AP Biology **Student Interactive Learning Guide**

North Salem University

MISSION: *Engage students to continuously learn, question, define and solve problems through critical and creative thinking.*

Summer 2021

Organic macromolecules are essential to life, each one having a unique function arising from the order and arrangement of atoms. Biological organization is established when cells join these small molecules together to form larger molecules and even organelles. The four main classes of biological macromolecules are ***carbohydrates****,* ***lipids****,* ***proteins*** *and* ***nucleic acids****. The structure and functions of these molecules are the main subject of this chapter. We will be going through this chapter VERY quickly as much of the information contained in it is considered "****prior knowledge****". The questions and activities that follow in this Interactive Learning Guide should help you focus on the most important points in the chapter.*

If you have any problems – feel free to drop me an email.

Chapter 5:
Structure and Function of Macromolecules

Chapter 5: Structure and Function of Macromolecules

OBJECTIVES:

Polymer Principles

___1. Explain how monomers are used to build polymers.
___2. List the four major classes of macromolecules.
___3. Compare condensation and hydrolysis.

Carbohydrates: Fuel and Building Material

___4. Describe the distinguishing characteristics of carbohydrates and explain how they are classified.
___5. Distinguish between monosaccharides and disaccharides.
___6. Describe the structure and functions of polysaccharides.

Lipids: Diverse Hydrophobic Molecules

___7. Explain what distinguishes lipids from other major classes of macromolecules.
___8. Describe the unique properties, building-block molecules, and biological importance of the three important groups of lipids: fats, phospholipids, and steroids.
___9. Identify an ester linkage and describe how it is formed.
___10. Distinguish between a saturated and an unsaturated fat and list some unique emergent properties that are a onsequence of these structural differences.

Proteins: Many Structures, Many Functions

___11. Describe the characteristics that distinguish proteins from the other major classes of macromolecules and xplain the biologically important functions of this group.
___12. List and describe the four major components of an amino acid. Explain how amino acids may be grouped according to the physical and chemical properties of the side chains.
___13. Identify a peptide bond and explain how it is formed.
___14. Distinguish between a polypeptide and a protein.
___15. Explain what determines protein conformation and why it is important.
___16. Define primary structure and describe how it may be deduced in the laboratory.
___17. Describe the two types of secondary protein structure. Explain the role of hydrogen bonds in maintaining he structure.
___18. Explain how weak interactions and disulfide bridges contribute to tertiary protein structure.
___19. Using collagen and hemoglobin as examples, describe quaternary protein structure.
___20. Define denaturation and explain how proteins may be denatured.

Nucleic Acids: Informational Polymers

___21. Describe the characteristics that distinguish nucleic acids from the other major groups of macromolecules.
___22. Summarize the functions of nucleic acids.
___23. List the major components of a nucleotide, and describe how these monomers are linked to form a nucleic cid.
___24. Distinguish between a pyrimidine and a purine.
___25. Briefly describe the three-dimensional structure of DNA.
___26. Explain how the structure of DNA and proteins can be used to document the hereditary background of an rganism.

KEY TERMS

Alpha helix
amino acid
beta (b) pleated sheet
carbohydrate
cellulose
chaperonin
chitin
cholesterol
condensation reaction
dehydration reaction
denaturation
deoxyribonucleic acid (DNA)
deoxyribose
disaccharide
disulfide bridge
double helix
fat
fatty acid
gene
glycogen
glycosidic linkage
hydrolysis
hydrophobic interaction
lipid
macromolecule
monomer
monosaccharide
nucleic acid
nucleotide
peptide bond
phospholipids
polymer
polynucleotide
polypeptide
polysaccharide
primary structure
proteins
purine
pyrimidine
quaternary structure
ribonucleic acid (RNA)
ribose
saturated fatty acid
secondary structure
starch
steroids
tertiary structure
triacylglycerol
unsaturated fatty acid
x–ray crystallography

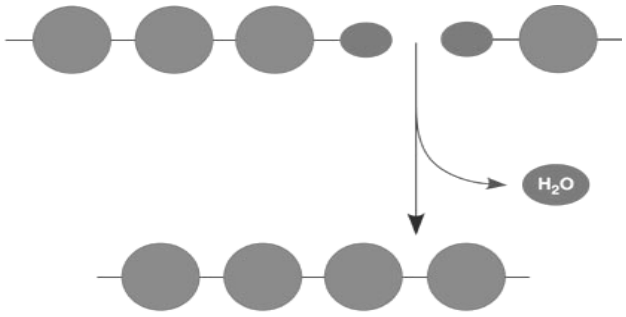
- -

WORD ROOTS:

