Chapter 5: The Structure and Function of Large Biological Molecules

5.1 Explain the processes by which polymers are assembled and disassembled.

5.2 Describe the structures and functions of simple and complex carbohydrates.

5.3 Describe the structures of three kinds of lipids and explain their functions.

5.4 List the main functions of proteins and describe the structures of amino acids and proteins.

5.5 Compare and contrast the structures of DNA and RNA and their component nucleotides, and describe the functions of these polynucleotides.

5.6 Explain how our ability to rapidly sequence DNA has affected biological inquiry and applications.

This chapter forms the heart of your study in the chemistry of biology. The macromolecules discussed here will be referenced numerous times in future chapters, so it is essential for you to master this information. As you study, consider the impact any change in the configuration of a molecule might have on its function at the cellular and organismal level.

Study Tip: Use Figure 5.1 in your text to develop an overall understanding of the role the four important classes of biological molecules play in the cell. The figure illustrates how the chapter is organized around the structure and function of macromolecules and summarizes what you will learn in this chapter. Return here when you finish this chapter, and you will appreciate how much information is conveyed in this single figure.

Concept 5.1 Macromolecules are polymers, built from monomers

LO 5.1: Explain the processes by which polymers are assembled and disassembled.

1. The most important large molecules found in all living things fall into just four main classes. Name them.

2. Circle the three classes that are called *macromolecules*. Define *macromolecule*.

3. What is a *polymer*? What is a *monomer*?

4. Using Figure 5.2a in your text as a guide, draw and label what occurs when two monomers are bonded. What is this type of reaction called?

5. Draw the reaction in which large molecules (polymers) are converted to monomers, labeling reactants, and products. What is this type of reaction called?

6. The root words of *hydrolysis* will be used many times to form other words you will learn this year. What does each root word mean?

   hydro-

   lysis-

7. Consider the following reaction:

$$C_6H_{12}O_6 + C_6H_{12}O_6 \rightarrow C_{12}H_{22}O_{11}$$

   a. The equation is not balanced; it is missing a molecule of water. Write it in on the correct side of the equation.

   b. Polymers are assembled and broken down in two types of reactions: *dehydration synthesis* and *hydrolysis.* Which kind of reaction is this?

   c. Is $C_6H_{12}O_6$ (glucose) a monomer or a polymer?

   d. To summarize, when two monomers are joined, a molecule of _____ is always removed.

Concept 5.2 Carbohydrates serve as fuel and building material

LO 5.2: Describe the structures and functions of simple and complex carbohydrates.

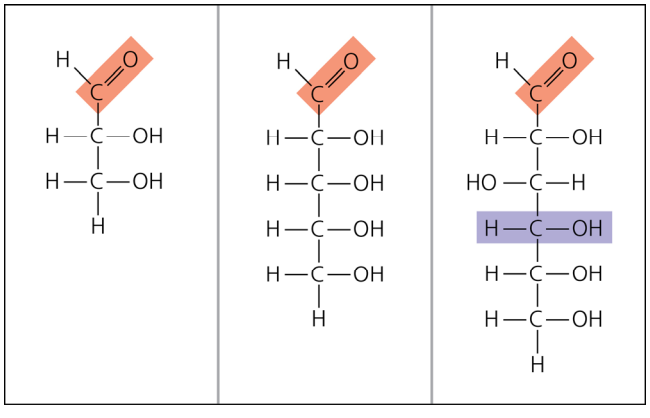
8. Let's look at carbohydrates, which include sugars and starches. First, what are the monomers of all carbohydrates?

9. Most monosaccharides are some multiple of CH_2O. For example, ribose is a five-carbon sugar with the formula $C_5H_{10}O_5$. It is a pentose sugar (from the root *penta–*, meaning five). What is the formula of a hexose sugar?

10. Here are three sugars. Label each of them. Notice that all sugars have the same two functional groups, listed below. Name each one.

