LECTURE PRESENTATIONS

For CAMPBELL BIOLOGY, NINTH EDITION

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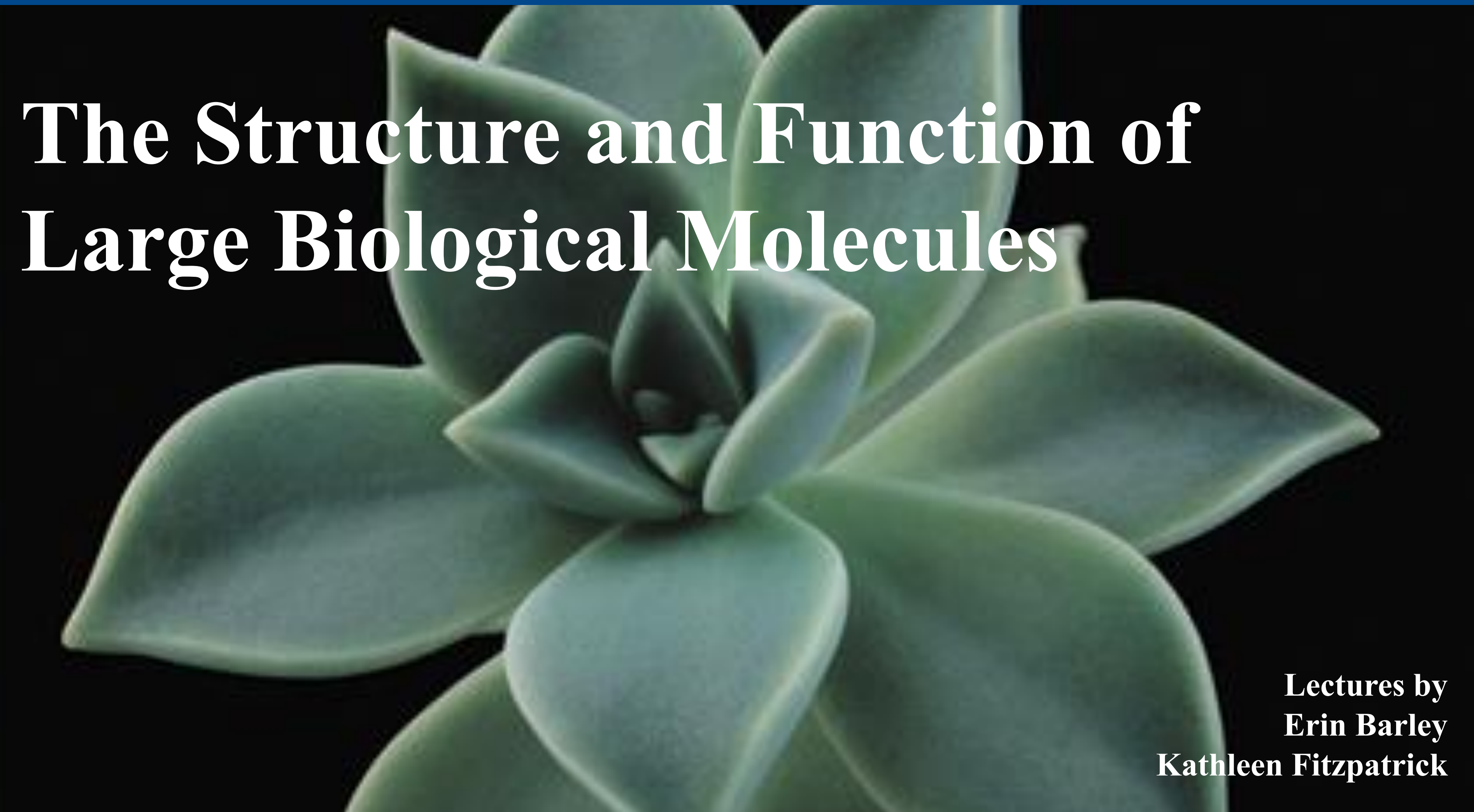
Chapter 5

The Structure and Function of Large Biological Molecules



Lectures by
Erin Barley
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Overview: The Molecules of Life

- All living things are made up of four classes of large biological molecules: carbohydrates, lipids, proteins, and nucleic acids
- Macromolecules are large molecules composed of thousands of covalently connected atoms
- Molecular structure and function are inseparable

Fig. 5-1

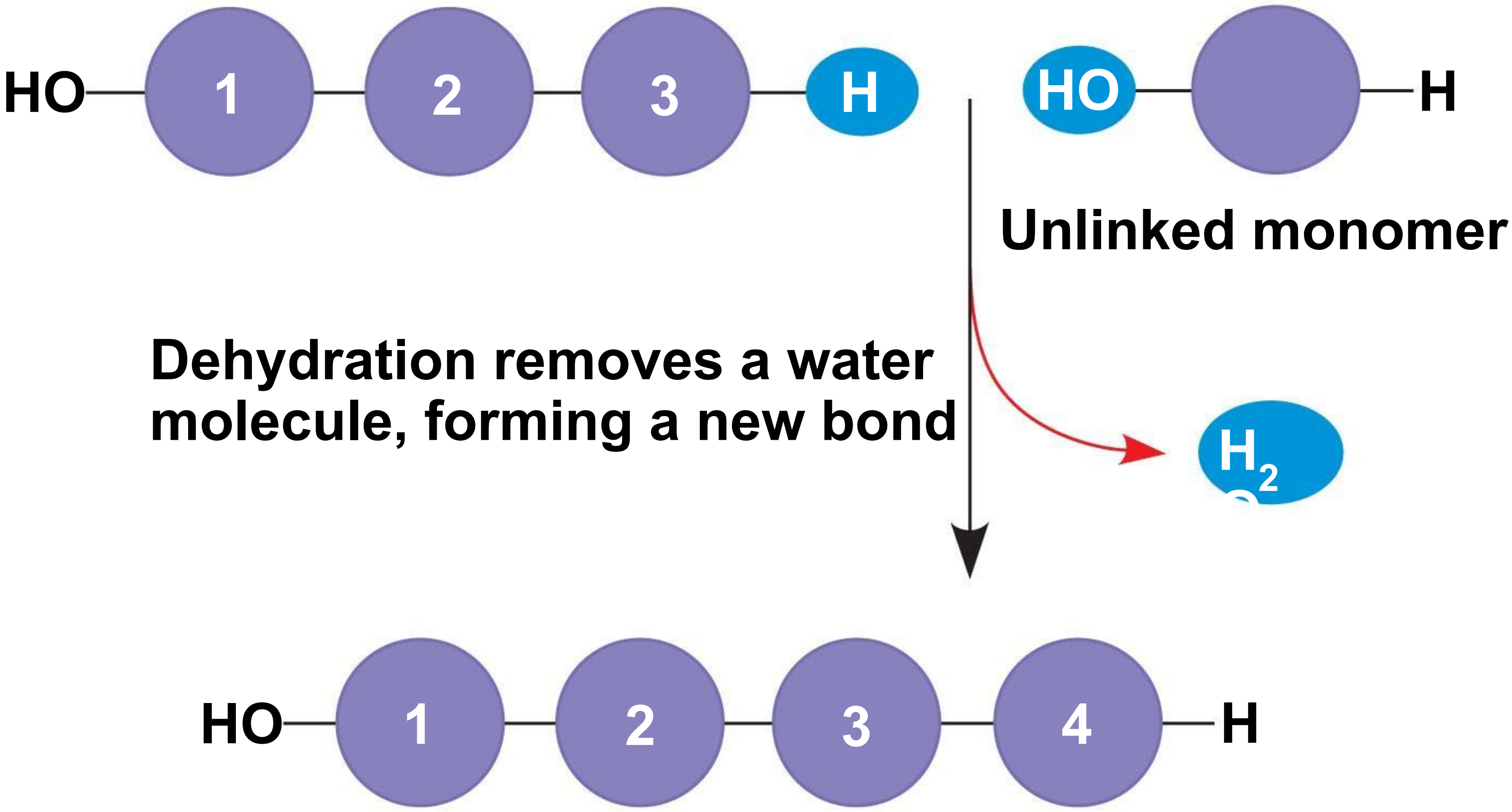
Concept 5.1: Most macromolecules are polymers, built from monomers

- A polymer is a long molecule consisting of many similar building blocks
- These small building-block molecules are called monomers
- Three of the four classes of life's organic molecules are polymers:
  - Carbohydrates
  - Proteins
  - Nucleic acids

The Synthesis and Breakdown of Polymers

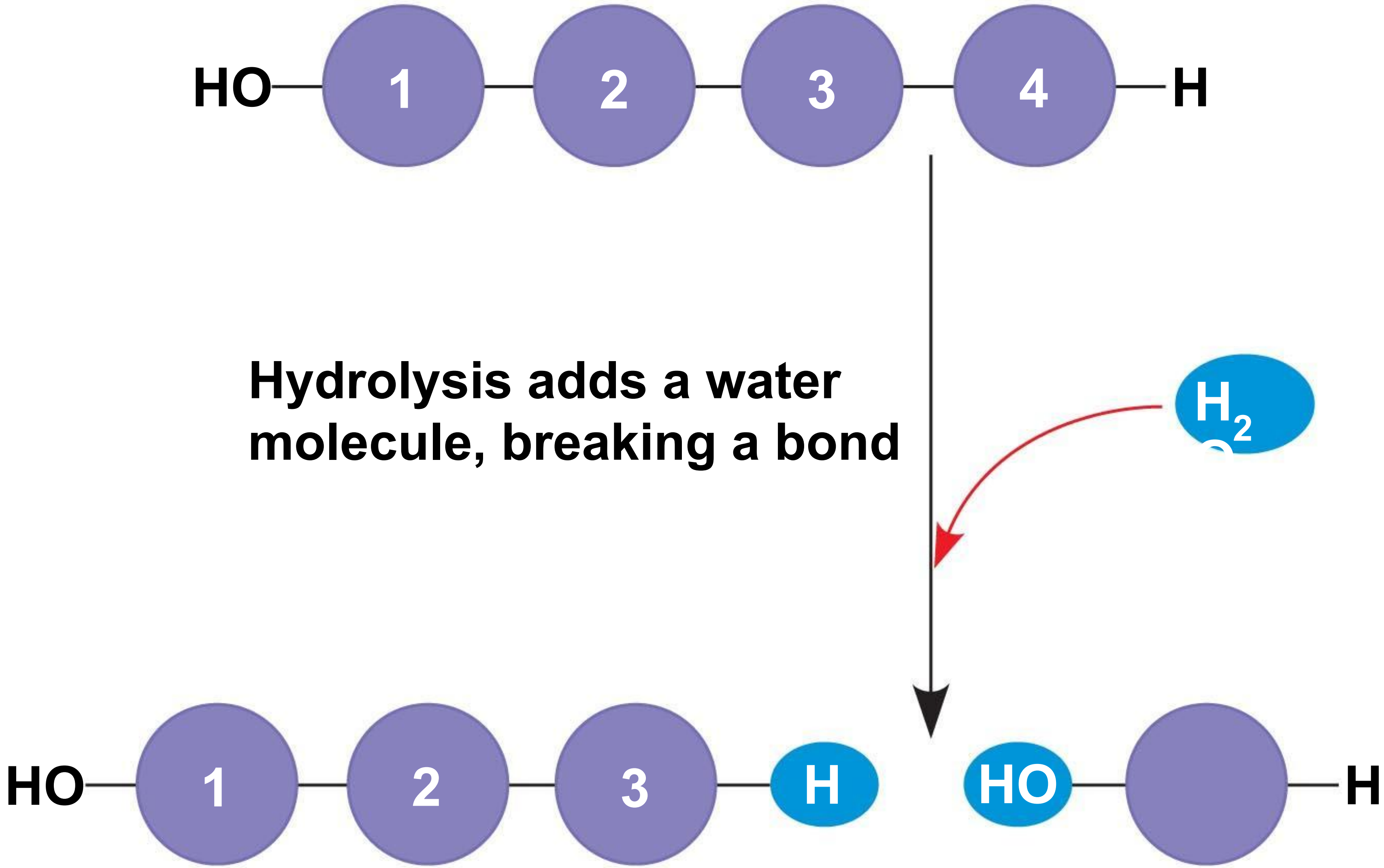
- A condensation reaction or more specifically a dehydration reaction occurs when two monomers bond together through the loss of a water molecule
- Enzymes are macromolecules that speed up the dehydration process
- Polymers are disassembled to monomers by hydrolysis

Fig. 5-2a



Dehydration reaction in the synthesis of a polymer

Fig. 5-2b



Hydrolysis of a polymer

The Diversity of Polymers

- Each cell has thousands of different kinds of macromolecules
- What is the basis of this diversity?
- An immense variety of polymers can be built from a small set of monomers

Carbohydrates

Concept 5.2: Carbohydrates serve as **fuel** and **building material**

- Carbohydrates include sugars and the **polymers of sugars**
- The simplest carbohydrates are **monosaccharides** = single sugars
- Carbohydrate macromolecules are **polysaccharides**, polymers composed of many sugar building blocks

Sugars

- Monosaccharides have molecular formulas that are usually multiples of $(CH_2O)n$
- Glucose ($C_6H_{12}O_6$) is the most common monosaccharide
- Most names of sugars end in -ose
- Monosaccharides are classified by
  - The location of the carbonyl group (as aldose or ketose)
  - The number of carbons in the carbon skeleton

Figure 5.3

The structure and classification of some monosaccharides

Aldoses vs. Ketoses

(aldehyde vs. Ketone sugars)

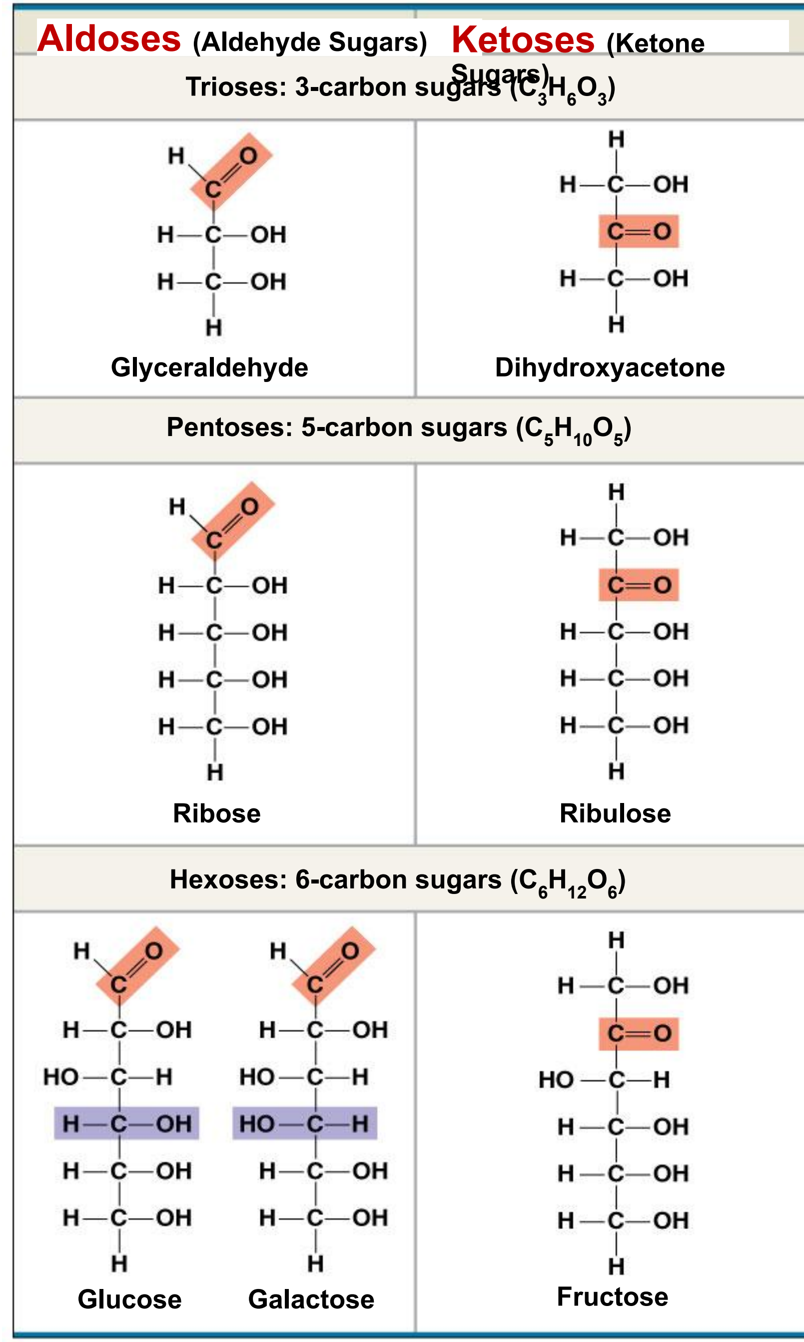
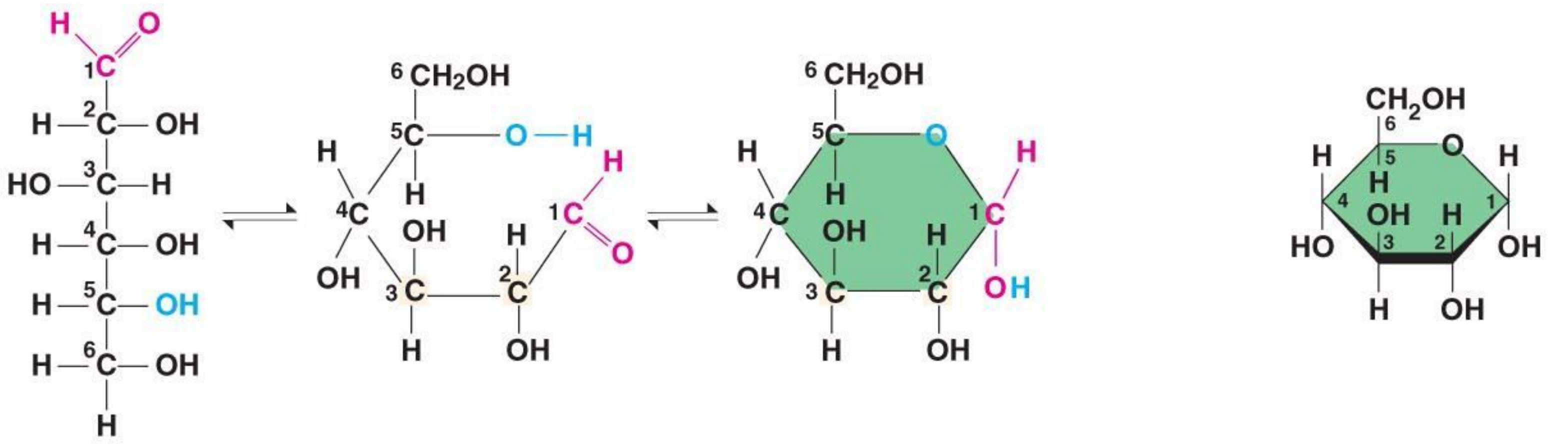


