Name______________________Period__________

Chapter 5: The Structure and Function of Large Biological Molecules

Concept 5.1 Macromolecules are polymers, built from monomers

1. The large molecules of all living things fall into just four main classes. Name them.

   Carbohydrates, Lipids, Proteins, Nucleic Acids

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

   Carbohydrates, Proteins, Nucleic Acids

   Macromolecule*s* are extremely large on the molecular scale, sometimes consisting of thousands of atoms.

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

   A polymer is a long chain-like molecule, consisting of many similar or identical building blocks linked by covalent bonds.

   A monomer is a smaller molecule that serves as the building blocks of polymers.

4. Monomers are connected in what type of reaction? What occurs in this reaction?

   Monomers are connected in a dehydration reaction.

   During a dehydration reaction, two monomer molecules are covalently bonded to each other, with the loss of a water molecule. In this reaction, each monomer contributes part of the water molecule that is released during the reaction. This reaction is repeated as monomers are added to the chain one by one, making a polymer.

5. Large molecules (polymers) are converted to monomers in what type of reaction?

   Polymers are disassembled to monomers by hydrolysis, a process that is essentially the reverse of the dehydration reaction.

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– water

   lysis break

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.

$$C_6H_{12}O_6 + C_6H_{12}O_6 \rightarrow C_{12}H_{22}O_{11} + H_2O$$

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

Dehydration synthesis

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

Monomer

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

Concept 5.2 Carbohydrates serve as fuel and building material

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

Monosaccharides, or simple sugars

9. Most monosaccharides are some multiple of (CH_2O). For example, ribose is a 5-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?

$C_6H_{12}O_6$

10. Here are the three hexose sugars. Label each of them. Notice that all sugars have the same two functional groups. Name them:

See page 70 of your text for the labeled figure.

C=O carbonyl group

—**OH** hydroxyl group

11. What is the difference between an *aldehyde sugar* and a *ketone sugar*?

Depending on the location of the carbonyl group, a sugar is either an aldose (aldehyde sugar) or a ketose (ketone sugar). Glucose, for example, is an aldose; fructose, an isomer of glucose, is a ketose. In aldehyde sugars, the carbonyl group is at the end of the carbon skeleton, while in the ketone sugars, the carbonyl group is within the carbon skeleton.

12. So, as a quick review, all of the sugars in the figure above have the same chemical formula: $C_6H_{12}O_6$. What term did you learn in Chapter 3 for compounds that have the same molecular formulas but different structural formulas?

    Isomers

13. Here is the abbreviated ring structure of glucose. Where are all the carbons?

    See page 71 of your text for the labeled figure.

    Each corner represents a carbon; each carbon in this figure is labeled 1 through 6.

14. Pay attention to the numbering system. This will be important as we progress in our study. Circle the number 3 carbon. Put a square around the number 5 carbon.

    See page 71 of your text for the labeled figure.

15. 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 polymer. Since the monomers are monosaccharides, the polymer is a *disaccharide*. Three disaccharides have the formula $C_{12}H_{22}O_{11}$. Name them below and fill out the chart.

Disaccharide	Formed from Which Two Monosaccharides?	Found Where?
Maltose	Glucose and glucose	Malt sugar used in brewing beer
Sucrose	Glucose and fructose	Table sugar
Lactose	Glucose and galactose	Milk

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

17. What is a *glycosidic linkage*?

    A glycoside linkage is a covalent bond formed between two monosaccharides by a dehydration reaction.

18. Here is a molecule of starch, which shows 1–4 glycosidic linkages. Translate and explain this terminology in terms of carbon numbering.

    See page 73 of your text for the labeled figure.

    When glucose forms a ring, the hydroxyl group attached to the number 1 carbon is positioned either below or above the plane of the ring. These two ring forms for glucose are called alpha and beta. In starch, all the glucose monomers are in the alpha configuration.

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

Type of Polysaccharide	Examples
Storage	Starch, glycogen
Structural	Cellulose, chitin

20. Why can you not digest cellulose? What organisms can?

Humans cannot digest cellulose because they lack the enzyme that can hydrolyze its beta linkages. Humans do posses enzymes that digest starch by hydrolyzing its alpha linkages; however, these enzymes cannot hydrolyze the beta linkages of cellulose because of the distinctly different shapes of these two molecules.

