Hogeschool van Arnhem en Nijmegen
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Course bi5b chemistry: Chapter 18
Amino acids and proteins



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Reference

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Fundamentals of General, Organic, and Biological

Chemistry

Seventh Edition

John McMurry
Cornell University

David S. Ballantine
Northern Illinois University

Carl A. Hoeger
University of California, San Diego

Virginia E. Peterson
University of Missouri, Columbia

PEARSON

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Voorkennis / eerder besproken

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- 18.1: Introductie biochemie
- 18.2: Proteïne structuur & functie
- 18.3: Aminozuren
- 18.4: Zuur-base eigenschappen van aminozuren (Zwitterionen)
- 18.5: Chiraliteit (“handedness”)
- 18.6: Moleculaire chiraliteit & aminozuren
- 18.7: Primaire proteïne structuur

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(Reference: Chapter18 from McMurry et al.)

Studiewijzer

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- 18.8
  - je weet welke interacties in eiwitten de ruimtelijke structuur bepalen
    - waterstofbruggen
    - ion-interacties (zoutbruggen)
    - hydrofobe interacties
    - zwavelbruggen

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(Reference: Chapter18 from McMurry et al.)

Studiewijzer

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- 18.9
  - je kan uitleggen wat de secundaire structuur van een eiwit is
    - alfa-helix en beta-plaat

- 18.10
  - je kan uitleggen wat de tertiaire structuur van een eiwit is
    - natief eiwit
    - geconjugeerd eiwit

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(Reference: Chapter18 from McMurry et al.)

Studiewijzer

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- 18.11
  - je kan uitleggen wat de quaternaire structuur van een eiwit is

- 18.12
  - je kent de chemische eigenschappen van een eiwit
    - hydrolyse
    - denatureren

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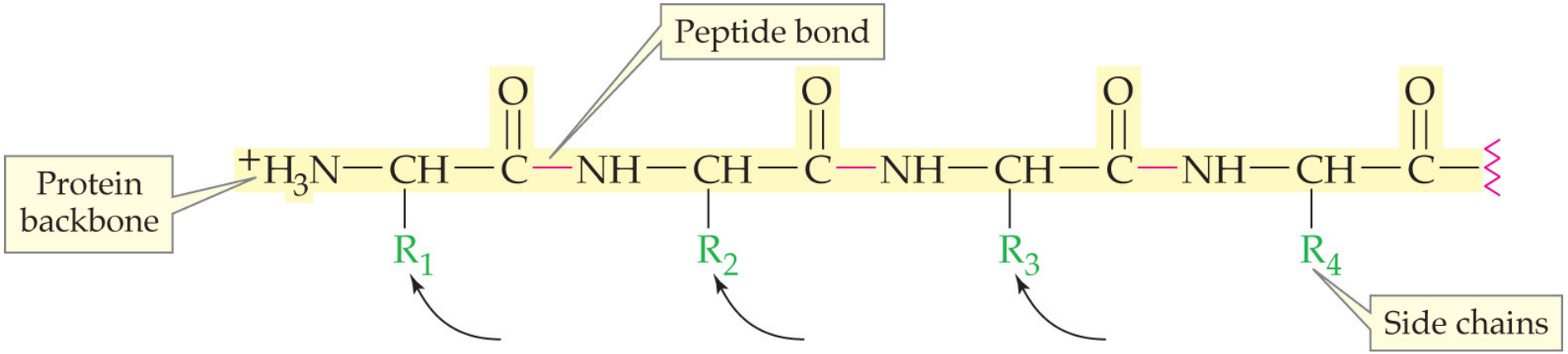
(Reference: Chapter18 from McMurry et al.)

18.7 Primaire structuur (“flashback”)

- **De volgorde waarin de aminozuren gekoppeld zijn.**



De peptideband is VLAK (“flashback”)

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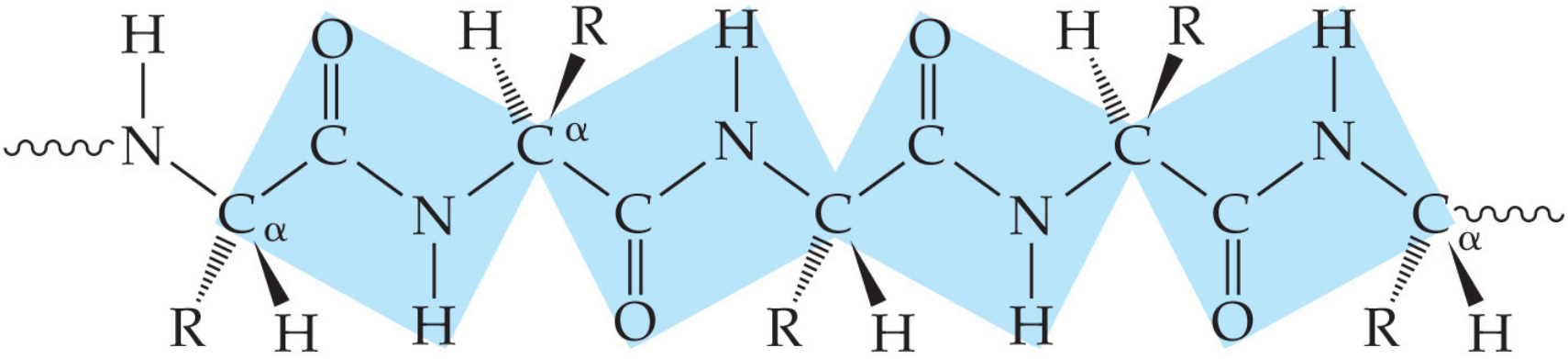
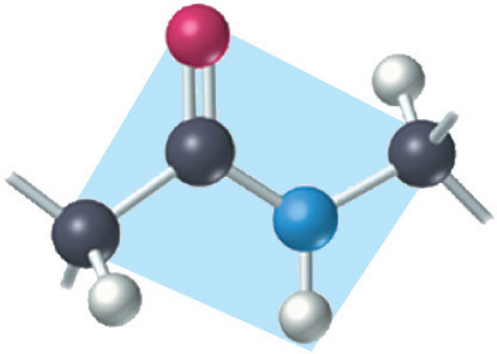
Planar units along a protein chain





18.8 Interacties in eiwitten

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- waterstofbruggen
- ion-interacties (zoutbruggen)
- hydrofobe interacties
- zwavelbruggen

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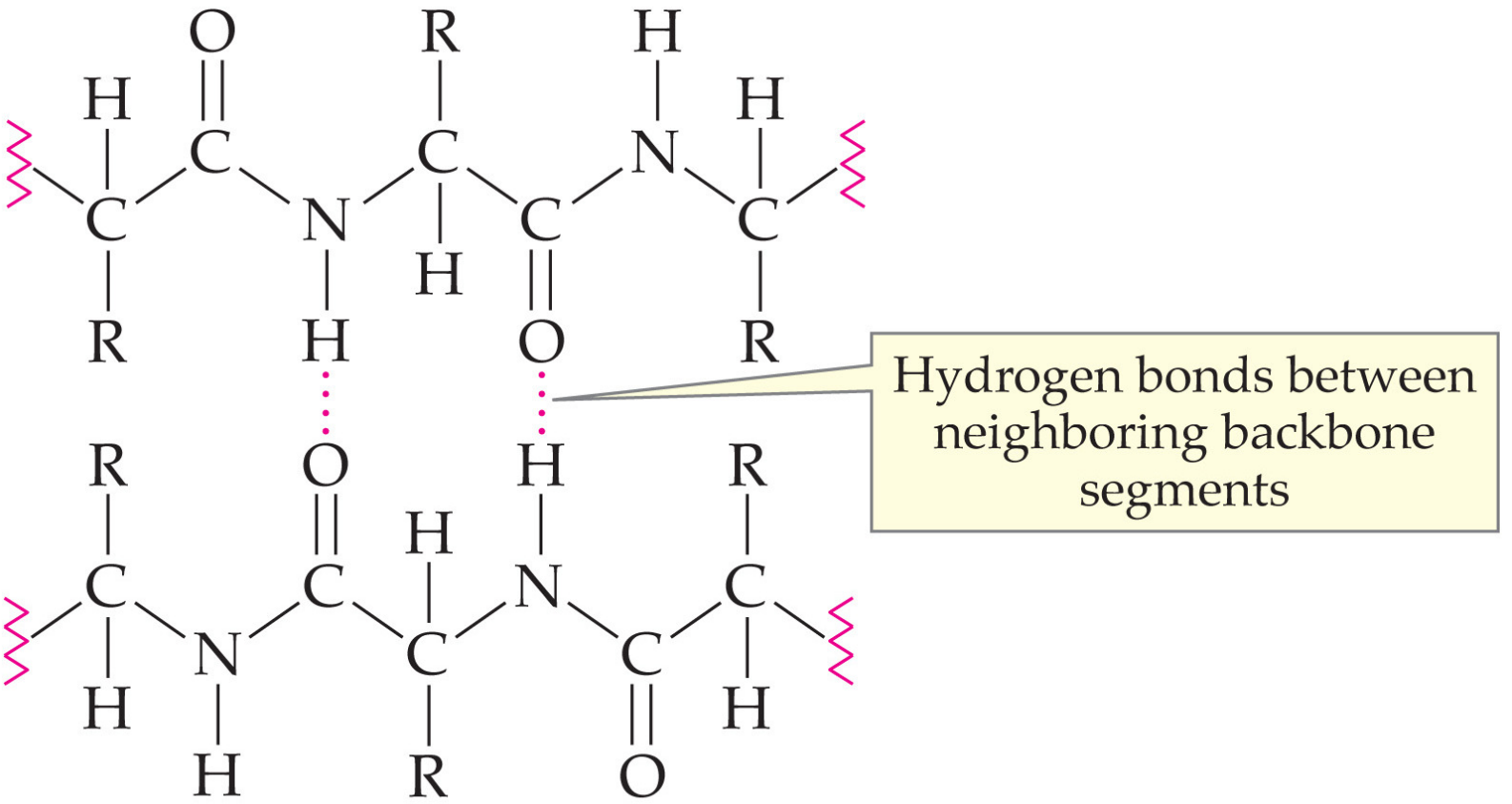
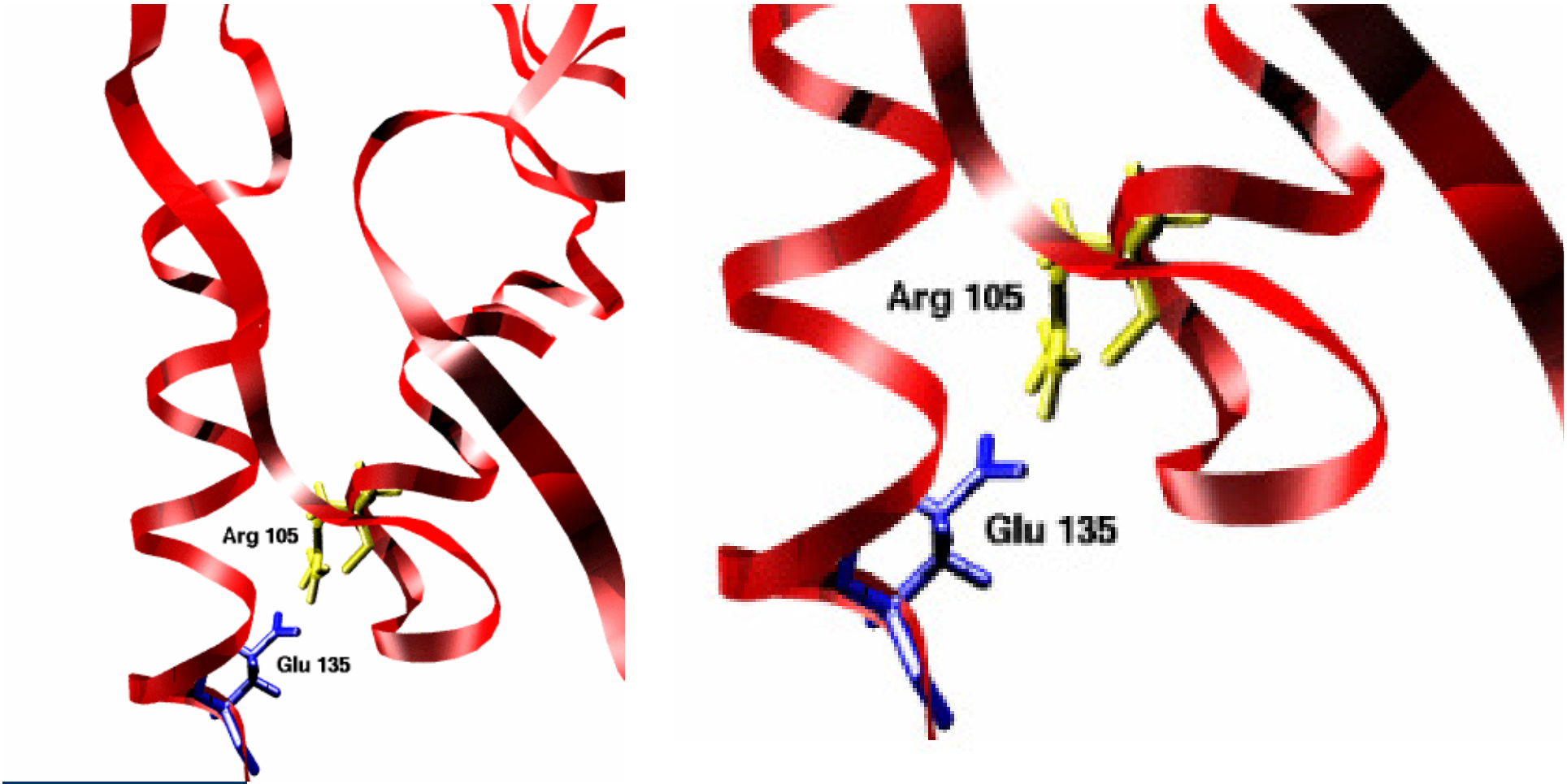
(Reference: Chapter18 from McMurry et al.)

