Chapter 5

The Structure and Function of Large Biological Molecules

Edited by Shawn Lester

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

Neil Campbell and Jane Reece

Lectures by Chris Romero, updated by Erin Barley with contributions from Joan Sharp

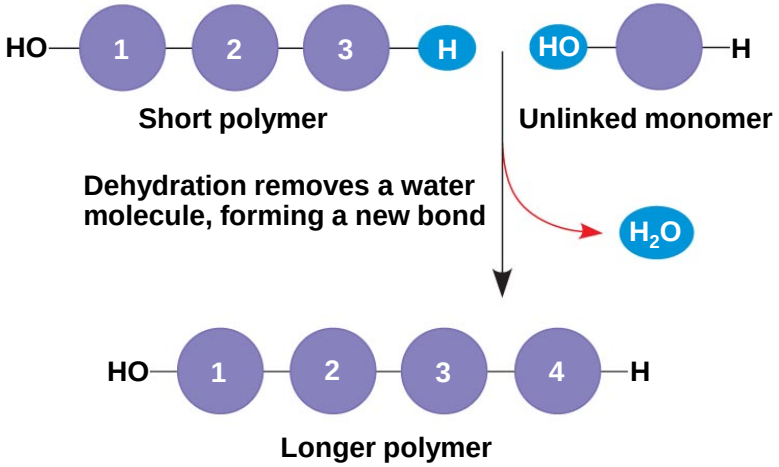
Learning objectives:

1. List and describe the four major classes of molecules
2. Describe the formation of a glycosidic linkage and distinguish between monosaccharides, disaccharides, and polysaccharides
3. Distinguish between saturated and unsaturated fats and between *cis* and *trans* fat molecules
4. explain the four levels of protein structure
5. Distinguish between the following pairs: pyrimidine and purine, nucleotide and nucleoside, ribose and deoxyribose, the 5′ end and 3′ end of a nucleotide

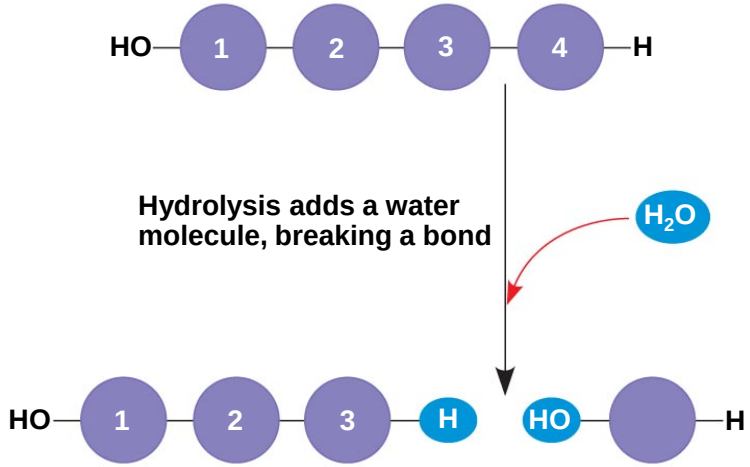
Overview: The Molecules of Life

- All living things are made up of four classes of large biological molecules: carbohydrates, lipids, proteins, and nucleic acids
- Within cells, small organic molecules are joined together to form larger molecules
- **Macromolecules** are large molecules composed of thousands of covalently connected atoms
- Molecular structure and function are inseparable

Concept 5.1: Macromolecules are polymers, built from monomers



(a) Dehydration reaction in the synthesis of a polymer



(b) Hydrolysis of a polymer

Concept 5.2: Carbohydrates serve as fuel and building material

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

Sugars

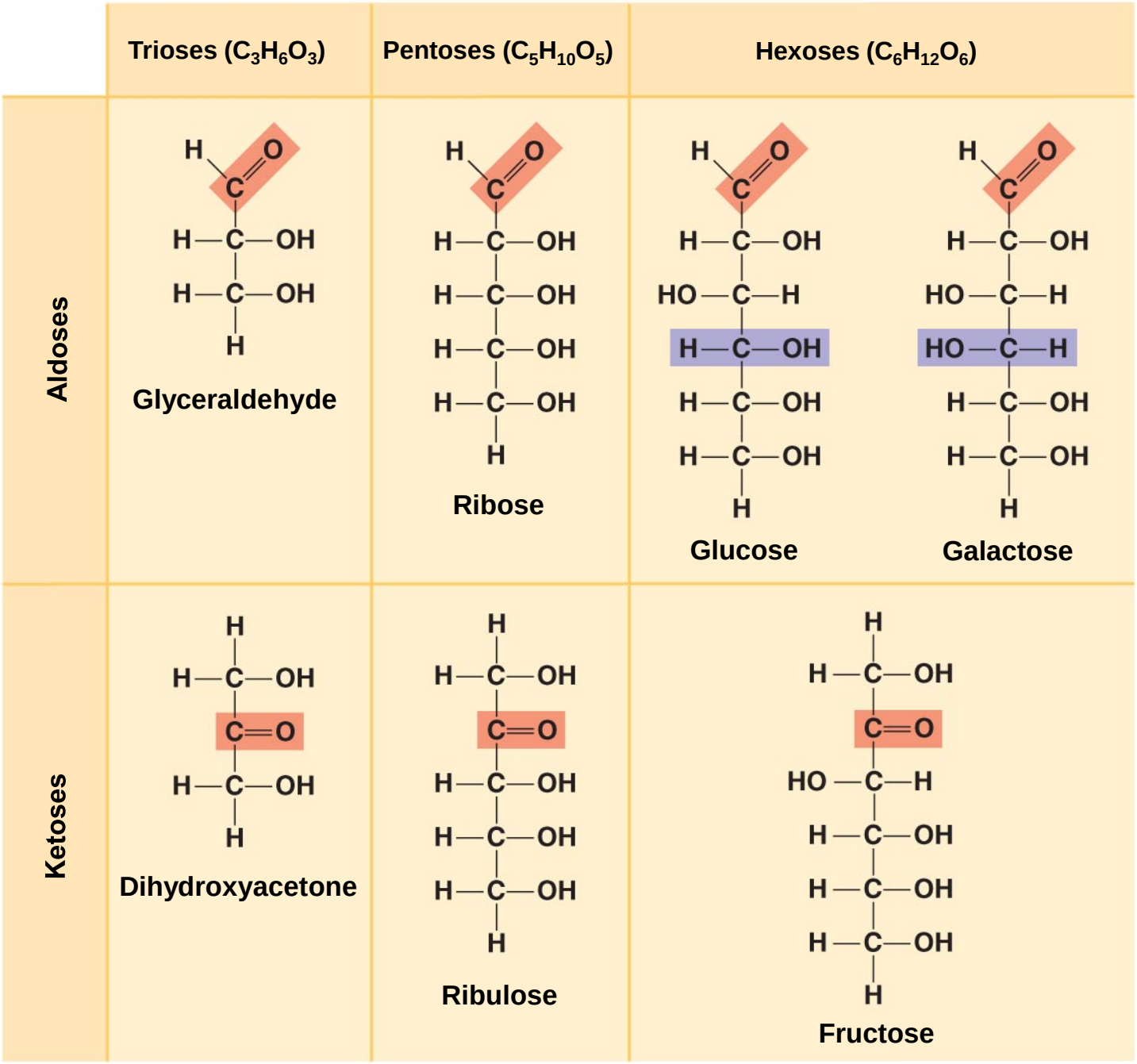
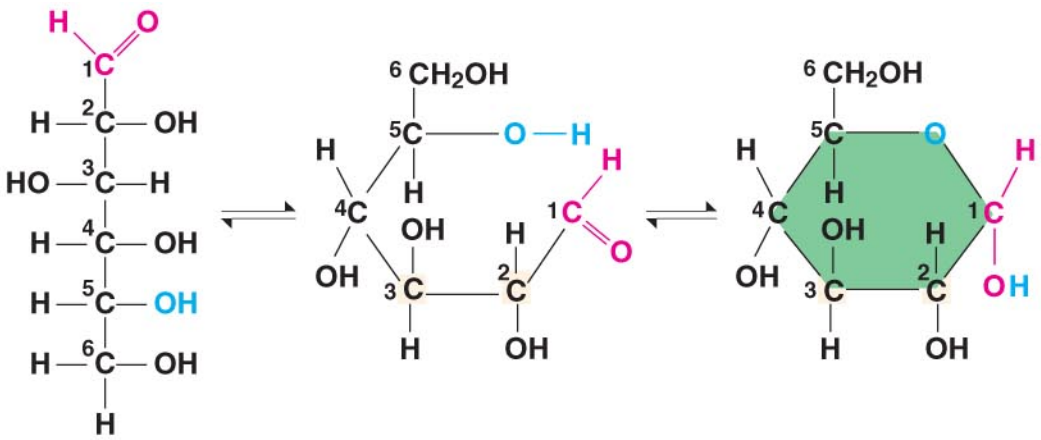
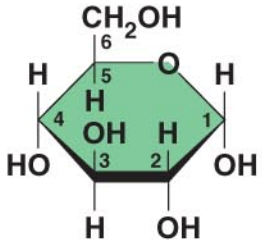


