

Macromolecule : PROTEIN

(Part 1 of 2)

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Overview

- 1. Amino acid**
- 2. Peptide bond**
3. Protein structure (Part 2)
4. Protein functions (Part 2)

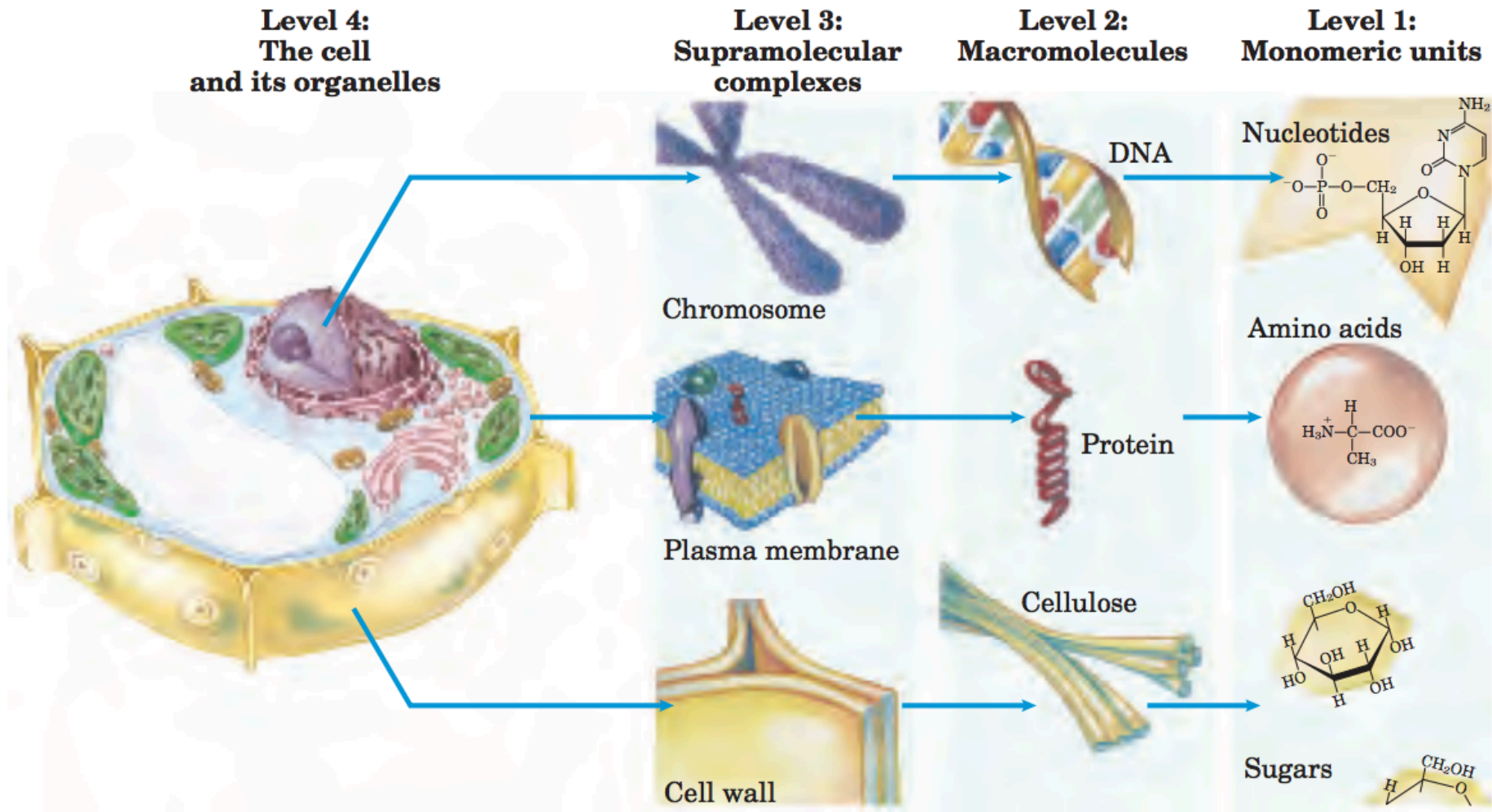
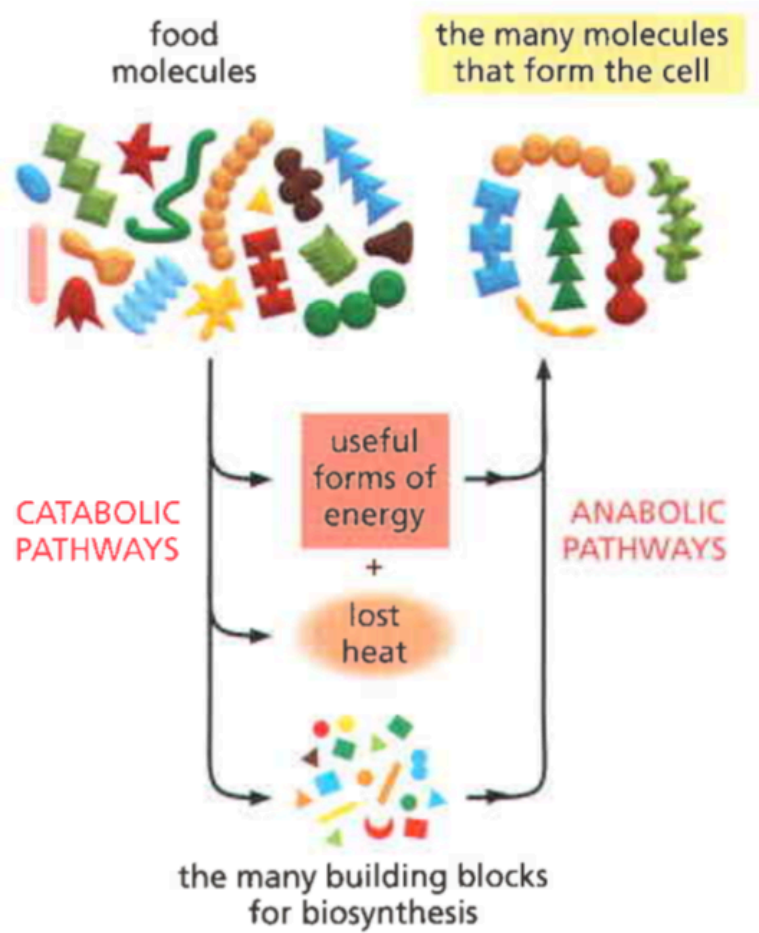


