CHAPTER 2 Chemical Components of Cells

CHEMICAL BONDS

2.1.a Review the properties that distinguish the chemistry of living things from the abiotic chemistry of solids, liquids, and gases.

2.1.b Distinguish between elements, atoms, ions, isotopes, molecules, and salts.

2.1.c State the location, charge, and relative size of protons, neutrons, and electrons and their numbers in an atom of carbon, hydrogen, oxygen, and nitrogen.

2.1.d Differentiate between atomic number and atomic weight and state how each is estimated.

2.1.e Express the concept of a mole and explain how to prepare a 100 mM solution.

2.1.f Relate how the behavior of atoms corresponds with their position in the periodic table and infer what this means for the chemical reactivity of the elements commonly found in living organisms.

2.1.g State the number of covalent bonds that can be formed by atoms of hydrogen, oxygen, nitrogen, and carbon and express how the electronic configuration of carbon, in particular, dictates the three-dimensional shape of organic molecules.

2.1.h Identify what determines the polarity of a chemical bond and summarize the consequences of this property for the solubility and hydrophobicity of a molecule or salt, as well as its ability to act as an acid or base.

2.1.i Recall the characteristics of a hydrophilic molecule.

2.1.j Distinguish between acids and bases and demonstrate how they cooperate to maintain the pH of cells.

2.1.k Differentiate between covalent and ionic bonds in terms of their electronic configuration, strength and stability, and their prevalence and role in biological systems.

2.1.l Contrast hydrogen bonds, electrostatic attractions, van der Waal's attractions, and the hydrophobic force in terms of how and when they form and the role they play in cell biology.

SMALL MOLECULES IN CELLS

2.2.a Distinguish between organic and inorganic compounds.

2.2.b Express how the chemical and physical properties of methyl groups ($-CH_3$), hydroxyl groups ($-OH$), carboxyl groups ($-COOH$), phosphate groups ($-PO_3^{2-}$), and amino groups ($-NH_2$) influence the behavior of molecules in which these groups typically occur.

2.2.c Illustrate how the processes of condensation and hydrolysis are central to the synthesis and breakdown of the large organic molecules of the cell from sets of smaller organic building blocks.

2.2.d Relate the different roles that sugars can play in the cell.

2.2.e Propose how a monosaccharide can form a ring structures in an aqueous solution.

2.2.f Evaluate the role that isomers play in biological systems.

2.2.g Define the terms fatty acid, steroid, phospholipid, and triacylglycerol and describe the structure, properties, and function of each.

2.2.h Summarize why the amphipathic nature of phospholipids is crucial for cell biology.

2.2.i Predict how the saturation of fatty acid tails affects the fluidity of cell membranes.

2.2.j Identify the features that all amino acids have in common.

2.2.k Summarize what makes amino acids chemically unique and categorize the 20 amino acids commonly found in proteins on the basis of their chemical properties.

2.2.l Express the difference between nucleotides and nucleosides.

2.2.m Contrast RNA and DNA and evaluate why these nucleic acids play different roles in cells.

2.2.n Outline the roles that phosphoanhydride, phosphodiester, and hydrogen bonds play in the actions of nucleotides and nucleic acids.

MACROMOLECULES IN CELLS

2.3.a Relate how the repetitive polymerization of monomers into polymers can yield macromolecules with diverse properties and functions.

2.3.b Assess the role that covalent and noncovalent bonds play in the three-dimensional conformation of macromolecules.

2.3.c Explain how weak, noncovalent bonds can lead to strong and specific associations between macromolecules or between an enzyme and its substrate.

2.3.d Review how investigators can experimentally differentiate between a macromolecule, such as a purified protein, and a loosely associated aggregate of heterogeneous, small organic molecules.

MULTIPLE CHOICE

1. Select the answer that BEST completes the following statement: Chemical reactions in living systems occur in an __________ environment, within a narrow range of temperatures.
   a. optimal
   b. organic
   c. extracellular
   d. aqueous

   ANS: D DIF: Easy REF: 2.1 OBJ: 2.1.a Review the properties that distinguish the chemistry of living things from the abiotic chemistry of solids, liquids, and gases. MSC: Remembering

2. Which subatomic particles contribute to the atomic number for any given element?
   a. protons

b. protons and neutrons
c. neutrons
d. protons and electrons

ANS: A DIF: Easy REF: 2.1 OBJ: 2.1.d Differentiate between atomic number and atomic weight and state how each is estimated. MSC: Remembering

3. Which subatomic particles contribute to the atomic mass for any given element?
   a. protons
   b. protons and neutrons
   c. neutrons
   d. protons and electrons

ANS: B DIF: Easy REF: 2.1 OBJ: 2.1.d Differentiate between atomic number and atomic weight and state how each is estimated. MSC: Remembering

4. Which subatomic particles can vary between isotopes of the same element, without changing the observed chemical properties?
   a. electrons
   b. protons and neutrons
   c. neutrons
   d. neutrons and electrons

ANS: C DIF: Easy REF: 2.1 OBJ: 2.1.b Distinguish between elements, atoms, ions, isotopes, molecules, and salts.
MSC: Remembering

5. Figure 2-5 depicts the structure of carbon. Use the information in the diagram to choose the correct atomic number and atomic weight, respectively, for an atom of carbon.

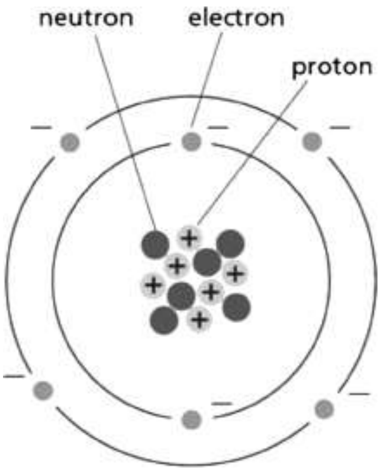

Figure 2-5

   a. 6; 12
   b. 12; 12
   c. 6; 18

d. 12; 6

ANS: A DIF: Easy REF: 2.1 OBJ: 2.1.d Differentiate between atomic number and atomic weight and state how each is estimated. | 2.1.c State the position, size and charge, of protons, neutrons, and electrons—and compute their relative numbers in an atom of carbon, hydrogen, oxygen, and nitrogen. MSC: Understanding

6. Carbon 14 is an unstable isotope of carbon that decays very slowly. Compared to the common, stable carbon 12 isotope, carbon 14 has two additional
   a. electrons.
   b. neutrons.
   c. protons.
   d. ions.

ANS: B DIF: Easy REF: 2.1 OBJ: 2.1.b Distinguish between elements, atoms, ions, isotopes, molecules, and salts.
MSC: Remembering

7. If the isotope ^{32}S has 16 protons and 16 neutrons, how many protons, neutrons, and electrons will the isotope ^{35}S have, respectively?
   a. 16; 20; 15
   b. 16; 19; 15
   c. 16; 19; 16
   d. 16; 19; 17

ANS: C DIF: Easy REF: 2.1 OBJ: 2.1.b Distinguish between elements, atoms, ions, isotopes, molecules, and salts.
MSC: Understanding

8. Avogadro's number was established as the total number of units (atoms or molecules) in a mole, and a mole of any substance is X grams of it, where X is equal to the substance's molecular weight. A standard unit, the mole, allows scientists to calculate concentrations of materials dissolved in solutions.
   Example: Sulfur has a molecular weight of 32. Therefore, 32 g of sulfur = 1 mole of sulfur = 6×10^{23} sulfur atoms.
   How many moles and atoms, respectively, are there in 120 grams of sulfur?
   a. 3.75; 6×10^{23}
   b. 32; 6×10^{23}
   c. 1.75; 1.05×10^{24}
   d. 3.75; 2.25×10^{24}

ANS: D DIF: Moderate REF: 2.1 OBJ: 2.1.e Express the concept of a mole and explain how to prepare a 100 mM solution. MSC: Applying

9. The first task you are assigned in your summer laboratory job is to prepare a concentrated NaOH stock solution. The molecular weight of NaOH is 40. How many grams of solid NaOH will you need to weigh out to obtain a 500 mL solution that has a concentration of 10 M?

a. 800 g
b. 200 g
c. 400 g
d. 160 g

ANS: B DIF: Moderate REF: 2.1 OBJ: 2.1.e Express the concept of a mole and explain how to prepare a 100 mM solution. MSC: Applying

10. You have a concentrated stock solution of 10 M NaOH and want to use it to produce a 150 mL solution of 3 M NaOH. What volume of water and stock solutions will you measure out to make this new solution?
    a. 135 mL of water; 15 mL of NaOH stock
    b. 115 mL of water; 35 mL of NaOH stock
    c. 100 mL of water; 50 mL of NaOH stock
    d. 105 mL of water; 45 mL of NaOH stock

    ANS: D DIF: Moderate REF: 2.1 OBJ: 2.1.e Express the concept of a mole and explain how to prepare a 100 mM solution. MSC: Applying

11. There are 90 naturally occurring elements on the earth, __________ of which compose 96% of the mass of living organisms.
    a. 4
    b. 6
    c. 7
    d. 8

    ANS: A DIF: Easy REF: 2.1 OBJ: 2.1.a Review the properties that distinguish the chemistry of living things from the abiotic chemistry of solids, liquids, and gases. MSC: Remembering

12. A covalent bond between two atoms is formed as a result of the
    a. sharing of electrons.
    b. loss of electrons from both atoms.
    c. loss of a proton from one atom.
    d. transfer of electrons from one atom to the other.

    ANS: A DIF: Easy REF: 2.1 OBJ: 2.1.k Differentiate between covalent and ionic bonds in terms of their electronic configuration, strength and stability, and their prevalence and role in biological systems. MSC: Remembering

13. An ionic bond between two atoms is formed as a result of the
    a. sharing of electrons.
    b. loss of electrons from both atoms.
    c. loss of a proton from one atom.
    d. transfer of electrons from one atom to the other.

    ANS: D DIF: Easy REF: 2.1 OBJ: 2.1.k Differentiate between covalent and ionic bonds in terms of their electronic configuration, strength and stability, and their prevalence and role in biological systems.

MSC: Remembering

14. Table 2-14 indicates the number and arrangement of electrons in the first four atomic electron shells for selected elements. On the basis of the information in the chart and what you know about atomic structure, which elements are chemically inert?