Fig. 5-3



(a) Linear and ring forms

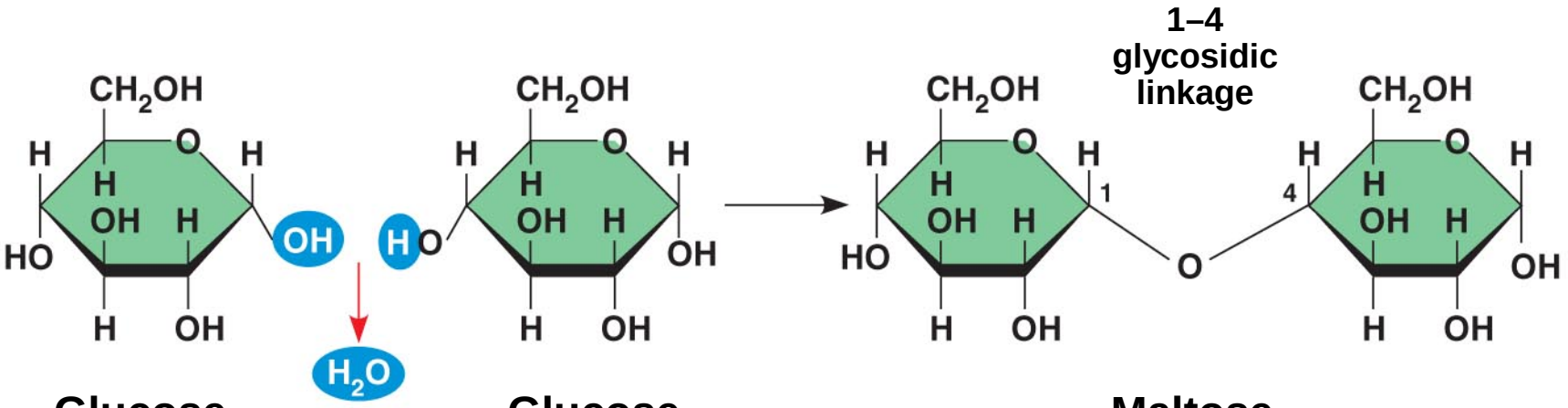
Fig. 5-4



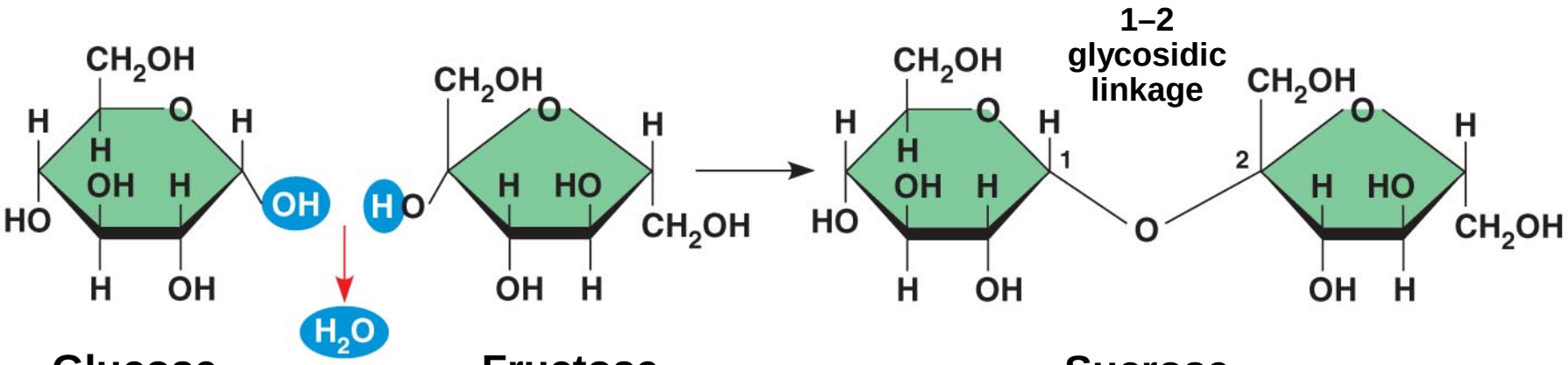
(b) Abbreviated ring structure

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

Fig. 5-5

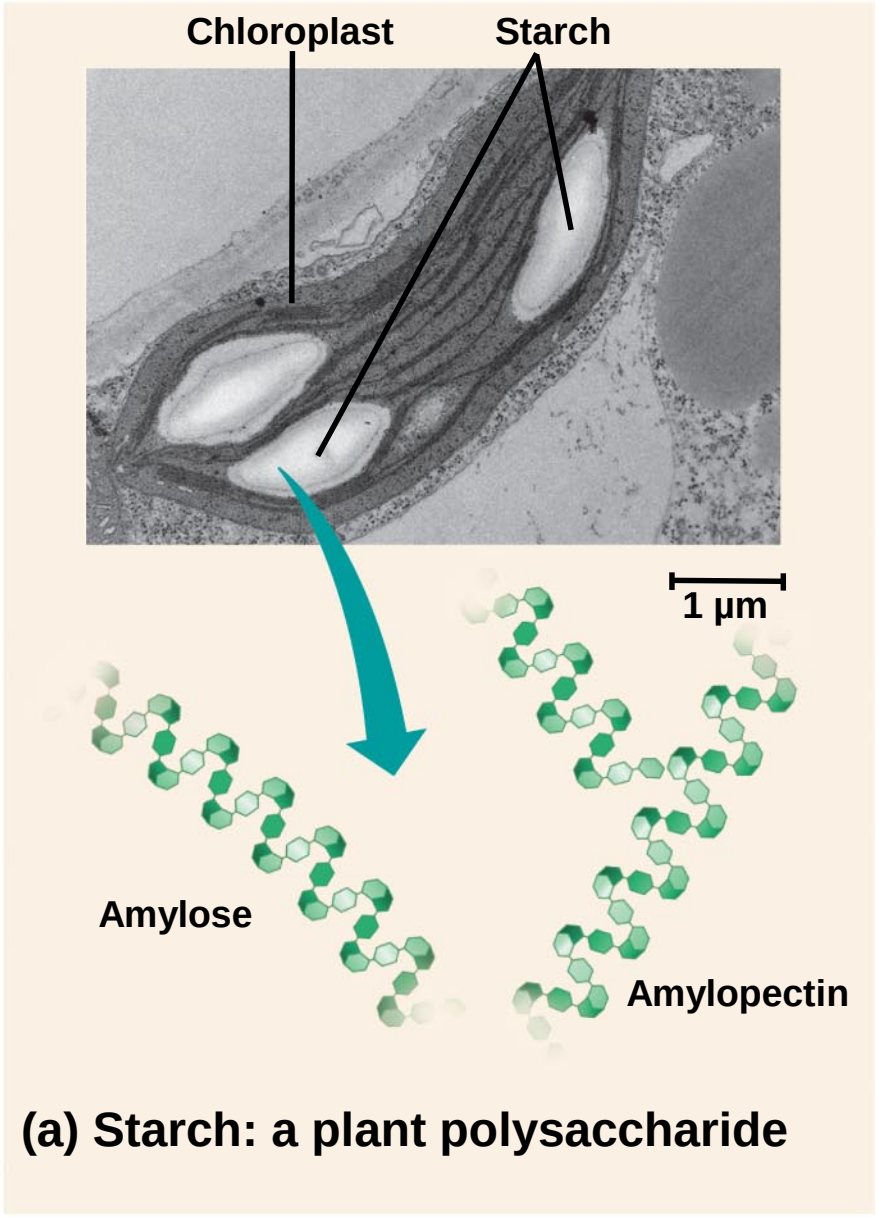


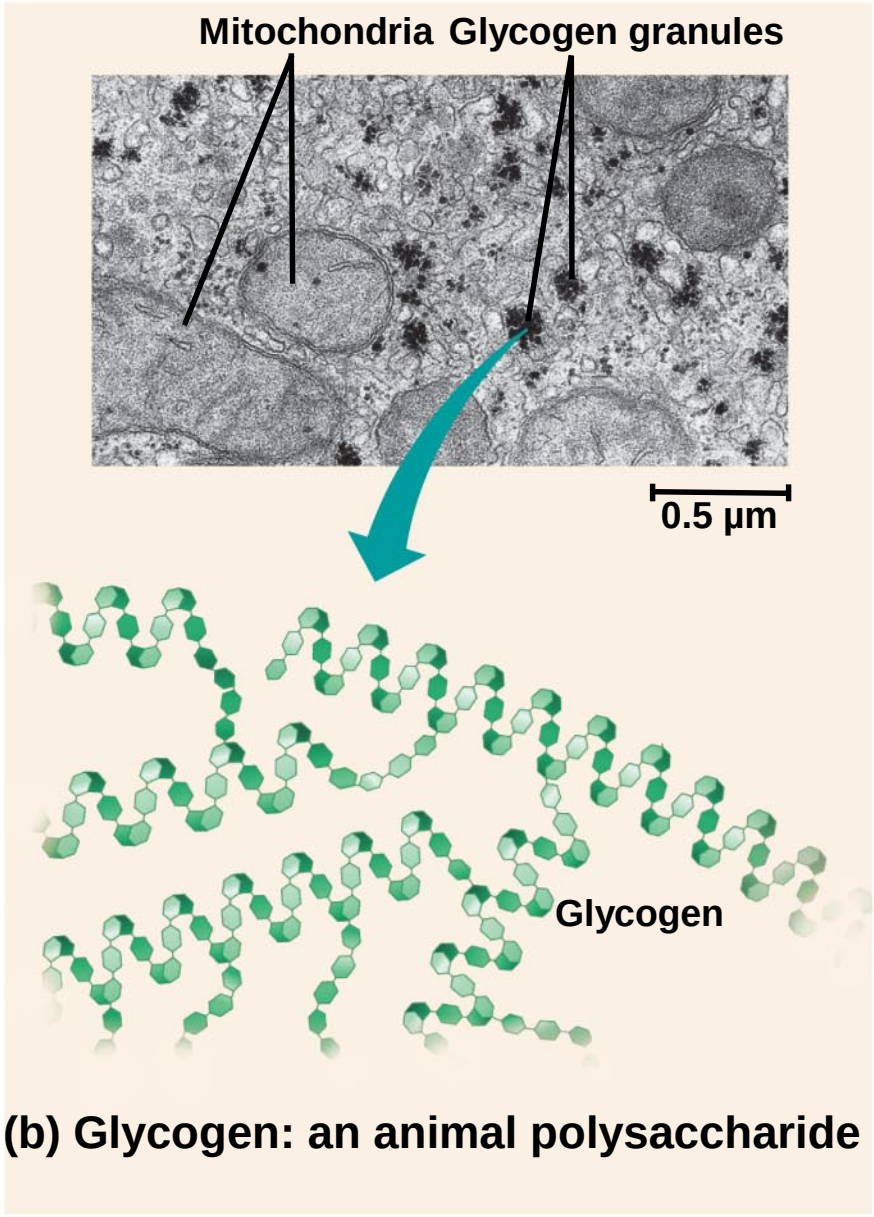
(a) Dehydration reaction in the synthesis of maltose



