# Principles of Life

THIRD EDITION

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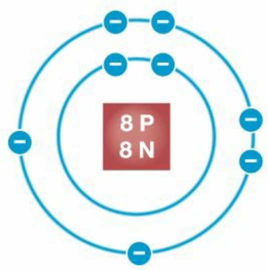
# Answers To All In-chapter Questions

## Chapter 2

### REVIEW & APPLY 2.1

1. The atomic number tells us the number of protons: 8. Since protons and neutrons have an atomic mass of $\sim 1 \sim 1$, subtracting the 8 protons from the mass of oxygen indicates that there are 16-8=8 $16 - 8 = 8$ neutrons.

2. 


Oxygen (O)

3. 18O $^{18}O$ has 8 protons (otherwise it would be a different element) and 8 electrons, but 2 additional neutrons, for a total of 10 in its nucleus.

4. Like oxygen, in its outermost shell, sulfur will have two electrons in its *s* orbital and 4 electrons in its three p$p$ orbitals.

## REVIEW & APPLY 2.2

1.

   a. Ionic bond: K+$K^+$ and Cl-$Cl^-$

   b. Nonpolar covalent

   c. Polar covalent, with δ+$\delta^+$ at the P$P$ end.

   d. Polar covalent, with δ+$\delta^+$ at the H$H$ end.

   e. Polar covalent, with δ+$\delta^+$ at the C$C$ end.

   f. Nonpolar covalent

## REVIEW & APPLY 2.3

1. Chemical-bond energy is stored in the bar and released and stored in different molecules during the digestion process. The released

energy is converted to mechanical energy to power muscle movement in the legs.

2. The total energy after the transformations is the same as that stored in the chemical bonds in the granola bar. However, the total usable energy after transformations is lower, as some energy is converted to entropy.

## REVIEW & APPLY 2.4

1.

   a. Endergonic; the stored energy in a complex structure is greater than that in the simpler molecules.

   b. Exergonic; energy is released when complex molecules are hydrolyzed.

2.

   a. The added substance would lower the activation energy needed to start the reaction.

   b. Heating would increase the kinetic energy of the molecules, making it more likely that collisions between sugar and water would have sufficient energy to supply the activation energy for the reaction.

## REVIEW & APPLY 2.5

1. Water has polar covalent bonds. Hydrogen bonds form in water between the δ+ H$\delta^{+}$ H on one molecule and the δ- O$\delta^{-}$ O on another molecule. These HH bonds must be broken for water to increase in temperature and eventually boil. Methane has nonpolar C-H$C - H$ bonds. When heat is applied to methane, the movement of the molecules increases immediately and the methane heats up because there are no hydrogen bonds to absorb the heat energy applied.

2. The pHpH of the blood is reduced by the increase in H+$H^{+}$. A buffer that reacts with the excess H+$H^{+}$ would reduce it and restore blood pHpH.

## REVIEW & APPLY 2.6

1. All those listed in Figure 2.16 except methyl which is nonpolar and would thus not interact well with the aqueous environment

encountered on the outside of biological molecules.

2. They have the same chemical formula but differ with respect to how the atoms are connected to one another.

## THINK LIKE A SCIENTIST

1. Suction would be created when the air pressure was lowered under the foot relative to the surroundings. Removing the air from the container would negate the pressure differential, and the foot would no longer stick to the surface.

2. Test whether polishing a surface to make it substantially smoother has any effect on a gecko's ability to cling to the surface. Geckos can climb on highly polished glass, indicating they are not grabbing onto imperfections on the surface.

3. There are numerous possibilities. For example, they could be used to attach surfaces together without the need for fasteners or adhesives.

## ANALYZE THE DATA, FIGURE 2.14

1. The comet water has a higher ratio of $D_2O$ than Earth water.

2. Because asteroid water has a similar isotopic signature as Earth water, and comet water does not, asteroids are a more likely source of Earth water.

3. The data were obtained from water analyzed directly from the comet after a probe landed on it. The data from the other comets were obtained from satellites of Earth-based instruments.

## FIGURE QUESTIONS

**Figure 2.1** The number of electrons is equal to the number of protons. An atom of the element chlorine thus has 17 electrons

**Figure 2.2** As atomic mass increases, chemical properties of the elements change and then abruptly, they repeat.

**Figure 2.3** One would be along the $x$ axis and the other along the $y$ axis, and they would have the same shapes as the $p$ orbital shown on the $z$ axis.

