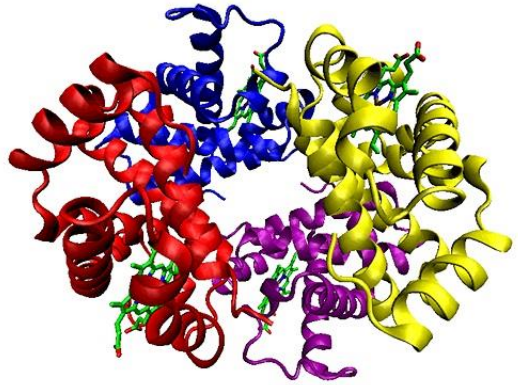
2302106 – Basic Organic Chemistry for ISE – Part II

Lecture 7-2

Biomolecules - Protein



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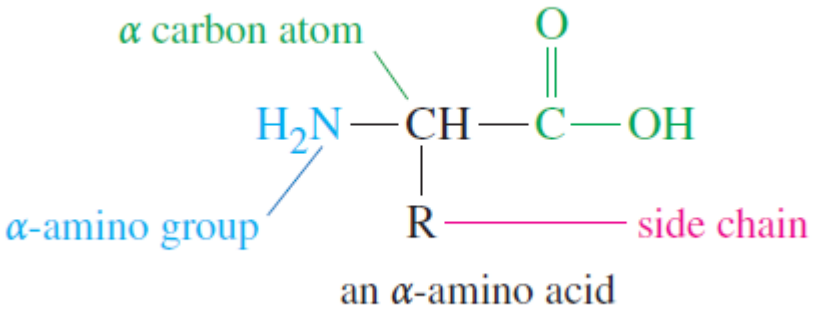
Recommended Textbook:

Chapter 23 and 25 in *Organic Chemistry*, 8th Edition, L. G. Wade, Jr., **2010**, Prentice Hall (Pearson Education)

Protein

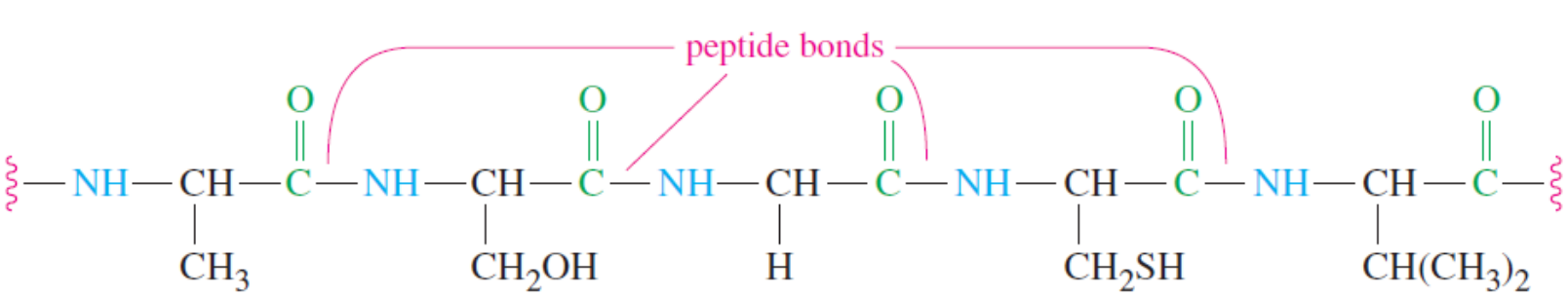
- Proteins are the **most abundant** organic molecules in **animals**, playing important roles in all aspects of cell structure and function

- Proteins are **biopolymers** of ***α*-amino acids**, so named because the amino group is bonded to the *α* carbon atom, next to the carbonyl group



an α-amino acid

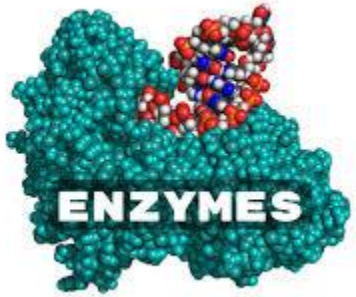
- The individual amino acid subunits are joined by **amide linkages** called **peptide bonds**