(b) Dehydration reaction in the synthesis of sucrose

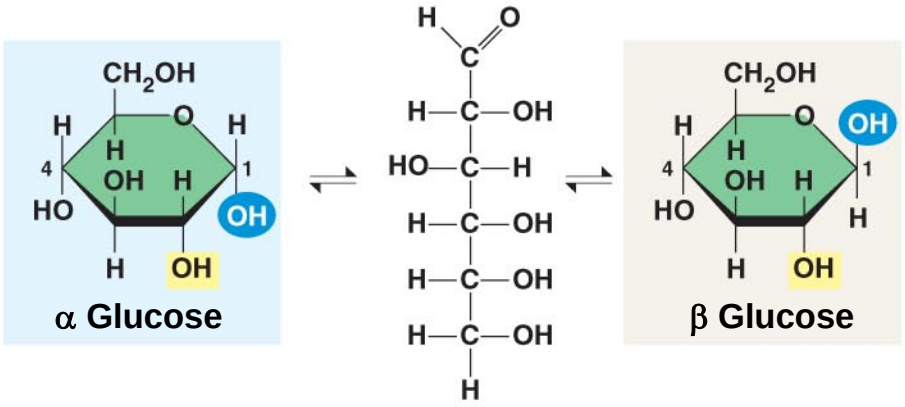
Fig. 5-6

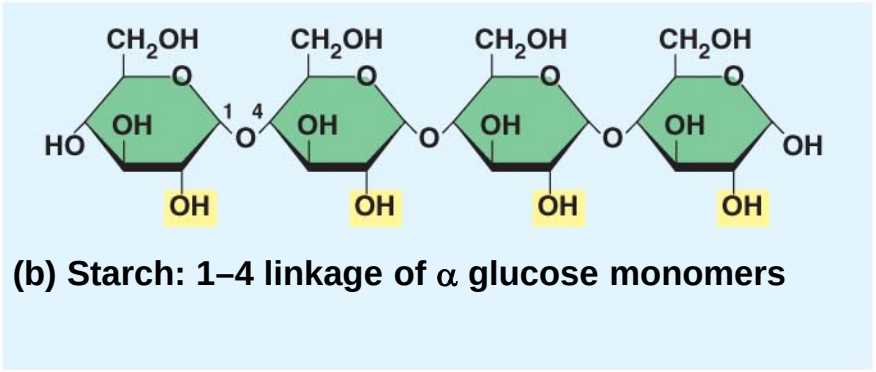




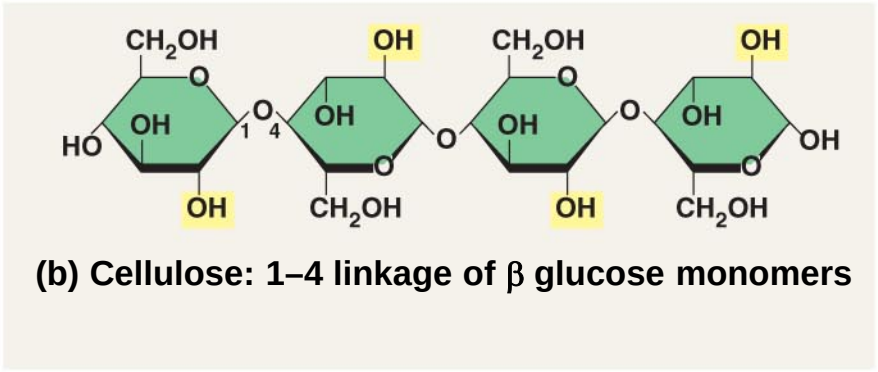
Structural Polysaccharides

(a) α and β glucose ring structures





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



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

Fig. 5-8

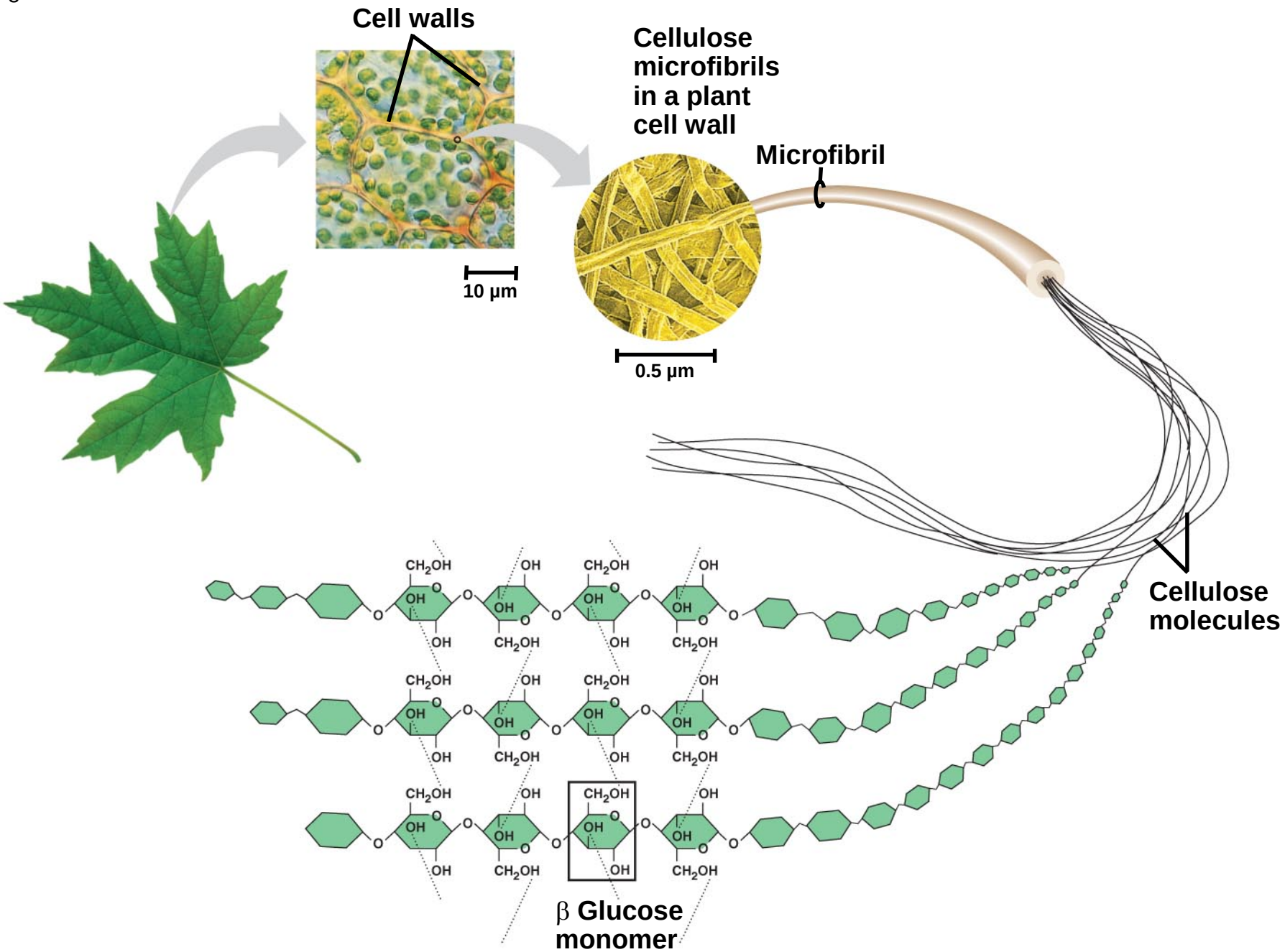
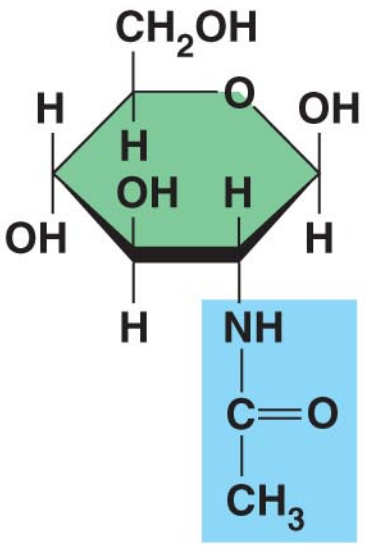
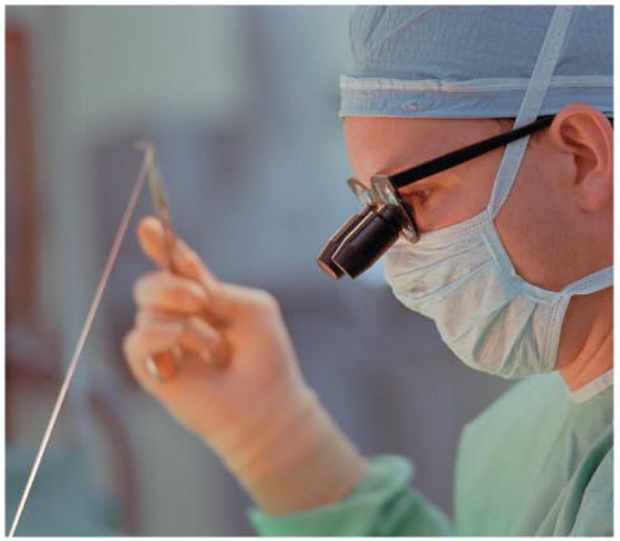


Fig. 5-10



(a) The structure of the chitin monomer.

(b) Chitin forms the exoskeleton of arthropods.

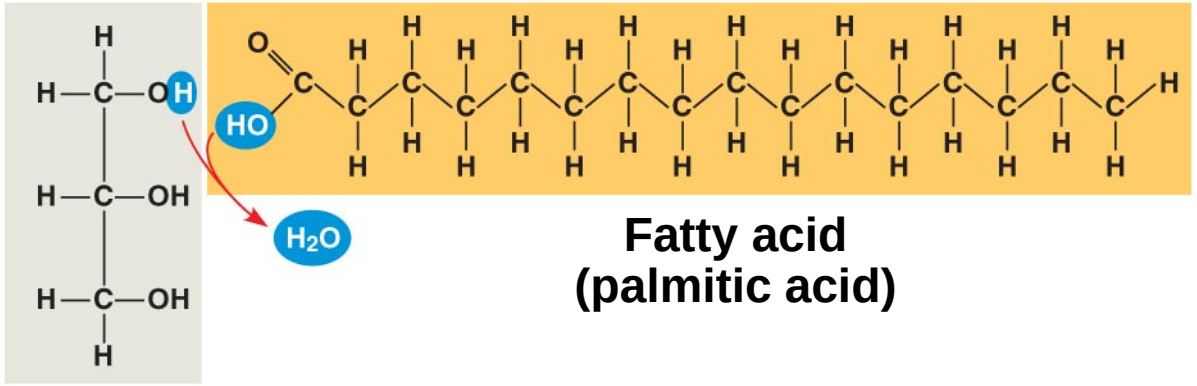


(c) Chitin is used to make a strong and flexible surgical thread.