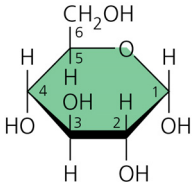
—C=O _____

—OH _____



11. Monosaccharides are classified by their number of carbons. All monosaccharides of a specific carbon number have the same chemical formula. What is the formula for all hexose sugars? _____ All triose sugars? _____

12. Here is the abbreviated ring structure of glucose. Glucose is a hexose sugar, but only one carbon is indicated on this figure. Explain where the five other carbons are found.



13. Pay attention to the numbering system. This will be important as we progress in our study. Circle the number 3 carbon and put a square around the number 5 carbon in question 12.

14. Let's look at our reaction in question 7 again: $C_6H_{12}O_6 + C_6H_{12}O_6 \rightarrow C_{12}H_{22}O_{11} + H_2O$

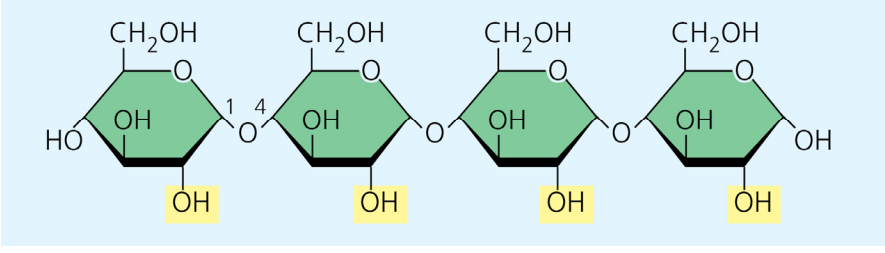
Notice that two monomers are joined to make a disaccharide polymer. Three important disaccharides have the formula $C_{12}H_{22}O_{11}$. Name them in the following chart and fill in the other boxes.

Disaccharide	Formed from Which Two Monosaccharides?	Found Where?

15. Have you noticed that all the sugars end in *–ose*? This root word means _____.

16. What is a *glycosidic linkage*?

17. Here is a partial molecule of starch, which shows 1–4 glycosidic linkages of α glucose monomers. Number the carbons in the first two sugars of this figure. Use this to explain what is meant by a 1–4 glycosidic linkage.



18. There are two categories of *polysaccharides*. Name them and give examples.

Type of Polysaccharide	Examples

19. Eat more fiber! We cannot digest fiber, which is cellulose, but can digest starch. Study Figures 5.7 (b) and (c) in your text. Notice how similar these two molecules are. Why can you not digest cellulose?

20. Name two organisms that can digest cellulose and explain how this is possible.

21. Let's review some key points about the carbohydrates. Each of the following prompts describes a unique carbohydrate. Name the correct carbohydrate for each.

    a. _____ Has 1–4 β glucose linkages

    b. _____ A storage polysaccharide produced by vertebrates that is stored in the liver

    c. _____ Two monomers of this molecule form maltose

    d. Glucose + _____ form sucrose

    e. _____ Monosaccharide commonly called "fruit sugar"

    f. _____ "Milk sugar"

    g. _____ Structural polysaccharide that gives cockroaches their crunch

    h. _____ Malt sugar; used to brew beer

    i. _____ Structural polysaccharide that comprises plant cell walls

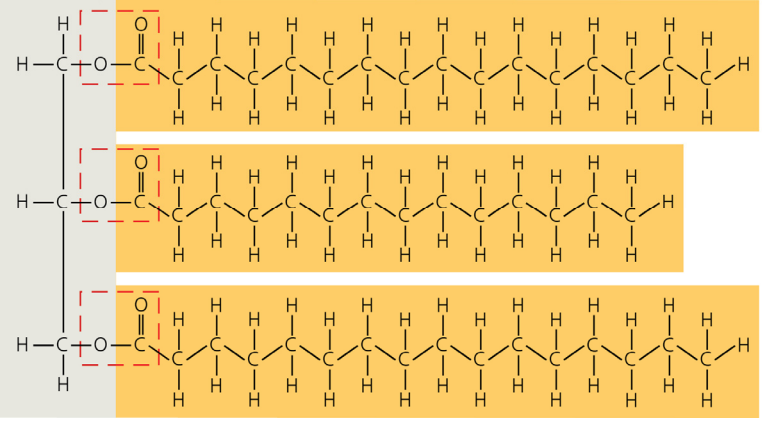
Concept 5.3 Lipids are a diverse group of hydrophobic molecules