Fig. 5-4

Linear and ring forms of glucose



(a) Linear and ring forms

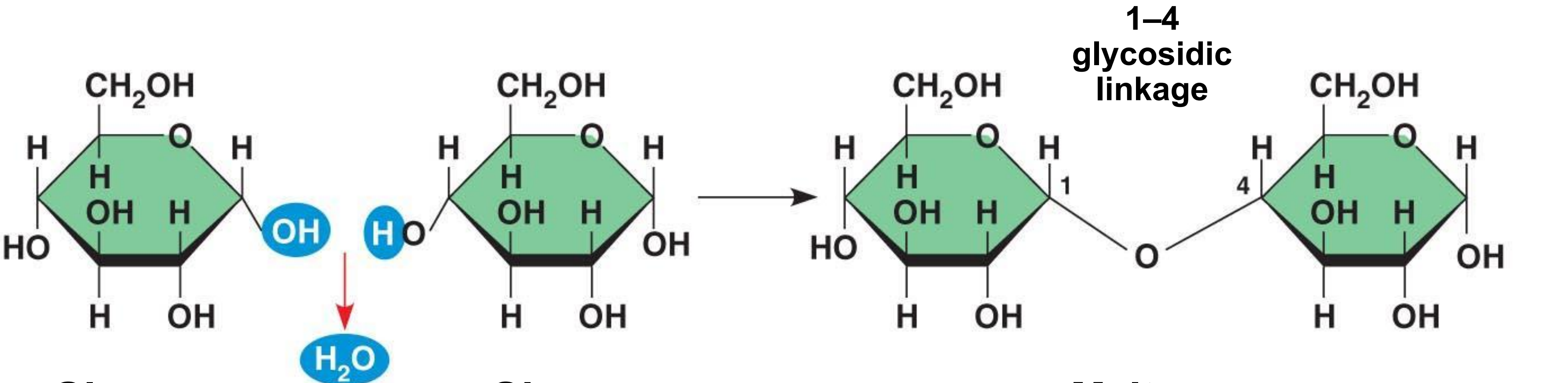
(b) Abbreviated ring structure

- **Though often drawn as linear skeletons, in aqueous solutions many sugars form rings**
- **Monosaccharides serve as a major fuel for cells and as raw material for building molecules**

- **A disaccharide is formed when a dehydration reaction joins two monosaccharides**
- **This covalent bond is called a glycosidic linkage**

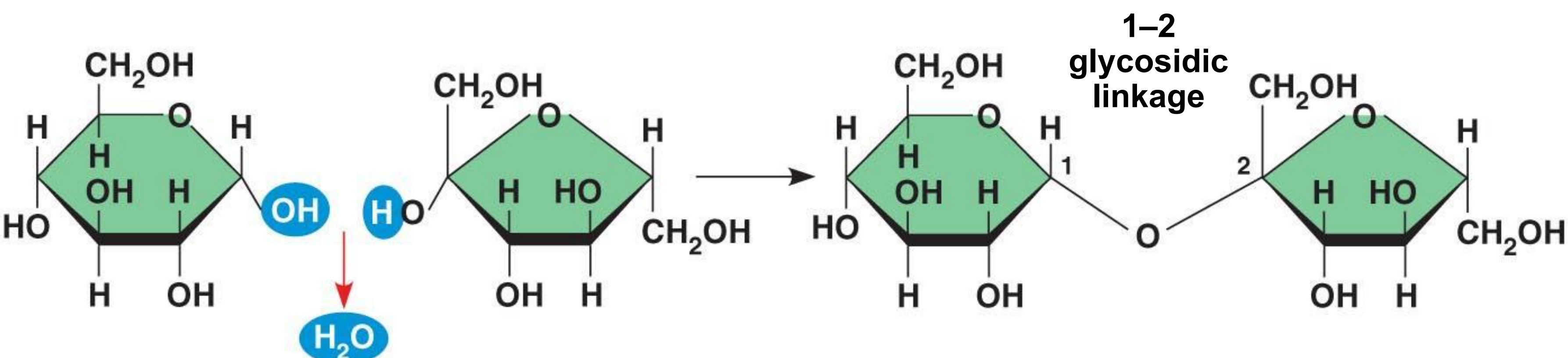
Fig. 5-5

Examples of disaccharide synthesis



Glucose Glucose Maltose

(a) Dehydration reaction in the synthesis of maltose



Glucose Fructose Sucrose

(b) Dehydration reaction in the synthesis of sucrose

Polysaccharides

- Polysaccharides = polymers of sugars
  - have storage and structural roles
- The structure and function of a polysaccharide are determined by its sugar monomers and the positions of glycosidic linkages

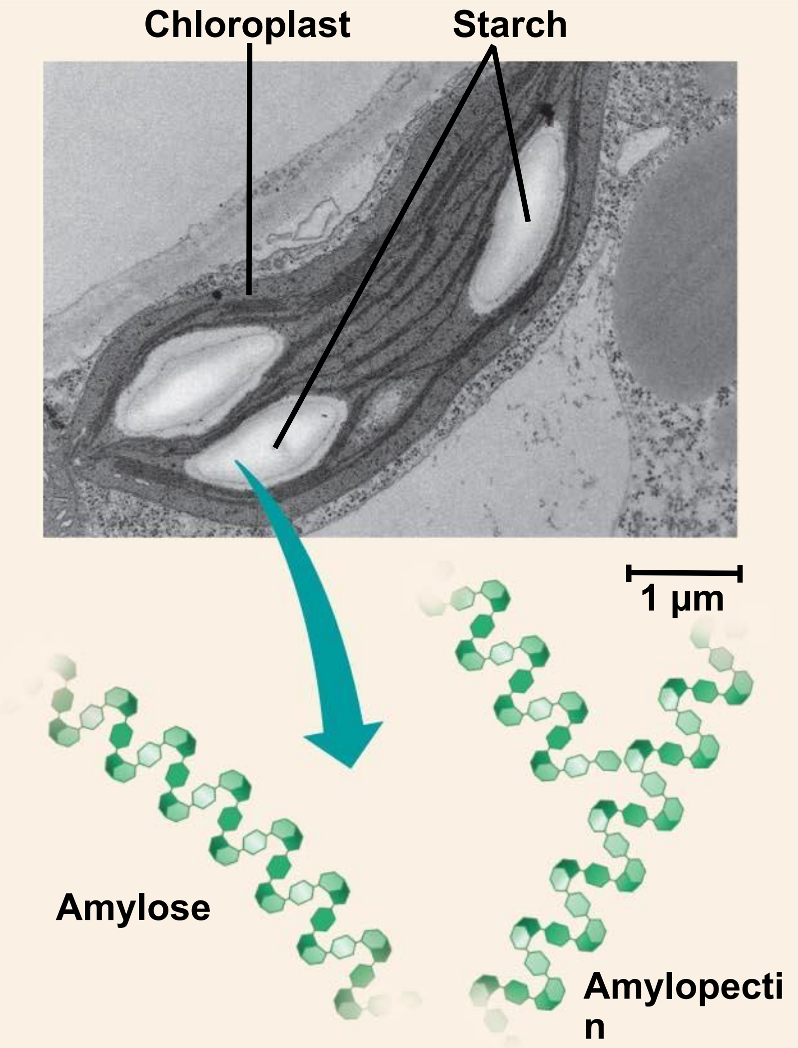
Storage Polysaccharides

Starch:

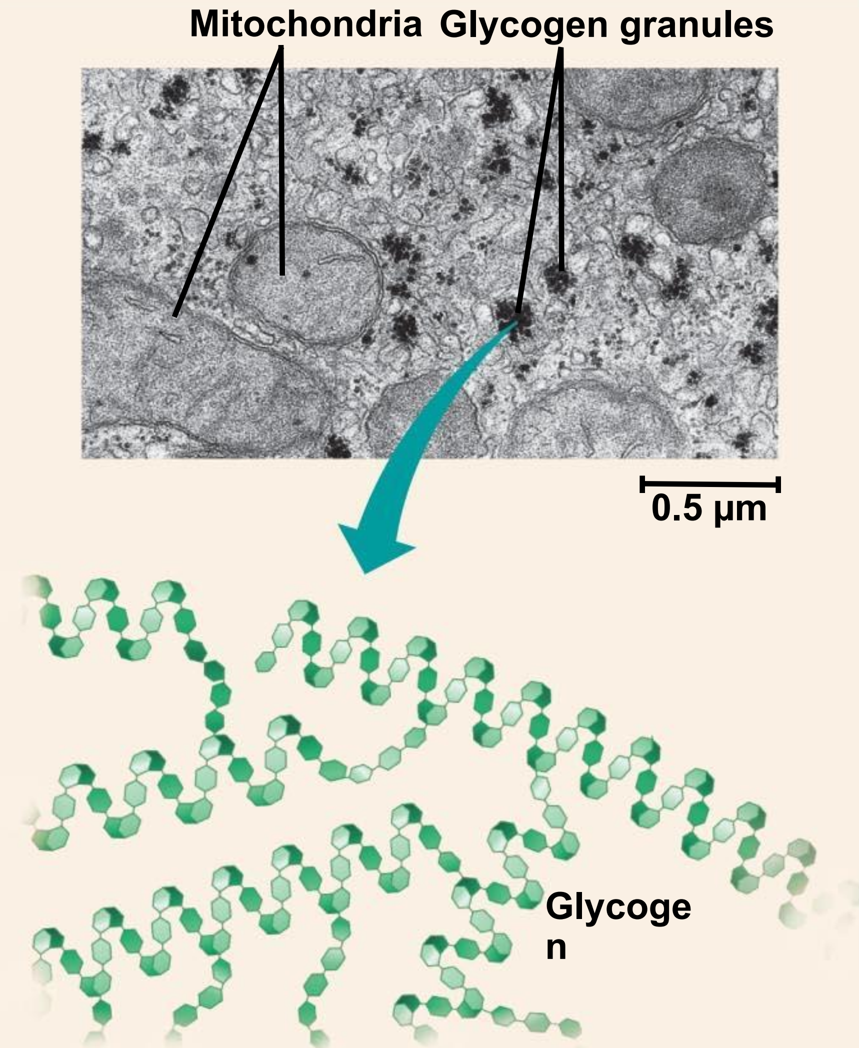
- A storage polysaccharide of plants, consists entirely of α-glucose monomers

- Plants store surplus starch as granules within chloroplasts and other plastids

Fig. 5-6



(a) Starch: a plant polysaccharide



(b) Glycogen: an animal polysaccharide

Glycogen:

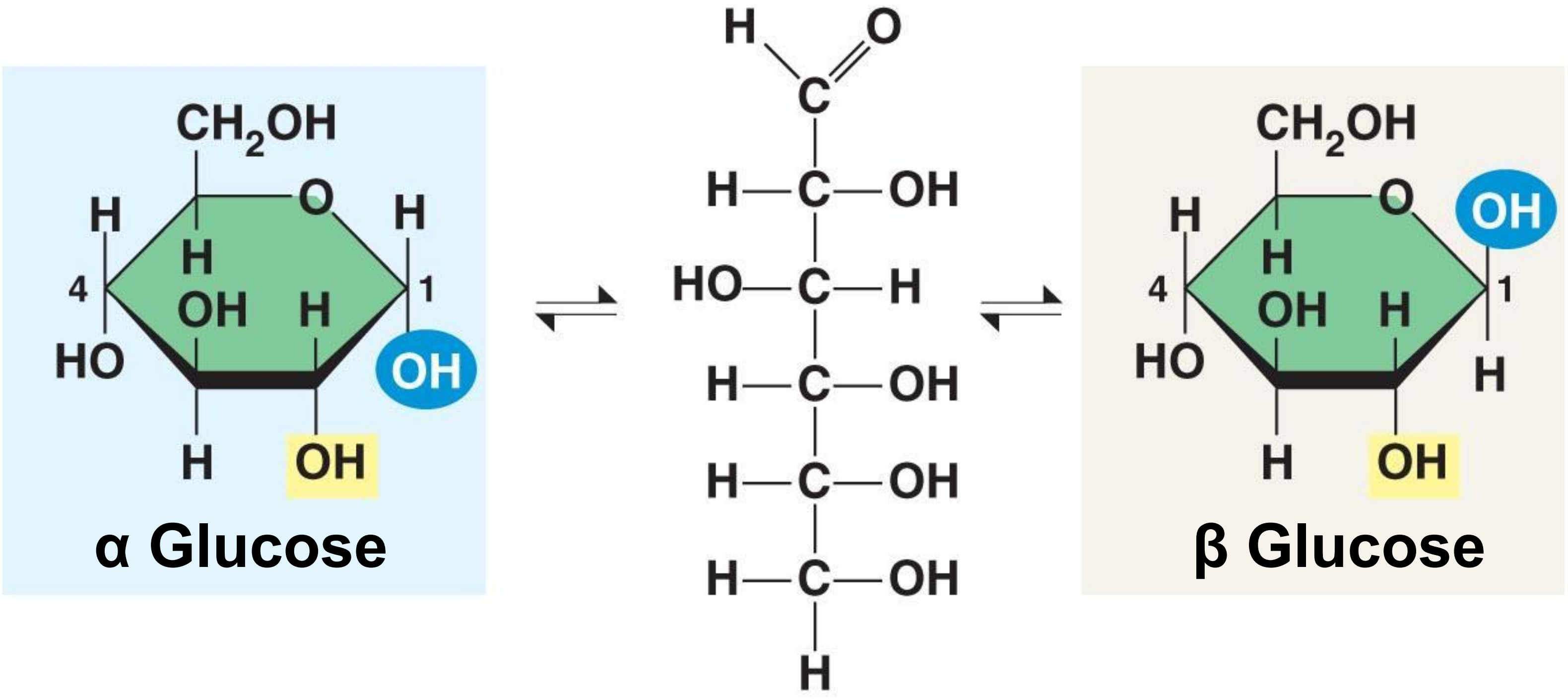
- Is a storage polysaccharide in animals
- Humans and other vertebrates store glycogen mainly in liver and muscle cells

Structural Polysaccharides

Cellulose:

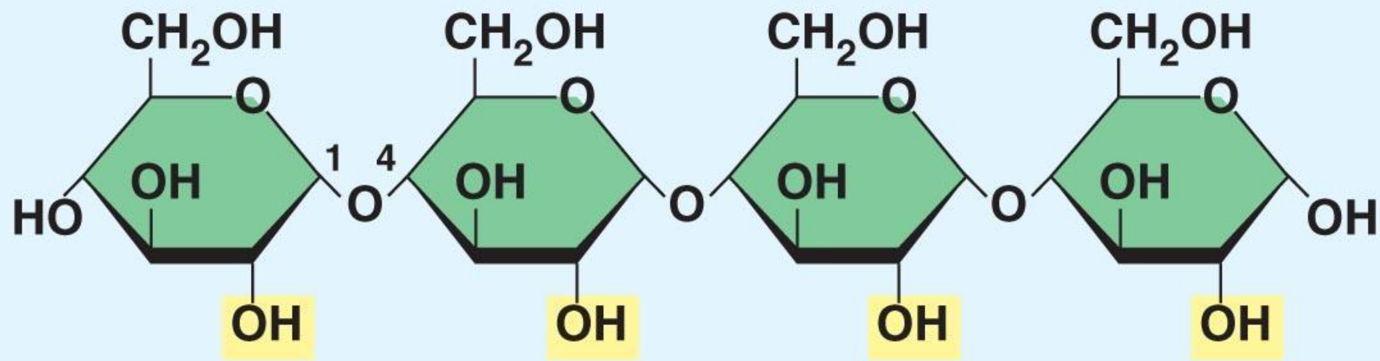
- The polysaccharide **cellulose** is a major component of the tough wall of plant cells
- Like starch, cellulose is a polymer of glucose, but the glycosidic linkages differ
- The difference is based on two ring forms for glucose: **alpha (α)** and **beta (β)**

Starch and cellulose structures

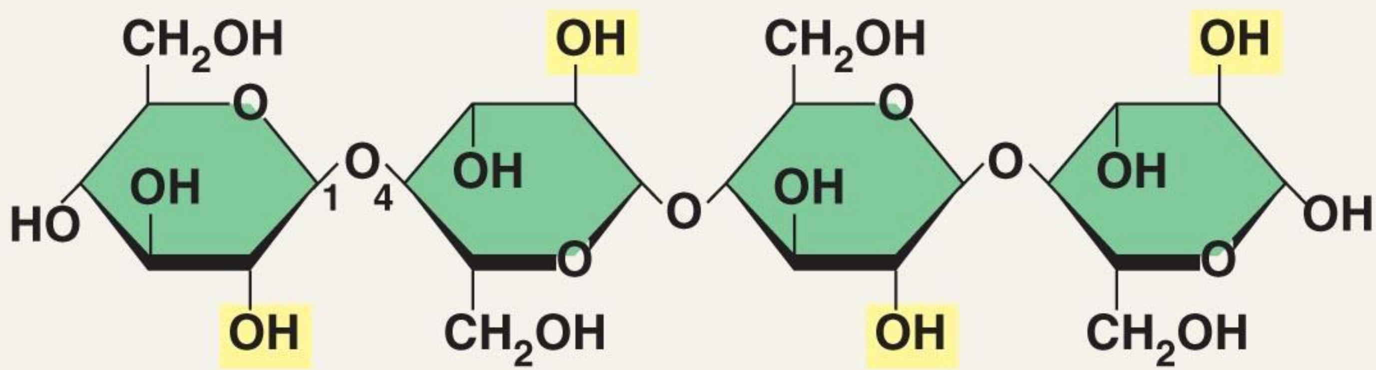


(a) α and β glucose ring structures

Fig. 5-7bc



(b) Starch: 1–4 linkage of α glucose monomers

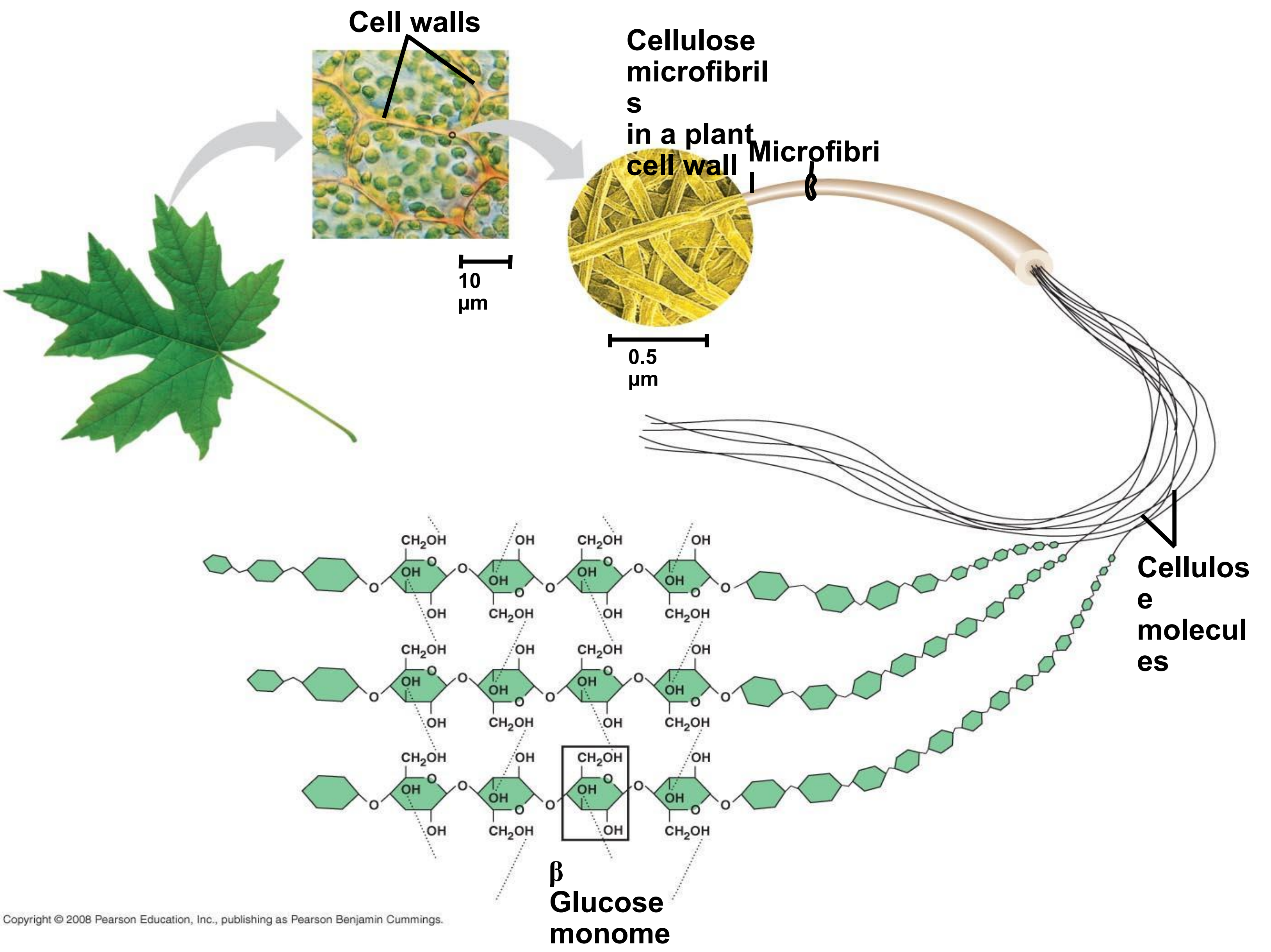


(c) Cellulose: 1–4 linkage of β glucose monomers

- Polymers with α glucose are helical
- Polymers with β glucose are straight
- In straight structures, H atoms on one strand can bond with OH groups on other strands
- Parallel cellulose molecules held together this way are grouped into microfibrils, which form strong building materials for plants