FIGURE 1-11 Structural hierarchy in the molecular organization of cells. In this plant cell, the nucleus is an organelle containing several types of supramolecular complexes, including chromosomes. Chro-

mosomes consist of macromolecules of DNA and many different proteins. Each type of macromolecule is made up of simple subunits—DNA of nucleotides (deoxyribonucleotides), for example.



Food → source of proteins, lipids and polysaccharides → enzymatic digestion → from large polymeric molecules into monomeric subunits - proteins into amino acids, polysaccharides into sugars, fats into fatty acids and glycerol → enter cytosol of cells → source of energy or as building blocks for other molecules.

THE ESSENTIAL AMINO ACIDS

- THREONINE
- METHIONINE
- LYSINE
- VALINE
- LEUCINE
- ISOLEUCINE
- HISTIDINE
- PHENYLALANINE
- TRYPTOPHAN

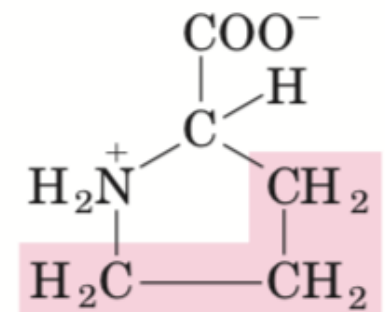
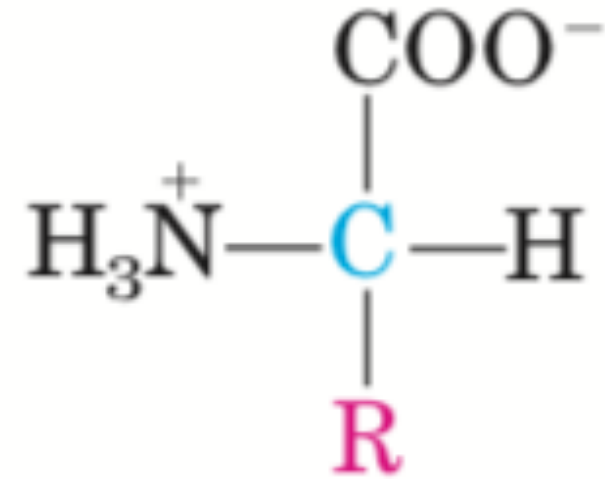
Figure 2-87 The nine essential amino acids. These cannot be synthesized by human cells and so must be supplied in the diet.

