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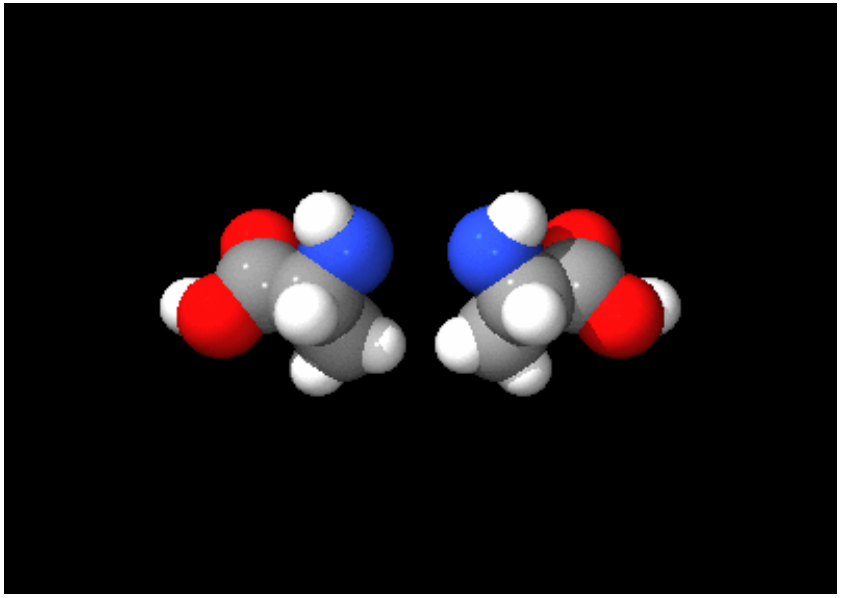
Amino acids



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Functions of amino acids

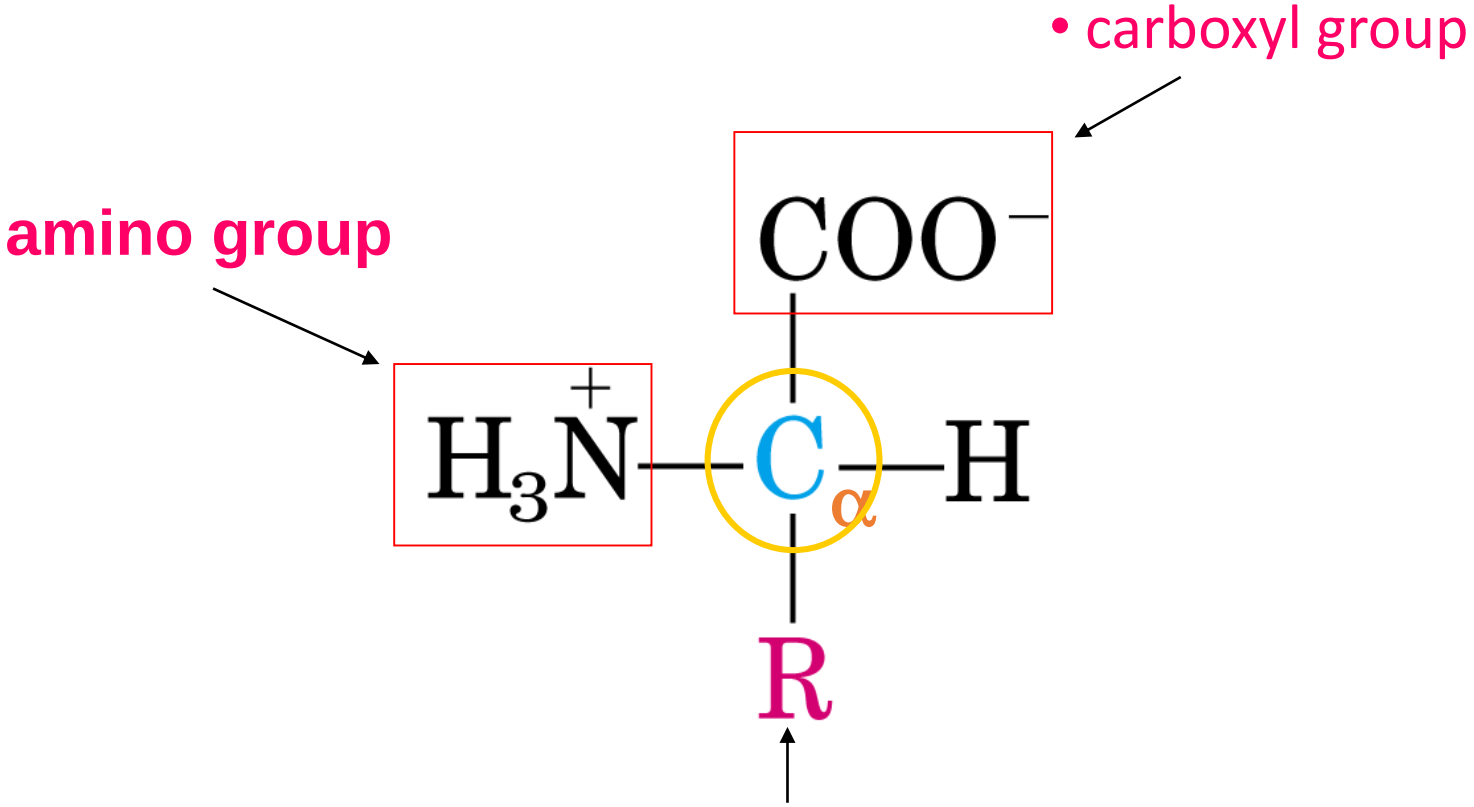
- A variety of roles in metabolism
  - the building blocks of proteins
  - forming parts of coenzymes
  - as precursors for the biosynthesis of molecules such as heme

Standard and nonstandard amino acids

- More than 300 different amino acids have been described in nature.
  - Standard α-amino acids:
    - Only *20 are commonly found as constituens of proteins*
  - Nonstandard amino acids:
    - Amino acid derivatives found in protein
    - Non-protein amino acid

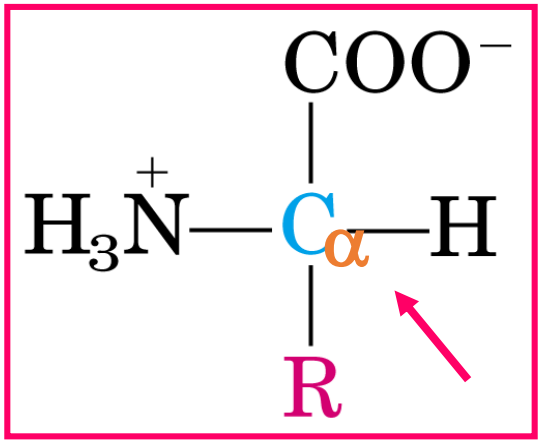
- Why are amino acids uniquely suited to their role as the building blocks of proteins?

General structure of α-amino acids *(Very important!)*



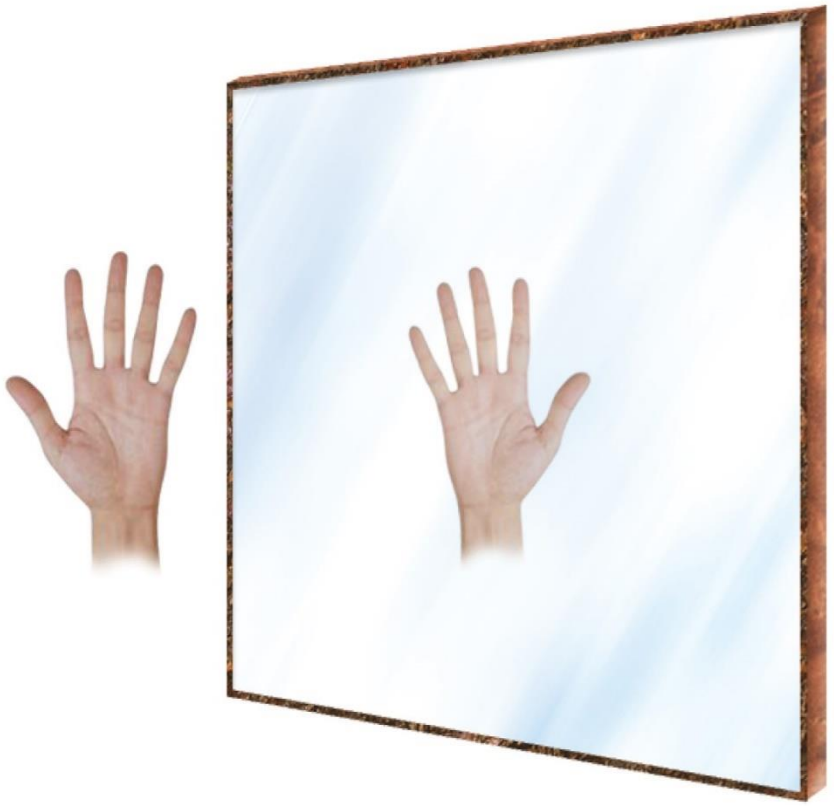
Stereochemistry of amino acids

- Configuration
- For all the common amino acids except Glycine, the α-carbon is bonded to four different groups.
- The α-carbon atom is thus a chiral center.