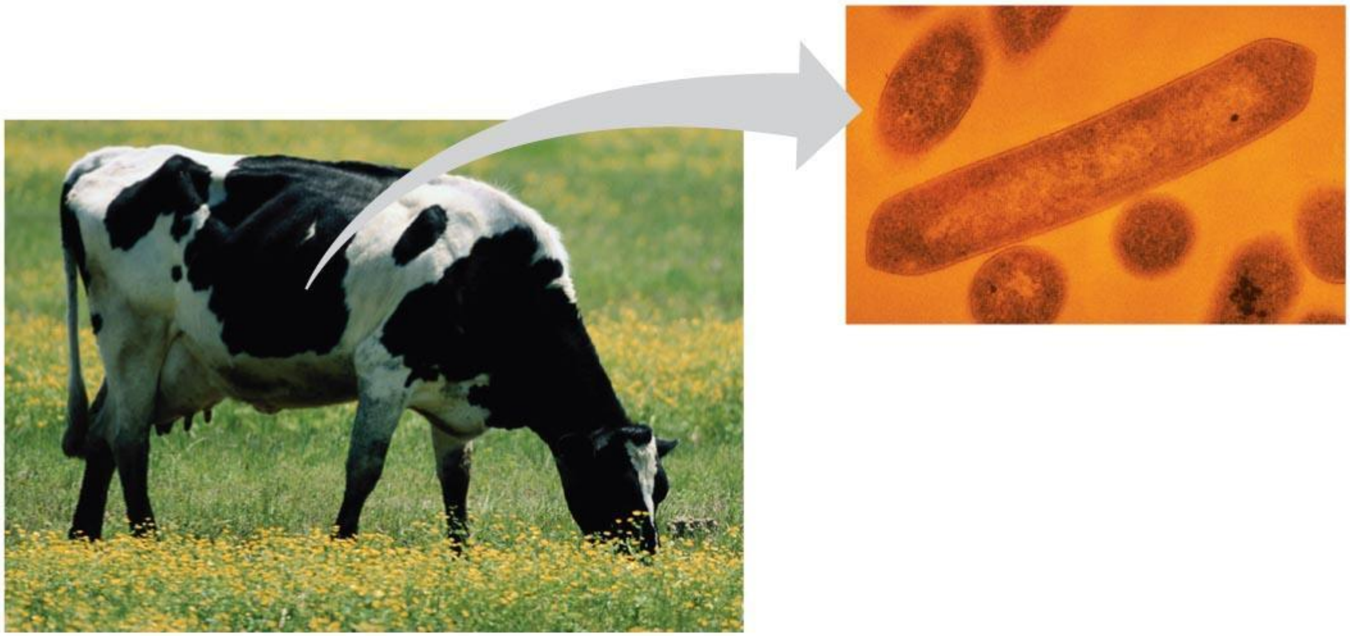
Fig. 5-8

The arrangement of cellulose in plant cell walls



- **Enzymes that digest starch by <u>hydrolyzing α linkages</u> <u>can't hydrolyze β linkages in cellulose</u>**
- **Cellulose in human food passes through the digestive tract as <u>insoluble fiber</u>**
- **Some microbes secrete enzymes to digest cellulose**
- **Many herbivores, from cows to termites, have <u>symbiotic relationships</u> with these microbes**

Fig. 5-9



Chitin

- Another structural polysaccharide, found in the exoskeleton of arthropods
- Chitin also provides structural support for the cell walls of many fungi

Fig. 5-10

Chitin, a structural polysaccharide

(a) The structure of the chitin monomer.

(b) Chitin forms the exoskeleton of arthropods.

(c) Chitin is used to make a strong and flexible surgical thread.

N-acetyl-Glucosamine

LIPIDS

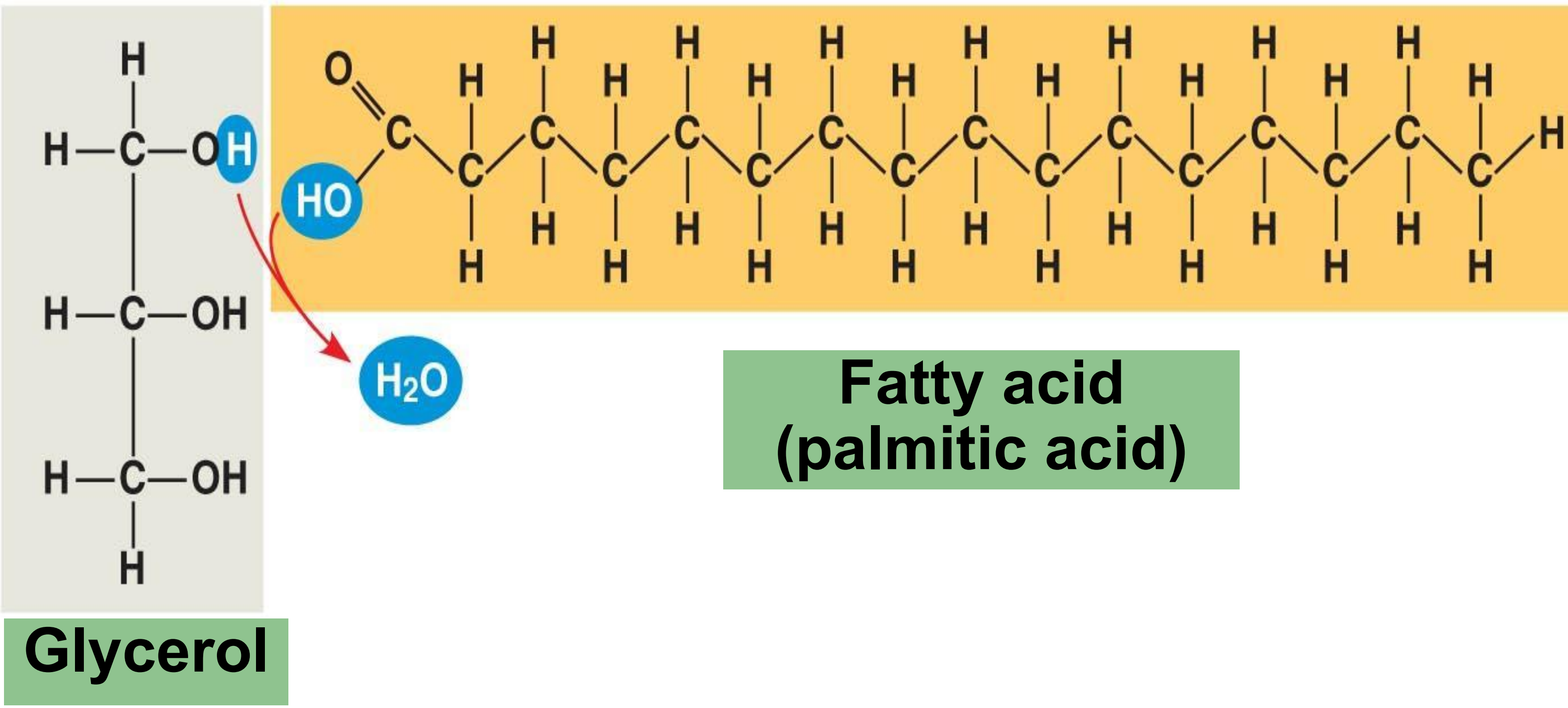
Concept 5.3: Lipids are a diverse group of hydrophobic molecules

- **Lipids** are the one class of large biological molecules that **do not form polymers**
- The unifying feature of lipids is **having little or no affinity for water**
- Lipids are hydrophobic because they **consist mostly of hydrocarbons**, which form **nonpolar covalent bonds**
- The most biologically important lipids are **fats, phospholipids, and steroids**

Fats

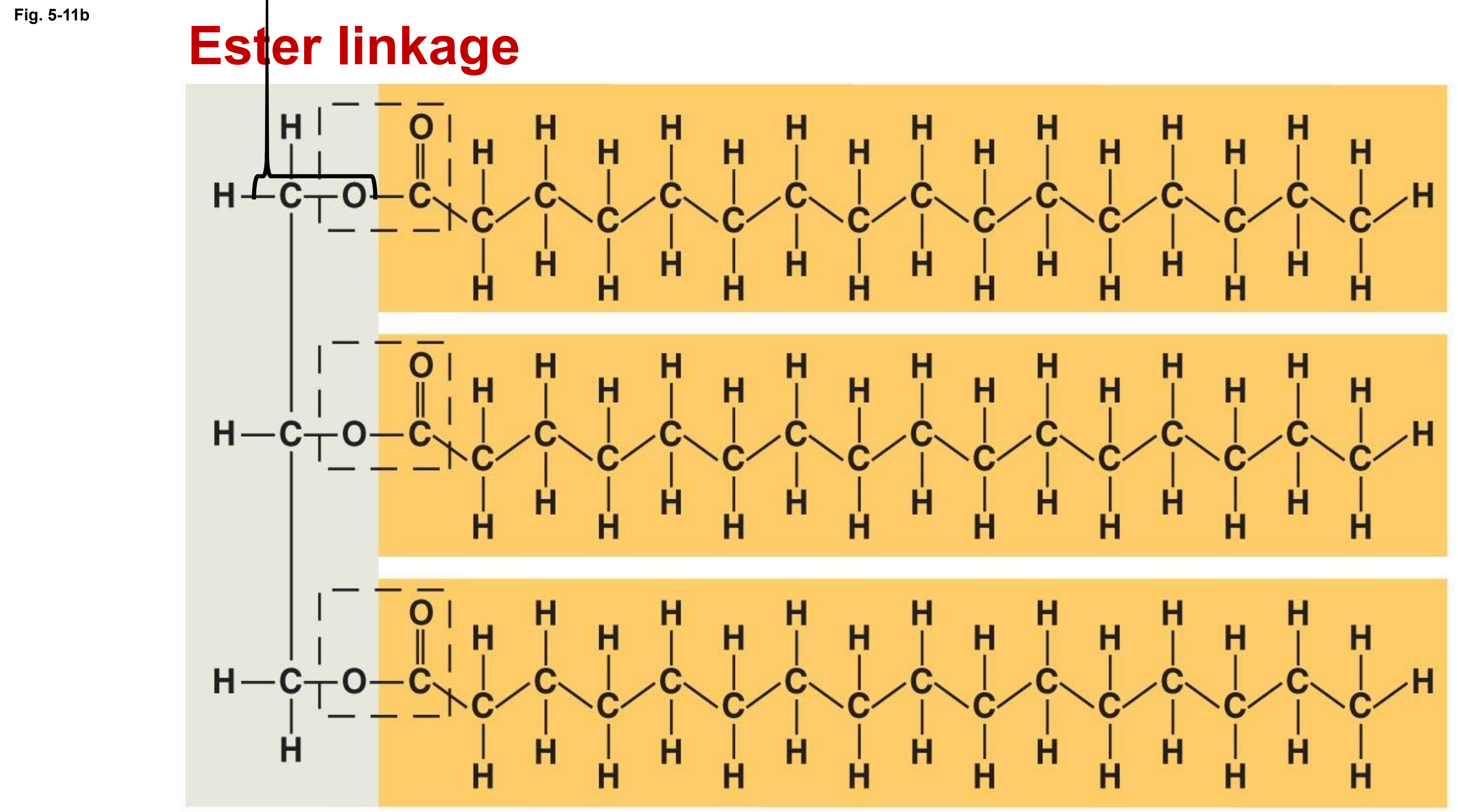
- Fats are constructed from two types of smaller molecules: glycerol and fatty acids
- Glycerol is a three-carbon alcohol with a hydroxyl group attached to each carbon
- A fatty acid consists of a carboxyl group attached to a long carbon skeleton

Fig. 5-11a



Dehydration reaction in the synthesis of a fat

Fig. 5-11b



Fat molecule (**triacylglycerol**)

Three fatty acids are joined to a glycerol by an ester linkage to from a triacylglycerol (or triglyceride).

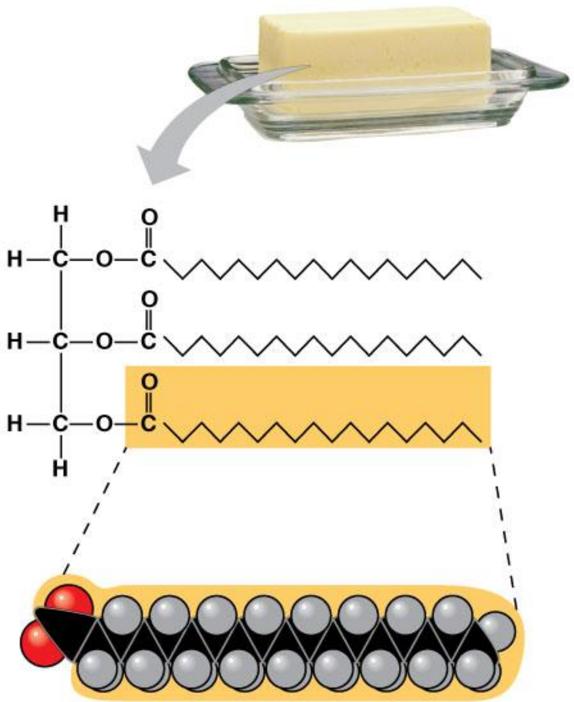
- **Fatty acids vary <u>in length</u> (number of carbons) and in the <u>number and locations of double bonds</u>**

- ***<u>Saturated fatty acids</u>* have the maximum number of hydrogen atoms possible and no double bonds**

- ***<u>Unsaturated fatty acids</u>* have one or more double bonds**

Figure 5.11

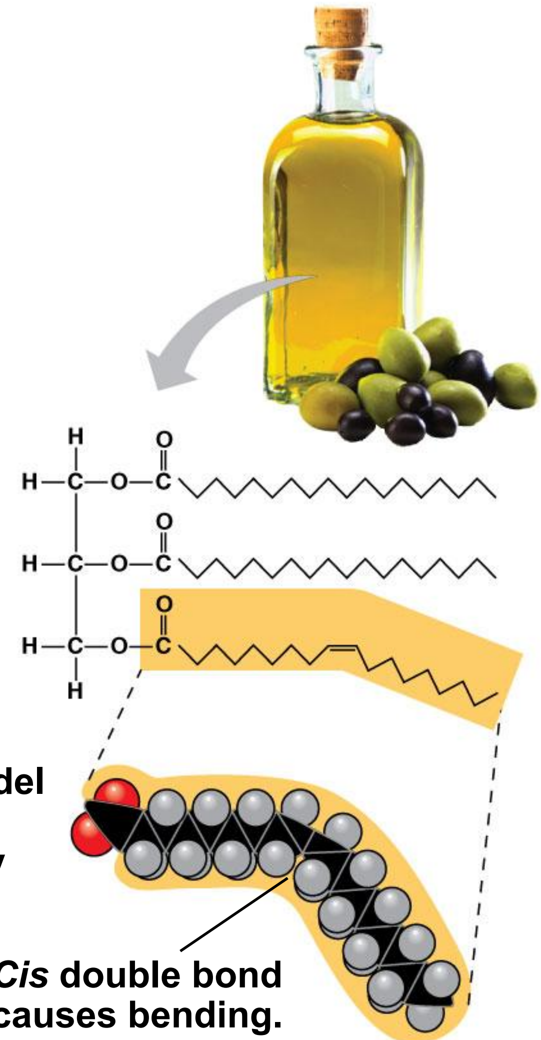
(a) Saturated fat



Structural formula of a saturated fat molecule

Space-filling model of stearic acid, a saturated fatty acid

(b) Unsaturated fat



Structural formula of an unsaturated fat molecule

Space-filling model of oleic acid, an unsaturated fatty acid

- **Fats made from saturated fatty acids are called <u>saturated fats</u>, and are <u>solid</u> at room temperature**

  - Most animal fats are saturated

- **Fats made from unsaturated fatty acids are called <u>unsaturated fats or oils</u>, and are <u>liquid</u> at room temperature**

  - Plant fats and fish fats are usually unsaturated

- **A diet rich in saturated fats may contribute to *<u>cardiovascular disease</u>* through plaque deposits**

- **The major function of fats is energy storage**
- **Humans and other mammals store their fat in adipose cells**
- **Adipose tissue also cushions vital organs and insulates the body**

Phospholipids

- **In a phospholipid, <u>two fatty acids</u> and a <u>phosphate group</u> are attached to <u>glycerol</u>**
- **The two fatty acid tails are hydrophobic, but the <u>phosphate group</u> and its attachments form a <u>hydrophilic head</u>**