Functions of PROTEIN

- Catalysis → enzymes
- Immunity → antibodies
- Growth & development → DNA binding proteins
- Transport of metabolites → carrier proteins
- Relaying biological signals – hormones
- Biological structures → fibrous proteins
- etc

Amino acid

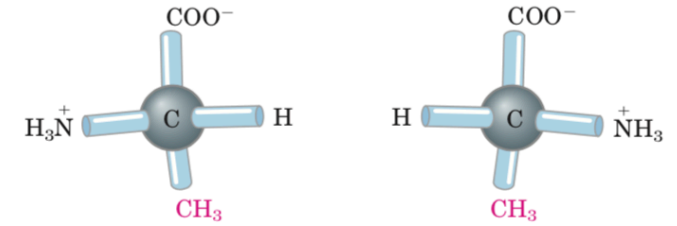
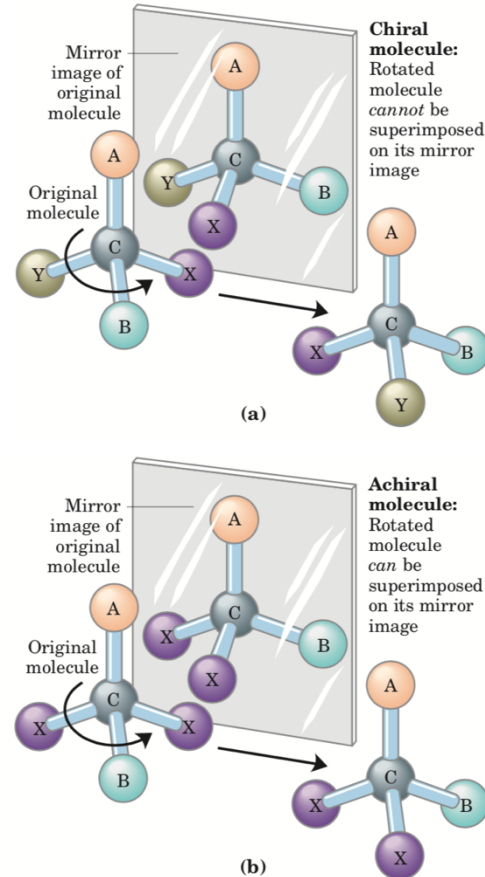
- Proteins are polymers of amino acids
- **20** different amino acids are commonly found in proteins → α -amino acids, except proline.
- **a carboxyl group** and **an amino group** bonded to the same carbon atom (the α carbon)
- Proteins differ from each other in their side chains, or **R groups**, which vary in structure, size, and electric charge, and which influence the solubility of the amino acids in water.



Proline

Only L-Amino Acids Are Found in Proteins

- The α -carbon atom is a **chiral center** \rightarrow the tetrahedral arrangement of the bonding orbitals around the α -carbon atom has the four different groups.
- Amino acids have two possible stereoisomers \rightarrow enantiomer \rightarrow nonsuperimposable mirror images of each other
- By Fischer's convention (Emil Fischer in 1891), L and D refer *only* to the absolute configuration of the four substituents around the chiral carbon, not to optical properties of the molecule.
- L-Amino acids are those with the α -amino group on the left, and D-amino acids have the α -amino group on the right.