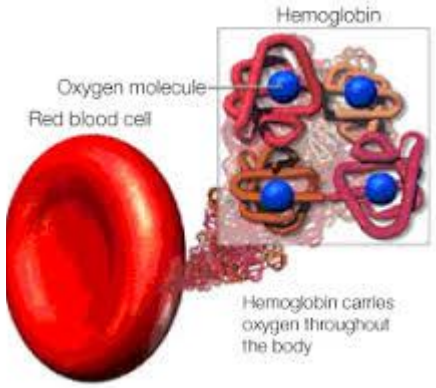


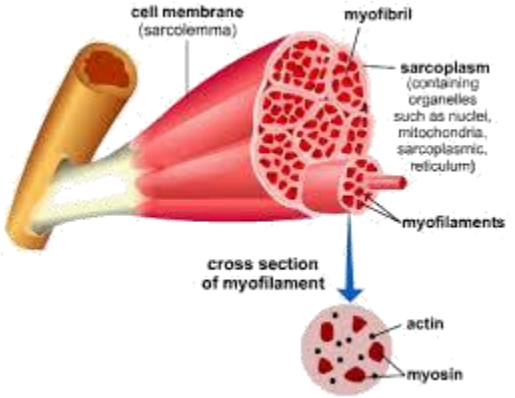
a short section of a protein

Protein – Examples

Class of Protein	Example	Function of Example
structural proteins	collagen, keratin	strengthen tendons, skin, hair, nails
enzymes	DNA polymerase	replicates and repairs DNA
transport proteins	hemoglobin	transports O_2 to the cells
contractile proteins	actin, myosin	cause contraction of muscles
protective proteins	antibodies	complex with foreign proteins
hormones	insulin	regulates glucose metabolism
toxins	snake venoms	incapacitate prey



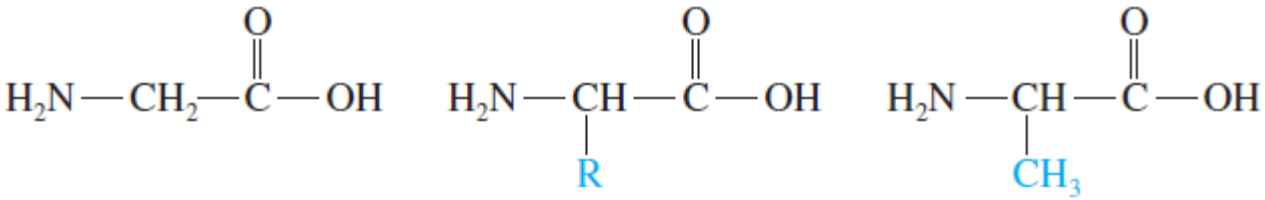




α-Amino Acids

- The term amino acid might mean any molecule containing both an **amino group** and any type of **acid group**; however, the term is almost always used to refer to an ***α*-amino carboxylic acid**

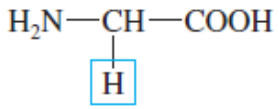
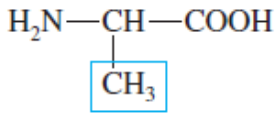
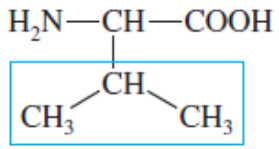
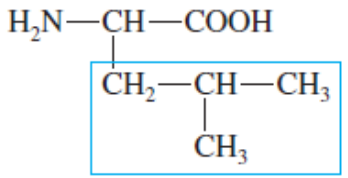
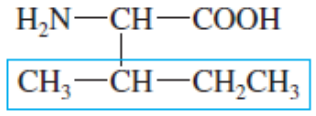
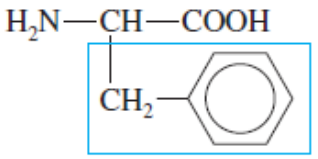
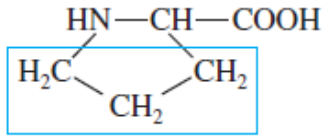
- The simplest *α*-amino acid is **aminoacetic acid**, called **glycine**. Other common amino acids have **side chains** (symbolised by **R**) substituted on the ***α* carbon;** for example, **alanine** is the amino acid with a **methyl side chain**



