Chapter 5: Structure and Function of Large Biological Molecules

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

Unlike lipids, carbohydrates, proteins, and nucleic acids are macromolecular chain-like molecules called polymers.

2. Define macromolecule.

Macromolecules are characterized by their relatively great size on the molecular scale.

3. What are polymers and monomers?

Polymers are long molecules consisting of many similar or identical building blocks linked by covalent bonds. Monomers are the smaller molecules that serve as repeating units within polymers.

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

Monomers are connected by a reaction in which two molecules are covalently bonded to each other through loss of a water molecule; this is known as a condensation reaction, specifically a dehydration reaction. When a bond forms between two monomers, each monomer contributes part of the water molecule that is lost.

5. Polymers are converted to monomers in what type of reaction?

Polymers are disassembled to monomers via hydrolysis, essentially the reverse of the dehydration reaction.

6. What does each root word of hydrolysis mean?

In ancient Greek, "hydro" means "water" and "lysis" means "separation."

7. Balance the following reaction: $C_6H_{12}O_6 + C_6H_{12}O_6 \rightarrow C_{12}H_{22}O_{11}$.

This is a dehydration reaction. Glucose, the non-water product, is a polymer. When two monomers are joined, a molecule of water is always removed.

8. Carbohydrates include sugars and starches. What are the monomers of all carboydrates?

The simplest carbohydrates are monosaccharides (simple sugars).

9. Most monosaccharides are some multiple of CH_2O. For example, ribose is a 5-carbon (pentose) sugar with the formula $C_5H_{10}O_5$. What is the formula of a hexose sugar?

$C_6H_{12}O_6$

10. Label the three hexose sugars. What are the two functional groups all sugars share?

All sugars have the functional groups carbonyl (C=O) and hydroxyl (–OH).

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

In ketones, the carbonyl group is within a carbon skeleton. In aldehydes, the carbonyl group is at the end of the carbon skeleton. This structural difference results in differing properties. Aldoses are sugars containing an aldehyde while ketoses contain a ketone.

12. All these sugars have the same chemical formula: $C_6H_{12}O_6$.

Compounds that have the same molecular formulas but different structural formulas are called isomers.

13. Where are all the carbons in the abbreviated ring structure of glucose? Circle the number 3 carbon. Put a square around the number 5 carbon.

Each corner of the hexagon represents a carbon atom.

14. Since the monomers in the reaction from #7 are monosaccharides, the polymer is a disaccharide. Name three disaccharides with the formula $C_{12}H_{22}O_{11}$.

Disaccharide	*Monosaccharides formed from*	*Where found*
lactose	glucose + galactose	major sugar in milk
maltose	glucose + glucose	product of starch digestion
sucrose	glucose + fructose	common table sugar

15. All sugars end in –ose.

This root word is a Latin suffix meaning "full of," "abounding in," "given to," or "like."

16. What is a glycosidic linkage?

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

17. A molecule of starch shows 1-4 glycosidic linkages. Translate and explain this terminology in terms of carbon numbering.

The bonding of two glucose units forms maltose. The glycosidic linkage joins the number 1 carbon of one glucose to the number 4 carbon of the second glucose.

18. What are the two categories of polysaccharides?

Type of polysaccharide	*Examples*
storage	starches (energy reserve for plants); glycogen (energy reserve for animals)
structural	arabinoxylans (plant and animal cell walls); cellulose (structural component of plants); chitin (structural component of many animals); pectins (primary cell walls, most non-woody parts of terrestrial plants)

19. Why can't you digest cellulose? What organisms can?

Unlike certain animals such as ruminants and termites, humans do not possess enzymes that can digest cellulose.

20. Match the correct carbohydrate to its property.

Starch has 1-4 B glucose linkages. Glycogen is a storage polysaccharide produced by vertebrates and stored in your liver. Two monomers of glucose form maltose. Glucose and fructose form sucrose. Fructose is a monosaccharide commonly called "fruit sugar." Lactose is known as "milk sugar." Chitin is a structural polysaccharide that gives cockroaches their delightful crunch. Maltose is malt sugar, used to brew beer. Cellulose is a structural polysaccharide that comprises plant cell walls.