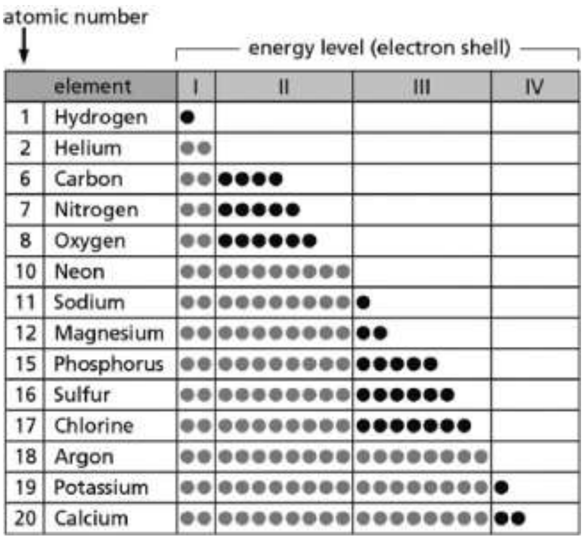

Table 2-14

a. carbon; sulfur
b. helium; neon
c. sodium; potassium
d. magnesium; calcium

ANS: B DIF: Easy REF: 2.1 OBJ: 2.1.f Relate how the behavior of atoms corresponds with their position in the periodic table and infer what this means for the chemical reactivity of the elements commonly found in living organisms.
MSC: Understanding

15. Table 2-14 indicates the number and arrangement of electrons in the first four atomic electron shells for selected elements. On the basis of the information in the chart and what you know about atomic structure, which elements will form ions with a net charge of +1 in solution?

atomic number ↓ energy level (electron shell)

	element	I	II	III	IV
1	Hydrogen	●			
2	Helium	●●			
6	Carbon	●●	●●●●		
7	Nitrogen	●●	●●●●●		
8	Oxygen	●●	●●●●●●		
10	Neon	●●	●●●●●●●●		
11	Sodium	●●	●●●●●●●●	●	
12	Magnesium	●●	●●●●●●●●	●●	
15	Phosphorus	●●	●●●●●●●●	●●●●●	
16	Sulfur	●●	●●●●●●●●	●●●●●●	
17	Chlorine	●●	●●●●●●●●	●●●●●●●	
18	Argon	●●	●●●●●●●●	●●●●●●●●	
19	Potassium	●●	●●●●●●●●	●●●●●●●●	●
20	Calcium	●●	●●●●●●●●	●●●●●●●●	●●

Table 2-14

a. carbon; sulfur
b. helium; neon
c. sodium; potassium
d. magnesium; calcium

ANS: C DIF: Easy REF: 2.1 OBJ: 2.1.f Relate how the behavior of atoms corresponds with their position in the periodic table and infer what this means for the chemical reactivity of the elements commonly found in living organisms. MSC: Understanding

16. Table 2-14 indicates the number and arrangement of electrons in the first four atomic electron shells for selected elements. On the basis of the information in the chart and what you know about atomic structure, which elements will form ions with a net charge of +2 in solution?

atomic number ↓ energy level (electron shell)

	element	I	II	III	IV
1	Hydrogen	●			
2	Helium	●●			
6	Carbon	●●	●●●●		
7	Nitrogen	●●	●●●●●		
8	Oxygen	●●	●●●●●●		
10	Neon	●●	●●●●●●●●		
11	Sodium	●●	●●●●●●●●	●	
12	Magnesium	●●	●●●●●●●●	●●	
15	Phosphorus	●●	●●●●●●●●	●●●●●	
16	Sulfur	●●	●●●●●●●●	●●●●●●	
17	Chlorine	●●	●●●●●●●●	●●●●●●●	
18	Argon	●●	●●●●●●●●	●●●●●●●●	
19	Potassium	●●	●●●●●●●●	●●●●●●●●	●
20	Calcium	●●	●●●●●●●●	●●●●●●●●	●●

Table 2-14

a. carbon; sulfur
b. helium; neon

c. sodium; potassium
d. magnesium; calcium

ANS: D DIF: Easy REF: 2.1 OBJ: 2.1.f Relate how the behavior of atoms corresponds with their position in the periodic table and infer what this means for the chemical reactivity of the elements commonly found in living organisms. MSC: Understanding

17. Table 2-14 indicates the number and arrangement of electrons in the first four atomic electron shells for selected elements. On the basis of the information in the chart and what you know about atomic structure, which elements form stable but reactive diatomic gases?

atomic number		energy level (electron shell)			
	element	I	II	III	IV
1	Hydrogen	●			
2	Helium	●●			
6	Carbon	●●	●●●●		
7	Nitrogen	●●	●●●●●		
8	Oxygen	●●	●●●●●●		
10	Neon	●●	●●●●●●●●		
11	Sodium	●●	●●●●●●●●	●	
12	Magnesium	●●	●●●●●●●●	●●	
15	Phosphorus	●●	●●●●●●●●	●●●●●	
16	Sulfur	●●	●●●●●●●●	●●●●●●	
17	Chlorine	●●	●●●●●●●●	●●●●●●●	
18	Argon	●●	●●●●●●●●	●●●●●●●●	
19	Potassium	●●	●●●●●●●●	●●●●●●●●	●
20	Calcium	●●	●●●●●●●●	●●●●●●●●	●●

Table 2-14

a. nitrogen; oxygen
b. helium; neon
c. sodium; potassium
d. magnesium; calcium

ANS: A
An oxygen atom with six outer electrons needs two more to attain a stable outer shell. This can be achieved by forming two covalent bonds with a second oxygen, as shown on the right. Similarly, a nitrogen atom needs three more electrons and makes three covalent bonds with another nitrogen atom.
DIF: Moderate REF: 2.1 OBJ: 2.1.f Relate how the behavior of atoms corresponds with their position in the periodic table and infer what this means for the chemical reactivity of the elements commonly found in living organisms.
MSC: Understanding

18. Which of the following factors DO NOT influence the length of a covalent bond?
a. the tendency of atoms to fill the outer electron shells
b. the attractive forces between negatively charged electrons and positively charged nuclei
c. the repulsive forces between the positively charged nuclei
d. the minimization of repulsive forces between the two nuclei by the cloud of shared electrons

ANS: A

The tendency to complete the outer electron shell is the reason covalent bonds form, but it does not address the length of the bond that is formed.

DIF: Difficult REF: 2.1 OBJ: 2.1.k Differentiate between covalent and ionic bonds in terms of their electronic configuration, strength and stability, and their prevalence and role in biological systems. MSC: Analyzing

19. Double covalent bonds are both shorter and stronger than single covalent bonds, but they also limit the geometry of the molecule because they
    a. create a new arrangement of electron shells.
    b. change the reactivity of the bonded atoms.
    c. limit the rotation of the bonded atoms.
    d. prevent additional bonds from being formed with the bonded atoms.

ANS: C DIF: Moderate REF: 2.1 OBJ: 2.1.k Differentiate between covalent and ionic bonds in terms of their electronic configuration, strength and stability, and their prevalence and role in biological systems. MSC: Understanding

20. Polar covalent bonds are formed when the electrons in the bond are not shared equally between the two nuclei. Which one of these molecules contains polar bonds?
    a. molecular oxygen
    b. methane
    c. propane
    d. water

ANS: D DIF: Easy REF: 2.1 OBJ: 2.1.h Identify what determines the polarity of a chemical bond and summarize the consequences of this property for the solubility and hydrophobicity of a molecule or salt, as well as its ability to act as an acid or base. MSC: Understanding

21. Carbon atoms can form double bonds with other carbon atoms, nitrogen atoms, and oxygen atoms. Double bonds can have important consequences for biological molecules because they are __________ compared to single covalent bonds.
    a. long
    b. rigid with respect to rotation
    c. weak
    d. unstable

ANS: B DIF: Easy REF: 2.1 OBJ: 2.1.g Calculate the number of bonds that can be formed by atoms of hydrogen, oxygen, nitrogen, and carbon—and express how the electronic configuration of carbon, in particular, dictates the three-dimensional shape of organic molecules. MSC: Remembering

22. Which combination of answers best completes the following statement: When atoms are held together by __________ __________, they are typically referred to as __________.
    a. hydrogen bonds; molecules
    b. ionic interactions; salts

c. ionic interactions; molecules
d. double bonds; nonpolar

ANS: B DIF: Easy REF: 2.1 OBJ: 2.1.k Differentiate between covalent and ionic bonds in terms of their electronic configuration, strength and stability, and their prevalence and role in biological systems. MSC: Understanding

23. Although covalent bonds are 10–100 times stronger than noncovalent interactions, many biological processes depend upon the number and type of noncovalent interactions between molecules. Which of the noncovalent interactions below will contribute most to the strong and specific binding of two molecules, such as a pair of proteins?
a. electrostatic attractions
b. hydrogen bonds
c. hydrophobic interactions
d. van der Waals attractions

ANS: A DIF: Easy REF: 2.1 OBJ: 2.1.l Contrast hydrogen bonds, electrostatic attractions, van der Waal's attractions, and the hydrophobic force in terms of how and when they form and the role they play in cell biology.
MSC: Analyzing

24. Which of the following expressions accurately describes the calculation of pH?
a. $pH = -\log_{10}[H^+]$
b. $pH = \log_{10}[H^+]$
c. $pH = -\log_{2}[H^+]$
d. $pH = -\log_{10}[OH^-]$

ANS: A DIF: Easy REF: 2.1 OBJ: 2.1.j Distinguish between acids and bases and demonstrate how they cooperate to maintain the pH of cells. MSC: Remembering

25. The pH of an aqueous solution is an indication of the concentration of available protons. However, you should not expect to find lone protons in solution; rather, the proton is added to a water molecule to form a/an __________ ion.
a. hydroxide
b. ammonium
c. chloride
d. hydronium

ANS: D DIF: Moderate REF: 2.1 OBJ: 2.1.j Distinguish between acids and bases and demonstrate how they cooperate to maintain the pH of cells. MSC: Understanding

26. Larger molecules have hydrogen-bonding networks that contribute to specific, high-affinity binding. Smaller molecules such as urea can also form these networks. How many hydrogen bonds can urea (Figure 2-26) form if dissolved in water?