18.8.1 Waterstofbruggen



(Reference: Chapter18 from McMurry et al.)

18.8.2 Zoutbruggen



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(Reference: Chapter18 from McMurry et al.)

18.8.3 Zoutbrug vs waterstofbrug

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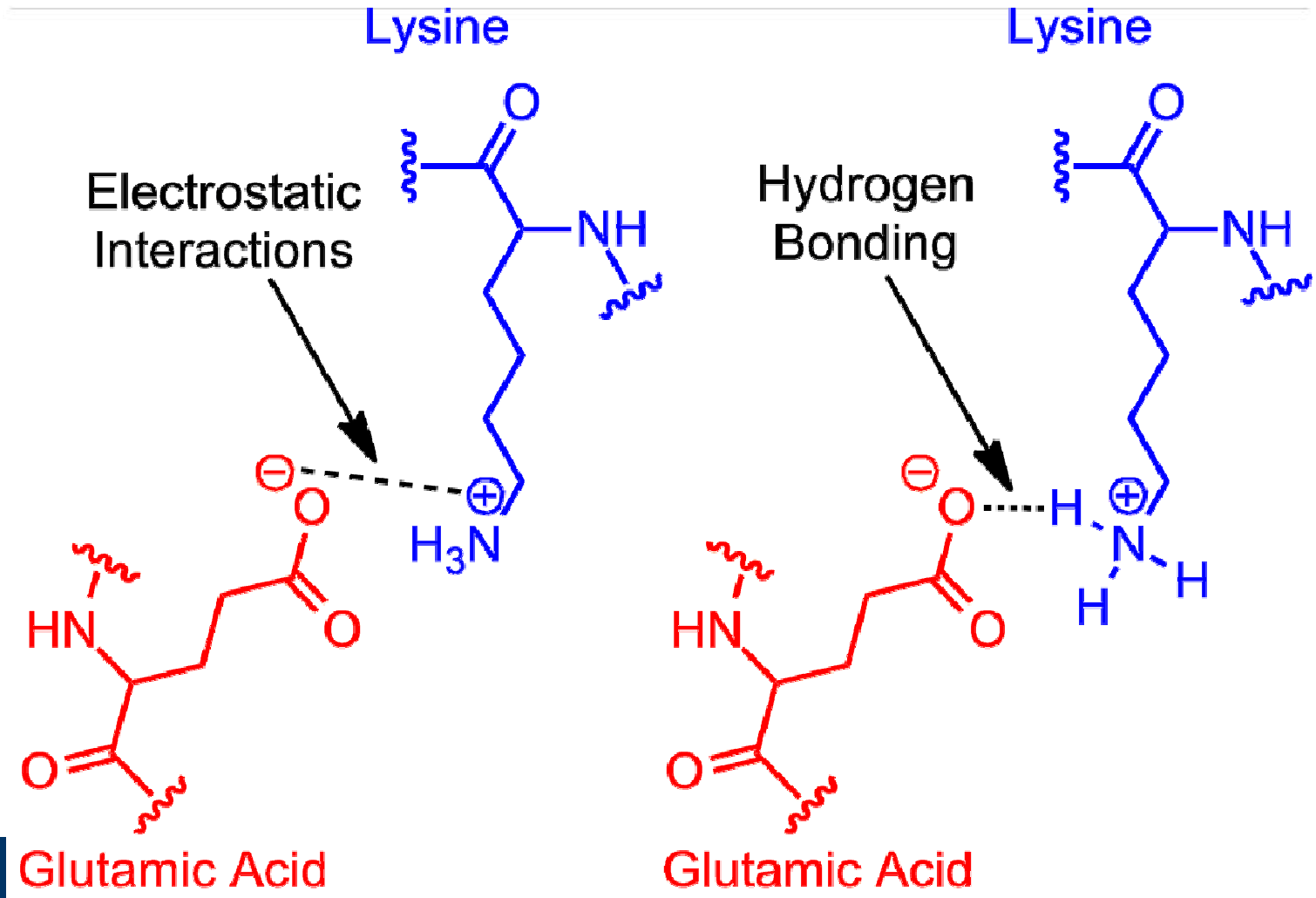

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a **salt bridge** is a combination of two noncovalent interactions: **hydrogen bonding** and **electrostatic interactions**.

(Reference: https://en.wikipedia.org/wiki/Salt_bridge_(protein_and_supramolecular)

18.8.4 Hydrofobe interacties

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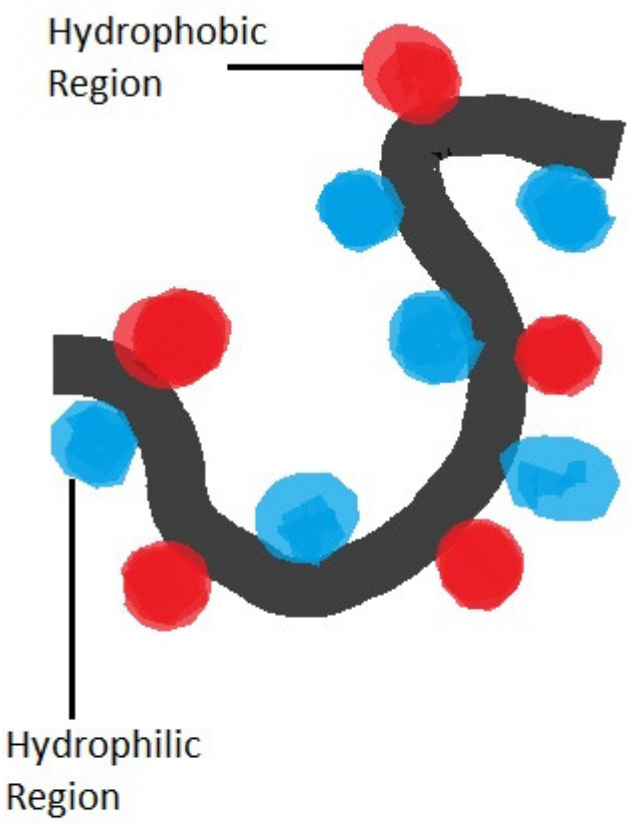

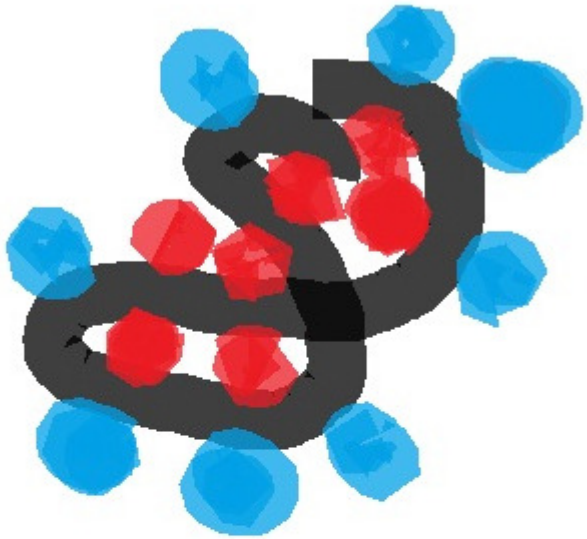

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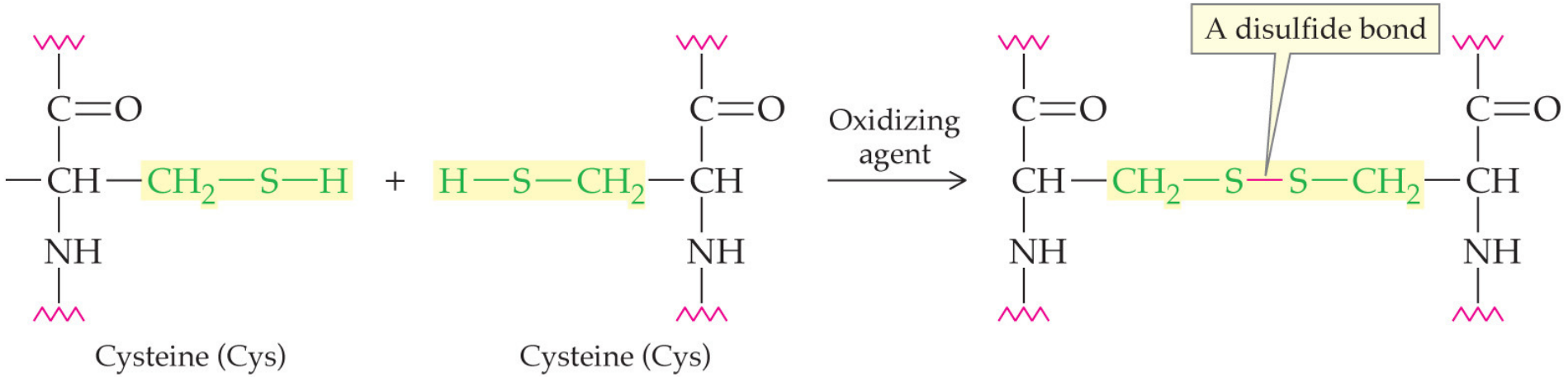
Isolated Protein

Protein in aqueous solution

(Reference: Chapter18 from McMurry et al.)

