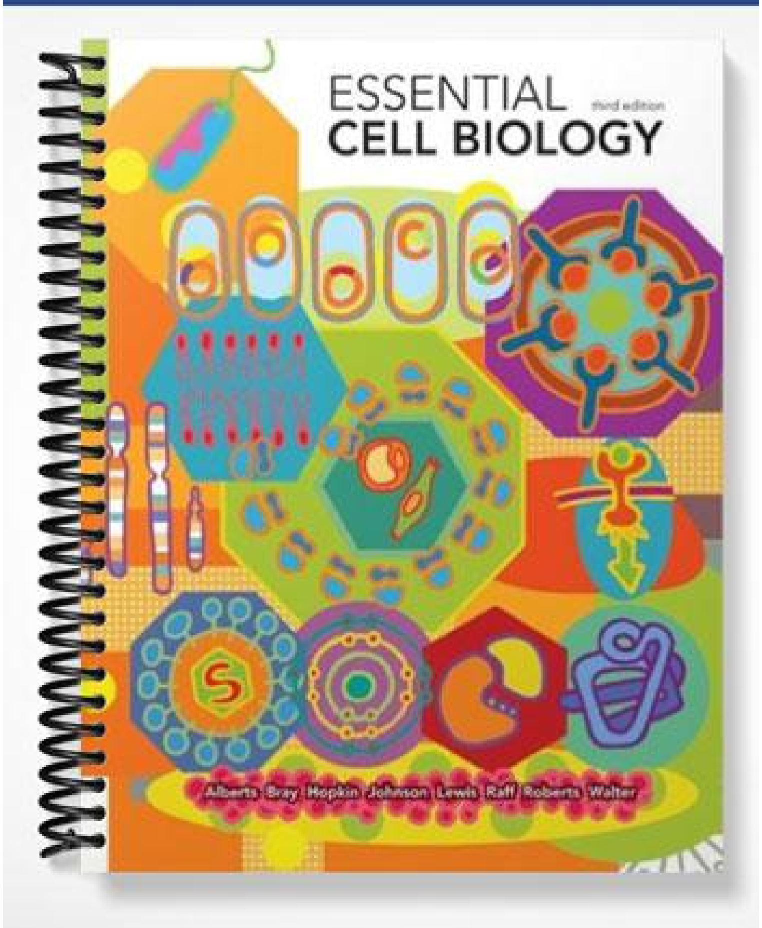
TEST BANK


ESSENTIAL
third edition
CELL BIOLOGY
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CHAPTER 2
CHEMICAL COMPONENTS OF CELLS

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Chemical Bonds

2-1 If the isotope ^{32}S has 16 protons and 16 neutrons, how many protons and how many neutrons will the isotope ^{35}S has?

2-2 A. If 0.5 mole of glucose weighs 90 g, what is the molecular weight of glucose?
B. What is the concentration, in grams per liter (g/l), of a 0.25 M solution of glucose?
C. How many molecules are there in 1 mole of glucose?

2-3 Which of the following elements is LEAST abundant in living organisms?
(a) Sulfur
(b) Carbon
(c) Oxygen
(d) Nitrogen
(e) Hydrogen

2-4 Your friend learns about Avogadro's number and thinks it is so huge that there may not even be a mole of living cells on Earth. You have recently heard that there are about 50 trillion (50×10^{12}) human cells in each adult human body, so you bet your friend $5 that there is more than a mole of cells on Earth. Once you learn that each human contains more bacterial cells (in the digestive system) than human cells, you are sure that you have won the bet. The human population is now more than 6 billion (6×10^{6}). What calculation can you show your friend to convince him you are right?

2-5 Atoms form covalent bonds with each other by
(a) sharing protons.
(b) sharing electrons.
(c) transferring electrons from one atom to the other.
(d) sharing neutrons.
(e) attraction of positive and negative charges.

2-6 A carbon atom contains six protons and six neutrons.
A. What are its atomic number and atomic weight?
B. How many electrons does it have?
C. What is its valence? How does this affect carbon's chemical behavior?
D. Carbon with an atomic weight of 14 is radioactive. How does it differ in structure from nonradioactive carbon? How does this difference affect its chemical behavior?