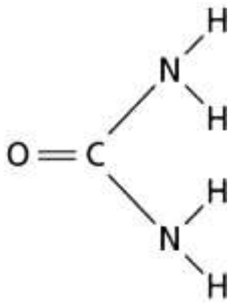

Figure 2-26

a. 6
b. 5
c. 3
d. 4

ANS: A

Urea can form at least six hydrogen bonds in water: two from the oxygen atom and one from each hydrogen atom.

DIF: Easy REF: 2.1 OBJ: 2.1.g Calculate the number of bonds that can be formed by atoms of hydrogen, oxygen, nitrogen, and carbon—and express how the electronic configuration of carbon, in particular, dictates the three-dimensional shape of organic molecules. MSC: Applying

27. Aromatic carbon compounds such as benzene are planar and very stable. Double-bond character extends around the entire ring, which is why it is often drawn as a hexagon with a circle inside. This characteristic is caused by electron

a. resonance.
b. pairing.
c. partial charge.
d. stacking.

ANS: A DIF: Easy REF: 2.1 OBJ: 2.1.c State the position, size and charge, of protons, neutrons, and electrons—and compute their relative numbers in an atom of carbon, hydrogen, oxygen, and nitrogen. MSC: Understanding

28. __________ play an important role in organizing lipid molecules with long hydrocarbon tails into biological membranes.

a. Hydrogen bonds
b. Ionic bonds
c. Hydrophobic forces
d. Van der Waals attractions

ANS: C DIF: Easy REF: 2.1 OBJ: 2.1.l Contrast hydrogen bonds, electrostatic attractions, van der Waal’s attractions, and the hydrophobic force in terms of how and when they form and the role they play in cell biology.

MSC: Understanding

29. Substances that release protons when they dissolve in water are acids. Which of the following household substance is acidic?
    a. coffee
    b. bleach
    c. hand soap
    d. water

    ANS: A DIF: Easy REF: 2.1 OBJ: 2.1.j Distinguish between acids and bases and demonstrate how they cooperate to maintain the pH of cells. MSC: Understanding

30. Cells contain buffers that help maintain a neutral pH. Which of the following statements is not relevant to how buffers work?
    a. Buffers are mixtures of weak acids and bases.
    b. Buffers can accept protons from acids.
    c. Buffers can donate protons to bases.
    d. Buffers catalyze oxidation-reduction reactions..

    ANS: D DIF: Easy REF: 2.1 OBJ: 2.1.j Distinguish between acids and bases and demonstrate how they cooperate to maintain the pH of cells. MSC: Analyzing

31. Which of the following monomer building blocks is necessary to assemble selectively permeable boundaries around and inside cells?
    a. sugars
    b. fatty acids
    c. amino acids
    d. nucleotides

    ANS: B DIF: Easy REF: 2.2 OBJ: 2.2.h Summarize why the amphipathic nature of fatty acids and phospholipids is crucial for cell biology. MSC: Remembering

32. There is incredible chemical diversity even in the simplest of cells. A typical bacterial cell contains more than 6000 different types of molecules. From the list below, select the class of molecules with the largest number of different types.
    a. nucleotides and precursors
    b. sugars and precursors
    c. amino acids and precursors
    d. fatty acids and precursors

    ANS: B DIF: Easy REF: 2.2 OBJ: 2.2.d Relate the different roles that sugars can play in the cell. MSC: Remembering

33. Which of the following are examples of isomers?
    a. glucose and galactose
    b. alanine and glycine
    c. adenine and guanine
    d. glycogen and cellulose

ANS: A

Glucose and galactose are both six-carbon sugars and thus both have the formula $C_6H_{12}O_6$. They are therefore isomers of each other. Adenine and guanine are bases containing different numbers of nitrogen and oxygen atoms. Glycogen and cellulose are different polymers of glucose. Alanine and glycine are amino acids with quite different side chains: a methyl group and a hydrogen atom, respectively.

DIF: Difficult REF: 2.2 OBJ: 2.2.f Evaluate the role that isomers play in biological systems. MSC: Understanding

34. Oligosaccharides are short sugar polymers that can become covalently linked to proteins and lipids through condensation reactions. These modified proteins and lipids are called glycoproteins and glycolipids, respectively. Within a protein, which of the amino acids (shown in Figure 2-34) is the most probable target for this type of modification?

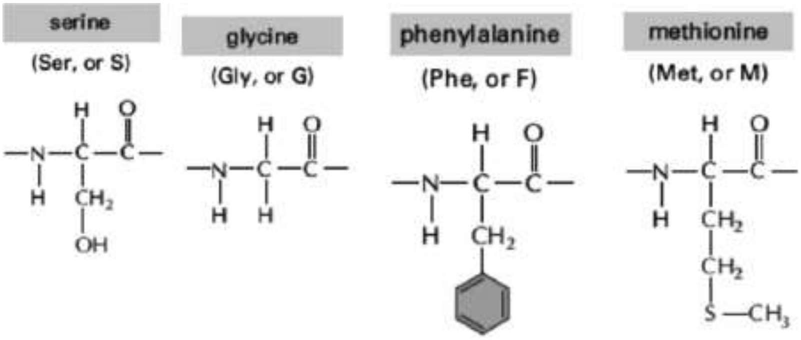

Figure 2-34

a. serine
b. glycine
c. phenylalanine
d. methionine

ANS: A DIF: Moderate REF: 2.2 OBJ: 2.2.k Summarize what makes amino acids chemically unique and categorize the 20 amino acids commonly found in proteins on the basis of their chemical properties. MSC: Applying

35. Many types of cells have stores of lipids in their cytoplasm, usually seen as fat droplets. What is the lipid most commonly found in these droplets?

a. cholesterol
b. palmitic acid
c. isoprene
d. triacylglycerol

ANS: D DIF: Easy REF: 2.2 OBJ: 2.2.g Define the terms fatty acid, steroid, phospholipid, and triacylglycerol and describe the structure, properties, and function of each. MSC: Remembering

36. Choose the answer that best fits the following statement: Cholesterol is an essential component of biological membranes. Although it is much smaller than the typical phospholipids and glycolipids in the membrane, it

is a/an __________ molecule, having both hydrophilic and hydrophobic regions.

a. polar
b. oxygen-containing
c. hydrophobic
d. amphipathic

ANS: D DIF: Easy REF: 2.2 OBJ: 2.2.g Define the terms fatty acid, steroid, phospholipid, and triacylglycerol and describe the structure, properties, and function of each. | 2.2.h Summarize why the amphipathic nature of phospholipids is crucial for cell biology. MSC: Understanding

37. Most types of molecules in the cell have asymmetric (chiral) carbons. Consequently there is the potential to have two different molecules that look much the same but are mirror images of each other and therefore not equivalent. These special types of isomers are called stereoisomers. Which of the four carbons circled in Figure 2-37 is the asymmetric carbon that determines whether the amino acid (threonine in this case) is a D or an L stereoisomer?

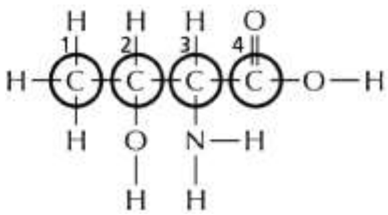

Figure 2-37

a. 1
b. 2
c. 3
d. 4

ANS: C
Two of the carbon atoms of threonine are asymmetric (numbered 2 and 3 in Figure 2-37) but by convention it is the α-carbon (number 3) that determines whether the amino acid is the D or L isomer.
DIF: Difficult REF: 2.2 OBJ: 2.2.f Evaluate the role that isomers play in biological systems. MSC: Applying

38. The amino acids glutamine and glutamic acid are shown in Figure 2-38. They differ only in the structure of part of their side chains (circled). At pH_7, what type of interactions are possible for glutamic acid but not for glutamine?

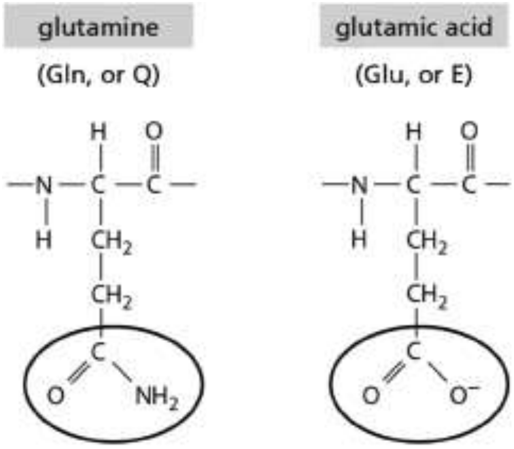

Figure 2-38

a. ionic bonds
b. hydrogen bonds
c. van der Waals interactions
d. covalent bonds

ANS: A DIF: Easy REF: 2.2 OBJ: 2.2.k Summarize what makes amino acids chemically unique and categorize the 20 amino acids commonly found in proteins on the basis of their chemical properties. MSC: Applying

39. Cells require one particular monosaccharide as a starting material to synthesize nucleotide building blocks. Which of the monosaccharides below fills this important role?
    a. glucose
    b. fructose
    c. ribulose
    d. ribose

ANS: D DIF: Easy REF: 2.2 OBJ: 2.2.d Relate the different roles that sugars can play in the cell. MSC: Remembering

40. DNA and RNA are different types of nucleic acid polymer. Which of the following is true of DNA but NOT true of RNA?
    a. It contains uracil.
    b. It contains thymine.
    c. It is single-stranded.
    d. It has 5′-to-3′ directionality.

ANS: C DIF: Easy REF: 2.2 OBJ: 2.2.m Contrast RNA and DNA and evaluate why these nucleic acids play different roles in cells. MSC: Remembering

41. The variety and arrangement of chemical groups on monomer subunits contribute to the conformation, reactivity, and surface of the macromolecule into which they become incorporated. What type of chemical group is circled on the nucleotide shown in Figure 2-41?