18.8.5 Zwavelbruggen



$$2\ RSH \rightleftharpoons RS\text{–}SR + 2\ H^+ + 2\ e^-$$

18.8.6 Zwavelbruggen

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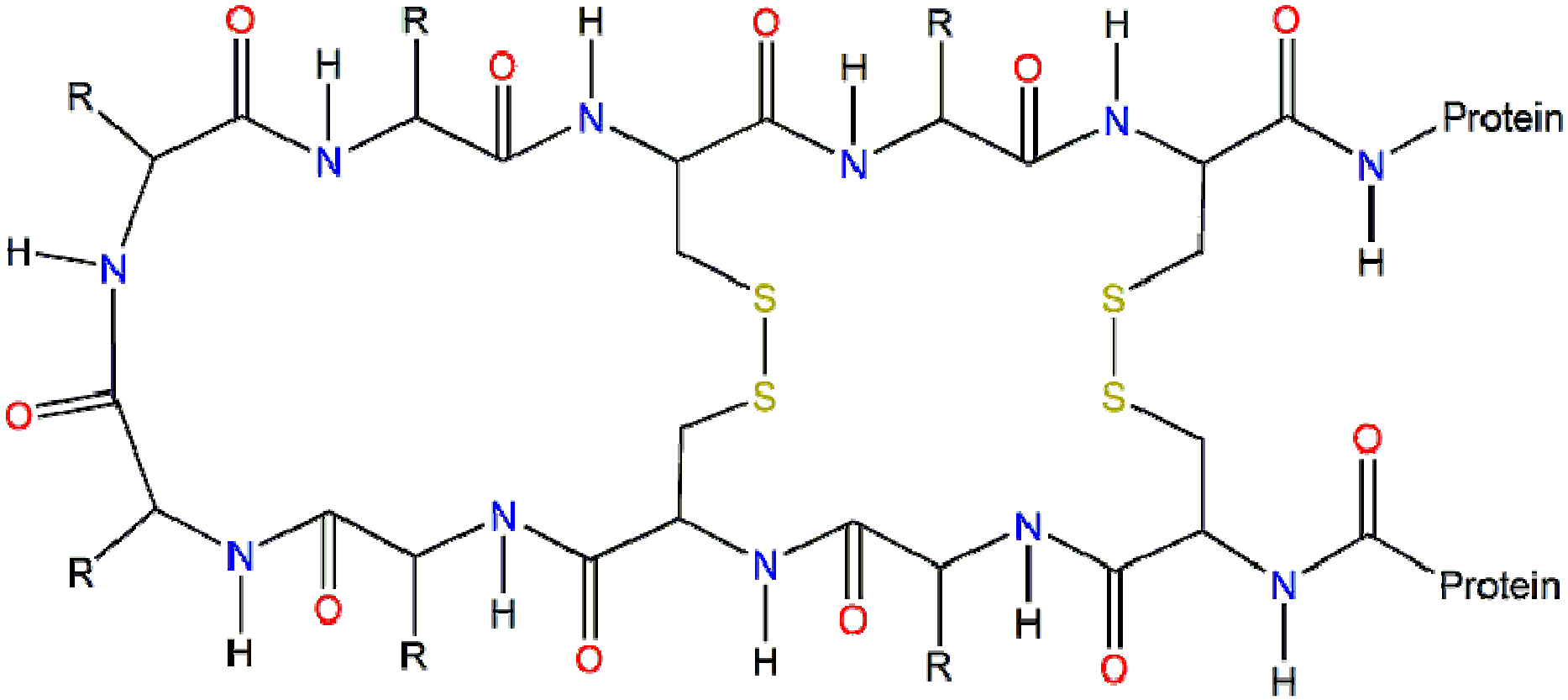

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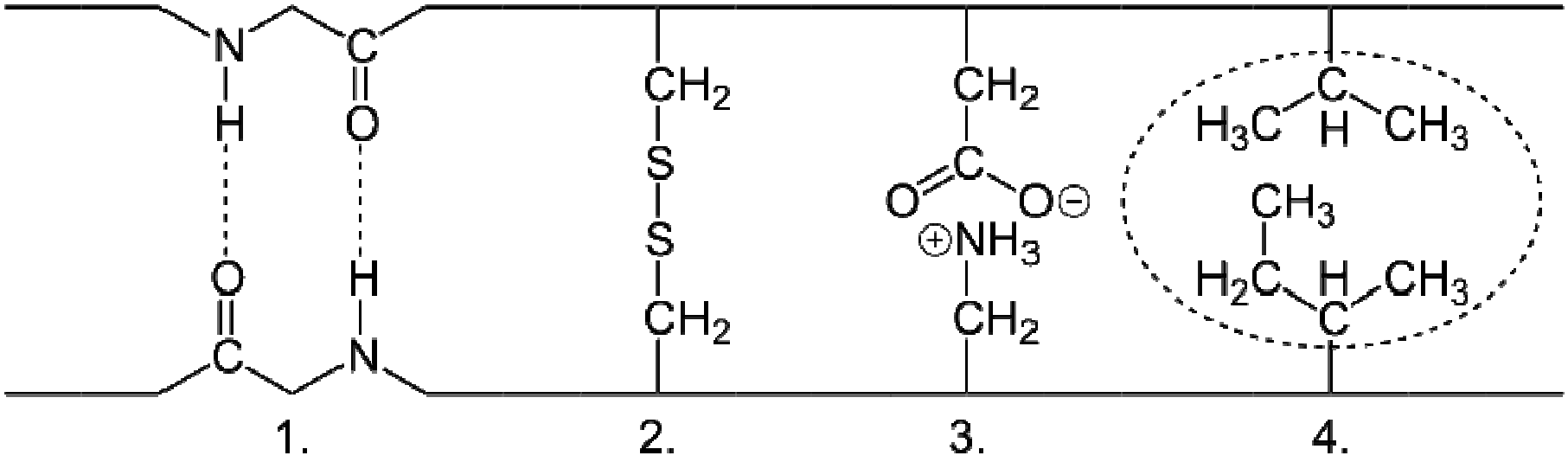
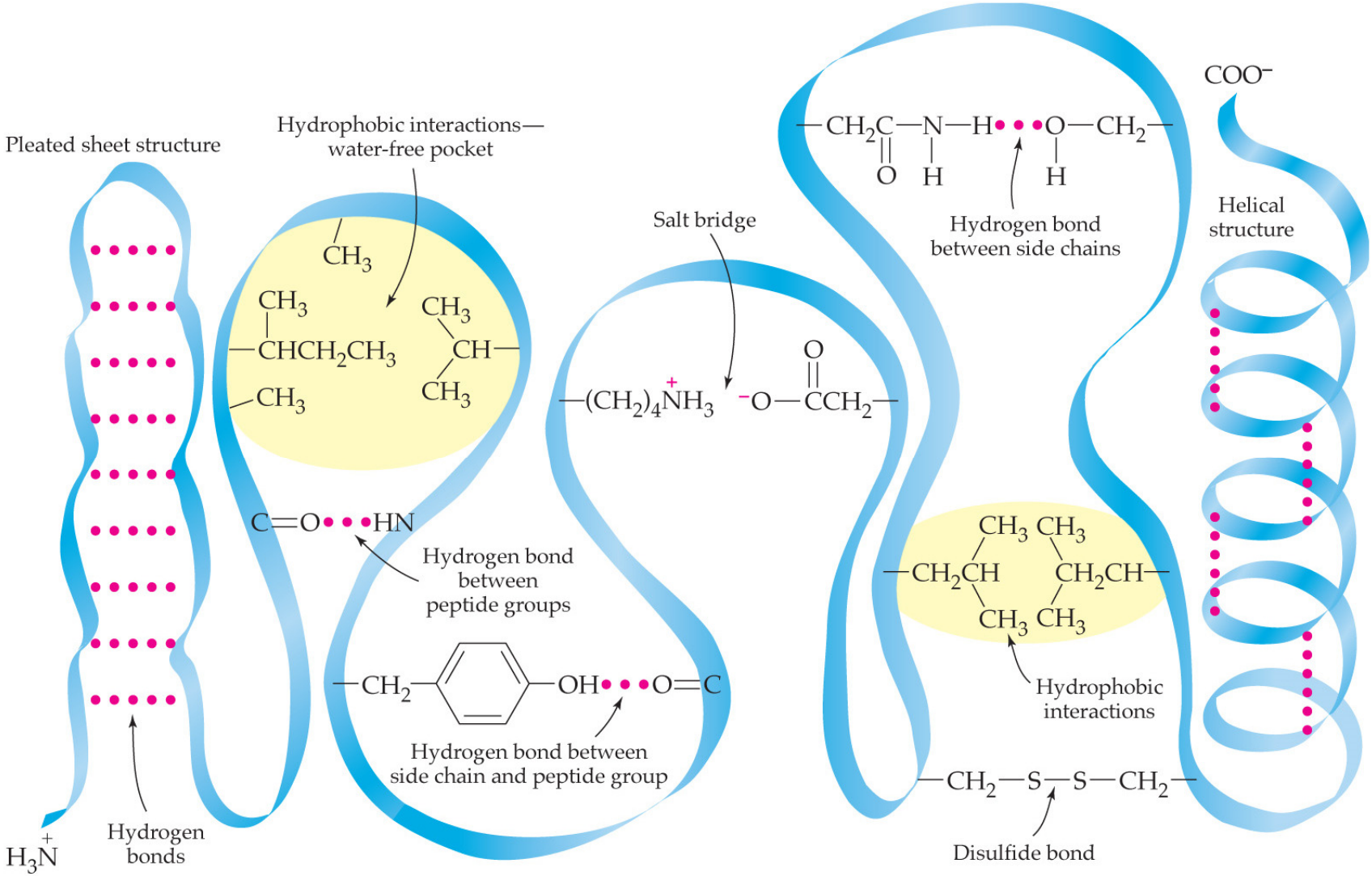
(Reference: Chapter18 from McMurry et al.)

18.8.7 Interacties in eiwit



(Reference: Chapter18 from McMurry et al.)

18.8.8 Interacties in eiwit



18.8.9 Interacties in eiwit

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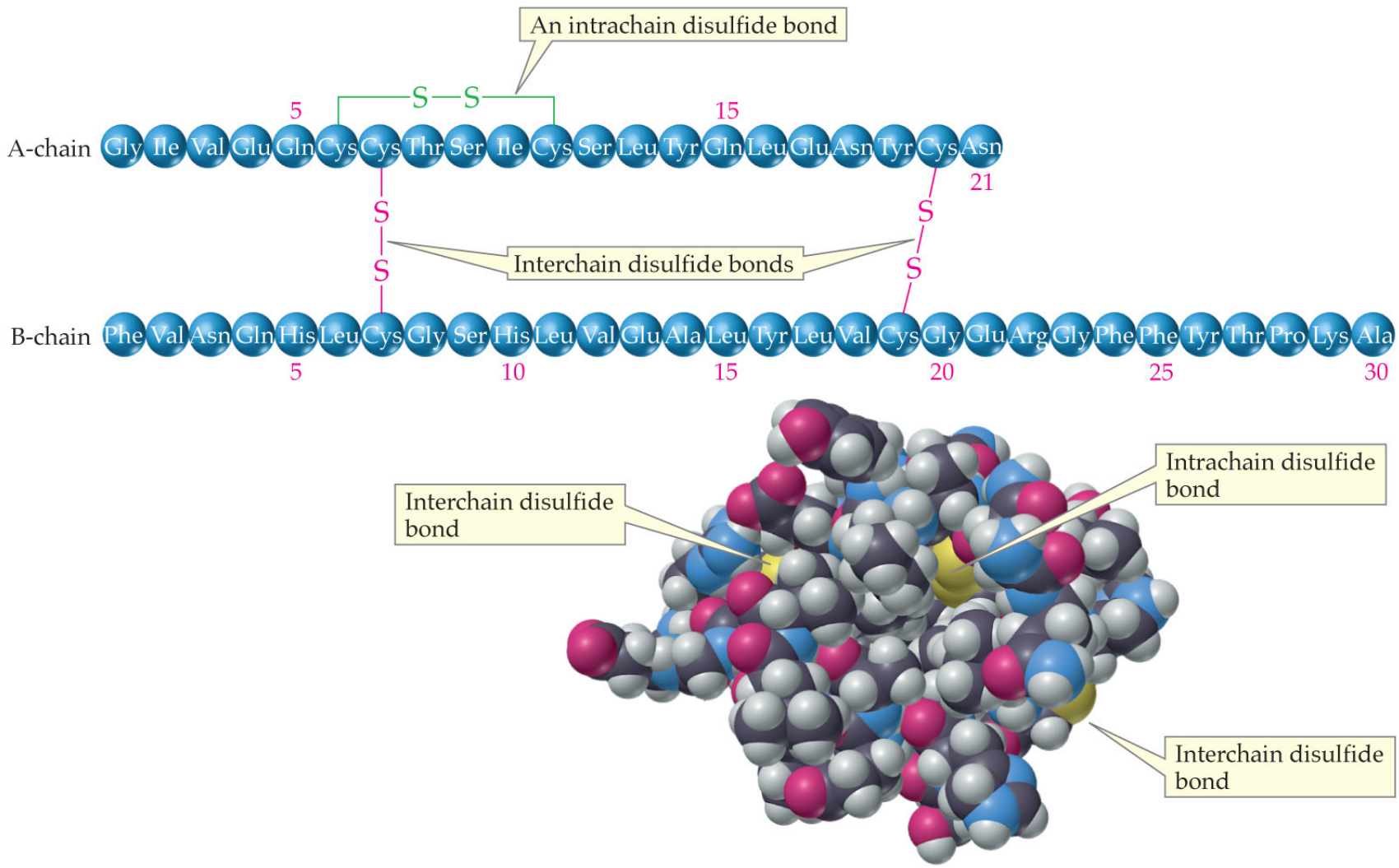
Structure of insulin



