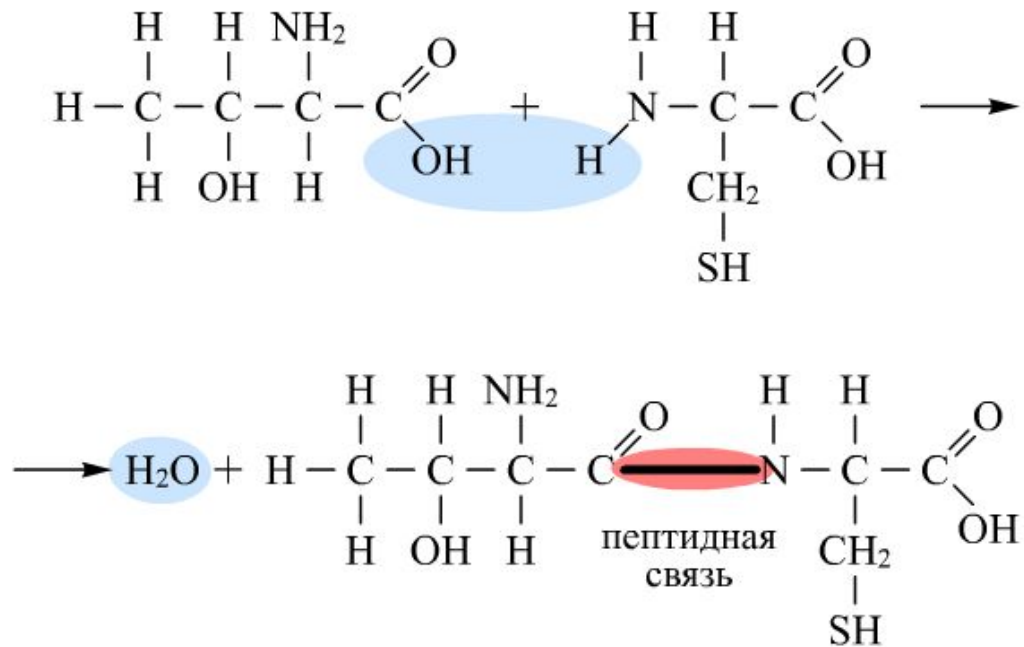


# Primary protein structure

The sequence of amino acid residues in the polypeptide chain linked peptide bonds.