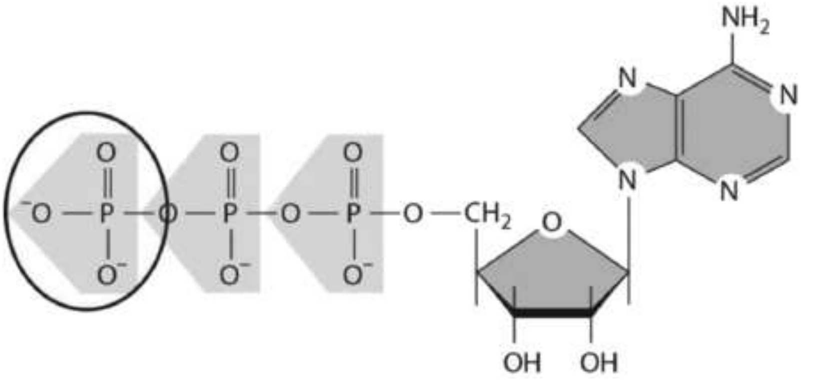

Figure 2-41

a. pyrophosphate
b. phosphoryl
c. carbonyl
d. carboxyl

ANS: B DIF: Easy REF: 2.2 OBJ: 2.2.n Outline the roles that phosphoanhydride, phosphodiester, and hydrogen bonds play in the actions of nucleotides and nucleic acids. MSC: Remembering

42. Both DNA and RNA are synthesized by covalently linking a nucleoside triphosphate to the previous nucleotide, constantly adding to a growing chain. In the case of DNA, the new strand becomes part of a stable helix. The two strands are complementary in sequence and antiparallel in directionality. What is the principal force that holds these two strands together?
    a. ionic interactions
    b. hydrogen bonds
    c. covalent bonds
    d. van der Waals interactions

    ANS: B DIF: Easy REF: 2.3 OBJ: 2.3.b Assess the role that covalent and noncovalent bonds play in the three-dimensional conformation of macromolecules. MSC: Remembering

43. Each nucleotide in DNA and RNA has an aromatic base. What is the principal force that keeps the bases in a polymer from interacting with water?
    a. hydrophobic interactions
    b. hydrogen bonds
    c. covalent bonds
    d. van der Waals interactions

    ANS: A DIF: Easy REF: 2.3 OBJ: 2.3.b Assess the role that covalent and noncovalent bonds play in the three-dimensional conformation of macromolecules. MSC: Remembering

44. Because there are four different monomer building blocks that can be used to assemble RNA polymers, the number of possible sequence combinations that can be created for an RNA molecule made of 100 nucleotides is
    a. 100^4.

b. 4^{100}.
c. 4 × 100.
d. 100/4.

ANS: B DIF: Easy REF: 2.3 OBJ: 2.3.a Relate how the repetitive polymerization of monomers into polymers can yield macromolecules with diverse properties and functions. MSC: Applying

45. There are 20^{100} different possible sequence combinations for a protein chain with 100 amino acids. In addition to the amino acid sequence of the protein, what other factors INCREASE the potential for diversity in these macromolecules?
a. free rotation around single bonds during synthesis
b. noncovalent interactions sampled as protein folds
c. the directionality of amino acids being added
d. the planar nature of the peptide bond

ANS: B DIF: Easy REF: 2.3 OBJ: 2.3.a Relate how the repetitive polymerization of monomers into polymers can yield macromolecules with diverse properties and functions. MSC: Analyzing

46. Macromolecules in the cell can often interact transiently as a result of noncovalent interactions. These weak interactions also produce stable, highly specific interactions between molecules. Which of the factors below is the most significant in determining whether the interaction will be transient or stable?
a. the size of each molecule
b. the concentration of each molecule
c. the rate of synthesis
d. surface complementarity between molecules

ANS: D DIF: Easy REF: 2.3 OBJ: 2.3.c Explain how weak, noncovalent bonds can lead to strong and specific associations between macromolecules or between an enzyme and its substrate. MSC: Understanding

47. Table 2-14 indicates the number and arrangement of electrons in the first four atomic electron shells for selected elements. On the basis of the information in the chart and what you know about atomic structure, which elements form stable but reactive diatomic gases?

atomic number		energy level (electron shell)			
	element	I	II	III	IV
1	Hydrogen	●			
2	Helium	●●			
6	Carbon	●●	●●●●		
7	Nitrogen	●●	●●●●●		
8	Oxygen	●●	●●●●●●		
10	Neon	●●	●●●●●●●●		
11	Sodium	●●	●●●●●●●●	●	
12	Magnesium	●●	●●●●●●●●	●●	
15	Phosphorus	●●	●●●●●●●●	●●●●●	
16	Sulfur	●●	●●●●●●●●	●●●●●●	
17	Chlorine	●●	●●●●●●●●	●●●●●●●	
18	Argon	●●	●●●●●●●●	●●●●●●●●	
19	Potassium	●●	●●●●●●●●	●●●●●●●●	●
20	Calcium	●●	●●●●●●●●	●●●●●●●●	●●

Table 2-14

a. nitrogen; oxygen
b. helium; neon
c. sodium; potassium
d. magnesium; calcium

ANS: A

An oxygen atom with six outer electrons needs two more to attain a stable outer shell. This can be achieved by forming two covalent bonds with a second oxygen, as shown on the right. Similarly, a nitrogen atom needs three more electrons and makes three covalent bonds with another nitrogen atom.

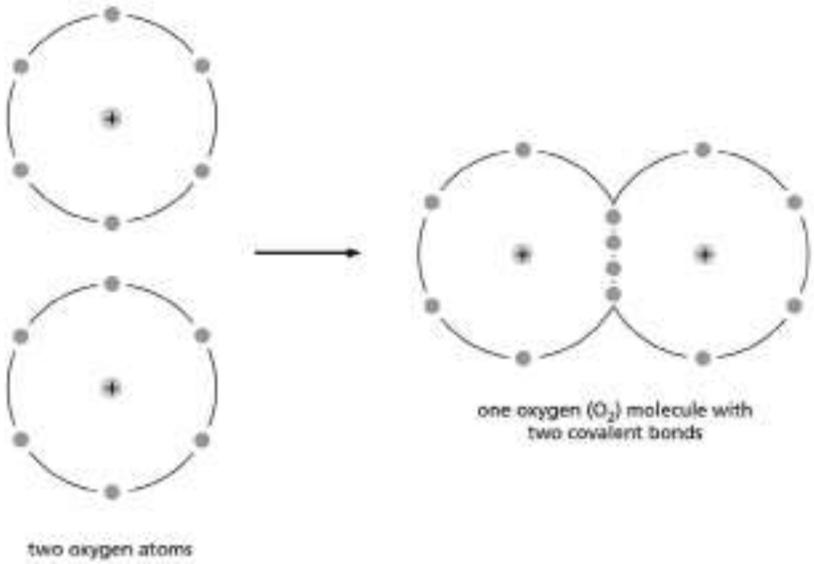

Figure 2-47A

DIF: Moderate REF: 2.1 OBJ: 2.1.f Relate how the behavior of atoms corresponds with their position in the periodic table and infer what this means for the chemical reactivity of the elements commonly found in living organisms.

MSC: Understanding

MATCHING

1. Oxygen, hydrogen, carbon, and nitrogen atoms are enriched in the cells and tissues of living organisms. The covalent bond geometries for these atoms influence the structure of larger biomolecules. Match the elements on the left with the bond geometries shown in Figure 2-48.

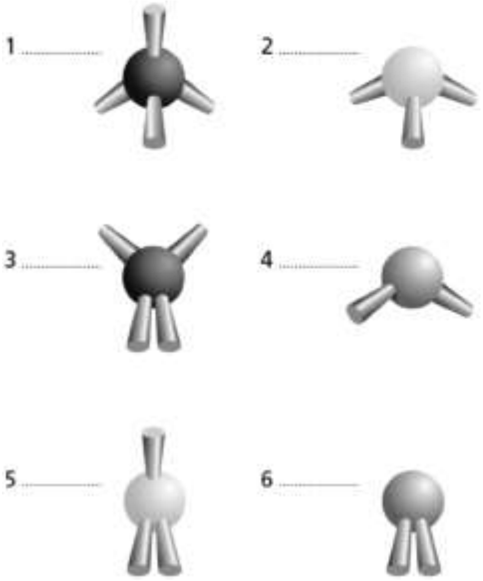

Figure 2-48

A. oxygen
B. carbon
C. nitrogen

1. ANS: B DIF: Easy REF: 2.1 OBJ: 2.1.g Calculate the number of bonds that can be formed by atoms of hydrogen, oxygen, nitrogen, and carbon—and express how the electronic configuration of carbon, in particular, dictates the three-dimensional shape of organic molecules. MSC: Understanding
2. ANS: C DIF: Easy REF: 2.1 OBJ: 2.1.g Calculate the number of bonds that can be formed by atoms of hydrogen, oxygen, nitrogen, and carbon—and express how the electronic configuration of carbon, in particular, dictates the three-dimensional shape of organic molecules. MSC: Understanding
3. ANS: B DIF: Easy REF: 2.1 OBJ: 2.1.g Calculate the number of bonds that can be formed by atoms of hydrogen, oxygen, nitrogen, and carbon—and express how the electronic configuration of carbon, in particular, dictates the three-dimensional shape of organic molecules. MSC: Understanding
4. ANS: A DIF: Easy REF: 2.1 OBJ: 2.1.g Calculate the number of bonds that can be formed by atoms of hydrogen, oxygen, nitrogen, and carbon—and express how the electronic configuration of carbon, in particular, dictates the three-dimensional shape of organic molecules. MSC: Understanding
5. ANS: C DIF: Easy REF: 2.1 OBJ: 2.1.g Calculate the number of bonds that can be formed by atoms of hydrogen, oxygen, nitrogen, and carbon—and express how the electronic configuration of carbon, in particular, dictates the three-dimensional shape of organic molecules. MSC: Understanding
6. ANS: A DIF: Easy REF: 2.1 OBJ: 2.1.g Calculate the number of bonds that can be formed by atoms of

hydrogen, oxygen, nitrogen, and carbon—and express how the electronic configuration of carbon, in particular, dictates the three-dimensional shape of organic molecules. MSC: Understanding

2. Indicate whether the molecules below are inorganic (A) or organic (B).
    1. glucose
    2. ethanol
    3. sodium chloride
    4. water
    5. cholesterol
    6. adenosine
    7. calcium
    8. glycine
    9. oxygen
    10. iron
    11. phospholipid