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

Lipids are grouped together because they are all hydrophobic, thus mixing poorly with water, if at all.

22. Identify the building blocks of fats on this figure.

The building blocks of fats are one glycerol molecule (gray) and three fatty acid molecules (yellow).

23. If a fat is composed of three fatty acids and one glycerol molecule, how many water molecules will be removed to form it?

During dehydration synthesis, one water molecule is removed for each fatty acid joined to the glycerol, for a total of three water molecules in the formation of one triacylglycerol.

25. Draw an unsaturated fatty acid chain that is 8 carbons long. Circle the element in your chain that makes it unsaturated, and explain what this means.

Unsaturated fatty acids have one or more double bonds, with one fewer H atom on each double-bonded C atom. Nearly all double bonds in naturally occurring fatty acids are cis bonds, which cause a bend in the segment of the hydrocarbon chain where they are located.

26. Name two saturated fats.

Butyric acid is found in butter and myristic acid is found in dairy products such as cow's milk.

27. Name two unsaturated fats.

Oleic acid is found in various animal and vegetable fats and oils. Palmitoleic acid can be found in human tissue.

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

At room temperature, the molecules of an unsaturated fat cannot pack together closely enough to solidify because of the kinks in some of their fatty acid hydrocarbon chains; cis double bonds cause bending.

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

Trans fats are unsaturated fats with trans double bonds. More than saturated fats, trans fats contribute to atherosclerosis, a cardiovascular disease caused by the accumulation of plaque deposits within the walls of blood vessels, causing inward protrusions that impede blood flow and reduce the resilience of the vessels.

30. List four important functions of fats.

Fats help store energy, insulate the body, protect vital organs through adipose tissues, and provide for long-term food storage in animals.

31. Label the structure of a phospholipid to show the phosphate group, the glycerol, and the fatty acid chains. Also indicate hydrophobic and hydrophilic regions.

32. Why is the "tail" hydrophobic?

The "tails" are hydrophobic because, as hydrocarbons, most of their bonds are relatively nonpolar carbon-hydrogen configurations.

33. Label which of the two fatty acid chains in #31 is unsaturated.

34. A phospholipid has a glycerol attached to a phosphate group and two fatty acid chains. The head is hydrophilic and the tail is hydrophobic. Sketch the phospholipid bilayer structure of a plasma membrane. Label the heads, tails, and location of water.

35. Why are the tails all located in the interior?

The hydrophobic tails are averse to contact with water.

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

This structure is a steroid known as cholesterol.

37. What are other examples of steroids?

Cortisol, nandrolone and estrogen are other examples of steroids.

38. Select five types of proteins and summarize each.

Type of protein	*Function*	*Example*
contractile, motor	movement	actin, myosin: responsible for muscle contraction
enzymatic	selective acceleration of chemical reactions	digestive enzymes: catalyze the hydrolysis of the polymers in food
defensive	protection against disease	antibodies: combat bacteria and viruses
hormonal	coordination of an organism's activities	insulin: helps regulate concentration of sugar in the blood of vertebrates
structural	physical support	keratin: hair, horns, feathers, and other skin appendages

39. Enzymes are an important type of protein. Label the active site, the substrate, and the products. Show what happens to water.

40. Is this reaction dehydration synthesis or hydrolysis?

This is a hydrolytic reaction.

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

42. What is represented by R? How many are there?

R refers to the twenty side chains of amino acids.

44. Define dipeptide, polypeptide, and peptide bond.

A peptide bond is a covalent bond between two amino acids positioned so that the carboxyl group of one is adjacent to the amino group of another so they can become joined by a dehydration reaction. A dipeptide is a molecule consisting of two amino acids joined by a single peptide bond. A polypeptide is a polymer of many amino acids linked by peptide bonds.