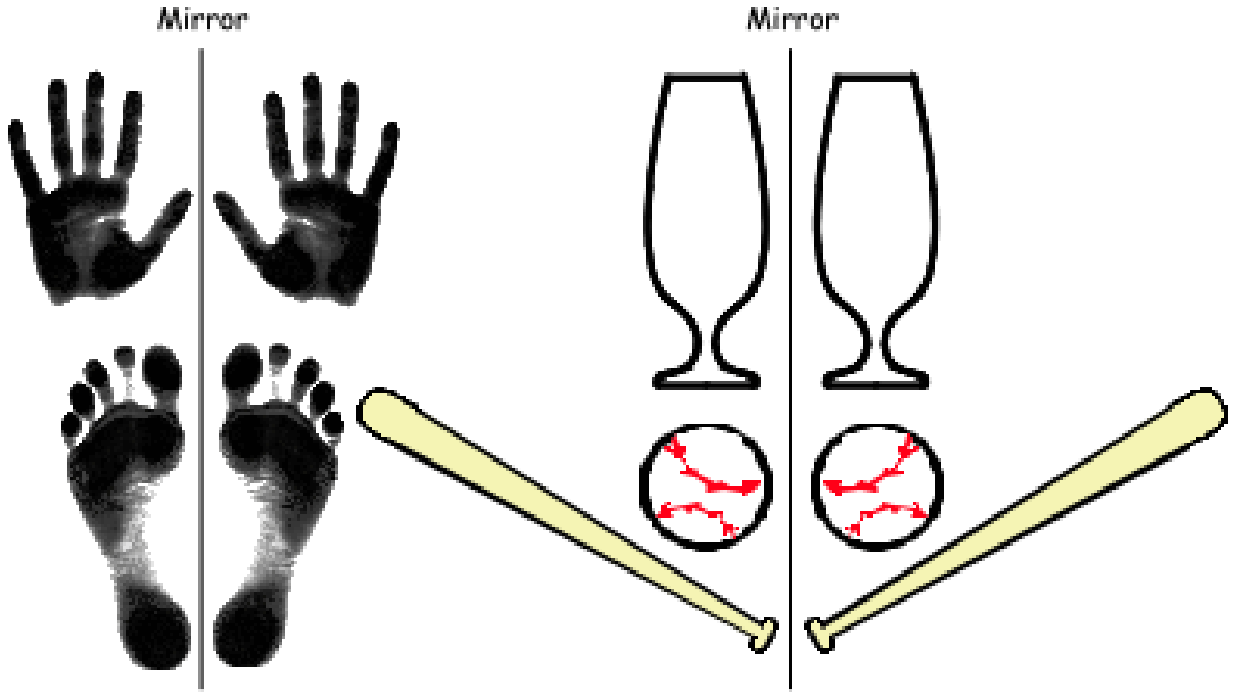
Chiral

- Chiral (from Greek *cheir*, meaning "hand"):
  - An object or a system cannot be superimposed on its mirror image.
  - One hand does not match the other when superimposed.



CHIRALITY

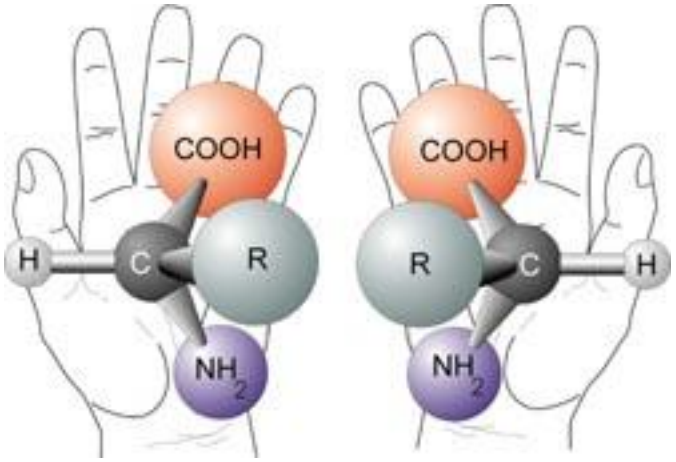
An object that cannot be superimposed on its mirror image is called chiral



Chiral objects
Nonsuperimposable
mirror images

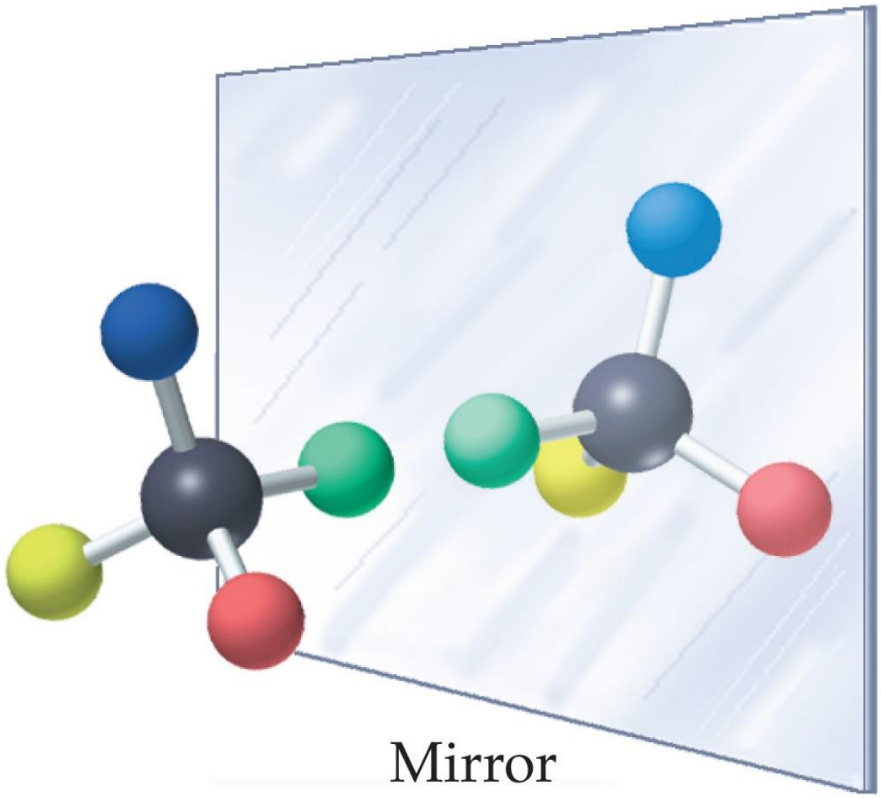
Nonchiral objects
Superimposable
mirror images

Chiral molecule



- Chiral molecule:
  - if a molecule has an atom bonded to four different groups, it can be chiral.

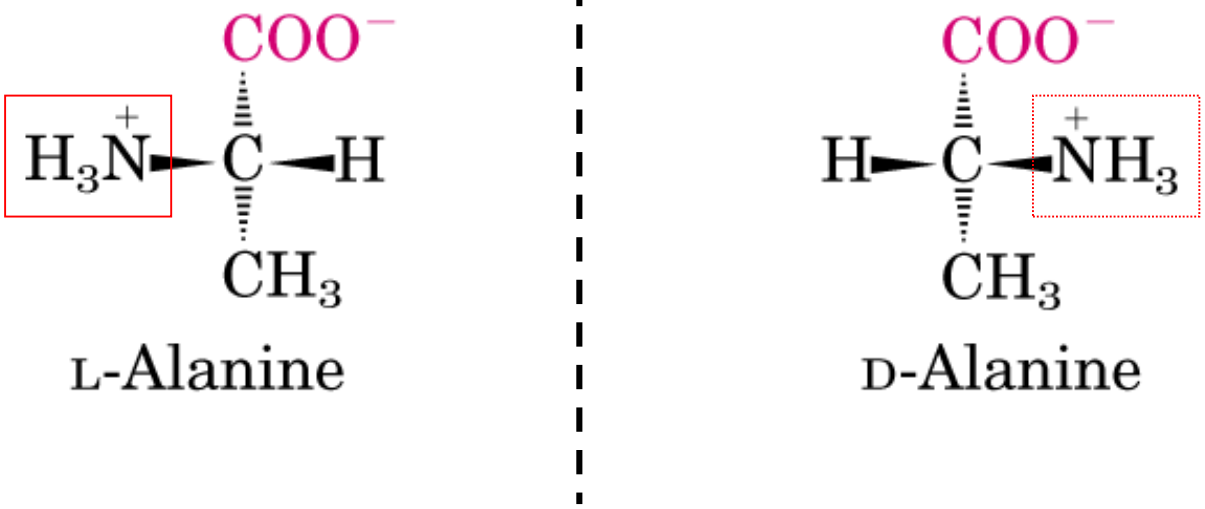
- Enantiomers:
  - a chiral molecule, has left- and right-handed isomers, called enantiomers.



- The two enantiomers of each amino acid are designated by D,L system according to the

  D- and L-glyceraldehyde.

- D: Dextrorotation; L: Levorotation



- **Only the *L-amino acids* have been found in proteins.**
- (D-isomers have been found only in small peptides of bacteria cell walls or in some peptide antibiotics).

The Classification of 20 standard Amino Acids (*very important!!!)*

- The name and abbreviation of amino acids
  - All the AAs were given a trivial (common) name.
    - Glutamate from wheat gluten.
    - Tyrosine from cheese (“tyros” in Greek).
  - Each AA is given a 3 letter abbreviation and 1 letter symbol.
    - They often the first three letter and the first letter. When there is confusion, an alternative is used.
- They should be remembered !

