Protein

▼ Figure 5.13 An overview of protein functions.

Enzymatic proteins

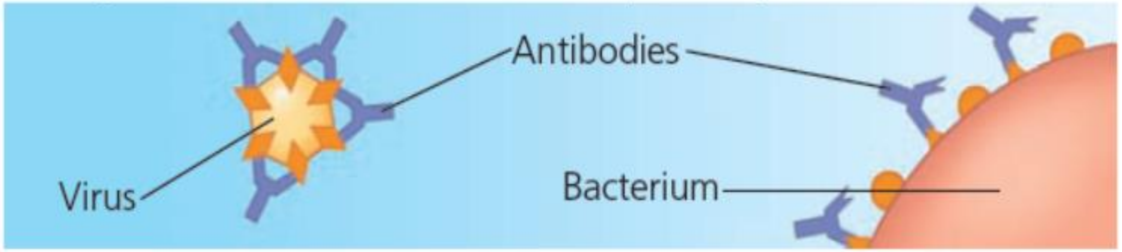
Function: Selective acceleration of chemical reactions

Example: Digestive enzymes catalyze the hydrolysis of bonds in food molecules.

Defensive proteins

Function: Protection against disease

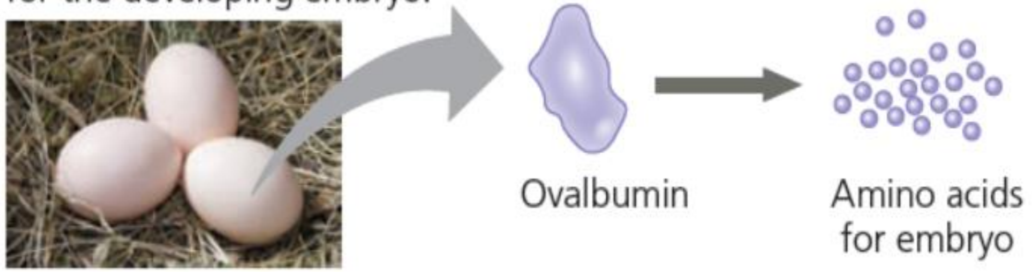
Example: Antibodies inactivate and help destroy viruses and bacteria.



Storage proteins

Function: Storage of amino acids

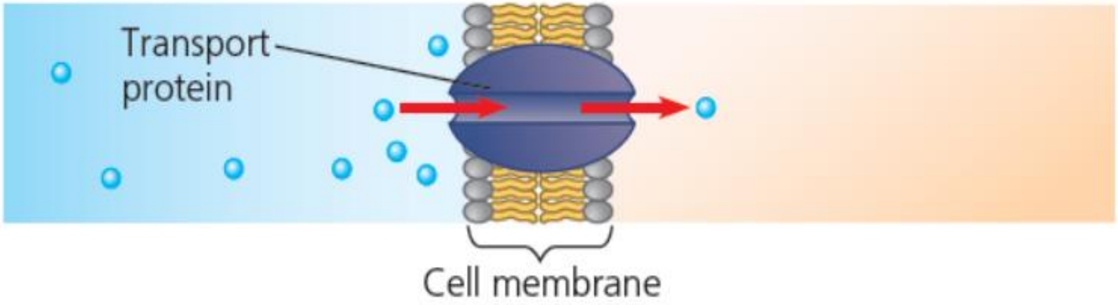
Examples: Casein, the protein of milk, is the major source of amino acids for baby mammals. Plants have storage proteins in their seeds. Ovalbumin is the protein of egg white, used as an amino acid source for the developing embryo.



Transport proteins

Function: Transport of substances

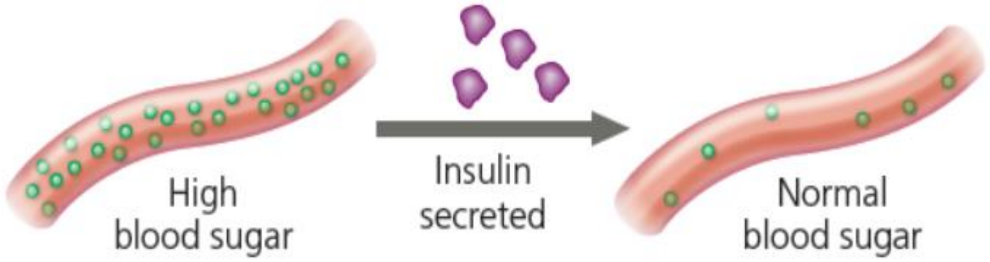
Examples: Hemoglobin, the iron-containing protein of vertebrate blood, transports oxygen from the lungs to other parts of the body. Other proteins transport molecules across membranes, as shown here.



Hormonal proteins

Function: Coordination of an organism's activities

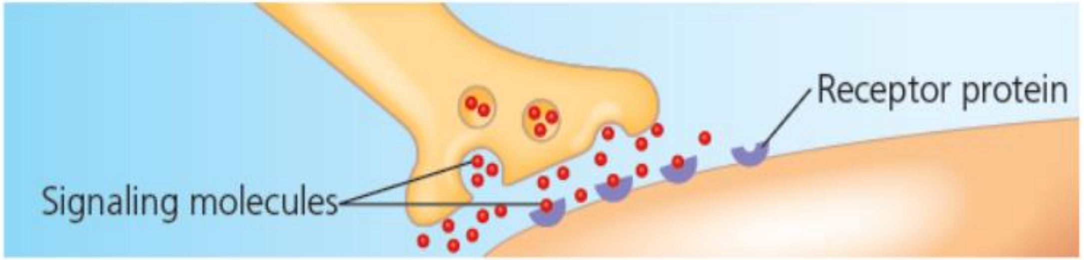
Example: Insulin, a hormone secreted by the pancreas, causes other tissues to take up glucose, thus regulating blood sugar concentration.



Receptor proteins

Function: Response of cell to chemical stimuli

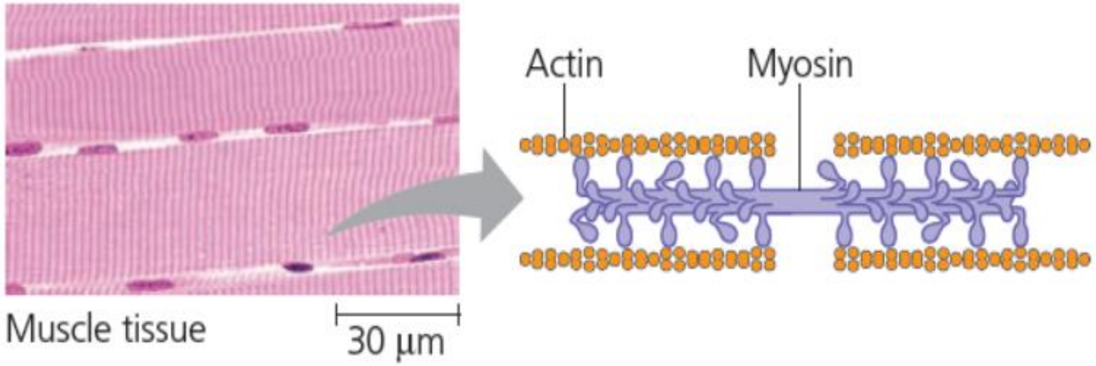
Example: Receptors built into the membrane of a nerve cell detect signaling molecules released by other nerve cells.



Contractile and motor proteins

Function: Movement

Examples: Motor proteins are responsible for the undulations of cilia and flagella. Actin and myosin proteins are responsible for the contraction of muscles.



Structural proteins

Function: Support

Examples: Keratin is the protein of hair, horns, feathers, and other skin appendages. Insects and spiders use silk fibers to make their cocoons and webs, respectively. Collagen and elastin proteins provide a fibrous framework in animal connective tissues.

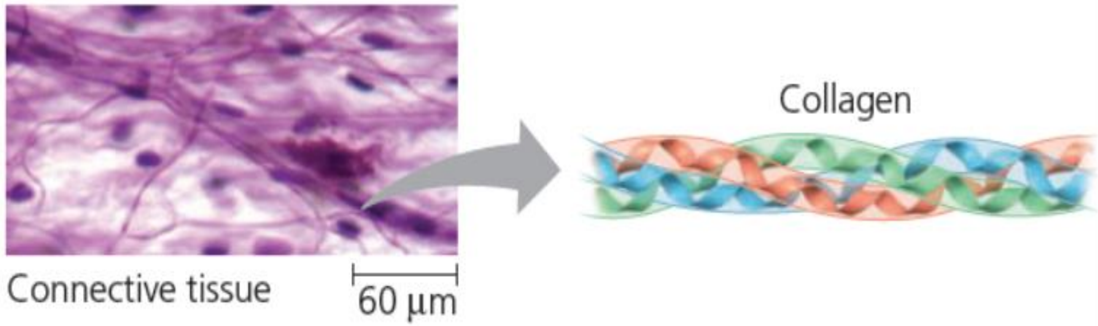
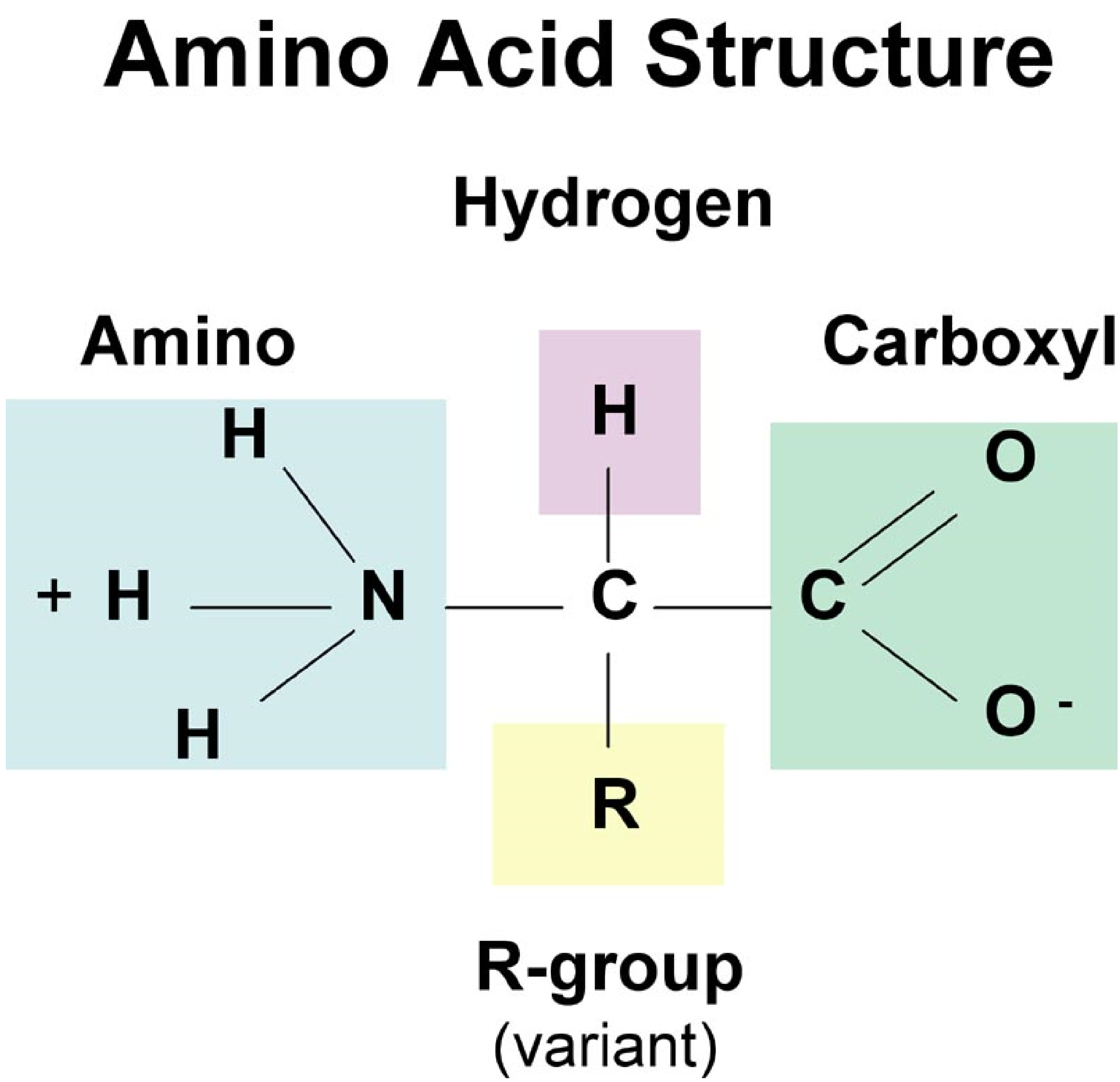


Table 3.2 The Many Functions of Proteins

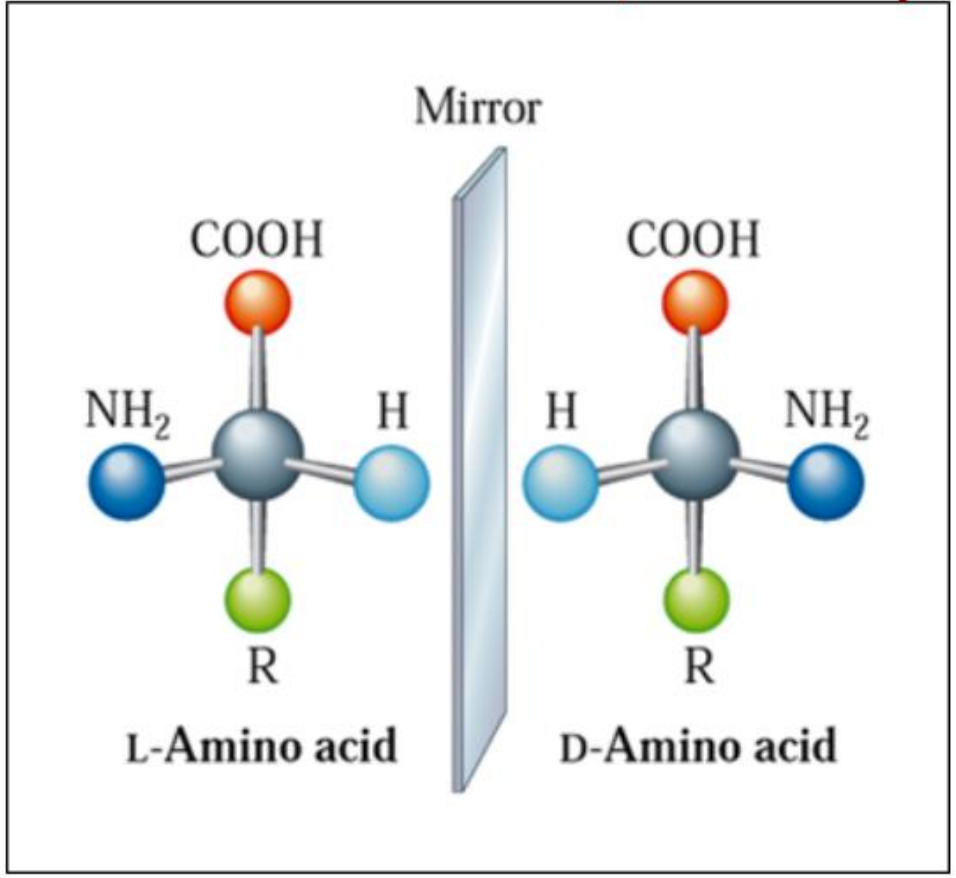
Function	Class of Protein	Examples	Use
Metabolism (Catalysis)	Enzymes	Hydrolytic enzymes	Cleave polysaccharides
		Proteases	Break down proteins
		Polymerases	Produce nucleic acids
		Kinases	Phosphorylate sugars and proteins
Defense	Immunoglobulins	Antibodies	Mark foreign proteins for elimination
Cell recognition	Toxins	Snake venom	Block nerve function
Transport throughout body	Cell surface antigens	MHC proteins	"Self" recognition
	Globins	Hemoglobin	Carries O_2 and CO_2 in blood
		Myoglobin	Carries O_2 and CO_2 in muscle
		Cytochromes	Electron transport
Membrane transport	Transporters	Sodium-potassium pump	Excitable membranes
		Proton pump	Chemiosmosis
		Anion channels	Transport Cl– ions
Structure/Support	Fibers	Collagen	Cartilage
		Keratin	Hair, nails
		Fibrin	Blood clot
Motion	Muscle	Actin	Contraction of muscle fibers
		Myosin	Contraction of muscle fibers
Osmotic regulation	Albumin	Serum albumin	Maintains osmotic concentration of blood
Regulation of gene action	Repressors	lac repressor	Regulates transcription
Regulation of body functions	Hormones	Insulin	Controls blood glucose levels
		Vasopressin	Increases water retention by kidneys
		Oxytocin	Regulates uterine contractions and milk production
Storage	Ion binding	Ferritin	Stores iron, especially in spleen
		Casein	Stores ions in milk
		Calmodulin	Binds calcium ions

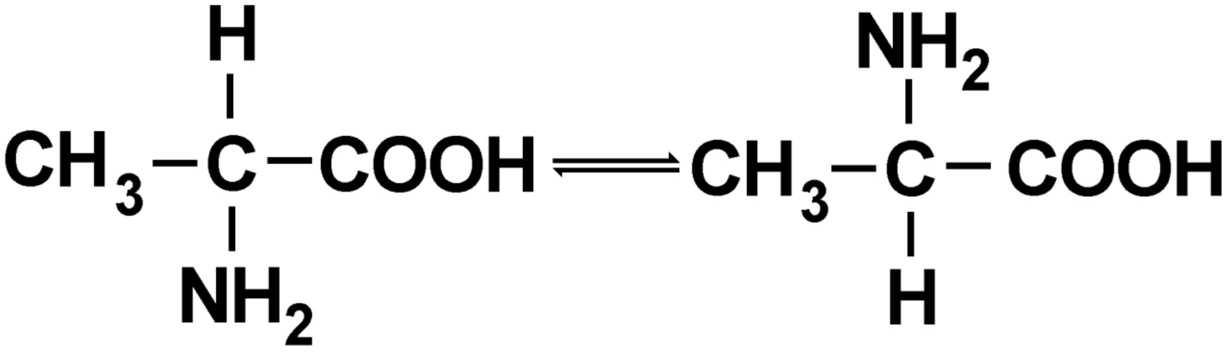


At the center of the amino acid is an asymmetric carbon atom called the alpha
(α) carbon.