45. Summarize the four levels of protein structure.

Level	*Explanation*	*Example*
Primary	unique sequence of amino acids	transthyretin
Secondary	coils and folds resulting from H bonds between repeating constituents of the polypeptide backbone	two types: alpha helix, beta pleated sheet
Alpha helix	fragile coil held together by H bonding between every fourth amino acid	hair
Beta pleated sheet	two or more strands of the polypeptide chain lying beside each other, connected by H bonds between parts of the two parallel polypeptide backbone	spiderweb
Tertiary	overall shape of polypeptide resulting from interactions between R groups (side chains) of various amino acids	transthyretin polypeptide
Quaternary	overall protein structure resulting from aggregation of polypeptide subunits	collagen, hemoglobin

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

47. Enzymes are globular proteins that exhibit at least tertiary structure. On this figure, identify and explain each interaction that folds this portion.

A hydrophobic reaction occurs as a polypeptide folds into its functional shape when amino acids with hydrophobic side chains end up in clusters at the core of the protein, out of contact with water (B). Once nonpolar amino acid side chains are close together, van der Waals interactions help hold them together (B). While the hydrogen bonds (A) between polar side chains and ionic bonds (D) between positively and negatively charged side chains that help stabilize tertiary structure are all weak interactions, their cumulative effect gives the protein a unique shape. Additionally, covalent bonds called disulfide bridges (C) form where two cysteine monomers are brought close together by the protein folding, riveting parts of the protein together.

48. Explain how the principle "change the structure, change the function" applies to sickle-cell disease. Why is the structure changed?

While normal red blood cells are disk-shaped, the abnormal hemoglobin molecules causing sickle-cell disease tend to crystallize, deforming afflicted cells into a sickle shape. When these angular cells clog tiny blood vessels, blood circulation can be direly impeded; thus cell dysfunction is induced by its abnormal structure.

49. 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 denaturated.

Denaturation happens when alteration in the pH, salt concentration, temperature, or other environmental aspects of a protein causes it to unravel and lose its native shape, thus becoming biologically inactive.

50. Chaperone proteins assist in the proper folding of proteins. Annotate this figure to explain the process.

First, an unfolded polypeptide enters the chaperonin cylinder from one end (1). 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 (2). Finally the cap comes off, and the properly folded protein is released (3).

51. The flow of genetic information is DNA to RNA to protein. Explain the process. Label the nucleus, DNA, mRNA, ribosome, and amino acids.

After a strand of mRNA is synthesized in the nucleus (1), it moves into the cytoplasm via a nuclear pore (2). Finally, at the ribosome it engages in the synthesis of protein (3).

52. The components of a nucleic acid are a sugar, a nitrogenous base, and a phosphate group. Label each.

*53. Label the end of the strand on the figure that has the number 5 sugar **5'** and the other end of the chain **3'**.*

54. Which of the five nitrogen bases are found in DNA?

DNA contains thymine, adenine, cytosine and guanine, but not uracil.

55. Which four are found in RNA?

RNA contains adenine, cytosine, guanine and uracil, but not thymine.

56. How do ribose and deoxyribose sugars differ?

Deoxyribose sugars lack an oxygen atom on the second carbon in the ring that is found in ribose sugars.

57. What are the three components of a nucleotide?

Nucleotides consist of a phosphate group, a sugar, and a nucleoside.

58. Consider the model of DNA proposed by James Watson and Francis Crick.

This shape is called a double helix.

59. Why are the strands said to be antiparallel?

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

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

Sugar and phosphate make up the "uprights."

61. What molecules make up the rungs?

The rungs are made up by base pairs joined by hydrogen bonding.

62. Provide the complementary base for the two nucleotides of DNA below.

Adenosine–Thymine; Cytosine–Guanine

63. In a DNA double helix, a region along one DNA strand has the sequence of nitrogenous bases: 5'-T A G G C T-3'. Write the complementary strand.

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