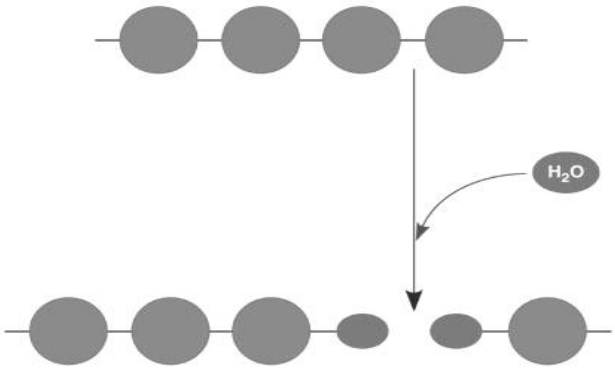
con- = together (*condensation reaction*: a reaction in which two molecules become covalently bonded to each other through the loss of a small molecule, usually water)
di- = two (*disaccharide*: two monosaccharides joined together)
glyco- = sweet (*glycogen*: a polysaccharide sugar used to store energy in animals)
hydro- = water; **-lyse** = break (*hydrolysis*: breaking chemical bonds by adding water)
macro- = large (*macromolecule*: a large molecule)
meros- = part (*polymer*: a chain made from smaller organic molecules)
mono- = single; **-sacchar** = sugar (*monosaccharide*: simplest type of sugar)
poly- = many (*polysaccharide*: many monosaccharides joined together)
tri- = three (*triacylglycerol*: three fatty acids linked to one glycerol molecule)

Chapter 5 - Guided Reading

1. Label the diagram below – identify the type of reaction, the monomer and polymer along with a brief description of the reaction.



2. Label the diagram below – identify the type of reaction, the monomer and polymer along with a brief description of the reaction.



3. The root words of dehydration synthesis (condensation) and hydrolysis will be used many times to form other words you will learn this year. What does each root word mean?

dehydrate -

synthesis -

hydro -

lysis -

4. What are **polysaccharides**?

5. List 3 functions of **polysaccharides**.

a)

b)

c)

6. Consider the following reaction: $C_6H_{12}O_6 + C_6H_{12}O_6 \longrightarrow C_{12}H_{22}O_{11}$

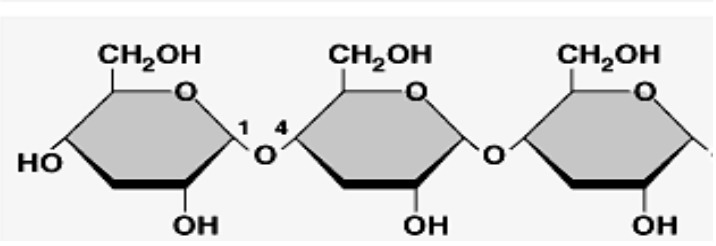
a. The equation is not balanced; it is missing a molecule of water. Write it in on the correct side of the equation.

b. So, what 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 removed.

7. To the right is a molecule of starch, which shows 1 - 4 glycosidic linkages. What are **glycosidic linkages** and define this terminology in terms of carbon numbering.



8. Compare and contrast **starch** and **glycogen**.

9. What is **chitin**?

10. Why are lipids grouped together?

11. What are the building blocks of fats and lipids?

12. If a fat is composed of **3 fatty acids** and **1 glycerol molecule**, how many water molecules will be removed to form it? Again, what is this process called?

13. List four important functions of fats.

a)

b)

c)

d)

14. Contrast **saturated** and **unsaturated** fats – how does this relate to the concept that structure and function are linked?

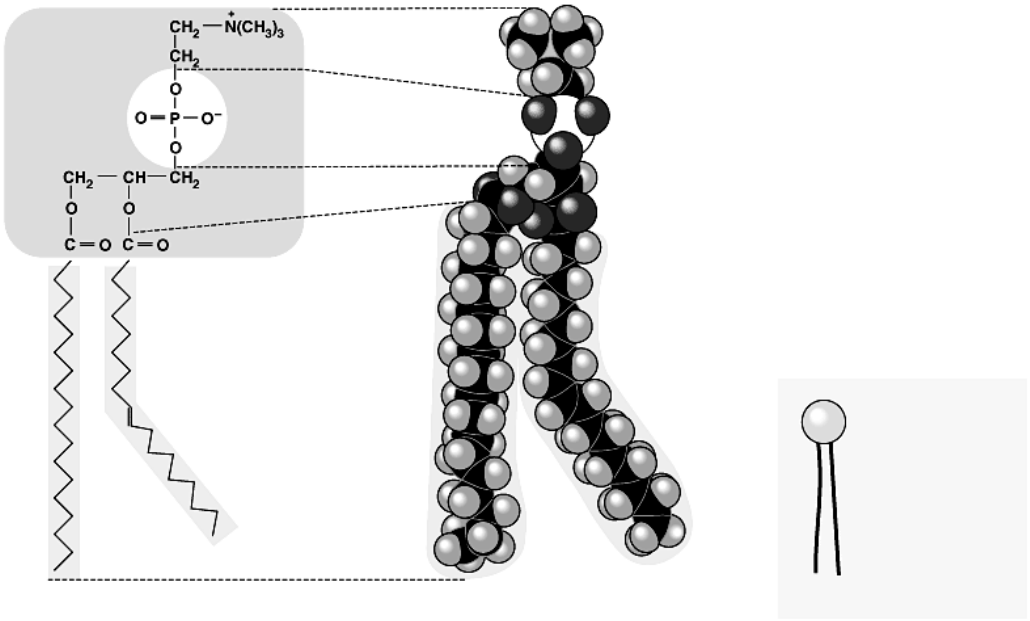
15. Name two saturated fats.