- Its four different partners are an **amino group, a carboxyl group, a hydrogen atom, and a variable group**

Handedness/Chirality of Amino Acids

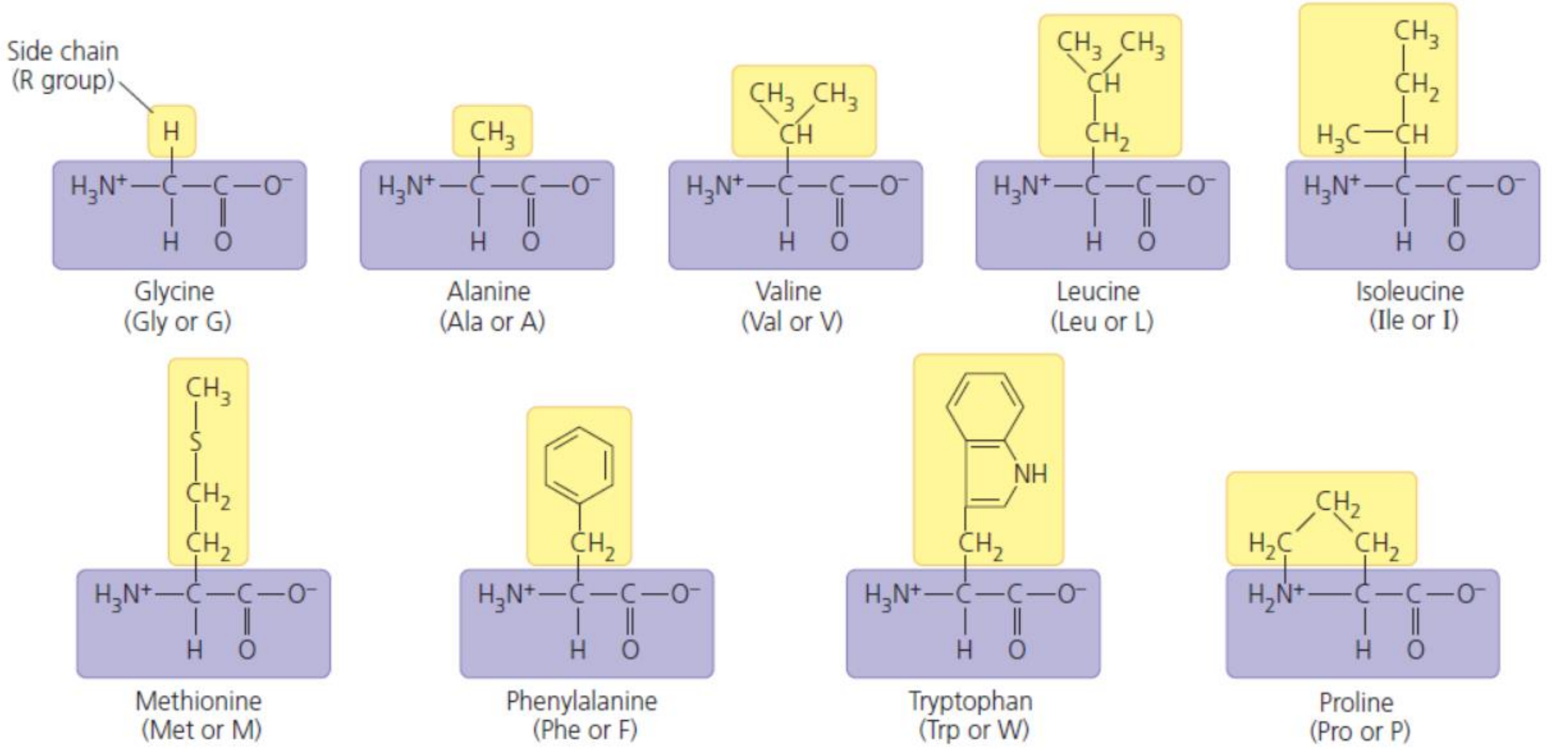




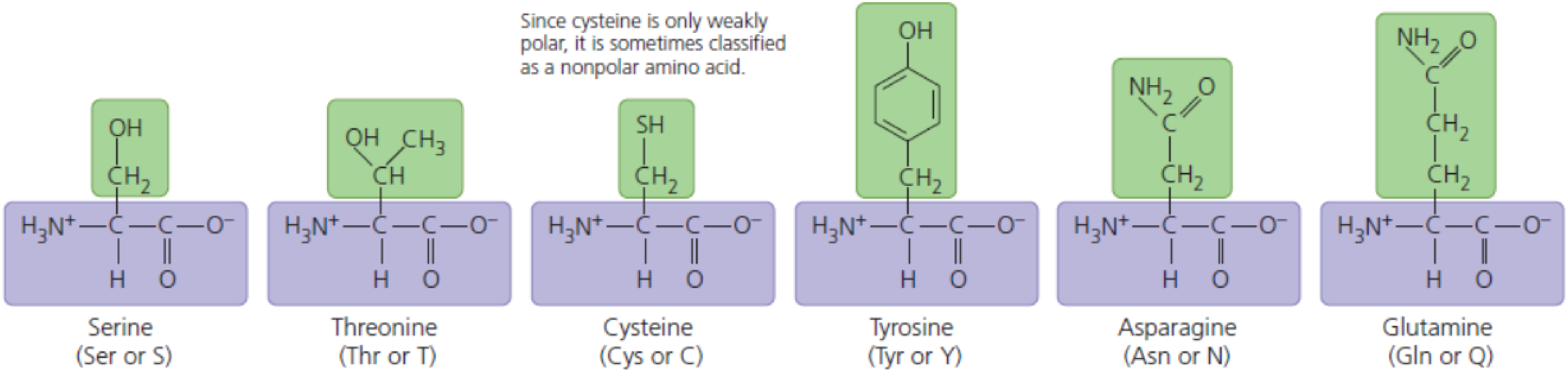
L-Alanine D-Alanine

▼ Figure 5.14 The 20 amino acids of proteins. The amino acids are grouped here according to the properties of their side chains (R groups) and shown in their prevailing ionic forms at pH 7.2, the pH within a cell. The three-letter and one-letter abbreviations for the amino acids are in parentheses. All of the amino acids used in proteins are L enantiomers (see Figure 4.7c).

Nonpolar side chains; hydrophobic



Polar side chains; hydrophilic



Electrically charged side chains; hydrophilic

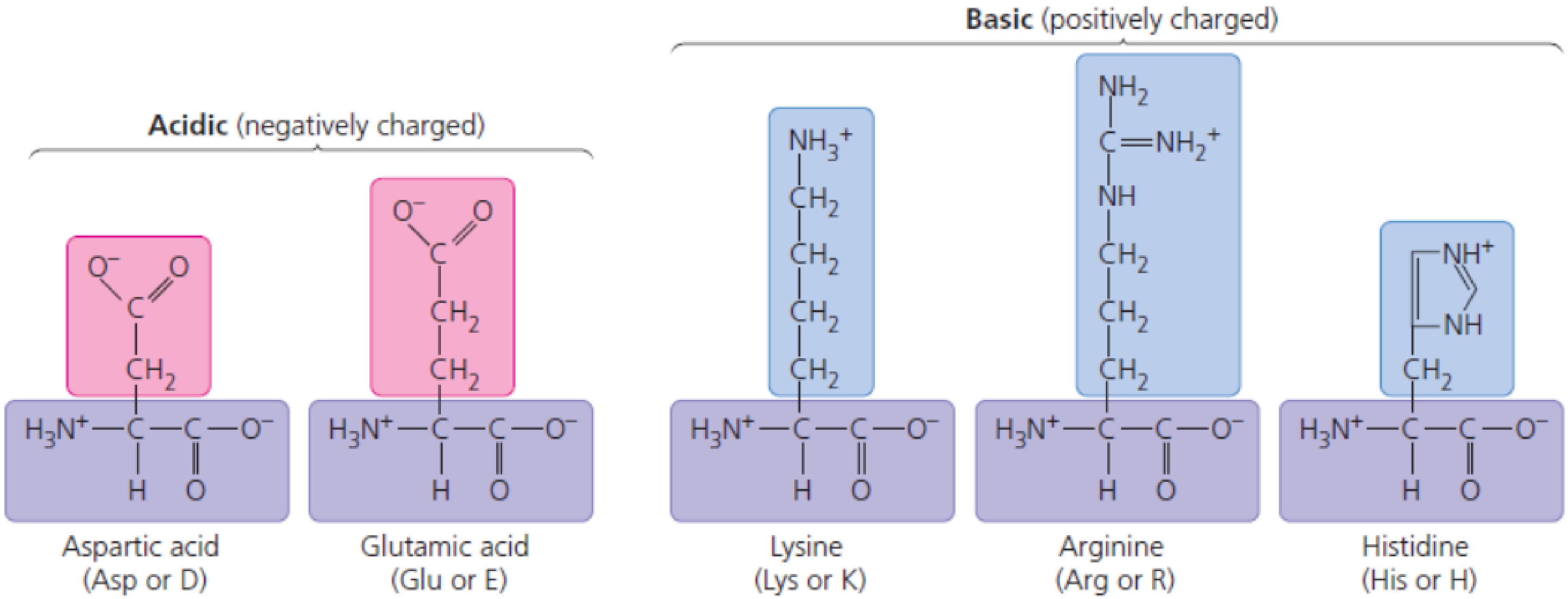


TABLE 18–1 Nonessential and Essential Amino Acids for Humans and the Albino Rat

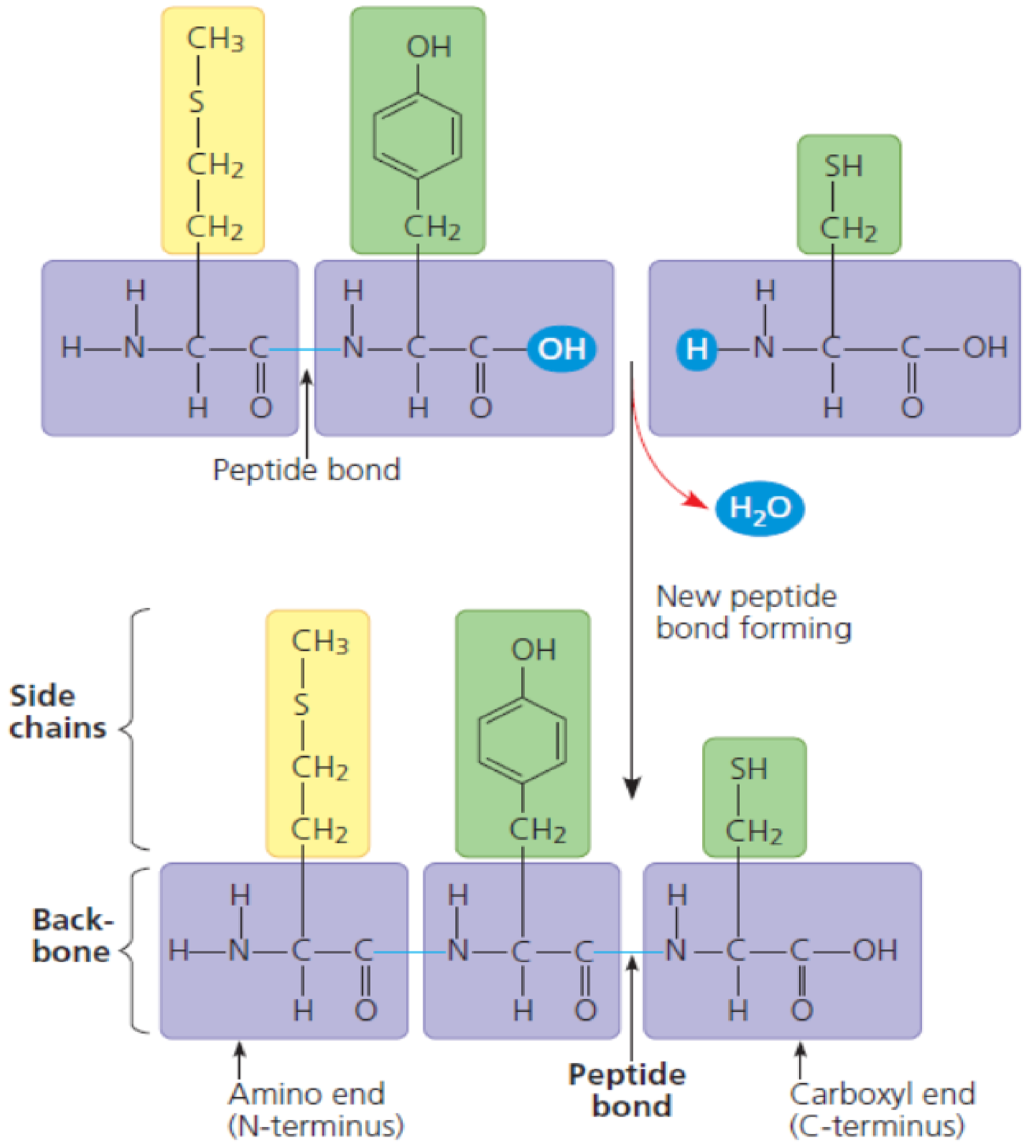
Nonessential	Conditionally essential*	Essential
Alanine	Arginine	Histidine
Asparagine	Cysteine	Isoleucine
Aspartate	Glutamine	Leucine
Glutamate	Glycine	Lysine
Serine	Proline	Methionine
	Tyrosine	Phenylalanine
		Threonine
		Tryptophan
		Valine

*Required to some degree in young, growing animals, and/or sometimes during illness.

Table 18-1
Lehninger Principles of Biochemistry, Fifth Edition

Polypeptides (Amino Acid Polymers)

Making a Polypeptide Chain



Note: dehydration synthesis.

Note: carboxyl group of one end attaches to amino group of another.

Note: peptide bond is formed.

Note: repeating this process builds a polypeptide.

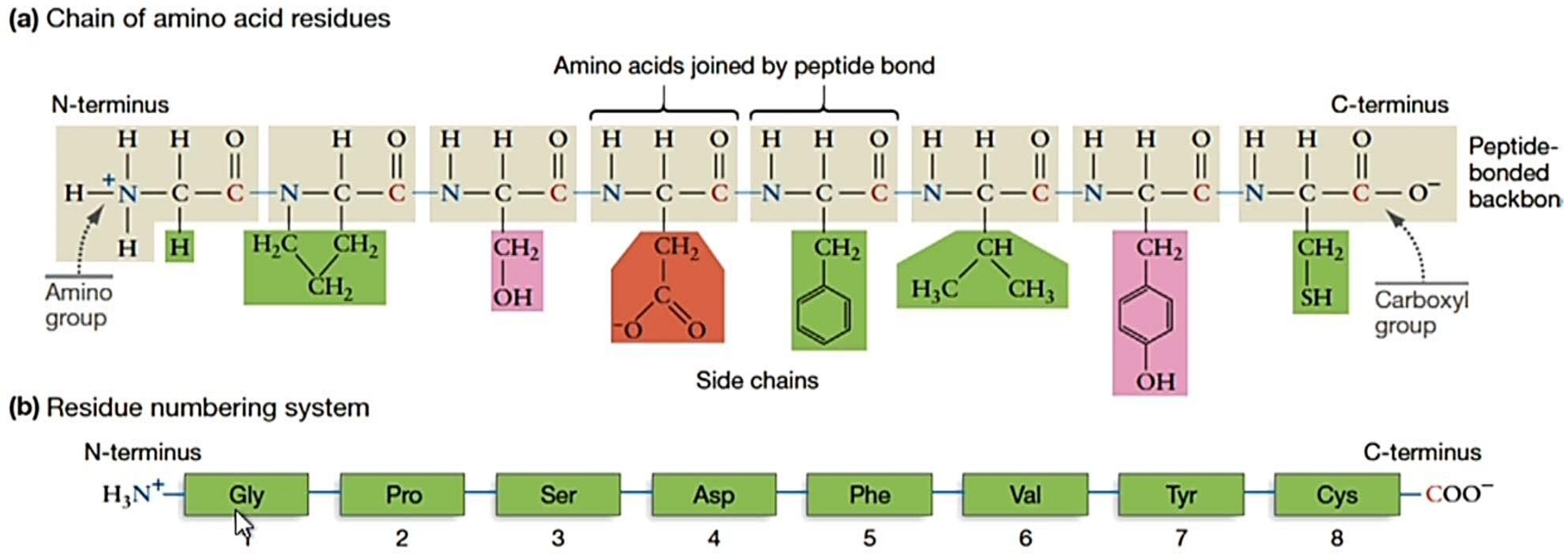


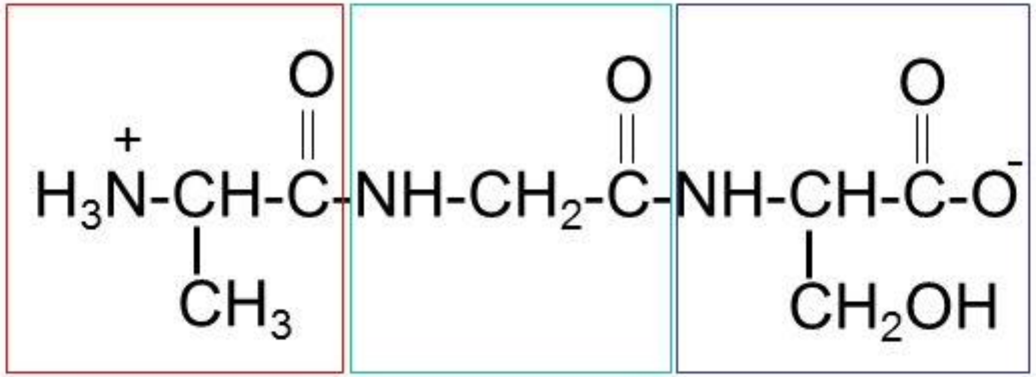
Figure 3.6 Amino Acids Polymerize to Form Chains.

Naming of peptides

- Begin from the N terminal.

- Drop "-ine" and it is replaced by "-yl".

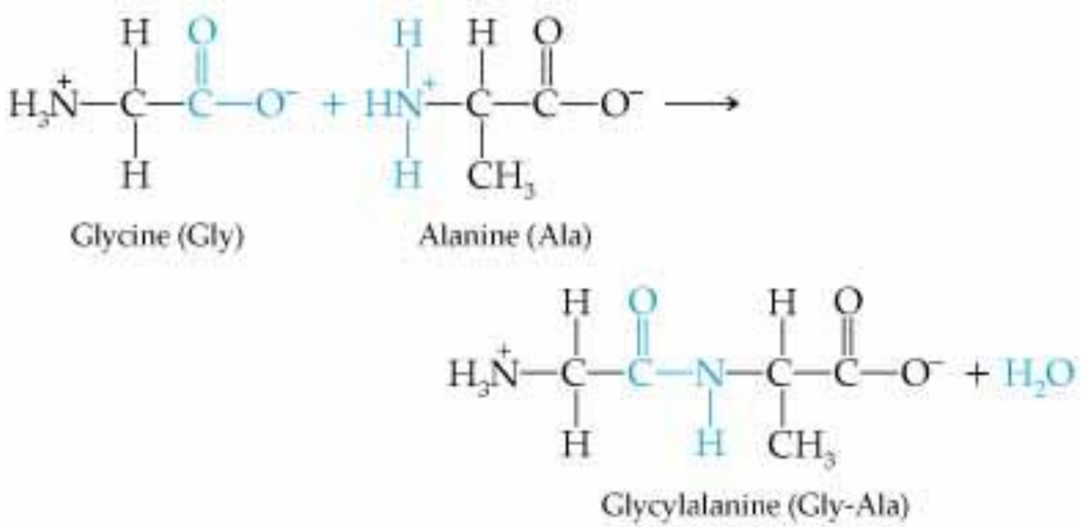
- Give the full name of amino acid at the C terminal.



