Chapter 2: Physical Biochemistry: Energy Conversion, Water, and Membranes

LEARNING OBJECTIVES

2.1 *Energy Conversion in Biological Systems*

2.1.a. Describe how sunlight is the source of all energy on Earth.

2.1.b. Differentiate between autotrophs and heterotrophs.

2.1.c. Explain the role of oxidation-reduction reactions in biological systems.

2.1.d. Differentiate between a system and its surroundings.

2.1.e. Differentiate among open, closed, and isolated systems.

2.1.f. Explain the first law of thermodynamics as it applies to biological systems.

2.1.g. Differentiate between endothermic and exothermic reactions.

2.1.h. State the second law of thermodynamics as it applies to biological systems.

2.1.i. Explain the concept of entropy and its role in biological systems.

2.1.j. Define Gibbs free energy, its relation to enthalpy and entropy, and its relation to equilibrium.

2.1.k. Identify the impacts of enthalpy, entropy, and temperature on free energy.

2.1.l. Differentiate between standard state condition and the biochemical standard state.

2.1.m. Differentiate between exergonic and endergonic reactions and explain how such reactions are coupled in biological systems.

2.1.n. Identify the characteristics of the ATP molecule that provide such a large standard free energy change for phosphoanhydride bond cleavage.

2.1.o. Describe the relationship between energy charge and concentrations of ATP, ADP, and AMP.

2.2 *Water Is Critical for Life Processes*

2.2.a. Identify hydrogen bond donors and hydrogen bond acceptors.

2.2.b. Describe how an antifreeze protein functions.

2.2.c. Differentiate among hydrogen bonds, ionic interactions, and van der Waals interactions.

2.2.d. State the concept of the hydrophobic effect and how it impacts protein folding.

2.2.e. Explain the impacts of hypotonic, isotonic, and hypertonic solutions on cells.

2.2.f. Identify the important aspects of plant, fungi, and bacterial cells that allow them to survive in a hypotonic environment.

2.2.g. Calculate the concentration of H^+ or OH^- given the OH^- or H^+ concentration.

2.2.h. Relate pH to the concentration of H^+ or OH^-.

2.2.i. Differentiate between weak acids and strong acids and between weak bases and strong bases.

2.2.j. Relate pH to pKa using the Henderson-Hasselbalch equation.

2.3 *Cell Membranes Function as Selective Hydrophobic Barriers*

2.3.a. Identify the characteristics of a phospholipid that contribute to membrane formation.

2.3.b. Relate the degree of saturation in phospholipids to the fluidity of the membrane.

2.3.c. Explain the various ways cholesterol impacts membrane structure.

2.3.d. Differentiate among the different types of membranes found in a eukaryotic cell.

Chapter 2: Physical Biochemistry: Energy Conversion, Water, and Membranes

MULTIPLE CHOICE

1. Energy conversion in living systems is required for what three types of work?
   a. osmotic work, chemical work, mechanical work
   b. osmotic work, chemical work, potential work
   c. kinetic work, chemical work, mechanical work
   d. osmotic work, photosynthetic work, mechanical work

   ANS: A DIF: Easy REF: 2.1
   OBJ: 2.1.a. Describe how sunlight is the source of all energy on Earth.
   MSC: Remembering

2. What chemical process is able to take place in the presence of solar energy?
   a. anaerobic respiration
   b. photosynthesis
   c. hydrogenation
   d. hydrolysis

   ANS: B DIF: Medium REF: 2.1
   OBJ: 2.1.a. Describe how sunlight is the source of all energy on Earth.
   MSC: Remembering

3. Which of the following is the correct solar energy reaction that takes place on the sun?
   a. $4\ He \rightarrow {}^4He$
   b. ${}^4He \rightarrow 4\ He$
   c. $4\ H \rightarrow {}^4He$
   d. ${}^4H \rightarrow 4\ H$

   ANS: C DIF: Medium REF: 2.1
   OBJ: 2.1.a. Describe how sunlight is the source of all energy on Earth.
   MSC: Understanding