**Figure 2.5**

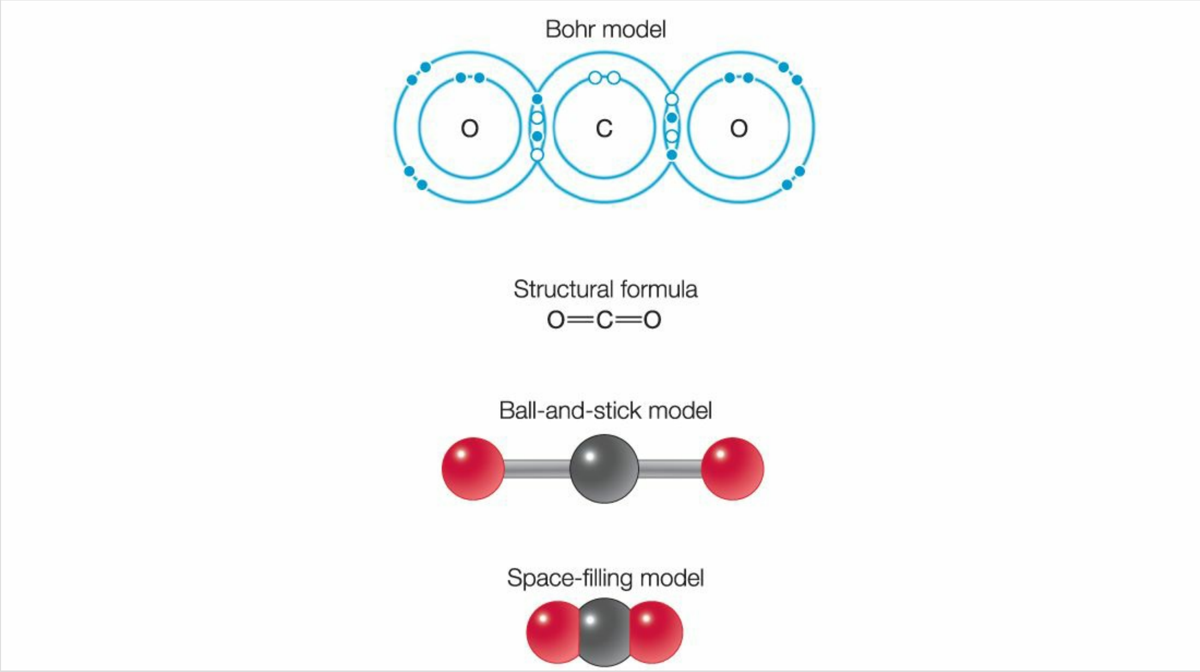



Figure 2.6

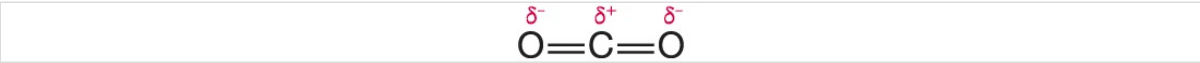
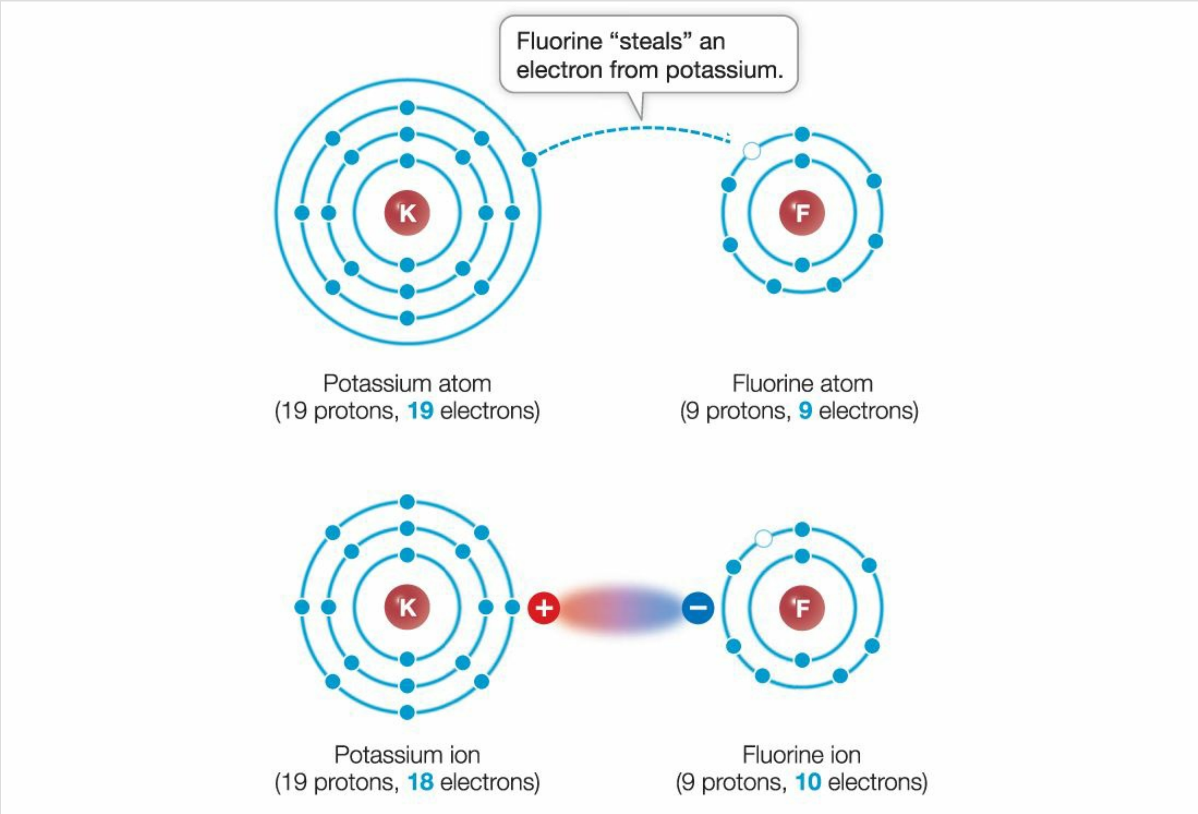



Figure 2.7




[Figure 2.8]() ClCl has a larger atomic weight (35.535.5, vs. 2323 for NaNa). Also, Cl-$Cl^-$ adds an electron to fill its outermost shell, whereas Na+ $Na^+$ loses an electron in its outermost shell.

[Figure 2.12]() 80% would still be usable after one transformation, and 80% of that 80% would still be usable after two transformations, and so on. Thus after three transformations, 0.83=0.512$0.8^3 = 0.512$, or 51% of the energy would still be usable; after five transformations it would be 0.85=0.328$0.8^5 = 0.328$, or 33%.

**Figure 2.13** No. The activation energy will likely prevent them from occurring very fast, and, once started, the concentration of reactants will decrease and that of products will increase, so the reaction will slow.

# VISUAL SUMMARY

## KEY CONCEPT 2.1

1. Al has 27-13=14$27-13=14$ neutrons and 13 protons.

2. First shell has 2 (full), second shell has 8 (full), and third shell has 3.

3. Isotopes differ in the number of neutrons in the nucleus, and thus in their atomic mass. The atomic number counts the number of protons in the nucleus, which does not vary for atoms of the same element.

## KEY CONCEPT 2.2

1. Two atoms of the same element have the same electronegativity. For a covalent bond to be polar, the two atoms must have different strengths of attraction to the electron. Polar bonds occur when

eletro- negativities of the atoms involved are significantly different.

2. If sodium loses an electron, it reaches a state in which the s$^{s}$ and p$^{p}$ orbitals of the outermost shell (which is then the next-most inner one) are full. For this reason, the electronegativity of sodium is quite low, and it readily gives up an electron to form a Na+$Na^{+}$ cation. In contrast, sharing their outermost electron with another atom in a covalent bond would yield two electrons in the outermost shell, which would fill the s$^{s}$ orbital, but the p$^{p}$ orbitals would still be empty. The exception is hydrogen, which would fill its outermost shell by sharing an electron in a covalent bond, thereby filling the s$^{s}$ orbital of the first shell, which is the only orbital in that shell.

3. CO2$CO_2$ has polar bonds between C$C$ and O$O$ and would form hydrogen bonds with water. C6H14$C_6H_{14}$ does not have polar bonds between C$C$ and C$C$, or between C$C$ and H$H$, and would not form hydrogen bonds with water.