From alanine
alanyl

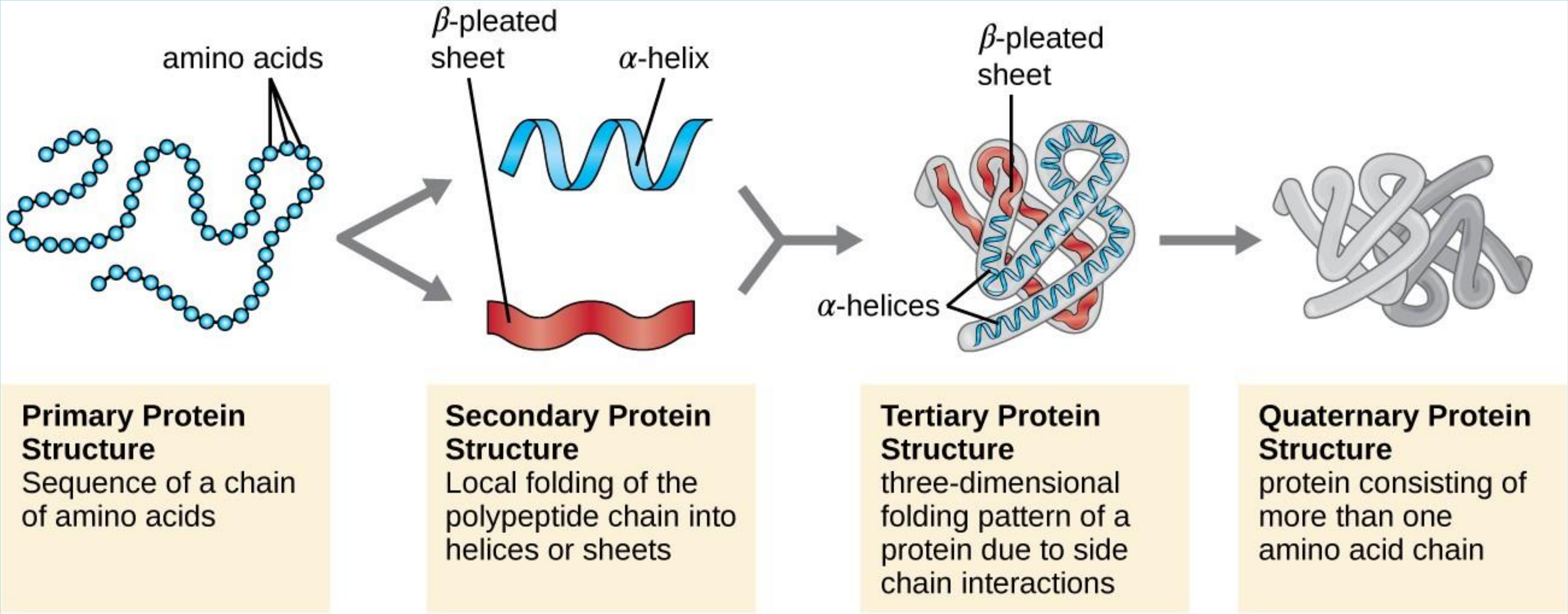
From glycine
glycyl

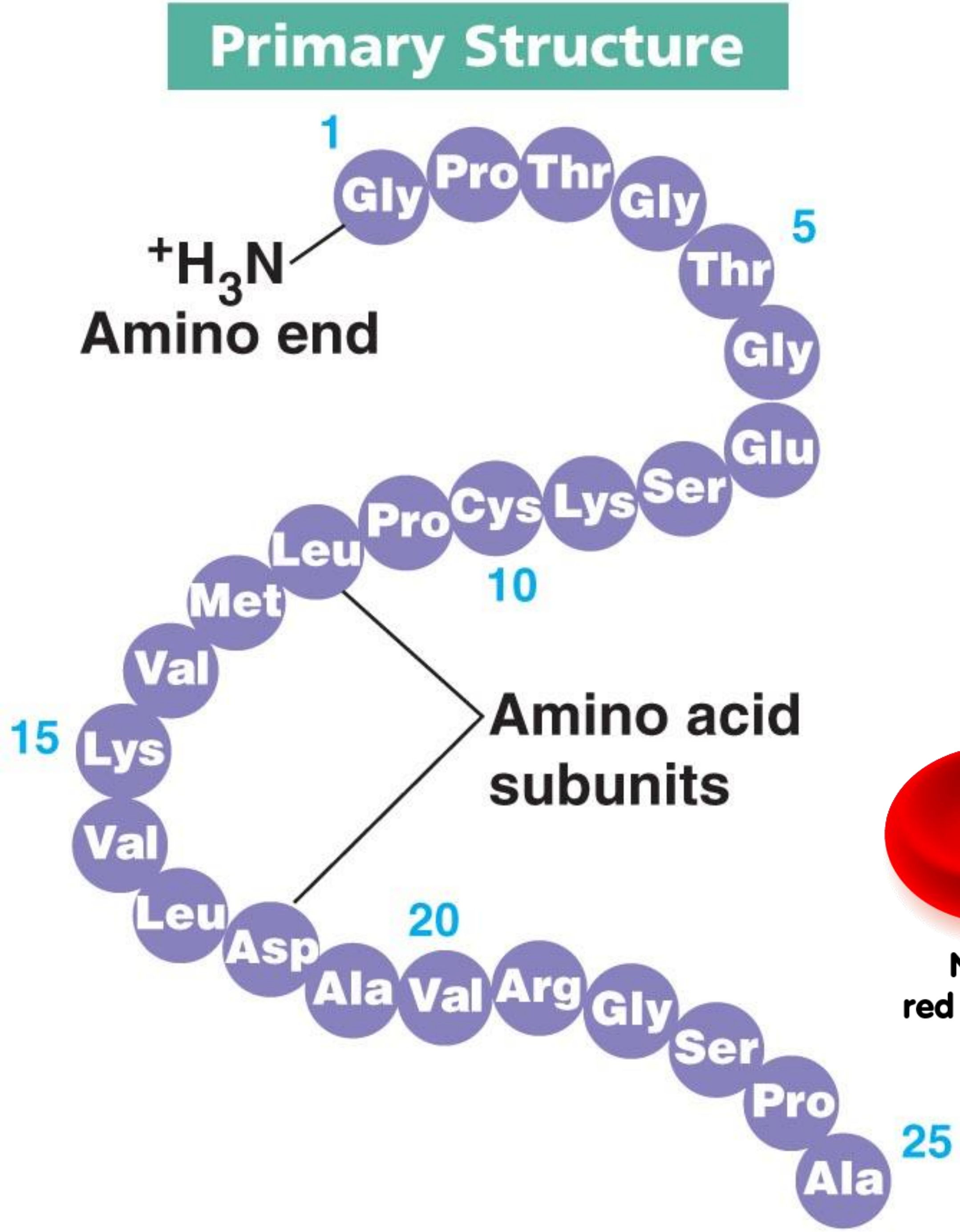
From serine
serine

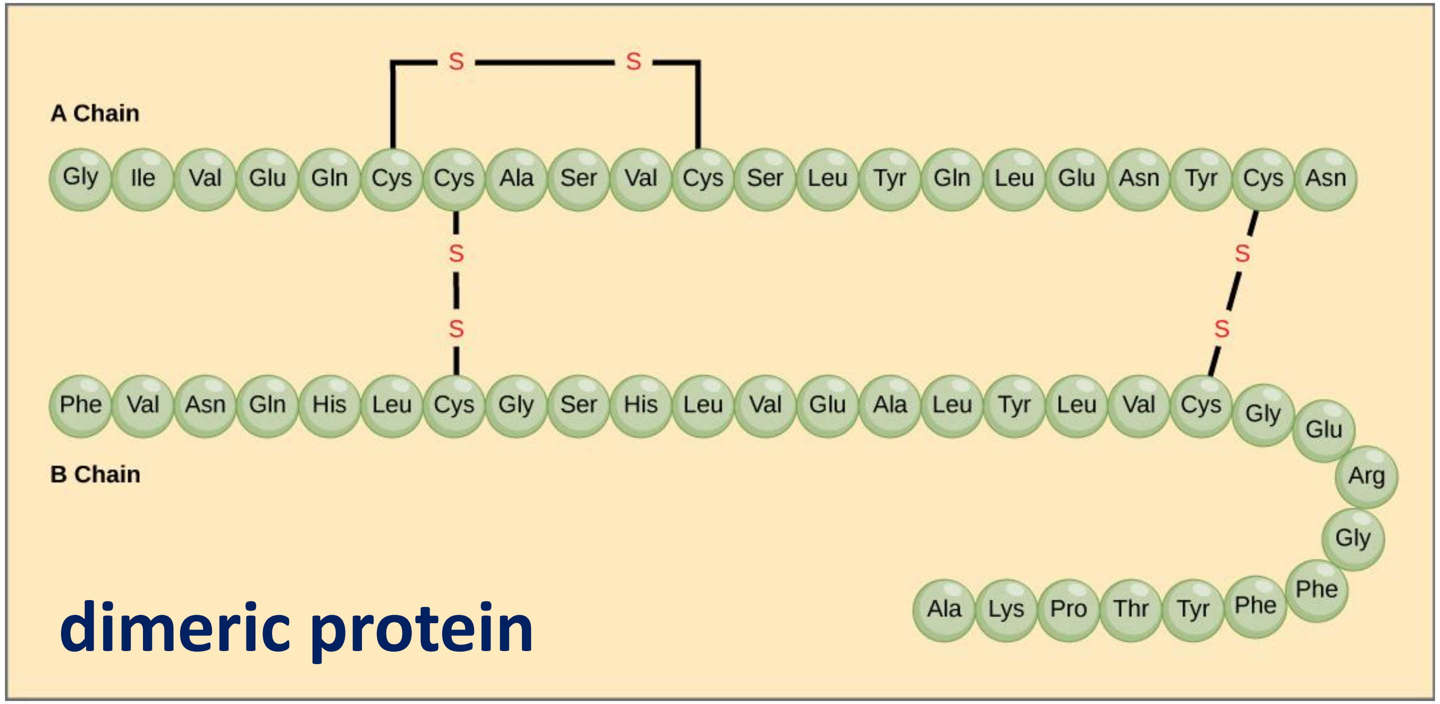


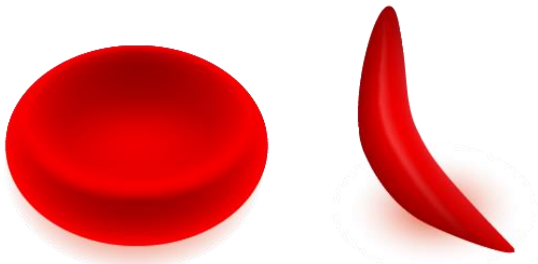
Alanylglycylserine
(Ala-Gly-Ser)

Levels of Protein Structu



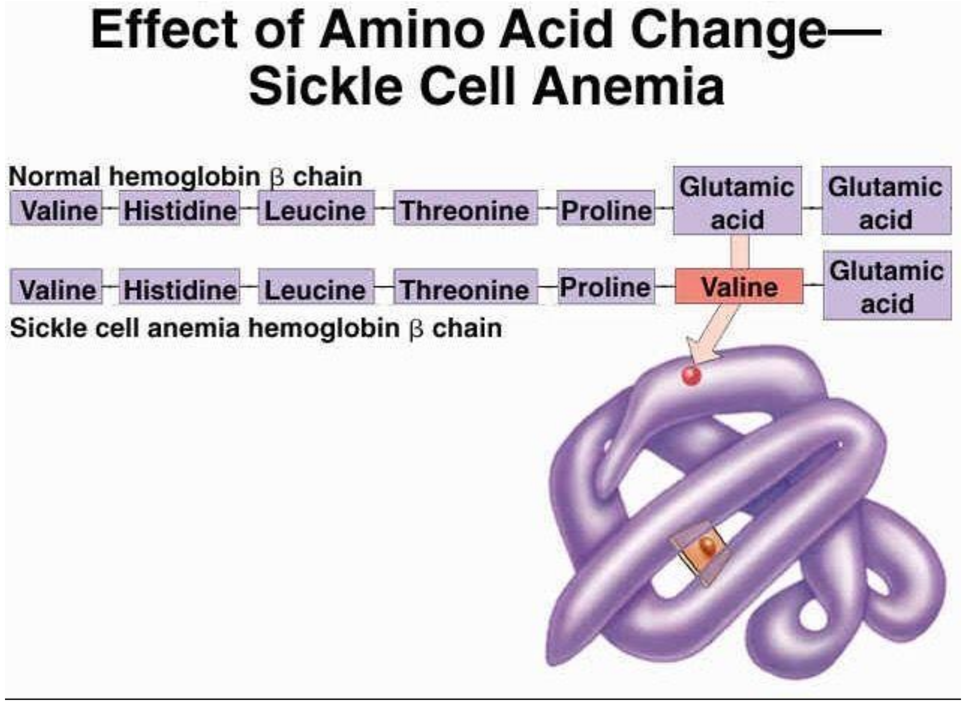


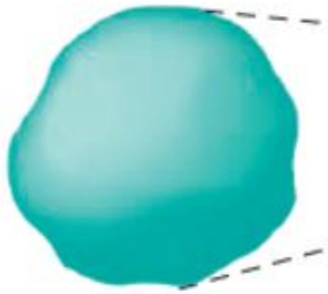
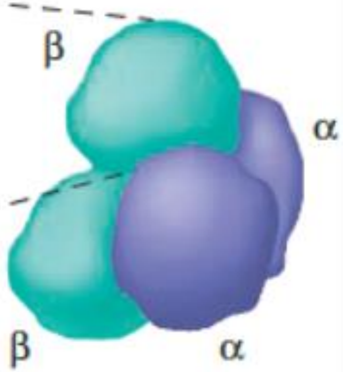
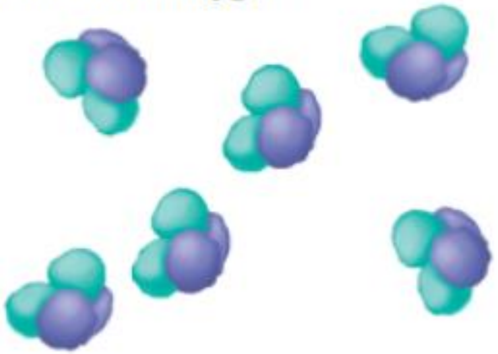
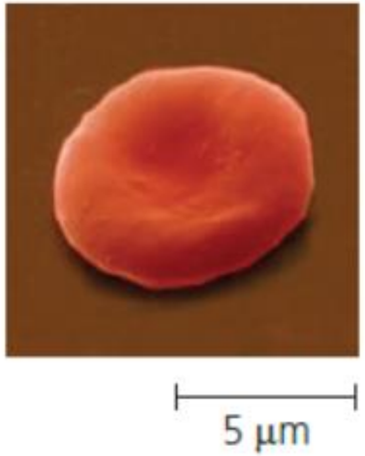
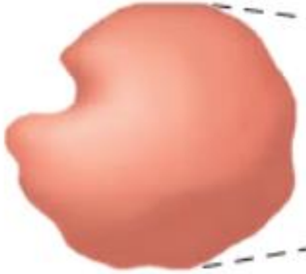
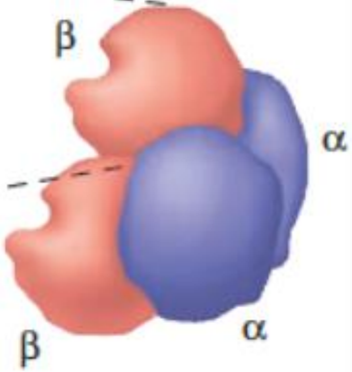
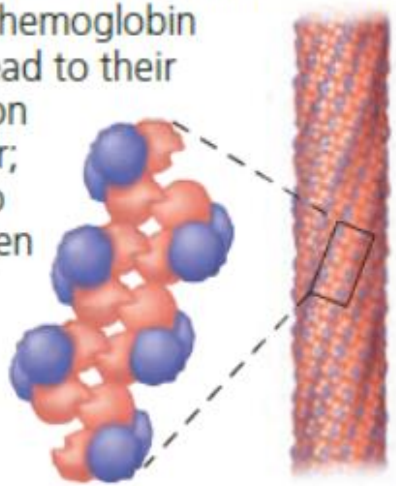
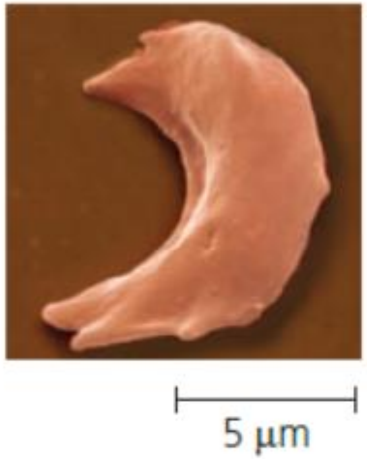




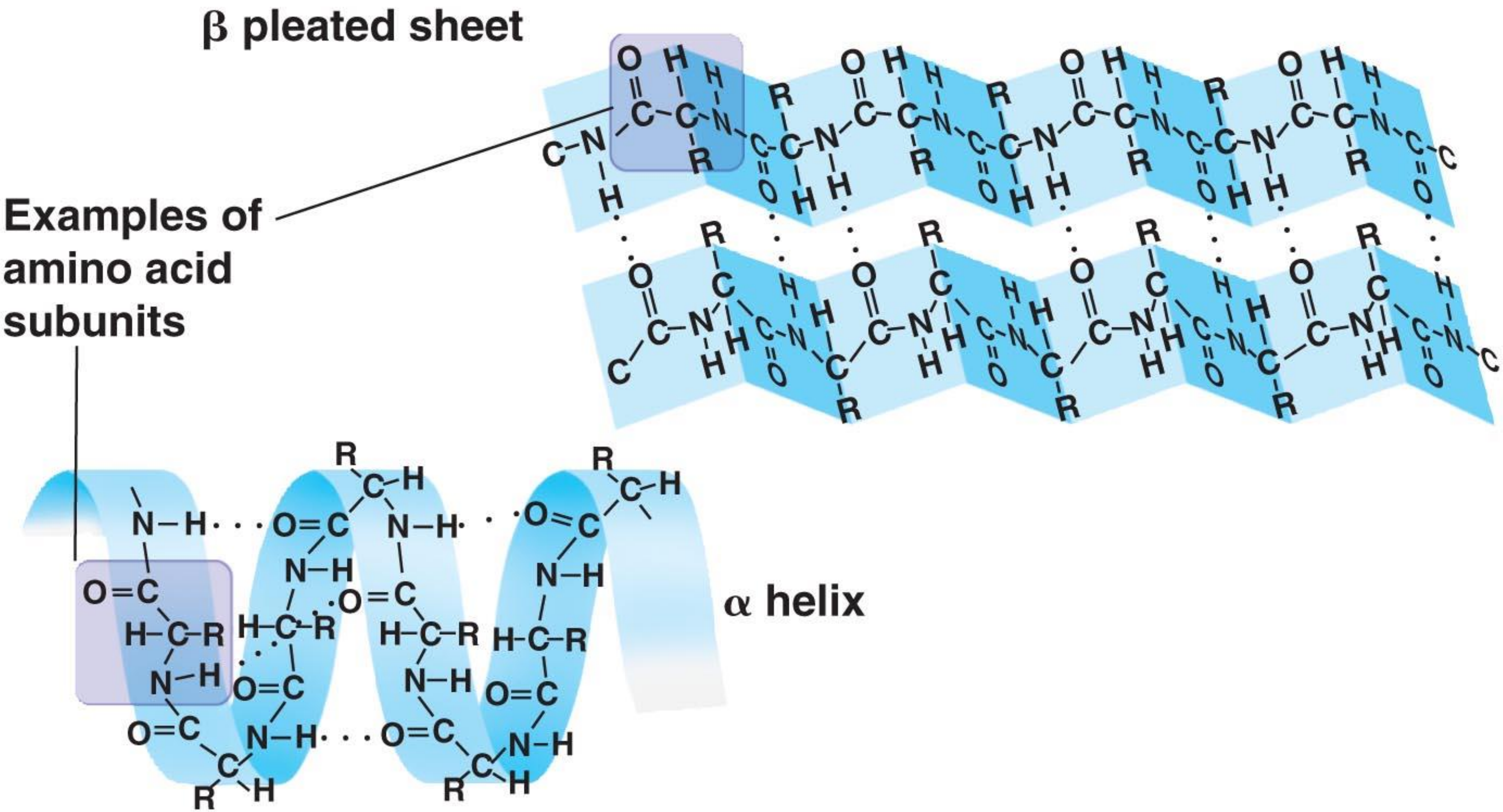
Normal red blood cell

Sickle cell

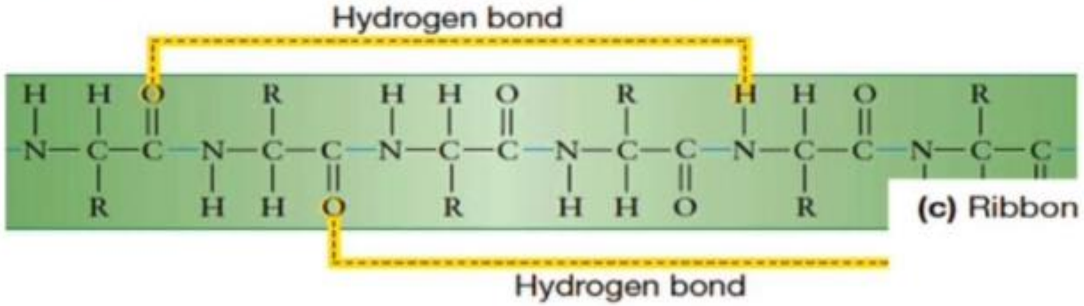


	Primary Structure	Secondary and Tertiary Structures	Quaternary Structure	Function	Red Blood Cell Shape
Normal hemoglobin		Normal β subunit 	Normal hemoglobin 	Normal hemoglobin proteins do not associate with one another; each carries oxygen. 	Normal red blood cells are full of individual hemoglobin proteins. 
Sickle-cell hemoglobin		Sickle-cell β subunit 	Sickle-cell hemoglobin 	Hydrophobic interactions between sickle-cell hemoglobin proteins lead to their aggregation into a fiber; capacity to carry oxygen is greatly reduced. 	Fibers of abnormal hemoglobin deform red blood cell into sickle shape. 