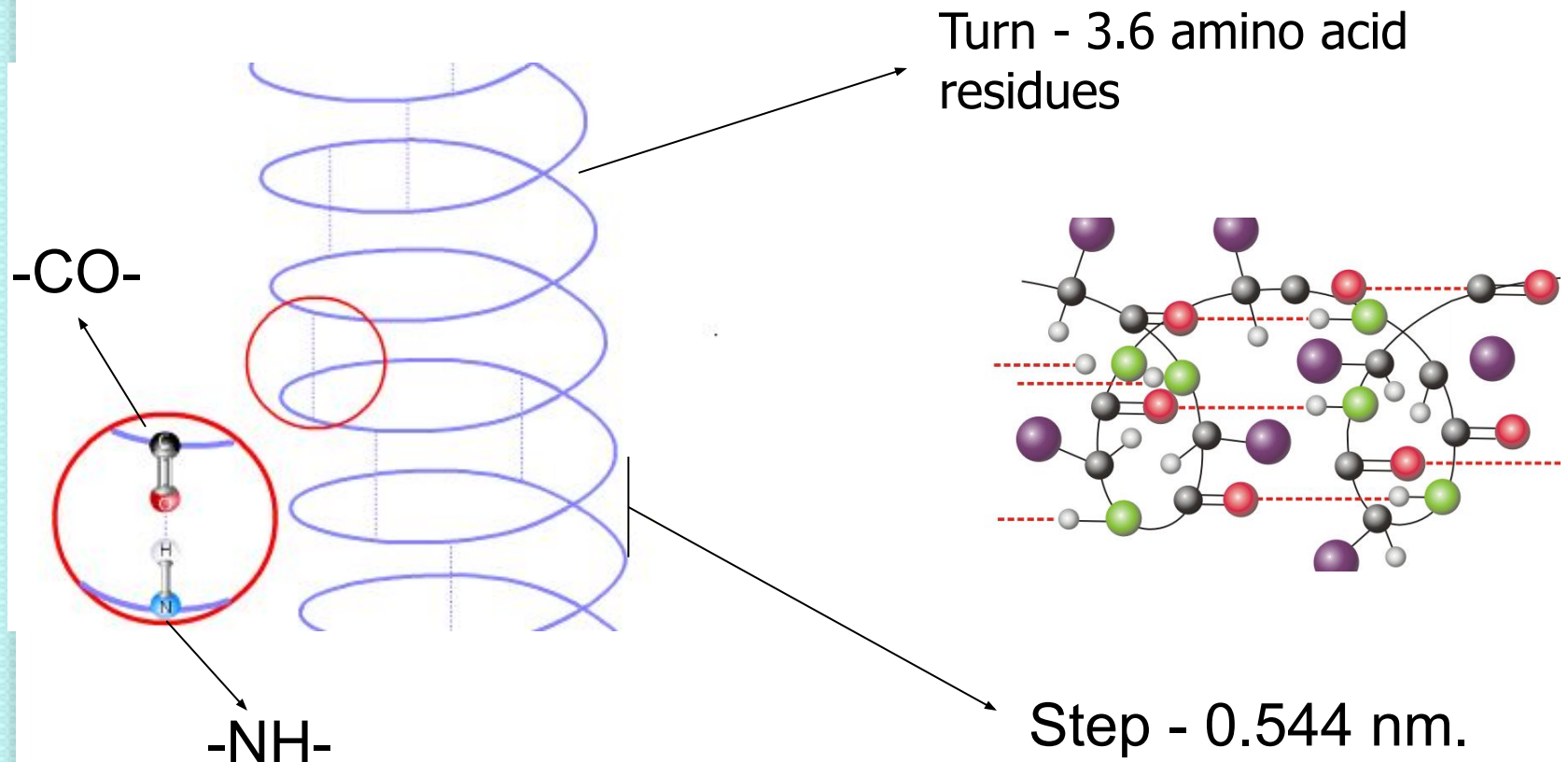
# The mechanism of peptide bond formation



# Secondary protein structure

**rolled into a spiral polypeptide chain.**

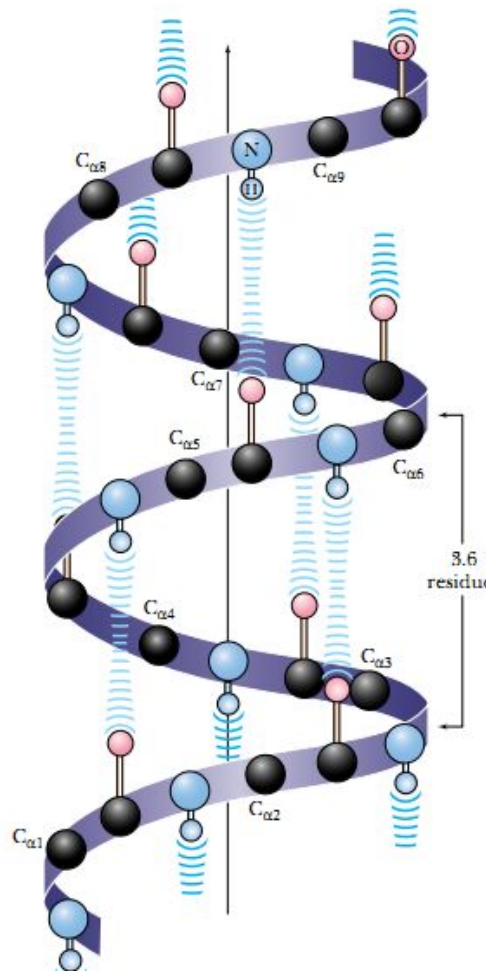
It is kept in space due to the formation of hydrogen bonds between the groups  $\text{-CO-}$  and  $\text{-NH-}$ , located on the neighboring spiral circles.