Worked example 18.5

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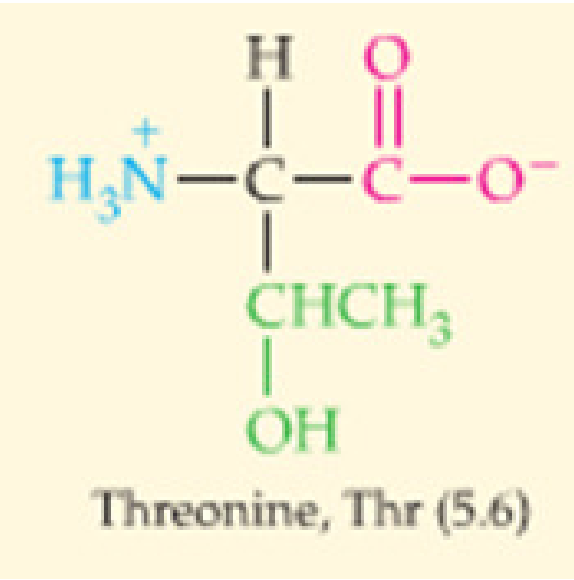
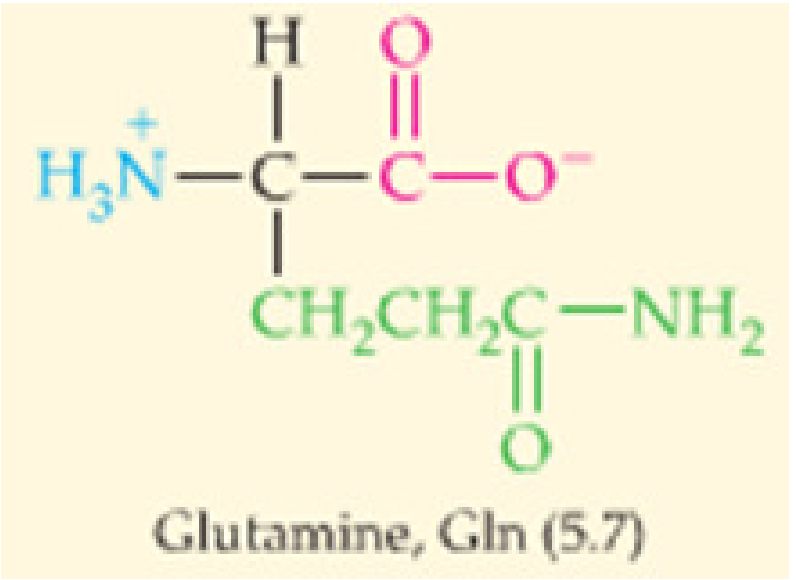
What type of noncovalent interaction occurs between the threonine and glutamine side chains? Draw the structures of these amino acids to show the interaction.



Threonine, Thr (5.6)



Glutamine, Gln (5.7)

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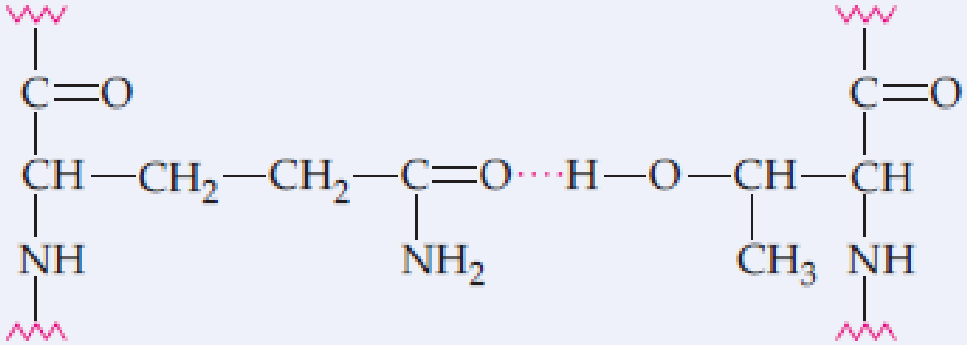
(Reference: Chapter18 from McMurry et al.)

Worked example 18.5

What type of noncovalent interaction occurs between the threonine and glutamine side chains? Draw the structures of these amino acids to show the interaction.

ANALYSIS The side chains of threonine and glutamine contain an amide group and a hydroxyl group, respectively. These groups do not form salt bridges because they do not ionize. They are polar and therefore not hydrophobic. They form a hydrogen bond between the oxygen of the amide carbonyl group and the hydrogen of the hydroxyl group.

The noncovalent, hydrogen bond interaction between threonine and glutamine is as follows:



(Reference: Chapter18 from McMurry et al.)

Problem 18.21a

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PROBLEM 18.21

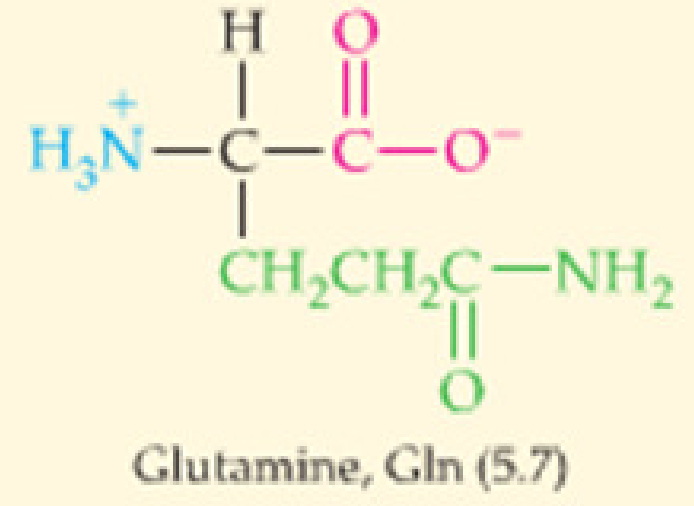
Look at Table 18.3 and identify the type of noncovalent interaction expected between the side chains of the following pairs of amino acids:

(a) Glutamine and serine

(b) Isoleucine and proline

(c) Aspartate and lysine

(d) Alanine and phenylalanine



Glutamine, Gln (5.7)

Serine, Ser (5.7)

(a) hydrogen bond

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Problem 18.21b

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PROBLEM 18.21

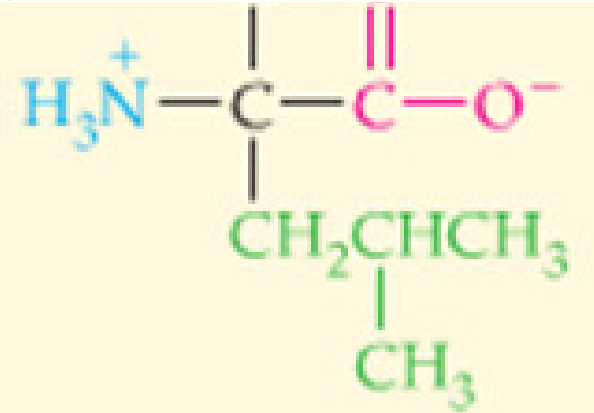
Look at Table 18.3 and identify the type of noncovalent interaction expected between the side chains of the following pairs of amino acids:

(a) Glutamine and serine

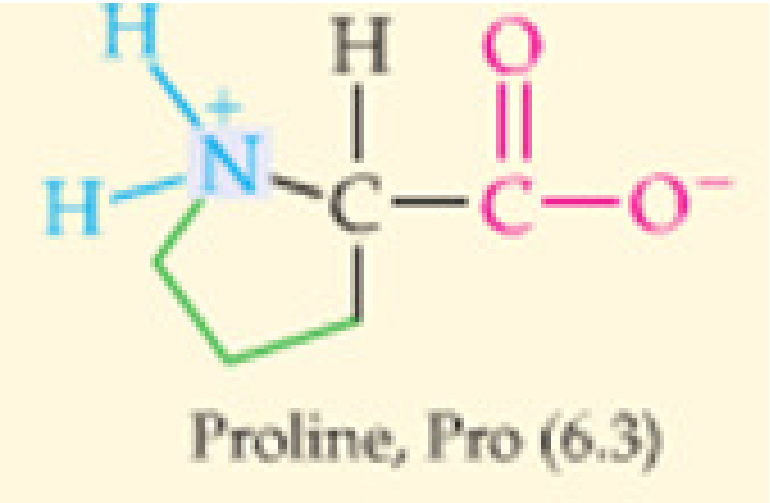
(b) Isoleucine and proline

(c) Aspartate and lysine

(d) Alanine and phenylalanine



Leucine, Leu (6.0)



Proline, Pro (6.3)

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(b) hydrophobic interaction

(Reference: Chapter18 from McMurry et al.)

Problem 18.21c

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PROBLEM 18.21

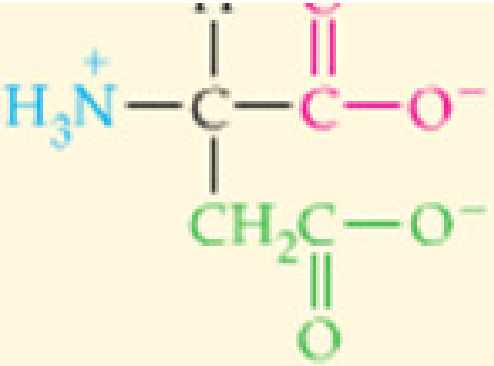
Look at Table 18.3 and identify the type of noncovalent interaction expected between the side chains of the following pairs of amino acids:

(a) Glutamine and serine

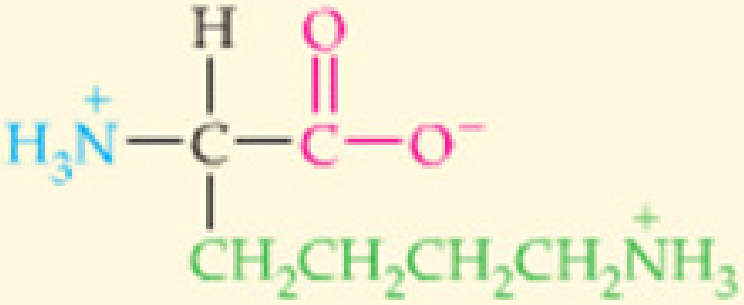
(b) Isoleucine and proline

(c) Aspartate and lysine

(d) Alanine and phenylalanine



Aspartic acid, Asp (3.0)
(Aspartate)



Lysine, Lys (9.7)

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(c) salt bridge

(Reference: Chapter18 from McMurry et al.)

Problem 18.21d

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PROBLEM 18.21

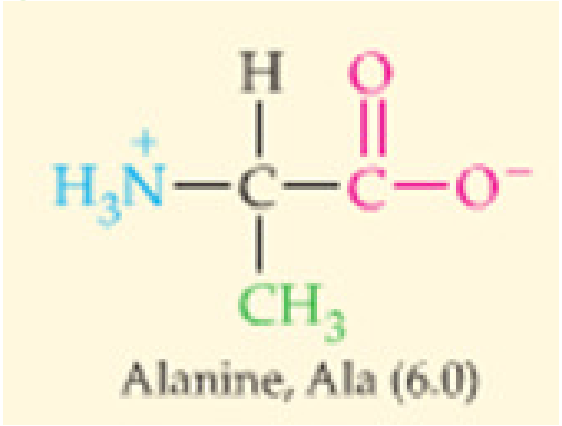
Look at Table 18.3 and identify the type of noncovalent interaction expected between the side chains of the following pairs of amino acids:

(a) Glutamine and serine

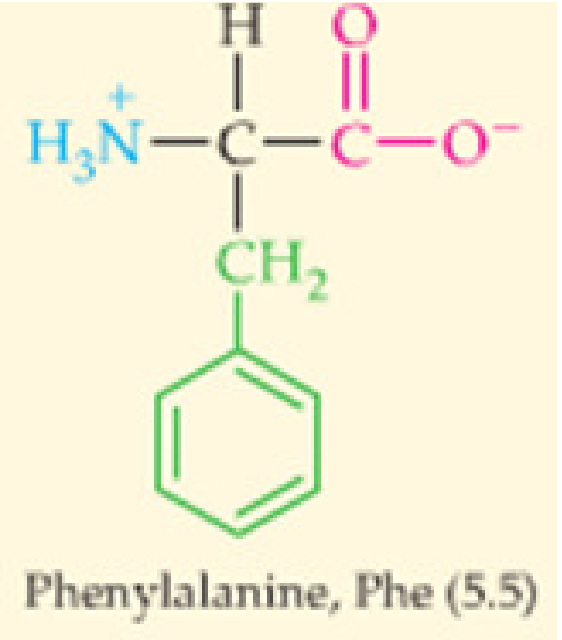
(b) Isoleucine and proline

(c) Aspartate and lysine

(d) Alanine and phenylalanine



Alanine, Ala (6.0)



Phenylalanine, Phe (5.5)

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(d) hydrophobic interaction

(Reference: Chapter18 from McMurry et al.)