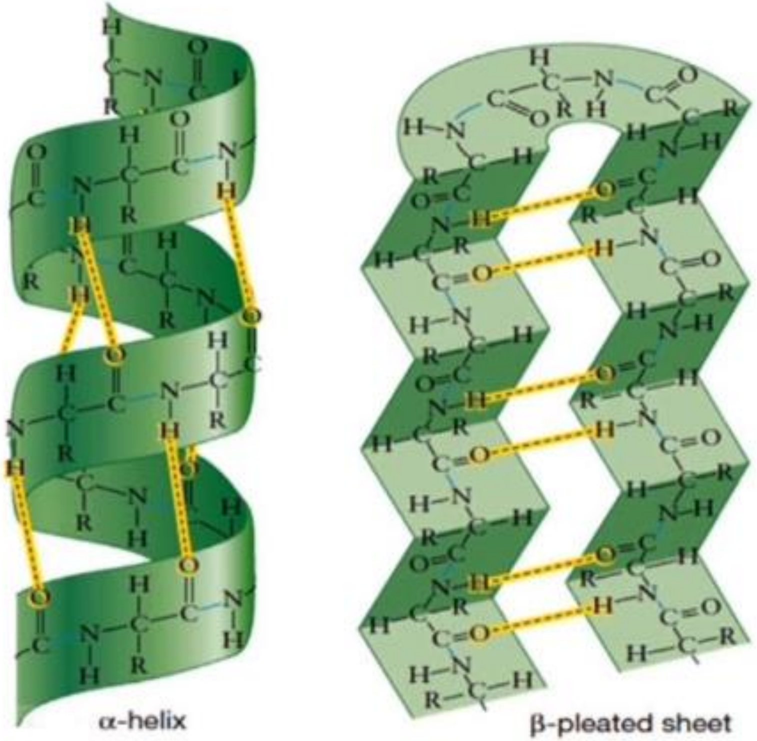
Secondary Structure



(a) Hydrogen bonds can form between nearby amino and carbonyl groups on the same polypeptide chain.



(b) Secondary structures of proteins result.



(c) Ribbon diagrams of secondary structure

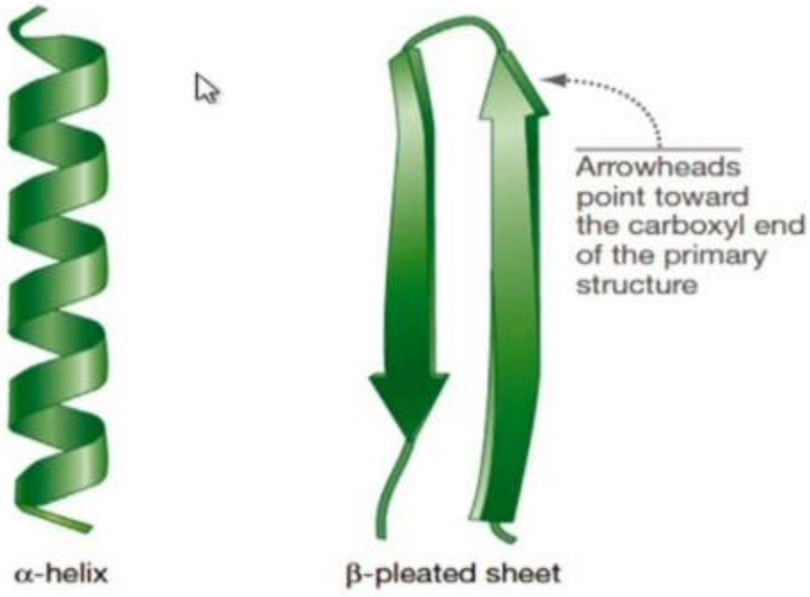
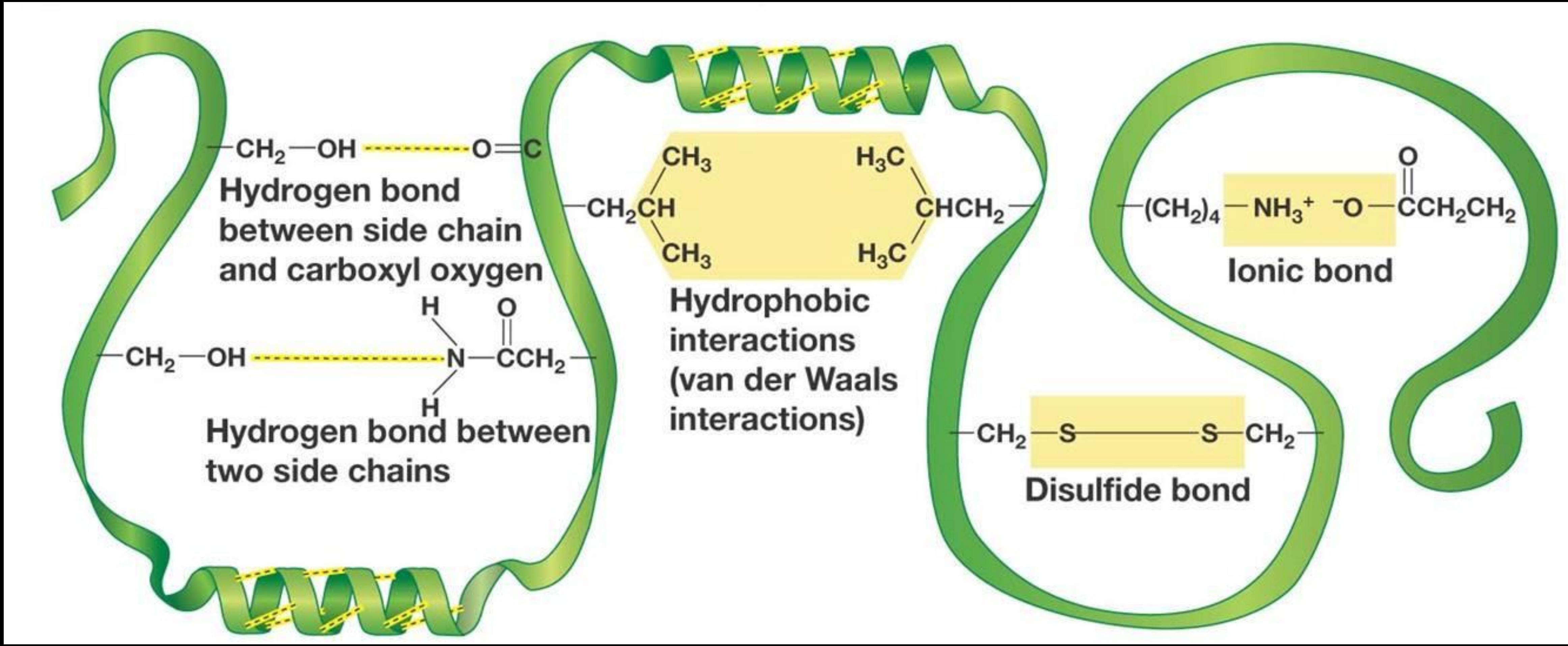


Figure 3.10 Secondary Structures of Proteins. (a) Neighboring regions in a polypeptide chain can form hydrogen bonds between N–H and C=O groups in the peptide-bonded backbone. **(b)** These interactions can result in helical coils or folds that form pleated-sheet structures in the polypeptide. **(c)** Ribbon diagrams represent secondary structures using coils for helices and parallel arrows for pleated sheets.

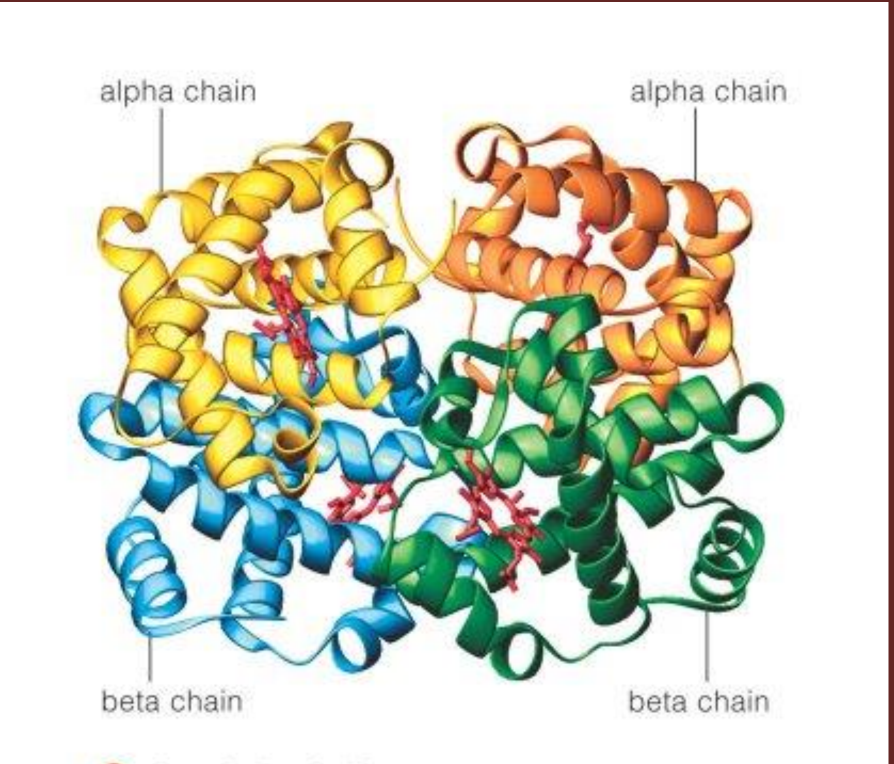
a. b.

FIGURE 3.18 **Fibrous proteins.**

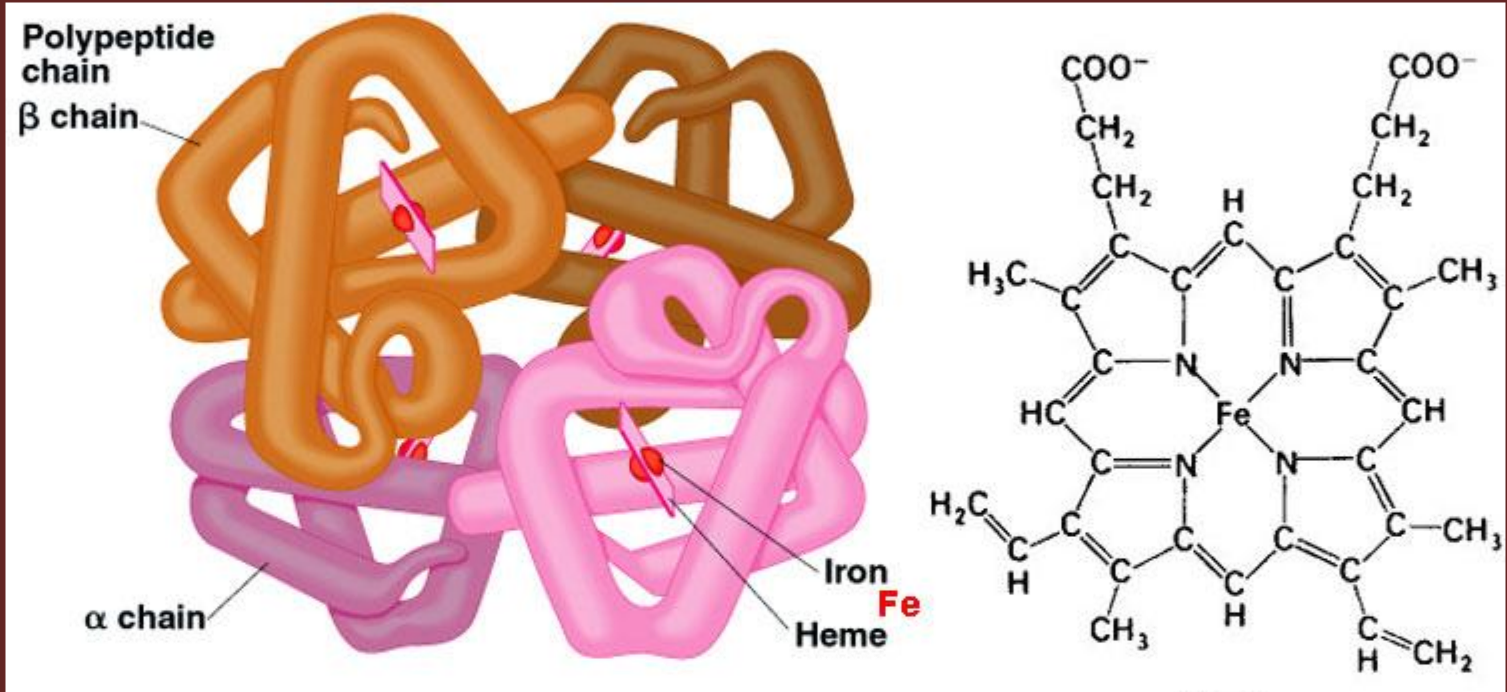
Tertiary structure



quaternary structure



b fourth level of protein structure



Heme
(Fe-protoporphyrin IX)

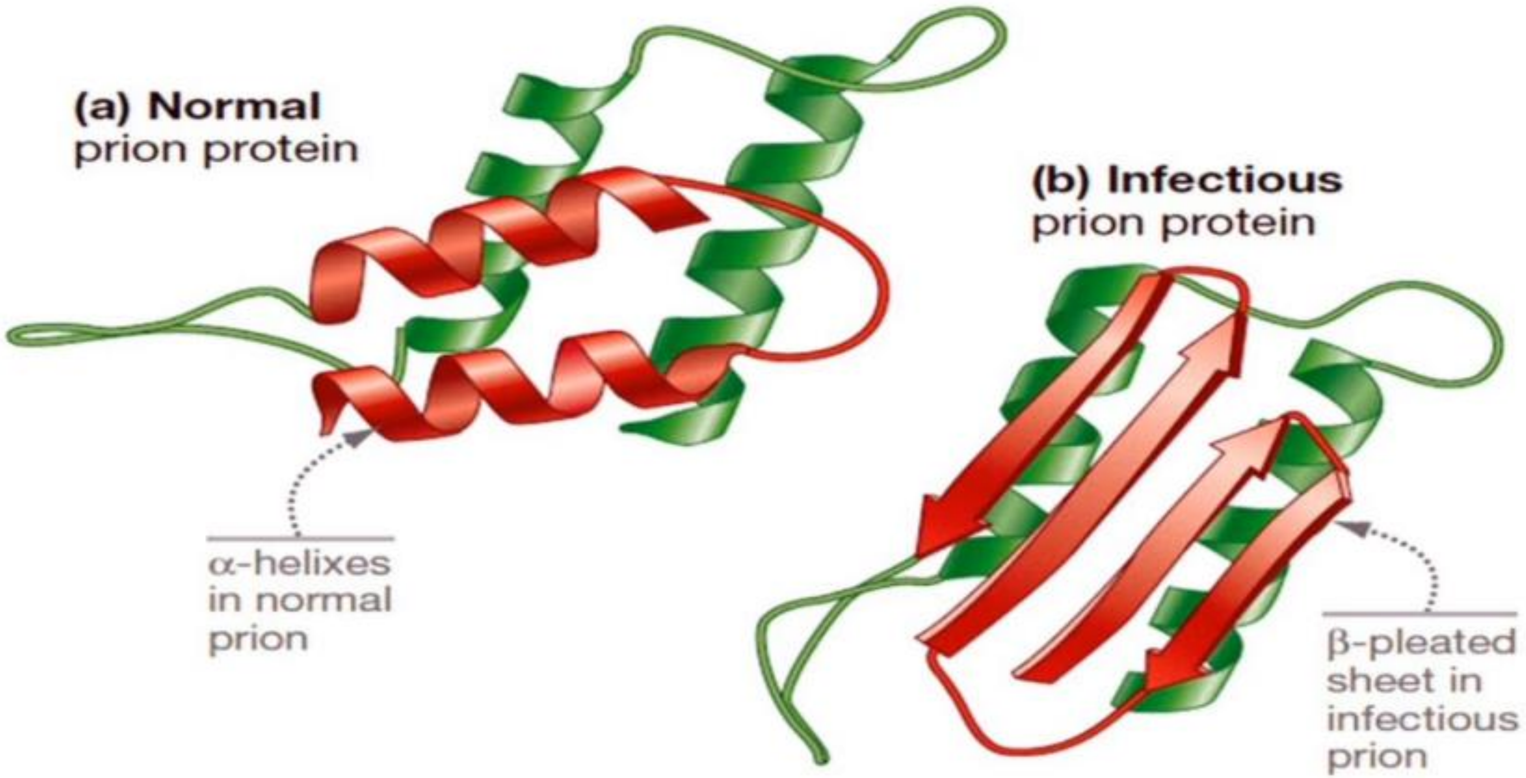


Figure 3.14 Prion Infectivity Is Linked to Structure. Ribbon diagram of **(a)** a normal, noninfectious prion protein with α-helices; and **(b)** the infectious form with β-pleated sheets that causes mad cow disease in cattle.

Figure 20.9 A telephone cord has three levels of structure. These structural levels are a good analogy for the first three levels of protein structure.

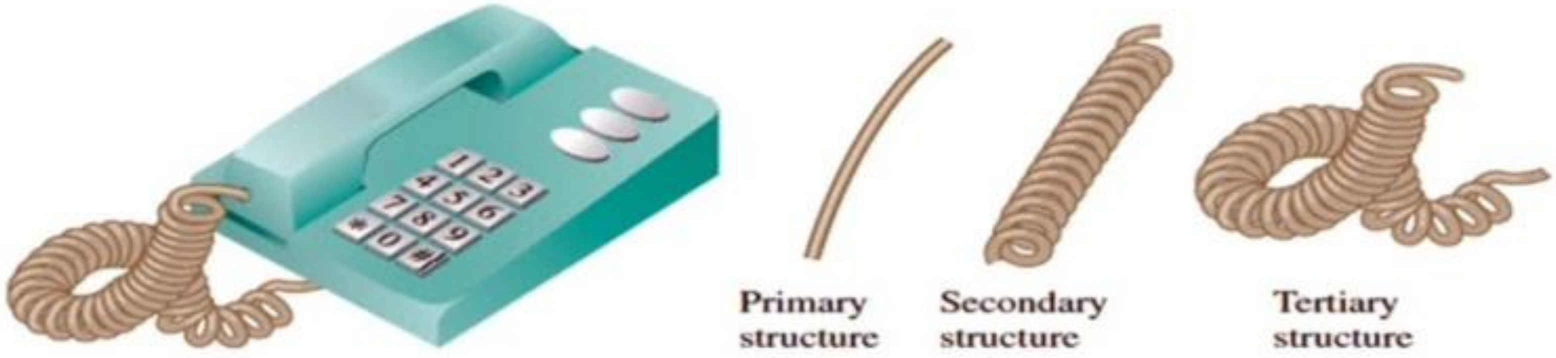


TABLE 16.6 Summary of Structural Levels in Proteins

Structural Level	Characteristics
Primary	Peptide bonds join amino acids in a specific sequence in a polypeptide.
Secondary	The coiled α helix, β-pleated sheet, or a triple helix forms by hydrogen bonding between peptide bonds along the chain.
Tertiary	A polypeptide folds into a compact, three-dimensional shape stabilized by interactions between R groups of amino acids to form a biologically active protein.
Quaternary	Two or more protein subunits combine to form a biologically active protein.