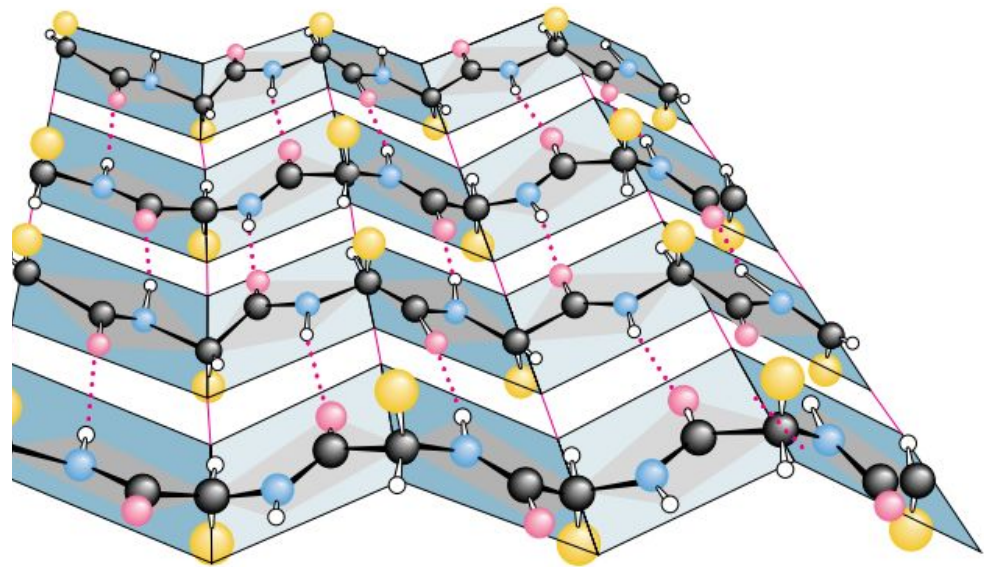


# Secondary structure

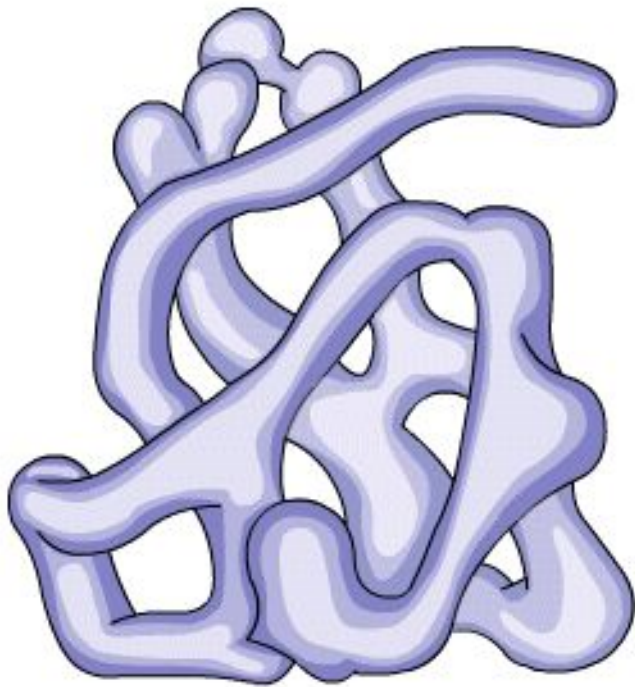
alpha-helix



pleated sheet







# Tertiary structure

The real three-dimensional configuration of a twisted spiral in the space of a polypeptide chain (that is, a spiral swirled into a spiral).

Supported by bonds between functional groups of radicals.