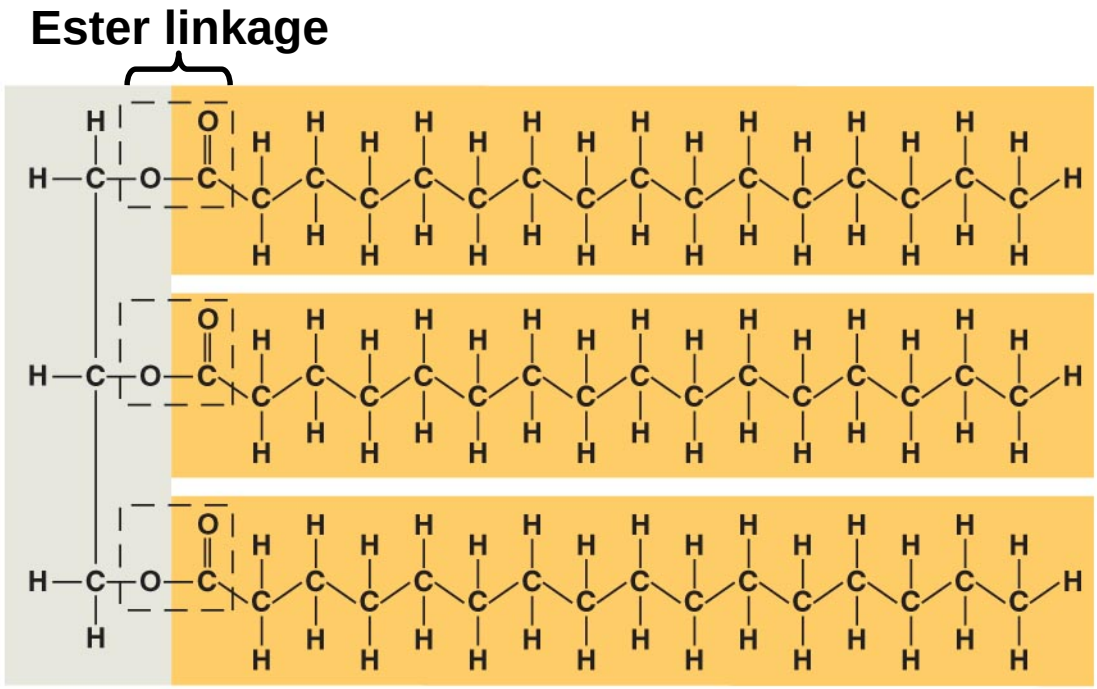
Concept 5.3: Lipids are a diverse group of hydrophobic molecules

- **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

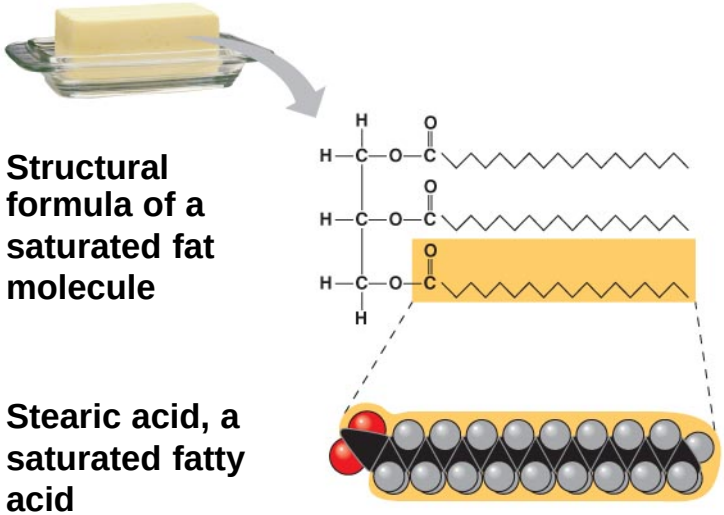


(a) Dehydration reaction in the synthesis of a fat



(b) Fat molecule (triacylglycerol)

Fig. 5-11



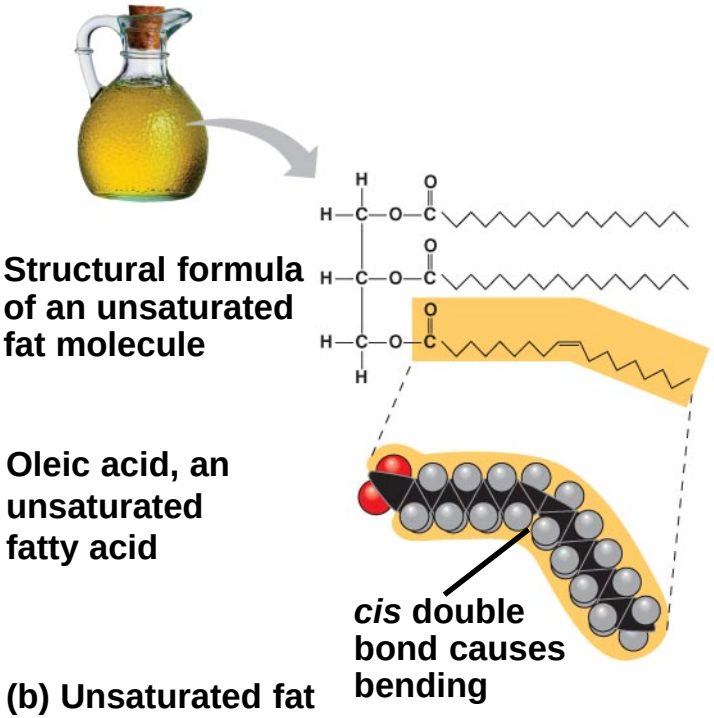


Fig. 5-12

Phospholipids

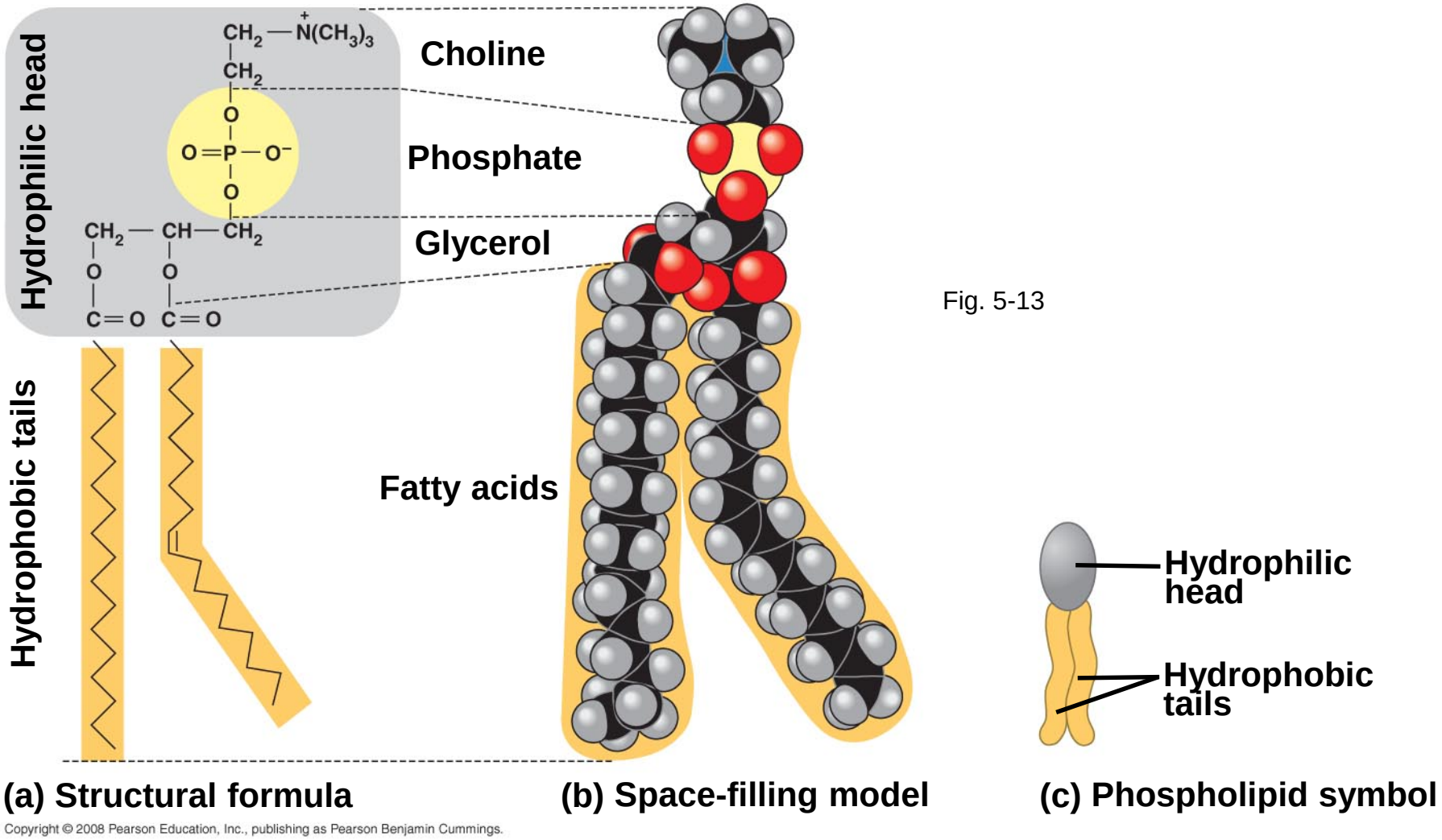
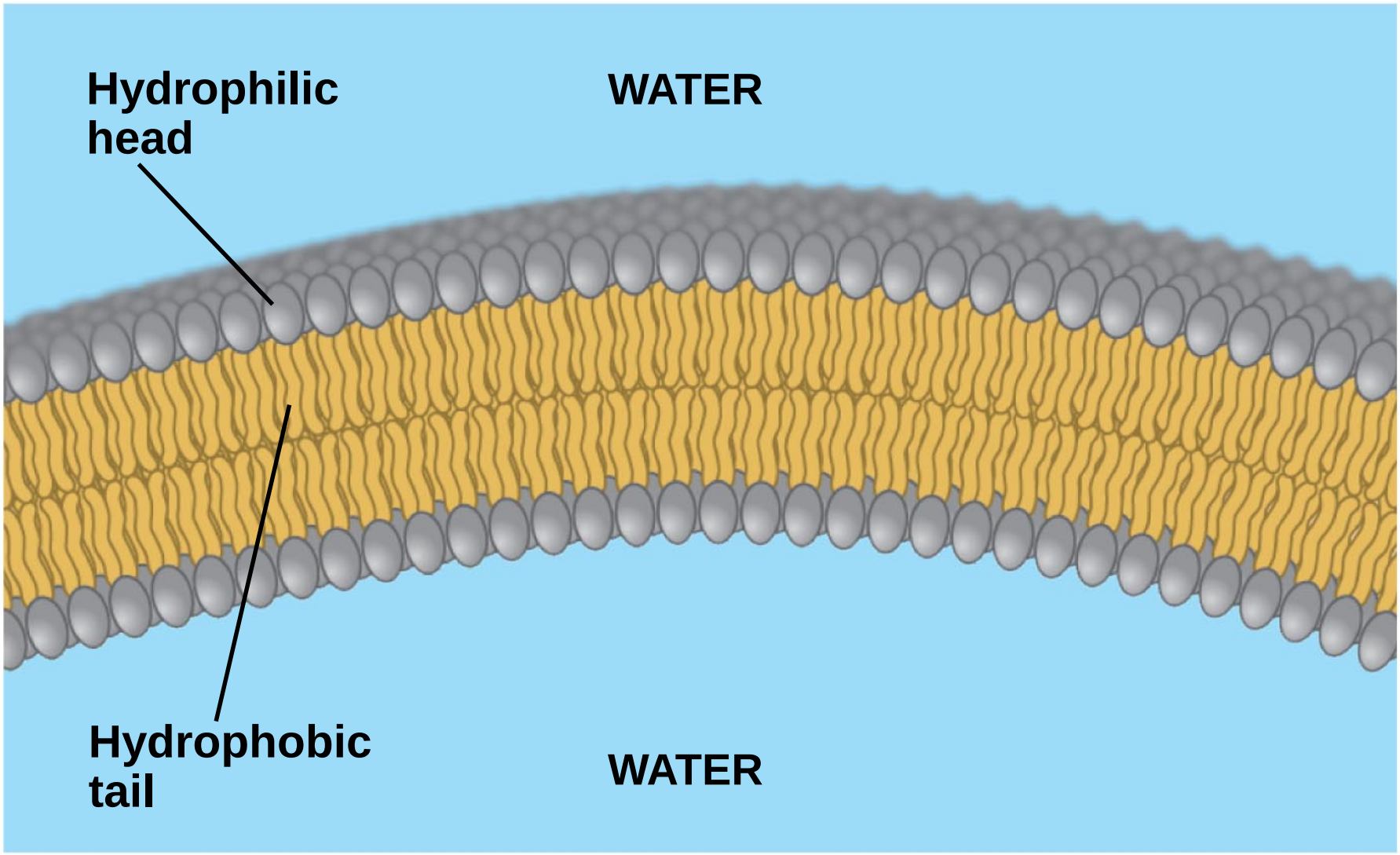
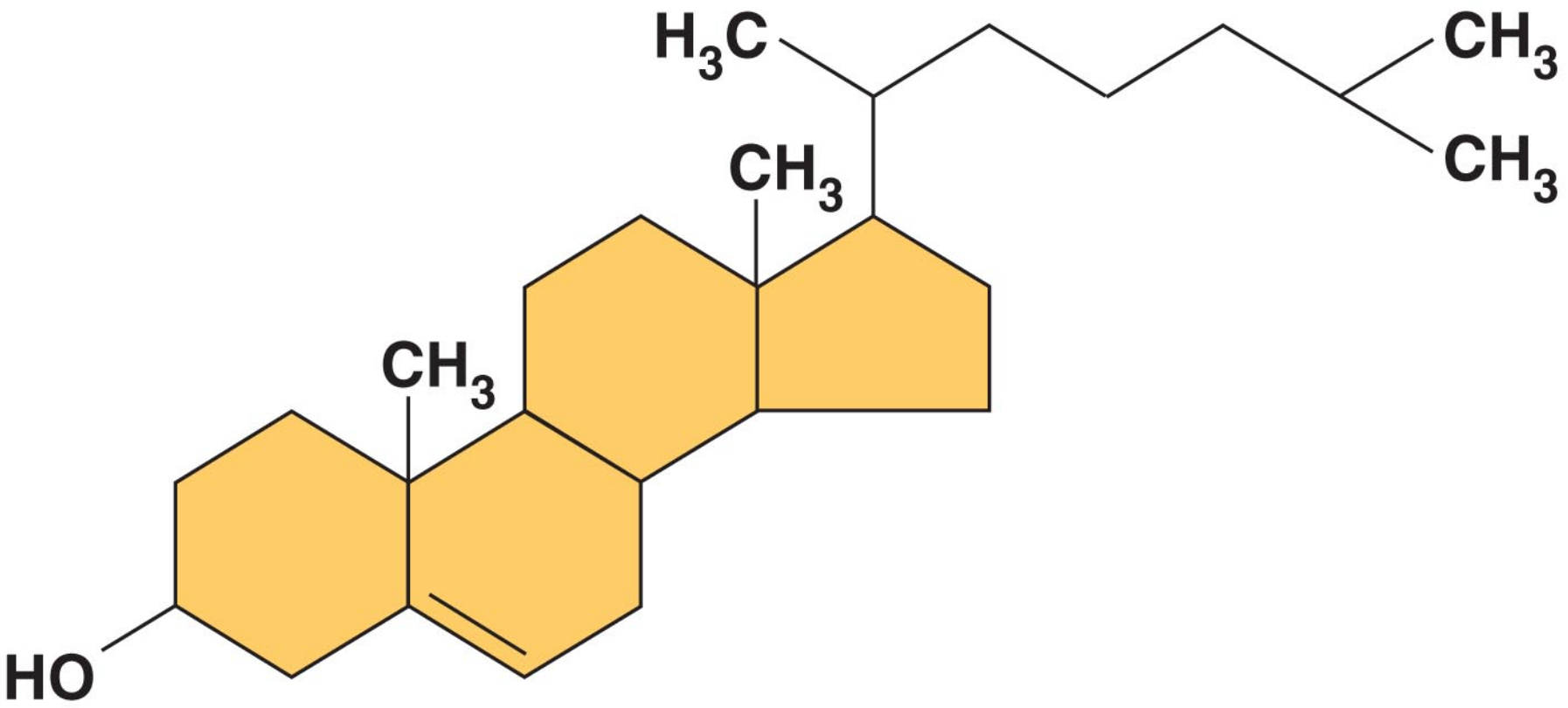