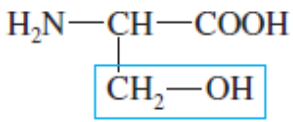
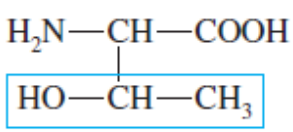
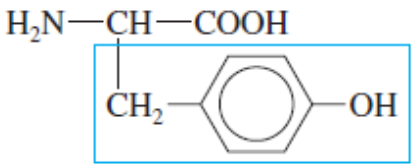
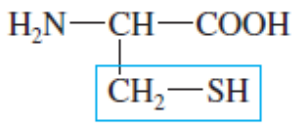
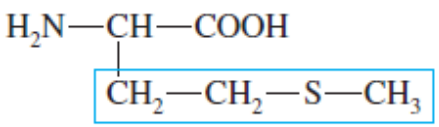
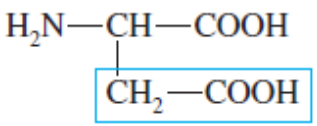
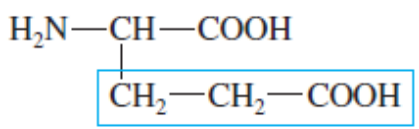
glycine | a substituted amino acid | alanine (R = CH_3)

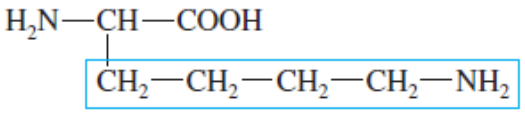
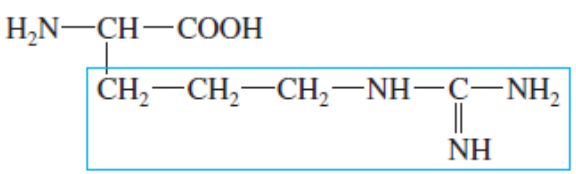
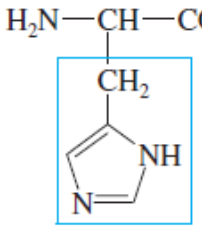
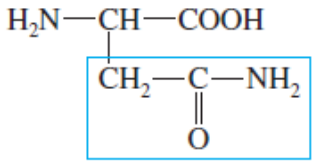
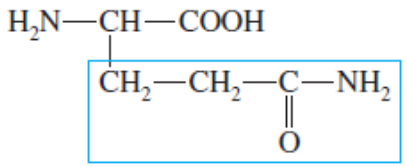
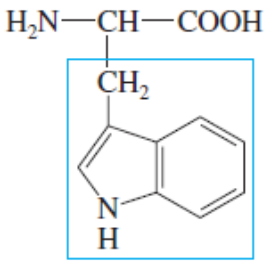
Standard α-Amino Acids

20 standard amino acids, grouped according to the chemical properties of side chains

Name	Symbol	Abbreviation	Structure	Functional Group in Side Chain	Isoelectric Point
side chain is nonpolar, H or alkyl					
glycine	G	Gly		none	6.0
alanine	A	Ala		alkyl group	6.0
*valine	V	Val		alkyl group	6.0
*leucine	L	Leu		alkyl group	6.0
*isoleucine	I	Ile		alkyl group	6.0
*phenylalanine	F	Phe		aromatic group	5.5
proline	P	Pro		rigid cyclic structure	6.3

*essential amino acid

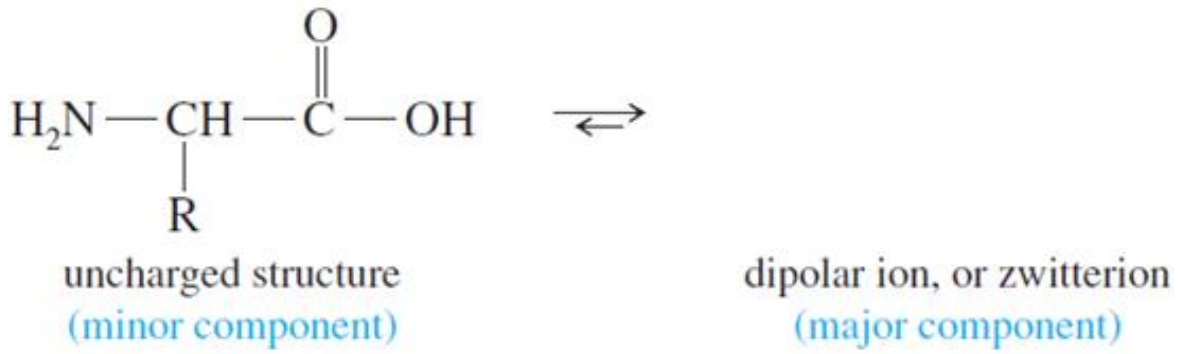
Name	Symbol	Abbreviation	Structure	Functional Group in Side Chain	Isoelectric Point
side chain contains an —OH					
serine	S	Ser		hydroxyl group	5.7
*threonine	T	Thr		hydroxyl group	5.6
tyrosine	Y	Tyr		phenolic —OH group	5.7
side chain contains sulfur					
cysteine	C	Cys		thiol	5.0
*methionine	M	Met		sulfide	5.7
side chain is acidic					
aspartic acid	D	Asp		carboxylic acid	2.8
glutamic acid	E	Glu		carboxylic acid	3.2