LO 5.3: Describe the structures of three kinds of lipids and explain their functions.

Lipids are not considered true polymers because they are not comprised of repeating subunits (such as monosaccharides or amino acids.) This is why question 23 asks about "building blocks" rather than the monomers.

22. Lipids include fats, waxes, oils, phospholipids, and steroids. What characteristic do all lipids share?

23. What are the building blocks of *fats*? Label them on this figure. Also label the ester linkages.



24. If a fat is composed of three fatty acids and one glycerol molecule, how many water molecules will be removed to form it? Again, what is this process called?

25. Draw a fatty acid chain that is eight carbons long and is *unsaturated*. Circle the element in your chain that makes it unsaturated and explain what this means.

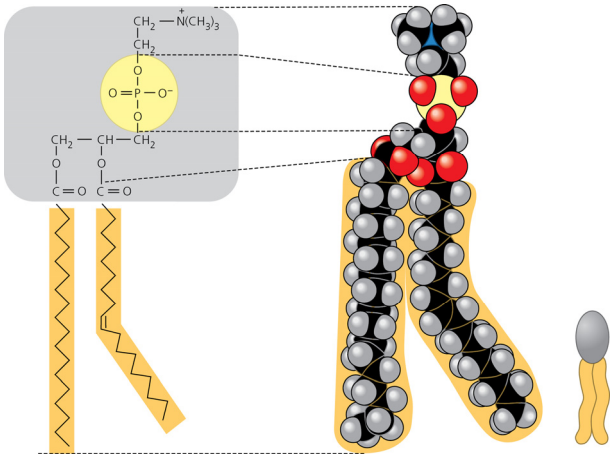
26. Identify two saturated fats and two unsaturated fats.

27. Why are many unsaturated fats liquid at room temperature?

28. What is a *trans* fat? Why should you limit them in your diet?

29. List four important functions of fats.

30. Here is a figure that shows the structure of a phospholipid. Label the sketch to show the *phosphate group*, the *glycerol*, and the *fatty acid chains*. Also indicate the region that is *hydrophobic* and the region that is *hydrophilic*.



31. Why are the "tails" hydrophobic?

32. Which of the two fatty acid chains in the figure with question 30 is unsaturated? Label it. How do you know it is unsaturated?

33. To summarize, a phospholipid has a glycerol attached to a phosphate group and two fatty acid chains. The head is hydrophilic, and the tail is hydrophobic. Now, sketch the phospholipid bilayer structure of a plasma membrane. Label the *hydrophilic heads*, *hydrophobic tails*, and *location of water*.

34. Study your sketch. Why are the tails all located in the interior?

35. Some people refer to the structure shown in a cholesterol molecule as three hexagons and a doghouse. Cholesterol and other steroids all have this general shape. Name two other steroids.

Concept 5.4 Proteins include a diversity of structures, resulting in a wide range of functions

LO 5.4: List the main functions of proteins and describe the structures of amino acids and proteins.

36. The monomers of proteins are *amino acids*. Sketch an amino acid here. Label the α or *central carbon*, *amino group*, *carboxyl group*, and *R group*.

37. What is represented by *R*? How many different R groups are there?

38. Figure 5.13 in your text is an important one! It shows many different functions of proteins. Summarize each type of protein here.