18.9 Secundaire structuur

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- **Ruimtelijke structuur in delen van het eiwit.**
  - **alfa-helix**
  - **beta-plaat**
  - **random coil**

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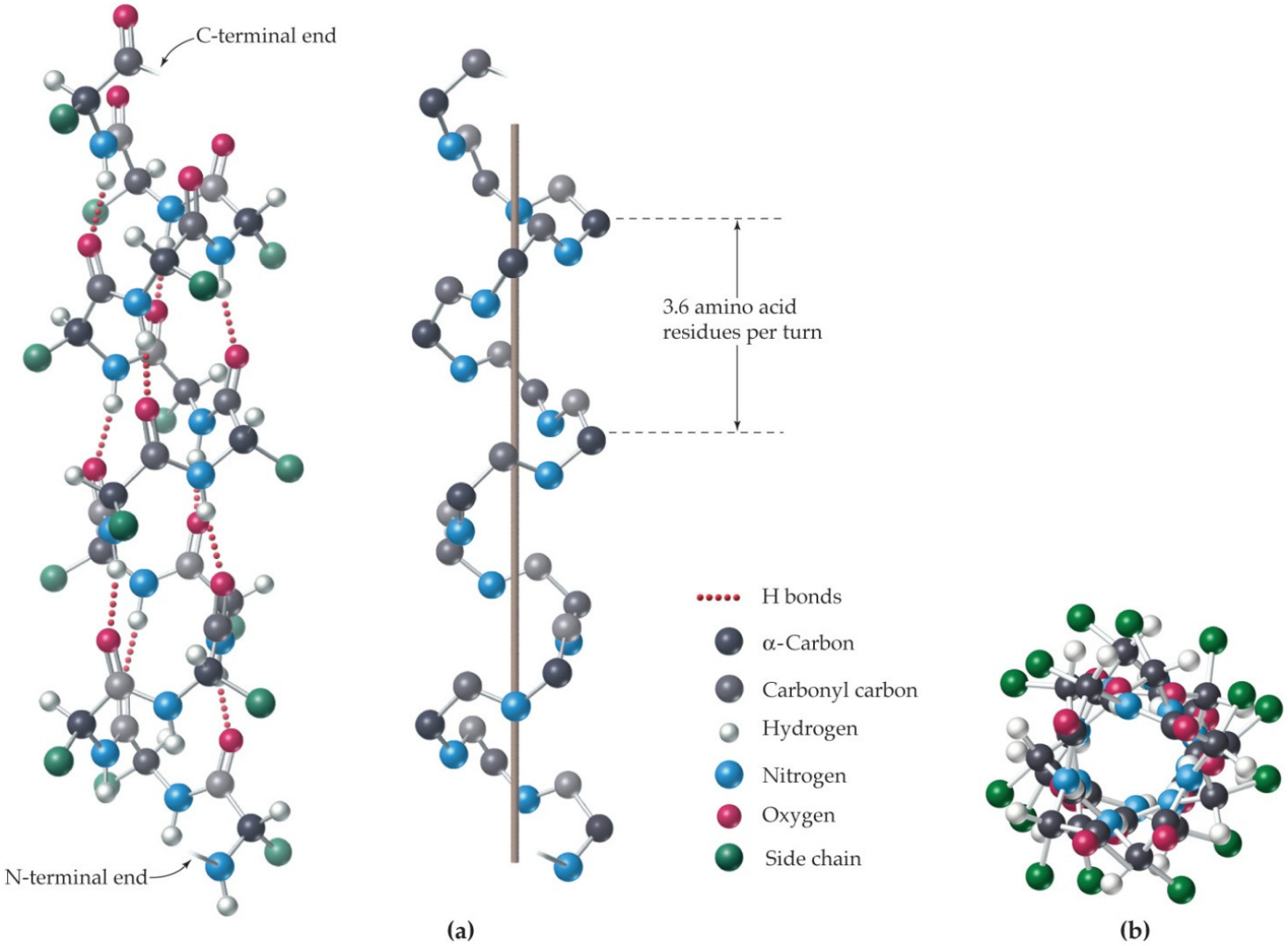
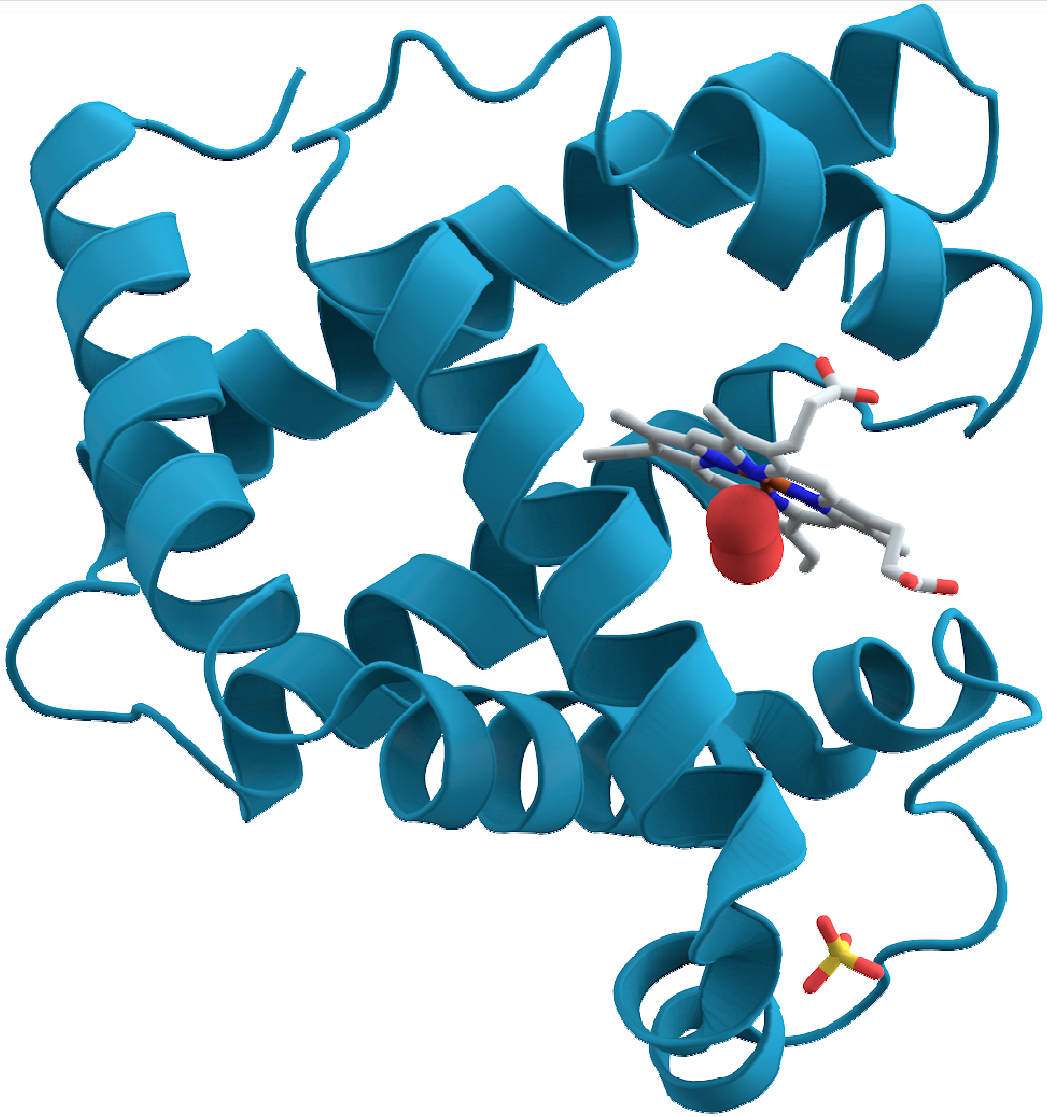
(Reference: Chapter18 from McMurry et al.)

18.9.1 Alfa-helix



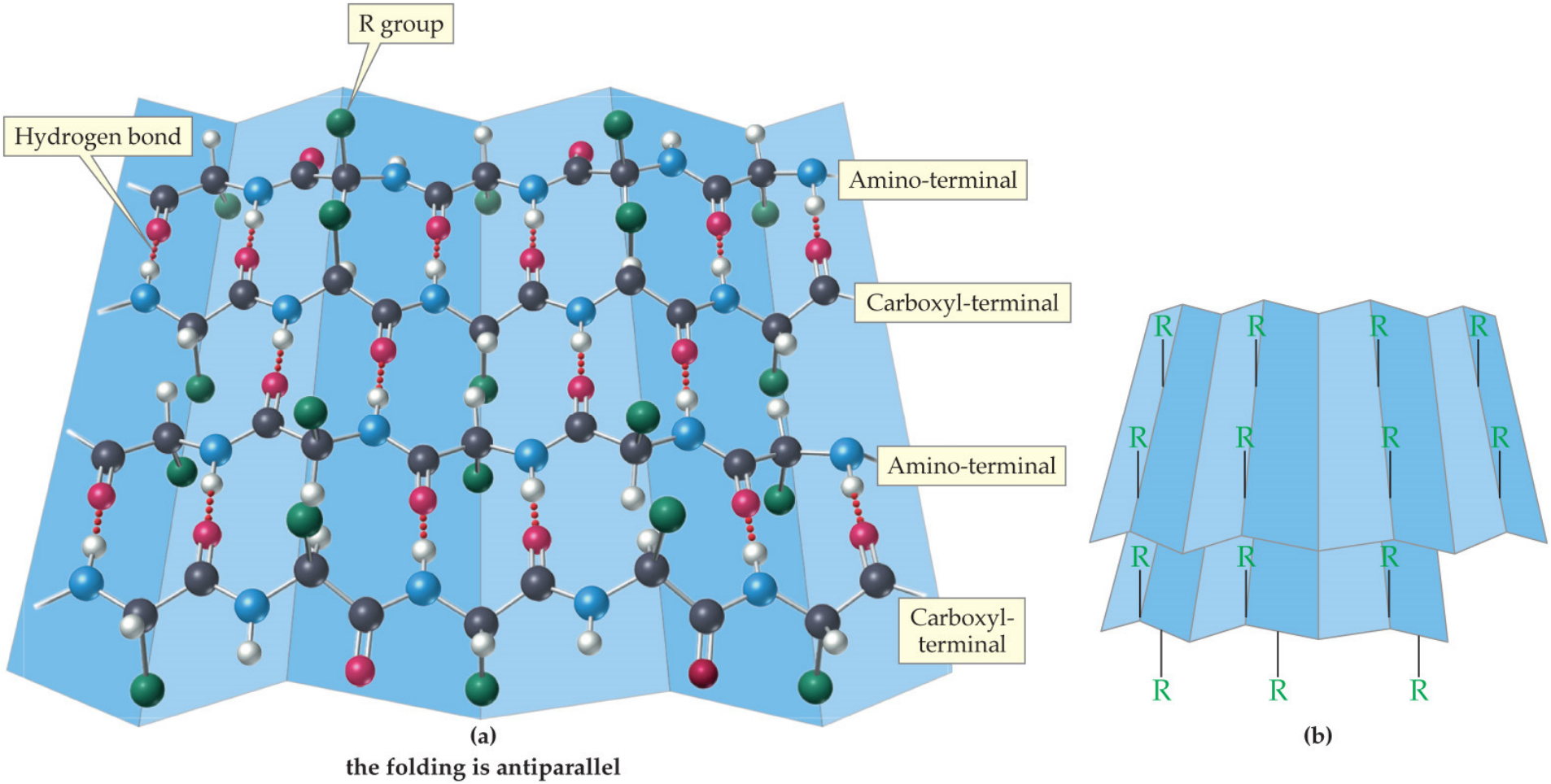
(Reference: Chapter18 from McMurry et al.)