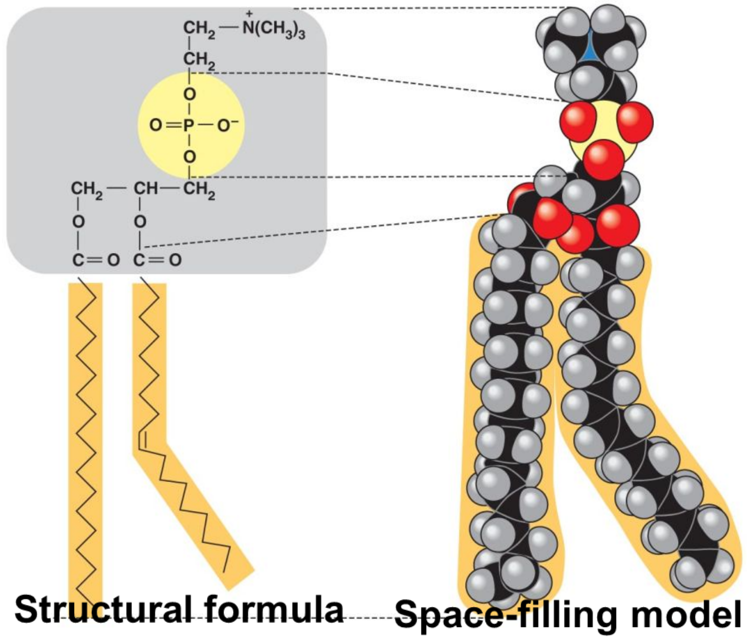
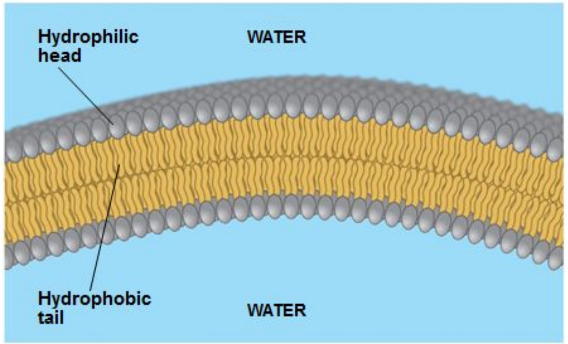


Fig. 5-13ab

- When phospholipids are added to water, they self-assemble into a bilayer, with the hydrophobic tails pointing toward the interior
- The structure of phospholipids results in a bilayer arrangement found in cell membranes
- Phospholipids are the *major component of all cell membranes*

Fig. 5-14

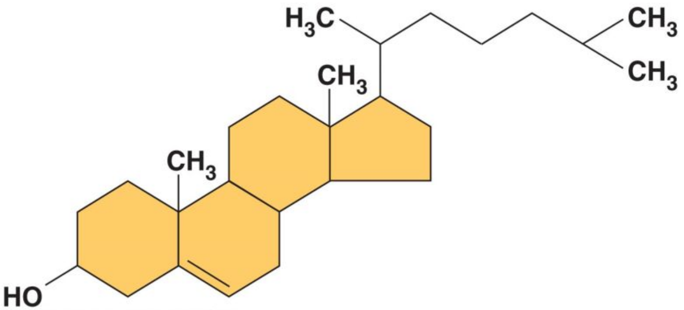


Steroids

- **Steroids are lipids characterized by a carbon skeleton consisting of four fused rings**

- **Cholesterol, an important steroid, is a component in animal cell membranes**

- **Although cholesterol is essential in animals, high levels in the blood may contribute to cardiovascular disease**



PROTEINS

Concept 5.4: Proteins have many structures, resulting in a wide range of functions

- Proteins account for more than <u>50%</u> of the dry mass of most cells

- Protein functions include:

  - structural support
  - Storage
  - Transport
  - cellular communications
  - movement, and
  - defense against foreign substances

Table 5-1

Table 5.1 An Overview of Protein Functions

Type of Protein	Function	Examples
Enzymatic proteins	Selective acceleration of chemical reactions	Digestive enzymes
Structural proteins	Support	Silk fibers; collagen and elastin in animal connective tissues; keratin in hair, horns, feathers, and other skin appendages
Storage proteins	Storage of amino acids	Ovalbumin in egg white; casein, the protein of milk; storage proteins in plant seeds
Transport proteins	Transport of other substances	Hemoglobin, transport proteins
Hormonal proteins	Coordination of an organism's activities	Insulin, a hormone secreted by the pancreas
Receptor proteins	Response of cell to chemical stimuli	Receptors in nerve cell membranes
Contractile and motor proteins	Movement	Actin and myosin in muscles, proteins in cilia and flagella
Defensive proteins	Protection against disease	Antibodies combat bacteria and viruses.

Figure 5.15a

Enzymatic proteins

Function: Selective acceleration of chemical reactions

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

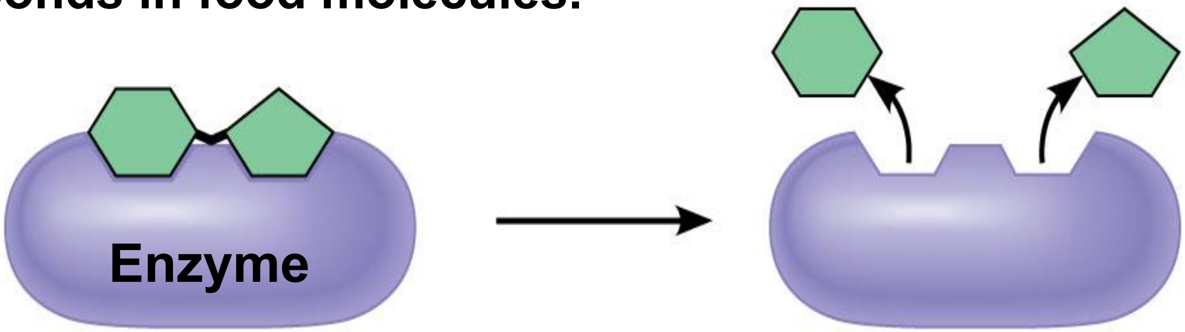


Figure 5.15b

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.

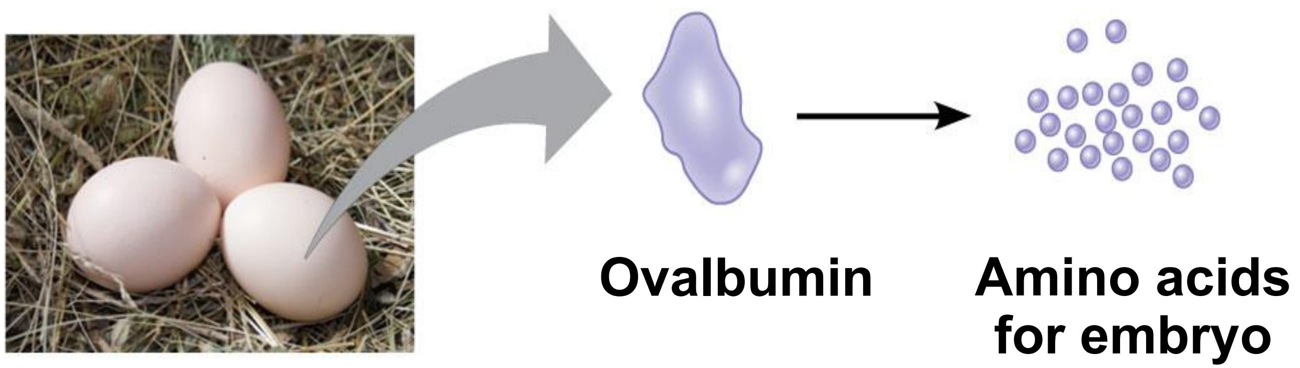


Figure 5.15c

Hormonal proteins

<u>Function</u>: 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

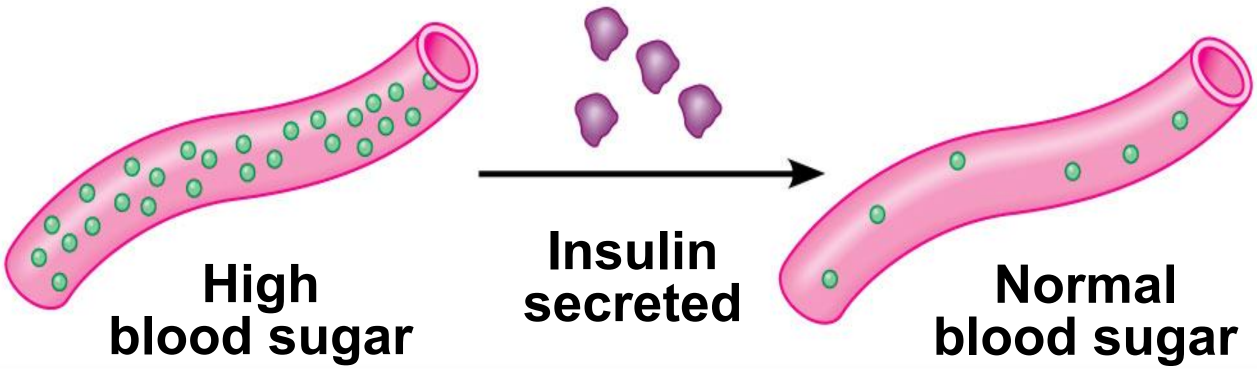
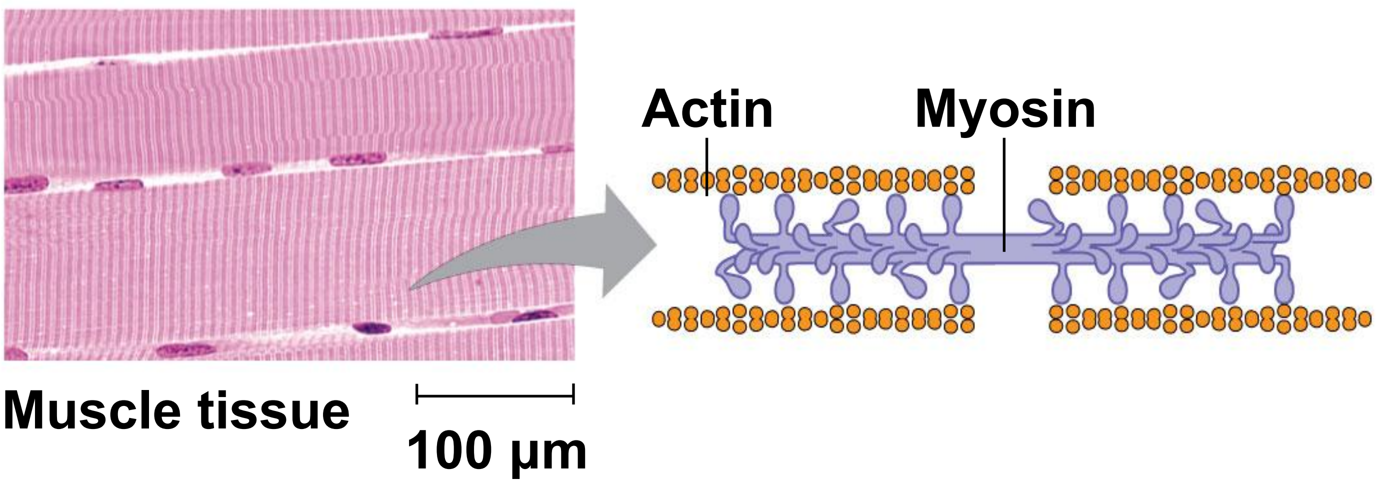


Figure 5.15d

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.



Muscle tissue

Figure 5.15e

Defensive proteins

Function: Protection against disease

Example: Antibodies inactivate and help destroy viruses and bacteria.

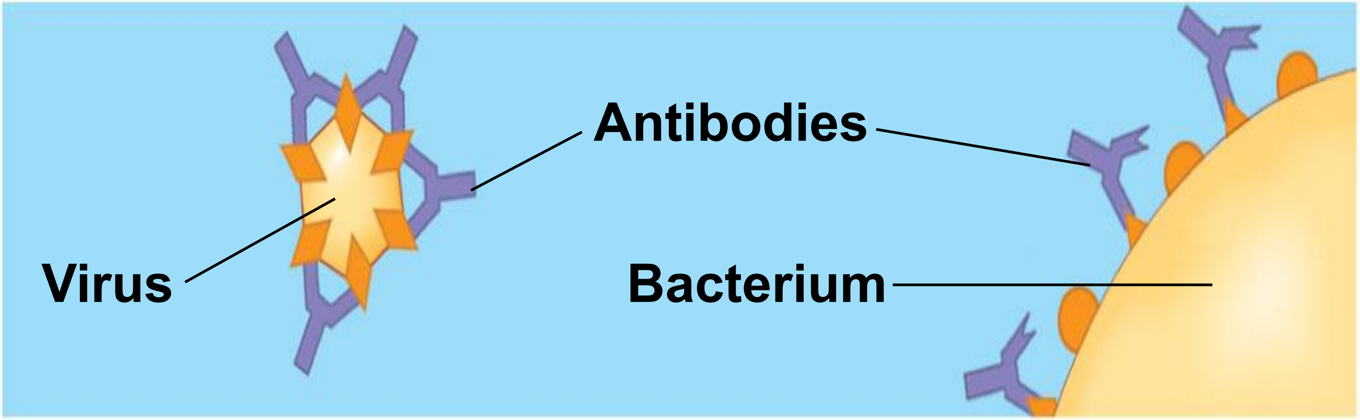


Figure 5.15f

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 cell membranes.

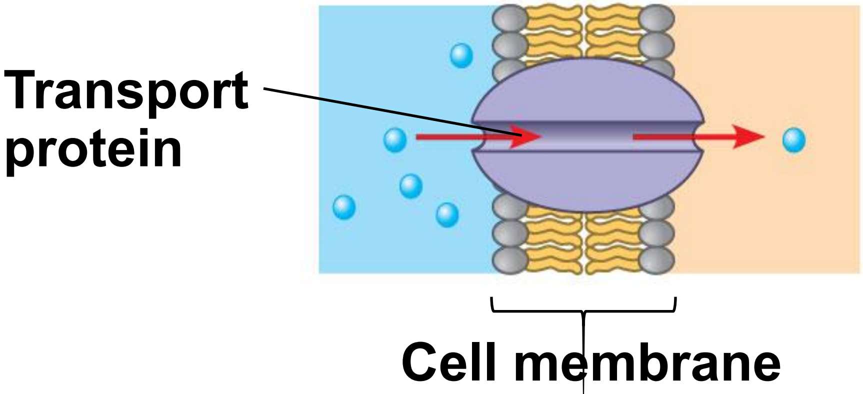


Figure 5.15g

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.

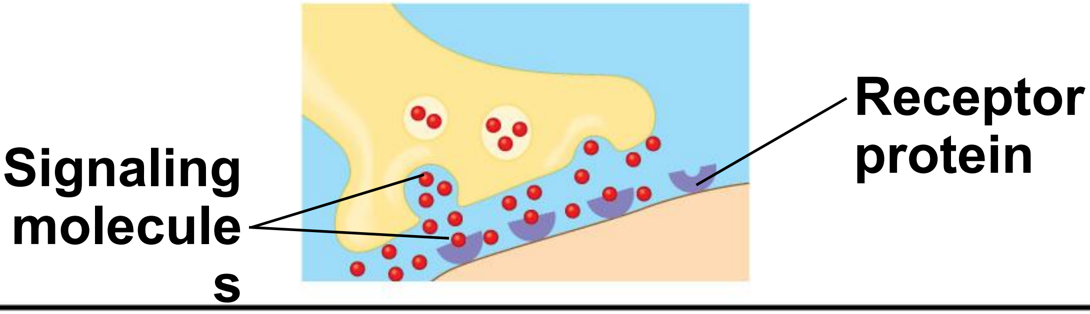
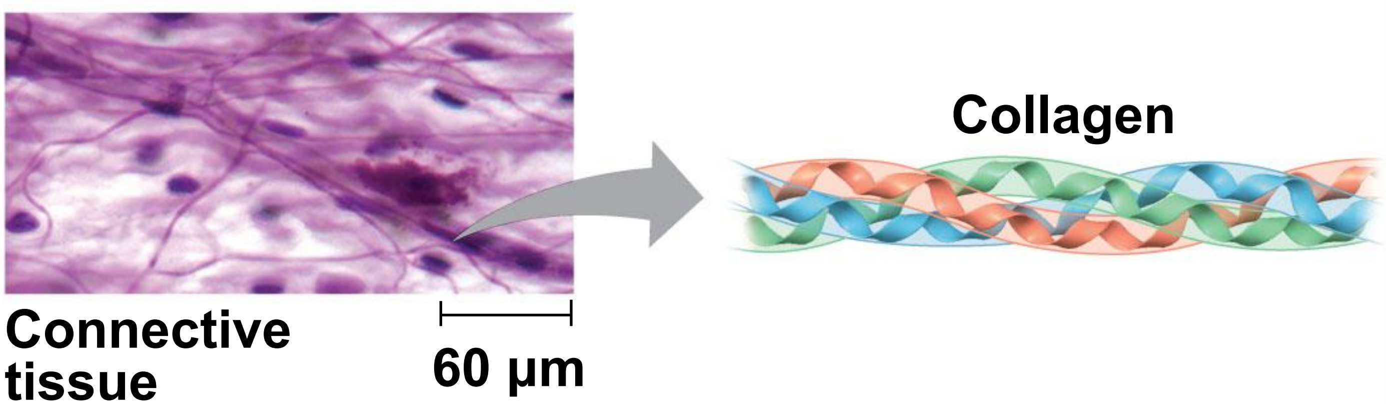


Figure 5.15h

Structural proteins

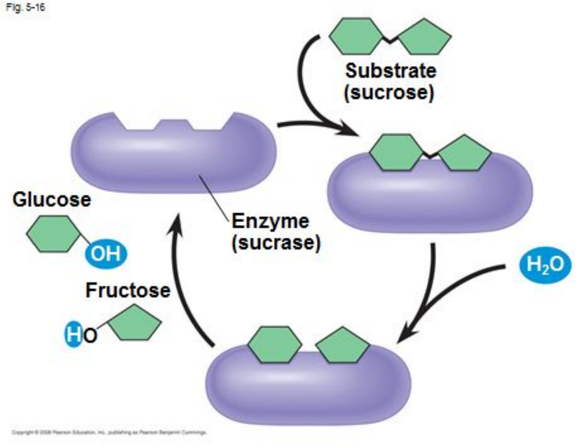
Function: Support

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.