## KEY CONCEPT 2.3

1. Kinetic energy is the energy of movement. Potential energy is stored energy.

2. (a) Potential energy (chemical-bond). (b) Kinetic energy (motion). (c) Kinetic energy (motion). (d) Kinetic energy (electromagnetic). (e) Potential energy (electric).

3. A strong chemical bond is one that is hard to break, meaning more energy is needed. Thus a strong bond has lower potential energy than a weak bond.

## KEY CONCEPT 2.4

1. Yes. Bond energy is one of two factors affecting whether a reaction is exergonic or endergonic; the other is the entropy change, which can be positive or negative for a particular reaction. In this example, if the entropy increase is sufficiently large, then the overall reaction can be exergonic (i.e., the free energy change is negative).

2. Hydrolysis reactions use water as a reactant, while condensation reactions produce water as a product. Hydrolysis tends to be exergonic, while condensation tends to be endergonic.

3. If the fish moves to warmer water, its body temperature and the rate of reactions will increase. Also, if the concentration of the reactants increases or the concentration of the products decreases, the

reaction rate will increase. Lowering the activation energy of the reaction will also increase the reaction rate.

## KEY CONCEPT 2.5

1. When water is heated, much of the energy is used to break hydrogen bonds rather than to increase the rate of movement of water molecules. Thus water absorbs a significant amount of heat without increasing in temperature.

2. Surface tension is caused by cohesion between molecules and makes the surface of liquids harder to penetrate. In water, hydrogen bonds hold molecules together quite tightly.

3. Water is a polar molecule, and polarity causes hydration shells to form around charged compounds, effectively dissolving them.

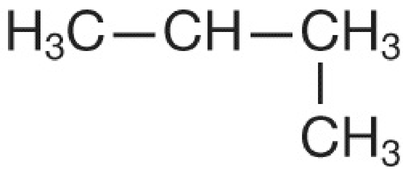
4. As water condenses and falls as rain, some CO2$CO_2$ dissolves in it, forming carbonic acid that then ionizes to give hydronium ions.

## KEY CONCEPT 2.6

1. The carboxyl group ionizes in water to -COO-$-COO^-$ and H3O+

$H_3O^+$.

2. Sulfur is a larger atom and thus shows lower electronegativity. The difference in electronegativity between SS and HH is thus smaller, implying that the covalent bond will be less polar.

3. $H_3C-CH_2-CH_2-CH_3$ and 

# Chapter 3

## REVIEW & APPLY 3.1

1. Fatty acids and triglycerides are both moderately sized molecules that are insoluble in water because they are hydrophobic. Glycerol, in contrast, is a small molecule with three hydrophilic -OH$-OH$ functional groups and is soluble in water.

2. Both are triglycerides, but oils have shorter and/or more unsaturated fatty acid chains reducing the number of van de Waals interactions, which makes them liquid at room temperature. Fats

have saturated fatty acid chains and are solid longer at room temperature.

3. Phospholipids are amphipathic, meaning they have both hydrophobic and hydrophilic parts. The hydrophilic “head” interacts with polar water molecules on the outside of the bilayer, and the hydrophobic “tails” are inside the bilayer, away from the water molecules. Triglycerides are hydrophobic and have no part that interacts with water molecules, so a stable bilayer structure cannot form (oil or fat droplets form instead).

## REVIEW & APPLY 3.2

1. See Figure 3.5. Fructose and glucose are structural isomers because not all the atoms in the molecule are attached to same groups. In glucose, carbon 1 is the only carbon attached to two oxygen atoms, while in fructose two oxygen atoms are bound to carbon 2. α$\alpha$-Mannose and α$\alpha$-glucose are stereoisomers; all atoms are attached to the same atoms but there is a spatial difference at carbon 2. In glucose the -OH$-\mathrm{OH}$ group is below the ring, whereas in mannose it is above the ring.

2. An oligosaccharide.

3. Because cellulose is a linear molecule possessing only 1,4 bonds, molecules can align neatly and close enough for many hydrogen bonds to form between them. Glycogen and starch have 1,6 bonds, making them branched and preventing close alignment and extensive hydrogen bonding with other molecules. More hydrogen bonding implies that the structure will be stronger.

## REVIEW & APPLY 3.3

1. A deoxyribose monosaccharide with no -OH$-OH$ group on carbon 2, a nitrogenous base attached to carbon 1, and one phosphate group attached to carbon 5.