2-7 An ionic bond between two atoms is formed as a result of the

(a) sharing of electrons.
(b) loss of a neutron from one atom.
(c) loss of electrons from both atoms.
(d) loss of a proton from one atom.
(e) transfer of electrons from one atom to the other.

2-8 Which of the following pairs of elements are likely to form ionic bonds? Use Figure Q2-8 if necessary.

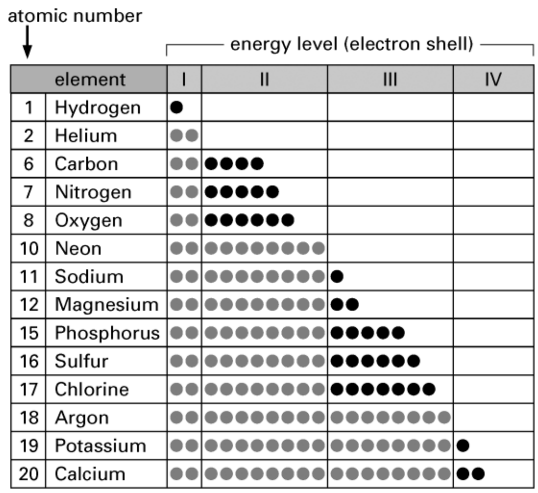

Figure Q2-8

(a) Hydrogen and hydrogen
(b) Magnesium and chlorine
(c) Carbon and oxygen
(d) Sulfur and hydrogen
(e) Carbon and chlorine

2-9 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.

Whereas ionic bonds form a(n) __________________, covalent bonds between atoms form a(n) __________________. These covalent bonds have a characteristic bond __________________and become stronger and more rigid when two electrons are shared in a(n) __________________. Equal sharing of electrons yields a(n) __________________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.

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

2-10 A. In what scientific units is the strength of a chemical bond usually expressed?

B. If 0.5 kilocalories of energy is required to break 6×10^{23} bonds of a particular type, what is the strength of this bond?

2-11 Approximately how many hydrogen bonds does it take to give an aggregate binding strength nearly equal to a single covalent bond?

(a) 1
(b) 3
(c) 50
(d) 500
(e) 5000

2-12 After looking at Figure Q2-8 above, which of the following pairs of atoms do you expect to be able to form double bonds with each other?

(a) Mg and Ca
(b) C and Cl
(c) S and O
(d) C and H
(e) He and O

2-13 A. Sketch three different ways 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?

2-14 Which of the following statements about hydrogen bonds are TRUE?

(a) They are weak covalent bonds that are easily disrupted by heat.
(b) They are weak bonds formed between hydrocarbons in water.
(c) They are weak bonds formed between nonpolar groups.
(d) They are weak bonds only formed in the presence of water.
(e) They are weak bonds involved in maintaining the conformation of macromolecules.

2-15 Based on what you know about the properties of water, which of the following statements about methanol (CH_3OH) are TRUE?

(a) Methanol molecules form more hydrogen bonds than water molecules do.
(b) The boiling point of methanol is higher than that of water.
(c) Salts such as NaCl are less soluble in methanol than in water.
(d) Methanol is a more cohesive liquid than water.
(e) Methanol has a higher surface tension than water.

2-16 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?

2-17 The amino acid histidine is often found in enzymes. Depending on the pH of its environment, sometimes histidine is neutral and other times it acquires a proton to become positively charged. Consider an enzyme with a histidine side chain that is known to play an important role in the function of the enzyme. It is not clear whether this histidine is required in its protonated or unprotonated state. To answer this question you measure enzyme activity over a range of pH, with the results shown in Figure Q2-17. Which form of histidine is necessary for the active enzyme?

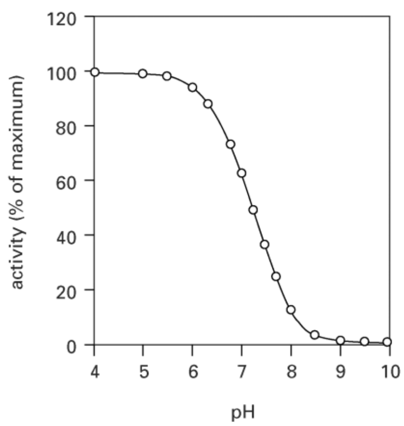

Figure Q2-17

Molecules in Cells

2-18 Match the chemical groups shown in the first list with their names selected from the second list.