Fig. 5-13

Fig. 5-14



Steroids



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

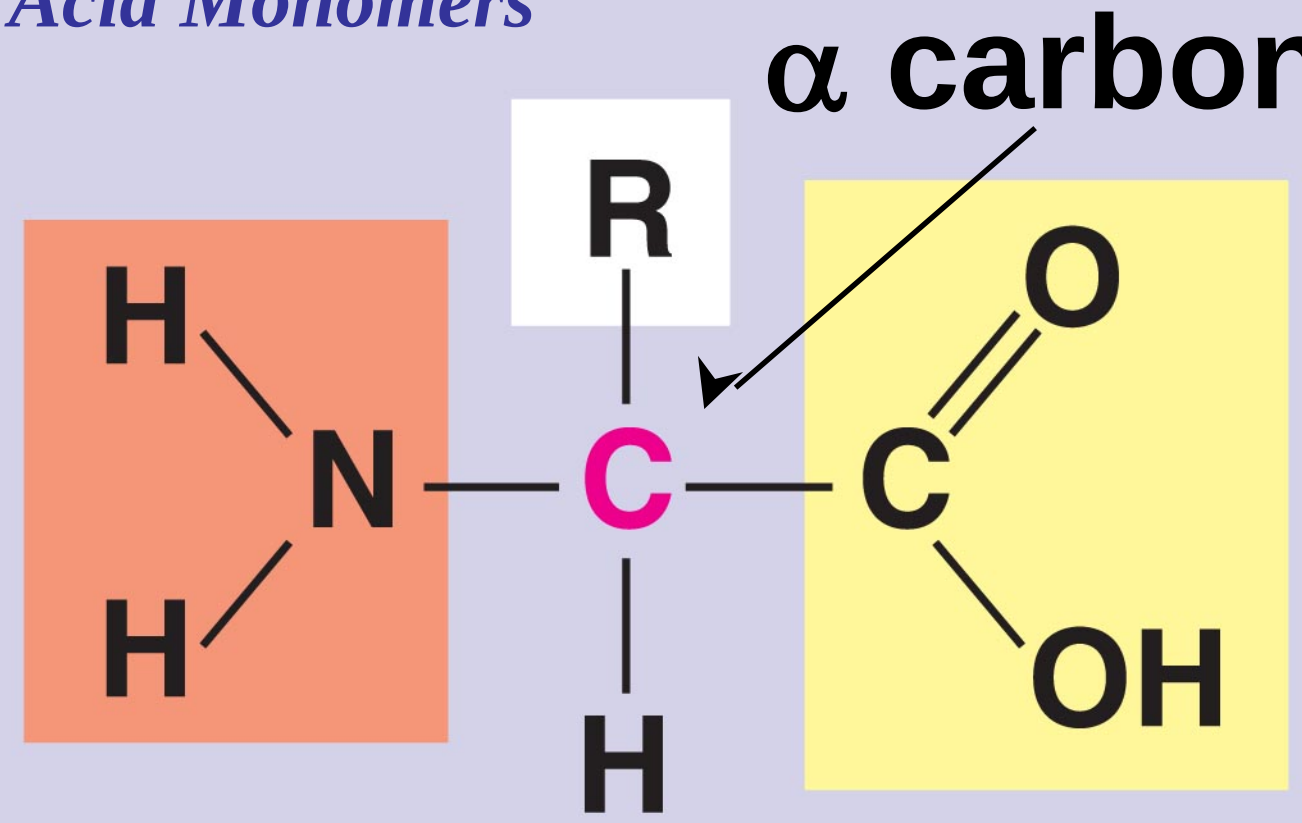
Table 5.1 An Overview of Protein Functions

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.