18.9.2 Alfa-helix

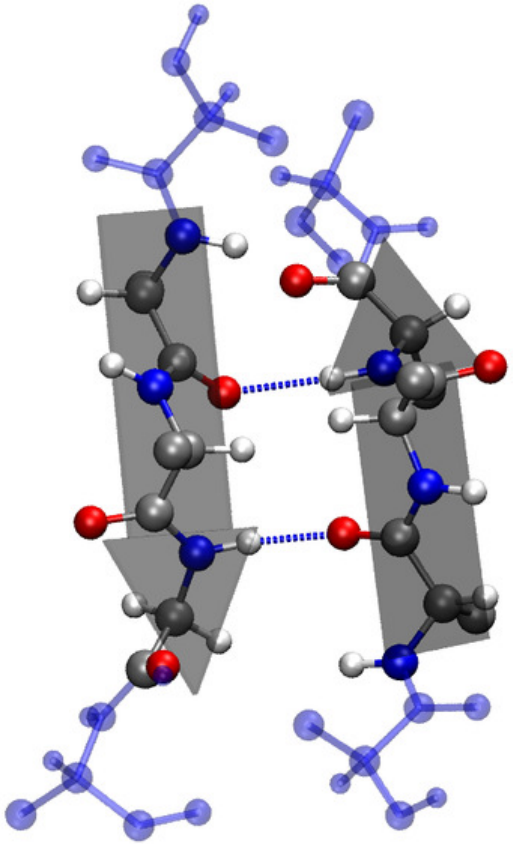


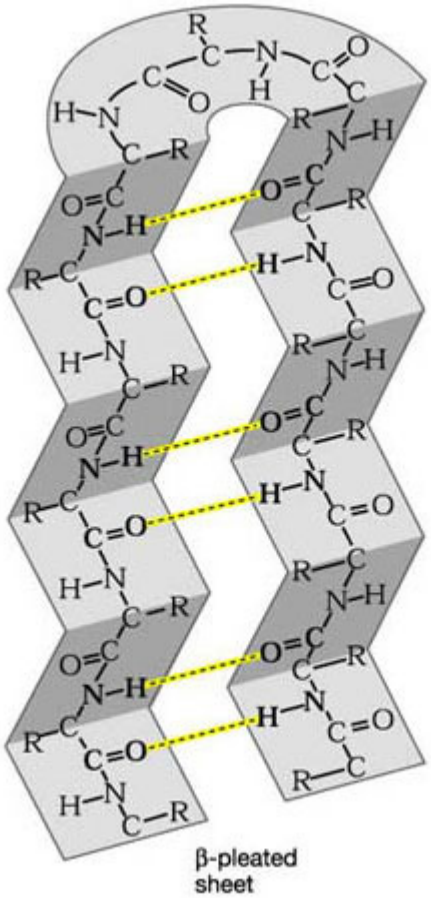
(Reference: Chapter18 from McMurry et al.)

18.9.3 Beta-plaat



18.9.4 Beta-plaat





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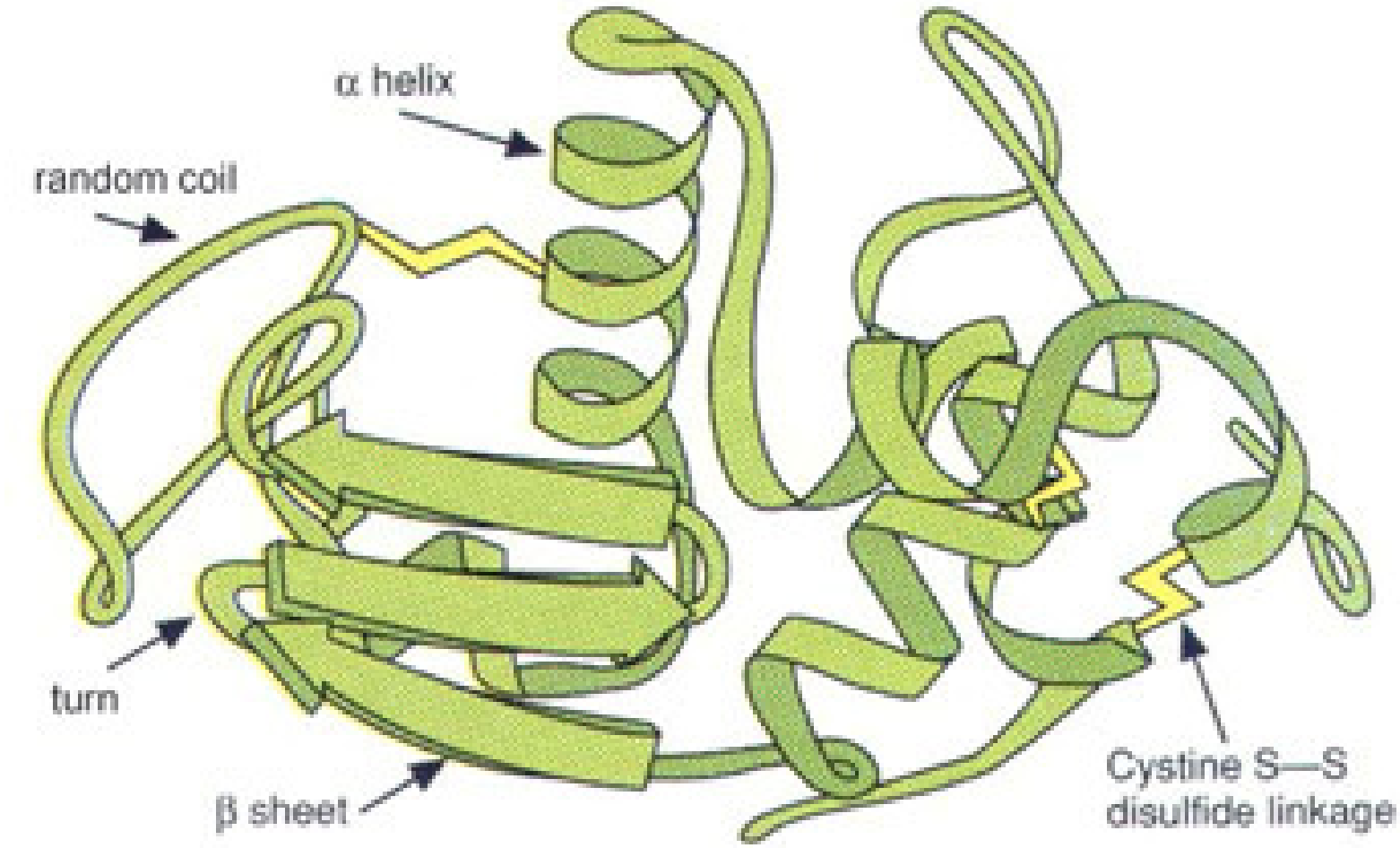
(Reference: Chapter18 from McMurry et al.)

18.9.5 Random coil



(Reference: Chapter18 from McMurry et al.)

Problem 18.23

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Examine the α-helix in Figure 18.5 and determine how many backbone C and N atoms are included in the loop between an amide hydrogen atom and the carbonyl oxygen to which it is hydrogen-bonded.

eleven backbone atoms

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(Reference: Chapter18 from McMurry et al.)

18.9.6 Indeling naar vorm

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- **Vezeleiwitten**
  - taai, onoplosbaar, lange ketens
- **Globulaire eiwitten**
  - water oplosbaar, ronde vorm

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18.9.7 Indeling naar vorm

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TABLE 18.4 Some Common Fibrous and Globular Proteins

Name	Occurrence and Function
Fibrous proteins (insoluble)	
Keratins	Found in skin, wool, feathers, hooves, silk, fingernails
Collagens	Found in animal hide, tendons, bone, eye cornea, and other connective tissue
Elastins	Found in blood vessels and ligaments, where ability of the tissue to stretch is important
Myosins	Found in muscle tissue
Fibrin	Found in blood clots
Globular proteins (soluble)	
Insulin	Regulatory hormone for controlling glucose metabolism
Ribonuclease	Enzyme that catalyzes RNA hydrolysis
Immunoglobulins	Proteins involved in immune response
Hemoglobin	Protein involved in oxygen transport
Albumins	Proteins that perform many transport functions in blood; protein in egg white

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(Reference: Chapter18 from McMurry et al.)

18.10 Tertiaire structuur

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- De totale ruimtelijke vorm van het eiwit
  - eenvoudig
    - bestaat alleen uit aminozuren
  - natief
    - de vorm waarin een proteïne zich normaal vouwt
  - geconjugeerd
    - bevat ook één of meerdere niet-aminozuur eenheden

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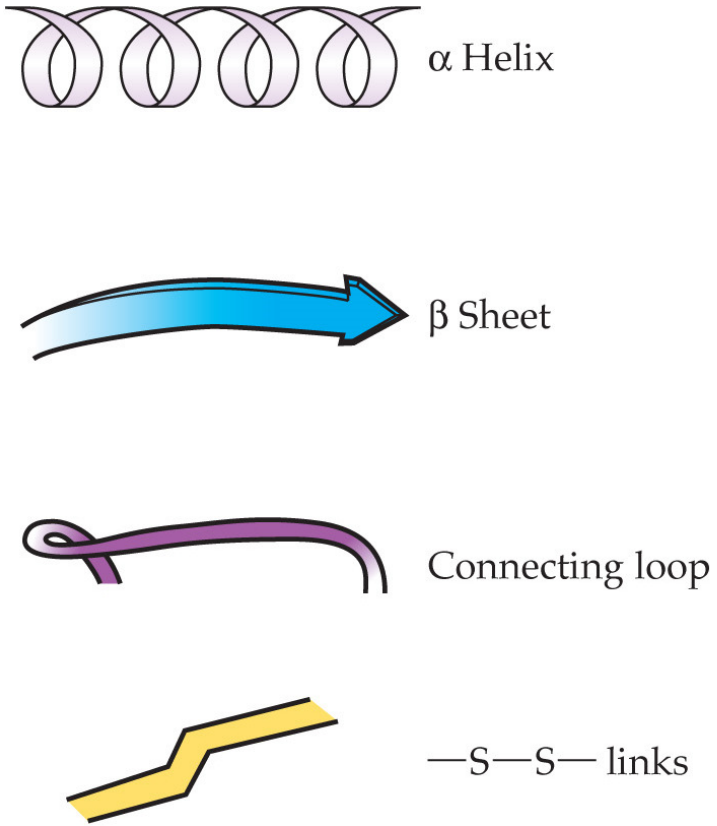
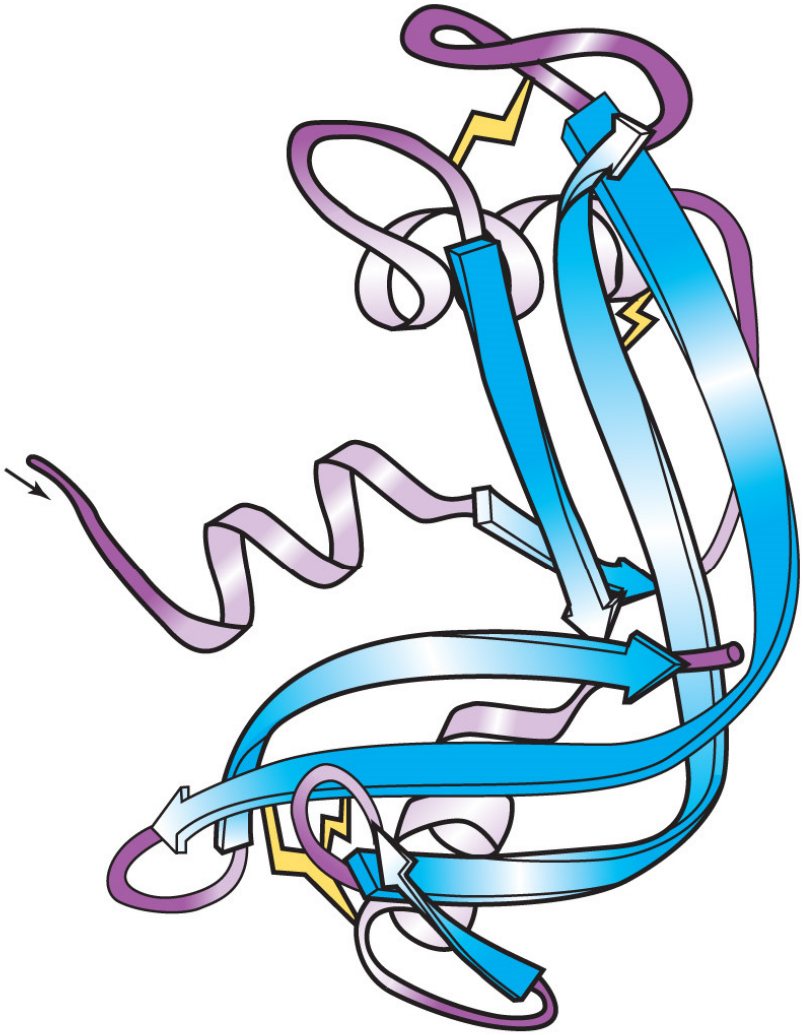
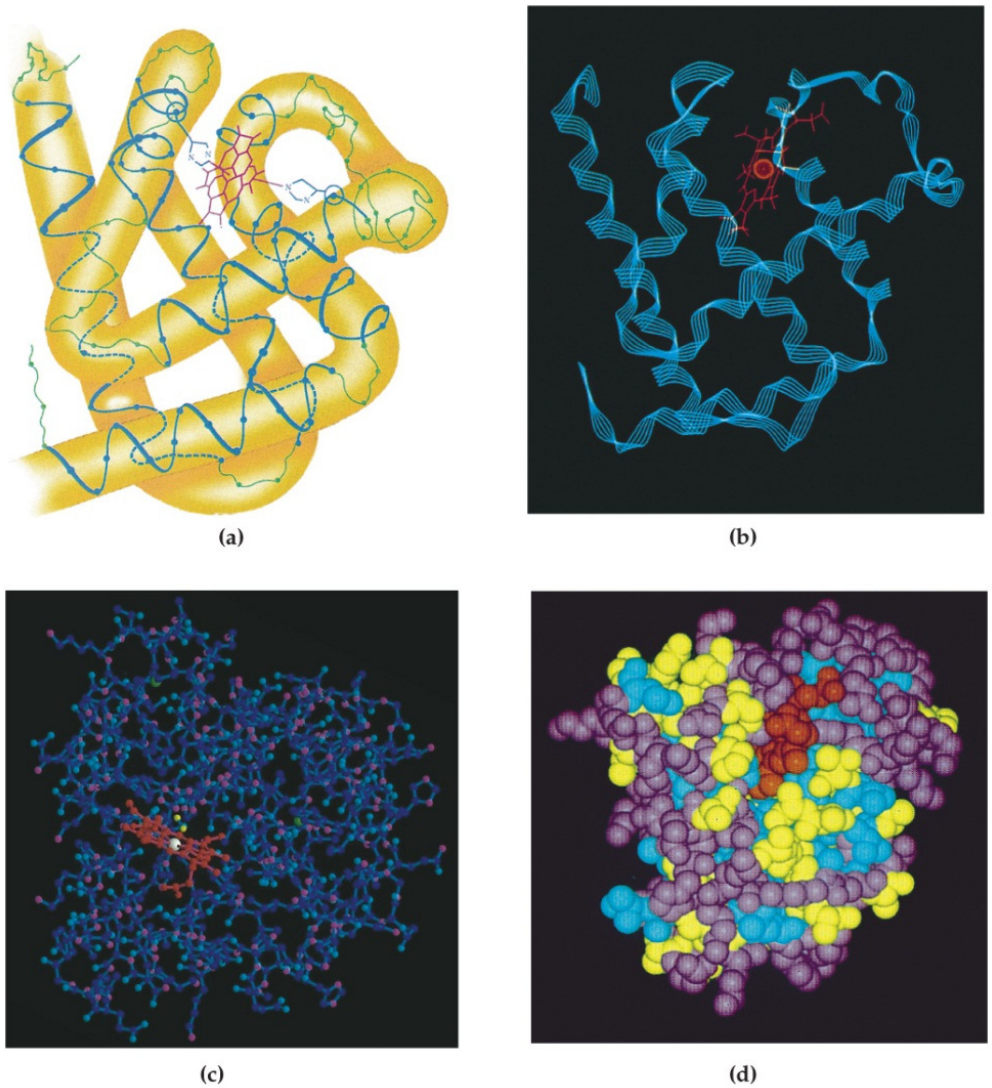
18.10.1 Tertiaire structuur