16. Name two unsaturated fats.

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

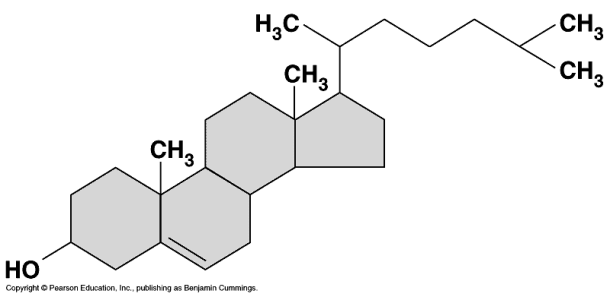
18. What is a **trans fat**? Why should you limit them in your diet?

19. Below is a figure that shows the structure of a ***phospholipid***. Label it 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***.



20. Why is the tail ***hydrophobic***?

21. Use the diagram to the right to explain how you would you recognize a basic steroid molecule?



22. List the eight types of proteins along with their basic function and a specific example of each.

Type of Protein	Function	Examples
Structural		
Storage		
Transport		
Hormonal		
Receptor		
Contractile		
Defensive		
Enzymatic		

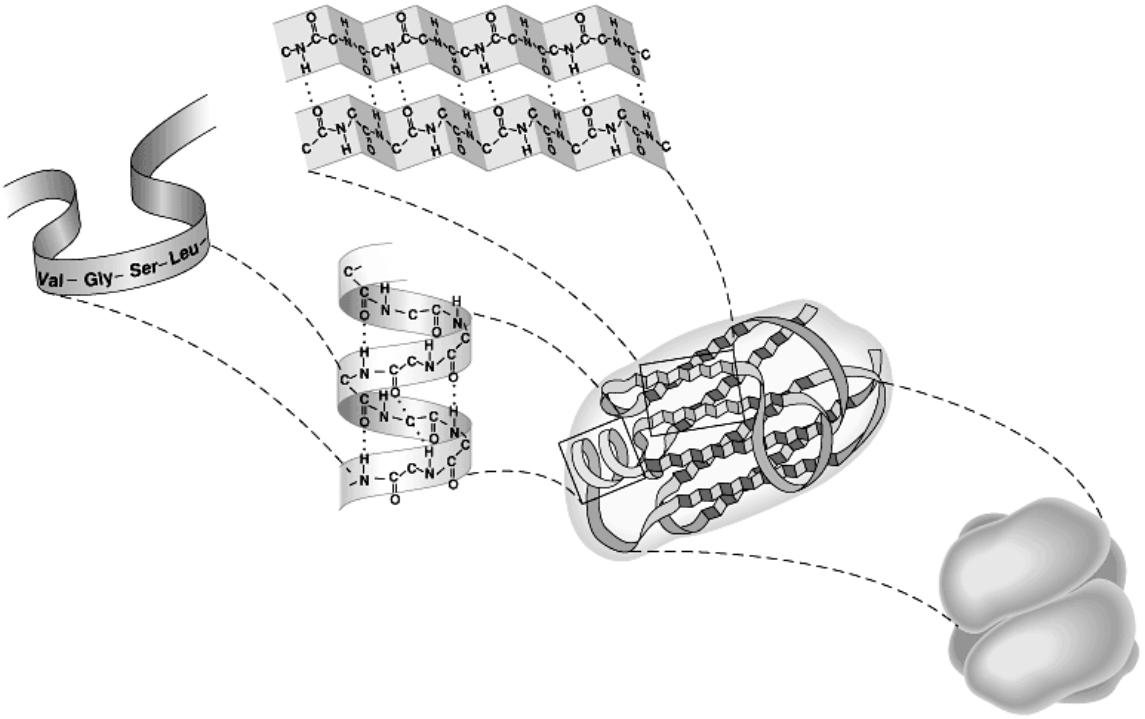
23. What are the names for the monomers and polymers of proteins?

24. Draw the dehydration synthesis of amino acids – note the **amino group**, the **carboxyl group** and the **alpha carbon**, circle the **water** molecule to be removed and then note the **peptide bond** formed when the two are joined.