TABLE 5.1

Names and Abbreviations of the Standard Amino Acids

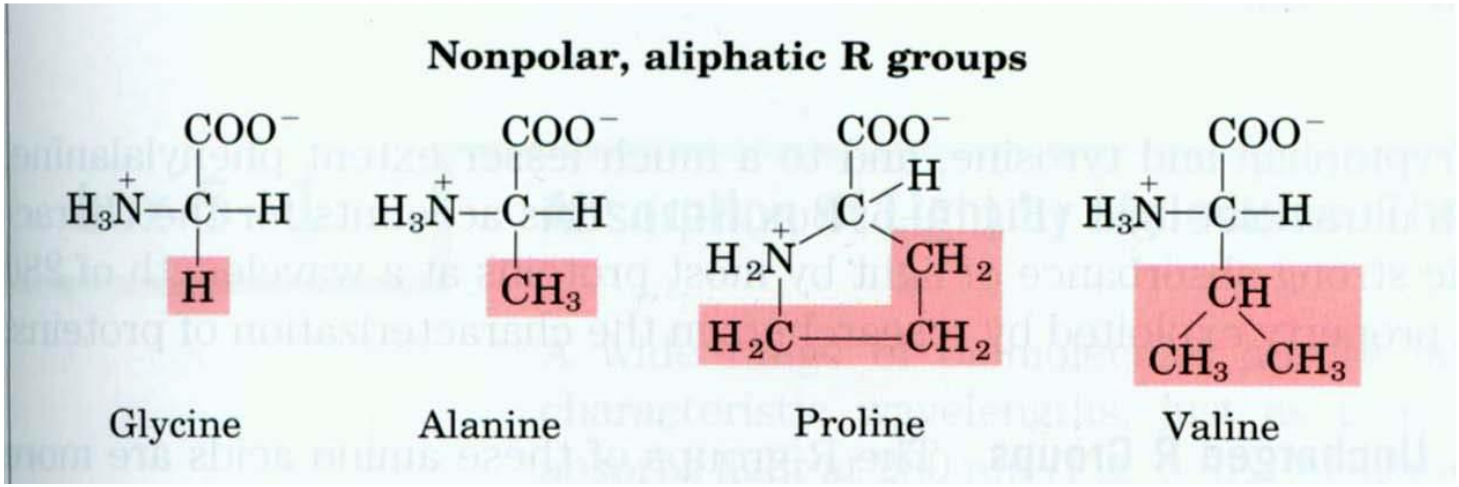
Amino Acid	Three-Letter Abbreviations	One-Letter Abbreviations
Alanine	Ala	A
Arginine	Arg	R
Asparagine	Asn	N
Aspartic acid	Asp	D
Cysteine	Cys	C
Glutamic acid	Glu	E
Glutamine	Gln	Q
Glycine	Gly	G
Histidine	His	H
Isoleucine	Ile	I
Leucine	Leu	L
Lysine	Lys	K
Methionine	Met	M
Phenylalanine	Phe	F
Proline	Pro	P
Serine	Ser	S
Threonine	Thr	T
Tryptophan	Trp	W
Tyrosine	Tyr	Y
Valine	Val	V

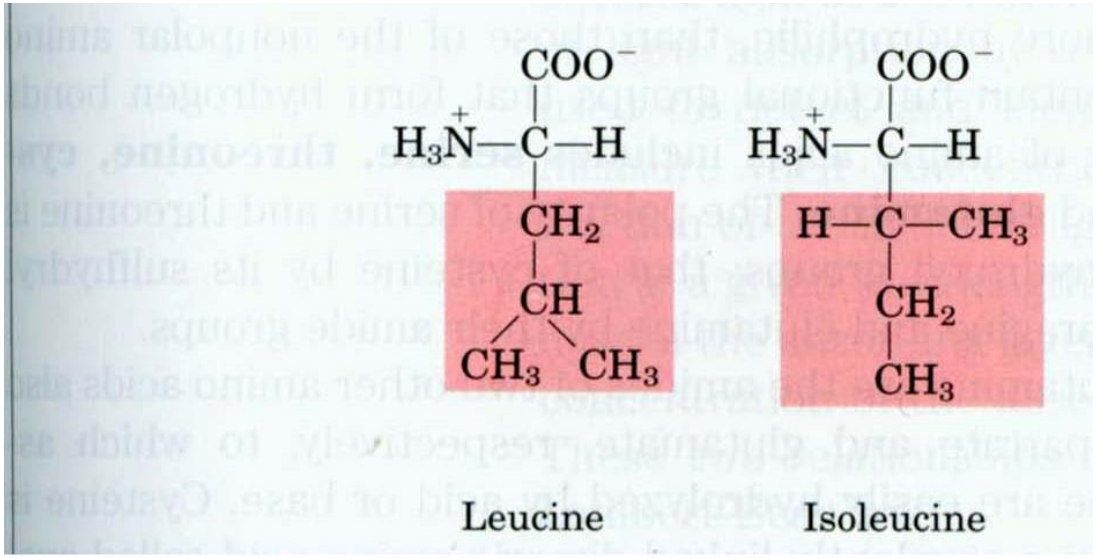
Classification of Amino Acids

- Based on polarity
  - Nonpolar, aliphatic amino acids
  - Polar, uncharged amino acids
  - Aromatic amino acids
  - Acidic amino acids
  - Basic amino acids

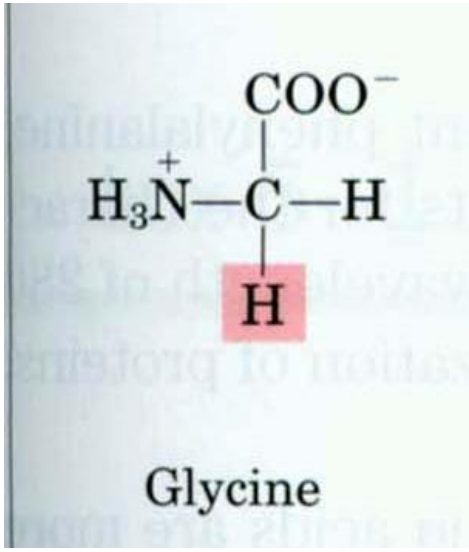
Nonpolar, aliphatic amino acids

- **Gly, Ala, Pro, Val, Leu, and Ile**



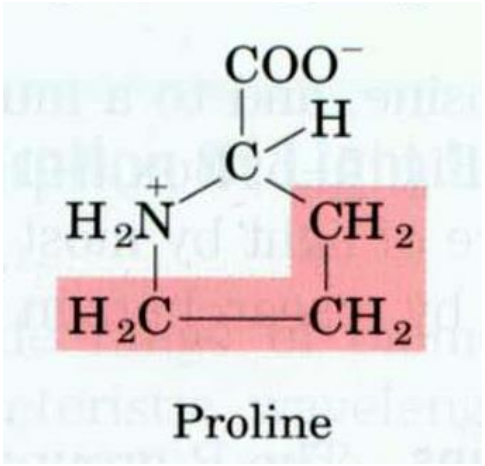


- Gly:
  - R group: hydrogen.
  - symmetric, not chiral.



Glycine

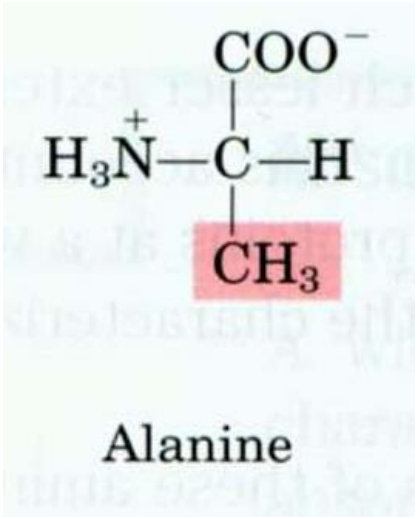
- Pro:
  - *Imino acid*.
  - five-membered ring structure, rigid in conformation.



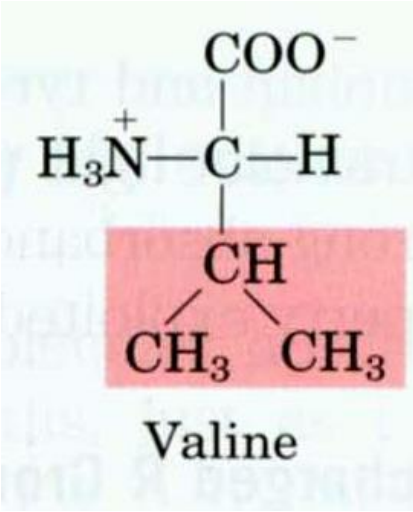
Proline

- **Ala, Val, Leu, and Ile**

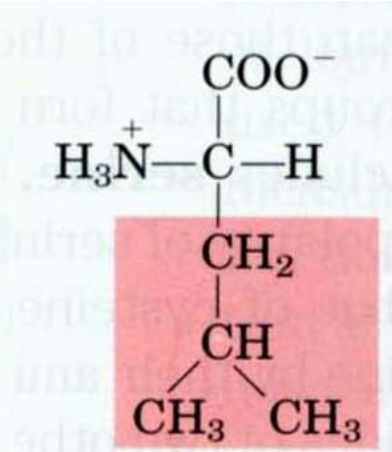
- Hydrocarbon R groups, often involved in hydrophobic interactions for stabilizing protein structure .