List 1

A. –OH
B. –C = O
C. –COOH
D. $–CH_3$
E. $–NH_2$

List 2

1. Amino
2. Aldehyde
3. Phosphate
4. Carboxyl
5. Carbonyl (ketone)
6. Methyl
7. Amido
8. Ester
9. Hydroxyl

2-19 Match the macromolecules shown in the first list with their small molecule building blocks from the second list.

List 1	**List 2**
A. Polysaccharides	1. Amino acids
B. DNA	2. Deoxyribonucleotides
C. RNA	3. Aldehydes
D. Proteins	4. Pyrophosphates
E. Lipids	5. Ribonucleotides
	6. Fatty acids
	7. Sugars
	8. Steroids

2-20 Which of the following are examples of isomers?

(a) ^{14}C and ^{12}C
(b) Alanine and glycine (c) Adenine and guanine
(d) Glycogen and cellulose
(e) Glucose and galactose

2-21 Which of the following is FALSE of condensation reactions?

(a) Produce many biological polymers from monomers.
(b) Consume H_2O molecules.
(c) Aid in storage of energy reserves.
(d) Are the opposite of hydrolysis reactions.
(e) Are usually catalyzed in cells by enzymes.

2-22 A. How many carbon atoms does the molecule represented in Figure Q2-22 have?
B. How many hydrogen atoms?
C. What type of molecule is it?

Figure Q2-22

2-23 On the phospholipid molecule in Figure Q2-23 label each numbered line with a correct term selected from the list below.

A. Phosphate
B. Nonpolar head group
C. Glycerol
D. Polar head group
E. Saturated fatty acid
F. Acetic acid
G. Sugar
H. Hydrophobic region
I. Hydrophilic region
J. Nonsaturated fatty acid

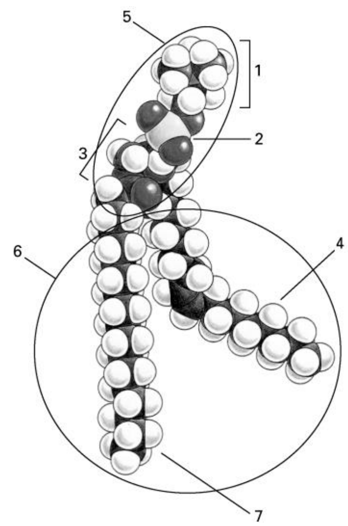

Figure Q2-23

2-24 Phospholipids can form bilayer membranes because they are
(a) hydrophobic.
(b) lipids.
(c) amphipathic.
(d) hydrophilic.
(e) amphoteric.

2-25 A. 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

B. Write the same sequence using the single letter code for amino acids.
C. 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?

2-26 Which of the following statements about amino acids is TRUE?

(a) Twenty-two amino acids are commonly found in proteins.
(b) Most of the amino acids used in protein biosynthesis have charged side chains.
(c) Amino acids are often linked together to form branched polymers.
(d) D- and L-amino acids are found in proteins.
(e) All amino acids contain an NH_2 and a COOH group.

2-27 Proteins can be modified by a reaction with acetate that results in the addition of an acetyl group to lysine side chains as shown in Figure Q2-27. The bond shown in the box in the acetylated lysine side chain is most like a(n)

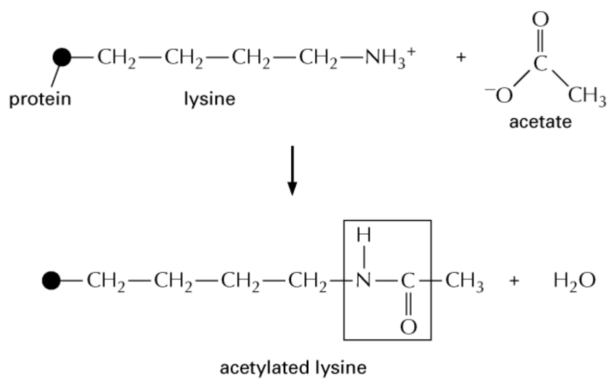

Figure Q2-27

(a) ester.
(b) peptide bond.
(c) phosphoanhydride bond.
(d) hydrogen bond.
(f) phosphoester bond.