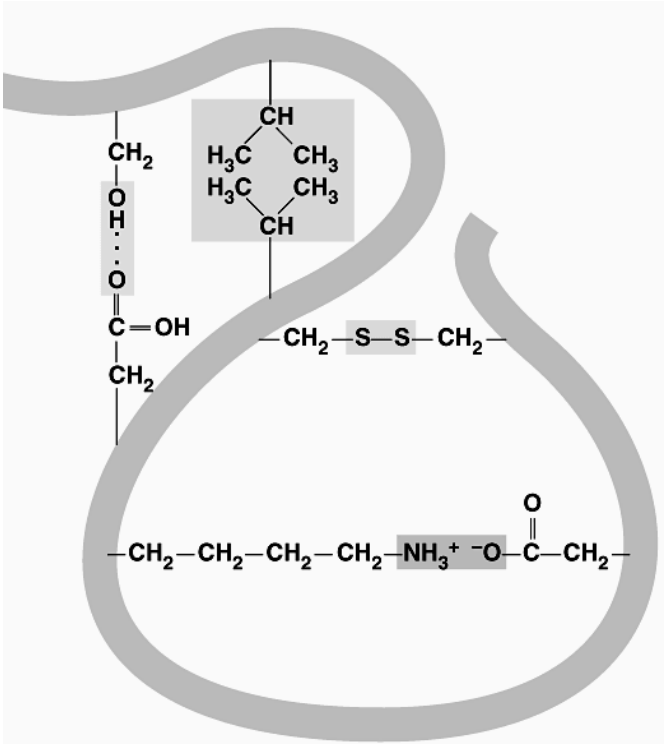
25. Describe the four levels of protein structure along with a specific example of each.

Protein Structure	Examples
Primary -	
Secondary -	
Tertiary -	
Quaternary -	

26. Label each of the levels of protein structure on the figure below.

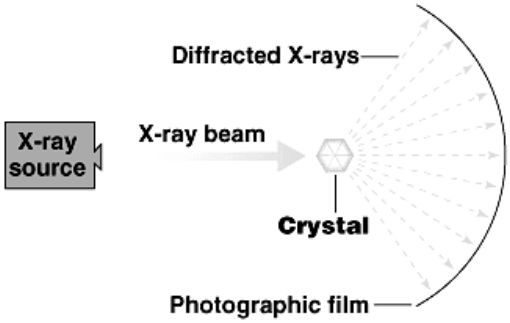


27. Label the diagram below and use it to describe some of the molecular interactions responsible for the tertiary structure of a protein.

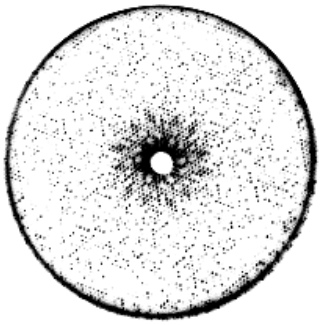


28. How does the characteristics of an amino acid – *nonpolar*, *polar*, *acidic* or *basic* relate to the issue of tertiary and quaternary structure?

29. Use the diagram below to help you describe the technique of x-ray crystallography.



❶ X-ray crystallography

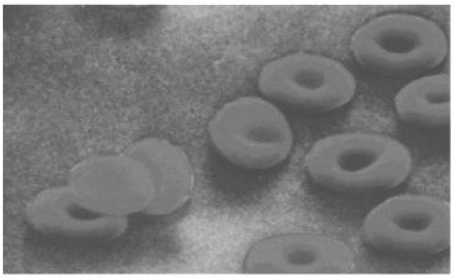


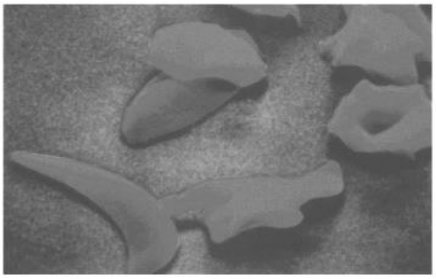
❷ X-ray diffraction pattern from the crystal of a protein

30. Do you remember when, in previous chapters, we said,

"Change the structure, change the function"?

Use the diagram below to help you explain how that principle applies to sickle-cell disease. Why is the structure changed?