(a) L-Alanine D-Alanine



(b) L-Alanine D-Alanine



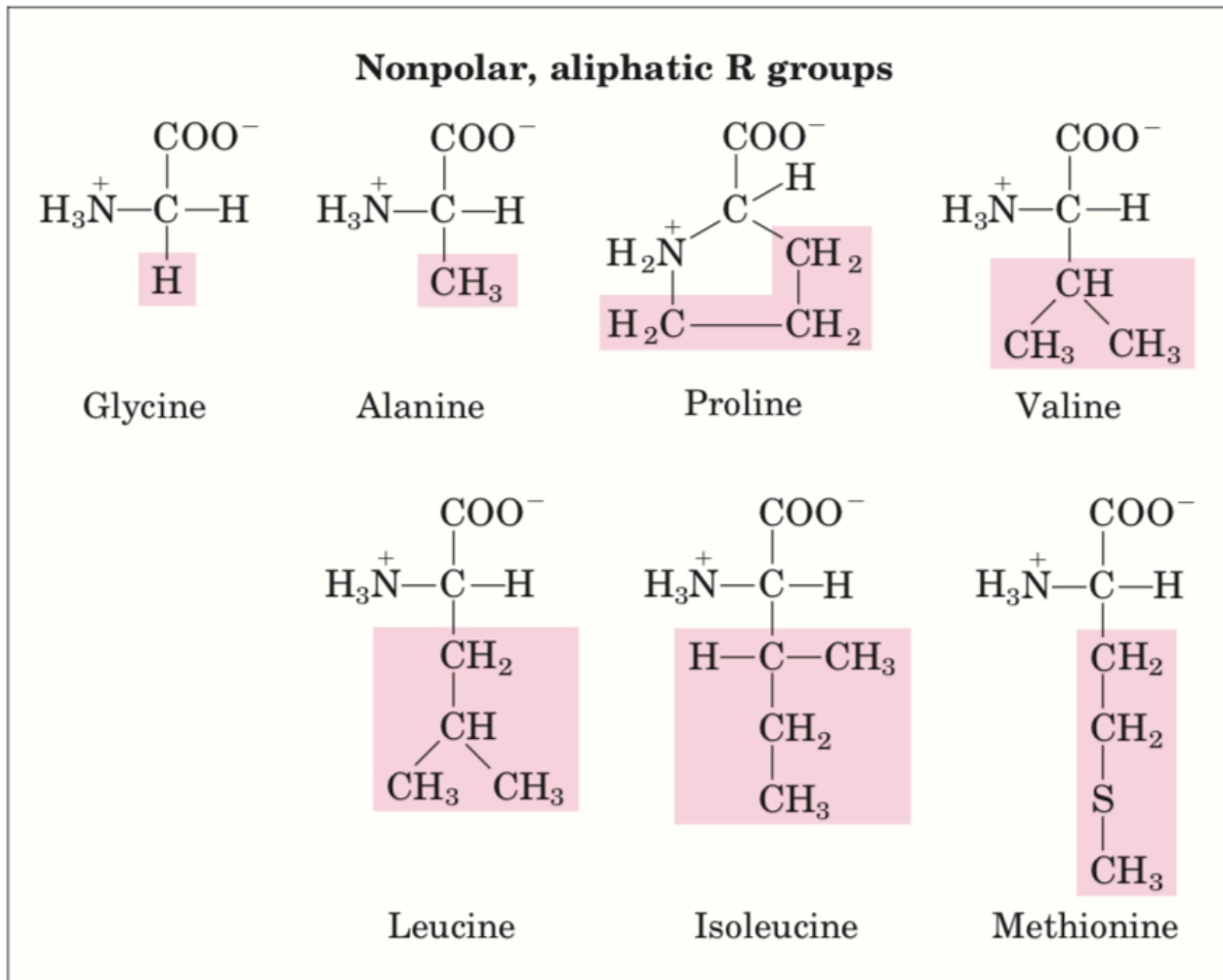
(c) L-Alanine D-Alanine

The Amino Acid Residues in Proteins Are L Stereoisomers

Cells are able to specifically synthesize the L isomers of amino acids because the active sites of enzymes are asymmetric, causing the reactions they catalyze to be stereospecific