2-28 DNA differs from RNA in

(a) the number of different bases used.
(b) the number of phosphates between the sugars in the sugar-phosphate backbone.
(c) the kind of sugar found in the sugar-phosphate backbone.
(d) one of the purines used.
(e) the chemical polarity of the polynucleotide chain.

2-29 Which of the following statements is FALSE about ATP?

(a) Contains high energy phosphoanhydride bonds.
(b) Is sometimes called the "universal currency" in the energy economy of cells.
(c) Can be incorporated into DNA.
(d) Can be hydrolyzed to release energy to power hundreds of reactions in cells.
(e) Comprises a sugar, phosphate groups, and a nitrogenous base.

2-30 Which of the following are likely to be disrupted by high concentrations of salt?
(a) A lipid bilayer
(b) The peptide bonds in a protein
(c) A complex of two proteins
(d) The sugar-phosphate backbone of a nucleic acid
(e) An oil droplet in water

Macromolecules in Cells

2-31 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 won't. What particular feature of a polypeptide chain makes you sure your $20 is safe, but that your project will have to be redone.

2-32 A protein chain folds into its stable and unique 3-D 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(es) 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. Packing tightly the hydrophobic interior core of a globular protein

acidic	nonpolar
basic	uncharged polar

2-33 DNA is negatively charged at physiological pH. A protein Z binds to DNA through noncovalent ionic interactions involving lysines. What will be the effect of acetylation of the lysine side chains (see Figure Q2-27) in protein Z on the strength of this binding?
(a) It should increase because the acetylated lysine will form a greater number of ionic interactions with DNA.
(b) It should decrease because the acetylated lysine no longer has a positive charge.
(c) It should have no effect because the unmodified lysine would not have formed an ionic interaction with the DNA.
(d) It should have no effect because the bond formed between lysine and the acetyl group still has a positive charge.
(e) It should decrease unless the DNA can become more negatively charged.

2-34 You are studying a microorganism in which a “male” turns pink in the presence of a “female.” The male becomes pink because a protein X secreted by the female binds to and activates a protein Y on the male that is responsible for the color change. You have isolated a strain of the microorganism that produces a mutant form of protein X. This strain behaves normally at temperatures lower than 37°C, but at higher temperatures it cannot turn pink. Could any of the following changes in mutant protein X explain your results? If so, which ones, and explain why.

(a) It makes an extra hydrogen bond to protein Y.
(b) It makes fewer hydrogen bonds to protein Y.
(c) It makes a covalent bond to protein Y.
(d) It is completely unfolded at temperatures lower than 37°C.
(e) It is completely unfolded at temperatures higher than 37°C.
(f) It is unable to bind to protein Y at any temperature.

Answers

2-1 16 proteins and 19 neutrons

2-2 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

2-3 (a) Sulfur is the least abundant element among the choices given.

2-4 Avogadro's number, or 6×10^{23}, is the number of atoms (or units) 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: $(6 \times 10^{9}) \times (50 \times 10^{12}) \times 2 = 6 \times 10^{23}$. Thus, there must be much more than a mole of living cells on Earth, and you win $5.

2-5 (b)

2-6 A. The atomic number of carbon, which is the number of protons, is six. The atomic weight, which is the number of protons plus neutrons, is 12.

B. The number of electrons, which equals the number of protons, is six.

C. The valence is the minimum number of electrons that must be lost or gained to fill the outer shell of electrons. The first shell can accommodate two electrons and the second shell, eight. Carbon therefore has a valence of four because it needs to gain four additional electrons (or would have to give up four electrons) to obtain a full outermost shell. Carbon is most stable when it shares four additional electrons with other atoms (including other carbon atoms) by forming four covalent bonds.

D. Carbon14 has two additional neutrons in its nucleus. As its electrons determine the chemical properties of an atom, carbon14 is chemically identical to carbon12.