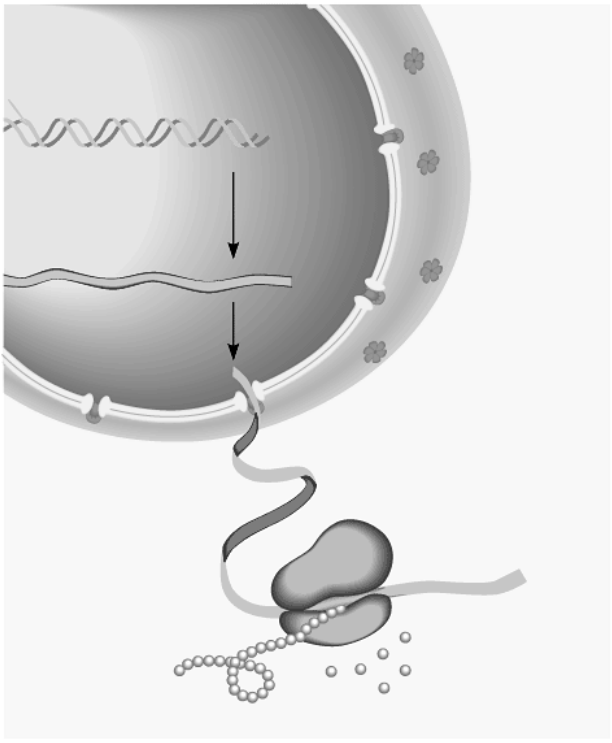




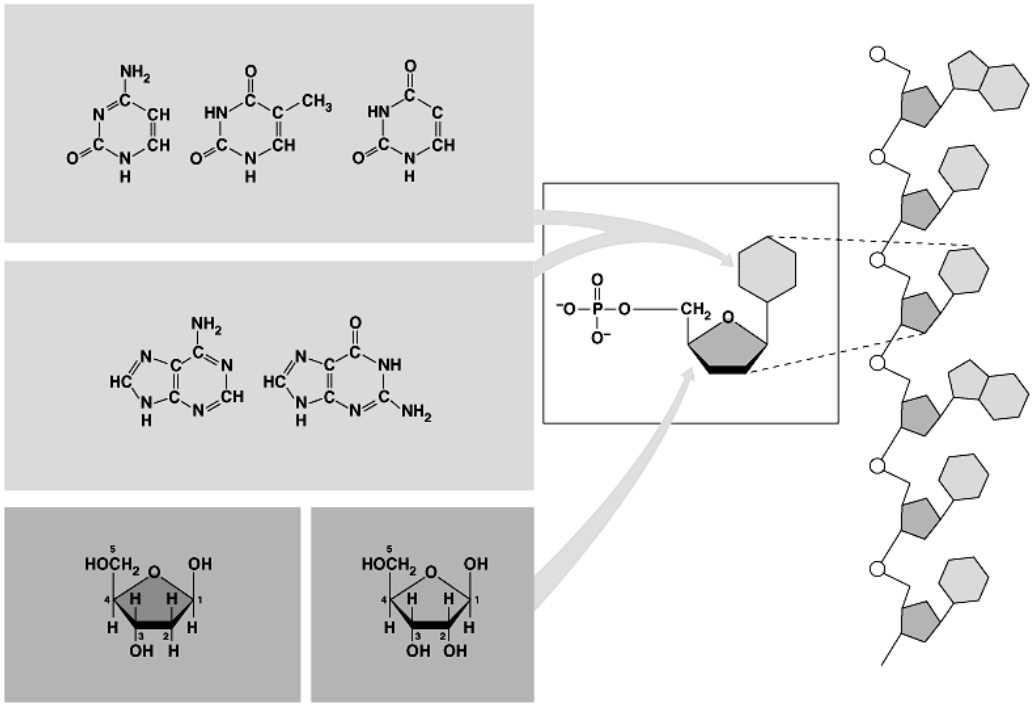
31. Besides mutation, which changes the primary structure of a protein, protein structure can be also be changed by **denaturation**. Define *denaturation*, and give at least two ways a protein may become denatured.

DNA and RNA will be the core topics of future chapters.
For now, you should just review the general functions and know the components.

32. The flow of genetic information is from DNA ----> RNA ----> protein.
Use this figure below to briefly explain the process. Be sure label the **nucleus**, **DNA**, **mRNA**, **ribosome**, **amino acids** and **protein.**



33. The components of a **nucleic acid** are a **sugar**, a **nitrogenous base** and a **phosphate group**. Label each on the figure below along with the **purines** and **pyrimidines**.



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

35. Which four are found in RNA?

36. How do ribose and **deoxy**ribose sugars differ chemically?

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

_____ _____ _____

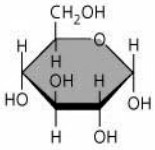
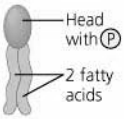
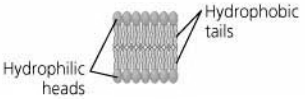
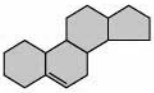
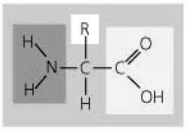
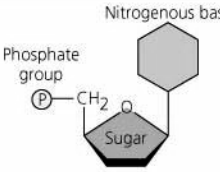
38. To the right is a model of DNA, which was proposed by James Watson and Francis Crick. What is this shape called?

39. What two molecules make up the "uprights" or side of the ladder?

40. What molecules make up the rungs of the ladder?

Organic Compound Summary Table.

This table is an excellent study tool. Use it to organize material from this chapter in your mind.