Name	Symbol	Abbreviation	Structure	Functional Group in Side Chain	Isoelectric Point
side chain is basic					
*lysine	K	Lys		amino group	9.7
*arginine	R	Arg		guanidino group	10.8
*histidine	H	His		imidazole ring	7.6
side chain contains nonbasic nitrogen					
asparagine	N	Asn		amide	5.4
glutamine	Q	Gln		amide	5.7
*tryptophan	W	Trp		indole	5.9

α-Amino Acids – Acid-Base Properties

- Although we commonly write amino acids with an intact carboxyl –COOH group and amino –NH_2 group, their actual structure is **ionic** and **depends on the pH**

- The carboxyl group loses a proton, giving a **carboxylate ion**, and the amino group is protonated to an **ammonium ion**. This structure is called a **zwitterion,** giving them some **unusual properties**

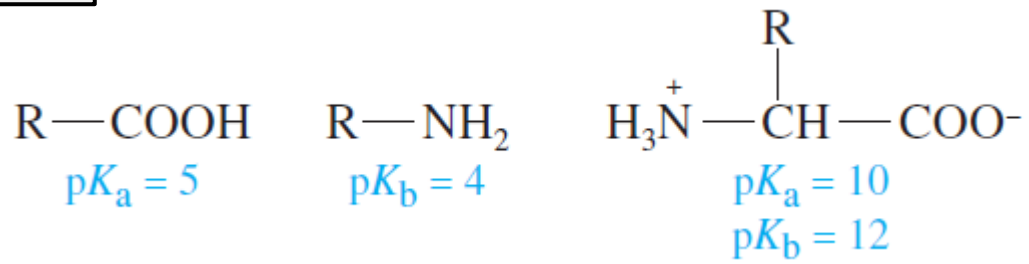


1) More **soluble in water** than they are in common organic solvents

2) high melting points, generally over 200 °C

3) much **larger dipole moments** than simple amines or simple acids

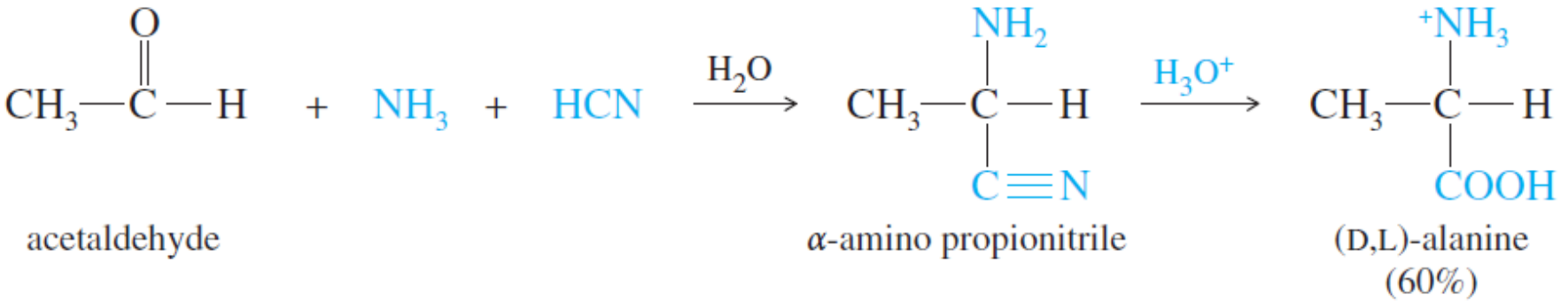
4) Less acidic than most carboxylic acids and **less basic than most amines**