- **Enzymes** are a type of protein that acts as a catalyst to speed up chemical reactions
- Enzymes can perform their functions repeatedly, functioning as workhorses that carry out the processes of life

Fig. 5-16



Polypeptides

- **Polypeptides are polymers built from the same set of 20 amino acids**
- **A protein consists of one or more <u>polypeptides</u>**

Amino Acid Monomers

- Amino acids are organic molecules with carboxyl and amino groups
- Amino acids differ in their properties due to differing side chains, called R groups

Figure 5.UN01

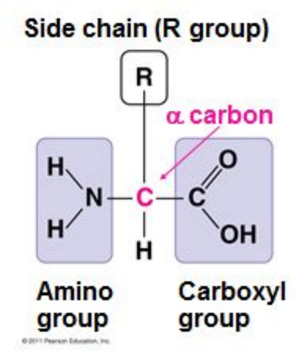
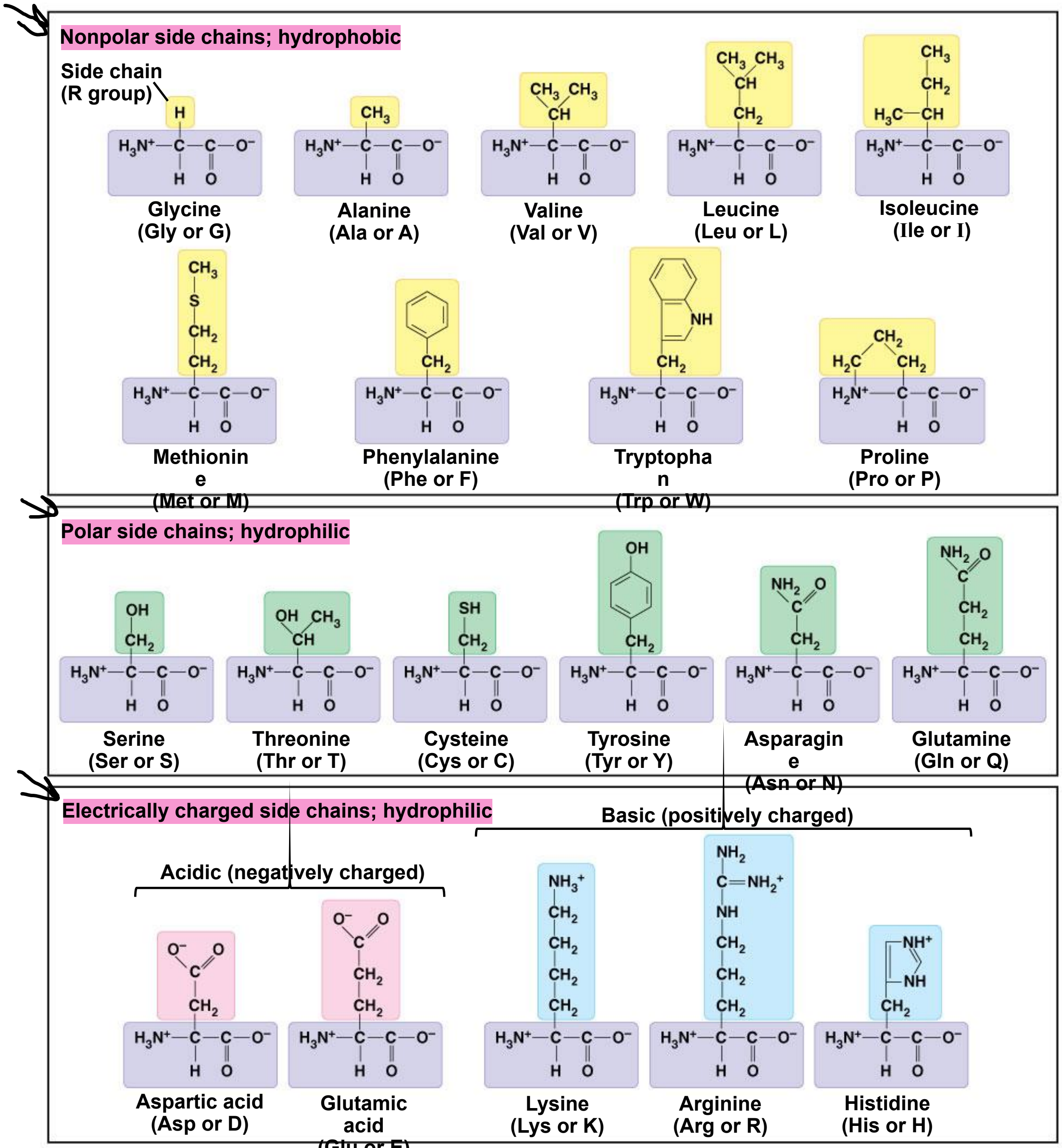


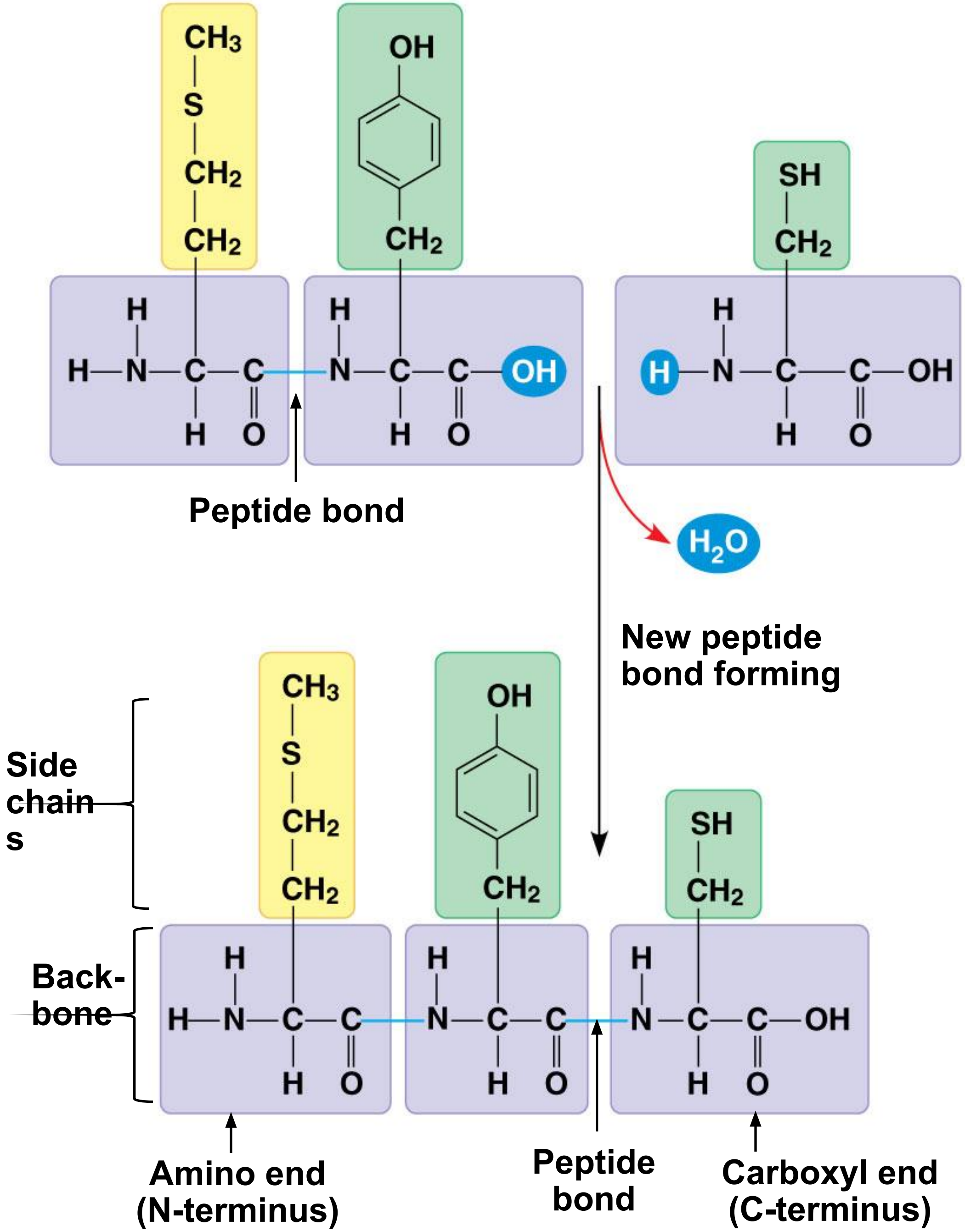
Figure 5.16


Nonpolar side chains; hydrophobic
Side chain (R group)
Glycine (Gly or G)
Alanine (Ala or A)
Valine (Val or V)
Leucine (Leu or L)
Isoleucine (Ile or I)
Methionine (Met or M)
Phenylalanine (Phe or F)
Tryptophan (Trp or W)
Proline (Pro or P)
Polar side chains; hydrophilic
Serine (Ser or S)
Threonine (Thr or T)
Cysteine (Cys or C)
Tyrosine (Tyr or Y)
Asparagine (Asn or N)
Glutamine (Gln or Q)
Electrically charged side chains; hydrophilic
Acidic (negatively charged)
Basic (positively charged)
Aspartic acid (Asp or D)
Glutamic acid (Glu or E)
Lysine (Lys or K)
Arginine (Arg or R)
Histidine (His or H)

Amino Acid Polymers

- **Amino acids are linked by peptide bonds**
- **A polypeptide is a polymer of amino acids**
- **Polypeptides range in length from a few to more than a thousand monomers**
- **Each polypeptide has a unique linear sequence of amino acids**

Figure 5.17

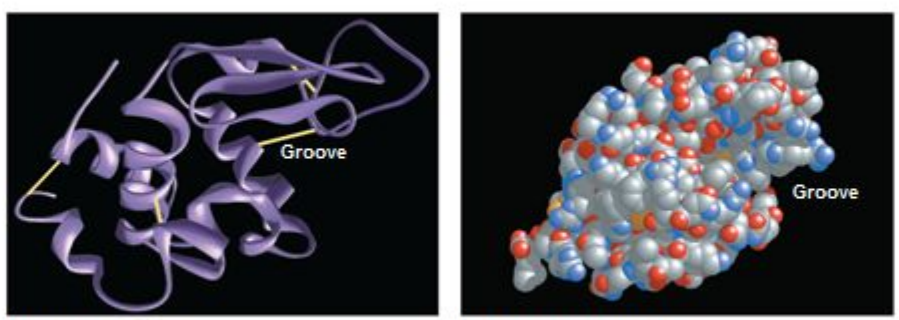


Peptide bond
H_2O
New peptide bond forming
Side chains
Back-bone
Amino end (N-terminus)
Peptide bond
Carboxyl end (C-terminus)

Protein Structure and Function

- A functional protein consists of one or more polypeptides twisted, folded, and coiled into a unique shape

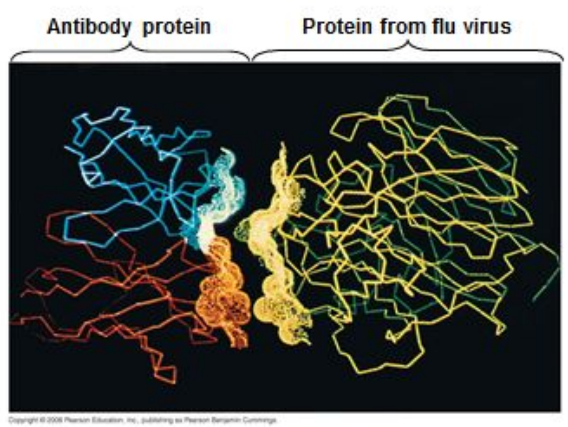
Figure 5.18



(a) A ribbon model (b) A space-filling model

- The <u>sequence</u> of amino acids determines a protein's three-dimensional structure
- A protein's structure <u>determines</u> its function

Fig. 5-20



Four Levels of Protein Structure

- **The <u>primary structure</u> *of a protein is its unique sequence of amino acids***
- **<u>Secondary structure</u>, found in most proteins, consists of *coils and folds in the polypeptide chain***
- **<u>Tertiary structure</u> is determined by *interactions among various side chains <u>(R groups)</u>***
- **<u>Quaternary structure</u> results when a protein consists of *multiple polypeptide chains***

Figure 5.20a

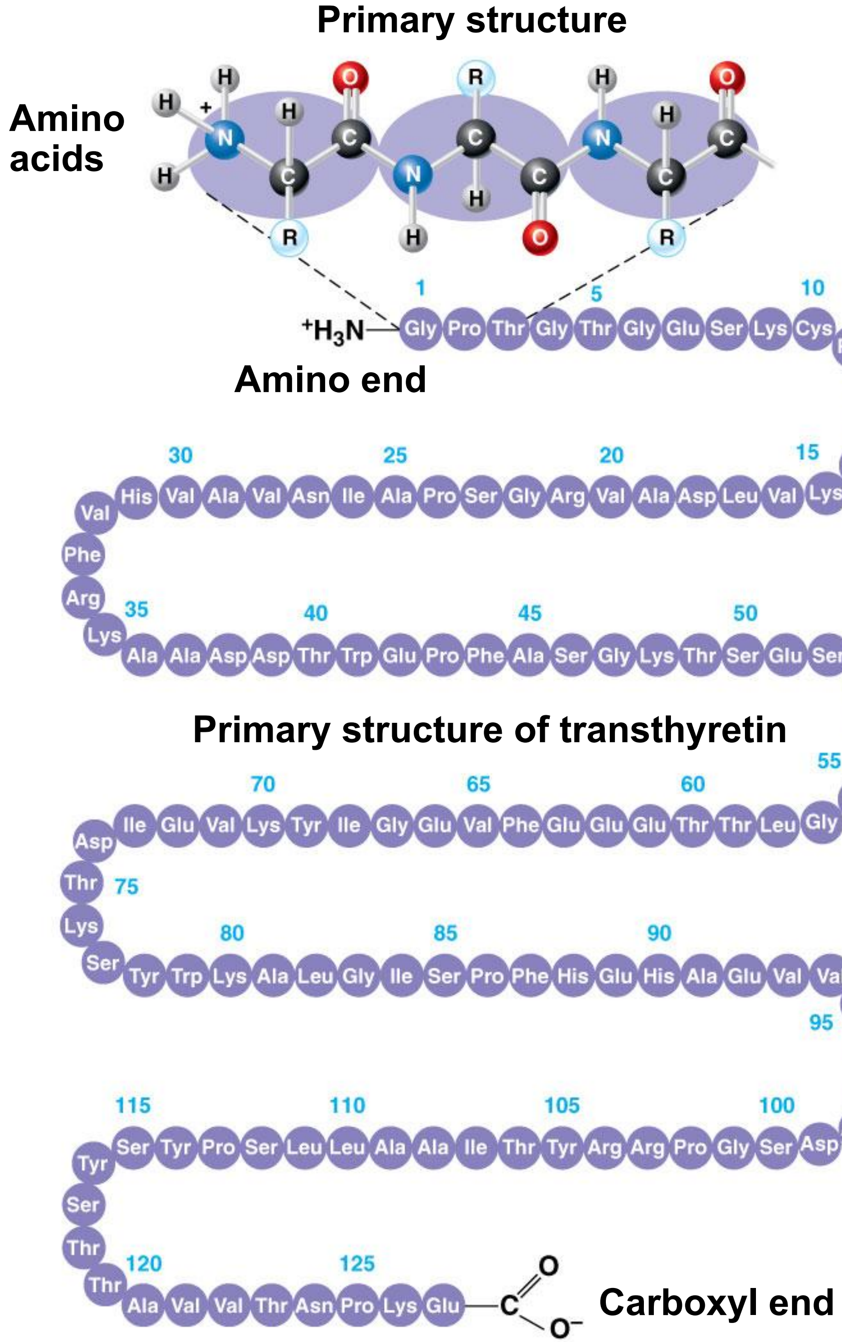
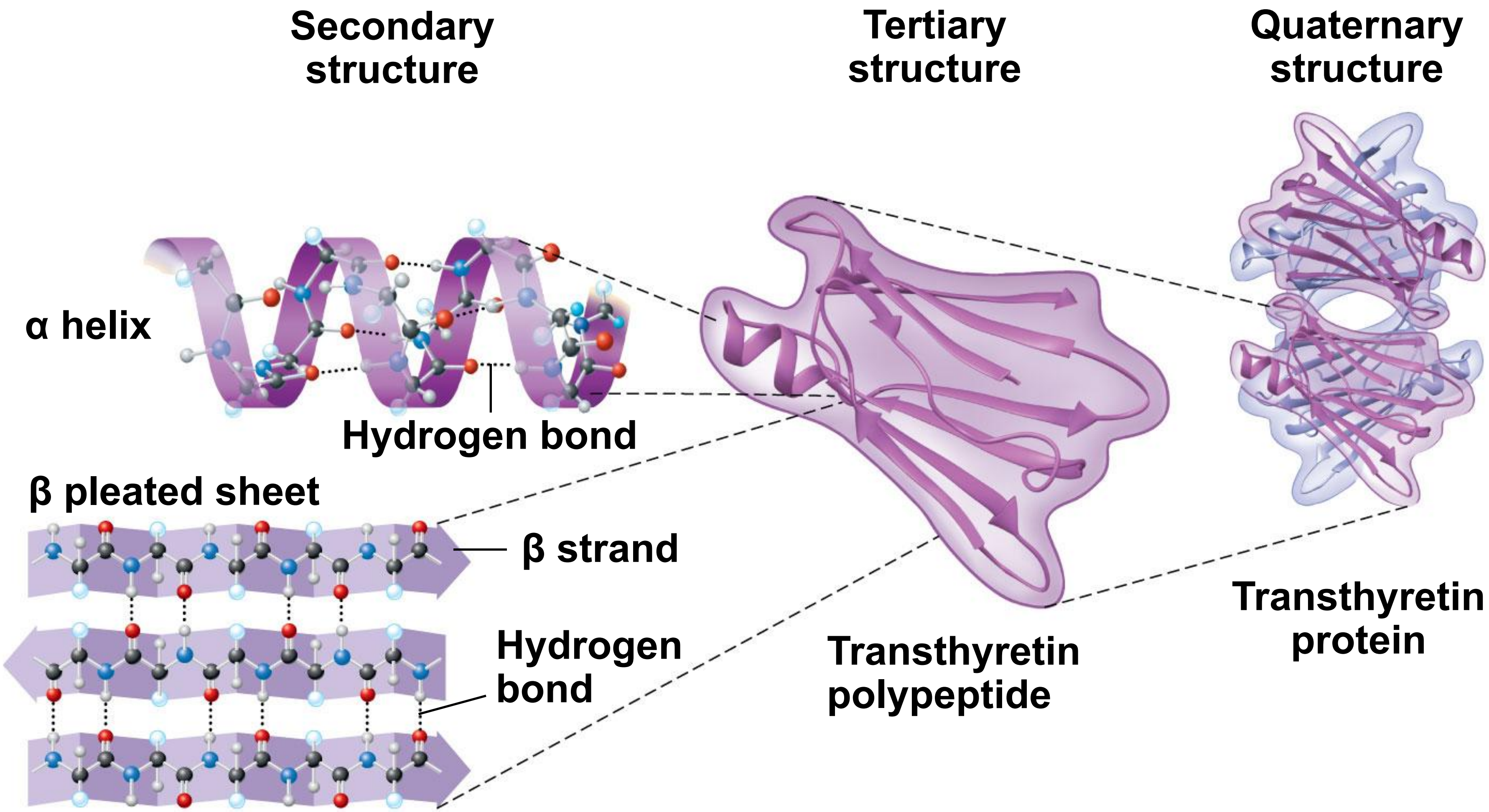

Primary structure
Amino acids
Amino end
Primary structure of transthyretin
Carboxyl end

Figure 5.20b

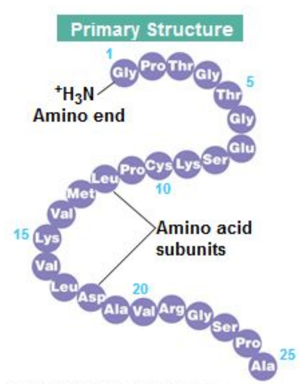


Secondary structure
Tertiary structure
Quaternary structure
α helix
Hydrogen bond
β pleated sheet
β strand
Hydrogen bond
Transthyretin polypeptide
Transthyretin protein

- <u>Primary structure</u>, the sequence of amino acids in a protein, is like the order of letters in a long word