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

Chapter 5: Summary of Key Concepts

POLYMER PRINCIPLES

- Most macromolecules are polymers **(pp. 62-63, FIGURE 5.2)** Carbohydrates, lipids, proteins, and nucleic acids are the four major classes of organic compounds in cells. Some of these compounds are very large and are called macromolecules. Most macromolecules are polymers, chains of identical or similar building blocks called monomers. Monomers form larger molecules by condensation reactions in which water molecules are released (dehydration). Polymers can disassemble by the reverse process, hydrolysis.
- An immense variety of polymers can be built from a small set of monomers (pp. 63-64) Each class of polymer is formed from a specific set of monomers. Although organisms share the same limited number of monomer types, each organism is unique because of the specific arrangement of monomers into polymers.

CARBOHYDRATES--FUEL AND BUILDING MATERIAL

- Sugars, the smallest carbohydrates, serve as fuel and carbon sources **(pp. 64-65, FIGURES 5.3-5.5)** Monosaccharides are the simplest carbohydrates. They are used directly for fuel, converted to other types of organic molecules, or used as monomers for polymers. Disaccharides consist of two monosaccharides connected by a glycosidic linkage.
- Polysaccharides, the polymers of sugars, have storage and structural roles **(pp. 66-68, FIGURES 5.6-5.9)**. The monosaccharide monomers of polysaccharides are connected by glycosidic linkages. Starch in plants and glycogen in animals are both storage polymers of glucose. Cellulose is an important structural polymer of glucose in plant cell walls. Starch, glycogen, and cellulose differ in the positions and orientations of their glycosidic linkages.

LIPIDS--DIVERSE HYDROPHOBIC MOLECULES

- Fats store large amounts of energy **(pp. 68-70, FIGURES 5.10-5.11)** Fats, also known as triacylglycerols, are constructed by the joining of a glycerol molecule to three fatty acids by dehydration reactions. Saturated fatty acids have the maximum number of hydrogen atoms. Unsaturated fatty acids (present in oils) have one or more double bonds in their hydrocarbon chains.
- Phospholipids are major components of cell membranes **(pp. 70-71, FIGURE 5.12-5.13)** Where fats have a third fatty acid linked to glycerol, phospholipids have a negatively charged phosphate group, which may be joined, in turn, to another small hydrophilic molecule. Thus, the "head" of a phospholipid is hydrophilic.
- Steroids include cholesterol and certain hormones **(p. 71, FIGURE 5.14)** Steroids have a basic structure of four fused rings of carbon atoms.

PROTEINS--MANY STRUCTURES, MANY FUNCTIONS

- A protein consists of one or more polypeptide chains folded into a specific three-dimensional conformation (p. 71).
- A polypeptide is a polymer of amino acids connected in a specific sequence **(pp. 71-74, FIGURES 5.15-5.16, TABLE 5.1)**. Polypeptides are constructed from 20 different amino acids, each with a characteristic side chain (R group). The carboxyl and amino groups of adjacent amino acids link together in peptide bonds.
- A protein's function depends on its specific conformation **(pp. 74-80, FIGURES 5.17-5.27**). The primary structure of a protein is its unique sequence of amino acids. Secondary structure is the folding or coiling of the polypeptide into repeating configurations, mainly the a helix and the b pleated sheet, which result from hydrogen bonding between parts of the polypeptide backbone. Tertiary structure is the overall three-dimensional shape of a polypeptide and results from interactions between amino acid side chains. Proteins made of more than one polypeptide chain (subunits) have a quaternary level of structure. The structure and function of a protein are sensitive to physical and chemical conditions. Protein shape is ultimately determined by its primary structure, but in the cell, proteins called chaperonins may help the folding process.

NUCLEIC ACIDS--INFORMATIONAL POLYMERS

- Nucleic acids store and transmit hereditary information **(pp. 80-81, FIGURE 5.28).** DNA stores information for the synthesis of specific proteins. RNA (specifically, mRNA) carries this genetic information to the protein-synthesizing machinery.
- A nucleic acid strand is a polymer of nucleotides **(p. 82, FIGURE 5.29)** Each nucleotide monomer consists of a pentose covalently bonded to a phosphate group and to one of four different nitrogenous bases (A, G, C, and T or U). RNA has ribose as its pentose; DNA has deoxyribose. RNA has U and DNA, T. In making a polynucleotide, nucleotides join to form a sugar-phosphate backbone from which the nitrogenous bases project. The sequence of bases along a gene specifies the amino acid sequence of a particular protein.
- Inheritance is based on replication of the DNA double helix **(pp. 82-83, FIGURE 5.30)** DNA is a helical, double-stranded macromolecule with bases projecting into the interior of the molecule. Because A always hydrogen-bonds to T, and C to G, the nucleotide sequences of the two strands are complementary. One strand can serve as a template for the formation of the other. This unique feature of DNA provides a mechanism for the continuity of life.
- We can use DNA and proteins as tape measures of evolution (p. 84, TABLE 5.2) Molecular comparisons help biologists sort out the evolutionary connections among species.

Chapter 5 - Review Questions

___1) Which of the following contains a carboxyl and an amino group?
A) amino acids B) fats C) sugars D) vinegar

___2) Which of the following statements about the monomers and polymers found in living organisms is *false*?
A) Cells typically make all of their macromolecules from a set of 40–50 common monomers and a few other ingredients that are rare.
B) The monomers used to make polymers are essentially universal.
C) Monomers serve as building blocks for polymers.
D) Monomers are joined together by the process of hydrolysis.