α-Amino Acids – Synthesis

The Strecker Synthesis; formation of amino acids from appropriate aldehydes

The Strecker synthesis of alanine



acetaldehyde

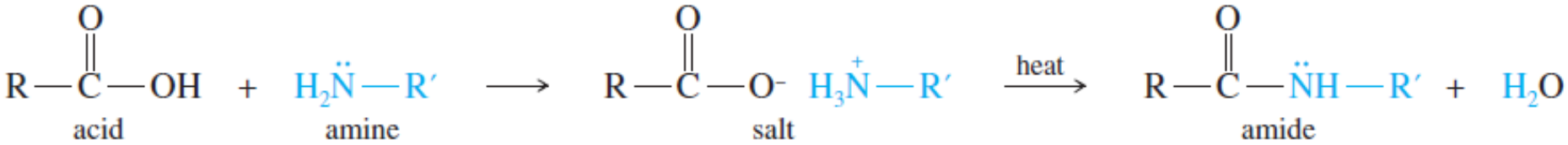
α-amino propionitrile

(D,L)-alanine
(60%)

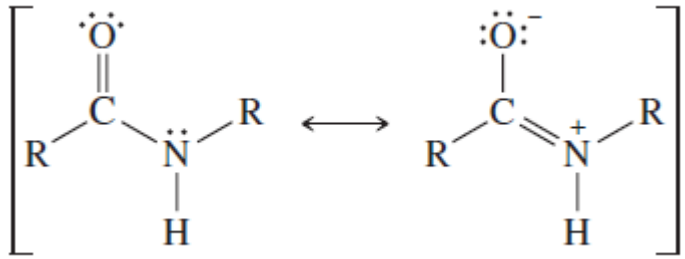
Mechanism:

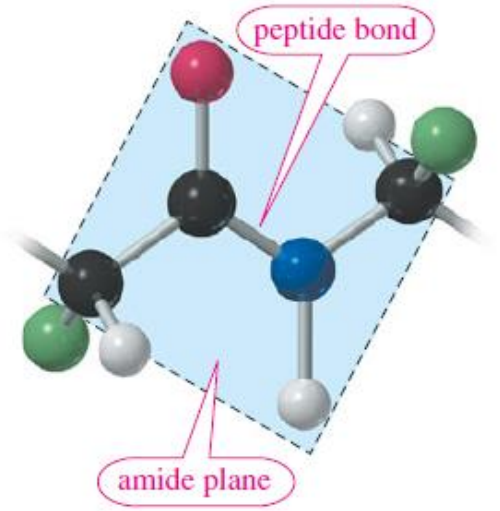
Peptides

- **Amines** and **acids** can condense, with the loss of water, to form **amides**



- Amides are the **most stable** acid derivatives. This stability is partly due to the strong **resonance interaction** between the nonbonding electrons on nitrogen and the carbonyl group