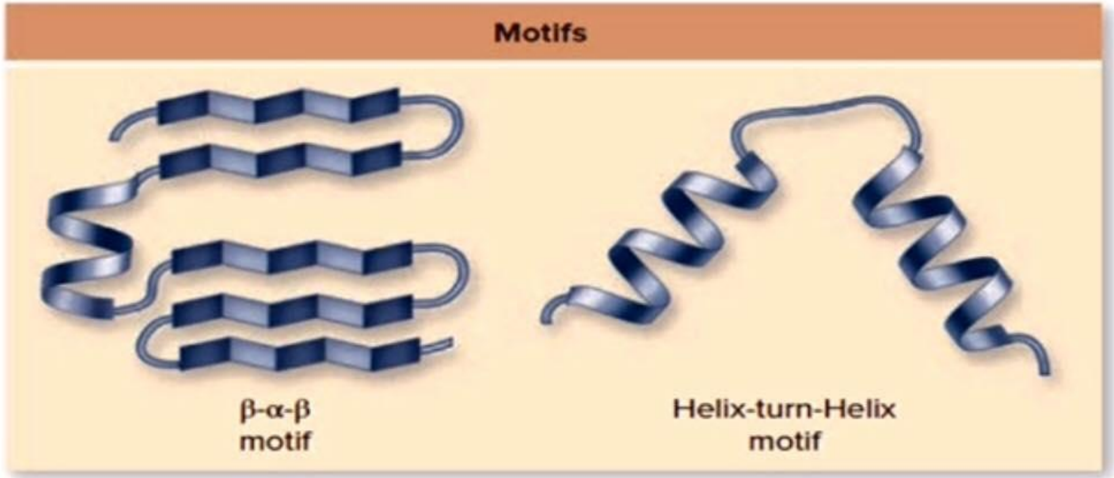
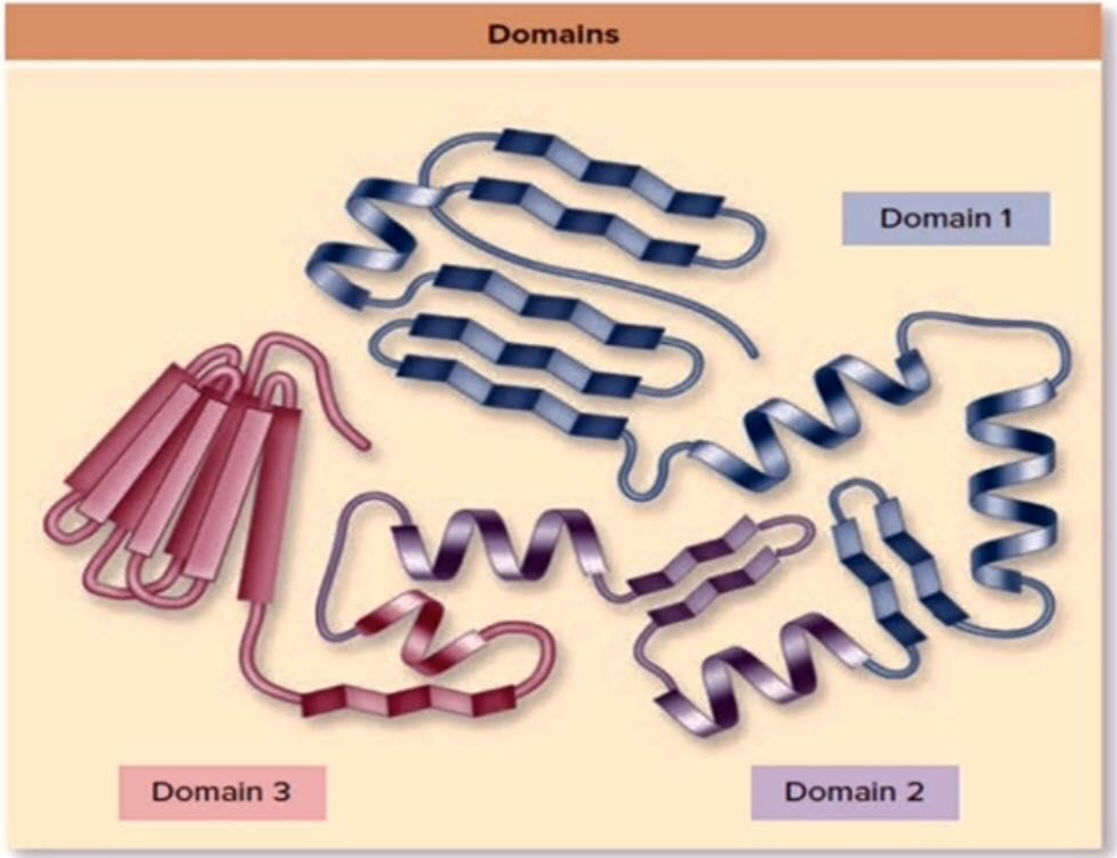
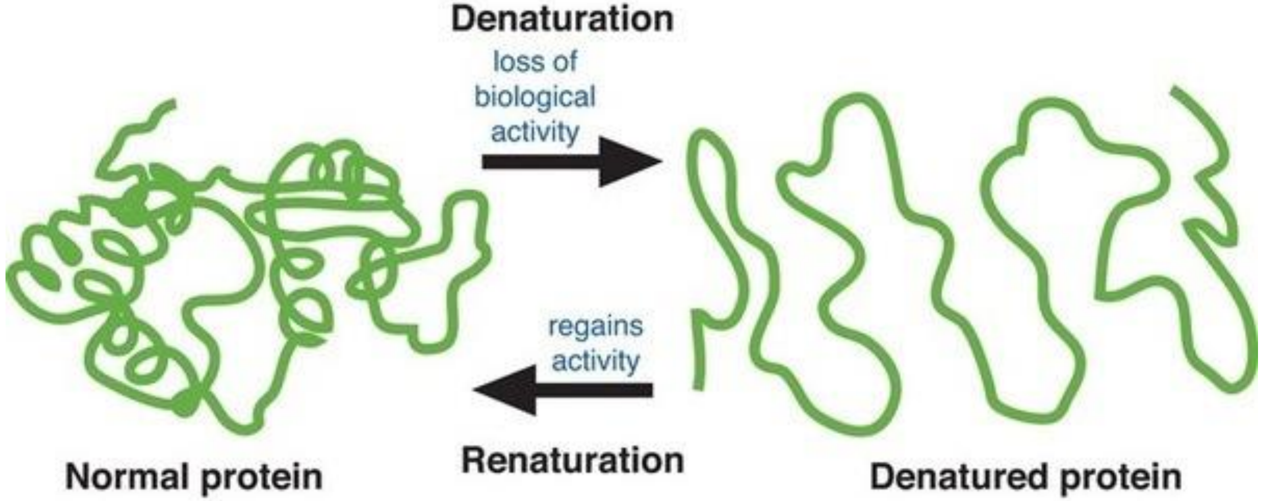


Figure 3.16 Motifs and domains. The elements of secondary structure can combine, fold, or crease to form motifs. These motifs are found in different proteins and can be used to predict function. Proteins also are made of larger domains, which are functionally distinct parts of a protein. The arrangement of these domains in space is the tertiary structure of a protein.



agents: pH, temp, ionic strength, solubility



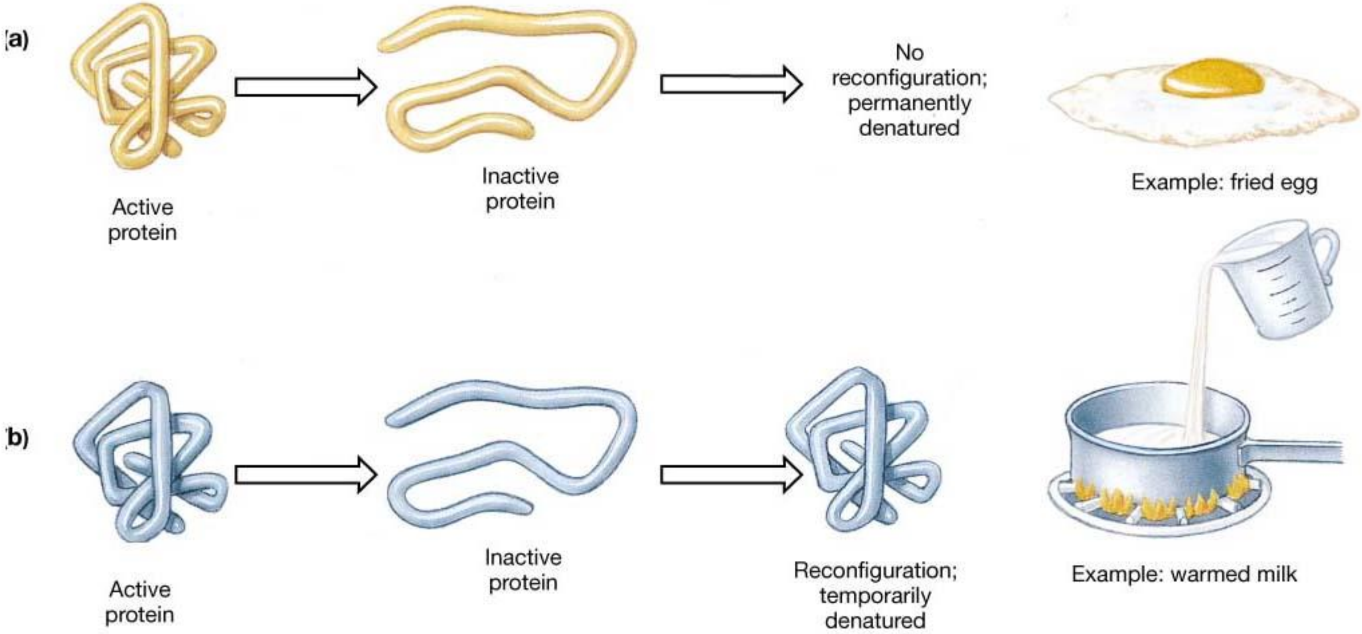
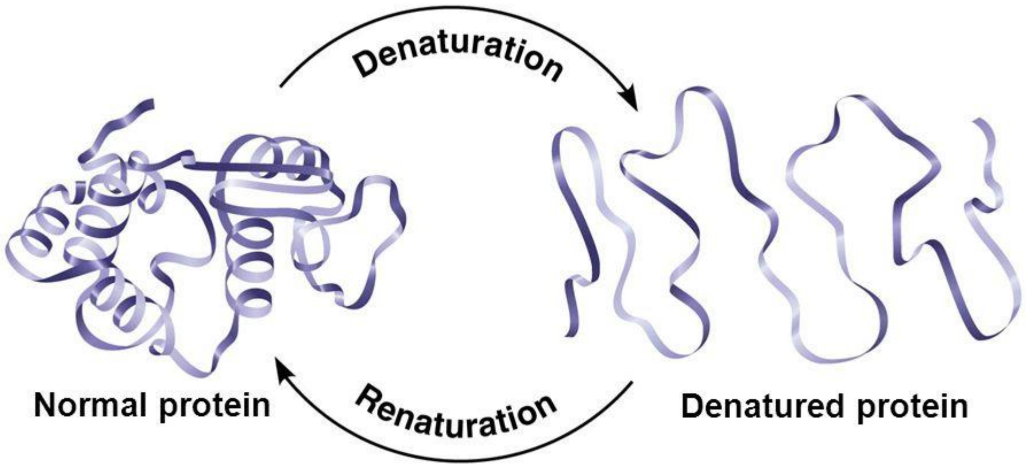


Figure 3.23-3



ตารางที่ 3.11 กลไกการเสียสภาพของโปรตีนจำแนกตามสิ่งที่ทำให้เสียสภาพ

สิ่งทำให้เสียสภาพ (denaturing agent)	กลไกการเสียสภาพ (mode of action)
ความร้อน	ทำให้พันธะไฮโดรเจนระหว่างโมเลกุลสั่นสะเทือนอย่างรุนแรง จนทำให้เกิดการตกตะกอน เช่น การทอดไข่ดาว
รังสีไมโครเวฟ	ทำให้เกิดการสะเทือนของโมเลกุลอย่างรุนแรงจนทำให้พันธะไฮโดรเจนแตกออก
รังสีอัลทราไวโอเลต	ทำให้พันธะไฮโดรเจนระหว่างโมเลกุลสั่นสะเทือนอย่างรุนแรง เช่น ผิวไหม้จากแสงแดด
การเขย่าอย่างรุนแรง (violent shaking)	ทำให้โมเลกุลโปรตีนทรงกลมยืดยาวออกจนพันกันยุ่ง เช่น การตีไข่ขาวให้เป็นครีมในการทำขนมเบื้องหรือเมอร์แรงก์ (merringe)
สารซักฟอก (detergent)	มีผลต่อพันธะของโซ่ข้าง (หมู่ R)
ตัวทำละลายอินทรีย์ (เช่น เอทานอล แอซีโตน)	มีผลต่อพันธะของโซ่ข้าง (หมู่ R) เนื่องจากตัวทำละลายอินทรีย์ทำลายพันธะไฮโดรเจนและทำให้โปรตีนเสียสภาพอย่างรวดเร็ว เช่น การทำลายแบคทีเรียด้วยเอทานอลร้อยละ 70
กรดแก่ และเบสแก่	ทำลายพันธะไฮโดรเจน และสะพานเกลือ (salt bridge) จนทำให้เกิดปฏิกิริยาสลายพันธะเพปไทด์ของโปรตีน
เกลือของโลหะหนัก (เช่น เกลือของ Hg^{2+}, Ag^{+}, Pb^{2+})	โลหะหนักจับกับหมู่ซัลฟ์ไฮดริลและเกิดเป็นเกลือที่เป็นพิษ (poisonous salt)
สารรีดิวซ์	รีดิวซ์พันธะไดซัลไฟด์ของโปรตีนเกิดเป็นกรดอะมิโนที่มีหมู่ซัลฟ์ไฮดริล

ตารางที่ 3.12 จุดประจุไฟฟ้าสมดุล (pI) ของโปรตีนบางชนิด

โปรตีน	pI	โปรตีน	pI	โปรตีน	pI
เพปซิน	< 1.0	บีตา-แลกโทโกลบูลิน	5.2	ไคโมทริปซิโนเจน	9.5
อัลบูมินในไข่ขาว	4.6	อินซูลิน	5.4	ไซโทโครม ซี	10.7
อัลบูมินในซีรัม	4.9	ฮีโมโกลบิน	6.8	ฮีสโทน	10.8
ยูรีเอส	5.0	ไมโอโกลบิน	7.0	ไลโซไซม	11.0

pI > pH ของสารละลาย	**net charge (–)**	**โปรตีนผลักกัน ไม่ตกตะกอน**
pI < pH ของสารละลาย	**net charge (+)**	
pI = pH ของสารละลาย	**net charge (0)**	**โปรตีนรวมกัน ตกตะกอน**

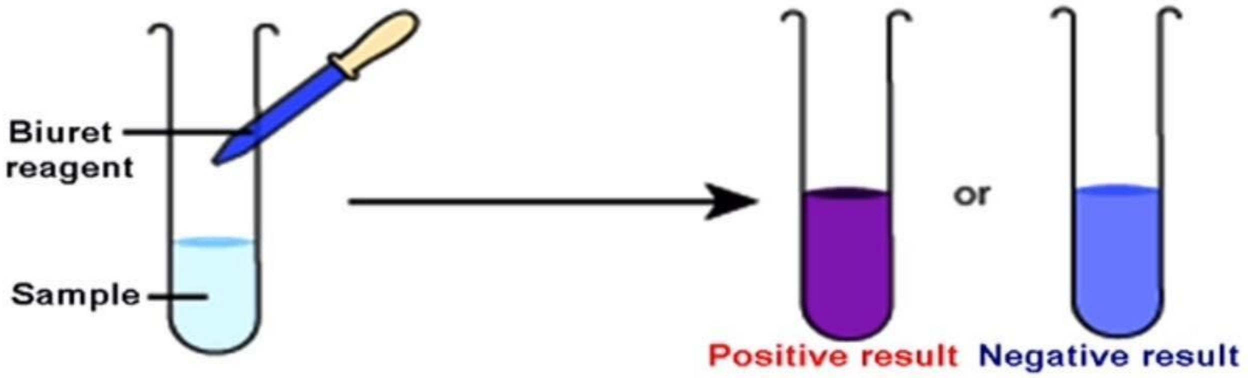
กรดอะมิโนแต่ละชนิดมีค่าความเป็นกรด-เบสที่ทำให้ประจุมีค่าสมดุลหรือมีจำนวนประจุบวกและประจุลบเท่ากัน เรียกค่าความเป็นกรด-เบสนี้ว่า **จุดไอโซอิเล็กทริก หรือจุดประจุไฟฟ้าสมดุล (isoelectric point, pI)**

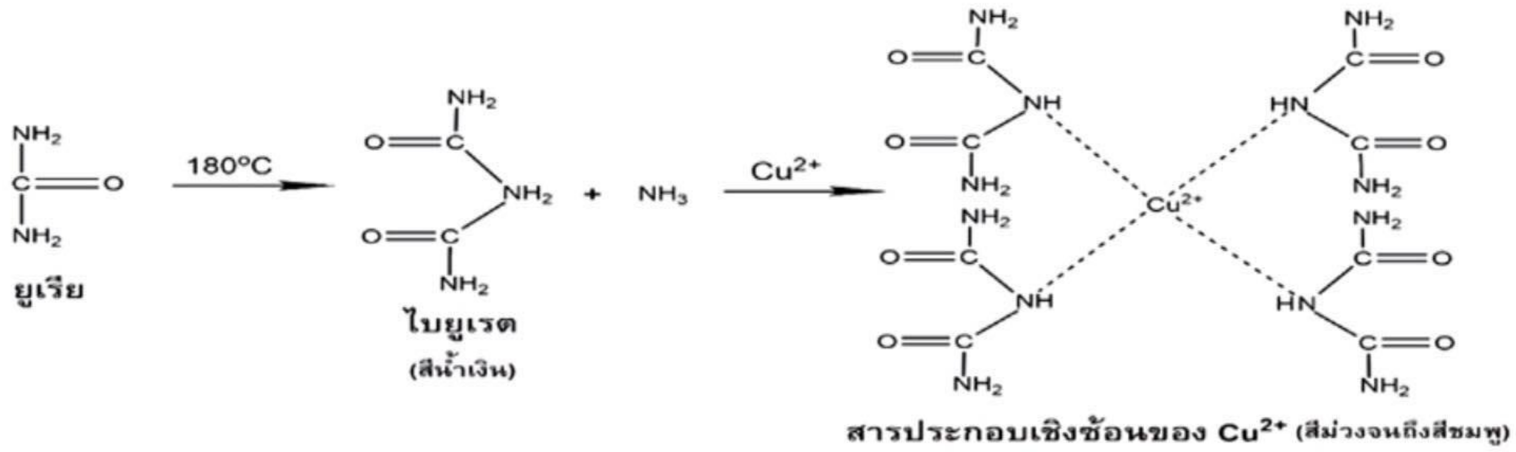
กรดอะมิโน	pI	กรดอะมิโน	pI	กรดอะมิโน	pI
ไกลซีน	5.97	เฟนิลอะลานีน	5.48	ไทโรซีน	5.66
อะลานีน	6.01	ทริปโตเฟน	5.88	กรดแอสพาร์ทิก	2.77
เวลีน	5.97	เซรีน	5.68	กรดกลูทามิก	3.22
ลิวซีน	5.98	ทรีโอนีน	5.87	ไลซีน	9.74
ไอโซลิวซีน	6.02	ซิสเทอีน	5.07	อาร์จินีน	10.76
โพรลีน	6.48	แอสพาราจีน	5.41	ฮีสทิดีน	7.59
เมไทโอนีน	5.74	กลูทามีน	5.65		

การทดสอบโปรตีน

Biuret test

ทดสอบสารที่มีพันธะเพปไทด์ (– CO–NH –) ตั้งแต่ 2 ตำแหน่งขึ้นไป ได้แก่ ไตรเพปไทด์ โอลิโกเพปไทด์ และโปรตีนที่มีโครงสร้างซับซ้อน