    1. ANS: B DIF: Easy REF: 2.2 OBJ: 2.2.a Distinguish between organic and inorganic compounds. MSC: Understanding
    2. ANS: B DIF: Easy REF: 2.2 OBJ: 2.2.a Distinguish between organic and inorganic compounds. MSC: Understanding
    3. ANS: A DIF: Easy REF: 2.2 OBJ: 2.2.a Distinguish between organic and inorganic compounds. MSC: Understanding
    4. ANS: A DIF: Easy REF: 2.2 OBJ: 2.2.a Distinguish between organic and inorganic compounds. MSC: Understanding
    5. ANS: B DIF: Easy REF: 2.2 OBJ: 2.2.a Distinguish between organic and inorganic compounds. MSC: Understanding
    6. ANS: B DIF: Easy REF: 2.2 OBJ: 2.2.a Distinguish between organic and inorganic compounds. MSC: Understanding
    7. ANS: A DIF: Easy REF: 2.2 OBJ: 2.2.a Distinguish between organic and inorganic compounds. MSC: Understanding
    8. ANS: B DIF: Easy REF: 2.2 OBJ: 2.2.a Distinguish between organic and inorganic compounds. MSC: Understanding
    9. ANS: A DIF: Easy REF: 2.2 OBJ: 2.2.a Distinguish between organic and inorganic compounds. MSC: Understanding
    10. ANS: A DIF: Easy REF: 2.2 OBJ: 2.2.a Distinguish between organic and inorganic compounds. MSC: Understanding
    11. ANS: B DIF: Easy REF: 2.2 OBJ: 2.2.a Distinguish between organic and inorganic compounds. MSC:

Understanding

3. On the phospholipid molecule in Figure 2-50, label each numbered line with the correct term selected from the list below.

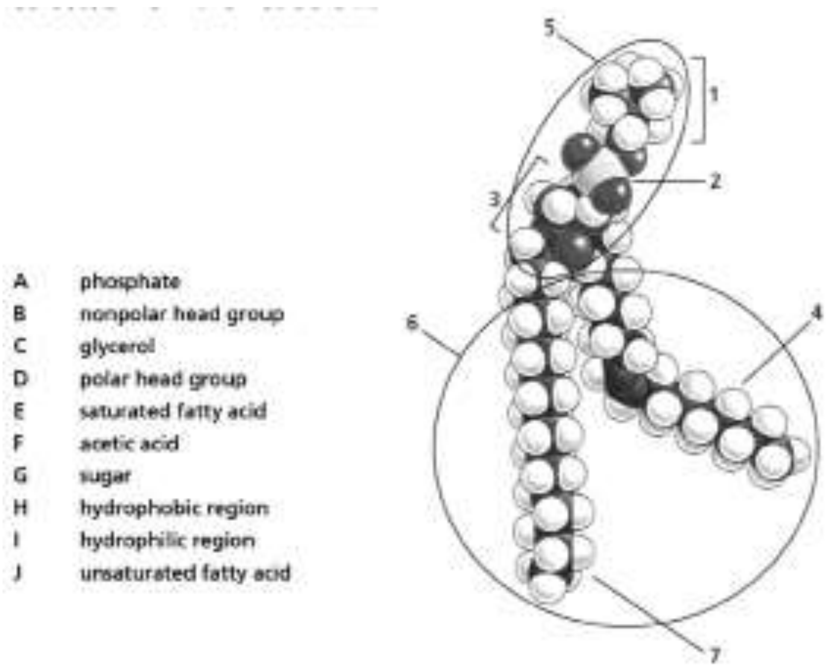

Figure 2-50

1. ANS: D DIF: Easy REF: 2.2 OBJ: 2.2.g Define the terms fatty acid, steroid, phospholipid, and triacylglycerol and describe the structure, properties, and function of each. MSC: Remembering
2. ANS: A DIF: Easy REF: 2.2 OBJ: 2.2.g Define the terms fatty acid, steroid, phospholipid, and triacylglycerol and describe the structure, properties, and function of each. MSC: Remembering
3. ANS: C DIF: Easy REF: 2.2 OBJ: 2.2.g Define the terms fatty acid, steroid, phospholipid, and triacylglycerol and describe the structure, properties, and function of each. MSC: Remembering
4. ANS: J DIF: Easy REF: 2.2 OBJ: 2.2.g Define the terms fatty acid, steroid, phospholipid, and triacylglycerol and describe the structure, properties, and function of each. MSC: Remembering
5. ANS: I DIF: Easy REF: 2.2 OBJ: 2.2.g Define the terms fatty acid, steroid, phospholipid, and triacylglycerol and describe the structure, properties, and function of each. MSC: Remembering
6. ANS: H DIF: Easy REF: 2.2 OBJ: 2.2.g Define the terms fatty acid, steroid, phospholipid, and triacylglycerol and describe the structure, properties, and function of each. MSC: Remembering
7. ANS: E DIF: Easy REF: 2.2 OBJ: 2.2.g Define the terms fatty acid, steroid, phospholipid, and triacylglycerol and describe the structure, properties, and function of each. MSC: Remembering

4. Match each term related to the structure of nucleic acids (A–I) with one of the descriptions provided.
   A. base
   B. glycosidic bond

C. nucleoside
D. nucleotide
E. phosphoanhydride bond
F. phosphoester bond
G. ribose
H. phosphodiester bond
I. deoxyribose

1. ____ the linkage between two nucleotides
2. ____ the linkage between the 5′ sugar hydroxyl and a phosphate group
3. ____ the nitrogen-containing aromatic ring
4. ____ five-carbon sugar found in DNA
5. ____ sugar unit linked to a base
6. ____ linkage between the sugar and the base
7. ____ linkages between phosphate groups
8. ____ sugar linked to a base and a phosphate
9. ____ five-carbon sugar found in RNA

1. ANS: H DIF: Moderate REF: 2.2 OBJ: 2.2.l Express the difference between nucleotides and nucleosides. | 2.2.m Contrast RNA and DNA and evaluate why these nucleic acids play different roles in cells. | 2.2.n Outline the roles that phosphoanhydride, phosphodiester, and hydrogen bonds play in the actions of nucleotides and nucleic acids. MSC: Analyzing

2. ANS: F DIF: Moderate REF: 2.2 OBJ: 2.2.l Express the difference between nucleotides and nucleosides. | 2.2.m Contrast RNA and DNA and evaluate why these nucleic acids play different roles in cells. | 2.2.n Outline the roles that phosphoanhydride, phosphodiester, and hydrogen bonds play in the actions of nucleotides and nucleic acids. MSC: Analyzing

3. ANS: A DIF: Moderate REF: 2.2 OBJ: 2.2.l Express the difference between nucleotides and nucleosides. | 2.2.m Contrast RNA and DNA and evaluate why these nucleic acids play different roles in cells. | 2.2.n Outline the roles that phosphoanhydride, phosphodiester, and hydrogen bonds play in the actions of nucleotides and nucleic acids. MSC: Analyzing

4. ANS: I DIF: Moderate REF: 2.2 OBJ: 2.2.l Express the difference between nucleotides and nucleosides. | 2.2.m Contrast RNA and DNA and evaluate why these nucleic acids play different roles in cells. | 2.2.n Outline the roles that phosphoanhydride, phosphodiester, and hydrogen bonds play in the actions of nucleotides and nucleic acids. MSC: Analyzing

5. ANS: C DIF: Moderate REF: 2.2 OBJ: 2.2.l Express the difference between nucleotides and nucleosides. | 2.2.m Contrast RNA and DNA and evaluate why these nucleic acids play different roles in cells. | 2.2.n Outline the roles that phosphoanhydride, phosphodiester, and hydrogen bonds play in the actions of nucleotides and nucleic acids. MSC: Analyzing

6. ANS: B DIF: Moderate REF: 2.2 OBJ: 2.2.l Express the difference between nucleotides and nucleosides. | 2.2.m Contrast RNA and DNA and evaluate why these nucleic acids play different roles in

cells. | 2.2.n Outline the roles that phosphoanhydride, phosphodiester, and hydrogen bonds play in the actions of nucleotides and nucleic acids. MSC: Analyzing

7. ANS: E DIF: Moderate REF: 2.2 OBJ: 2.2.l Express the difference between nucleotides and nucleosides. | 2.2.m Contrast RNA and DNA and evaluate why these nucleic acids play different roles in cells. | 2.2.n Outline the roles that phosphoanhydride, phosphodiester, and hydrogen bonds play in the actions of nucleotides and nucleic acids. MSC: Analyzing
8. ANS: D DIF: Moderate REF: 2.2 OBJ: 2.2.l Express the difference between nucleotides and nucleosides. | 2.2.m Contrast RNA and DNA and evaluate why these nucleic acids play different roles in cells. | 2.2.n Outline the roles that phosphoanhydride, phosphodiester, and hydrogen bonds play in the actions of nucleotides and nucleic acids. MSC: Analyzing
9. ANS: G DIF: Moderate REF: 2.2 OBJ: 2.2.l Express the difference between nucleotides and nucleosides. | 2.2.m Contrast RNA and DNA and evaluate why these nucleic acids play different roles in cells. | 2.2.n Outline the roles that phosphoanhydride, phosphodiester, and hydrogen bonds play in the actions of nucleotides and nucleic acids. MSC: Analyzing

SHORT ANSWER

1. Indicate whether the statements below are TRUE or FALSE. If a statement is false, explain why it is false.
   A. The chemistry of life is carried out and coordinated primarily by the action of small molecules.
   B. Carbon-based compounds make up the vast majority of molecules found in cells.
   C. The chemical reactions in living systems are loosely regulated, allowing for a wide range of products and more rapid evolution.

   ANS:
   A. False. Although small molecules are important in many processes, the chemical reactions in living systems are regulated by the coordinated action of large polymeric molecules.
   B. True
   C. False. The chemical reactions in living systems are very tightly controlled, ensuring that events occur at the proper time and at the proper location inside the cell.

   DIF: Easy REF: 2.1 OBJ: 2.1.a Review the properties that distinguish the chemistry of living things from the abiotic chemistry of solids, liquids, and gases. MSC: Evaluating

2. A. If 0.5 mole of glucose weighs 90 g, what is the molecular mass of glucose?
   B. How much glucose do you have to add to water to produce 1 liter of a 0.25 M solution of glucose?
   C. How many molecules are there in 1 mole of glucose?