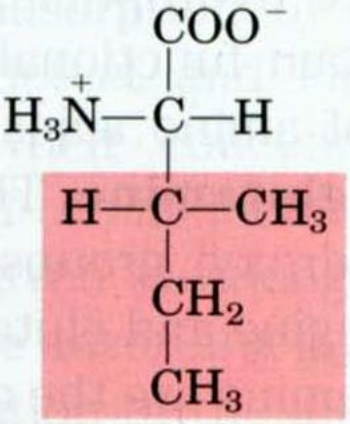
Alanine



Valine



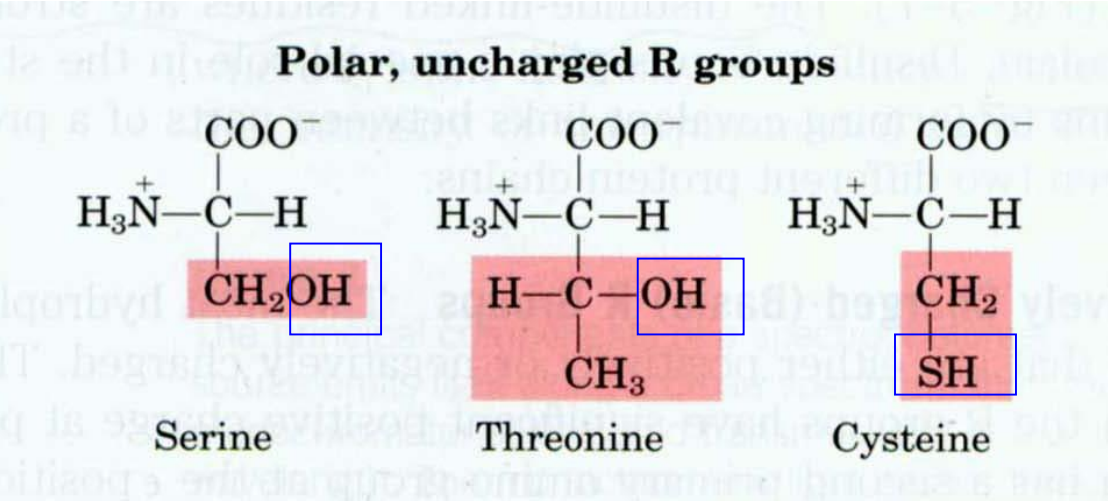
Leucine

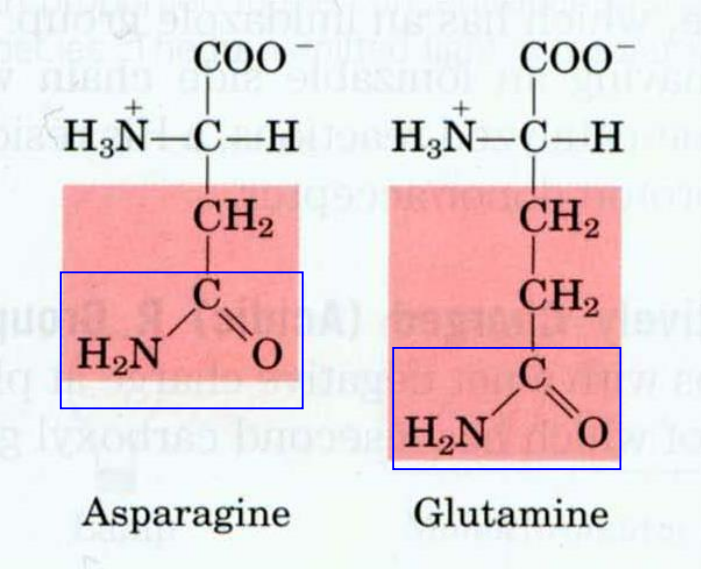


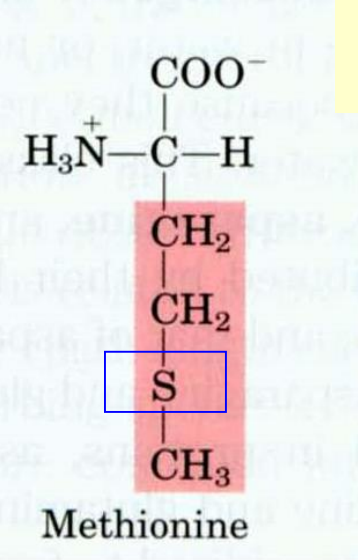
Isoleucine

Polar, uncharged amino acids

- **Ser, Thr, Cys, Asn, Gln and Met.**





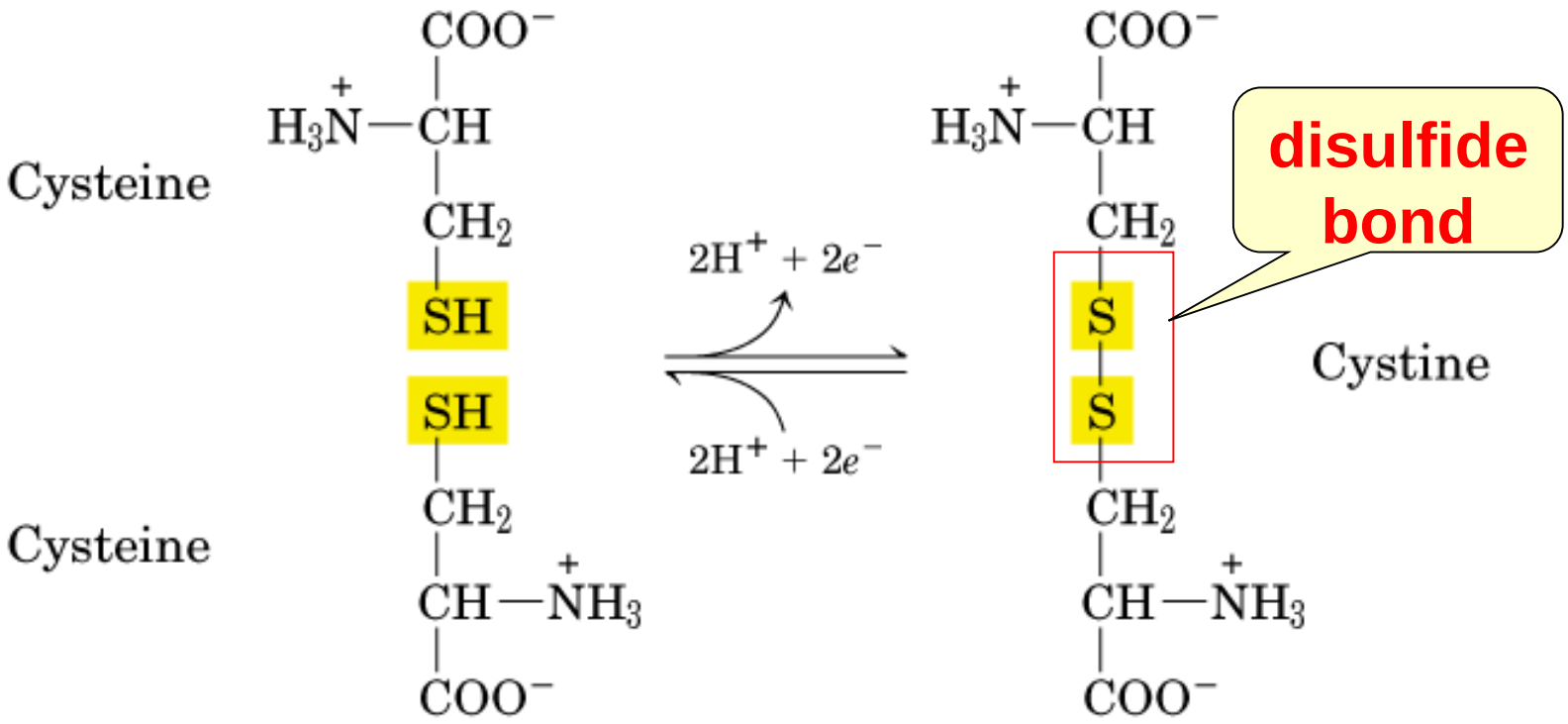


- **R group:**
Hydrophilic
  - Hydroxyl groups
  - Sulfur atoms
  - Amide groups

➢Disulfide bonds

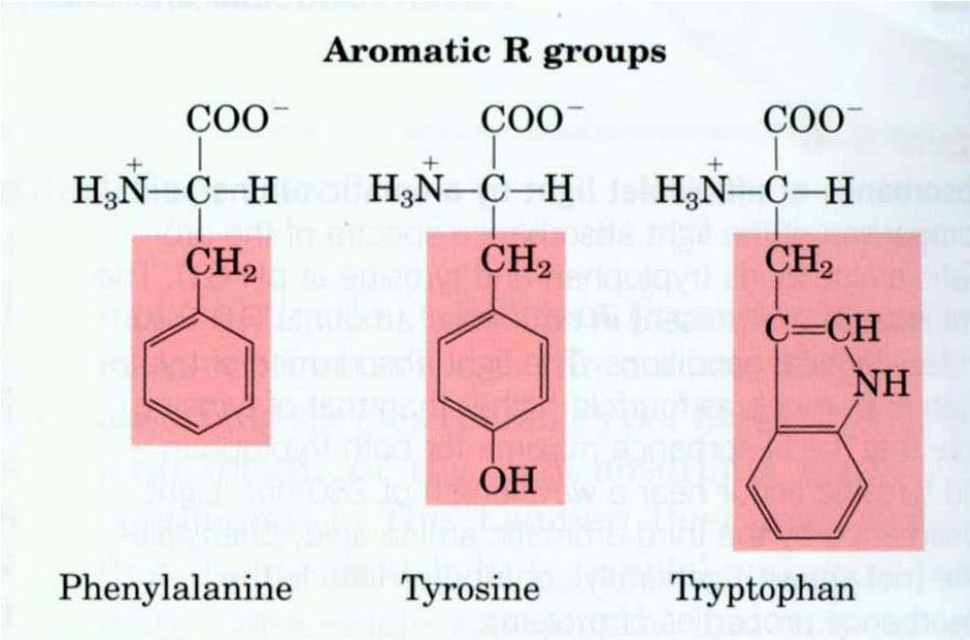
➢**-SH group of two Cys in proteins can be *oxidized to form a covalent disulfide bond.***