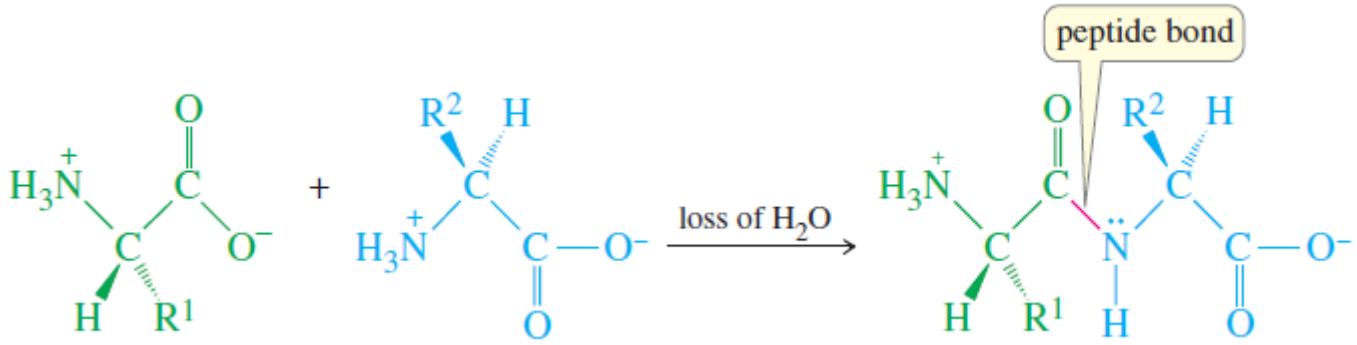




- The amide linkage between the amino acids is called a **peptide bond**

Peptides

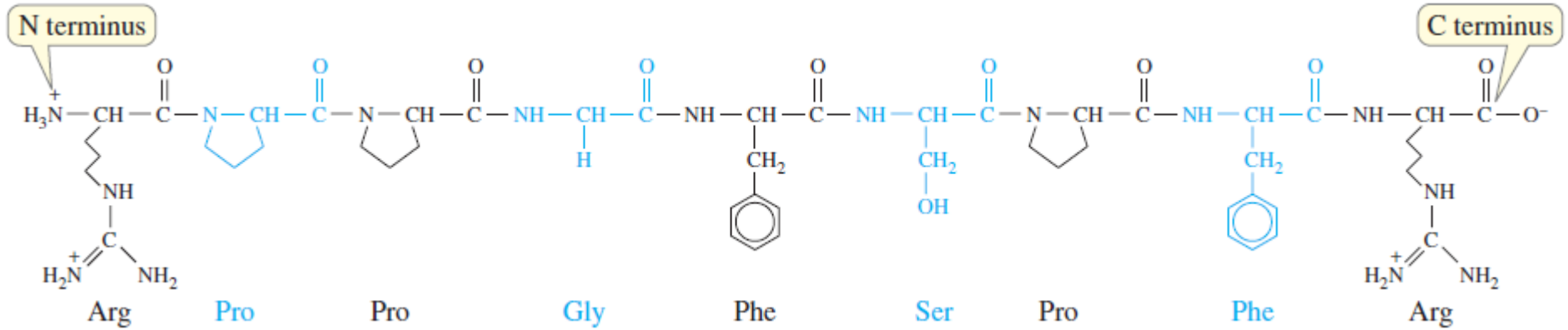
- A **peptide** is a compound containing two or more amino acids linked by amide bonds
- Under the proper conditions, the amino group of one amino acid condenses with the carboxyl group of another
- The product is an amide called a ***dipeptide*** because it consists of two amino acids



- A **polypeptide** is a peptide containing many amino acid residues but usually having a molecular weight of less than about **5000**
- **Proteins** contain more amino acid units, with molecular weights ranging from about **5000** to about **40,000,000**

Peptides

- Nonapeptide **bradykinin**, a human hormone that helps to control blood pressure

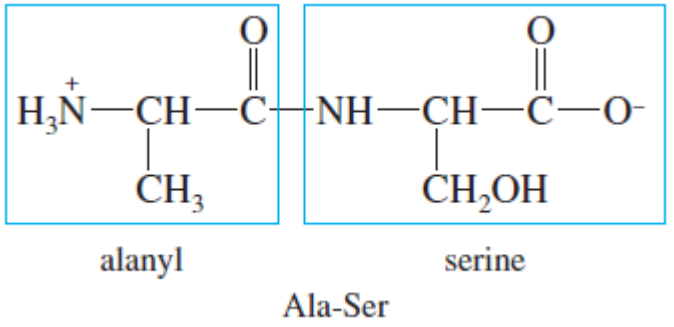


- The end of the peptide with the free amino group ($-NH_3^+$) is called the **N terminus**
- The end with the free carboxyl group ($-CO_2^-$) is called the **C terminus**

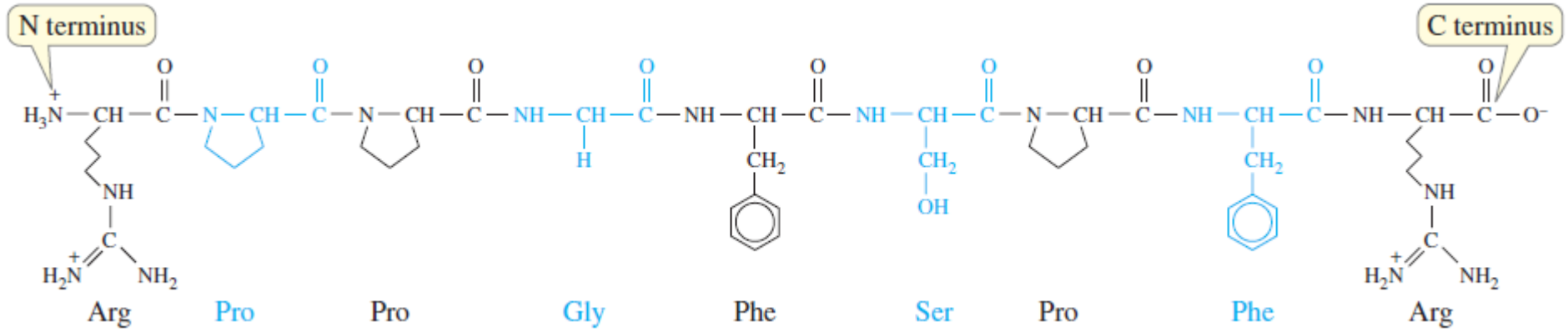
- Peptide structures are generally drawn with the **N terminus at the left** and the **C terminus at the right**