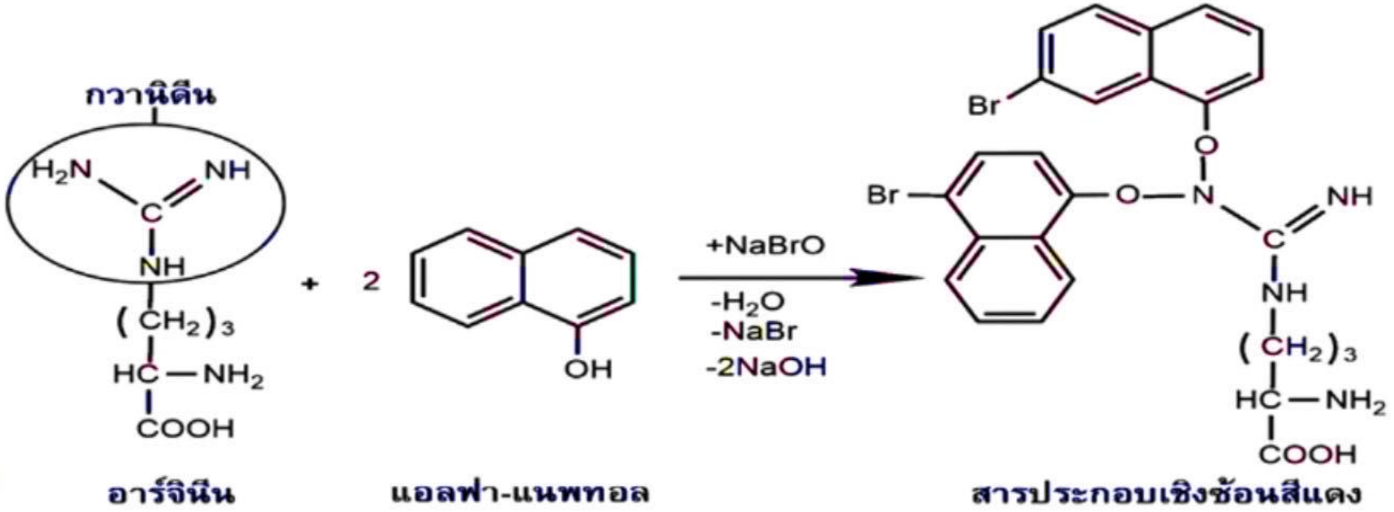


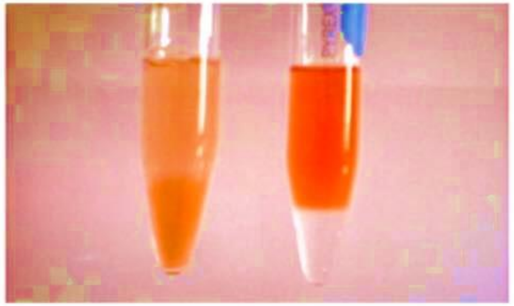
Sulfur test ทดสอบกรดอะมิโนที่มีกำมะถันเป็นองค์ประกอบ ได้แก่ ซีสเทอีน และซิสทีน ยกเว้นเมไทโอนีน

$$Na_2S + (CH_3COO)_2Pb \longrightarrow PbS + 2CH_3COONa$$

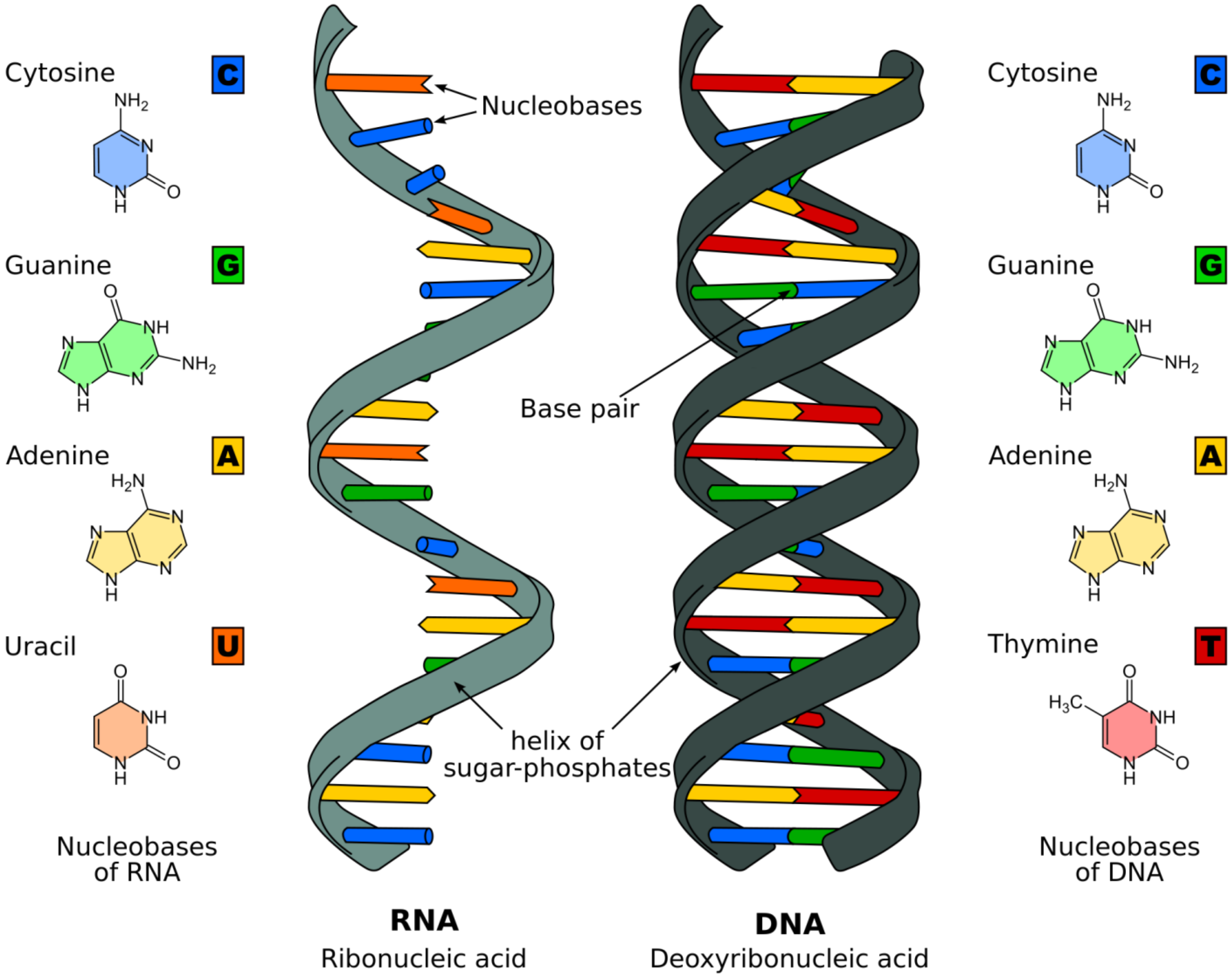
ตะกอนดำ

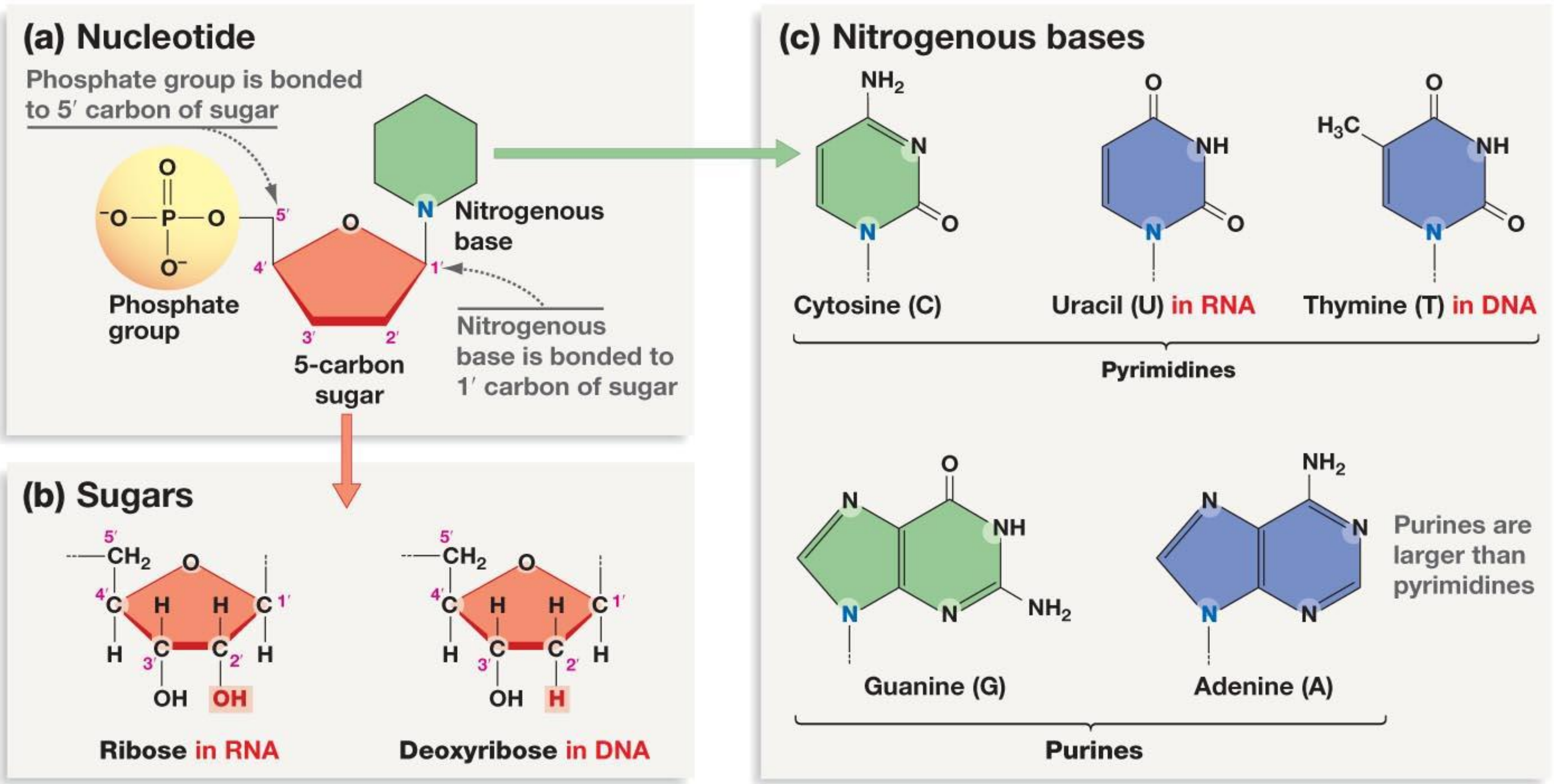
Sakaguchi reaction ใช้ทดสอบกรดอะมิโนอาร์จีนีนที่มีโซ่ข้าง เป็นกวานิดีน (guanidine)





Nucleic acids




(a) Nucleotide
Phosphate group is bonded to 5′ carbon of sugar
O
$^{-}$O—P—O
O^{-}
5′
O
N
Nitrogenous base
4′
1′
Phosphate group
3′
2′
5-carbon sugar
Nitrogenous base is bonded to 1′ carbon of sugar
(b) Sugars
5′
CH_2
O
4′
C
H
H
C
1′
H
C
3′
C
2′
H
OH
OH
Ribose in RNA
5′
CH_2
O
4′
C
H
H
C
1′
H
C
3′
C
2′
H
OH
H
Deoxyribose in DNA
(c) Nitrogenous bases
NH_2
N
O
N
Cytosine (C)
O
NH
O
N
Uracil (U) in RNA
H_3C
O
NH
O
N
Thymine (T) in DNA
Pyrimidines
O
N
NH
N
N
NH_2
Guanine (G)
NH_2
N
N
N
N
Adenine (A)
Purines are larger than pyrimidines
Purines

DNA double helix is made of two strands.

Each strand is a chain of of antiparallel nucleotides.

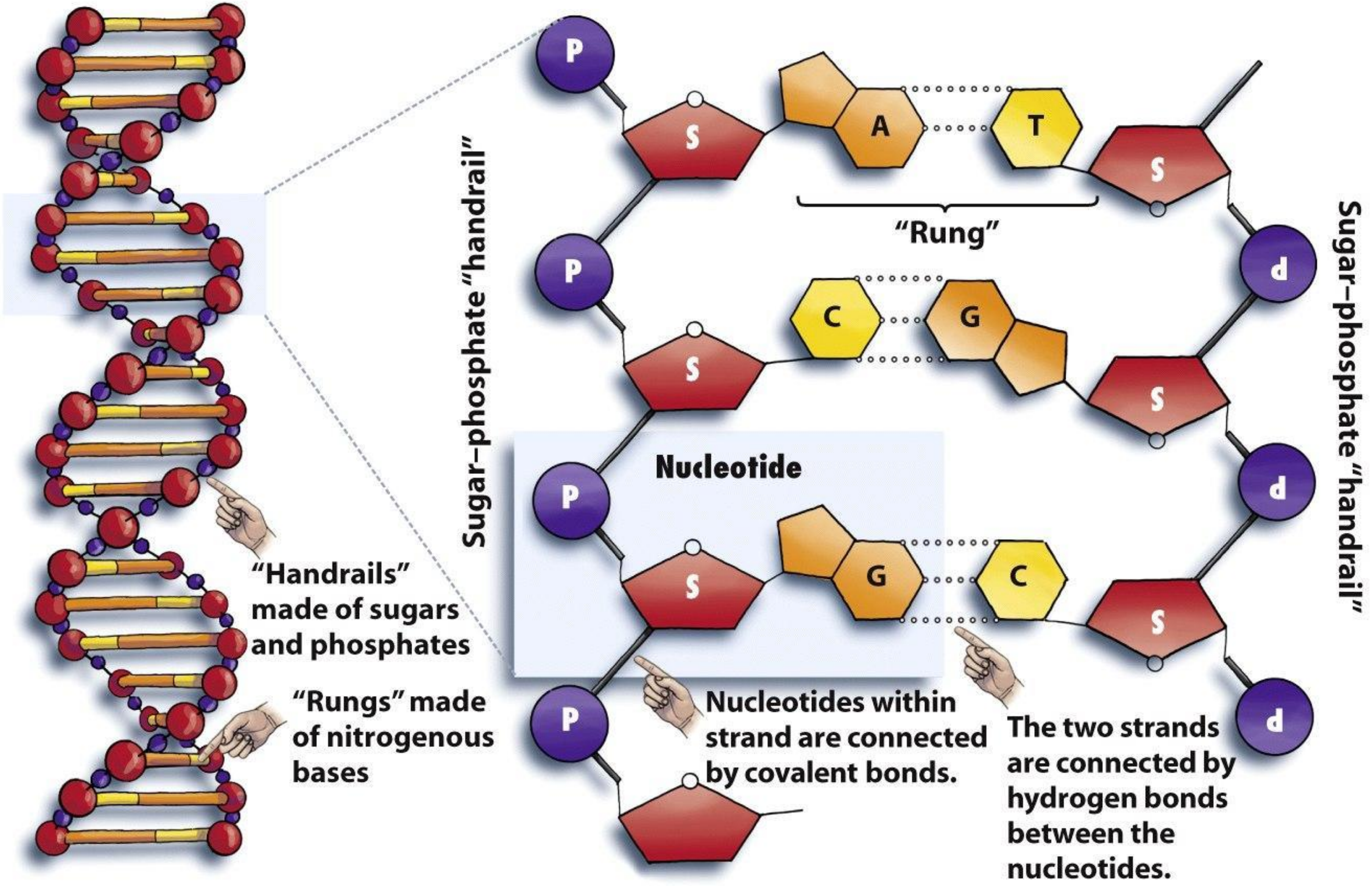


Figure 2-13ab Biology: Science for Life, 2/e

A purine-purine pair is too wide and a pyrimidine-pyrimidine pair too narrow to account for the 2-nm diameter of the double helix.

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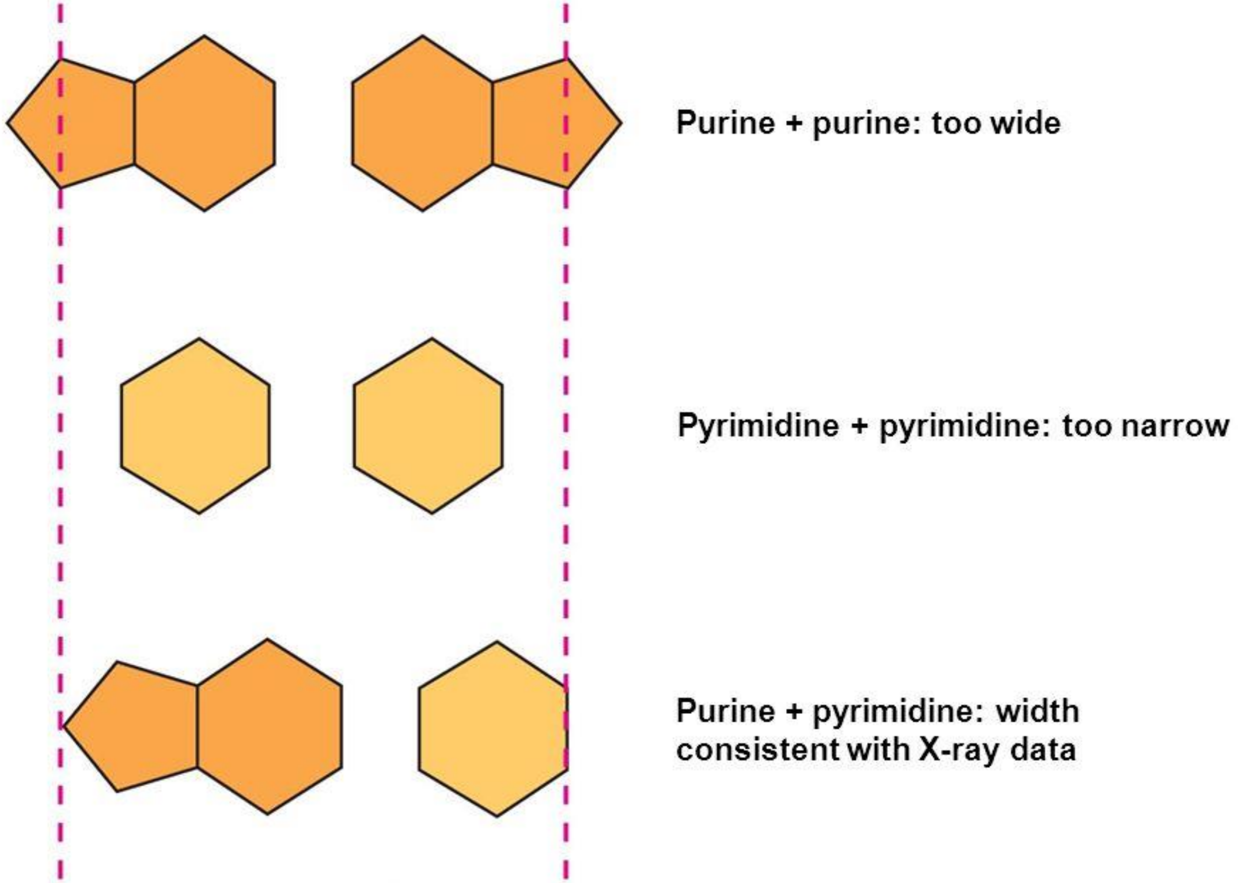


Chargaff's Rule: Rule of Base Pairing

Table 8.1 Base composition of DNA from different sources and ratios of bases

Source of DNA	A	T	G	C	Ratio A/T	Ratio G/C	Ratio (A + G)/(T + C)
E. coli	26.0	23.9	24.9	25.2	1.09	0.99	1.04
Yeast	31.3	32.9	18.7	17.1	0.95	1.09	1.00
Sea urchin	32.8	32.1	17.7	18.4	1.02	0.96	1.00
Rat	28.6	28.4	21.4	21.5	1.01	1.00	1.00
Human	30.3	30.3	19.5	19.9	1.00	0.98	0.99