➢ **Disulfide bonds: play a special role in the structures of many proteins by forming covalent links.**



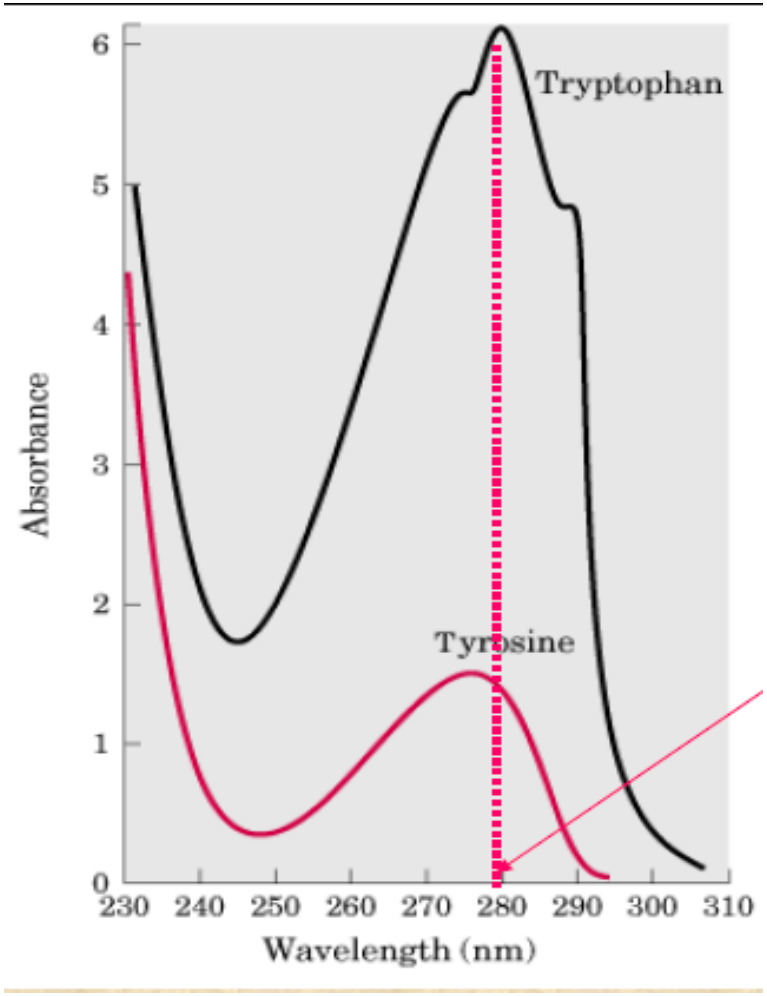
Aromatic amino acids

- **Phe, Tyr and Trp.**
  - **Phe and Tyr: benzene rings.**
  - **Tryptophan: indole ring.**



- **The -OH group in Tyr is an important functional group in proteins. (phosphorylation, hydrogen bond, etc), polar**

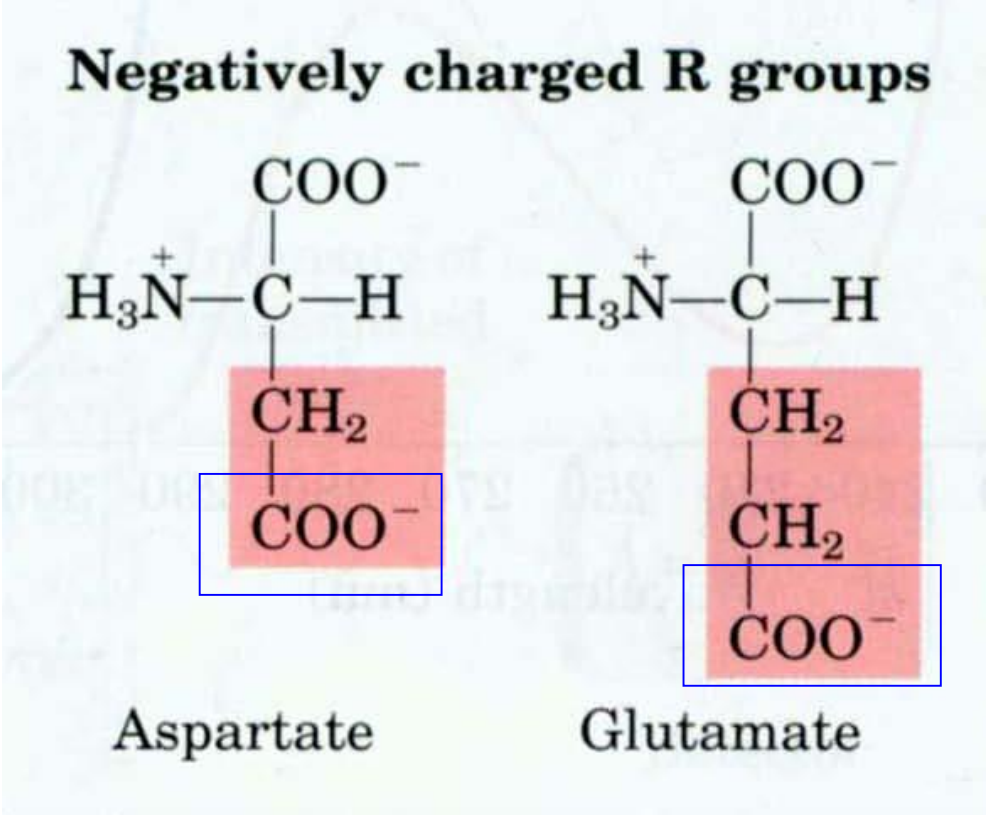
•**They are jointly responsible for the light absorption of proteins at 280 nm.**



- Proteins in solution absorb UV light with absorbance maximum at 280nm.
- Measuring protein content by photo spectrometry.