   ANS:
   A. 180 daltons. A mole of a substance has a mass equivalent to its molecular weight expressed in grams.
   B. 45 g/L
   C. 6×10^{23} molecules

   DIF: Moderate REF: 2.1 OBJ: 2.1.e Express the concept of a mole and explain how to prepare a 100 mM solution.

MSC: Applying

3. You explain to a friend what you have learned about Avogadro's number. Your friend thinks the number is so large that he doubts there is even a mole of living cells on the Earth. You have recently heard that there are about 50 trillion (5×10^{13}) human cells in each adult human body and that each human body carries more bacterial cells (the microbiome) than human cells, and the human population is approximately 7.6 billion (7.6×10^{9}). Armed with this information, you bet your friend $5 that there is more than a mole of cells on Earth. Write out the calculation that proves you are correct.

ANS: Avogadro's number, or 6×10^{23}, is the number of atoms or molecules in a mole. If you multiply the number of people on Earth by the number of cells in the human body, then double it to account for the bacteria, you will calculate: $(7 \times 10^{9}) \times (1 \times 10^{14}) = 7 \times 10^{23}$. Thus, even when only considering the human population and the associated microbial populations, you can estimate more than a mole of living cells on Earth. You win $5.

DIF: Difficult REF: 2.1 OBJ: 2.1.e Express the concept of a mole and explain how to prepare a 100 mM solution.

MSC: Applying

4. Indicate whether the statements below are TRUE or FALSE. If a statement is false, explain why it is false.
   A. Electron shells fill discrete regions around the nucleus of the atom and limit the number of electrons that can occupy a specific orbit.
   B. H, C, O, and N are the most common elements in biological molecules because they are the most stable.
   C. Some atoms are more stable when they lose one or two electrons, even though this means they will have a net positive charge.

ANS:

A. True

B. False. H, C, N, and O are the most common elements in biological molecules because their outer shells are unfilled, making them highly reactive.

C. True

DIF: Easy REF: 2.1 OBJ: 2.1.a Review the properties that distinguish the chemistry of living things from the abiotic chemistry of solids, liquids, and gases. | 2.1.b Distinguish between elements, atoms, ions, isotopes, molecules, and salts.

MSC: Evaluating

5. For each of the following sentences, fill in the blanks with the best word or phrase selected from the list below. Not all words or phrases will be used; each word or phrase should be used only once.

charge	length	polar
covalent	molecule	salt
double bond	noncovalent	single bond
ionic	nonpolar	weight

Whereas ionic bonds form a/an __________, covalent bonds between atoms form a/an __________. These covalent bonds have a characteristic bond __________ and become stronger and more rigid when two electrons are shared in a/an __________. Equal sharing of electrons yields a/an __________ covalent bond. If one atom participating in the bond has a stronger affinity for the electron, this produces a partial negative charge on one atom and a partial positive charge on the other. These __________ covalent bonds should not be confused with the weaker __________ bonds that are critical for the three-dimensional structure of biological molecules and for interactions between these molecules.

ANS: Whereas ionic bonds form a **salt**, covalent bonds between atoms form a **molecule**. These covalent bonds have a characteristic bond **length** and become stronger and more rigid when two electrons are shared in a **double bond**. Equal sharing of electrons yields a **nonpolar** covalent bond. If one atom participating in the bond has a stronger affinity for the electron, this produces a partial negative charge on one atom and a partial positive charge on the other. These **polar** covalent bonds should not be confused with the weaker **noncovalent** bonds that are critical for the three-dimensional structure of biological molecules and for interactions between these molecules.

DIF: Easy REF: 2.1 OBJ: 2.1.k Differentiate between covalent and ionic bonds in terms of their electronic configuration, strength and stability, and their prevalence and role in biological systems. MSC: Understanding

6. Indicate whether the statements below are TRUE or FALSE. If a statement is false, explain why it is false.
   A. Electrons are constantly moving around the nucleus of the atom, but they can move only in discrete regions.
   B. There is no limit to the number of electrons that can occupy the fourth electron shell.
   C. Atoms with unfilled outer electron shells are especially stable and are therefore less reactive.

   ANS:
   A. True
   B. False. The fourth electron shell has the capacity to hold 18 electrons.
   C. False. Atoms that have their outer electron shells filled are the most stable and least reactive. Atoms with unfilled outer shells are more reactive because they tend to share or transfer electrons to fill and therefore stabilize the outer shell.

   DIF: Easy REF: 2.1 OBJ: 2.1.k Differentiate between covalent and ionic bonds in terms of their electronic configuration, strength and stability, and their prevalence and role in biological systems. MSC: Evaluating

7. Table 2-14 indicates the number and arrangement of electrons in the first four atomic electron shells for selected elements. Use the information in the table to fill in the blanks for A–E. There may be more than one answer for each.

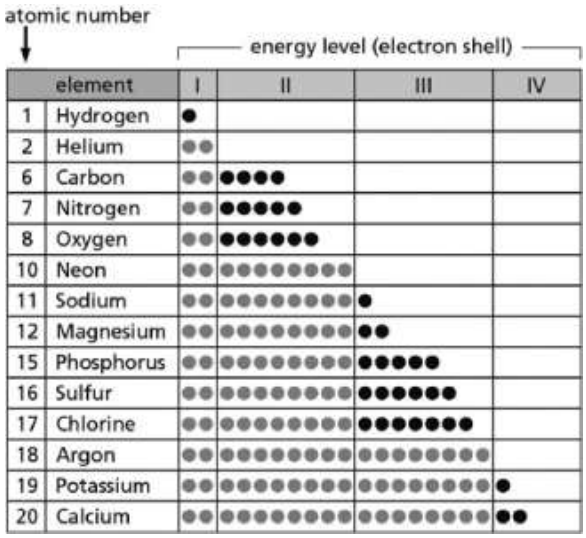

Table 2-14

A. __________ are chemically inert.

B. __________ form ions with a net charge of +1 in solution.

C. __________ form stable but reactive diatomic gases.

D. __________ form ions with a net charge of −1 in solution.

E. __________ form ions with a net charge of +2 in solution.

ANS:

A. Helium and neon

B. Sodium and potassium

C. Nitrogen and oxygen

D. Chlorine

E. Calcium and magnesium

DIF: Easy REF: 2.1 OBJ: 2.1.f Relate how the behavior of atoms corresponds with their position in the periodic table and infer what this means for the chemical reactivity of the elements commonly found in living organisms.

MSC: Understanding

8. Indicate whether the statements below are TRUE or FALSE. If a statement is false, explain why it is false.

A. H, C, N and O constitute 99% of the total number of atoms found in the human body.

B. Copper, zinc, and manganese are among 11 nonessential trace elements that contribute less than 0.1% of all the atoms in the human body.

C. Approximately 0.9% of the atoms in the human body come from seven essential elements—Na, Mg, K, Ca, P, S, and Cl—all of which form stable ions in aqueous solution.

ANS:

A. True

B. False. Cu, Zn, and Mn are essential trace elements in the human body.

C. False. Na, Mg, K, Ca, and Cl form ions in aqueous solution, but P and S form covalent bonds in order to fill their outer electron shells.

DIF: Moderate REF: 2.1 OBJ: 2.1.a Review the properties that distinguish the chemistry of living things from the abiotic chemistry of solids, liquids, and gases. MSC: Evaluating

9. A. In which scientific unit is the strength of a chemical bond usually expressed?
   B. If 0.5 kilocalories of energy are required to break 6×10^{23} bonds of a particular type, what is the strength of this bond?

ANS:

A. kilocalories per mole (or kilojoules per mole)

B. 0.5 kcal/mole

DIF: Moderate REF: 2.1 OBJ: 2.1.k Differentiate between covalent and ionic bonds in terms of their electronic configuration, strength and stability, and their prevalence and role in biological systems. MSC: Understanding

10. The relative strengths of covalent bonds and van der Waals interactions remain the same when tested in a vacuum or in water. However, this is not true of hydrogen bonds or ionic bonds, whose bond strengths are lowered considerably in the presence of water. Explain these observations.

ANS: We estimate bond strengths by measuring the amount of energy needed to break them. As explained in Panel 2–7 in the text (pp. 78–79), in an aqueous solution, water can form hydrogen bonds with any polar molecules that are capably of forming hydrogen bonds with each other. This formation of bonds with water takes away from the net energy that would be gained from the molecules forming hydrogen bonds with each other, as they would in a vacuum. Similarly, water forms favorable electrostatic interactions with ions, thereby greatly weakening the ionic bonds that form between positive and negative ions in a vacuum (see Panel 2–7). Thus, for example, solid table salt (NaCl) readily dissociates in water, producing separate Na^+ and Cl^- ions as it dissolves. In contrast, covalent bonds and van der Waals attractions have an intrinsic bond strength that is independent of the aqueous environment, because changes in water molecule associations are not involved in the formation of these two types of bonds.

DIF: Difficult REF: 2.1 OBJ: 2.1.l Contrast hydrogen bonds, electrostatic attractions, van der Waal's attractions, and the hydrophobic force in terms of how and when they form and the role they play in cell biology. MSC: Understanding

11. Indicate whether the statements below are TRUE or FALSE. If a statement is false, explain why it is false.
   A. Any covalently bonded H atom can participate in a hydrogen bond if it comes in close proximity with an oxygen atom that forms part of a water molecule.
   B. Protons are constantly moving between water molecules, which means there is an overall equilibrium between hydroxyl ions and hydronium ions in aqueous solutions.
   C. A strong base is defined as a molecule that can readily remove protons from water.
   D. Electrons are always shared equally between covalently bonded atoms.

ANS:

A. False. Hydrogen atoms that are covalently bonded to carbon atoms do not participate in hydrogen bonds because these hydrogens have almost no net positive charge.

B. True

C. True

D. False. There are many covalent bonds in which the electrons are shared unequally between bonded atoms. This occurs when one atom is more electronegative than the other. These covalent bonds are referred to as polar covalent bonds.