4. What is the final molecule made from the oxidation of H_2O by solar energy?
   a. ozone
   b. glucose
   c. fructose
   d. carbon dioxide

   ANS: B DIF: Medium REF: 2.1
   OBJ: 2.1.c. Explain the role of oxidation-reduction reactions in biological systems.
   MSC: Understanding

5. The difference between an oxidation reaction and a reduction reaction is that oxidation is the __________ and reduction is the __________.
   a. loss of electrons; gain of electrons
   b. gain of electrons; loss of electrons
   c. loss of protons; gain of protons
   d. gain of protons; loss of protons

   ANS: A DIF: Medium REF: 2.1
   OBJ: 2.1.c. Explain the role of oxidation-reduction reactions in biological systems.
   MSC: Analyzing

6. Which of the following correctly describes the relationship between an ice cube melting on the table and the air surrounding it?
   a. The ice cube is the system and the air is the surroundings.
   b. The air is the system and the ice cube is the surroundings.
   c. The ice cube is the system and only the air is the universe.
   d. The air is the system and only the ice cube is the universe.

   ANS: A DIF: Medium REF: 2.1
   OBJ: 2.1.d. Differentiate between a system and its surroundings.
   MSC: Evaluating

7. Which of the following is an example of a system?
   a. the universe
   b. the air
   c. a test tube with reaction components
   d. outer space

   ANS: C DIF: Easy REF: 2.1
   OBJ: 2.1.d. Differentiate between a system and its surroundings.
   MSC: Understanding

8. A hot pack on your arm is an example of what kind of system?
   a. open
   b. closed
   c. isolated
   d. surroundings

   ANS: B DIF: Medium REF: 2.1
   OBJ: 2.1.e. Differentiate among open, closed, and isolated systems.
   MSC: Applying

9. Which of the following best describes an open system?
   a. Matter and energy are freely exchanged with the surroundings.
   b. Energy is exchanged with the surroundings but matter is not.
   c. Matter is exchanged with the surroundings but energy is not.
   d. Neither matter nor energy is exchanged with the surroundings.

   ANS: A DIF: Easy REF: 2.1
   OBJ: 2.1.e. Differentiate among open, closed, and isolated systems.
   MSC: Understanding

10. Which of the following best defines the first law of thermodynamics?
    a. All spontaneous processes in the universe tend toward dispersal of energy.
    b. Total amount of energy in the universe is a constant.
    c. There is no entropy at zero Kelvin.
    d. Entropy is a measure of disorder.

    ANS: B DIF: Medium REF: 2.1
    OBJ: 2.1.f. Explain the first law of thermodynamics as it applies to biological systems.
    MSC: Understanding

11. Energy conversion in a biological system operates under constant __________ and constant __________.
   a. heat; pressure
   b. work; heat
   c. pressure; volume
   d. volume; heat

   ANS: C DIF: Medium REF: 2.1
   OBJ: 2.1.f. Explain the first law of thermodynamics as it applies to biological systems.
   MSC: Applying

12. Given a biological system at 1 atm with $\Delta H = 16$ kJ/g, what is the internal energy of the system?
   a. 15 kJ/g
   b. 16 kJ/g
   c. 14 kJ/g
   d. Not enough information is given to calculate the answer.

   ANS: B DIF: Difficult REF: 2.1
   OBJ: 2.1.f. Explain the first law of thermodynamics as it applies to biological systems.
   MSC: Applying

13. The combustion of gasoline is considered exothermic because heat is
   a. transferred from the surroundings to the system.
   b. transferred from the system to the surroundings.
   c. transferred to the universe.
   d. not transferred.