Type of Protein	Function	Example

39. Study Figure 5.14 in your text. See if you can understand why some R groups are nonpolar, some polar, and others electrically charged (acidic or basic). If you were given an R group, could you place it in the correct group? Work on the R groups until you can see common elements in each category and then summarize what is common to the category.

Category	Common Elements
Nonpolar	
Polar	
Electrically charged	

40. Define these terms:

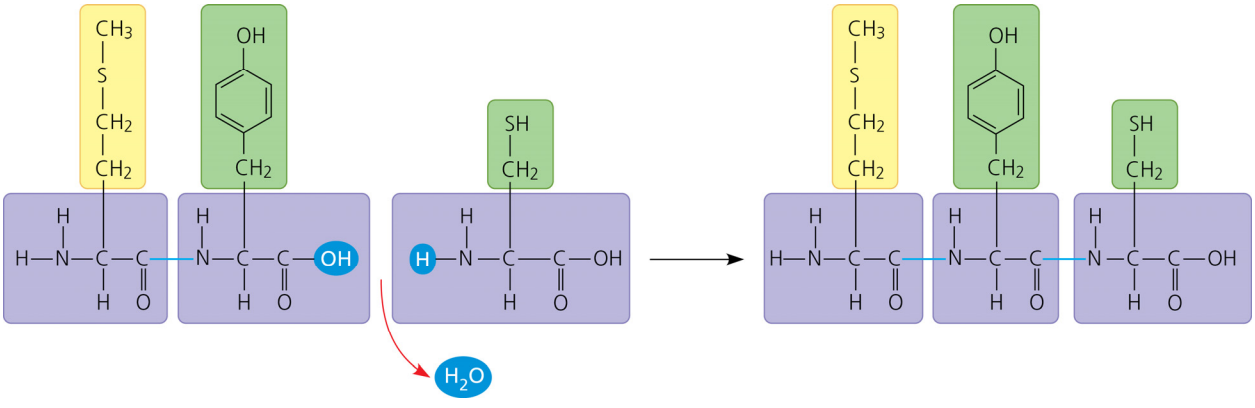
peptide bond

dipeptide

polypeptide

dehydration synthesis

Label each of these terms on the diagram below. Also label an R group, a central carbon, an amino group and the carbon backbone.

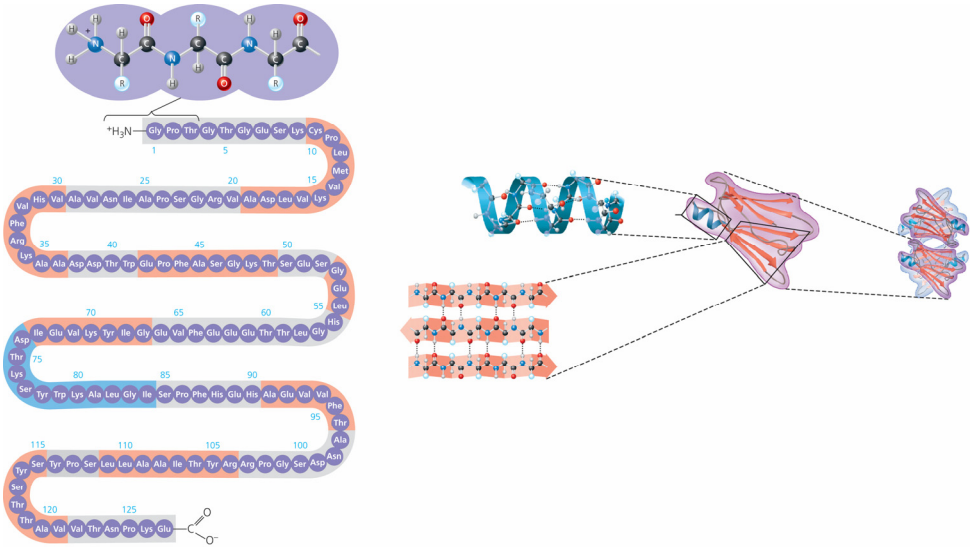


41. Figures 5.16 and 5.17 in your text show you how proteins will be represented throughout the text. Become familiar with the different forms the artists use to convey information to the reader. This information will improve your reading comprehension where proteins are involved. Which types of diagrams were used to represent rhodopsin?