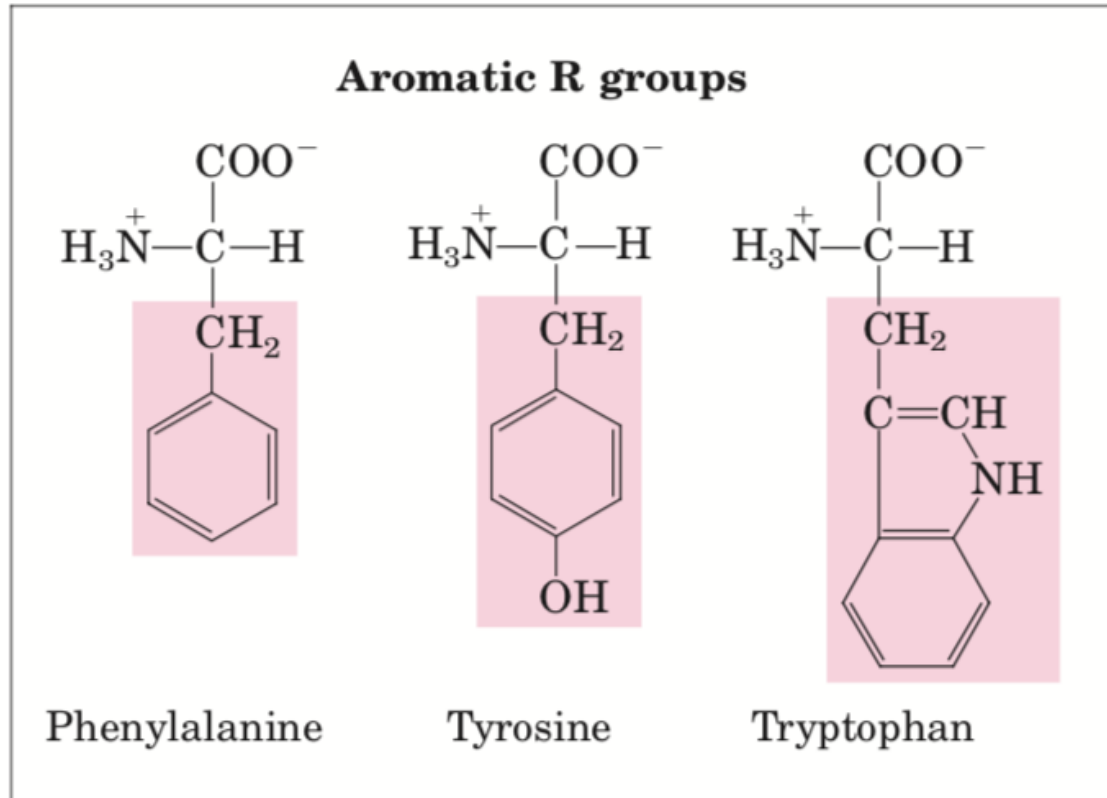
Amino Acids Can Be Classified by R Group

1. Nonpolar, Aliphatic R Groups

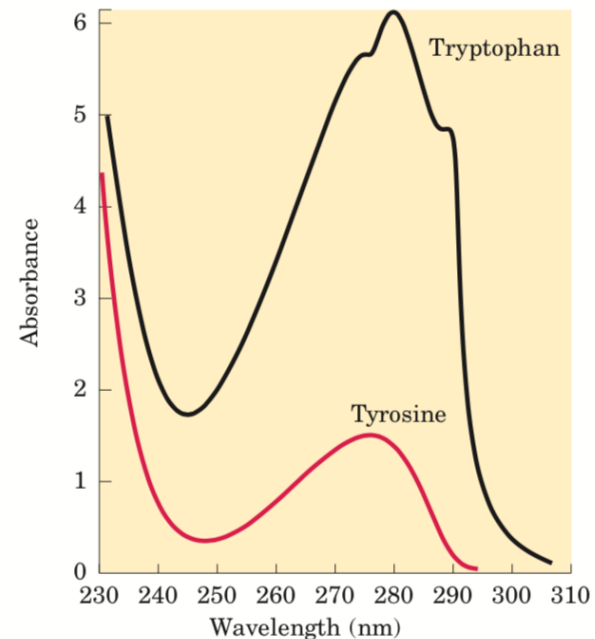


- nonpolar and hydrophobic
- **Glycine** has the simplest structure → nonpolar but no real contribution to hydrophobic interactions.
- **Methionine** → sulfur-containing amino acids, has a non-polar thioether group
- **Proline** has an aliphatic side chain with a cyclic structure.