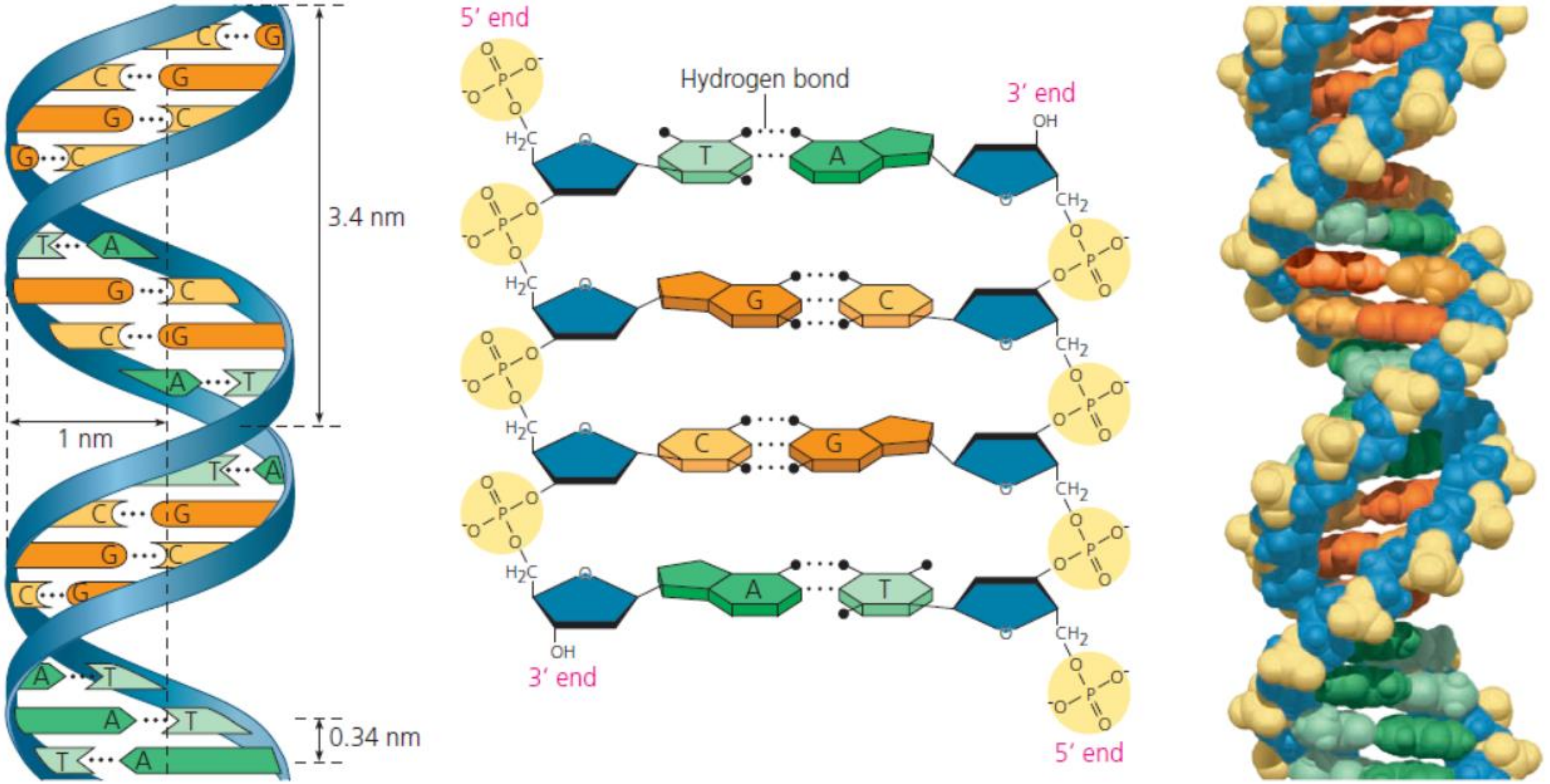
Table 8.1
Genetics Essentials: Concepts and Connections, First Edition

All DNA, A=T & G=C, that is, A+G/T+C = 1

เพิ่มเติม

Names of Nucleosides and Nucleotides

Base	Nucleosides	Nucleotides
RNA		
Adenine (A)	Adenosine (A)	Adenosine 5'-monophosphate (AMP)
Guanine (G)	Guanosine (G)	Guanosine 5'-monophosphate (GMP)
Cytosine (C)	Cytidine (C)	Cytidine 5'-monophosphate (CMP)
Uracil (U)	Uridine (U)	Uridine 5'-monophosphate (UMP)
DNA		
Adenine (A)	Deoxyadenosine (A)	Deoxyadenosine 5'-monophosphate (dAMP)
Guanine (G)	Deoxyguanosine (G)	Deoxyguanosine 5'-monophosphate (dGMP)
Cytosine (C)	Deoxycytidine (C)	Deoxycytidine 5'-monophosphate (dCMP)
Thymine (T)	Deoxythymidine (T)	Deoxythymidine 5'-monophosphate (dTMP)

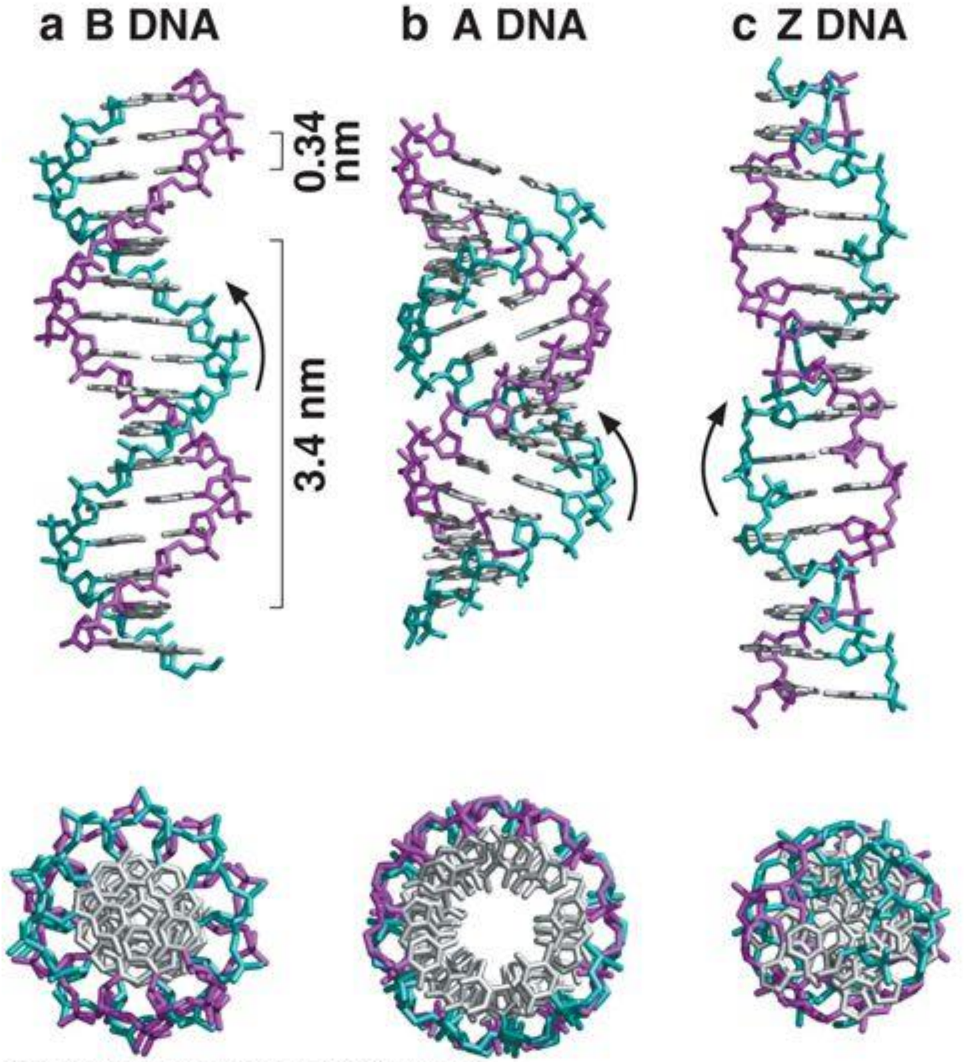


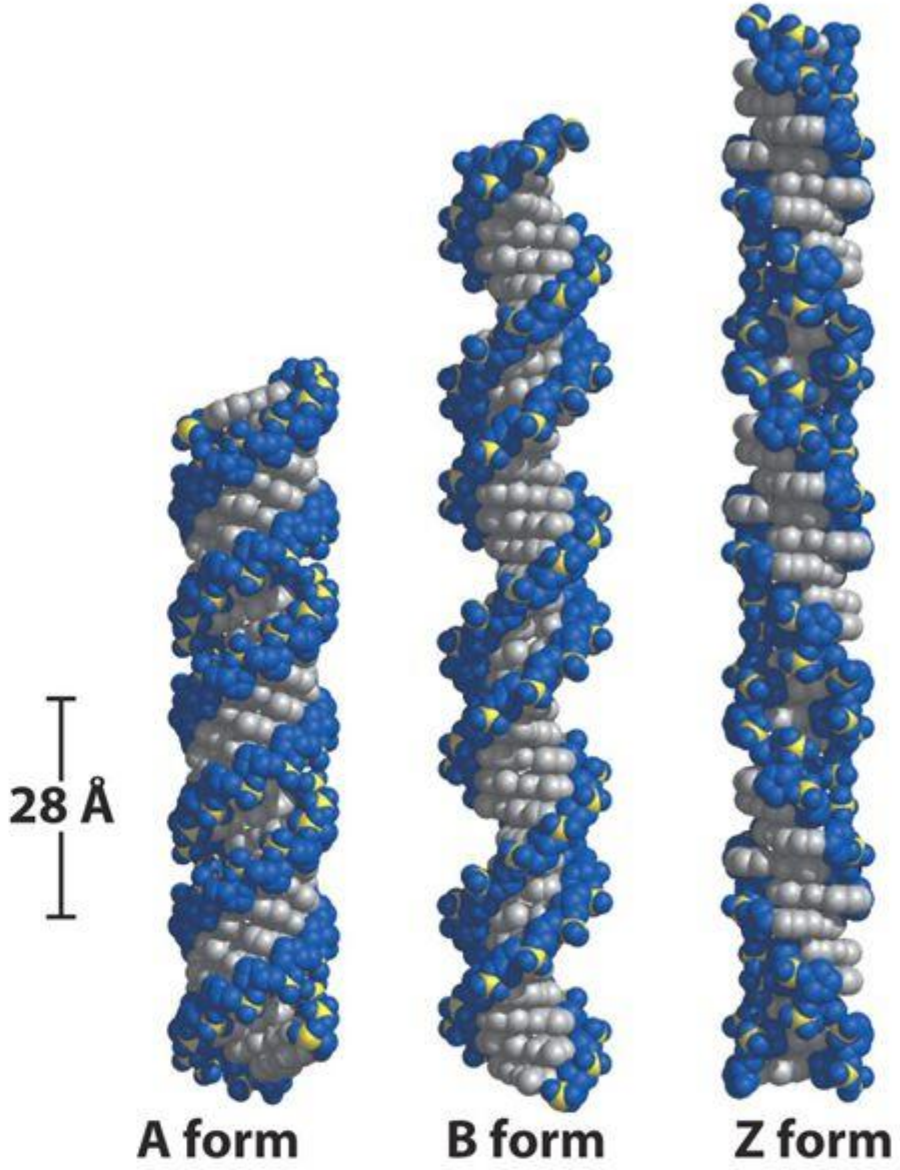
(a) Key features of DNA structure. The "ribbons" in this diagram represent the sugar-phosphate backbones of the two DNA strands. The helix is "right-handed," curving up to the right. The two strands are held together by hydrogen bonds (dotted lines) between the nitrogenous bases, which are paired in the interior of the double helix.

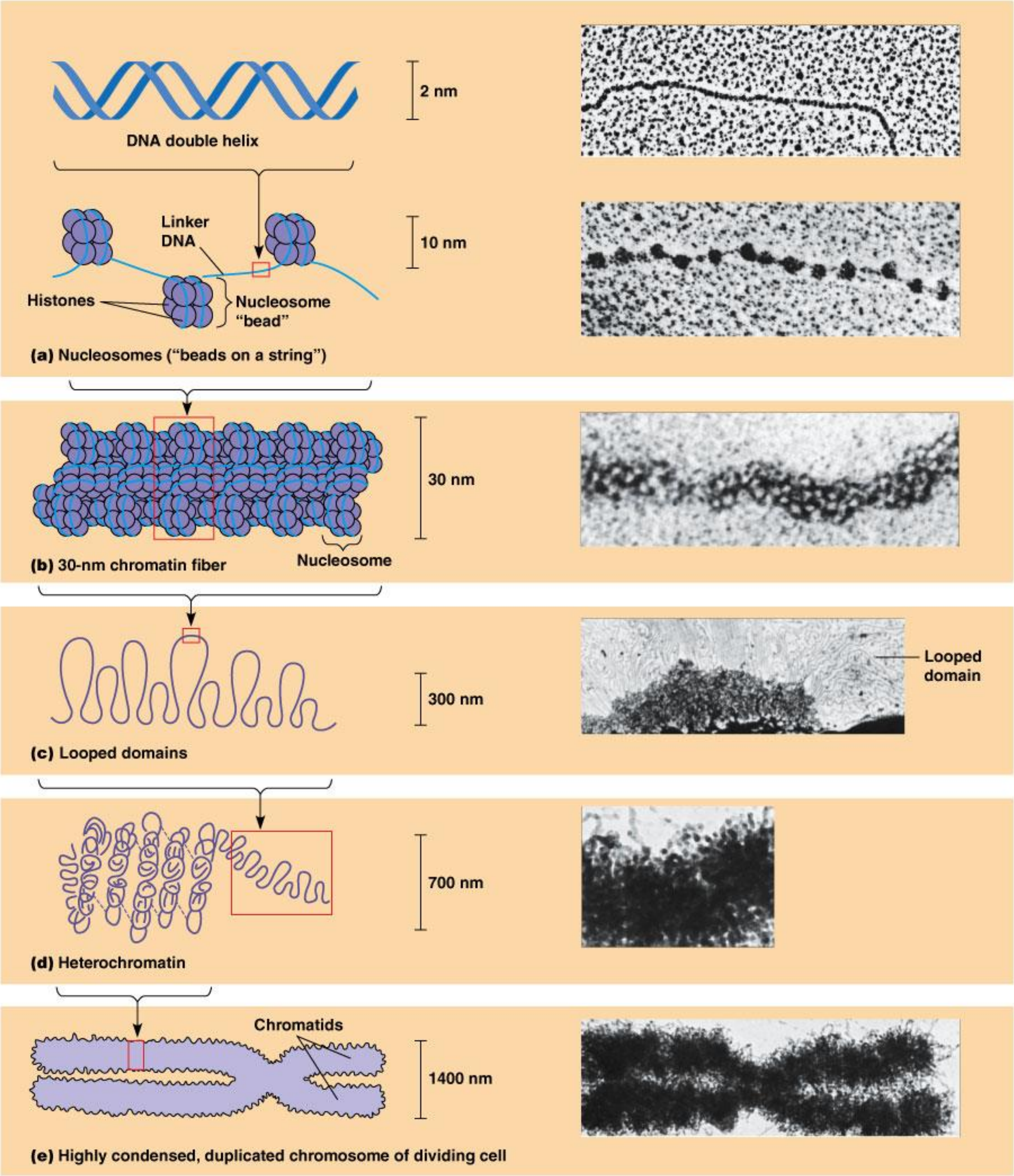
(b) Partial chemical structure. For clarity, the two DNA strands are shown untwisted in this partial chemical structure. Strong covalent bonds link the units of each strand, while weaker hydrogen bonds between the bases hold one strand to the other. Notice that the strands are antiparallel, meaning that they are oriented in opposite directions, like the lanes of a divided highway.

(c) Space-filling model. The tight stacking of the base pairs is clear in this computer-generated, space-filling model. Van der Waals interactions between the stacked pairs play a major role in holding the molecule together.

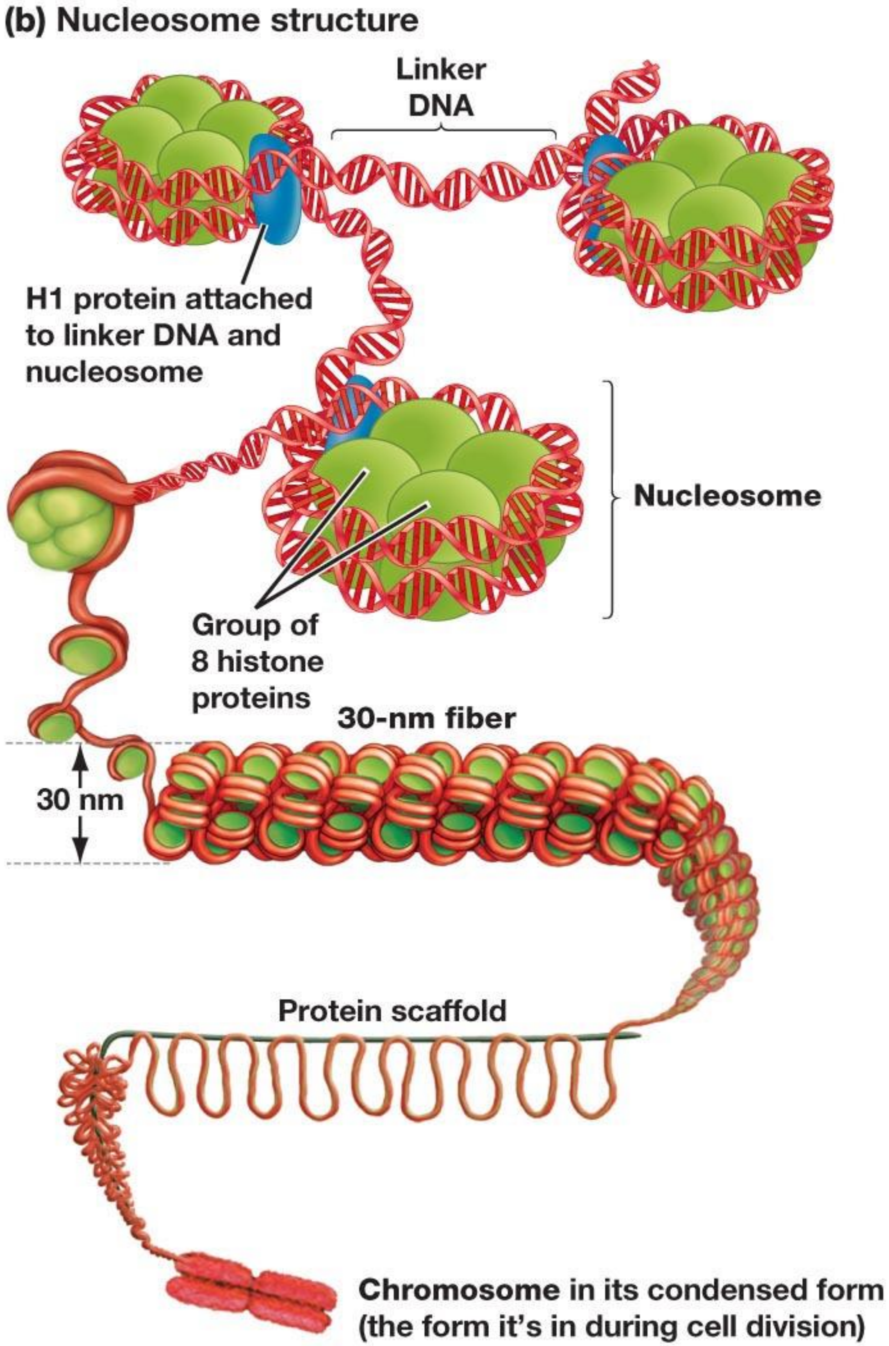
The double helix exists in multiple conformations







2 nm
DNA double helix
Linker
DNA
10 nm
Histones
Nucleosome
"bead"
(a) Nucleosomes ("beads on a string")
30 nm
(b) 30-nm chromatin fiber
Nucleosome
300 nm
Looped
domain
(c) Looped domains
700 nm
(d) Heterochromatin
Chromatids
1400 nm
(e) Highly condensed, duplicated chromosome of dividing cell