- Primary structure is <u>determined</u> by **inherited genetic information**

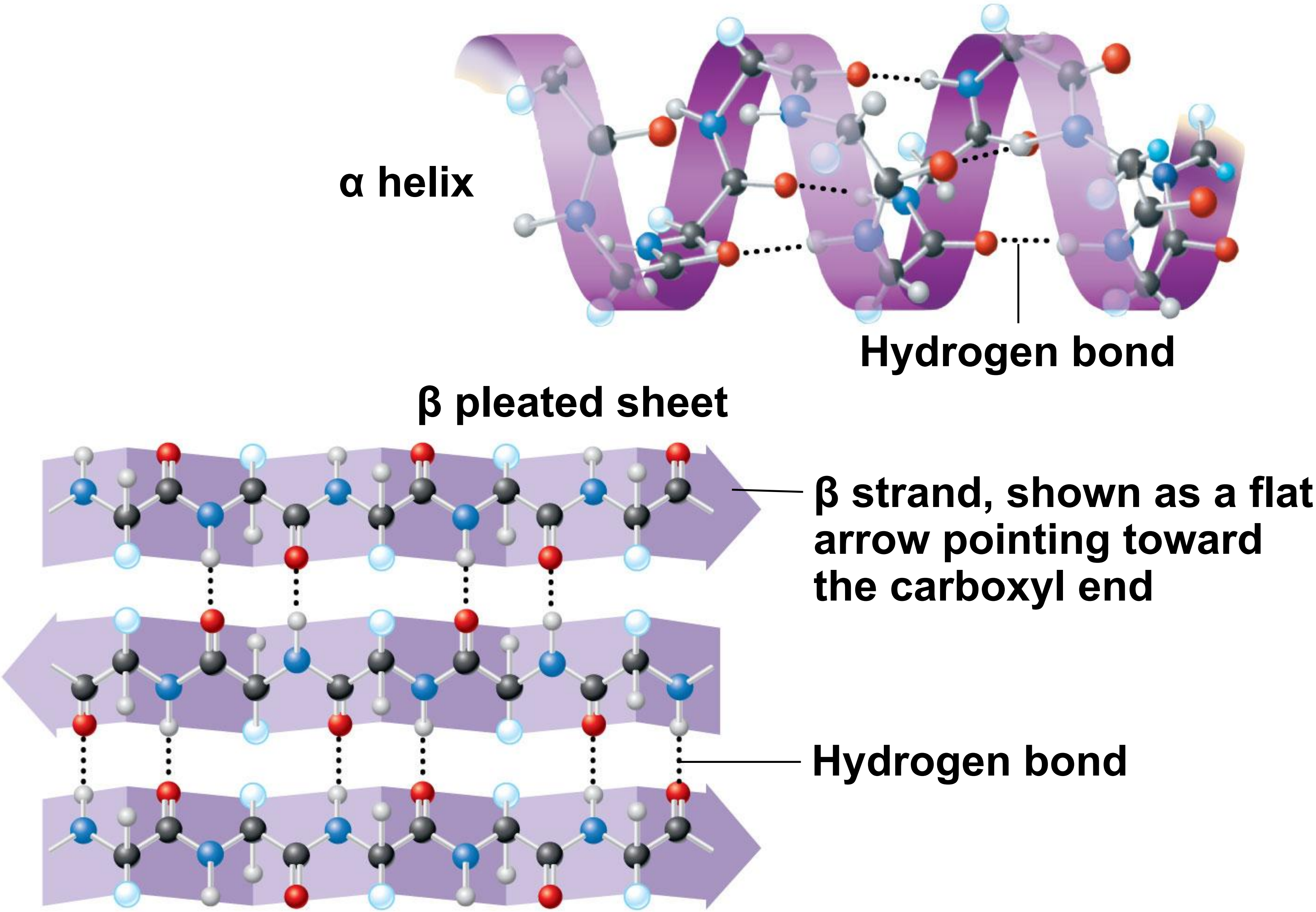
Fig. 5-21a



- **The coils and folds of <u>secondary structure</u> result from <u>hydrogen bonds</u> between repeating constituents of the polypeptide backbone**
- **Typical secondary structures are a coil called an <u>α helix</u> and a folded structure called a <u>β pleated sheet</u>**

Figure 5.20c

Secondary structure



- **Tertiary structure is determined by <u>interactions between R groups</u>, rather than interactions between backbone constituents**
- **These interactions between R groups include hydrogen bonds, ionic bonds, hydrophobic interactions, and van der Waals interactions**
- **Strong covalent bonds called <u>disulfide bridges</u> may reinforce the protein's structure**

Figure 5.20e

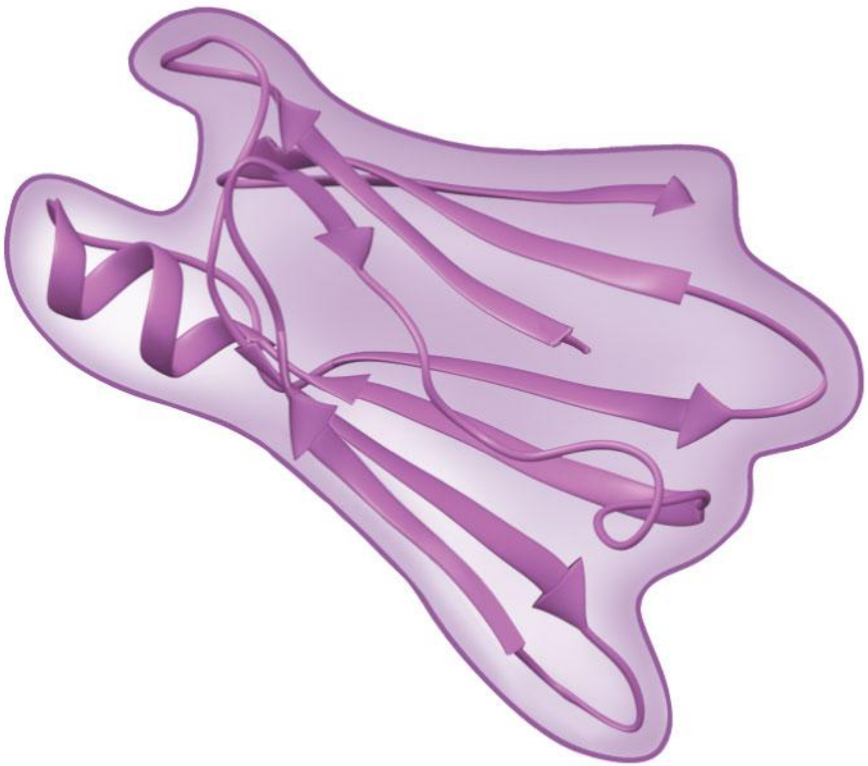
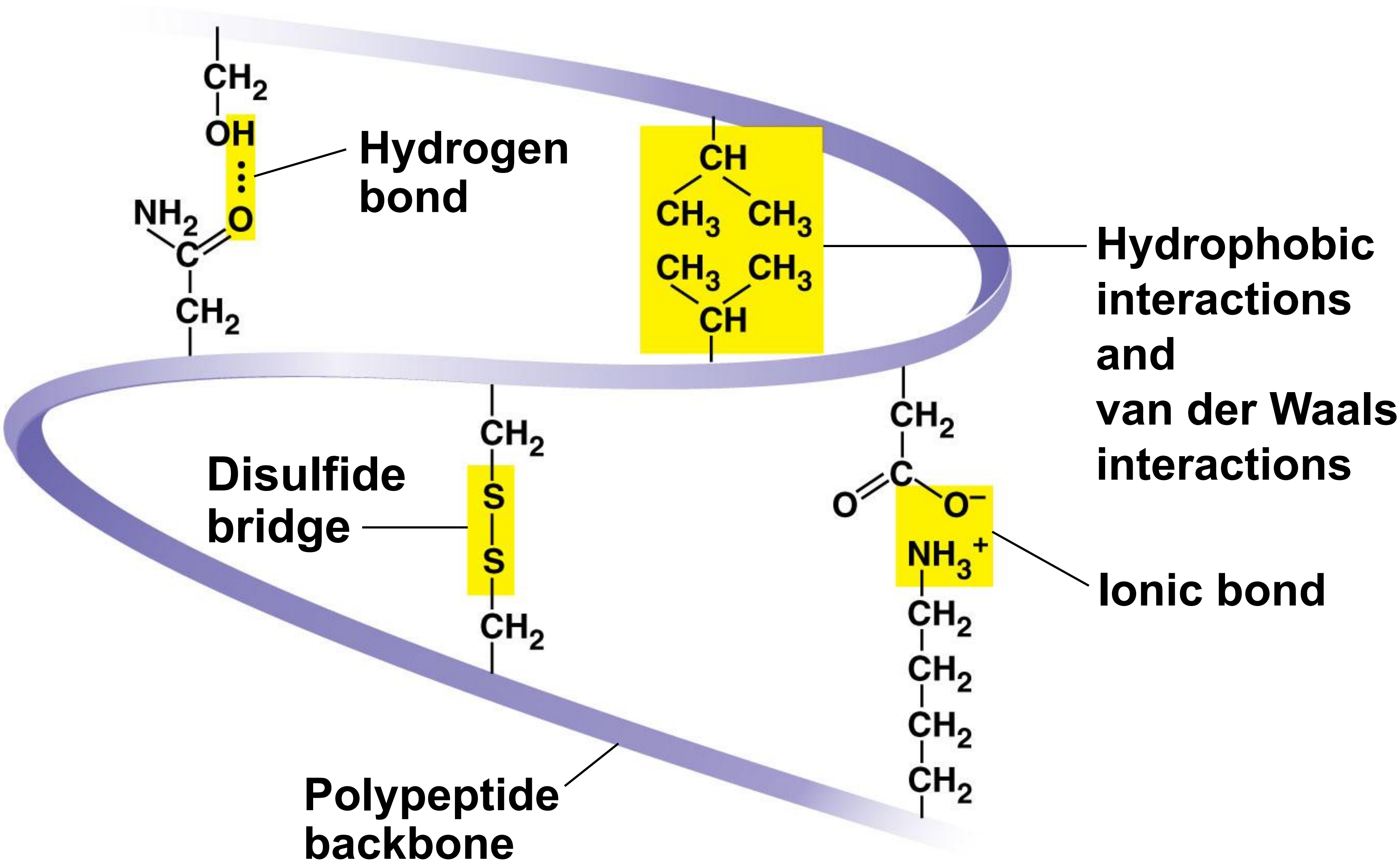


Figure 5.20f

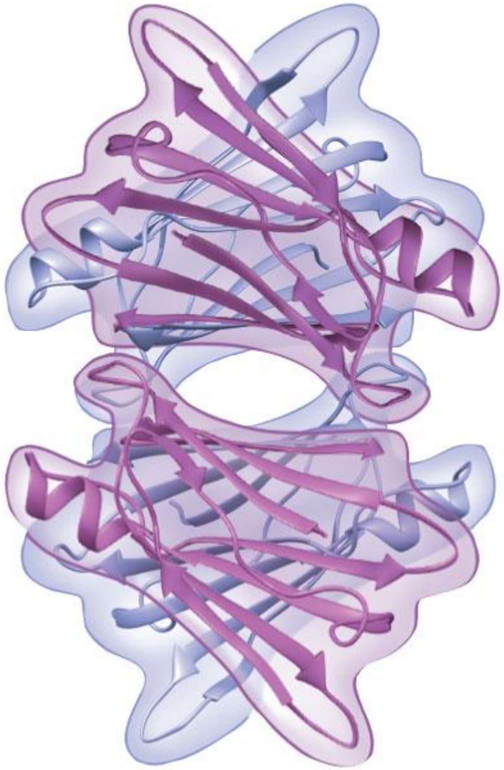


CH2
OH
NH2
C
O
CH2
Hydrogen bond
CH
CH3 CH3
CH3 CH3
CH
Hydrophobic interactions and van der Waals interactions
CH2
S
S
CH2
Disulfide bridge
CH2
C
O
O−
NH3+
CH2
CH2
CH2
CH2
Ionic bond
Polypeptide backbone

- **Quaternary structure** results when **two or more polypeptide** chains form one macromolecule
- Collagen is a **fibrous protein** consisting of **three polypeptides** coiled like a rope
- Hemoglobin is a **globular protein** consisting of four polypeptides: **two alpha** and **two beta chains**

Figure 5.20g

Quaternary structure



Transthyretin protein (four identical polypeptides)

Figure 5.20h

Collagen

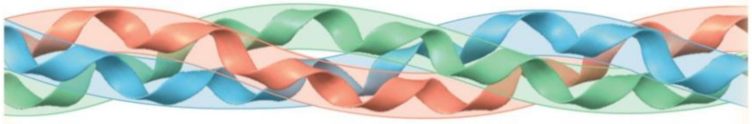
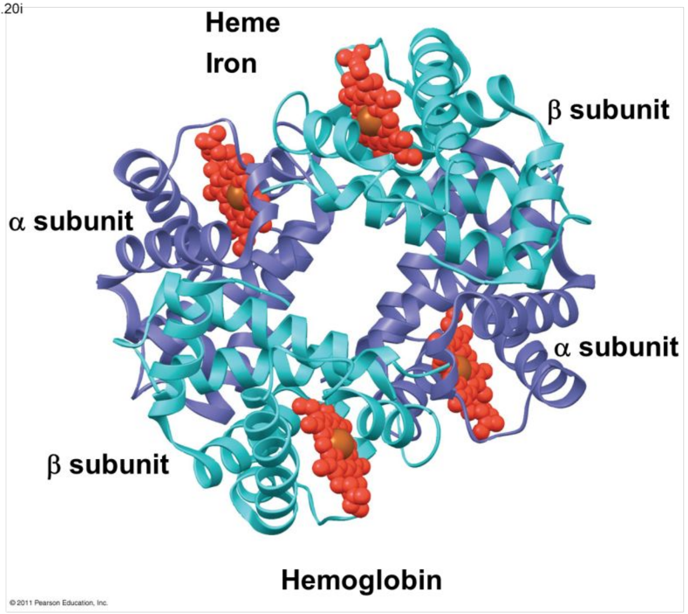


Figure 5.20i



Sickle-Cell Disease: A Change in Primary Structure

- **A slight change in primary structure can affect a protein's structure and ability to function**
- **<u>Sickle-cell disease</u>, an inherited blood disorder, results from a single amino acid substitution in the protein hemoglobin**

Figure 5.21

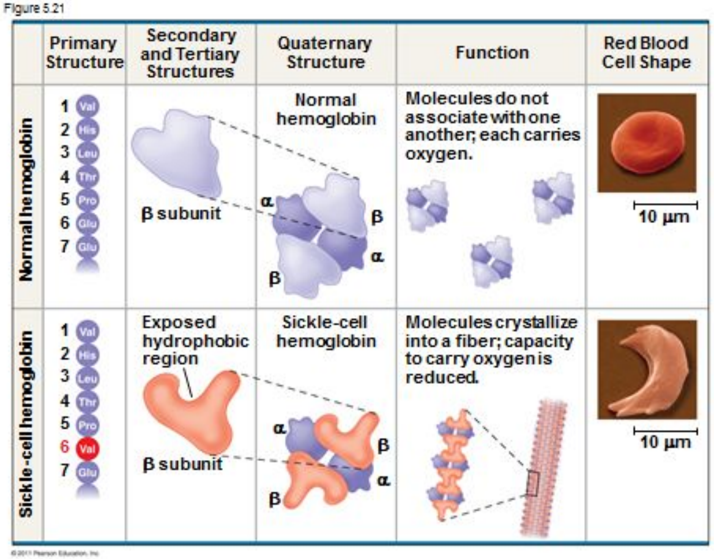
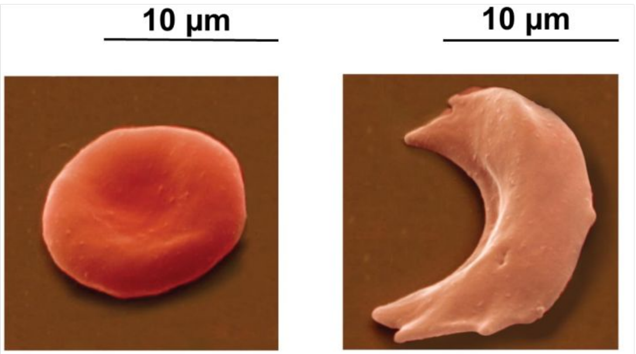


Fig. 5-22c



Normal red blood cells are full of individual hemoglobin molecules, each carrying oxygen.

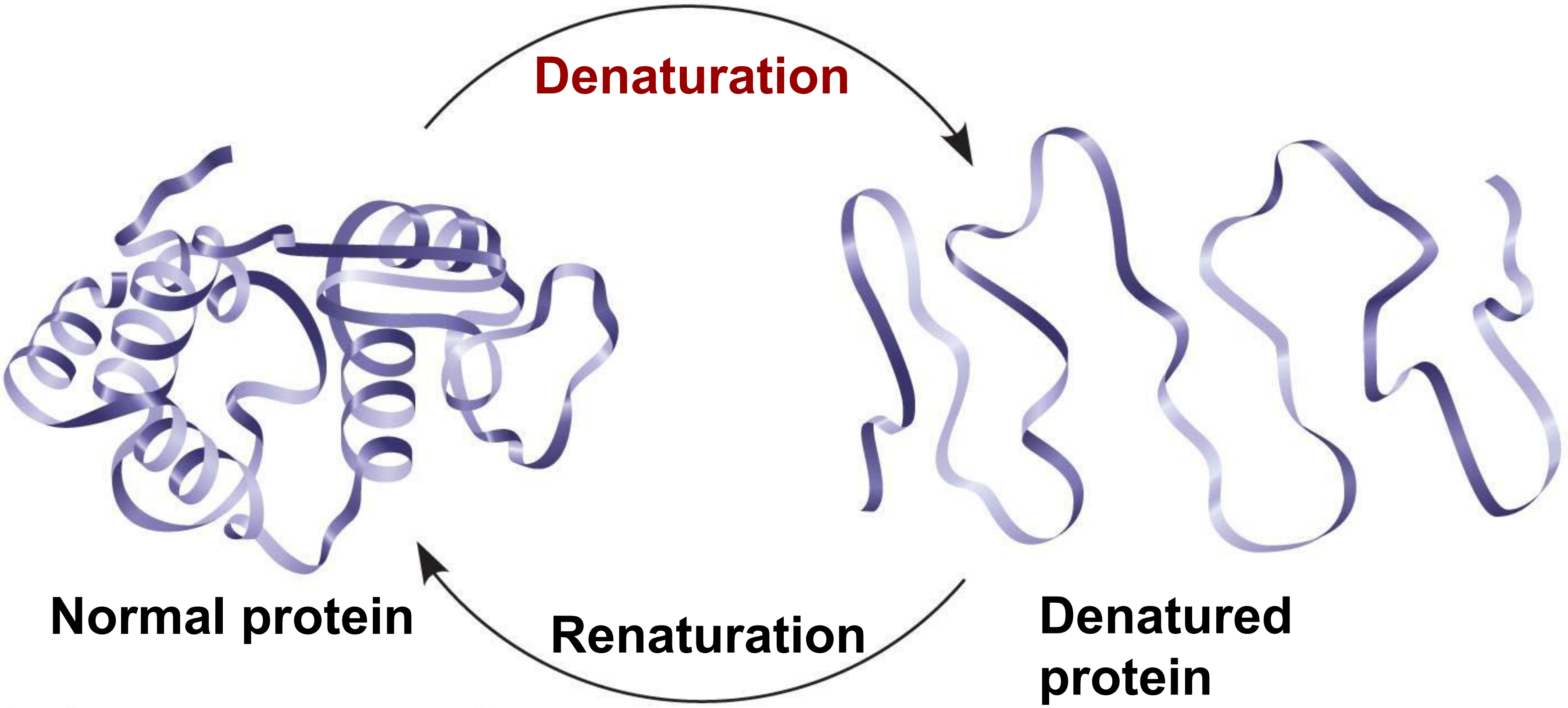
Fibers of abnormal hemoglobin deform red blood cell into sickle shape.

What Determines Protein Structure?