   ANS: B DIF: Medium REF: 2.1
   OBJ: 2.1.g. Differentiate between endothermic and exothermic reactions.
   MSC: Understanding

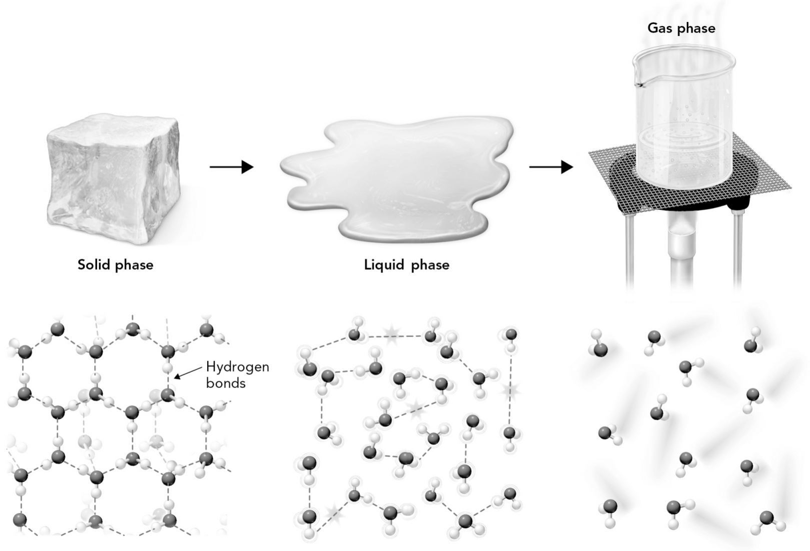
14. Given 80 grams of water, how many calories are required to raise the temperature 1°C?
   a. 4.184 calories
   b. 15.7 calories
   c. 80 calories
   d. Not enough information is given to calculate the answer.

   ANS: C DIF: Medium REF: 2.1
   OBJ: 2.1.g. Differentiate between endothermic and exothermic reactions.
   MSC: Applying

15. The oxidation of glucose releases 15.7 kJ/g. Is this reaction spontaneous?
   a. Yes, because it is exothermic.
   b. No, because it is exothermic.
   c. Yes, because it is endothermic.
   d. The answer cannot be determined.

   ANS: D DIF: Difficult REF: 2.1
   OBJ: 2.1.g. Differentiate between endothermic and exothermic reactions.
   MSC: Analyzing

16. In the figure below, which state of matter has the highest entropy?



a. solid phase
b. liquid phase
c. gas phase
d. all are equal entropy.

ANS: C DIF: Easy REF: 2.1
OBJ: 2.1.f. Explain the first law of thermodynamics as it applies to biological systems.
MSC: Remembering

17. For a reaction to be spontaneous, the change in the entropy of the universe must be
a. greater than zero.
b. less than zero.
c. equal to zero.
d. equal to 1.

ANS: A DIF: Easy REF: 2.1
OBJ: 2.1.i. Explain the concept of entropy and its role in biological systems.
MSC: Understanding

18. The example of water freezing into ice shows
a. an increase in entropy of the system.
b. a decrease in entropy of the system.
c. no change in the entropy of the system.
d. a decrease in the entropy of the surroundings.

ANS: B DIF: Medium REF: 2.1
OBJ: 2.1.f. Explain the first law of thermodynamics as it applies to biological systems.
MSC: Applying

19. The change in entropy of a system is a function of a change in
   a. temperature and pressure.
   b. volume and pressure.
   c. enthalpy and pressure.
   d. enthalpy and temperature.

   ANS: D DIF: Difficult REF: 2.1
   OBJ: 2.1.f. Explain the first law of thermodynamics as it applies to biological systems.
   MSC: Understanding

20. *Gibbs free energy* can best be defined as the
   a. difference between the enthalpy and entropy of a system at a given temperature.
   b. difference between exothermic and endothermic energy of a system at a given temperature.
   c. addition of enthalpy and entropy of a system at a given temperature.
   d. difference between pressure and volume at a given temperature.