Polypeptides

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

Amino Acid Monomers

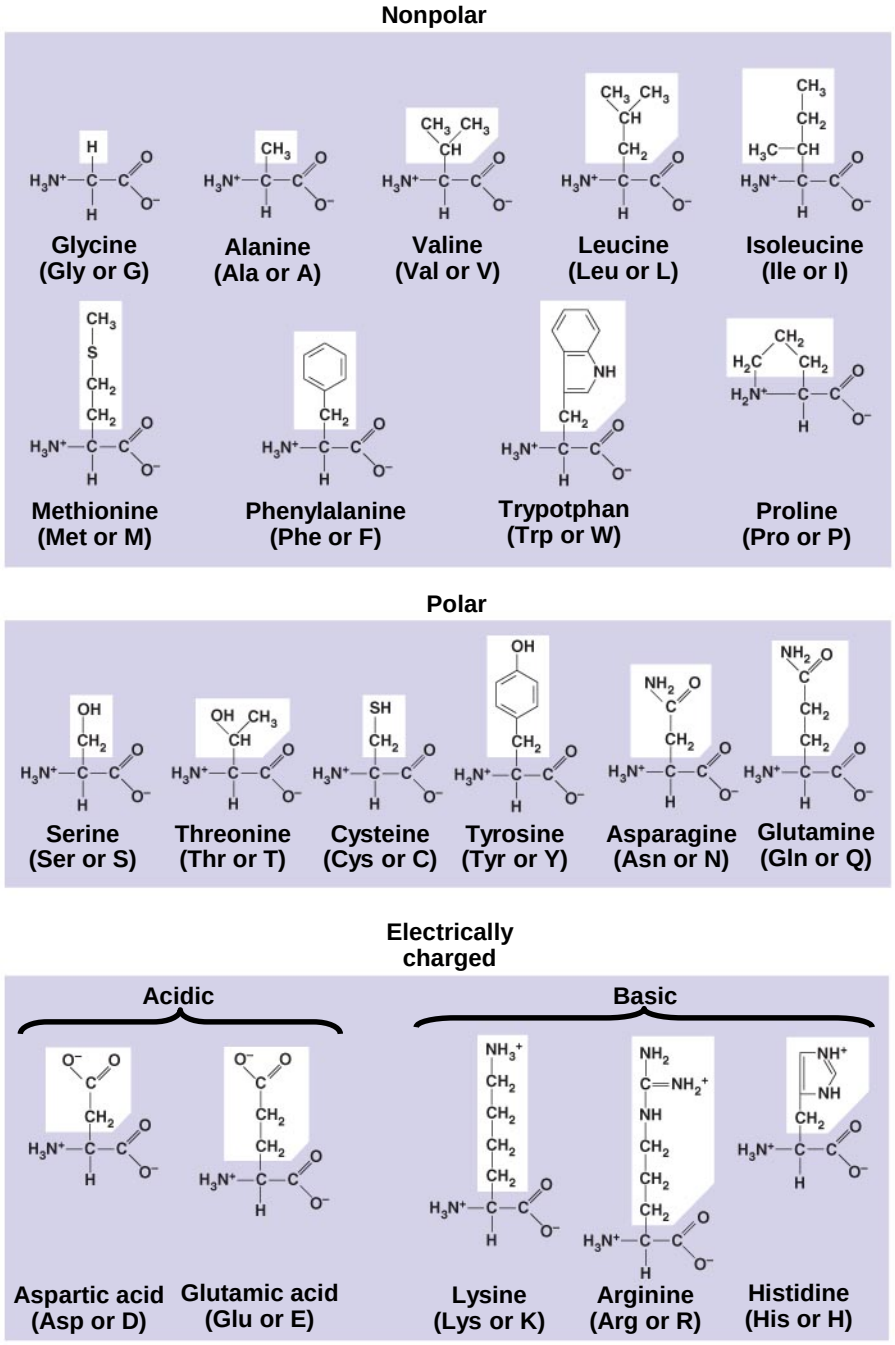


Amino group

Carboxyl group

Fig. 5-UN1

Fig. 5-17



Amino Acid Polymers

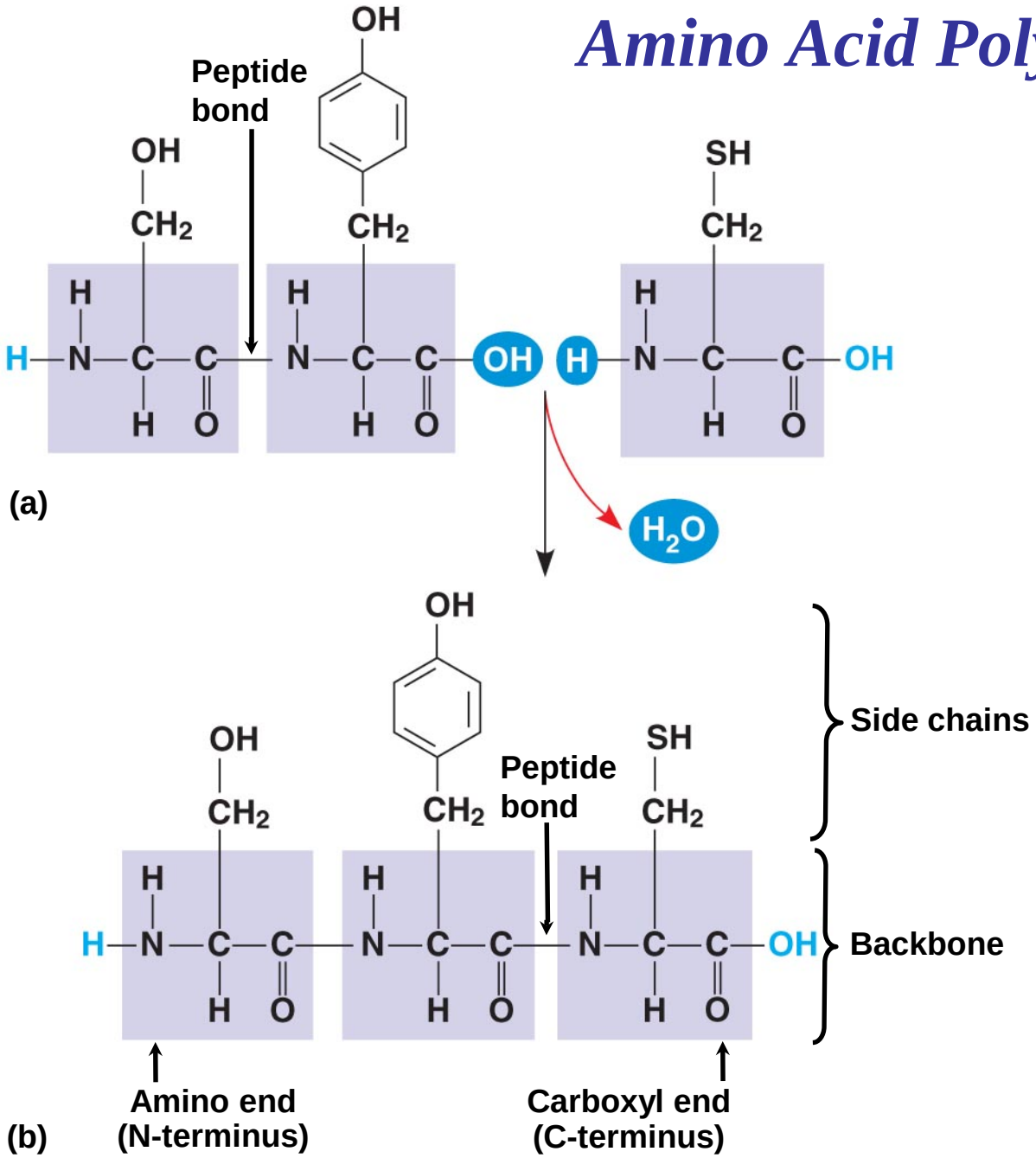
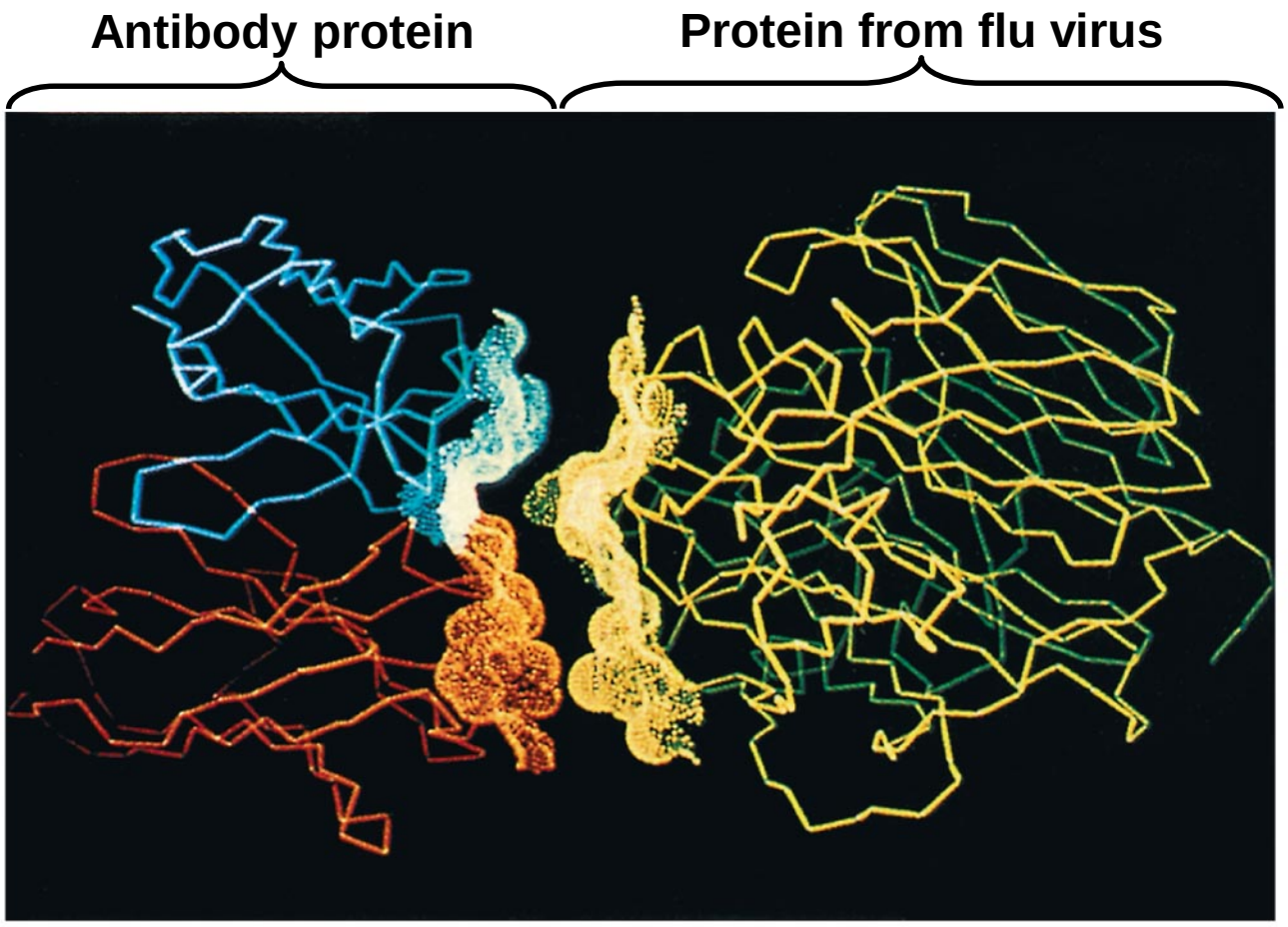