DIF: Easy REF: 2.1 OBJ: 2.1.j Distinguish between acids and bases and demonstrate how they cooperate to maintain the pH of cells. | 2.1.k Differentiate between covalent and ionic bonds in terms of their electronic configuration, strength and stability, and their prevalence and role in biological systems. | 2.1.l Contrast hydrogen bonds, electrostatic attractions, van der Waal's attractions, and the hydrophobic force in terms of how and when they form and the role they play in cell biology. MSC: Evaluating

12. A. What is the pH of pure water?

B. What concentration of hydronium ions does a solution of pH_8 contain?

C. Complete the following reaction:

$CH_3COOH + H_2O \leftrightarrow$ __________.

D. Will the reaction in (C) occur more readily (be driven to the right) if the pH of the solution is high?

ANS:

A. pH_7

B. 10^{-8} M

C. $CH_3COO^- + H_3O^+$

D. Yes. If the pH is high, then the concentration of hydronium ions will be low. Therefore the rightward reaction, which produces hydronium ions, will be favored.

DIF: Easy REF: 2.1 OBJ: 2.1.j Distinguish between acids and bases and demonstrate how they cooperate to maintain the pH of cells. MSC: Remembering

13. Indicate whether the statements below are TRUE or FALSE. If a statement is false, explain why it is false.

A. A disaccharide consists of a sugar covalently linked to another molecule such as an amino acid or a nucleotide.

B. The hydroxyl groups on monosaccharides are reaction hot spots and can be replaced by other functional groups to produce derivatives of the original sugar.

C. The presence of double bonds in the hydrocarbon tail of a fatty acid does not greatly influence its structure.

ANS:

A. False. A disaccharide consists of two sugar molecules that undergo a condensation reaction to form a covalent bond (known as a glycosidic linkage).

B. True

C. False. The presence of a double bond in the hydrocarbon chain of a fatty acid causes a kink in the chain, decreasing its flexibility and packing with neighboring hydrocarbon chains.

DIF: Easy REF: 2.2 OBJ: 2.2.b Express how the chemical and physical properties of methyl groups ($-CH_3$), hydroxyl groups ($-OH$), carboxyl groups ($-COOH$), phosphate groups ($-PO_3^{2-}$), and amino groups ($-NH_2$) influence the behavior of molecules in which these groups typically occur. | 2.2.c Illustrate how the processes of condensation and hydrolysis drive the synthesis and breakdown of the large organic molecules of the cell from sets of smaller organic building blocks. | 2.2.i Predict how the saturation of fatty acid tails affects the fluidity of cell membranes. MSC: Evaluating

14. A. How many carbon atoms does the molecule represented in Figure 2-65 have?
    B. How many hydrogen atoms does it have?
    C. What type of molecule is it?

Figure 2-65

ANS:
A. 20 carbon atoms
B. 31 hydrogen atoms
C. a fatty acid
DIF: Easy REF: 2.2 OBJ: 2.2.g Define the terms fatty acid, steroid, phospholipid, and triacylglycerol and describe the structure, properties, and function of each. MSC: Understanding

15. 1. Write out the sequence of amino acids in the following peptide, using the full names of the amino acids: Pro-Val-Thr-Gly-Lys-Cys-Glu.
    2. Write the same sequence with the single-letter code for amino acids.
    3. According to the conventional way of writing the sequence of a peptide or a protein, which is the C-terminal amino acid and which is the N-terminal amino acid in the above peptide?

ANS:
1. proline-valine-threonine-glycine-lysine-cysteine-glutamic acid (or glutamate)
2. PVTGKCE
3. The C-terminal is glutamic acid (or glutamate); the N-terminal is proline.
DIF: Easy REF: 2.2 OBJ: 2.2.k Summarize what makes amino acids chemically unique and categorize the 20 amino acids commonly found in proteins on the basis of their chemical properties. MSC: Remembering

16. For each of the following sentences, fill in the blanks with the best word or phrase selected from the list below. Not all words or phrases will be used; each word or phrase should be used only once.

amino	ionized	polypeptides
α-carbon	length	protein
carbon	noncovalent	R group
carboxyl	peptide bonds	side chains
hydroxide		

Proteins are __________ built from amino acids, which each have an amino group and a __________ group attached to the central __________. There are 20 possible __________ that differ in structure and are generally referred to as “R.” In solutions of neutral pH, amino acids are __________, carrying both a positive and a negative charge. When a protein is made, amino acids are linked together through __________, which are formed by condensation reactions between the carboxyl end of the last amino acid and the __________ end of the next amino acid to be added to the growing chain.

ANS: Proteins are **polypeptides** built from amino acids, which each have an amino group and a **carboxyl** group attached to the central **α-carbon**. There are twenty possible **side chains** that differ in structure and are generally referred to as "R." In solutions of neutral pH, amino acids are **ionized**, carrying both a positive and negative charge. When a protein is made, amino acids are linked together through **peptide bonds**, which are formed by condensation reactions between the carboxyl end of the last amino acid and the **amino** end of the next amino acid to be added to the growing chain.

DIF: Easy REF: 2.2 OBJ: 2.2.j Identify the features that all amino acids have in common. | 2.2.k Summarize what makes amino acids chemically unique and categorize the 20 amino acids commonly found in proteins on the basis of their chemical properties. MSC: Understanding

17. Indicate whether the statements below are TRUE or FALSE. If a statement is false, explain why it is false.
    A. "Nonpolar interactions" is simply another way of saying "van der Waals attractions."
    B. Condensation reactions occur in the synthesis of all the macromolecules found in cells.
    C. All proteins and RNAs pass through many unstable conformations as they are folded, finally settling on one single, preferred conformation.

    ANS:

    A. False. Van der Waals attractions describe the general attractive forces between all atoms. The contact distance between any two nonbonded atoms is the sum of the van der Waals radii. Nonpolar interactions are based on the exclusion of hydrophobic molecules from a hydrophilic environment.
    B. True
    C. True

    DIF: Easy REF: 2.2 OBJ: 2.2.c Illustrate how the processes of condensation and hydrolysis drive the synthesis and breakdown of the large organic molecules of the cell from sets of smaller organic building blocks.

    MSC: Evaluating

18. A protein chain folds into its stable and unique three-dimensional structure, or conformation, by making many noncovalent bonds between different parts of the chain. Such noncovalent bonds are also critical for interactions with other proteins and cellular molecules. From the list provided, choose the class or classes of amino acids that are most important for the interactions detailed below.
    A. forming ionic bonds with negatively charged DNA
    B. forming hydrogen bonds to aid solubility in water
    C. binding to another water-soluble protein
    D. localizing an "integral membrane" protein that spans a lipid bilayer
    E. tightly packing the hydrophobic interior core of a globular protein

acidic	nonpolar
basic	uncharged polar

    ANS:

    A. basic

B. uncharged polar

C. uncharged polar, basic, and acidic

D. nonpolar

E. nonpolar

DIF: Moderate REF: 2.2 OBJ: 2.2.k Summarize what makes amino acids chemically unique and categorize the 20 amino acids commonly found in proteins on the basis of their chemical properties. MSC: Analyzing

19. The amino acid histidine is often found in enzymes. Depending on the pH of its environment, sometimes histidine is neutral and at other times it acquires a proton and becomes positively charged. Consider an enzyme with a histidine side chain that is known to have an important role in the function of the enzyme. It is not clear whether this histidine is required in its protonated or its unprotonated state. To answer this question, you measure enzyme activity over a range of pH, with the results shown in Figure 2-70. Which form of histidine is necessary for the active enzyme?

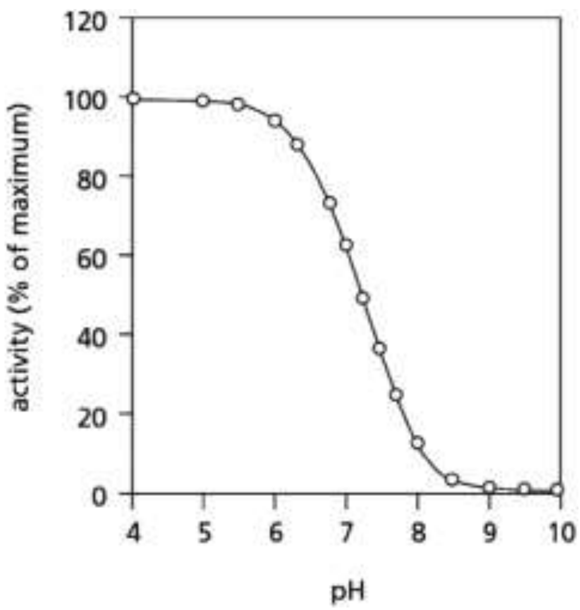

Figure 2-70

ANS: Assuming that the change in enzyme activity is due to the change in the protonation state of histidine, the enzyme must require histidine in the protonated, charged state. The enzyme is active only at low, acidic pH, where the proton (or hydronium ion) concentration is high; thus, the loss of a proton from histidine will be disfavored so that histidine is likely to be protonated.

DIF: Difficult REF: 2.1 OBJ: 2.1.j Distinguish between acids and bases and demonstrate how they cooperate to maintain the pH of cells. MSC: Applying

20. Silicon is an element that, like carbon, has four vacancies in its outer electron shell and therefore has the same bonding chemistry as carbon. Silicon is not found to any significant degree in the molecules found in living systems, however. Does this difference arise because elemental carbon is more abundant than silicon? What other explanations are there for the preferential selection of carbon over silicon as the basis for the

molecules of life?

ANS: According to Figure 2-4 in your textbook, silicon is actually more abundant in the Earth's crust than carbon, so this is not likely to be the reason that carbon was used preferentially. Carbon might have been the element of choice in living systems because it is lighter than silicon and forms shorter covalent bonds with other elements. Shorter bonds are typically stronger and more stable.
DIF: Difficult REF: 2.1 OBJ: 2.1.a Review the properties that distinguish the chemistry of living things from the abiotic chemistry of solids, liquids, and gases. MSC: Applying

21. Selenium (Se) is an element required in the human body in trace amounts. Selenium is obtained through the diet and levels of selenium found in food depend greatly on the soil where it is grown. Once ingested and absorbed as selenate, it can become incorporated into a small number of polypeptides. These selenoproteins are formed when selenium replaces an element that is found in 2 of the 20 "standard" amino acids. Using your knowledge of atomic structure, the periodic table in Figure 2-7, and the structure of amino acids found in Panel 2–5, deduce which two amino acids may be converted to "seleno" amino acids and used to make selenoproteins.