Ribonuclease

18.10.2 4 keer myoglobine



(Reference: Chapter18 from McMurry et al.)

KEY CONCEPT PROBLEM 18.25

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KEY CONCEPT PROBLEM 18.25

Hydrogen bonds are important in stabilizing both the secondary and tertiary structures of proteins. How do the groups that form hydrogen bonds in the secondary and tertiary structures differ?

Secondary structure: stabilized by hydrogen bonds between amide nitrogens and carbonyl oxygens of polypeptide backbone. Tertiary structure: stabilized by hydrogen bonds between amino acid side-chain groups.

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(Reference: Chapter18 from McMurry et al.)

18.10.3 Geconjugeerde eiwitten

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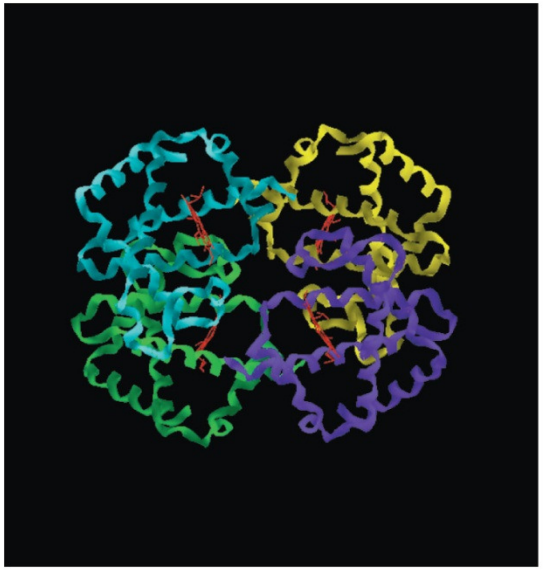
TABLE 18.5 Some Examples of Conjugated Proteins

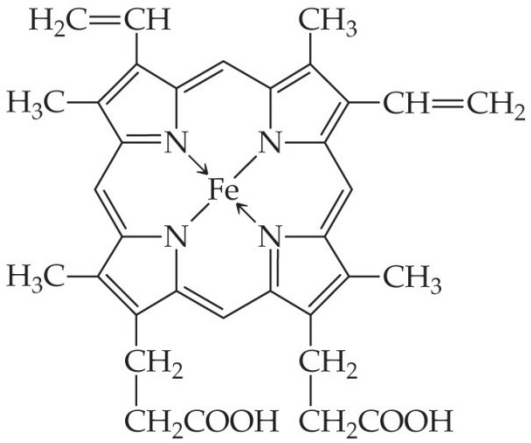
CLASS OF PROTEIN	NONPROTEIN PART	EXAMPLES
Glycoproteins	Carbohydrates	Glycoproteins in cell membranes (Section 24.7)
Lipoproteins	Lipids	High- and low-density lipoproteins that transport cholesterol and other lipids through the body (Section 25.2)
Metalloproteins	Metal ions	The enzyme cytochrome oxidase, necessary for biological energy production, and many other enzymes
Phosphoproteins	Phosphate groups	Milk casein, which provides essential nutrients to infants
Hemoproteins	Heme	Hemoglobin (transplants oxygen) and myoglobin (stores oxygen)
Nucleoproteins	RNA (ribonucleic acid)	Found in cell ribosomes, where they take part in protein synthesis

18.11 Quaternaire structuur

- **Een functioneel eiwit bestaande uit twee of meer eiwitketens**
- **Hemoglobine**



(a)



(b)

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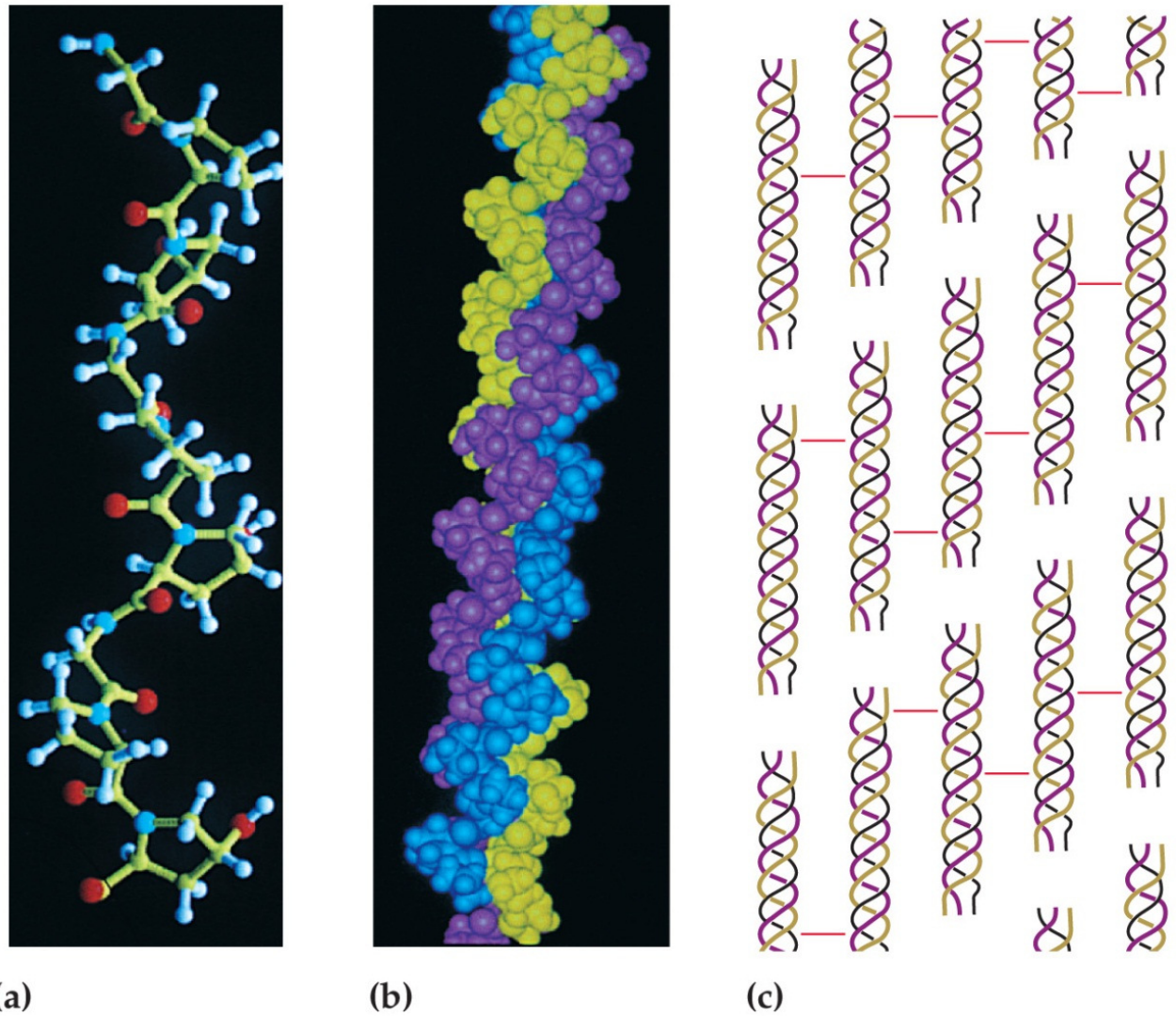
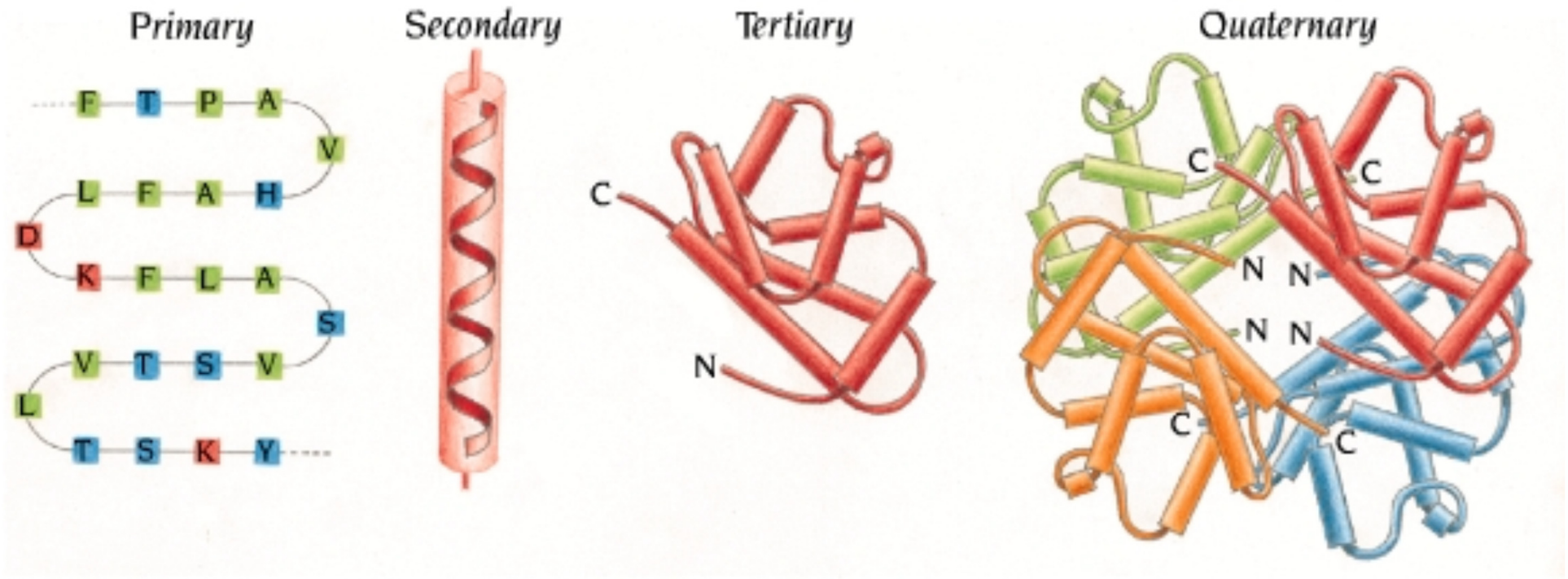
18.11.1 Collageen