Peptides – Nomenclature

- The names of peptides reflect the names of the **amino acid residues** involved in the amide linkages, **beginning at the N terminus**; All **except the last** are given the ***-yl* suffix** of acyl groups



alanylserine



arginyl prolyl prolyl glycyl phenylalanyl seryl prolyl phenylalanyl arginine

- A **shorthand system** is more convenient, representing each amino acid by its three-letter abbreviation : **Arg-Pro-Pro-Gly-Phe-Ser-Pro-Phe-Arg**

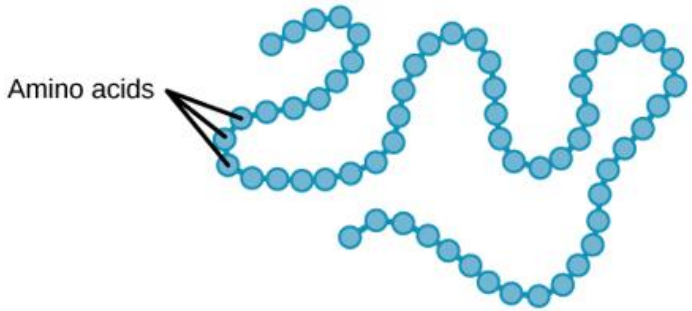
- **Single-letter symbols** are becoming widely used as well : **RPPGFSPFR**

Proteins – Structure

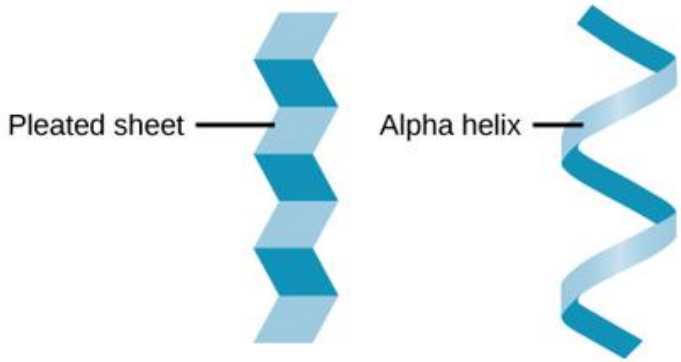
- **Proteins** contain more amino acid units, with molecular weights ranging from about **5000** to about **40,000,000**

Level of Protein Structure:

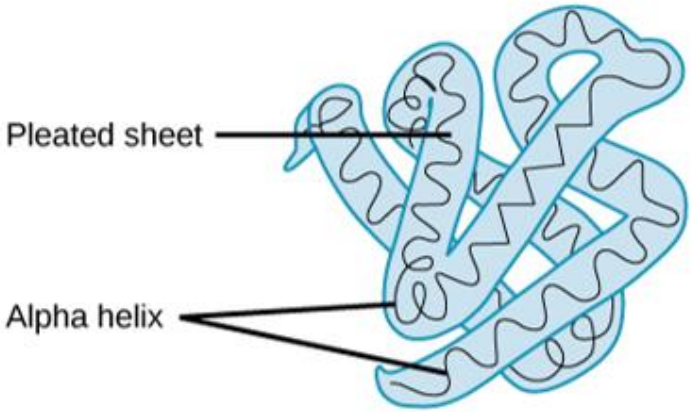
1) Primary: sequence of a chain of amino acids



2) Secondary: folding of peptide into a repeating pattern due to H-bonding of peptide backbone