Fig. 5-18

Protein Structure and Function



Four Levels of Protein Structure

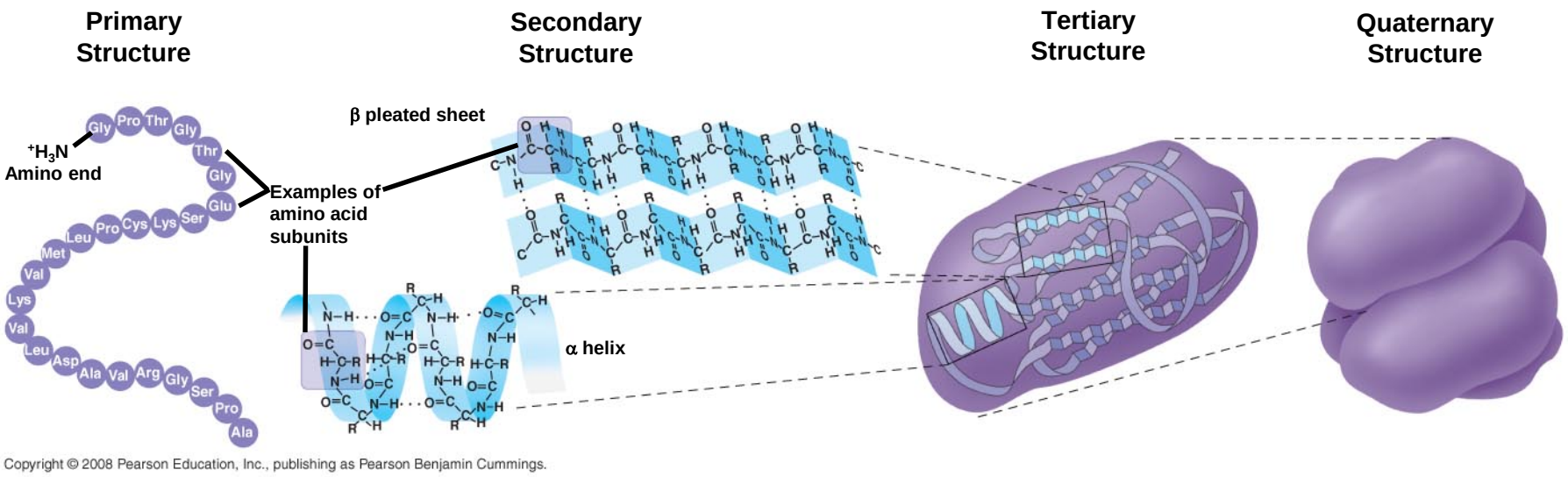
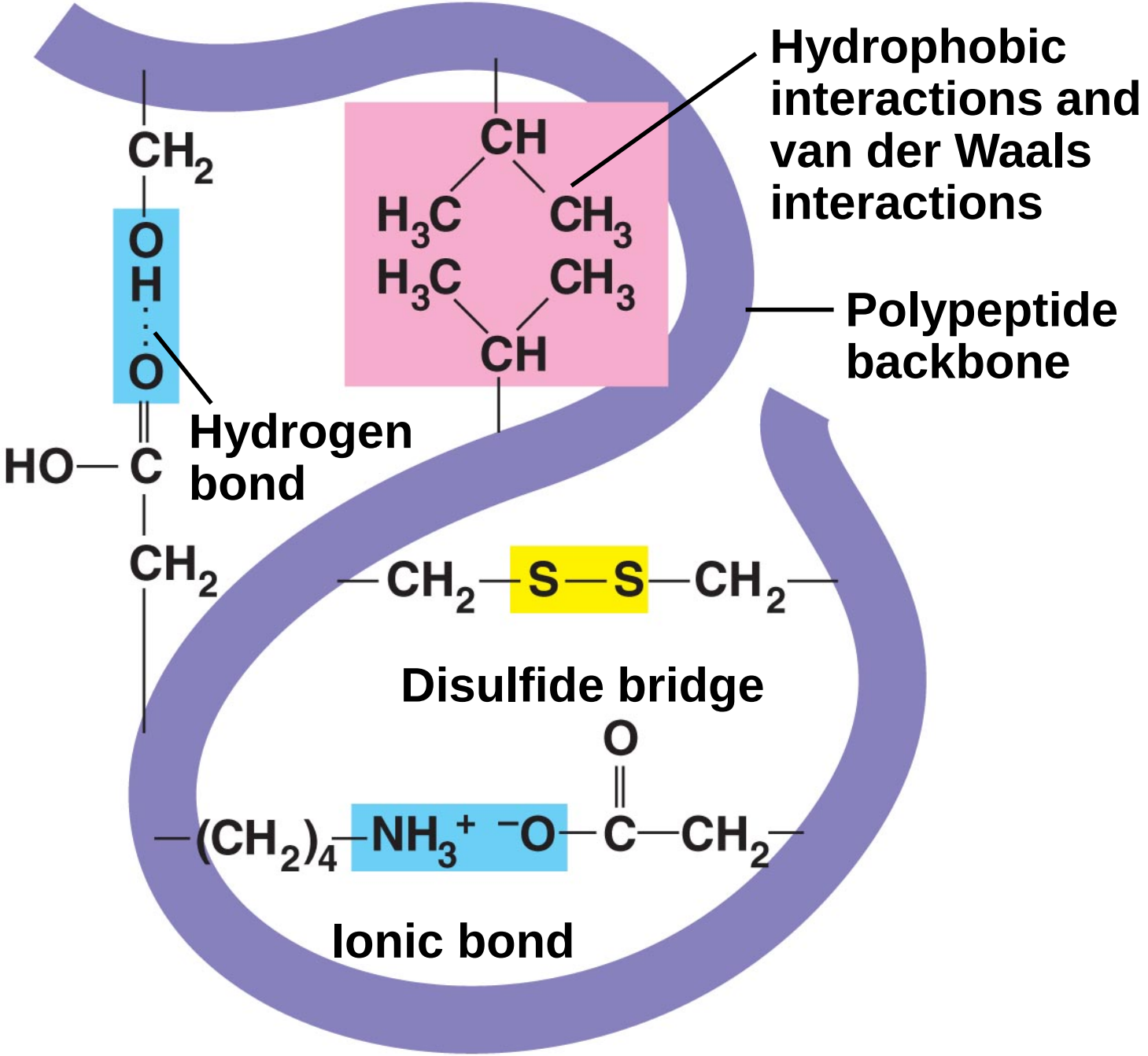


Fig. 5-21f



What Determines Protein Structure?