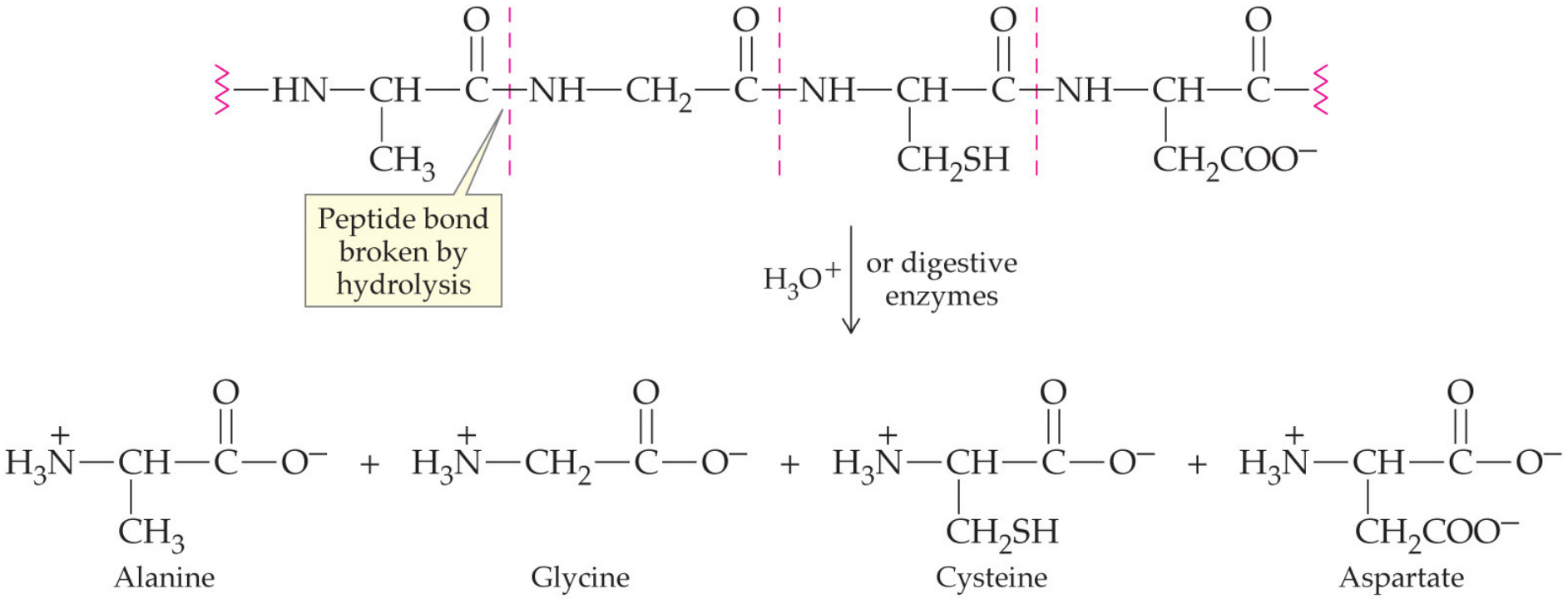
(Reference: Chapter18 from McMurry et al.)

18.11.2 De verschillende structuren



18.12 Chemische eigenschappen

- **Hydrolyse**



18.12.1 Denaturatie

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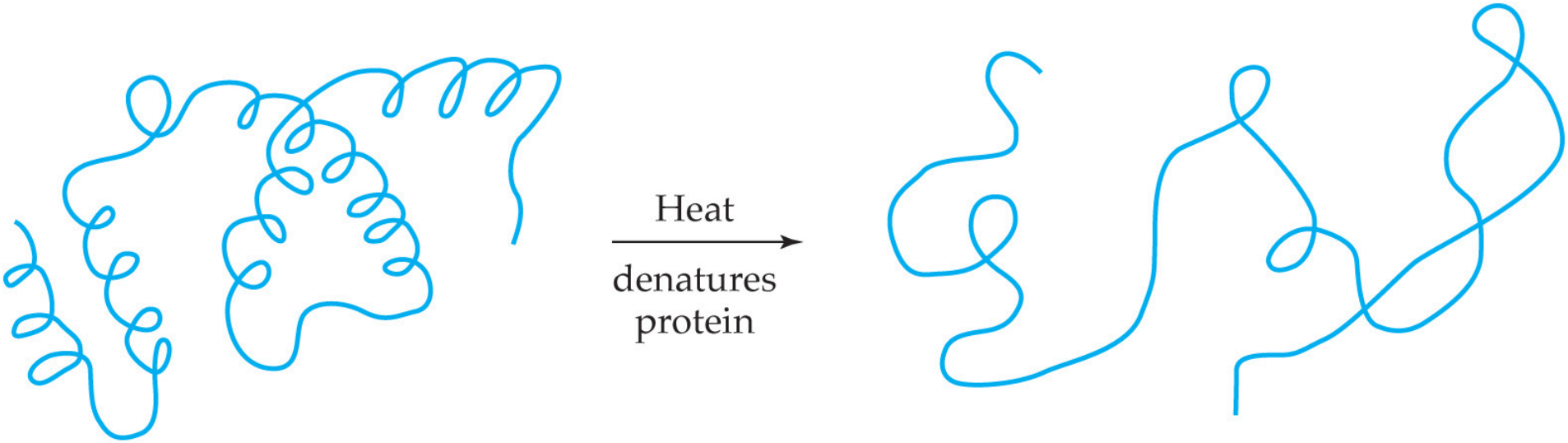
- **De natieve structuur veranderen**



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18.12.2 Denaturatie

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- Verhitten
  - zwakke interacties worden verbroken
- Mechanisch “schudden” (mixen)
  - luchtbellen in het eiwit brengen
- Detergentia (zepen)
  - hydrofobe interacties worden verbroken
- Organische stoffen
  - polaire oplosmiddelen verbreken H-bruggen
- pH veranderen
  - reactie met zure/basische zijketens en verbreken van zoutbruggen
- Anorganische zouten
  - verbreken van zoutbruggen

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KEY CONCEPT PROBLEM 18.27

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KEY CONCEPT PROBLEM 18.27

Identify the following statements as descriptive of the secondary, tertiary, or quaternary structure of a protein. What type(s) of interaction(s) stabilize each type of structure?

(a) The polypeptide chain has a number of bends and twists, resulting in a compact structure.

(b) The polypeptide backbone forms a right-handed coil.

(c) The four polypeptide chains are arranged in a spherical shape.

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(Reference: Chapter18 from McMurry et al.)

Terugblik #1

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1. What are the structural features of amino acids? *Amino acids* in body fluids have an ionized carboxylic acid group ($-COO^-$), an ionized amino group ($-NH_3^+$), and a side-chain R group bonded to a central carbon atom (the α-carbon). Twenty different amino acids occur in *proteins* (Table 18.3), connected by *peptide bonds* (amide bonds) formed between the carboxyl group of one amino acid and the amino group of the next (*see Problems 1–4, 6, 34–37, 86, 88, 89, 92, 94*).

2. What are the properties of amino acids? Amino acid side chains have acidic or basic functional groups or neutral groups that are either polar or nonpolar. In glycine, the "side chain" is a hydrogen atom. The dipolar ion in which the amino and carboxylic acid groups are both ionized is known as a *zwitterion*. For each amino acid, there is a distinctive *isoelectric point*—the pH at which the numbers of positive and negative charges in a solution are equal. At more acidic pH, some carboxylic acid groups are not ionized; at more basic pH, some amino groups are not ionized (*see Problems 2, 3, 5, 7, 8, 28, 38–41, 72, 73, 78, 79, 95*).

3. Why do amino acids have "handedness"? An object, including a molecule, has "handedness" —is *chiral*—when it has no plane of symmetry and thus has mirror images that cannot be superimposed on each other. A simple molecule can be identified as chiral if it contains a carbon atom bonded to four different groups. All α-amino acids except glycine meet this condition by having four different groups bonded to the α-carbon (*see Problems 9–14, 33, 42–49*).

backbone carbonyl groups and amide hydrogens of adjacent protein chains. *Noncovalent interactions* between side chains include ionic bonding between acidic and basic groups (*salt bridges*), and *hydrophobic interactions* among nonpolar groups. Covalent sulfur–sulfur bonds (*disulfide bonds*) can form bridges between the side chains in cysteine (*see Problems 21, 22, 29, 55–58, 90, 91*).

6. What are the secondary and tertiary structures of proteins? *Secondary structures* include the regular, repeating three-dimensional structures held in place by hydrogen bonding between backbone atoms within a chain or in adjacent chains. The α-helix is a coil with hydrogen bonding between carbonyl oxygen atoms and amide hydrogen atoms four amino acid residues farther along the same chain. The β-sheet is a pleated sheet with adjacent protein-chain segments connected by hydrogen bonding between peptide groups. The adjacent chains in the β-sheet may be parts of the same protein chain or different protein chains. Secondary structure mainly determines the properties of *fibrous proteins*, which are tough and insoluble. *Tertiary structure* is the overall three-dimensional shape of a folded protein chain. Tertiary structure determines the properties of *globular proteins*, which are water-soluble, with hydrophilic groups on the outside and hydrophobic groups on the inside. Globular proteins often contain regions of α-helix and/or β-sheet secondary structures (*see Problems 23–25, 30–32, 54, 57, 64, 65, 80, 81, 85–88*).

7. What is quaternary protein structure? Proteins that

(Reference: Chapter18 from McMurry et al.)

Terugblik #2

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lems 9–14, 33, 42–49).

4. What is the primary structure of a protein and what conventions are used for drawing and naming primary structures? Proteins are polymers of amino acids (*polypeptides*). Their *primary structure* is the linear sequence in which the amino acids are connected by peptide bonds. Using formulas or amino acid abbreviations, the primary structures are written with the amino-terminal end on the left ($^{+}H_3N$ —) and the carboxyl-terminal end on the right (—COO^{-}). To name a peptide, the names of the amino acids are combined, starting at the amino-terminal end, with the endings of all but the carboxyl-terminal amino acid changed to *-yl*. Primary structures are often represented by combining three-letter abbreviations for the amino acids (*see Problems 15–19, 50–53, 63, 66, 67, 74–78*).

5. What types of interactions determine the overall shapes of proteins? Protein chains are drawn into their distinctive and biochemically active shapes by attractions between atoms along their backbones and between atoms in side-chain groups. Hydrogen bonding can occur between the

7. What is quaternary protein structure? Proteins that incorporate more than one peptide chain are said to have *quaternary structure*. In a quaternary structure, two or more folded protein subunits are united in a single structure by noncovalent interactions. Hemoglobin, for example, consists of two pairs of subunits, with a nonprotein heme molecule in each of the four subunits. Collagen is a fibrous protein composed of protein chains twisted together in triple helixes (*see Problems 26, 27, 80, 81*).

8. What chemical properties do proteins have? The peptide bonds are broken by *hydrolysis*, which may occur in acidic solution or during enzyme-catalyzed digestion of proteins in food. The end result of hydrolysis is production of the individual amino acids from the protein. *Denaturation* is the loss of overall structure by a protein while retaining its primary structure. Among the agents that cause denaturation are heat, mechanical agitation, pH change, and exposure to a variety of chemical agents, including detergents (*see Problems 20, 60, 61, 68–71, 82–85, 96–99*).

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(Reference: Chapter18 from McMurry et al.)