3) Tertiary: three dimensional folding pattern due to side chain interaction



4) Quaternary: protein that consists of more than one peptide chain

Proteins – Classification

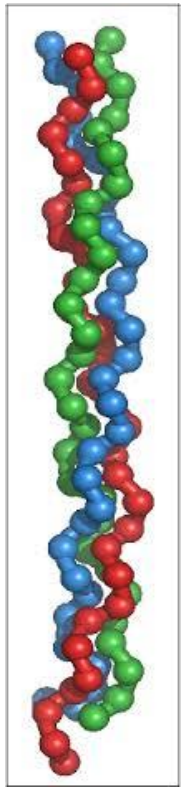
- Proteins may be classified according to their **chemical composition**, their **shape**, or their **function**
- By **chemical composition :** ***simple*** and ***conjugated*** proteins
  - ***Simple proteins***: those that hydrolyse to give **only amino acids**
  - ***Conjugated proteins***: bonded to a nonprotein **prosthetic group** such as a sugar, a nucleic acid, a lipid, or some other group

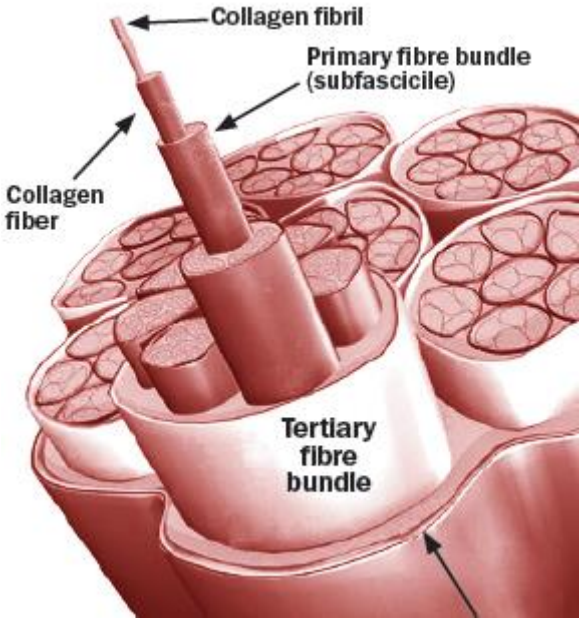
TABLE 24-3 Classes of Conjugated Proteins

Class	Prosthetic Group	Examples
glycoproteins	carbohydrates	γ-globulin, interferon
nucleoproteins	nucleic acids	ribosomes, viruses
lipoproteins	fats, cholesterol	high-density lipoprotein
metalloproteins	a complexed metal	hemoglobin, cytochromes

Proteins – Classification

- By **shape :** ***fibrous*** and ***globular*** proteins



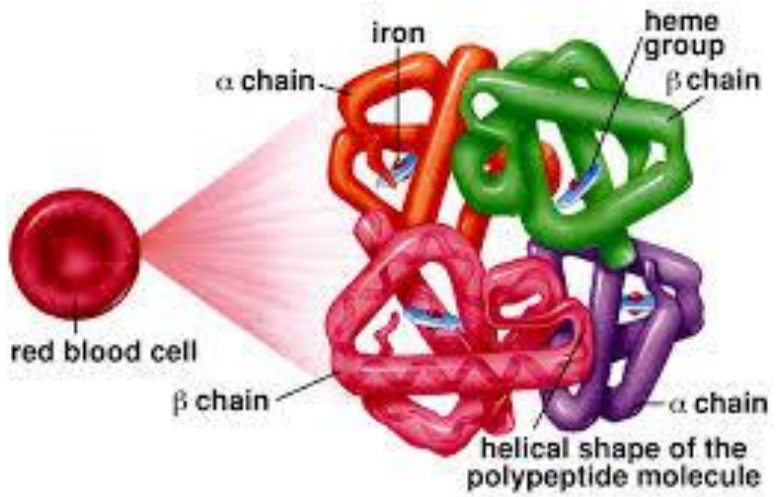


- ***Fibrous proteins***: stringy, tough, and usually insoluble in water. They function primarily as **structural parts** of the organism

Examples : *α*-keratin in hooves and fingernails, and collagen in tendons

- ***Globular proteins***: are folded into roughly spherical shapes. They usually function as **enzymes**, **hormones**, or **transport** proteins

Transport proteins bind to specific molecules and transport them in the blood or through the cell membrane; for example, **hemoglobin** transports oxygen in the blood



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Keywords:

α-Amino Acids

- Structure
- Side chains
- Acid-base properties
- Synthesis

Peptides and Proteins

- Peptide bond
- Nomenclature
- Level of protein structure
- Functions