___3) Which of the following statements about dehydration synthesis is *false*?
A) One monomer loses a hydrogen atom, and the other loses a hydroxyl group.
B) H_2O is formed as the monomers are joined.
C) Covalent bonds are formed between the monomers.
D) Animal digestive systems utilize this process to break down food.

___4) The results of dehydration synthesis can be reversed by -
A) condensation. C) polymerization
B) hydrolysis. D) the addition of an amino group.

___5) The molecular formula of most monosaccharides represents a multiple of -
A) CH_3O. B) CH_2O. C) CHO. D) CHO_2.

___6) A molecule with the formula $C_{55}H_{110}O_{55}$ is probably a(n) -
A) oil. B) steroid. C) protein. D) polysaccharide.

___7) Many names for sugars end in the suffix -
A) -acid. B) -ose. C) -hyde. D) -ase.

___8) A disaccharide forms when -
A) two monosaccharides join by dehydration synthesis.
B) two starches join by dehydration synthesis.
C) two monosaccharides join by hydrolysis.
D) two starches join by hydrolysis.

___9) High-fructose corn syrup is made from corn. The main carbohydrate in corn is a polysaccharide called -
A) fructose. B) starch. C) hydrocarbon. D) cellulose.

___10) Foods that are high in fiber are most likely derived from -
A) plants. B) dairy products. C) red meats. D) fish.

___11) The storage form of carbohydrates is _____ in animals and _____ in plants.
A) starch . . . glycogen C) cellulose . . . glycogen
B) glycogen . . . starch D) glycogen . . . cellulose

___12) Which of the following organisms contain the polysaccharide chitin?
A) animals and plants C) fungi and insects
B) plants and bacteria D) insects and plants

___13) An oil may be converted into a substance that is solid at room temperature by -
A) adding hydrogens, decreasing the number of double bonds in the molecules.
B) removing water, causing a dehydration synthesis reaction to occur.
C) removing hydrogens, increasing the number of double bonds.
D) cooling it, so that double bonds form and the fats solidify.

___14) What feature of fats makes them hydrophobic?
A) Fats have carboxyl groups.
B) Fats include one glycerol molecule.
C) Fats have polar fatty acids.
D) Fats have nonpolar hydrocarbon chains.

___15) Fatty acids are -
A) composed of carbon, hydrogen, and oxygen in a 1:2:1 ratio.
B) composed of carbon, hydrogen, glycerol, and a phosphate group.
C) hydrophobic.
D) composed of four linked rings.

___16) Fatty acids with double bonds between some of their carbons are said to be -
A) unsaturated.
B) saturated.
C) completely hydrogenated.
D) monoglycerides.

___17) The development of atherosclerotic disease can result from a diet high in -
A) fiber.
B) protein.
C) saturated fats.
D) sugars.

___18) If you were to add olive oil to your food as part of a diet to lower your risk of atherosclerotic disease, you would use olive oil that -
A) is liquid at room temperature.
B) is hydrogenated.
C) is modified to be solid at room temperature.
D) has lard added to it.

___19) Which of the following statements about animal cell lipids is *false*?
A) Fats are a form of lipid that function to store energy.
B) Phospholipids are important components of cell membranes.
C) Many lipids function as enzymes.
D) Cholesterol is a type of lipid that is a component of cell membranes and steroid hormones.

___20) A phospholipid is composed of -
A) one fatty acid molecule linked to three glycerol molecules.
B) one glycerol molecule linked to three phosphate groups.
C) one fatty acid molecule linked to one glycerol molecule and two phosphate groups.
D) one glycerol molecule linked to one phosphate group and two fatty acids.

___21) Which of the following substances is a lipid?
A) DNA B) cellulose C) steroids D) enzymes

___22) A major type of lipid found in cell membranes is -
A) triglycerides. B) phospholipids. C) glycerol. D) waxes.

___23) Amino acids can be distinguished from one another by -
A) the number of R groups found on the amino acid molecules.
B) the chemical properties of their R groups.
C) the type of bond between the R group and the rest of the amino acid molecule.
D) the chemical properties of their amino and carboxyl groups.

___24) Proteins differ from one another because -
A) the peptide bonds linking amino acids differ from protein to protein.
B) the sequence of amino acids in the polypeptide chain differs from protein to protein.
C) each protein contains its own unique sequence of sugar molecules.
D) the number of nucleotides found in each protein varies from molecule to molecule.

___25) Glucose molecules are to starch as _____ are to proteins.
A) monosaccharides B) amino acids C) fatty acids D) oils

___26) Peptide bonds -
A) are used to form amino acids.
B) form between fatty acids.
C) are formed by a hydrolysis reaction.
D) link amino acids.