   ANS: A DIF: Difficult REF: 2.1
   OBJ: 2.1.j. Define Gibbs free energy, its relation to enthalpy and entropy, and its relation to equilibrium. MSC: Understanding

21. For a given reaction with a $\Delta G < 0$, the reaction is
   a. favorable in the reverse direction.
   b. favorable in the forward direction.
   c. unfavorable in both directions.
   d. favorable in both directions.

   ANS: B DIF: Medium REF: 2.1
   OBJ: 2.1.j. Define Gibbs free energy, its relation to enthalpy and entropy, and its relation to equilibrium. MSC: Understanding

22. If a reaction has a $\Delta H > 0$ and a $\Delta S < 0$, then ___________ and the reaction is ___________ at all temperatures.
   a. $\Delta G < 0$; spontaneous
   b. $\Delta G > 0$; spontaneous
   c. $\Delta G < 0$; nonspontaneous
   d. $\Delta G > 0$; nonspontaneous

   ANS: D DIF: Medium REF: 2.1
   OBJ: 2.1.j. Define Gibbs free energy, its relation to enthalpy and entropy, and its relation to equilibrium. MSC: Applying

23. If $\Delta G = 0$ for a reaction, then this reaction
   a. is favorable in the forward direction.
   b. is favorable in the reverse direction.
   c. is at equilibrium.
   d. cannot occur.

   ANS: C DIF: Medium REF: 2.1
   OBJ: 2.1.j. Define Gibbs free energy, its relation to enthalpy and entropy, and its relation to equilibrium. MSC: Analyzing

24. If a reaction has a $\Delta H < 0$ and $\Delta S < 0$, under which conditions would the reaction be spontaneous in the forward direction?
a. low temperatures
b. high temperatures
c. high pressure
d. low pressure

ANS: A DIF: Medium REF: 2.1
OBJ: 2.1.k. Identify the impacts of enthalpy, entropy, and temperature on free energy.
MSC: Evaluating

25. The standard free energy change is defined under what set of conditions?
a. 1 atm, 298 K, 1 M
b. 1 atm, 273 K, 1 M
c. 100 kPa, 273 K, 1 M
d. 100 kPa, 298 K, 1 M

ANS: A DIF: Difficult REF: 2.1
OBJ: 2.1.l. Differentiate between standard state condition and the biochemical standard state.
MSC: Understanding

26. If the equilibrium constant (K_{eq}) is greater than 1, which direction will the reaction proceed?
a. spontaneously to products
b. spontaneously to reactants
c. neither direction
d. Not enough information is given to determine the direction of reaction.

ANS: A DIF: Easy REF: 2.1
OBJ: 2.1.l. Differentiate between standard state condition and the biochemical standard state.
MSC: Applying

27. If the equilibrium constant (K_{eq}) is greater than 1, what is the value of $\Delta G°$?
a. $\Delta G° > 0$
b. $\Delta G° = 0$
c. $\Delta G° < 0$
d. $\Delta G° > 1$

ANS: C DIF: Difficult REF: 2.1
OBJ: 2.1.l. Differentiate between standard state condition and the biochemical standard state.
MSC: Applying

28. Under what conditions could a biological reaction spontaneously proceed to reactants if the $\Delta G° > 0$?
a. Reactant concentrations are greater than product concentrations.
b. Product concentrations are greater than reactant concentrations.
c. Reactant concentrations are equal to product concentrations.
d. There are no conditions where this could happen.

ANS: B DIF: Difficult REF: 2.1
OBJ: 2.1.l. Differentiate between standard state condition and the biochemical standard state.
MSC: Evaluating

29. If the Gibbs free energy change value for a reaction is less than zero, this reaction is
   a. exergonic.
   b. endergonic.
   c. exothermic.
   d. endothermic.