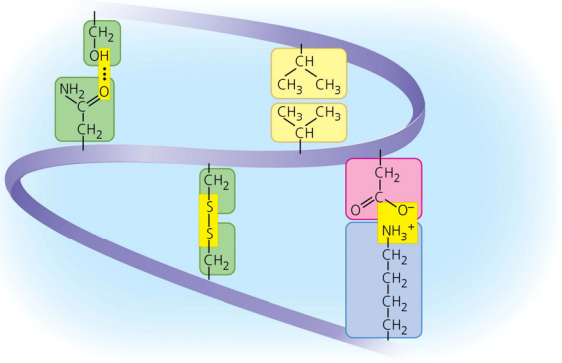
42. There are four levels of protein structure. Refer to Figure 5.18 in your text and summarize each level in the following table.

Level of Protein Structure	Explanation	Example
Primary		
Secondary α *helix* β *pleated sheet*		
Tertiary		
Quaternary		

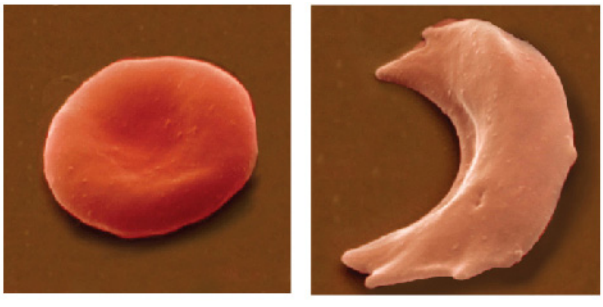
43. Label each of the levels of protein structure on this figure.



44. Enzymes are globular proteins that exhibit at least tertiary structure. Use this figure to identify and explain each interaction that folds this protein fragment.



45. Do you remember when, in Chapter 4, we said, "To change the structure will change the function"? Explain how this principle applies to sickle-cell disease. What causes the change in shape of the red blood cells shown below?



46. Besides mutation, which changes the primary structure of a protein, protein structure can be changed by denaturation. Define *denaturation* and give at least three ways a protein may become denatured.

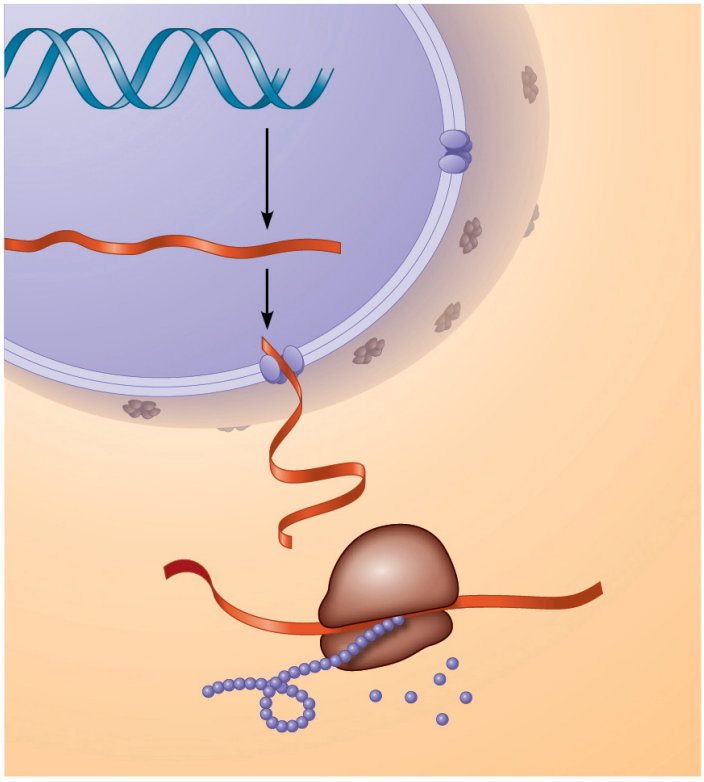
47. Misfolded proteins in a cell are a serious problem. What are four diseases that are associated with the accumulation of misfolded proteins?