___27) Structural proteins -
A) include receptor molecules.
B) include hemoglobin.
C) are found in hair and tendons.
D) include ovalbumin, a protein found in egg white.

___28) A scientist suspects that the food in an ecosystem may have been contaminated with radioactive nitrogen over a period of months. Which of the following substances could be examined for radioactivity to test the hypothesis?
A) the cell walls of plants growing in the ecosystem
B) the hair produced by humans living in the ecosystem
C) the sugars produced during photosynthesis by plants growing in the ecosystem
D) the cholesterol in the cell membranes of organisms living in the ecosystem

___29) Which of the following characteristics of protein will remain intact if the protein is denatured?
A) the shape of the protein
B) the function of the protein
C) the number of amino acids in the protein
D) the binding properties of the protein

___30) The primary structure of a protein is -
A) an α helix or a pleated sheet.
B) the amino acid sequence of the polypeptide chain.
C) composed of two or more polypeptide chains.
D) maintained by hydrogen bonds.

___31) Which of the following is an example of secondary structure in a protein?
A) a particular amino acid sequence
B) an alpha helix
C) a globular shape
D) the joining of two polypeptide chains

___32) The tertiary structure of a polypeptide refers to -
A) its size.
B) the presence of pleated sheets.
C) the amino acids of which it is made.
D) the overall three-dimensional structure.

___33) A protein containing more than one polypeptide chain exhibits the _____ level of protein structure.
A) primary B) secondary C) tertiary D) quaternary

___34) How are genes used by cells to build proteins?
A) The genes in DNA direct the synthesis of an RNA molecule, which is used to build a protein.
B) The genes in RNA direct the synthesis of a DNA molecule, which is used to build a protein.
C) DNA is transcribed into an amino acid sequence.
D) The genes in RNA direct the synthesis of proteins directly.

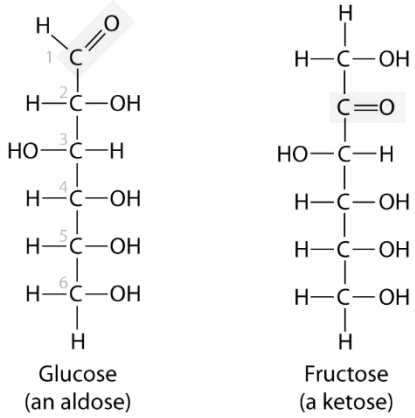
___35) Which of the following statements regarding nucleotides is *false*?
A) Nucleotides contain lipids.
B) Nucleotides contain sugar molecules.
C) Nucleotides can be linked together to form nucleic acids.
D) Nucleotides contain nitrogenous bases.

___36) Which of the following options correctly pairs a polymer and its monomer?
A) cellulose, amino acids
B) DNA, nucleotides
C) collagen, nucleic acids
D) RNA, ribose

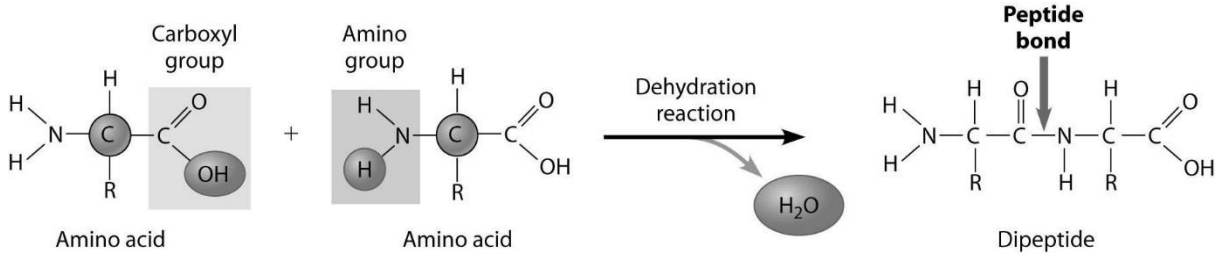
___37) DNA differs from RNA because DNA -
A) contains thymine in place of uracil.
B) consists of a single rather than a double polynucleotide strand.
C) contains the sugar ribose rather than the sugar deoxyribose.
D) contains phosphate groups not found in RNA.

___38) You work for a company that manufactures food products. A new "wonder food" is being distributed by a rival company. The researchers in your company determine that the "wonder food" contains only carbon, oxygen, and hydrogen. At this point, your researchers can say with certainty that the food -
A) includes proteins.
B) could only be made of triglycerides.
C) could only be made of carbohydrates.
D) does not include proteins or nucleic acids.

___39) These two molecules are structural isomers.
What is the difference between them?
A) the number of carbon atoms
B) the number of hydrogen atoms
C) the location of a double-bonded oxygen atom
D) Only one of them has a double bond between carbon atoms.



___40) How are these two amino acids attached together?



A) amino group to amino group
B) amino group to carboxylic acid group
C) carboxylic acid group to carboxylic acid group
D) through a hydrolysis reaction