- Chemical conditions can affect structure
  - Alterations in pH
  - Salt concentration
  - Temperature
  - Other environmental factors

Loss of a protein's native structure is called **denaturation** (A denatured protein is biologically inactive)

Fig. 5-23


Denaturation
Normal protein
Renaturation
Denatured
protein

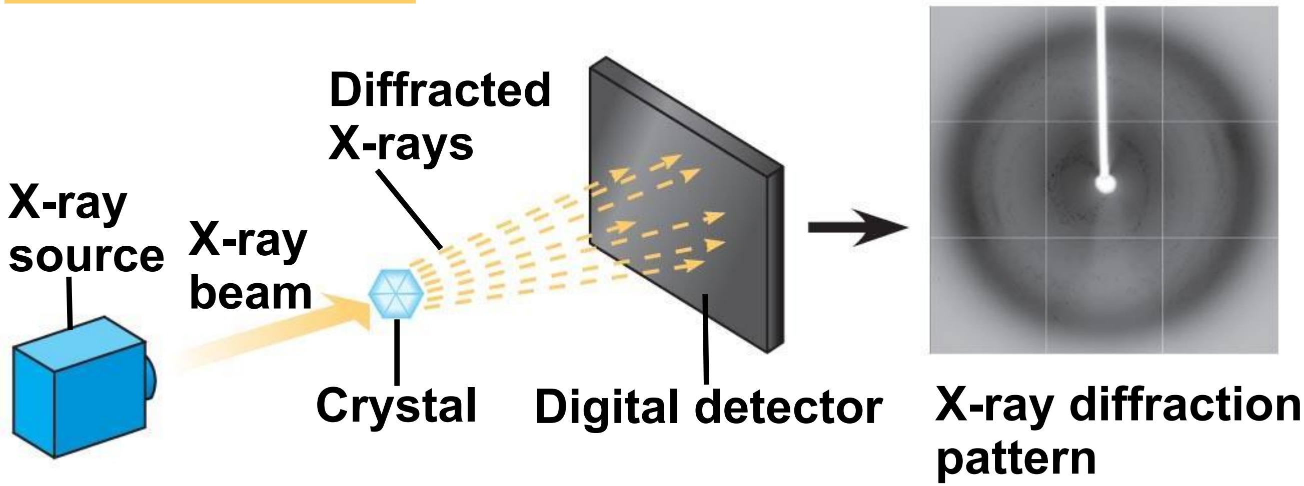
Protein Folding in the Cell

- **It is <u>hard to predict</u> a protein's structure from its primary structure**
- **Most proteins probably go through several states on their way to a <u>stable structure</u>**
- **<u>Chaperonins</u>** ***are protein molecules that assist the proper folding of other proteins***

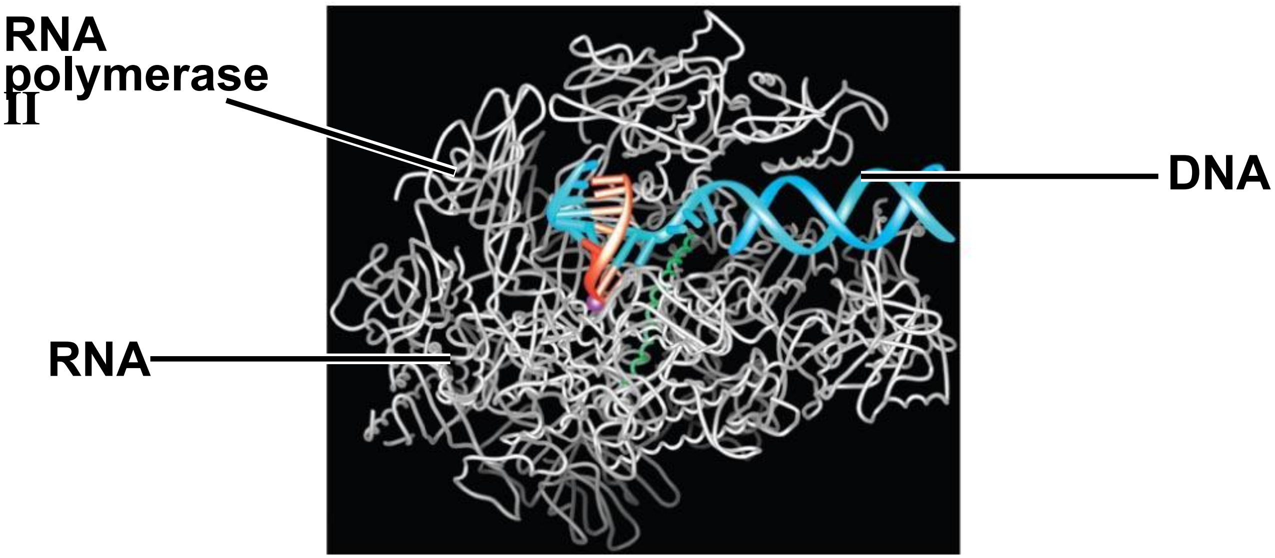
- **Scientists use <u>X-ray crystallography</u> to determine a protein's structure**
- **Another method is <u>nuclear magnetic resonance (NMR) spectroscopy</u>, which does not require protein crystallization**
- **<u>Bioinformatics</u> uses computer programs to predict protein structure from amino acid sequences**

Fig. 5-25

EXPERIMENT



RESULTS



Nucleic acids

Concept 5.5: Nucleic acids store and transmit hereditary information

- The amino acid sequence of a polypeptide is programmed by a unit of inheritance called a **gene**
- Genes are made of DNA, a **nucleic acid**

The Roles of Nucleic Acids

- There are two types of nucleic acids:
  - Deoxyribonucleic acid (DNA)
  - Ribonucleic acid (RNA)
- DNA directs synthesis of messenger RNA (mRNA) and, through mRNA, controls protein synthesis
- Protein synthesis occurs in ribosomes

Fig. 5-26-1

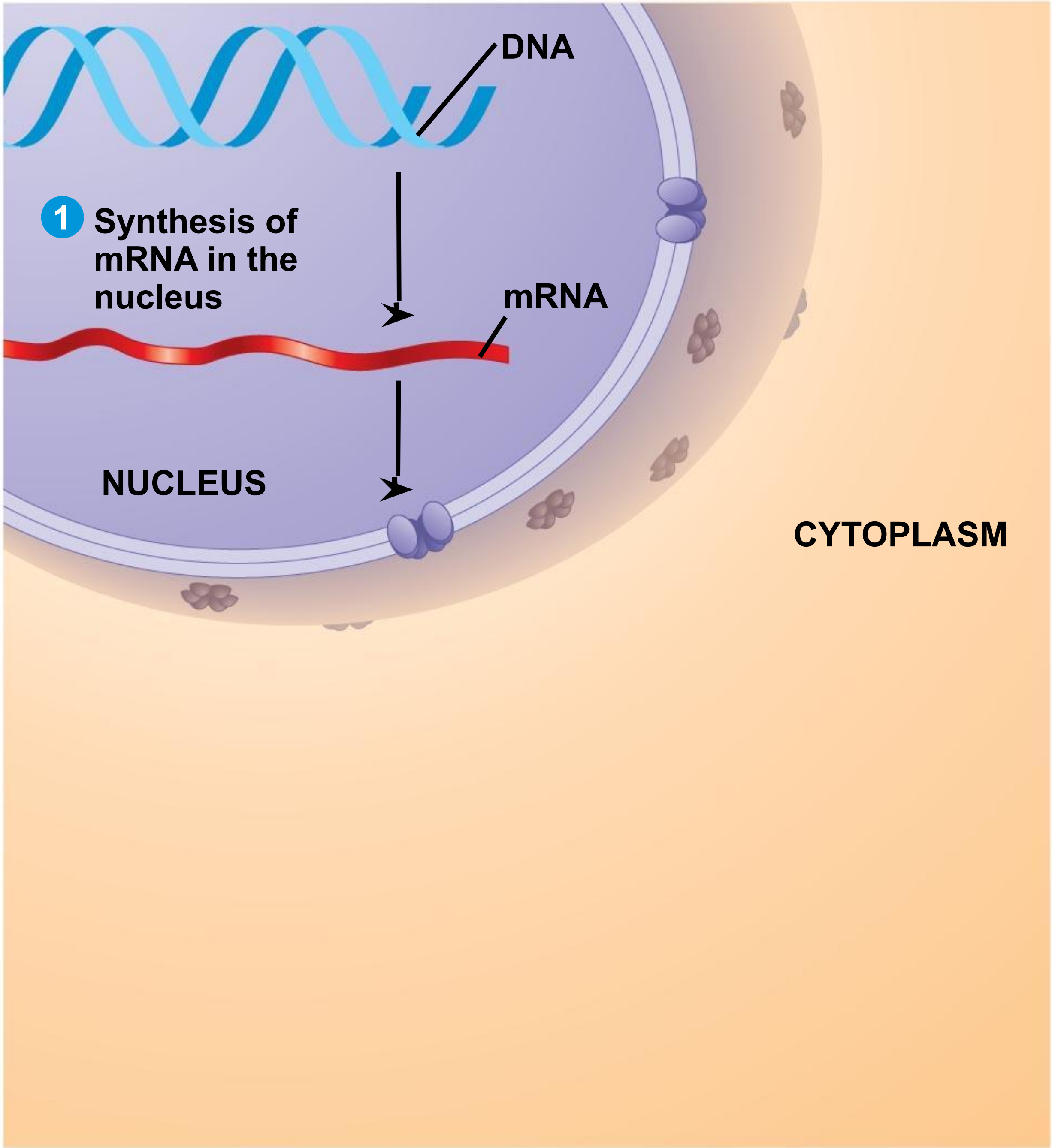

DNA
1 Synthesis of mRNA in the nucleus
mRNA
NUCLEUS
CYTOPLASM

Fig. 5-26-2

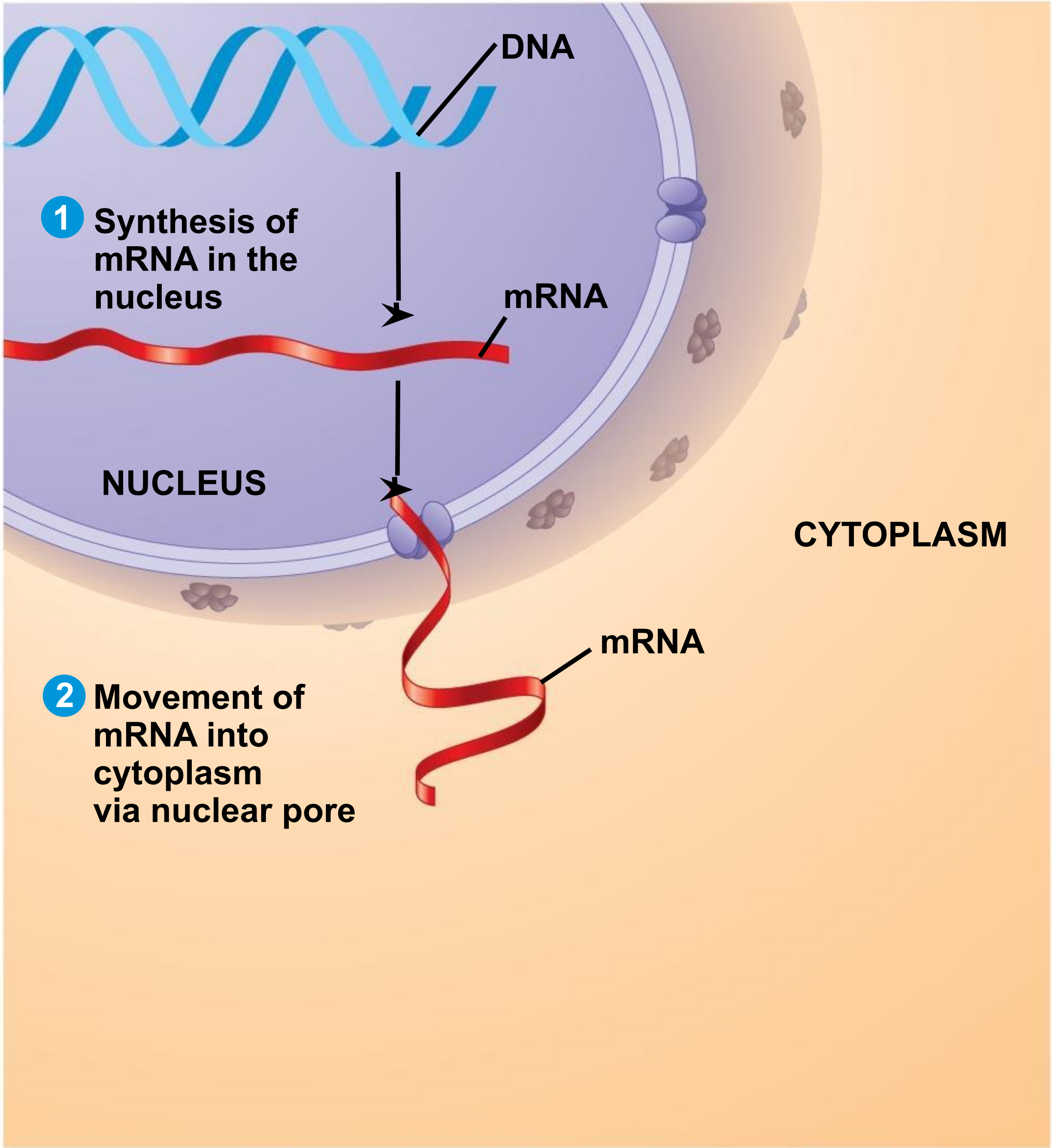
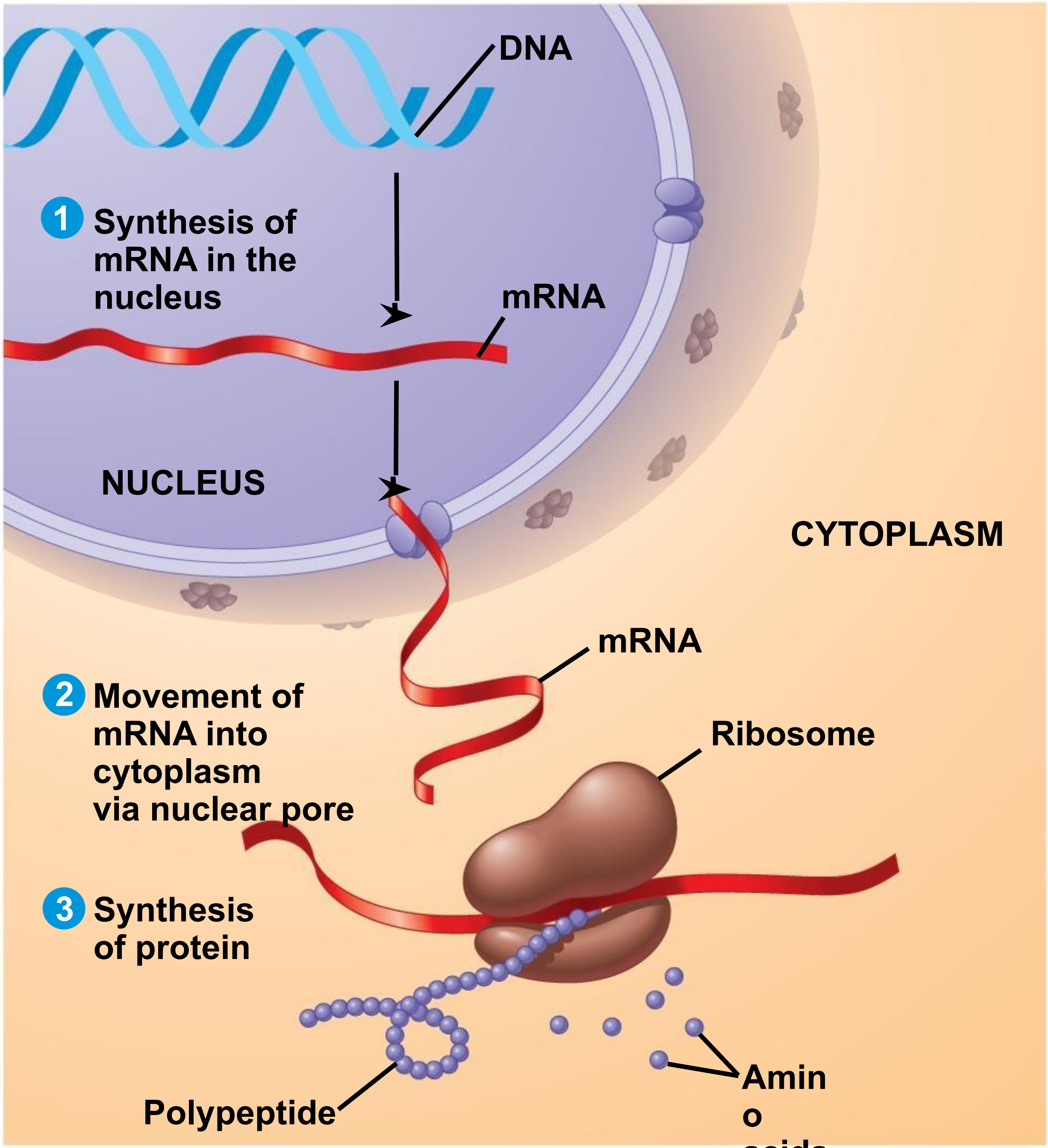

DNA
1 Synthesis of mRNA in the nucleus
mRNA
NUCLEUS
CYTOPLASM
mRNA
2 Movement of mRNA into cytoplasm via nuclear pore

Fig. 5-26-3


DNA
1 Synthesis of mRNA in the nucleus
mRNA
NUCLEUS
CYTOPLASM
mRNA
2 Movement of mRNA into cytoplasm via nuclear pore
Ribosome
3 Synthesis of protein
Polypeptide
Amin
o
acids