2-7 (e)

2-8 (b) Magnesium has a valence of two and chlorine has a valence of one. Thus, two chlorine atoms can each accept an electron donated by magnesium to yield a salt, designated as $MgCl_2$ that contains twice as many Cl^- chlorine anions as Mg^{2+} magnesium cations. All ions in this salt will have full outermost electron shells.

2-9 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.

2-10 A. kilocalories per mole (*or* kilojoules per mole)
B. 0.5 kcal/mole

2-11 (c)

2-12 (c) Sulfur and oxygen both require two electrons to fill their outer shell and can do so by sharing four electrons and forming a double bond.

2-13 A. See Figure A2-13A.
B. See Figure A2-13B.

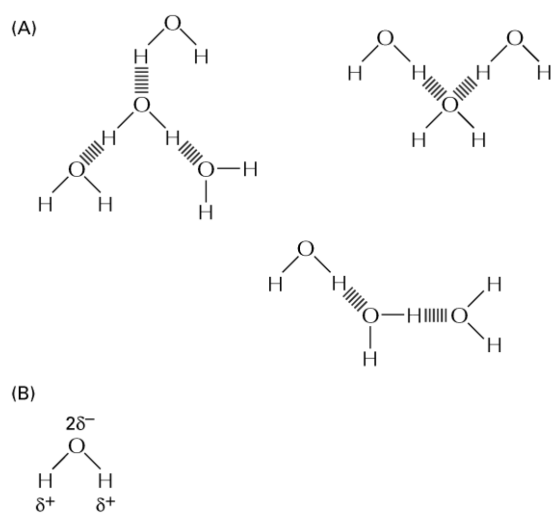

Figure A2-13

C. Hydrogen can form one; oxygen two.

2-14 Choice (e) is the answer. Hydrogen bonds are critical for maintaining the conformation, or 3-D structure, of biological macromolecules like proteins and nucleic acids. Choice (a) is false because hydrogen bonds are not covalent. Choice (b) is false because the nonpolar-CH groups on hydrocarbons cannot form good hydrogen bonds, in water or out of it. Choice (c) is essentially another way of stating choice (b) and thus is false. Choice (d) is false because many molecules besides water can form hydrogen bonds and do so regardless of whether or not water is present.

2-15 Choice (c) is the answer. In methanol one of the hydrogens of a water molecule has been replaced by a nonpolar methyl group. Methanol will form fewer hydrogen bonds (thus choice (a) is false) and make fewer ionic interactions than water does. The ability of water to dissolve salts is a direct consequence of its ability to make ionic interactions. Salts are therefore less soluble in methanol. Choices (b), (d), and (e) are all false because the high boiling point, high degree of cohesion, and high surface tension of water are all a result of the extensive hydrogen bonding between water molecules. As methanol makes fewer hydrogen bonds, its boiling point will be lower, it will be less cohesive, and it will have a lower surface tension than water.

2-16 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.

2-17 Assuming 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 and thus loss of a proton from histidine will be disfavored so that histidine is likely to be protonated.

2-18 A—9; B—5; C—4; D—6; E—1

2-19 A—7; B—2; C—5; D—1; E—6

2-20 (e) Glucose and galactose are both six-carbon sugars and thus both have the formula $C_6H_{12}O_6$. They are thus isomers of each other. ^{14}C and ^{12}C are examples of isotopes. 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.

2-21 Choice (b) is the answer. A condensation reaction releases a water molecule when forming polymers (like polysaccharide energy reserves) from monomeric units (like simple sugars), whereas the reverse hydrolysis reaction consumes a water molecule (thus, choices (a), (c), and (d) are correct). Most synthetic reactions in cells are catalyzed by enzymes (thus choice (e) is correct).

2-22 A. 20 carbon atoms
B. 31 hydrogen atoms
C. A fatty acid (Figure A2-22 is an arachidonic acid).