**Disulfide bridges** (-S-S-) between sulfur atoms.

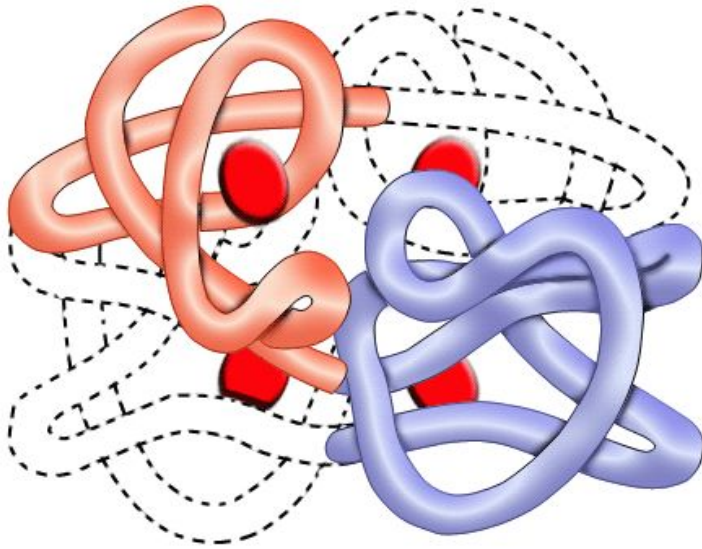
**Ester bridges** between carboxylic (-COOH) and hydroxyl groups (-OH).

**Salt bridges** between the carboxyl group (-COOH) and the amino group (-NH<sub>2</sub>).

# Quaternary protein structure

Form of interaction between multiple polypeptide chains.

Among themselves, polypeptide chains are connected by hydrogen, ionic, hydrophobic and other bonds.



The hemoglobin molecule is constructed from four polypeptide chains ( $M_r = 17000$  each). When coupled with oxygen, the molecule changes its quaternary structure, capturing oxygen.

It is the spatial structure that determines the chemical and biological properties of proteins

**PRIMARY  
STRUCTURE  
(AMINO ACID SEQUENCE)**

...AGWYVWPTGHR<sub>L</sub>AVAYGA<sub>A</sub>VWPI<sub>A</sub>VL...

**SECONDARY  
STRUCTURE  
(FOLDING PATTERNS)**



**TERTIARY  
STRUCTURE  
(OVERALL 3-D STRUCTURE)**



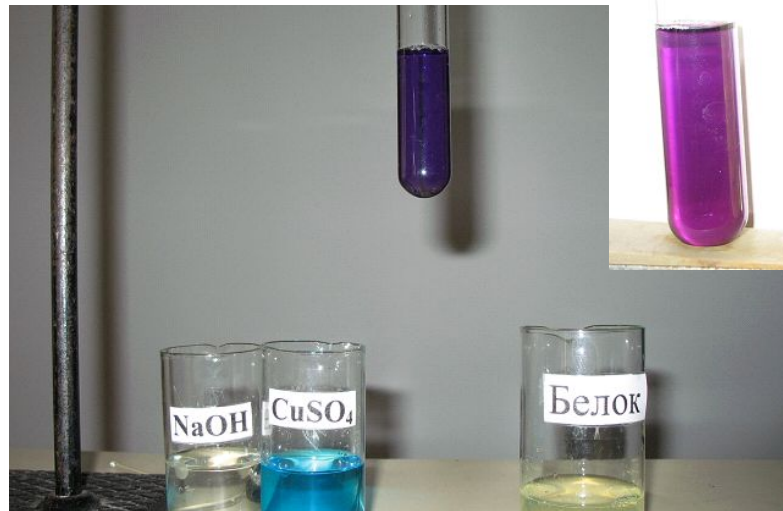
**QUATERNARY  
STRUCTURE  
(ASSEMBLY OF INDIVIDUAL  
PROTEINS INTO A COMPLEX)**



# Qualitative reactions to the protein

## Biuret's test

Violet coloration of protein solution under the action of copper (II) salts in alkaline medium



## Xanthoproteic reaction

Yellow color of the protein solution with the addition of concentrated nitric acid