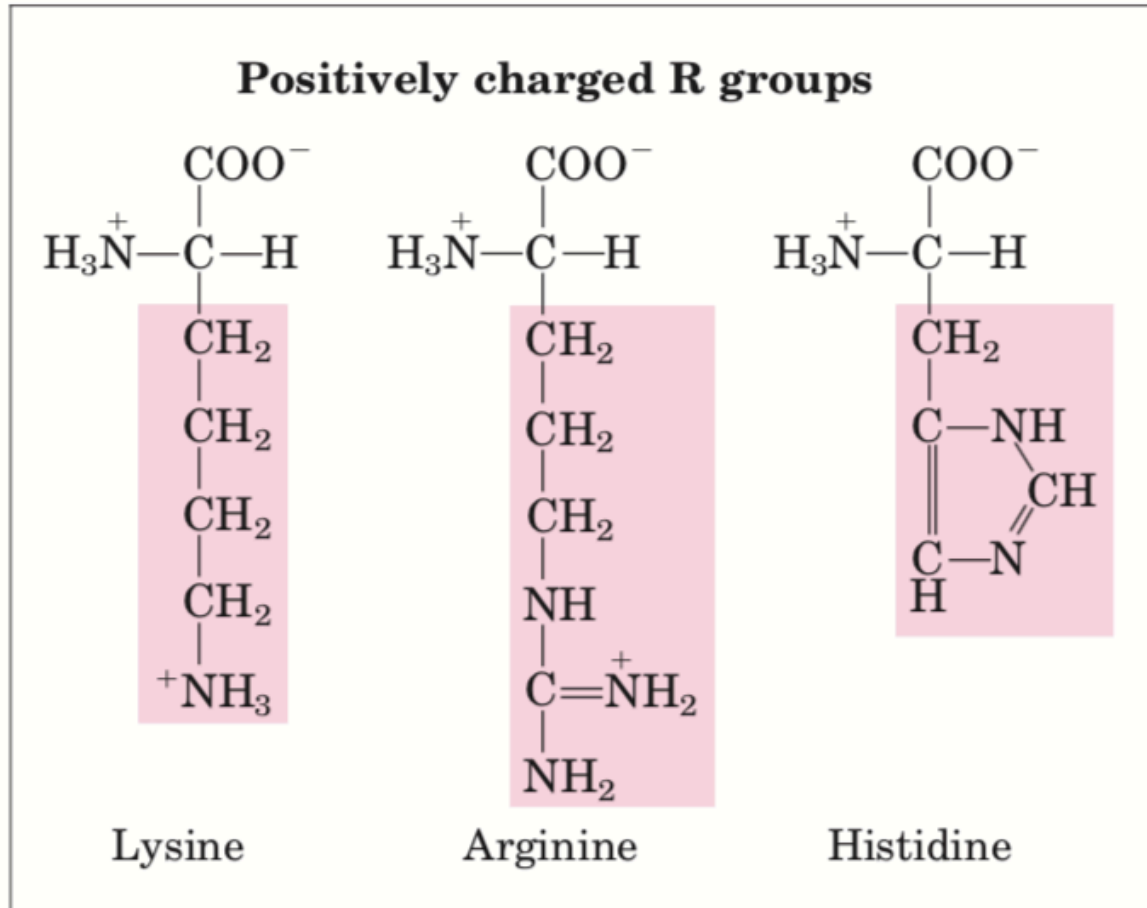
2. Aromatic R Groups



- aromatic side chains → relatively nonpolar (hydrophobic)
- The hydroxyl group of tyrosine can form hydrogen bonds → an important functional group in some enzymes
- Tryptophan and tyrosine, absorb ultraviolet light → the characteristic strong absorbance of light by most proteins at a wavelength of 280 nm