The Structure of Nucleic Acids

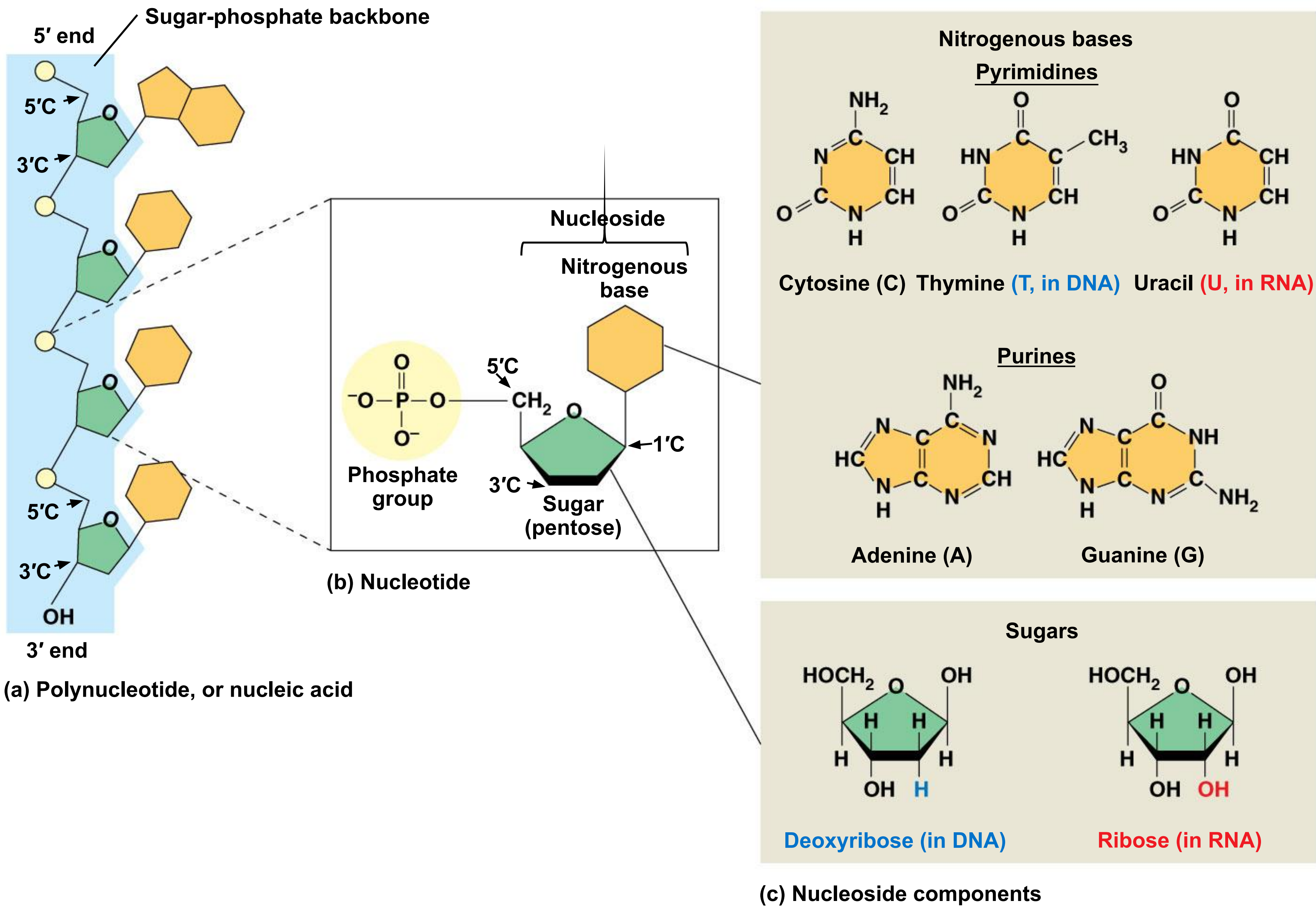
- **Nucleic acids are <u>polymers</u> called polynucleotides**
- **Each polynucleotide is made of monomers called <u>nucleotides</u>**
- **<u>Each nucleotide consists</u> of: a nitrogenous base, <u>a pentose sugar</u>, and <u>a phosphate group</u>**
- **The portion of a nucleotide without the phosphate group is called a <u>*nucleoside*</u>**

Nucleotide Monomers

- **There are two families of nitrogenous bases:**
  - ***Pyrimidines*** **(cytosine, thymine, and uracil) have a** **single six-membered ring**
  - ***Purines*** **(adenine and guanine) have a** **six-membered ring fused to a five-membered ring**

- **In DNA, the sugar is** **deoxyribose****; in RNA, the sugar is** **ribose**

Figure 5.26

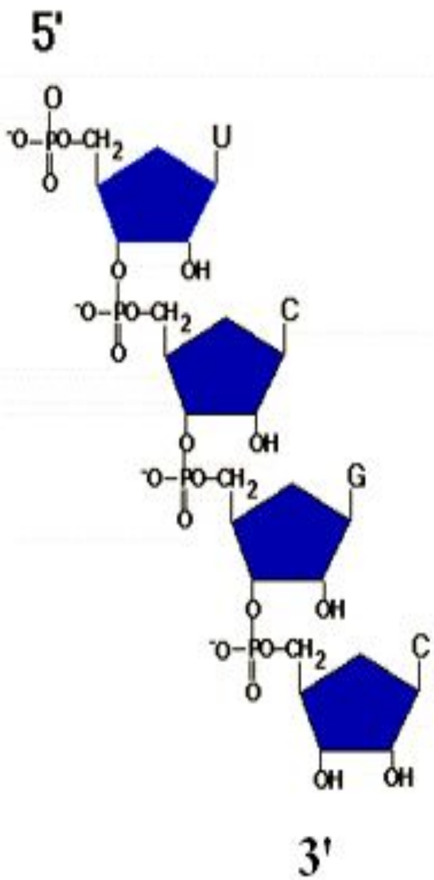

Sugar-phosphate backbone
5′ end
5′C
3′C
O
OH
3′ end
(a) Polynucleotide, or nucleic acid
Nucleoside
Nitrogenous base
O
⁻O—P—O
O⁻
Phosphate group
5′C
CH2
1′C
3′C
Sugar (pentose)
(b) Nucleotide
Nitrogenous bases
Pyrimidines
Cytosine (C)
Thymine (T, in DNA)
Uracil (U, in RNA)
Purines
Adenine (A)
Guanine (G)
Sugars
HOCH2
OH
Deoxyribose (in DNA)
Ribose (in RNA)
(c) Nucleoside components

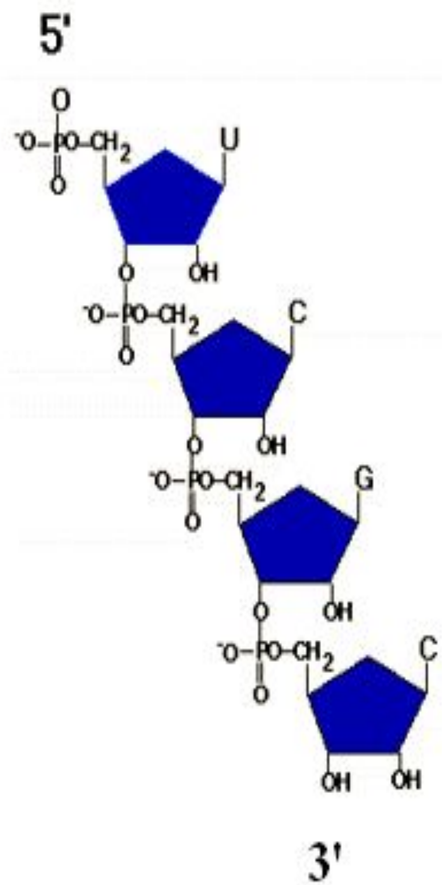
Nucleotide Polymers

- **Nucleotide polymers are linked together to build a polynucleotide**
- **Adjacent nucleotides are joined by *covalent bonds* that form between the –OH group on the 3′ carbon of one nucleotide and the phosphate on the 5′ carbon on the next**
- **The sequence of bases along a DNA or mRNA polymer is unique for each gene**

The DNA Double Helix

- **A DNA molecule has two polynucleotides <u>spiraling</u> around an <u>imaginary axis</u>, forming a <u>double helix</u>**
- **In the DNA double helix, the two backbones run in <u>opposite 5′ → 3′ directions</u> from each other, an arrangement referred to as <u>antiparallel</u>**
- **The <u>nitrogenous bases in DNA pair up and form hydrogen bonds</u>: adenine (A) always with thymine (T), and guanine (G) always with cytosine (C)**


5'
U
C
G
C
3'


5'
U
C
G
C
3'

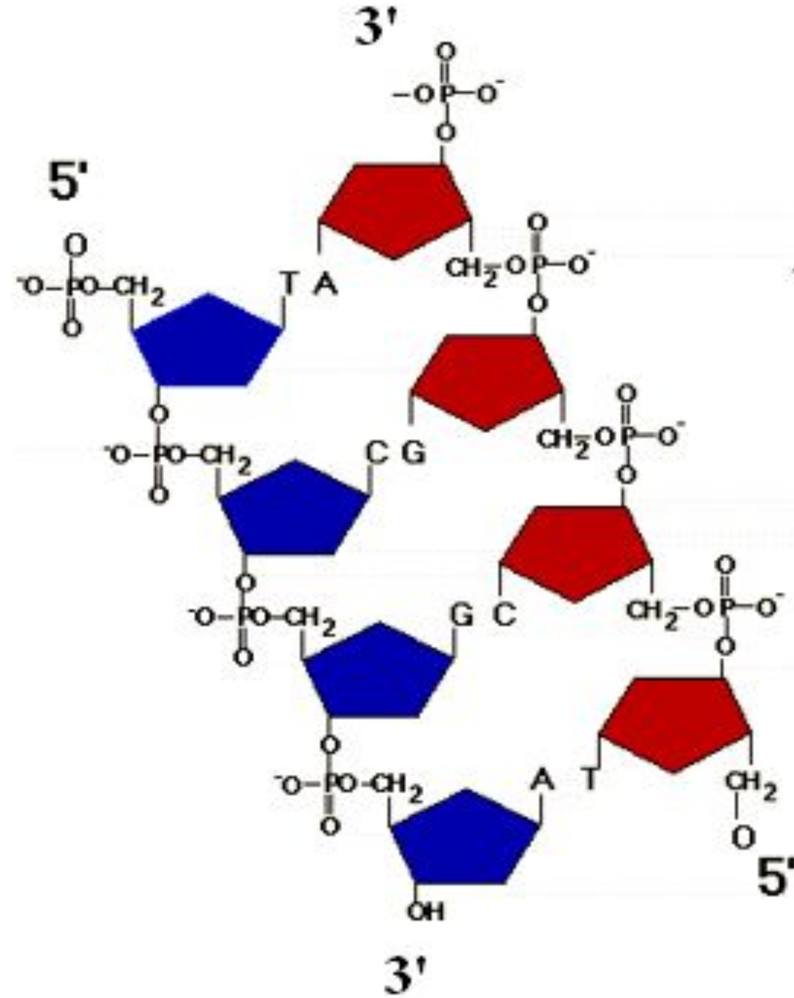
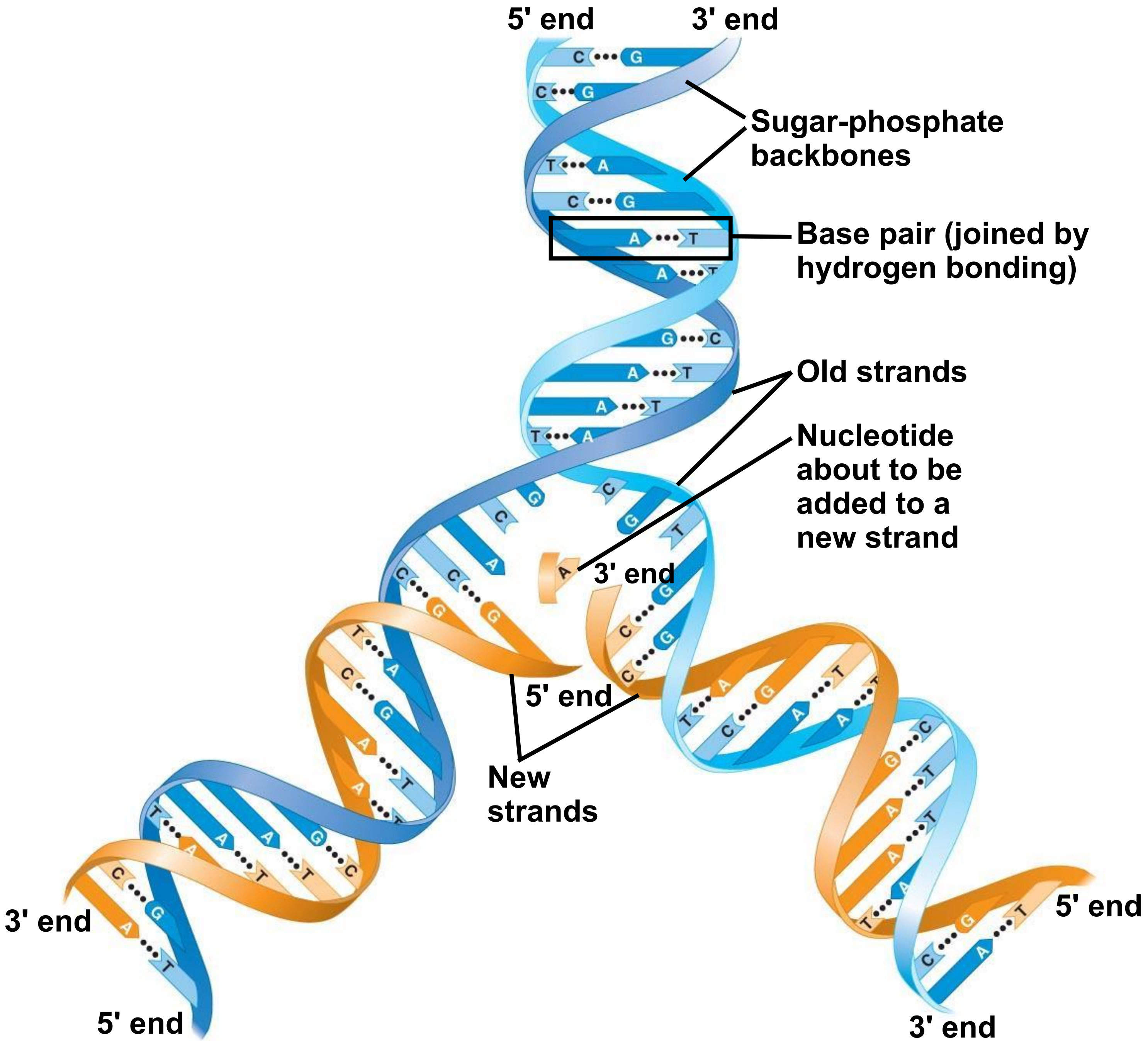

3'
5'
T A
C G
G C
A T
5'
3'

Fig. 5-28


5' end
3' end
Sugar-phosphate backbones
Base pair (joined by hydrogen bonding)
Old strands
Nucleotide about to be added to a new strand
3' end
5' end
New strands
3' end
5' end
5' end
3' end

DNA and Proteins as Tape Measures of Evolution

- **The linear sequences of nucleotides in DNA molecules are passed from parents to offspring**
- **Two closely related species are more similar in DNA than are more distantly related species**
- **Molecular biology can be used to assess evolutionary kinship**

Summary

Figure 5.UN02

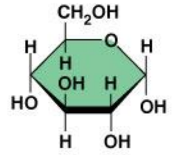
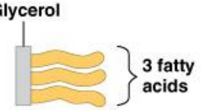
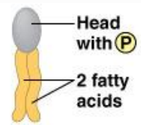
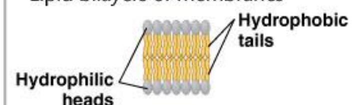
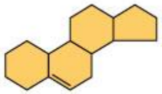
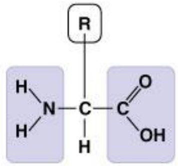
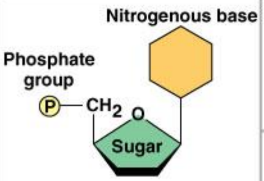
Large Biological Molecules	Components	Examples	Functions
CONCEPT 5.2 Carbohydrates serve as fuel and building material	 Monosaccharide monomer	**Monosaccharides:** glucose, fructose	Fuel; carbon sources that can be converted to other molecules or combined into polymers
		Disaccharides: lactose, sucrose	
		Polysaccharides: • Cellulose (plants) • Starch (plants) • Glycogen (animals) • Chitin (animals and fungi)	 • Strengthens plant cell walls • Stores glucose for energy • Stores glucose for energy • Strengthens exoskeletons and fungal cell walls
CONCEPT 5.3 Lipids are a diverse group of hydrophobic molecules		**Triacylglycerols** (fats or oils): glycerol + 3 fatty acids	Important energy source 
		**Phospholipids:** phosphate group + 2 fatty acids	Lipid bilayers of membranes 
	 Steroid backbone	**Steroids:** four fused rings with attached chemical groups	• Component of cell membranes (cholesterol) • Signaling molecules that travel through the body (hormones)
CONCEPT 5.4 Proteins include a diversity of structures, resulting in a wide range of functions	 Amino acid monomer (20 types)	• Enzymes • Structural proteins • Storage proteins • Transport proteins • Hormones • Receptor proteins • Motor proteins • Defensive proteins	• Catalyze chemical reactions • Provide structural support • Store amino acids • Transport substances • Coordinate organismal responses • Receive signals from outside cell • Function in cell movement • Protect against disease
CONCEPT 5.5 Nucleic acids store, transmit, and help express hereditary information	 Nucleotide monomer	**DNA:** • Sugar = deoxyribose • Nitrogenous bases = C, G, A, T • Usually double-stranded	Stores hereditary information
		RNA: • Sugar = ribose • Nitrogenous bases = C, G, A, U • Usually single-stranded	Various functions during gene expression, including carrying instructions from DNA to ribosomes

Figure 5.UN02a

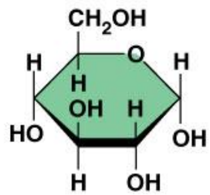
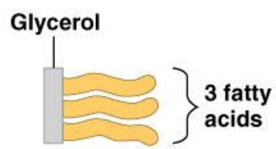
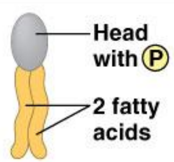
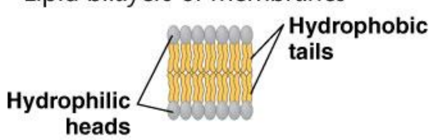
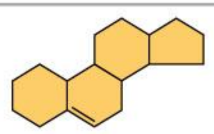
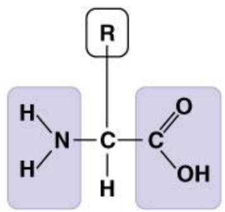
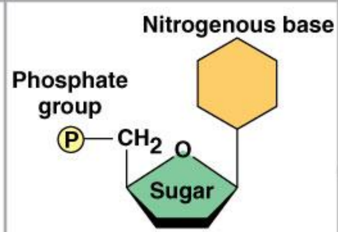
Large Biological Molecules	Components	Examples	Functions
CONCEPT 5.2 Carbohydrates serve as fuel and building material	 Monosaccharide monomer	**Monosaccharides:** glucose, fructose	Fuel; carbon sources that can be converted to other molecules or combined into polymers
		Disaccharides: lactose, sucrose	
		Polysaccharides: • Cellulose (plants) • Starch (plants) • Glycogen (animals) • Chitin (animals and fungi)	• Strengthens plant cell walls • Stores glucose for energy • Stores glucose for energy • Strengthens exoskeletons and fungal cell walls
CONCEPT 5.3 Lipids are a diverse group of hydrophobic molecules		**Triacylglycerols** (fats or oils): glycerol + 3 fatty acids	Important energy source 
		**Phospholipids:** phosphate group + 2 fatty acids	Lipid bilayers of membranes 
	 Steroid backbone	**Steroids:** four fused rings with attached chemical groups	• Component of cell membranes (cholesterol) • Signaling molecules that travel through the body (hormones)

Figure 5.UN02b

Large Biological Molecules	Components	Examples	Functions
CONCEPT 5.4 **Proteins include a diversity of structures, resulting in a wide range of functions**	 **Amino acid monomer (20 types)**	• Enzymes • Structural proteins • Storage proteins • Transport proteins • Hormones • Receptor proteins • Motor proteins • Defensive proteins	• Catalyze chemical reactions • Provide structural support • Store amino acids • Transport substances • Coordinate organismal responses • Receive signals from outside cell • Function in cell movement • Protect against disease
CONCEPT 5.5 **Nucleic acids store, transmit, and help express hereditary information**	 **Nucleotide monomer**	**DNA:**  • Sugar = deoxyribose • Nitrogenous bases = C, G, A, T • Usually double-stranded	Stores hereditary information
		RNA:  • Sugar = ribose • Nitrogenous bases = C, G, A, U • Usually single-stranded	Various functions during gene expression, including carrying instructions from DNA to ribosomes