2.

| Nucleic acid | Sugar in nucleotide | Bases present | Single or double stranded? |
|---|---|---|---|
| **RNA** | **Ribose** | **Adenine** | **Single** |
| | | Cytosine | |
| | | Guanine | |

| | | | |
|---|---|---|---|
| | | Uracil | |
| **DNA** | **Deoxyribose** | **Adenine** | **Double** |
| | | Cytosine | |
| | | Guanine | |
| | | Thymine | |

3. Replication copies DNA$\mathrm{DNA}$. Transcription makes a complementary RNA$\mathrm{RNA}$ copy of one strand of DNA$\mathrm{DNA}$. Translation synthesizes protein using RNA$\mathrm{RNA}$ sequence information.

## REVIEW & APPLY 3.4

1. The α$\alpha$ helix and β$\beta$ pleated sheet. Both are stabilized by hydrogen bonds.

2. When hair is ironed, hydrogen bonds between molecules are disrupted by the heat and then are re-formed in dry hair in disfavored orientations. As hair gets wet, molecules of water facilitate hydrogen bonds returning to favored, original orientations. When hair is chemically treated, the chemicals break

the original disulfide bridges in the keratin, and then they re-form between different cysteines within and between the molecules of keratin.

3. At pH $\mathrm{pH}$ 7 the glutamic acid side chain is ionized such that it carries a negative charge. The same side chain is more likely to be uncharged at pH $\mathrm{pH}$ 4 because the higher concentration of H3O+ $H_3O^+$ makes it more likely that the ionization reaction will reverse, adding a proton (H+) $(H^+)$ to the -COO- $-COO^-$ group and making it an uncharged -COOH $-COOH$ group. Such a large change in charge at this site is likely to disrupt structure.

4. Heat, pH $\mathrm{pH}$, polar solutes, and even nonpolar substances can denature proteins by interfering with the covalent bonds, hydrogen bonds, ionic bonds, and van der Waals forces that stabilize secondary, tertiary, and quaternary structures.

## REVIEW & APPLY 3.5

1. Ligand binding initially involves the formation of several weak bonds that alter the structure of the rest of the molecule. In addition

to leading to a better fit (more bonds or stronger bonds) in the induced fit model of substrate binding, binding might cause an active site to become available.

2. Enzymes speed up chemical reactions, without changing the overall reaction. They speed reactions by reducing the activation energy required.

3. Competitive inhibition occurs when a regulator (that has similar structure to substrate) binds noncovalently at the active site, preventing the normal substrate from binding.

## FIGURE QUESTIONS

**Figure 3.1** The single -OH$-\mathrm{OH}$ group in vitamin A$\mathrm{A}$ is not sufficient to make this large molecule soluble in water. Lipids are defined based on their water insolubility, and most of the vitamin A$\mathrm{A}$ molecule has nonpolar bonds.

**Figure 3.3** Yes. Ions are charged and have large polar hydration shells around them (water molecules attracted to their charge). The bilayer has a hydrophobic core that would have to be disrupted to allow this charged aggregation to pass through.

**Figure 3.7** Starch, because it is less compact, meaning -O-−O− and -OH−OH groups in the glucose rings are more available for hydrogen bonding with water. Cellulose will have the fewest because it is so compact.

**Figure 3.10** A G-CG − C base pair has three hydrogen bonds that must be broken to pull it apart (denature it) and thus requires more energy (about 50% more).

**Figure 3.11** Because of complementary base pairing, knowing the sequence of one strand allows the sequence of the other strand to be determined. Either strand thus has all the information needed to determine the double-strand sequence of the molecule.

**Figure 3.13** The newly formed RNARNA strand will have a complementary sequence (CC in place of GG, GG in place of CC, AA in place of TT, UU in place of AA) relative to the DNADNA strand. Also, the RNARNA strand will lack the base TT (it will have UU instead), and it will have ribose (not deoxyribose) in its sugar–phosphate backbone. In addition, it will have opposite orientation: if the DNADNA template is oriented 3′-to-5′3′-to-5′, the RNARNA strand will be oriented 5′-to-3′ 5′-to-3′ in the same direction, because complementary base pairing requires antiparallel orientation.