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

a. starch Has 1–4 B glucose linkages

b. glycogen Is a storage polysaccharide produced by vertebrates; stored in your liver

c glucose Two monomers of this form maltose

d. fructose Glucose + fructose form sucrose

e. fructose Monosaccharide commonly called "fruit sugar"

f. lactose "Milk sugar"

g. chitin Structural polysaccharide that gives cockroaches their crunch

h. maltose Malt sugar; used to brew beer

i. cellulose Structural polysaccharide that comprises plant cell walls

Concept 5.3 Lipids are a diverse group of hydrophobic molecules

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

All lipids mix poorly, if at all, with water.

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

The building blocks of fats are glycerol and fatty acids. In the figure below, the glycerol molecule is in gray, and the three fatty acids are in yellow.

See page 75 of your text for the labeled figure.

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?

One water molecule is removed for each fatty acid joined to the glycerol, equaling three water molecules for every triacylglycerol formed. This process is called dehydration synthesis.

25. On the figure with question 23, label the ester linkages.

See page 75 of your text for the labeled figure.

26. 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.

See page 75 of your text for the labeled figure.

Unsaturated fatty acids have one or more double bond, with one fewer hydrogen atom on each double-bonded carbon. Nearly all double bonds in naturally occurring fatty acids are cis bonds, which cause a kink in the hydrocarbon chain whenever they occur.

27. Name two saturated fats.

Possible examples include lard, butter, or most animal fats.

28. Name two unsaturated fats.

Possible examples include olive oil, cod liver oil or most plant or fish fats.

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

The kinks where the cis bonds are located prevent the molecules from packing together closely enough to solidify at room temperature.

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

A trans fat is an unsaturated fat with a trans double bond; the result of the process of hydrogenating vegetable oils to prevent lipids from separating out in liquid (oil) form. Trans fats should be limited in your diet because they have been found to contribute to atherosclerosis, a cardiovascular disease caused by plaque buildup within the walls of blood vessels.

31. List four important functions of fats.

Energy storage, long-term food reserve in mammals, adipose tissue cushions vital organs, body insulation.

32. 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*.

See page 76 in your text for the labeled figure.

33. Why are the "tails" hydrophobic?

The "tails" are hydrophic (avoid water) because they are hydrcarbon. As previously discussed in chapter 4, hydrocarbons are hydrophobic compounds because the great majority of their bonds are relatively nonpolar carbon-to-hydrogen.

34. Which of the two fatty acid chains in the figure with question 31 is unsaturated? Label it. How do you know it is unsaturated?

The fatty acid chain on the right is unsaturated. We know this because of the kink in the chain, indicating a double bond.

35. 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 hydrophilc heads, hydrophobic tails, and location of water.

See page 77 of your text for the labeled figure.

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

The tails are in contact with each other and remote from water because they are hydrophobic.

37. Some people refer to this structure as three hexagons and a doghouse. What is it?

See page 77 in your text for the labeled figure.

Cholesterol, a steroid

38. What are other examples of steroids?

Possible examples include vertebrate sex hormones.

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

39. Figure 5.15 is an important one! It shows many different functions of proteins.. Select any five types of proteins and summarize each type here.

See page 78 of your text for the labeled figure.

Type of Protein	Function	Example
Enzymes (Answers may vary; text gives eight types.)	Accelerate chemical reactions	Maltase, pepsin, sucrase
Storage	Storage of amino acids	Casein, which is the major source of amino acids for baby mammals; ovalbumin, the protein of egg white
Motor and contractile proteins	Movement	Actin, myosin
Transport proteins	Transport	Proteins embedded in the plasma membranes; aquaporins; hemoglobin
Receptor proteins	Response of cell to chemical stimuli	G protein-coupled receptors; tyrosine kinase receptors

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

See page 78 in your text for the labeled figure.

41. What is represented by *R*? How many are there?

R refers to the side chains of amino acids. There are 20.

42. Study the figure. 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.

See page 79 in your text for the labeled figure.

43. Define these terms:

peptide bond: A covalent bond in which two amino acids are joined by a dehydration reaction.

dipeptide:A polymer of two amino acids linked by a peptide bond.

polypeptide:A polymer of many amino acids linked by a peptide bond.

See page 80 of your text for the labeled figure.