   ANS: A   DIF: Easy   REF: 2.1
   OBJ: 2.1.m. Differentiate between exergonic and endergonic reactions and explain how such reactions are coupled in biological systems.   MSC: Remembering

30. What chemical reaction causes ATP to be a *high-energy* molecule?
   a. cleavage of phosphoanhydride bond
   b. transfer of an adenylyl group to form a reactive intermediate
   c. hydrolysis of phosphoryl group
   d. oxidation of phosphoanhydride bond

   ANS: B   DIF: Difficult   REF: 2.1
   OBJ: 2.1.n. Identify the characteristics of the ATP molecule that provide such a large standard free energy change for phosphoanhydride bond cleavage.   MSC: Analyzing

31. The transfer of a phosphate from ATP to another molecule produces a(n)
   a. low-energy intermediate.
   b. highly reactive intermediate.
   c. neutral energy intermediate.
   d. It is not possible to transfer a phosphate to another molecule.

   ANS: B   DIF: Easy   REF: 2.1
   OBJ: 2.1.n. Identify the characteristics of the ATP molecule that provide such a large standard free energy change for phosphoanhydride bond cleavage.   MSC: Understanding

32. The __________ system controls the interconversion among ATP, ADP, and AMP.
   a. phosphorylate
   b. adenylate
   c. energy conversion
   d. metabolism

   ANS: B   DIF: Easy   REF: 2.1
   OBJ: 2.1.o. Describe the relationship between energy charge and concentrations of ATP, ADP, and AMP.   MSC: Remembering

33. Given the energy charge equation below, if a biological system has an EC = 0.8, what is true about the concentrations of ATP, ADP, and AMP in the system?

$$EC = \frac{[ATP] + 0.5[ADP]}{[ATP] + [ADP] + [AMP]}$$

   a. The concentrations are all equal.
   b. There is more ADP in the system than ATP or AMP.
   c. There is more ATP in the system than ADP or AMP.
   d. There is more AMP in the system than ATP and ADP.

   ANS: C   DIF: Difficult   REF: 2.1
   OBJ: 2.1.o. Describe the relationship between energy charge and concentrations of ATP, ADP, and AMP.   MSC: Applying

34. Under steady-state conditions in a mammalian cell, the adenine nucleotide concentrations are [ATP] = 3.3 mM, [ADP] = 1.2 mM, and [AMP] = 0.2 mM. What is the energy charge of this cell?
a. 0.83
b. 0.95
c. 0.72
d. 1.2

ANS: A DIF: Difficult REF: 2.1
OBJ: 2.1.o. Describe the relationship between energy charge and concentrations of ATP, ADP, and AMP. MSC: Applying

35. In a hydrogen bond between a water molecule and another water molecule,
a. a hydrogen ion on the water molecule forms an ionic bond with the oxygen ion on the other water.
b. the hydrogen bond typically forms between the oxygen atom of the water and the hydrogen on the other water.
c. a hydrogen on the water molecule forms a covalent bond to a hydrogen atom on the other water.
d. the hydrogen atom forms an ionic bond with a carbon on the other water.

ANS: B DIF: Medium REF: 2.2
OBJ: 2.2.a. Identify hydrogen bond donors and hydrogen bond acceptors.
MSC: Applying

36. Hydrogen bonds in liquid water are formed between
a. two hydrogen atoms on the same molecule.
b. the oxygen of one molecule and the hydrogen of another.
c. protons and hydroxides.
d. two oxygen atoms on different molecules.

ANS: B DIF: Medium REF: 2.2
OBJ: 2.2.a. Identify hydrogen bond donors and hydrogen bond acceptors.
MSC: Understanding

37. Organisms on Earth cannot easily exist at temperatures below 0°C because at that temperature
a. hydrogen bonds cannot exist.
b. water does not exist in a tetrahedron.
c. ice crystals form in the organism.
d. proton hopping cannot occur.

ANS: C DIF: Easy REF: 2.2
OBJ: 2.2.b. Describe how an antifreeze protein functions. MSC: Understanding

38. Describe how an antifreeze protein functions.
a. Regularly spaced tyrosine residues prevent the ice crystals from growing.
b. Regularly spaced threonine resides prevent the ice crystals from growing.
c. Flickering clusters of hydrogen bonds prevent the ice crystals from growing.
d. The antifreeze protein prevents the water wires from forming.