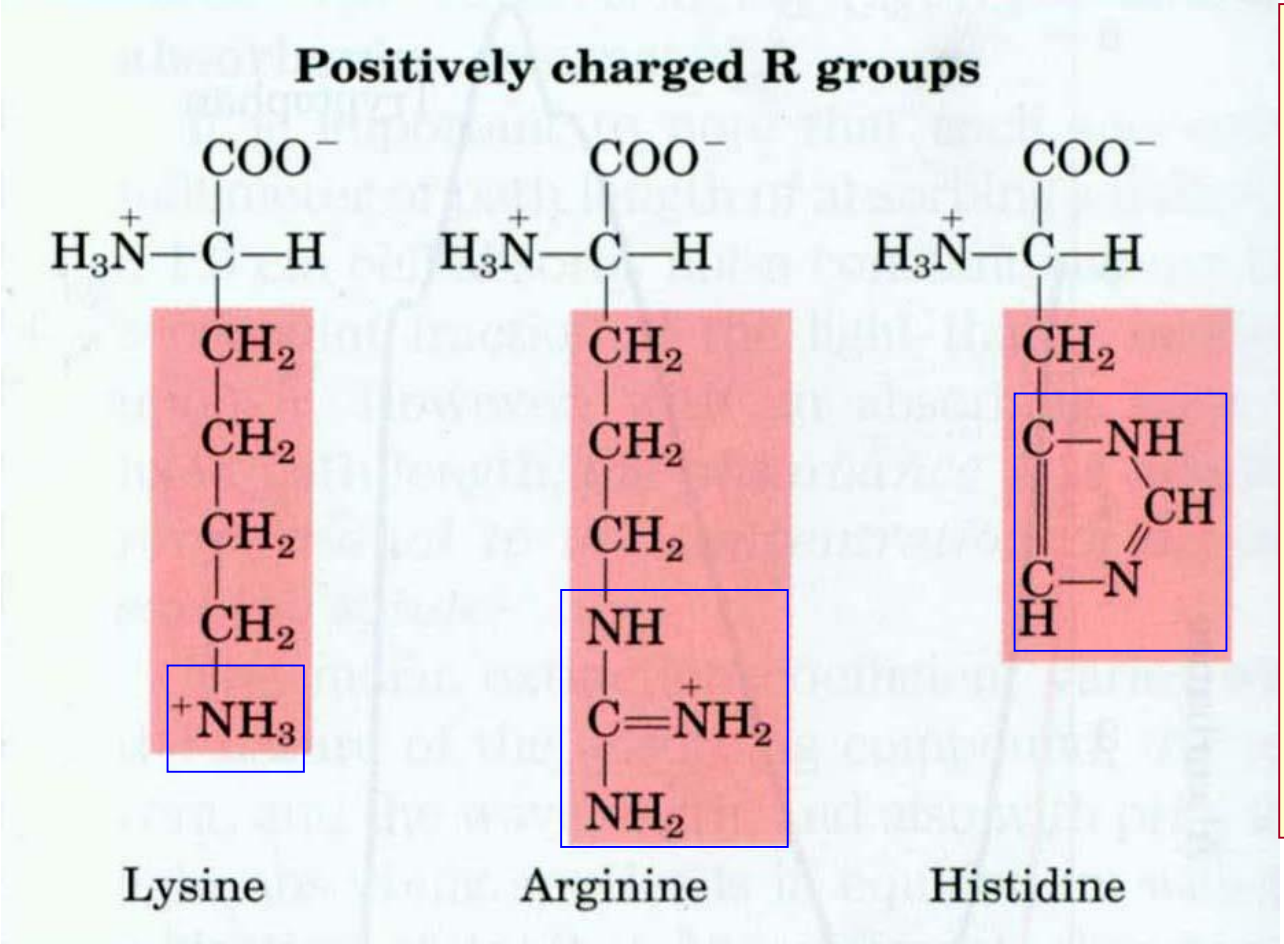
Acidic amino acids

- Asp and Glu
  - Have carboxyl in their R groups.



Basic amino acids

- Lys, Arg, and His.



- R groups
  - Amino
  - Guanidino
  - Imidazole
- Positive charged R groups at pH 7.0

- **Note these structural features**

1. All 20 are α-amino acids
2. For 19 of the 20, the α -amino group is primary; for proline, it is secondary (imino acid)
3. Except glycine, the α -carbons for 19 of them are asymmetric (or chiral).

- **Nonpolar Amino Acids**

Ala Val Leu Ile Gly Pro Phe Trp

- **Polar,Uncharged Amino Acids**

Ser Thr Cys Asn Gln Met Tyr

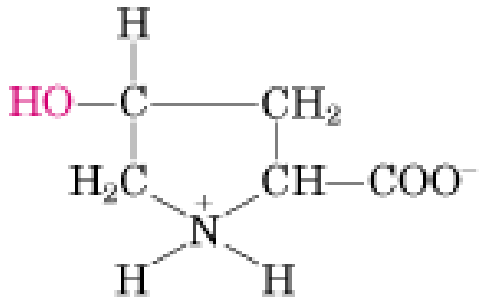
Aromatic

- **Acidic Amino Acids** Asp Glu

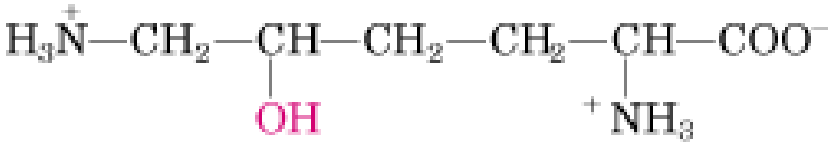
- **Basic Amino Acids** Lys Arg His

Nonstandard amino acids

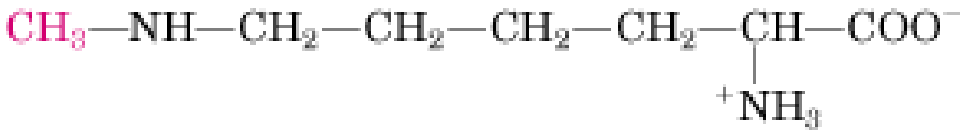
- **Amino acid derivatives found in proteins**
  - 4-Hydroxyproline **and 5-hydroxylysine in collagen.**
  - **6-*N*-Methyllysine in myosin.**



4-Hydroxyproline

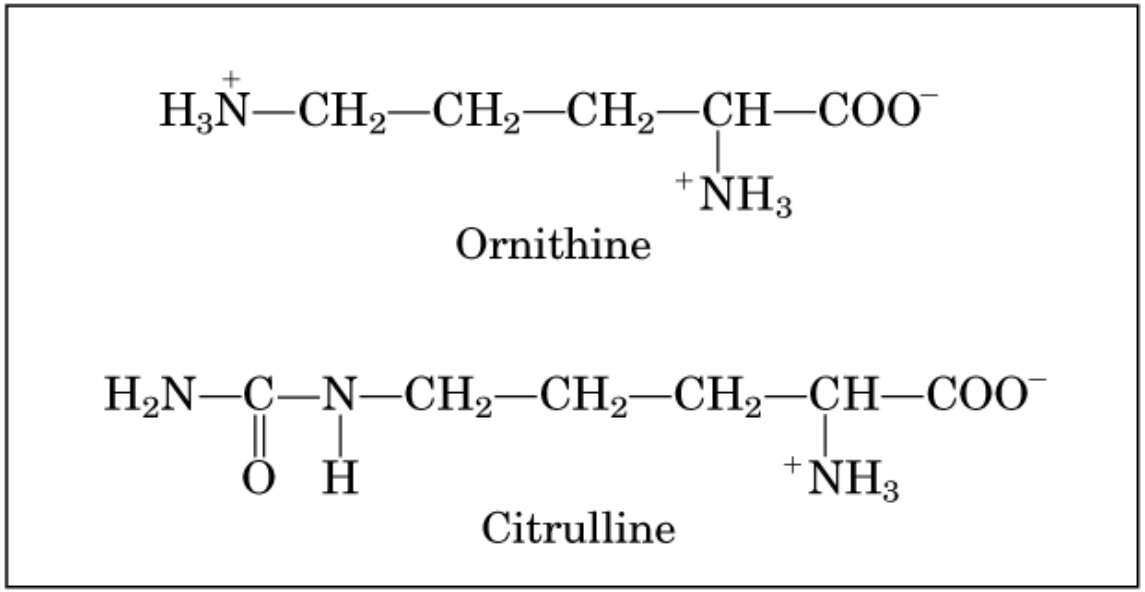


5-Hydroxylysine



6-*N*-Methyllysine

Many additional nonstandard amino acids are found in cells, but not in proteins



- Ornithine and citrulline
- Intermediates in amino acid metabolism.

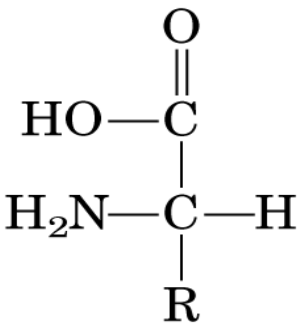
Essential and non-essential amino acids

- Essential amino acids (or indispensable amino acids):
  - Cannot be synthesized by the humans, must be supplied in the diet
  - 8: Phe, Val, Thr, Trp, Ile, Met, Leu, Lys
- Semi-essential amino acids:
  - 2: His and Arg
  - Required by infants and growing children

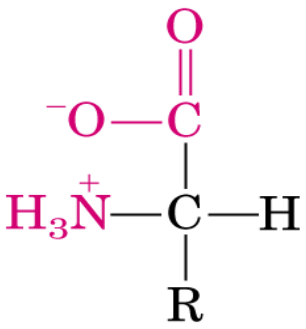
Acid/base properties of AAs

(Very important!)

- Amino acid has both a basic amine group and an acidic carboxylic acid group.
- In neutral solution (pH 7.0), the amino acid contains a negative charge and a positive charge. It is called a *zwitterion* (German for "hybrid ion").