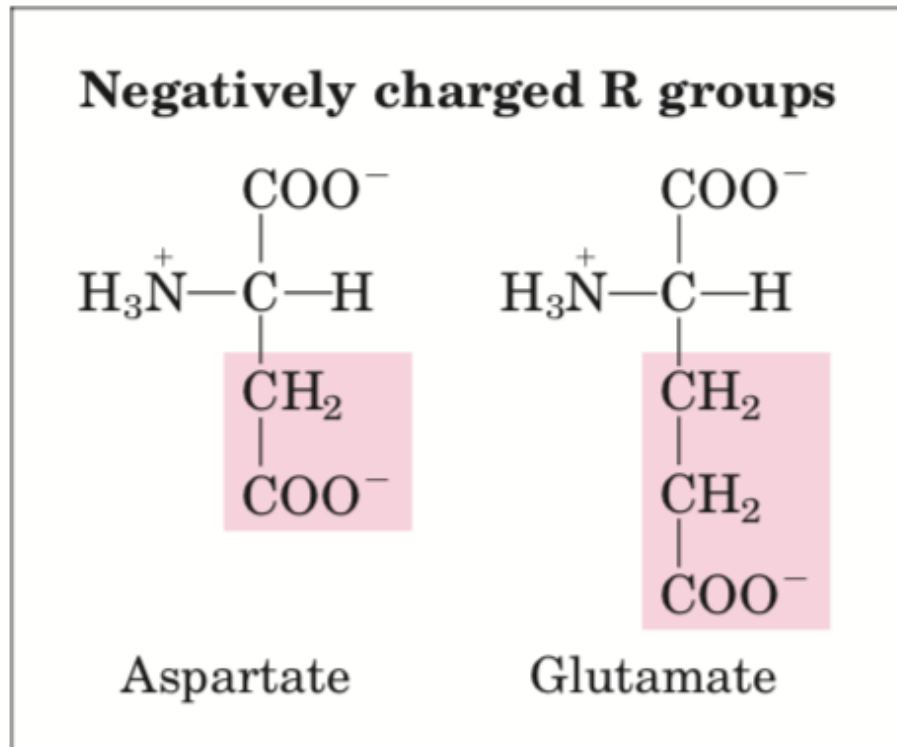
4. Positively Charged (Basic) R Groups



positively charged :

Lysine, has a second primary amino group
Arginine, has a guanidino group;
Histidine, has an imidazole group.

5. Negatively Charged (Acidic) R Groups



each of which has a second carboxyl group
→ negatively charge

TABLE 3-1 Properties and Conventions Associated with the Common Amino Acids Found in Proteins

Amino acid	Abbreviation/ symbol	M_r	pK_a values			pI	Hydropathy index*	Occurrence in proteins (%) [†]
			pK_1 (—COOH)	pK_2 (—NH ₃ ⁺)	pK_R (R group)			
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
Proline	Pro P	115	1.99	10.96		6.48	1.6	5.2
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
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

The peptides and proteins, polymers of amino acids

- Two amino acid molecules can be covalently joined through a substituted amide linkage, termed a **peptide bond**, to yield a dipeptide.
- **Oligopeptide** → a few amino acids are joined
- **polypeptide** → many amino acids are joined. MW < 10.000
- **Proteins** → have thousands of amino acid residues.
- In a peptide, the amino acid residue at the end with a free α -amino group is the **amino-terminal** (or *N*-terminal) residue; the residue at the other end, which has a free carboxyl group, is the **carboxyl-terminal** (C-terminal) residue.

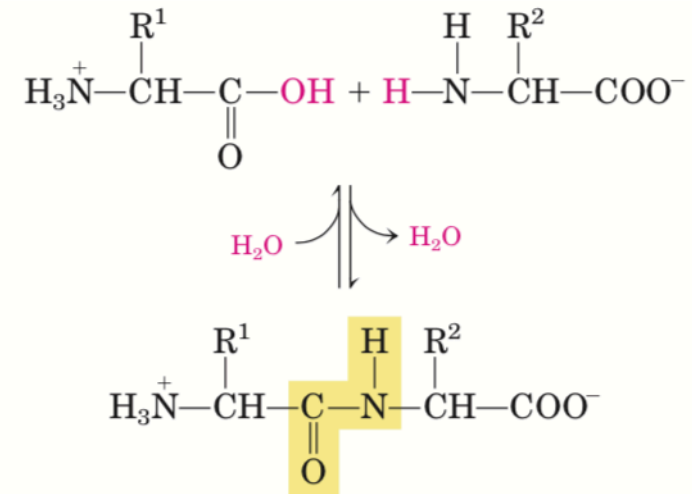
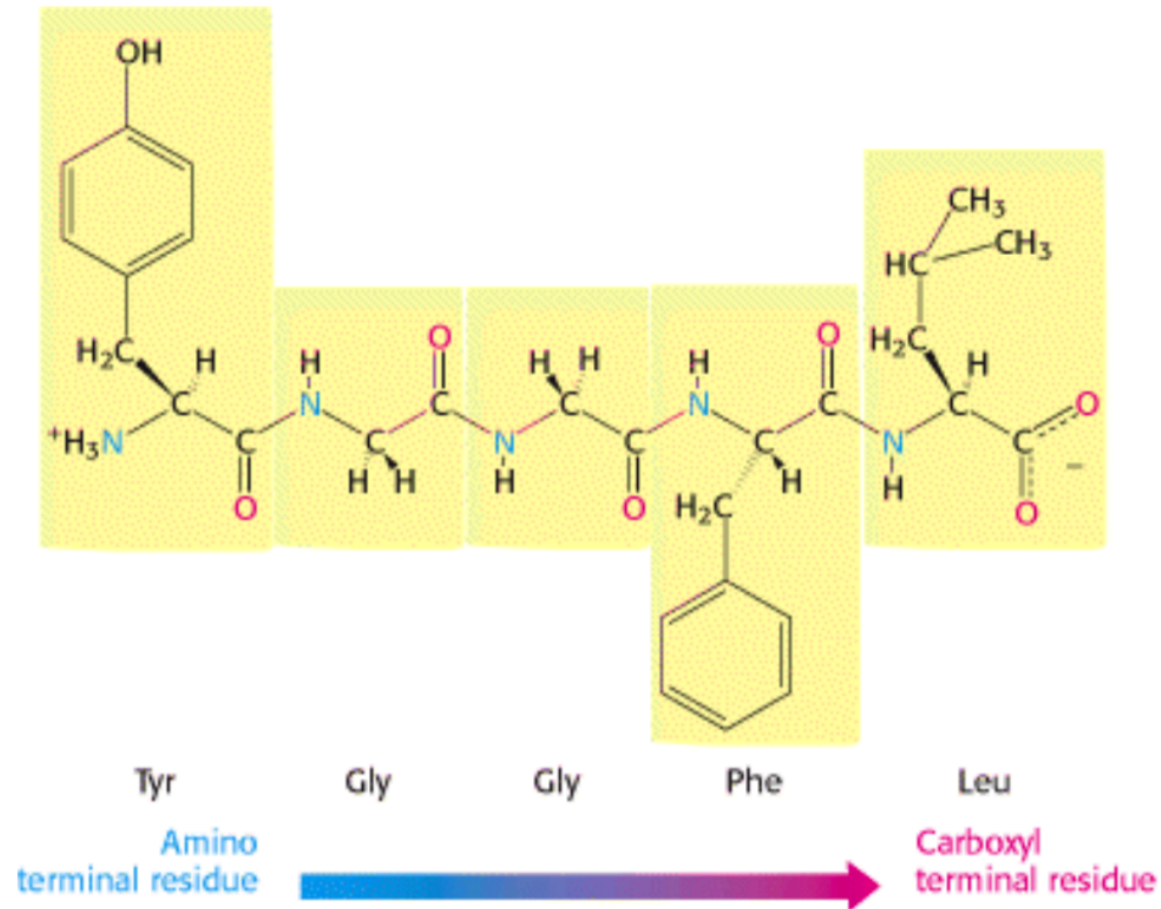