Concept 5.5 Nucleic acids store, transmit, and help express hereditary information

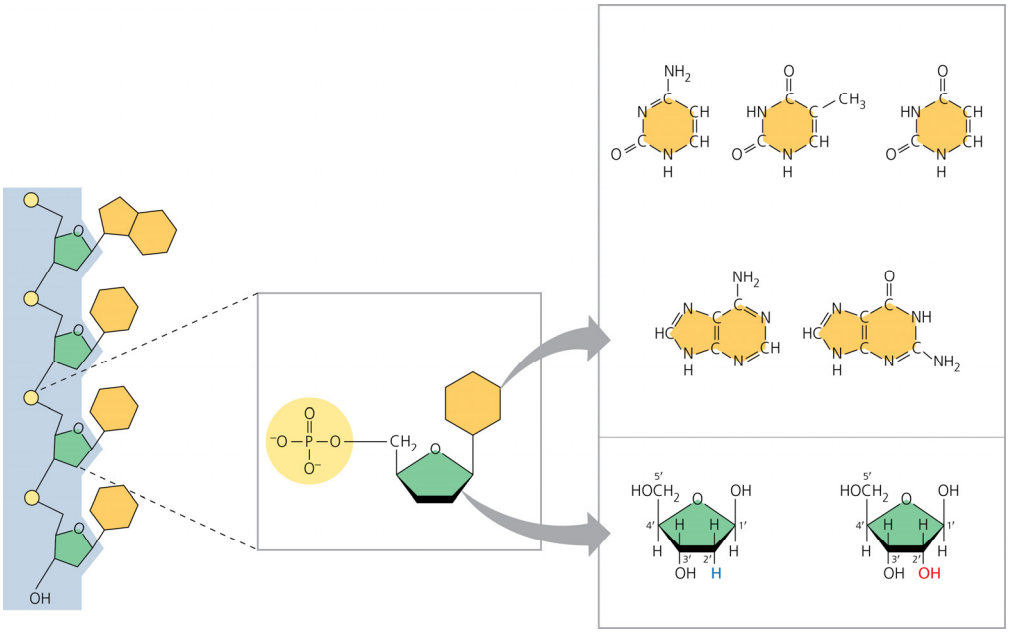
LO 5.5: Compare and contrast the structures of DNA and RNA and their component nucleotides, and describe the functions of these polynucleotides.

The nucleic acids DNA and RNA are the core topics of Chapter 17. For now, you should just review the general functions and know the components.

48. The flow of genetic information is from DNA → RNA → protein. Use this figure to explain the three major steps of the process. Label the *nucleus*, *DNA*, *mRNA*, *ribosome*, and *amino acids*.



49. The monomers that link to produce a nucleic acid are called *nucleotides.* The components of a nucleotide are a *sugar*, a *nitrogenous base*, and a *phosphate group*. Label each on the following figure. Then, label each nitrogenous base, and indicate which are *purines* and which are *pyrimidines*. Finally, label *deoxyribose* and *ribose*.



50. You may recall that early in this chapter we looked at the numbering system for the carbons of a sugar. Label the end of the strand on the left side of the figure above that has the number 5 sugar **5′** and the other end of the chain **3′**. Finally, label one nucleotide.

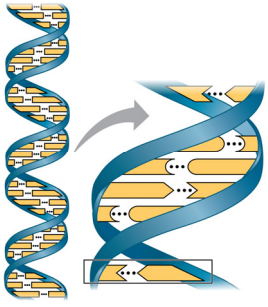
51. Notice that there are five nitrogen bases. Which four are found in DNA?