44. There are four levels of protein structure. Refer to Figure 5.20, and summarize each level in the following table.

Level of Protein Structure	Explanation	Example
Primary	Linked series of amino acids with a unique sequence	Transthyretin
Secondary *α helix* *β pleated sheet*	Coils and folds resulting from the hydrogen bonds between the repeating constituents of the polypeptide backbone Alpha helix: Delicate coil held together by hydrogen bonding between every fourth amino acid Beta pleated sheet: Two or more strands of the polypeptide chain lying side by side, connected by hydrogen bonds between parts of the two parallel polypoptide backbone	Protein of hair Protein of spider web
Tertiary	Overall shape of the polypeptide resulting from interactions between the side chains (R groups) of the various amino acids	Transthyretin polypeptide
Quaternary	Overall protein structure that results from the aggregation of these polypeptide subunits	Globular transthyretin protein, collagen, hemoglobin

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

See pages 82-83 of your text for the labeled figure.

From Left to Right: Primary, Secondary, Tertiary, Quaternary

46. Enzymes are globular proteins that exhibit at least tertiary structure. As you study Figure 5.20 in your text, use this figure to identify and explain each interaction that folds this protein fragment.

See page 83 in your text for the labeled figure.

Hydrophobic interaction: amino acids with hydrophobic R groups end up in clusters at the core of the protein, out of contact with water.

Van der Waals interaction: transient interactions between R groups

Hydrogen Bond: weak bonds between the hydrogen of one R group and the oxygen or nitrogen of another R group

Disulfide Bridge: links between the sulfhydryl groups of two cysteine amino acids, sulfur to sulfur

Ionic Bond: bonds between an R group that is positively charged and an R group that is negatively charged

These interactions tend to fold an amino acid chain into a distinctive three-dimensional form.

47. Do you remember when, in Chapter 4, we said, "To change the structure, change the function"? Explain how this principle applies to sickle-cell disease. Why is the structure changed?

See page 84 of your text for the labeled figure.

Sickle-cell disease is an inherited blood disorder caused by the substitution of one amino acid (valine) for the normal one (glutamic acid) at a particular position in the primary structure of hemoglobin, the protein that carried oxygen in red blood cells. This changes the typical three-dimensional shape of hemoglobin. Normal red blood cells are disk-shaped, but in sickle-cell disease, the abnormal hemoglobin molecules tend to crystallize, deforming some of the cells into sickle shapes.

48. 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.

Denaturation is the changing of a protein during which the protein unravels and loses its native shape because the weak chemical bonds and interactions within a protein have been destroyed. Possible examples of ways a protein may become denatured include alteration of pH, salt concentration, temperature, transfer from aqueous environment to nonpolar solvent, chemicals, and excessive heat.

49. *Chaperone proteins* or *chaperonins* assist in the proper folding of proteins. Annotate this figure to explain the process.

See page 85 of your text for the labeled figure.

From Left to Right:

1. An unfolded polypeptide enters the cylinder from one end.

2. The cap attaches, causing the cylinder to change shape in such a way that it creates a hydrophilic environment for the folding of the polypeptide.

3. The cap comes off, and the properly folded protein is released.

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

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

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

See page 86 of your text for the labeled figure

The mRNA molecule interacts with the cell's protein-synthesizing machinery to direct production of a polypeptide, which folds into all or part of a protein. The sites of protein synthesis are tiny structures called ribosomes. In a eukaryotic cell, ribosomes are in the cytoplasm, but DNA resides in the nucleus. Messenger RNA conveys genetic instructions for building proteins from nucleus to the cytoplasm

51. The components of a nucleic acid are a *sugar*, a *nitrogenous base*, and a *phosphate group*. Label each on the figure below.

See page 87 of your text for the labeled figure

52. 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 below that has the number 5 sugar **5'** and the other end of the chain **3'**. Finally, label one nucleotide.

See page 87 of your text for the labeled figure

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

Adenine, guanine, cytosine, thymine

54. Which four are found in RNA?

Adenine, guanine, cytosine, uracil

55. How do ribose and deoxyribose sugars differ?

Deoxyribose sugar lacks an oxygen atom on the second carbon in the ring.

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

Phosphate group, sugar, nucleoside

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

See page 89 of your text for the figure.

Double helix

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

The strands are said to be antiparallel because they run in opposite 5' → 3' directions from each other.

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

Sugar and phosphate

60. What molecules make up the "rungs"?

Base pairs joined by hydrogen bonding

61. In a DNA double helix, a region along one DNA strand has this sequence of nitrogenous bases:

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

Write the complementary strand. Indicate the 5' and 3' ends of the new strand.

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

Test Your Understanding Answers

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

1. d 2. a 3. b 4. a 5. b 6. c 7. b

This summary table from the Chapter 5 Review is an excellent study tool. Use it to organize material from this chapter in your mind.

See page 90 for this table.