FIGURE 3-13 Formation of a peptide bond by condensation. The α -amino group of one amino acid (with R² group) acts as a nucleophile to displace the hydroxyl group of another amino acid (with R¹ group), forming a peptide bond (shaded in yellow). Amino groups are good nucleophiles, but the hydroxyl group is a poor leaving group and is not readily displaced. At physiological pH, the reaction shown does not occur to any appreciable extent.

By convention, *the amino end is taken to be the beginning of a polypeptide chain*



Pentapeptide (YGGFL) → Leu-enkephalin
→ an opioid peptide that modulates the perception of pain.

the sequence of amino acids in a polypeptide chain is written starting with the aminoterminal residue.

TABLE 3-2 Molecular Data on Some Proteins

	<i>Molecular weight</i>	<i>Number of residues</i>	<i>Number of polypeptide chains</i>
Cytochrome c (human)	13,000	104	1
Ribonuclease A (bovine pancreas)	13,700	124	1
Lysozyme (chicken egg white)	13,930	129	1
Myoglobin (equine heart)	16,890	153	1
Chymotrypsin (bovine pancreas)	21,600	241	3
Chymotrypsinogen (bovine)	22,000	245	1
Hemoglobin (human)	64,500	574	4
Serum albumin (human)	68,500	609	1
Hexokinase (yeast)	102,000	972	2
RNA polymerase (<i>E. coli</i>)	450,000	4,158	5
Apolipoprotein B (human)	513,000	4,536	1
Glutamine synthetase (<i>E. coli</i>)	619,000	5,628	12
Titin (human)	2,993,000	26,926	1

- The mean molecular weight of an amino acid residue is about 110.
- The mass of a protein is expressed in units of daltons; one *dalton* is equal to one atomic mass unit
→ A unit of mass very nearly equal to that of a hydrogen atom John Dalton (1766-1844)
- A protein with a molecular weight of 50,000 has a mass of 50,000 daltons, or 50 kd (kilodaltons)

Recommended video for learning

- <https://www.youtube.com/watch?v=wvTv8TqWC48>
- <https://www.youtube.com/watch?v=qBRFIMcxZNM>
- <https://www.youtube.com/watch?v=2BsnnhMC0Ms>

References

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