ANS: Sulfur is the only element found exclusively in 2 of the 20 amino acids. This element is located directly above selenium in the periodic table, indicating that these elements have the same number of electrons in their outer shell and both prefer to form bonds with other atoms to fill their outer orbital. If selenium instead of sulfur is incorporated into cysteine or methionine, the altered "seleno" amino acids will be produced (selenocysteine and selenomethionine). We can expect that this substitution will alter the nature of the proteins in which these amino acids are incorporated because selenium is a larger atom than sulfur.
DIF: Difficult REF: 2.2 OBJ: 2.2.k Summarize what makes amino acids chemically unique and categorize the 20 amino acids commonly found in proteins on the basis of their chemical properties. MSC: Applying

22. The cell is able to harvest energy from various processes in order to generate ATP molecules. These ATPs represent a form of stored energy that can be used later to drive other important processes. Explain how the cell can convert the chemical energy stored in ATP to generate mechanical energy; for example, changing the shape of a protein.

ANS: The terminal phosphate group is typically hydrolyzed and the energy released from this chemical bond is often "reinvested" to generate a new bond that links the phosphate group to a protein. This addition of a phosphate group can cause a change in the protein's conformation. This conformational change is usually associated with change in function or transient interactions with other macromolecules, generating a domino effect within the cell.
DIF: Easy REF: 2.2 OBJ: 2.2.b Express how the chemical and physical properties of methyl groups ($-CH_3$), hydroxyl groups ($-OH$), carboxyl groups ($-COOH$), phosphate groups ($-PO_3^{2-}$), and amino groups ($-NH_2$) influence the behavior of molecules in which these groups typically occur. MSC: Understanding

23. It is now a routine task to determine the exact order in which individual subunits have been linked together in polynucleotides (DNA) and polypeptides (proteins). However, it remains difficult to determine the arrangement of monomers in a polysaccharide. Explain why this is the case.

ANS: Nucleotides and amino acids have an intrinsic directionality, and the mechanism by which monomers are added into a growing polymer is always the same. This yields a linear polymer with the same directionality as the monomers. Polysaccharides are produced by linking monosaccharides together. The monosaccharides can be either added directly or modified to produce various derivatives before addition. Beyond this, there are multiple sites on each monosaccharide where addition can occur, producing highly complex, branched polymers.
DIF: Moderate REF: 2.2 OBJ: 2.2.c Illustrate how the processes of condensation and hydrolysis drive the synthesis and breakdown of the large organic molecules of the cell from sets of smaller organic building blocks.
MSC: Evaluating

24. As a protein is made, the polypeptide is in an extended conformation, with every amino acid exposed to the aqueous environment. Although both polar and charged side chains can mix readily with water, this is not the case for nonpolar side chains. Explain how hydrophobic interactions may play a role in the early stages of protein folding, and have an influence on the final protein conformation.

    ANS: One reason that nonpolar groups are excluded from an aqueous environment is that a hydrophobic surface would organize water into a highly structured network of hydrogen bonds, which is energetically unfavorable. Thus, you would expect that nonpolar amino acids would group together early, forming "hydrophobic pockets," while the polar and charged side chains remain at the interface of the surrounding solution. In the final, folded protein, most of the nonpolar amino acids will remain buried inside the protein. This fold is more stable because nonpolar atoms are prevented from contact with water and remain in contact with each other.
    DIF: Moderate REF: 2.3 OBJ: 2.3.b Assess the role that covalent and noncovalent bonds play in the three-dimensional conformation of macromolecules. MSC: Applying

25. You are trying to make a synthetic copy of a particular protein but accidentally join the amino acids together in exactly the reverse order. One of your classmates says the two proteins must be identical, and bets you $20 that your synthetic protein will have exactly the same biological activity as the original. After having read this chapter, you have no hesitation in staking your $20 that it will not. What particular feature of a polypeptide chain makes you sure your $20 is safe and that the project must be restarted?

    ANS: As a peptide bond has a distinct chemical polarity, a polypeptide chain also has a distinct polarity. The reversed protein chain cannot make the same noncovalent interactions during folding and thus will not adopt the same three-dimensional structure as the original protein. The activities of these two proteins will definitely be different, because the activity of a protein depends on its three-dimensional structure. It is unlikely that the reverse chain will fold into any well-defined, and hence functionally useful, structure at all, because it has not passed the stringent selective pressures imposed during evolution.
    DIF: Easy REF: 2.3 OBJ: 2.3.a Relate how the repetitive polymerization of monomers into polymers can yield macromolecules with diverse properties and functions. MSC: Evaluating

26. Your lab director requests that you add new growth medium to the mammalian cell cultures before heading home from the lab on a Friday night. Unfortunately, you need to make fresh medium because all the premixed bottles of medium have been used. One of the ingredients you know you need to add is a mix of

the essential amino acids (those that cannot be made by the cells, but are needed in proteins). On the shelf of dry chemicals you find the amino acids you need, and you mix them into your medium, along with all the other necessary nutrients, and replace the old medium with your new medium. On Sunday, you come in to the lab just to check on your cells and find that the cells have not grown. You are sure you made the medium correctly, but on checking you see that somebody wrote a note on the dry mixture of amino acids you used: “Note: this mixture contains only D-amino acids.”

A. What is the meaning of the note and how does it explain the lack of cell growth in your culture?
B. Are there any organisms that could grow using this mixture? Justify your answer.

ANS:

A. The note indicates that the mixture contains only one of the two possible stereoisomers (L or D). Because mammalian cells use only the L stereoisomer, the D-amino acid mixture could not be used and therefore it is as though no amino acids were added at all.
B. Not unless L-amino acids were also mixed in. Certain types of bacteria use D-amino acids to produce their cell walls, but they would still require L-amino acids for the rest of the proteins they make.

DIF: Difficult REF: 2.2 OBJ: 2.2.f Evaluate the role that isomers play in biological systems. MSC: Evaluating

27. Eukaryotic cells have their DNA molecules inside their nuclei. However, to package all the DNA into such a small volume requires the cell to use specialized proteins called histones. Histones have amino acid sequences enriched for lysines and arginines.

A. What problem might a cell face in trying to package DNA into a small volume without histones, and how do these special packaging proteins alleviate the problem?
B. Lysine side chains are substrates for enzymes called acetylases. A diagram of an acetylated lysine side chain is shown in Figure 2-78. How do you think the acetylation of lysines in histone proteins will affect the ability of a histone to perform its role (refer to your answer in part A)?

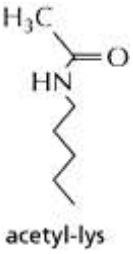

Figure 2-78

ANS:

A. DNA is a nucleic acid polymer in which each monomer has a negatively charged phosphate group. The negative charges will naturally repel each other, so in order to wrap the high density of negative charges into a small space, positively charged molecules must be present. Histones accomplish this because they are rich in lysines and arginines, which are positively charged in solution at pH_7.
B. A histone with acetylated lysine residues will not be as good at packaging the DNA. The addition of the acetyl group to the terminal amino on the lysine side chain lowers the histone’s net positive charge, which makes it less effective at buffering the negative charges on the DNA backbone.

DIF: Difficult REF: 2.3 OBJ: 2.3.c Explain how weak, noncovalent bonds can lead to strong and specific associations between macromolecules or between an enzyme and its substrate. MSC: Understanding

28. A. Sketch three different ways in which three water molecules could be held together by hydrogen-bonding.
    B. On a sketch of a single water molecule, indicate the distribution of positive and negative charge (using the symbols δ^+ and δ^-).
    C. How many hydrogen bonds can a hydrogen atom in a water molecule form? How many hydrogen bonds can the oxygen atom in a water molecule form?

    ANS:
    A. See Figure 2-79 A.
    B. See Figure 2-79 B.
    C. Hydrogen can form one; oxygen can form two.

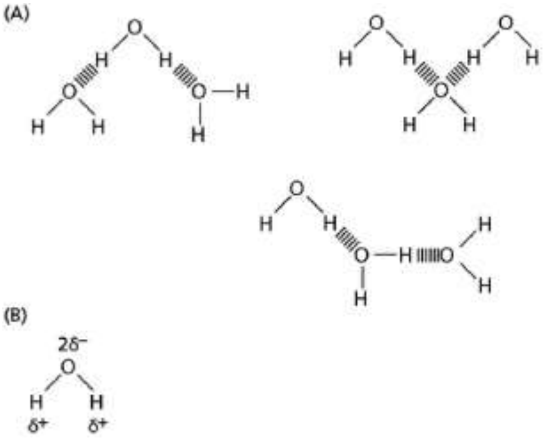

Figure 2-79

DIF: Easy REF: 2.1 OBJ: 2.1.l Contrast hydrogen bonds, electrostatic attractions, van der Waal's attractions, and the hydrophobic force in terms of how and when they form and the role they play in cell biology. MSC: Creating

29. You are trying to make a synthetic copy of a particular protein but accidentally join the amino acids together in exactly the reverse order. One of your classmates says the two proteins must be identical, and bets you $20 that your synthetic protein will have exactly the same biological activity as the original. After having read this chapter, you have no hesitation in staking your $20 that it will not. What particular feature of a polypeptide chain makes you sure your $20 is safe and that the project must be restarted?

    ANS: As a peptide bond has a distinct chemical polarity, a polypeptide chain also has a distinct polarity (see Figure A2-80). The reversed protein chain cannot make the same noncovalent interactions during folding and thus will not adopt the same three-dimensional structure as the original protein. The activities of these two proteins will definitely be different, because the activity of a protein depends on its three-dimensional structure. It is unlikely that the reverse chain will fold into any well-defined, and hence functionally useful, structure at all, because it has not passed the stringent selective pressures imposed during evolution.

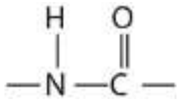

Figure 2-80A

DIF: Easy REF: 2.3 OBJ: 2.3.a Relate how the repetitive polymerization of monomers into polymers can yield macromolecules with diverse properties and functions. MSC: Evaluating