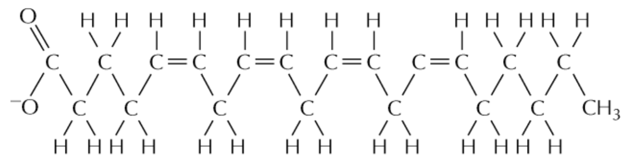

Figure A2-22

2-23 1—D; 2—A; 3—C; 4—J; 5—I; 6—H; 7—E

2-24 (c)

2-25 A. proline-valine-threonine-glycine-lysine-cysteine-glutamic acid (*or* glutamate)
B. PVTGKCQ
C. C-terminal is glutamic acid (*or* glutamate); N-terminal is proline.

2-26 Choice (e) is true. As their name implies, all amino acids have at lease one amino (NH2) group and at least one acidic carboxylic (COOH) group. It is through these two groups that they form peptide bonds. There are 20 common amino acids (choice (a) is false), and four or five of these have charged side chains (choice (b) is false). Each amino acid forms only two covalent bonds with other amino acids, one bond at the amino group and another at the carboxyl group (choice (c) is false); an exception to this is cysteine, because the side chains of two cysteines can form a covalent sulfhydryl bond to crosslink different regions of a polypeptide chain. Choice (d) is false because only L-amino acids are found in proteins.

2-27 (b) The indicated bond is an amide. Like a peptide bond, it is formed by reaction between a carboxyl group and an amino group.

2-28 (c) RNA contains the ribose sugar whereas DNA contains the deoxyribose sugar. They also differ in one of the pyrimidine bases used; RNA contains the pyrimidine uracil, while DNA instead contains thymine. All the other features are the same.

2-29 (c) ATP is used in energy conversions, contains ribose, and can be incorporated into RNA. But synthesis of DNA requires the deoxyribose form of the nucleotide, dATP. All the other statements about ATP are true.

2-30 Choice (c) is correct. Noncovalent ionic interactions such as those that hold two proteins together are most likely to be disrupted by salt. Lipid bilayers (choice (a)) and a lipid droplet (choice (e)) are held together by “hydrophobic interactions” on which salt will have no effect. Choices (b) and (d)are examples of covalent bonds, which are not disrupted by salt.

2-31 As a peptide bond has a distinct chemical polarity, a polypeptide chain also has a distinct polarity. (See Figure A2-31.) The reversed protein chains cannot make the same noncovalent interactions during folding and thus will not adopt the same 3-D structure as the original protein. The activities of these two proteins will definitely be different, since the activity of a protein depends on its 3-D 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.

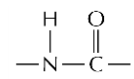

Figure A2-31

2-32 A. basic
B. uncharged polar
C. uncharged polar, basic, and acidic
D. nonpolar
E. nonpolar

2-33 Choice (b) is correct. Unmodified lysine side chains are positively charged and hence attractive to the negatively charged DNA (thus choice (c) is incorrect). Because acetylation neutralizes the positive charge (thus choice (d) is incorrect), the acetylated form of protein Z will form fewer ionic bonds with DNA (thus choice (a) is incorrect), and thus the strength of the interaction will decrease. Choice (e) is incorrect, since increasing the number of negative charges on DNA would have no effect once the positive charge on the lysine has been neutralized.

2-34 Choices (b) and (e) are possible explanations. If protein X makes fewer hydrogen bonds to protein Y, the two proteins will bind less tightly and may come apart at temperatures above 37°C. Thermal motion is one of the forces that can disrupt the weak noncovalent bonds responsible for holding X and Y together. The male will, therefore, not be able to turn pink above 37°C. Weak noncovalent bonds are also responsible for folding X into the proper 3-D structure. If protein X is completely unfolded at elevated temperatures it will not be able to bind to protein Y, so choice (e) could be the correct answer. In contrast, choice (d) would explain a protein X that is able to bind to protein Y only at high temperatures, and would result in a strain that would turn pink only at high temperatures. Choice (a) would produce a protein X that would bind to protein Y more tightly than the normal protein, and would therefore be likely to bind (and turn pink) at temperatures above 37°C. If a covalent bond was made (choice (c)), it is unlikely that such a bond would be disrupted by any temperature in which the microorganism could survive; the microorganism would therefore turn pink at any temperature. Choice (f) would result in a strain that could not turn pink at any temperature.