52. Which four nitrogenous bases are found in RNA?

53. How do ribose and deoxyribose sugars differ?

54. To summarize, what are the three components of a nucleotide?

55. Below is a model of DNA, which was proposed by James Watson and Francis Crick What is this shape called?



56. Why are the strands said to be *antiparallel*?

57. What two molecules make up the "uprights"?

58. What molecules make up the "rungs"?

59. In a DNA double helix, a region along one DNA strand has the sequence of nucleotides shown below. Underneath it, show the sequence of nucleotides that would be found on the complementary strand. Indicate the 5′ and 3′ ends of the new strand.

5′ T **A G G C C T-3**

Concept 5.6 Genomics and proteomics have transformed biological inquiry and applications

LO 5.6: Explain how our ability to rapidly sequence DNA has affected biological inquiry and applications.

60. Our current understanding of many areas of biology has been transformed by *genomics* and *proteomics*. Turn to *Make Connections* Figure 5.26 in your text to see examples of how these areas of study are being applied. You will see each of these discoveries in future chapters. Describe each and give an example of its application.

	Description	Application example
Genomics		
Proteomics		

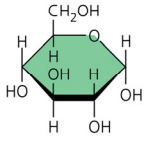
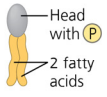
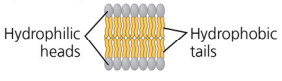
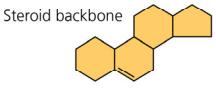
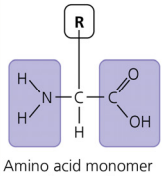
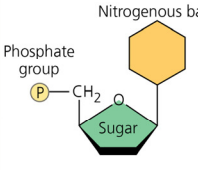
61. How can DNA and protein sequences serve as tape measures of evolution? (The *Scientific Skills Exercise* on p. 89 of your text illustrates this.)

Test Your Understanding, p. 91.

Now you should be ready to test your knowledge. Place your answers here:

1. _____ 2. _____ 3. _____ 4. _____ 5. _____ 6. _____ 7. _____

This summary table is a valuable review tool for this entire chapter. Can you cover parts of the chart and fill in the blocks from memory? This would be an excellent study technique to help you organize and learn the important information in this chapter.

Large Biological Molecules	Components	Examples	Functions
CONCEPT 5.2 **Carbohydrates serve as fuel and building material** *(pp. 68–72)* ? *Compare starch and cellulose. What role does each play in the human body?*	 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)	• Cellulose strengthens plant cell walls • Starch stores glucose for energy in plants • Glycogen stores glucose for energy in animals • Chitin strengthens animal exoskeletons and fungal cell walls
CONCEPT 5.3 **Lipids are a diverse group of hydrophobic molecules** *(pp. 72–75)* ? *Why are lipids not considered to be polymers or macromolecules?*		**Triacylglycerols** (fats or oils): glycerol + three fatty acids	Important energy source 
		**Phospholipids:** glycerol + phosphate group + two fatty acids	Lipid bilayers of membranes 
		**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** *(pp. 75–83)* ? *Explain the basis for the great diversity of proteins.*	 Amino acid monomer (20 types)	• Enzymes • Defensive proteins • Storage proteins • Transport proteins • Hormones • Receptor proteins • Motor proteins • Structural proteins	• Catalyze chemical reactions • Protect against disease • Store amino acids • Transport substances • Coordinate organismal responses • Receive signals from outside cell • Function in cell movement • Provide structural support
CONCEPT 5.5 **Nucleic acids store, transmit, and help express hereditary information** *(pp. 84–86)* ? *What role does complementary base pairing play in nucleic acids?*	 Nucleotide (monomer of a polynucleotide)	**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 in gene expression, including carrying instructions from DNA to ribosomes