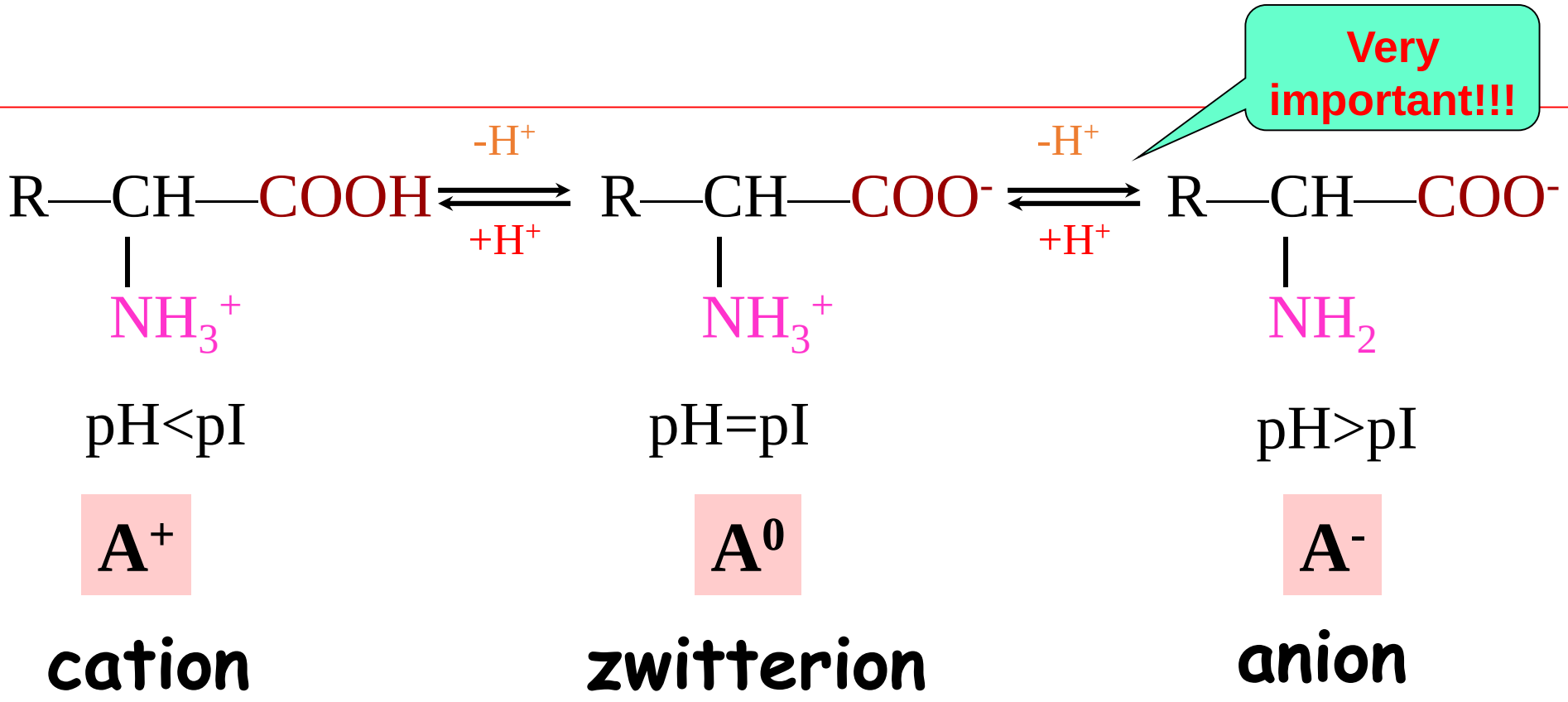
Nonionic form



Zwitterionic form

•AAs ionize to various states depending on pH values.

• pI: there is a specific pH (designated isoelectric point, pI) at which an AA has equal positive and negative charge (no net electric charge) .

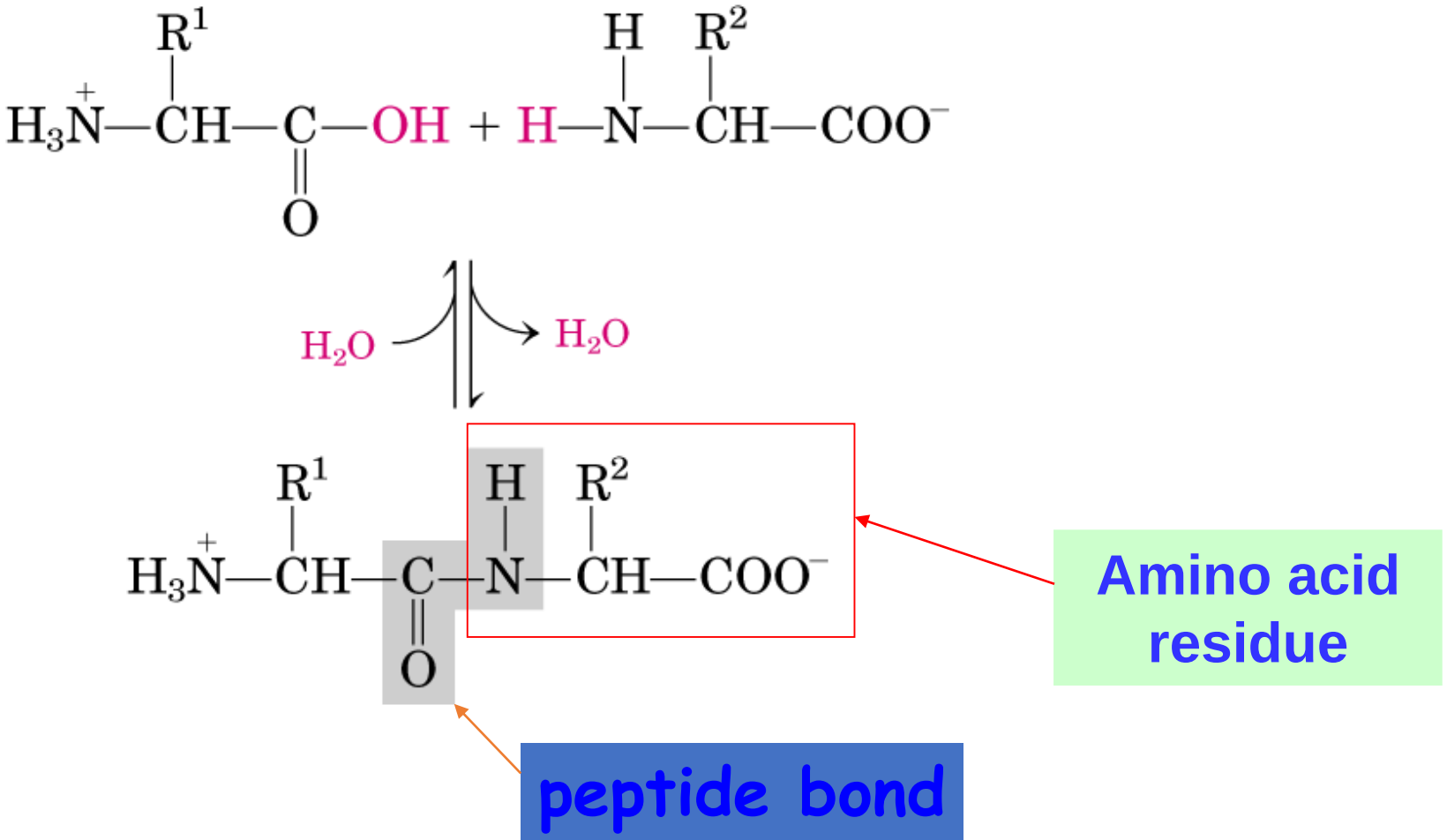


Properties and Conventions Associated with the Standard Amino Acids

Amino acid	Abbreviated names		M_r	pK_a values: pK_1 (—COOH)	pK_2 ($—NH_3^+$)	pK_R (R group)	pI	Hydropathy index*	Occurrence in proteins (%)†
Nonpolar, aliphatic R groups									
Glycine	Gly	G	75	2.34	9.60		5.97	−0.4	7.2
Alanine	Ala	A	89	2.34	9.69		6.01	1.8	7.8
Valine	Val	V	117	2.32	9.62		5.97	4.2	6.6
Leucine	Leu	L	131	2.36	9.60		5.98	3.8	9.1
Isoleucine	Ile	I	131	2.36	9.68		6.02	4.5	5.3
Methionine	Met	M	149	2.28	9.21		5.74	1.9	2.3
Aromatic R groups									
Phenylalanine	Phe	F	165	1.83	9.13		5.48	2.8	3.9
Tyrosine	Tyr	Y	181	2.20	9.11	10.07	5.66	−1.3	3.2
Tryptophan	Trp	W	204	2.38	9.39		5.89	−0.9	1.4
Polar, uncharged R groups									
Serine	Ser	S	105	2.21	9.15		5.68	−0.8	6.8
Proline	Pro	P	115	1.99	10.96		6.48	1.6	5.2
Threonine	Thr	T	119	2.11	9.62		5.87	−0.7	5.9
Cysteine	Cys	C	121	1.96	10.28	8.18	5.07	2.5	1.9
Asparagine	Asn	N	132	2.02	8.80		5.41	−3.5	4.3
Glutamine	Gln	Q	146	2.17	9.13		5.65	−3.5	4.2
Positively charged R groups									
Lysine	Lys	K	146	2.18	8.95	10.53	9.74	−3.9	5.9
Histidine	His	H	155	1.82	9.17	6.00	7.59	−3.2	2.3
Arginine	Arg	R	174	2.17	9.04	12.48	10.76	−4.5	5.1
Negatively charged R groups									
Aspartate	Asp	D	133	1.88	9.60	3.65	2.77	−3.5	5.3
Glutamate	Glu	E	147	2.19	9.67	4.25	3.22	−3.5	6.3

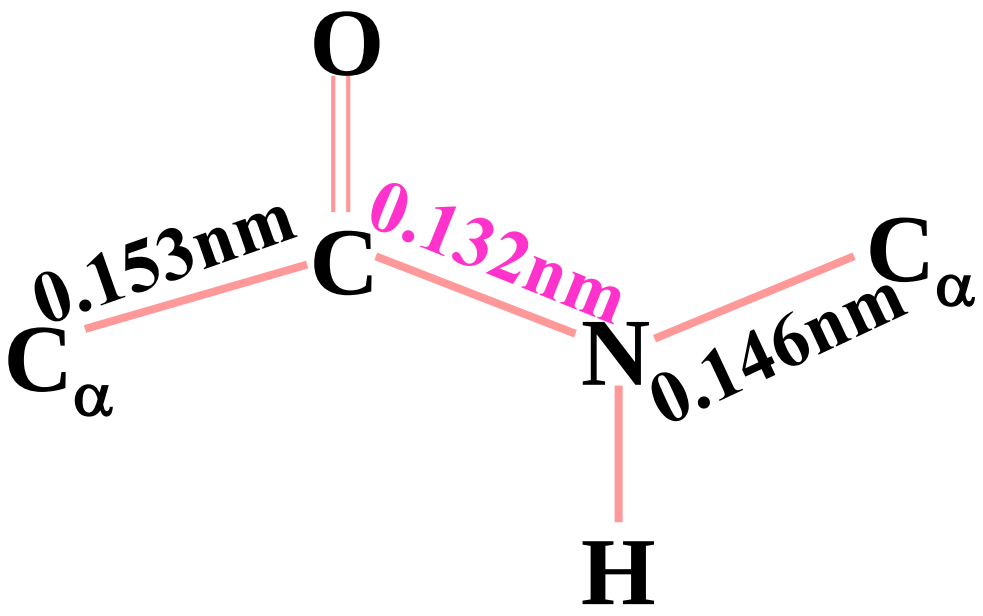
Polypeptides

Peptide bond: the special name given to the amide bond between the carboxyl group of one amino acid and the -amino group of another.