**Figure 3.18** O$O$ or N$N$ as these form polar bonds with H$H$.

**Figure 3.21** No. The conformational change is due to alterations of quaternary, tertiary, or possibly secondary structure through alterations of ionic bonds, hydrogen bonds, and van der Waals interactions.

**Figure 3.22** A catalyst speeds the reaction but does not alter free energy change. Thus you will get more energy per unit of time but not more energy per molecule of reactant.

## THINK LIKE A SCIENTIST

1. For proteins, nitrogen-containing molecules such as ammonia (NH3)$(NH_3)$ and CO2$CO_2$ could supply important functional groups. For carbohydrates, methane (CH4)$(CH_4)$ and CO2$CO_2$ could supply the needed components.

2. Energy for the reaction and activation energy would be required. This could be done via heat (early Earth had volcanoes) or electrical energy (from lightning storms). In the case of the Miller–Urey simulation, electrical discharges were supplied to the apparatus.

3. The simulation supported the hypothesis for the possible terrestrial

origin of monomers necessary for life on Earth.

## ANALYZE THE DATA FIGURE 3.19

1. Disulfide bonds began forming almost immediately after reoxidation began. Enzyme activity began appearing 100 minutes after reoxidation began. There are two reasons for the delay between the beginning of disulfide bond formation and the reappearance of enzyme activity. First, there are four disulfide bonds in the protein, all of which have to re-form before enzyme activity is restored. In other words, the first disulfide bonds to form aren't sufficient to restore activity, so there is a lag before activity reappears. Second, there are other chemical interactions, such as hydrogen bonding and hydrophobic interactions, that occur after the protein has initially folded due to disulfide bond formation and which are also necessary for enzyme activity.

2. The absorption peak for the native protein was at about 278 nm; the peak for the reduced (denatured) protein was at about 275 nm. Reoxidation resulted in a return to the native spectrum. Under the denaturation conditions of these experiments, as long as the primary structure of RNase ARNase A is retained, the proper environmental

conditions will result in a return to the native structure and a fully functional molecule.

# VISUAL SUMMARY

## KEY CONCEPT 3.1

1. The degree of saturation of fatty acids determines whether a triglyceride will be a solid (fat) or liquid (oil) at room temperature. Less saturation prevents tighter packing, making the triglyceride more likely to be an oil.

2. It means it has a hydrophilic end and a hydrophobic end.

3. Because the middle of the bilayer is hydrophobic.

## KEY CONCEPT 3.2

1. The presence of numerous polar -OH$-\mathrm{OH}$ groups makes these molecules hydrophilic, which coupled with their smaller size, allows dissolution in water.

2. Cellulose has only β-1, 4$\beta - 1, 4$ bonds. Starch has α-1, 4$\alpha - 1, 4$

bonds and is branched, with 1,6 bonds at carbon 6.

3. They are important structural compounds and are the primary constituent of plant cell walls (as cellulose).

## KEY CONCEPT 3.3

1. RNA has a uracil instead of thymine base, ribose instead of deoxyribose sugar, and one instead of two strands.

2. Hydrogen bonding between particular pairs of bases (G$G$ with C$C$, and A$A$ with T$T$ or U$U$).

3. Knowing the sequence of one strand allows the other strand to be accurately determined because of complementary base pairing.

## KEY CONCEPT 3.4

1. Serine and cysteine are not too dissimilar in their side chains—they are about the same size, and both are polar (though serine has higher polarity with its OH$OH$ group compared with cysteine's SH $SH$ group), which explains why substitutions generally have little effect. The two cysteines that cause problems when substituted

either reside in the active site or are involved in a disulfide bridge that stabilizes structure. Given that it is two cysteines that cause problems, the latter explanation seems more likely.

2. Yes, the active site is determined by tertiary—and possibly quaternary—structure, and the folding can result in distant amino acids in the primary structure being very close together in the active site.

3. For the proteins in the aqueous region, hydrophilic side chains would be on the outside, and hydrophobic side chains would be on the inside. For the proteins in the lipid bilayer, the opposite would be true: hydrophilic side chains would be on the inside, and hydrophobic side chains would be on the outside.

## KEY CONCEPT 3.5

1. They can orient substrates appropriately; strain certain chemical bonds (weakening them); or temporarily add or remove chemical groups in the reaction.

2. Cofactors are nonprotein molecules or inorganic ions that bind to a protein to allow function. Some cofactors are used by numerous