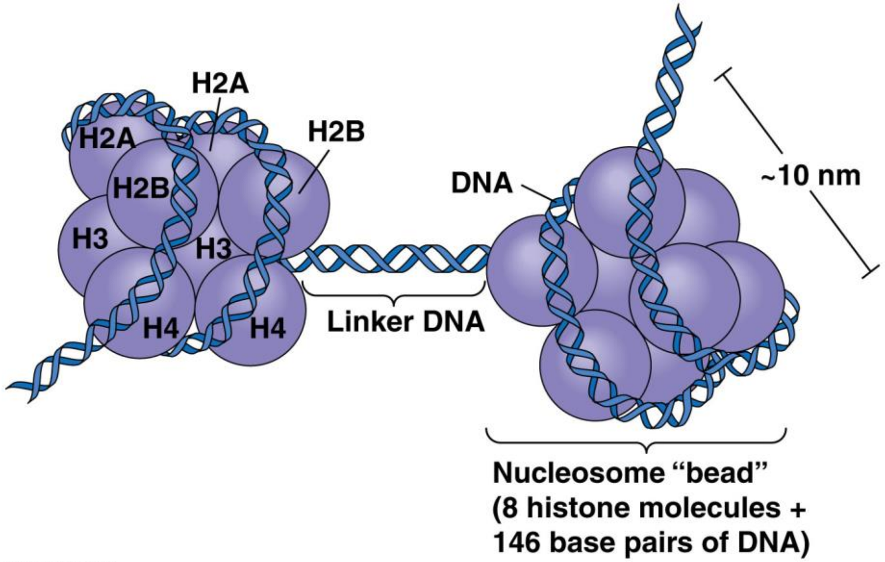


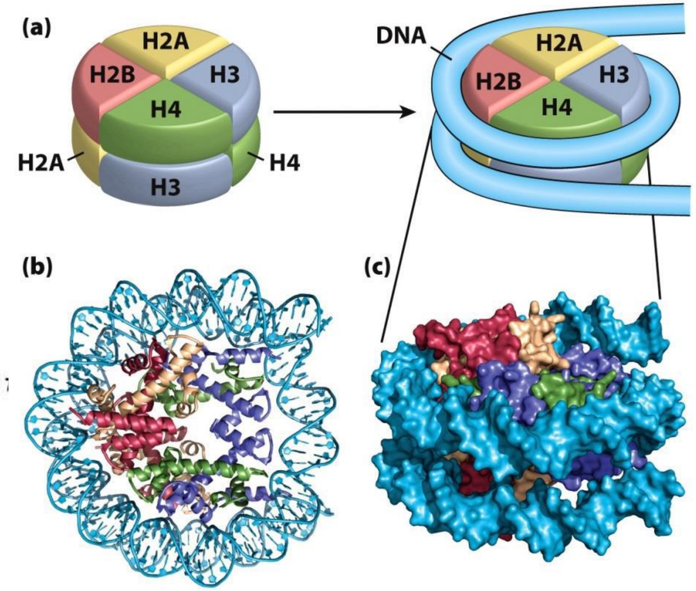
(b) Nucleosome structure
Linker
DNA
H1 protein attached
to linker DNA and
nucleosome
Nucleosome
Group of
8 histone
proteins
30-nm fiber
30 nm
Protein scaffold
Chromosome in its condensed form
(the form it's in during cell division)

TABLE 5.4 The Major Histone Proteins

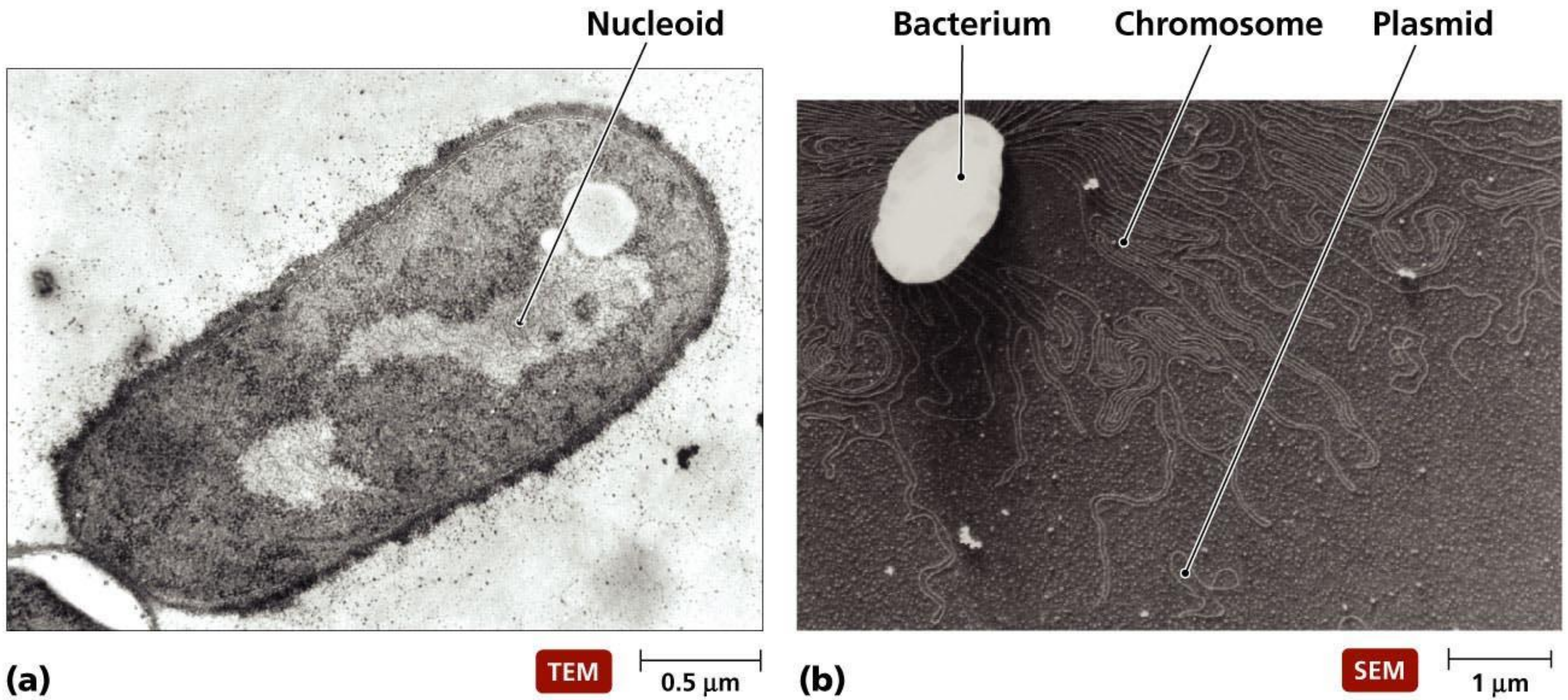
Histone[a]	Molecular weight	Number of amino acids	Percentage lysine + arginine
H1	22,500	244	30.8
H2A	13,960	129	20.2
H2B	13,774	125	22.4
H3	15,273	135	22.9
H4	11,236	102	24.5

[a] Data are for rabbit (H1) and bovine histones.

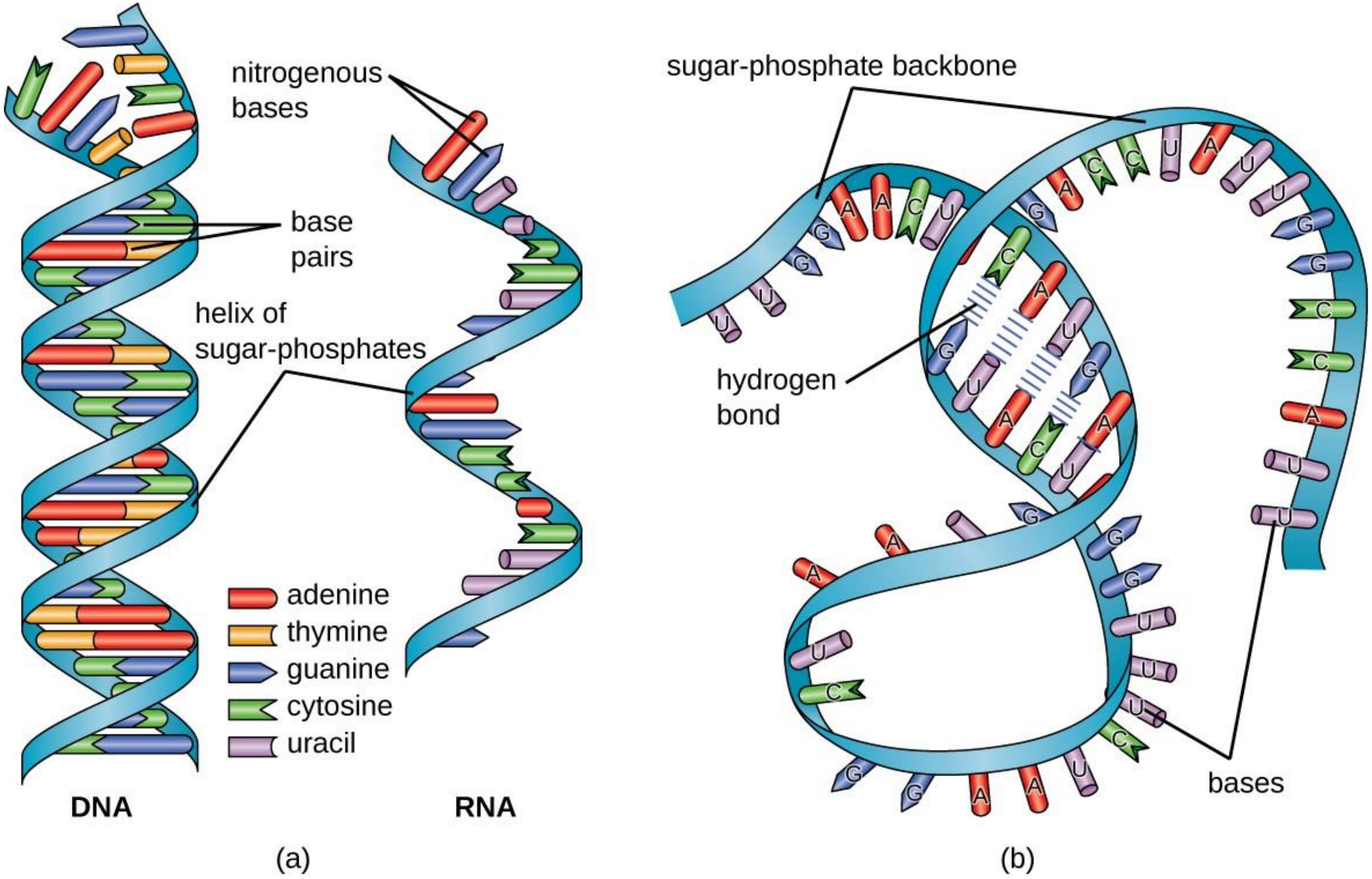




Bacterial chromosome



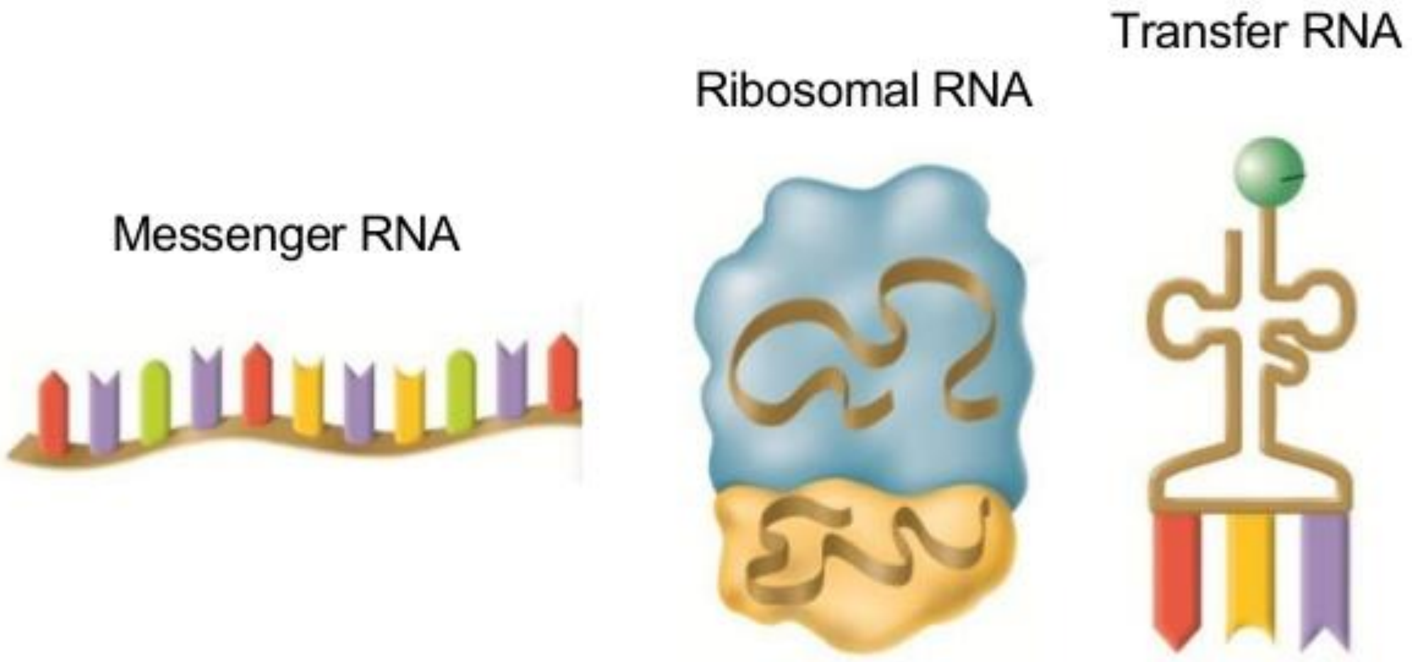
RNA

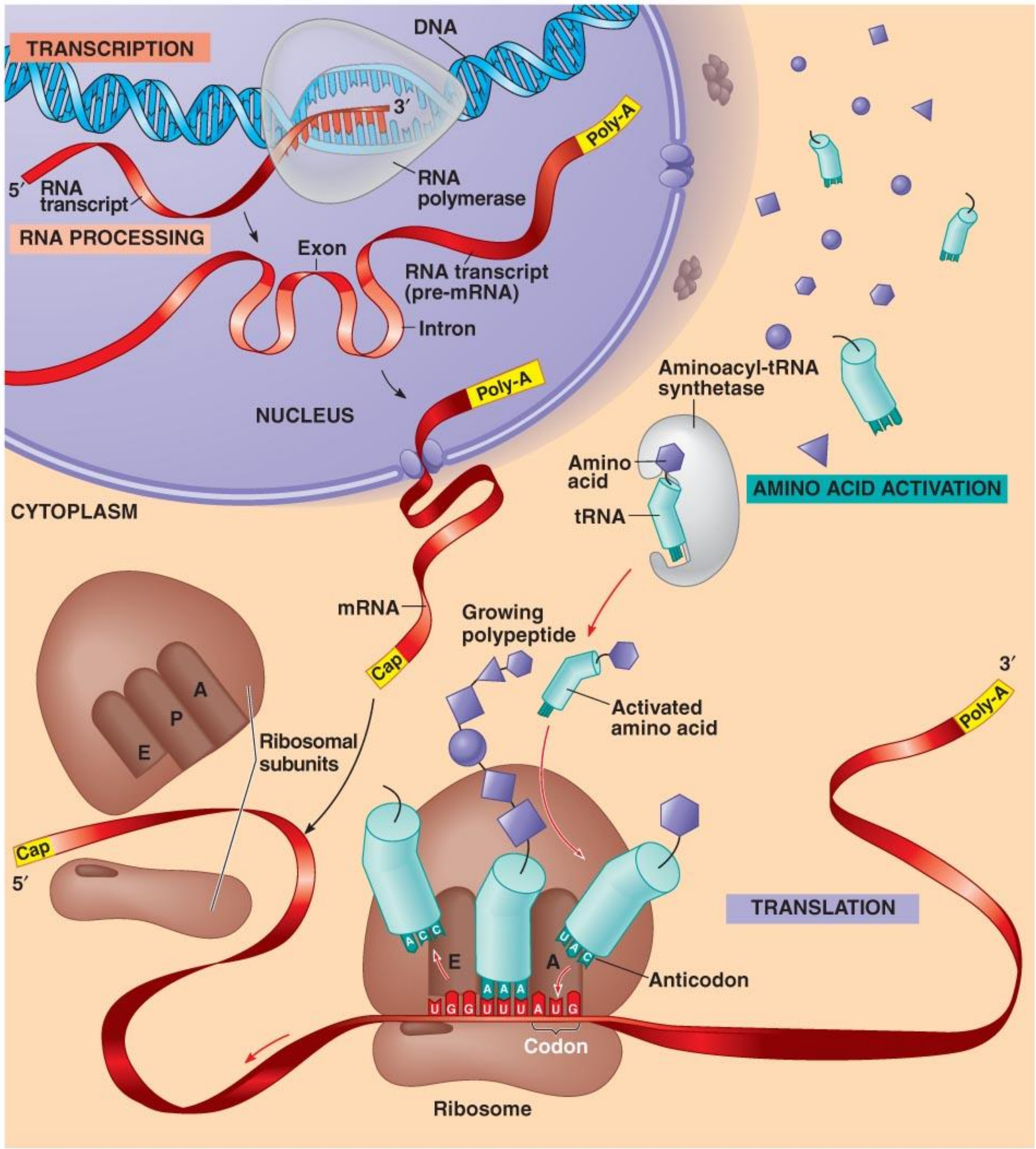


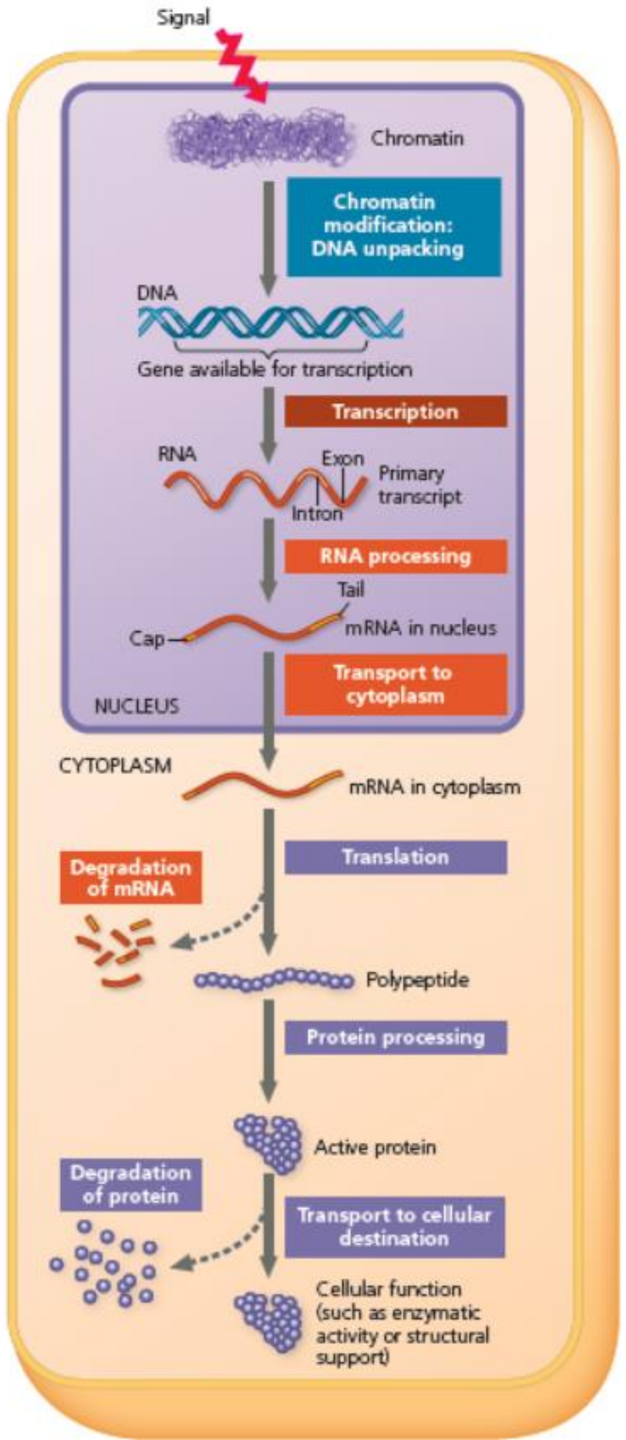
nitrogenous bases
base pairs
helix of sugar-phosphates
adenine
thymine
guanine
cytosine
uracil
DNA
RNA
(a)
sugar-phosphate backbone
hydrogen bond
bases
(b)

Types of RNA

The three main types of RNA are:




TRANSCRIPTION
DNA
3′
5′
RNA transcript
RNA polymerase
Poly-A
RNA PROCESSING
Exon
RNA transcript (pre-mRNA)
Intron
NUCLEUS
Poly-A
Aminoacyl-tRNA synthetase
Amino acid
tRNA
AMINO ACID ACTIVATION
CYTOPLASM
mRNA
Growing polypeptide
Activated amino acid
Cap
A
P
E
Ribosomal subunits
3′
Poly-A
Cap
5′
TRANSLATION
E
A
Anticodon
Codon
Ribosome


Signal
Chromatin
Chromatin modification: DNA unpacking
DNA
Gene available for transcription
Transcription
RNA
Exon
Primary transcript
Intron
RNA processing
Tail
Cap
mRNA in nucleus
NUCLEUS
Transport to cytoplasm
CYTOPLASM
mRNA in cytoplasm
Degradation of mRNA
Translation
Polypeptide
Protein processing
Active protein
Degradation of protein
Transport to cellular destination
Cellular function (such as enzymatic activity or structural support)