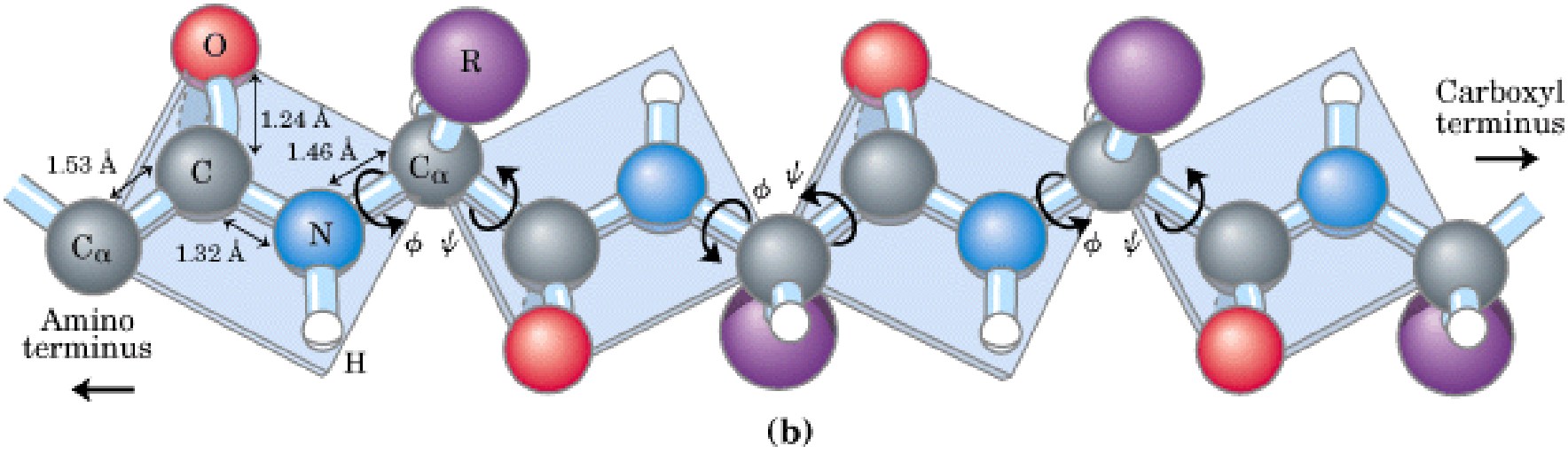


Characteristics of the peptide bond

- The peptide bond have partial double bond feature
  - about 0.132nm (C-N single bond, 0.149nm; C=N double bond, 0.127nm),
  - *rigid and unable to rotate freely*.



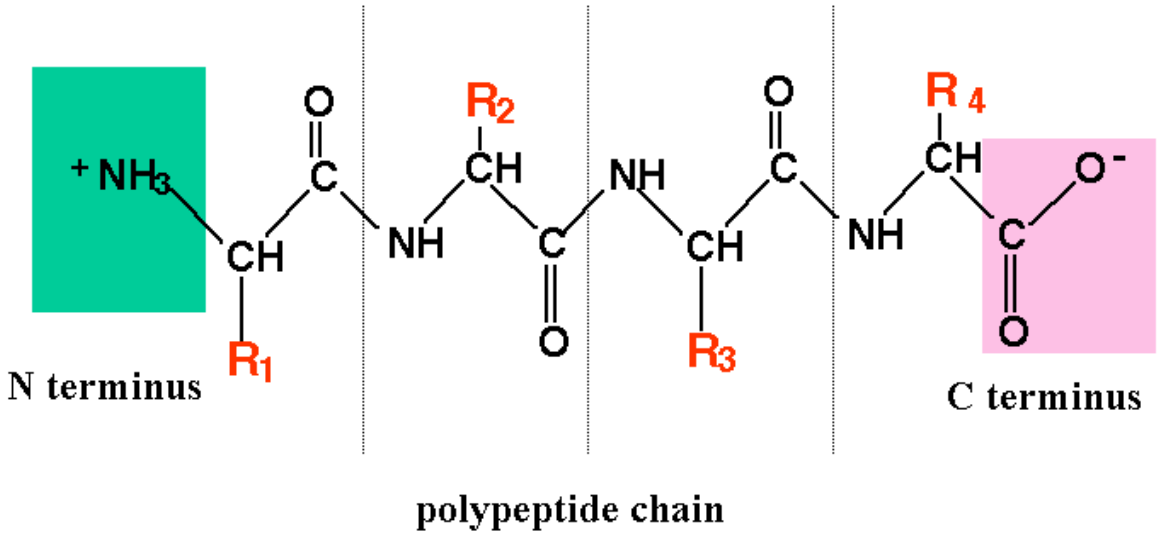
- The peptide bond is planar, trans-configuration and uncharged.
- Peptide plane: the six atoms attached to the peptide bond are coplanar.
- the carbonyl oxygen and the amide hydrogen are in trans positions.



The peptide chain is directional.

- Amino-terminal or N-terminal: the end having a free a-amino group.
- Carboxyl-terminal or C-terminal: the end having a free a-carboxyl group.
- By convention, the N-terminal is taken as the beginning of the peptide chain, and put at the left (C-terminal at the right).

Peptide = chain of amino acids

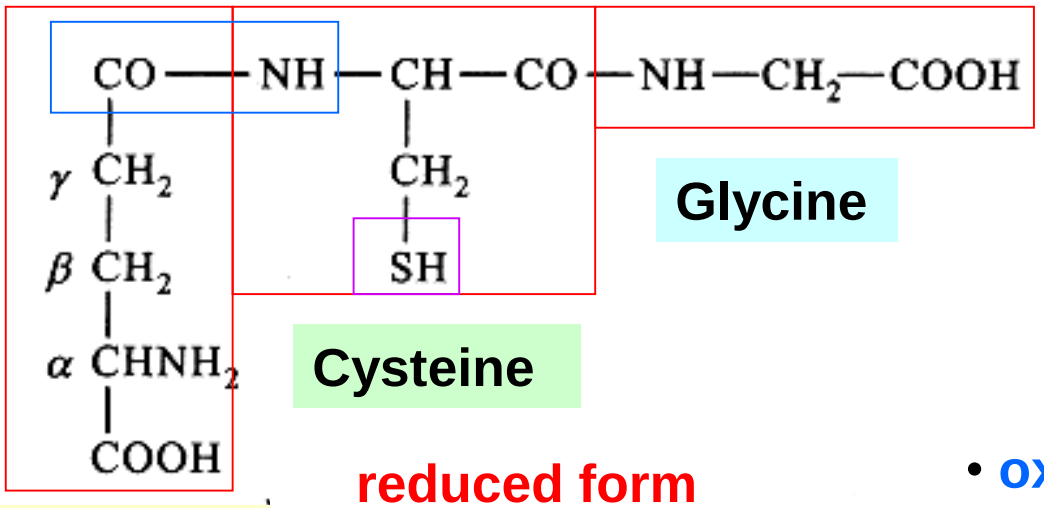


Polymers of amino acids

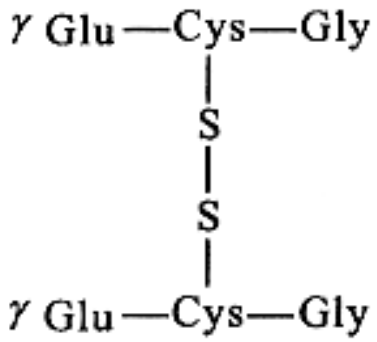
- Peptides can be classified according to how many amino acids they contain
  - Dipeptide: 2 amino acid residues, tripeptide: 3 residues, and so on
  - Oligopeptide: 12~20 residues
  - Polypeptide: many residues

Biologically important peptide

- Glutathione (GSH)
  - Tripeptide: glutamic acid, cysteine and glycine;
  - Function: important in biological oxidation-reduction reactions, has reduced and oxidized form.
  - It's the most important molecule you need to stay healthy and prevent disease.



reduced form
GSH



- oxidized form glutathione disulfide (GSSG)

Key Points

- General structure of α-amino acids
- Chiral, D- and L-forms of AAs
- The Classification of Amino Acids
  - Nonpolar, uncharged polar, aromatic, acidic and basic amino acids
- Essential amino acids
- Zwitterion, pI
- Characteristics of the peptide bond
- Glutathione (GSH): structure and function