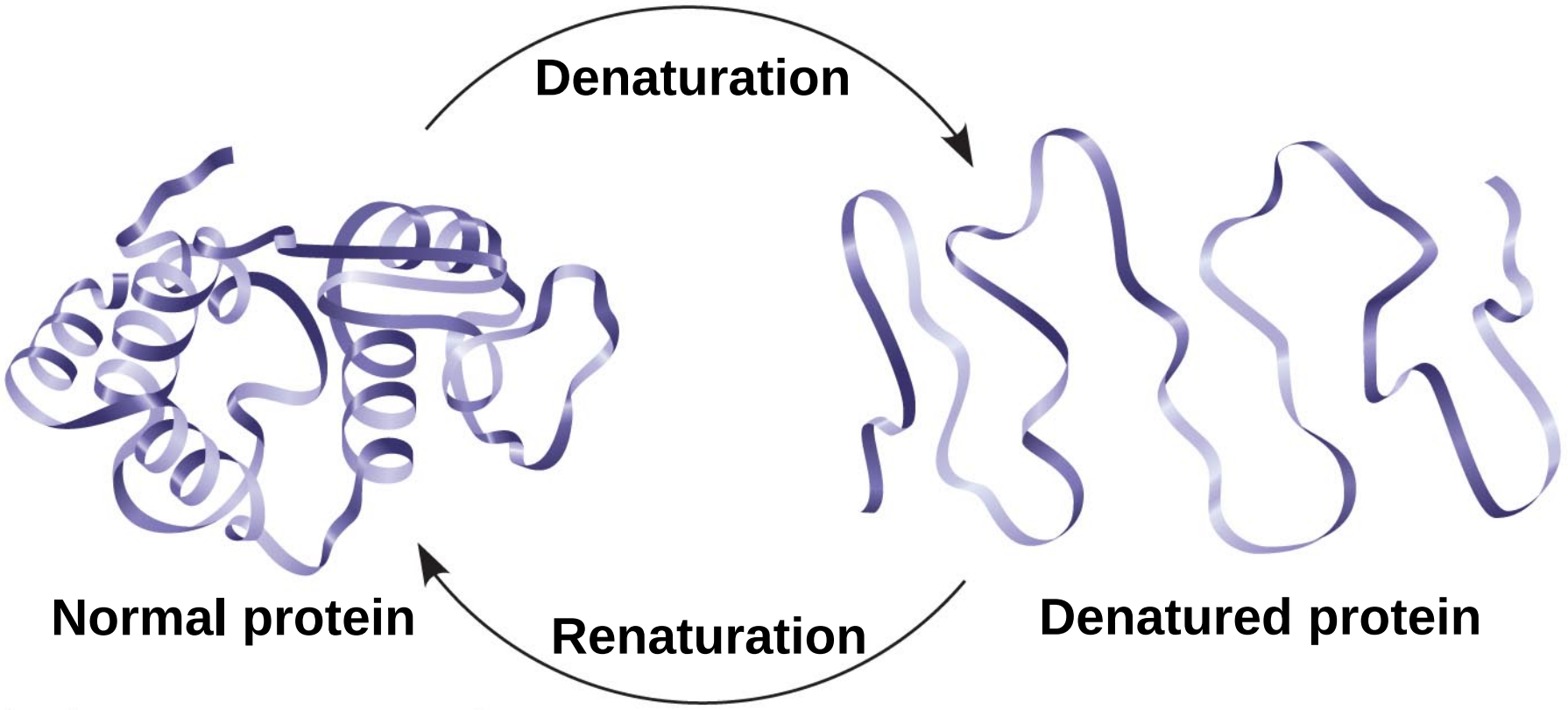


Fig. 5-23

Concept 5.5: Nucleic acids store and transmit hereditary information

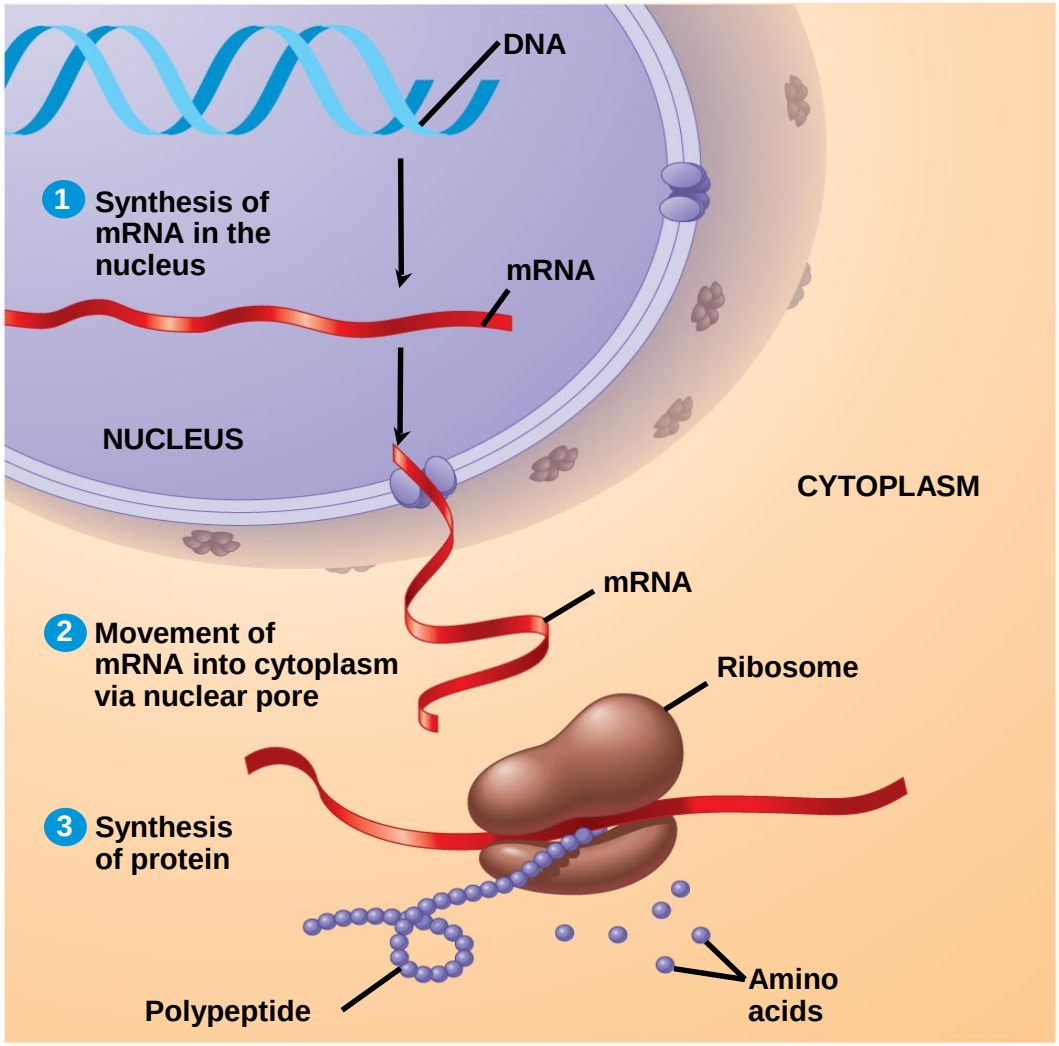


Fig. 5-26-3

The Structure of Nucleic Acids

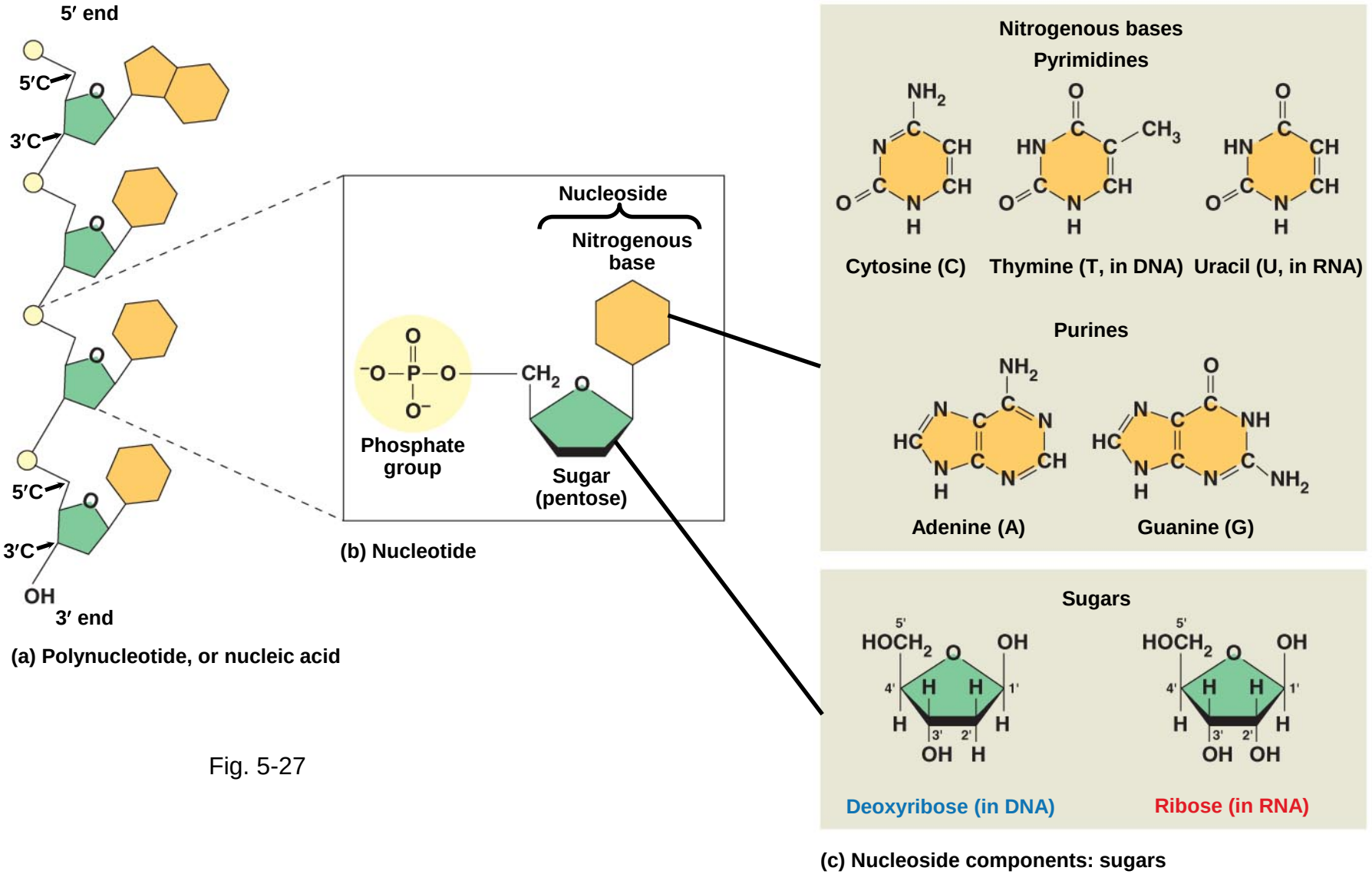


Fig. 5-27

The DNA Double Helix

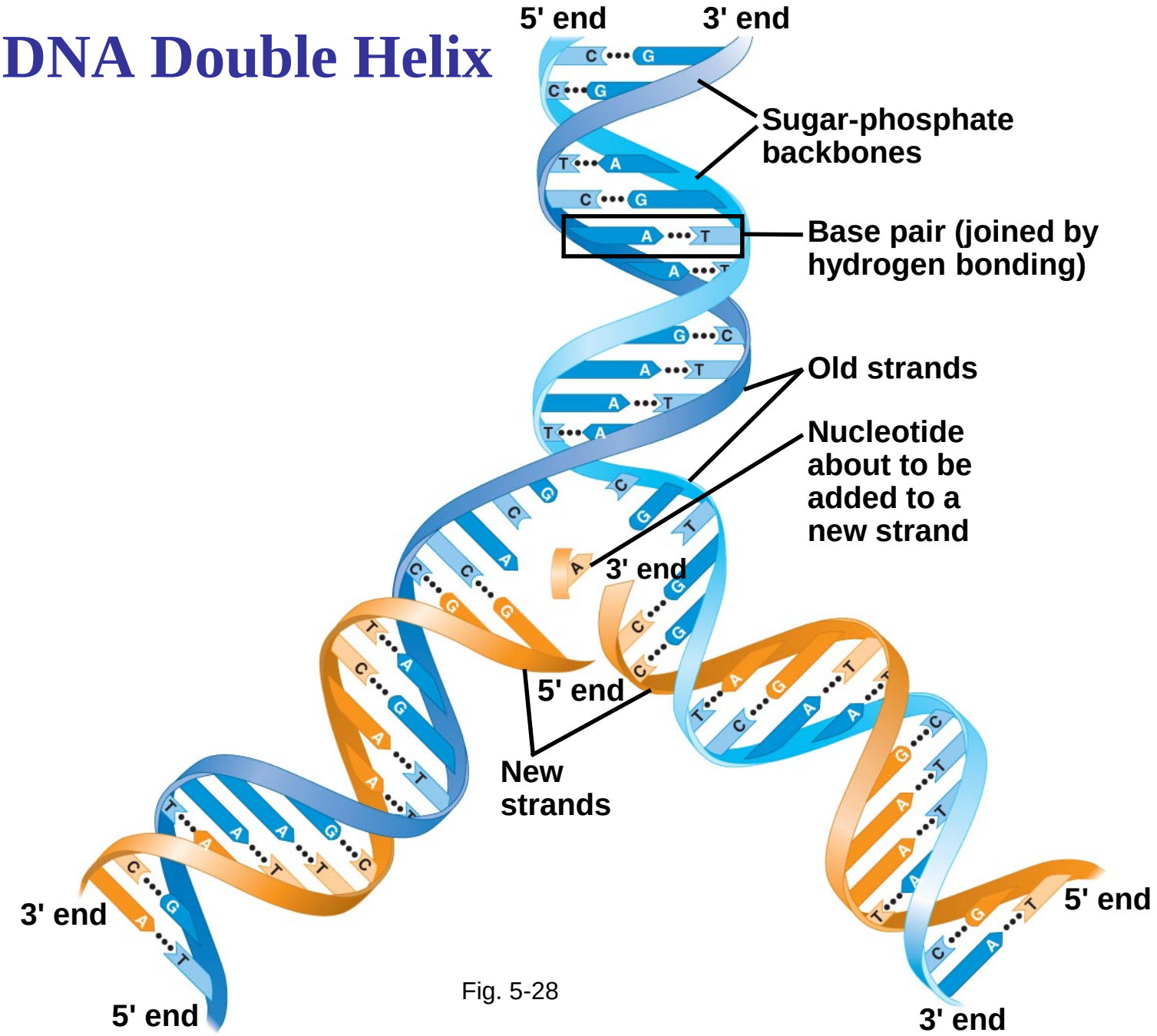


Fig. 5-28

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

In summary:

Fig. 5-UN2

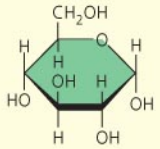
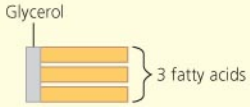
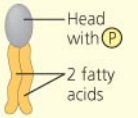
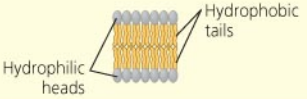
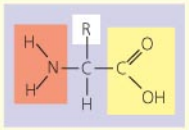
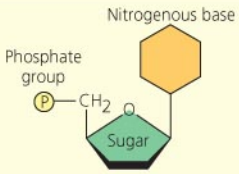
Large Biological Molecules	Components	Examples	Functions
Concept 5.2 **Carbohydrates** serve as fuel and building material	 Monosaccharide monomer	Monosaccharides: glucose, fructose	Fuel; carbon sources that can be converted to other molecules or combined into polymers
		Disaccharides: lactose, sucrose	
		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 and are not macromolecules		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) • Signals that travel through the body (hormones)
Concept 5.4 **Proteins** have many 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 and transmit hereditary information	 Nucleotide monomer	DNA: • Sugar = deoxyribose • Nitrogenous bases = C, G, A, T • Usually double-stranded	Stores all hereditary information
		RNA: • Sugar = ribose • Nitrogenous bases = C, G, A, U • Usually single-stranded	Carries protein-coding instructions from DNA to protein-synthesizing machinery

Fig. 5-UN9

	Monomers or components	Polymer or larger molecule	Type of linkage
Sugars	Monosaccharides	Polysaccharides	Glycosidic linkages
Lipids	Fatty acids	Triacylglycerols	Ester linkages
Proteins	Amino acids	Polypeptides	Peptide bonds
Nucleic acids	Nucleotides	Polynucleotides	Phosphodiester linkages

- What is a *polymer?* What is a *monomer'?*
- Monomers are connected in what type of reaction? What occurs in this reaction?
- Large molecules (polymers) are converted to monomers in what type of reaction?

Disaccharide	**Formed from Which Two Monosaccharides?**

What are the structures and levels of protein structure shown?