ANS: B DIF: Medium REF: 2.2
OBJ: 2.2.b. Describe how an antifreeze protein functions. MSC: Applying

39. A hydrogen bond can form between a hydrogen atom on a(n)
   a. electronegative donor group and another electronegative atom.
   b. cationic atom and another hydrogen.
   c. nonpolar donor group and an electronegative atom.
   d. ionic atom and another anion.

   ANS: A DIF: Medium REF: 2.2
   OBJ: 2.2.c. Differentiate among hydrogen bonds, ionic interactions, and van der Waals interactions. MSC: Remembering

40. The interaction between an amino group and a carboxylate group is best characterized as
   a. hydrogen bonds.
   b. ionic interactions.
   c. van der Waals interactions.
   d. a covalent bond.

   ANS: B DIF: Easy REF: 2.2
   OBJ: 2.2.c. Differentiate among hydrogen bonds, ionic interactions, and van der Waals interactions. MSC: Understanding

41. The interaction between nonpolar molecules is best characterized as
   a. a hydrogen bond.
   b. ionic interactions.
   c. van der Waals interactions.
   d. a covalent bond.

   ANS: C DIF: Easy REF: 2.2
   OBJ: 2.2.c. Differentiate among hydrogen bonds, ionic interactions, and van der Waals interactions. MSC: Understanding

42. An organism in equilibrium with its environment is no longer alive because
   a. homeostasis is required for life.
   b. heterostasis is required for life.
   c. an organism requires only exergonic reactions to be alive.
   d. an organism requires only endergonic reactions to be alive.

   ANS: A DIF: Easy REF: 2.1
   OBJ: 2.1.f. Explain the first law of thermodynamics as it applies to biological systems.
   MSC: Understanding

43. Hydrophobic interactions between nonpolar molecules result from the
   a. tendency to maximize water's interaction with nonpolar molecules.
   b. strong attractions between nonpolar molecules.
   c. water becoming more ordered around the nonpolar molecule.
   d. water ionically bonding to the nonpolar molecule.

   ANS: C DIF: Medium REF: 2.2
   OBJ: 2.2.d. State the concept of the hydrophobic effect and how it impacts protein folding.
   MSC: Applying

44. Limonene is a nonpolar molecule. The water molecules around it forms
   a. hydrogen bonds with itself and entropy decreases.
   b. ionic bonds with itself and the entropy decreases.
   c. hydrogen bonds with limonene and the entropy increases.
   d. covalent bonds with limonene and entropy increases.

   ANS: A DIF: Difficult REF: 2.2
   OBJ: 2.2.d. State the concept of the hydrophobic effect and how it impacts protein folding.
   MSC: Applying

45. As a protein folds, what are the stabilizing forces that help keep the protein folded?
   a. hydrophilic amino acids on the interior and hydrophobic amino acids on the exterior
   b. increase in entropy in the surrounding water
   c. favorable change in free energy
   d. hydrophobic amino acids on the interior and hydrophilic amino acids on the exterior

   ANS: D DIF: Medium REF: 2.2
   OBJ: 2.2.d. State the concept of the hydrophobic effect and how it impacts protein folding.
   MSC: Remembering

46. Freezing point depression, boiling point elevation, and osmotic pressure are all what kind of properties?
   a. intrinsic properties
   b. colligative properties
   c. state functions
   d. hydrophobic effects

   ANS: B DIF: Easy REF: 2.2
   OBJ: 2.2.d. State the concept of the hydrophobic effect and how it impacts protein folding.
   MSC: Remembering

47. The effects of solutes on the colligative properties of a solution depend only on the
   a. chemical properties of the solutes.
   b. molecular mass of the solutes.
   c. overall charge of the solute.
   d. number of solute particles.

   ANS: D DIF: Easy REF: 2.2
   OBJ: 2.2.e. Explain the impacts of hypotonic, isotonic, and hypertonic solutions on cells.
   MSC: Remembering

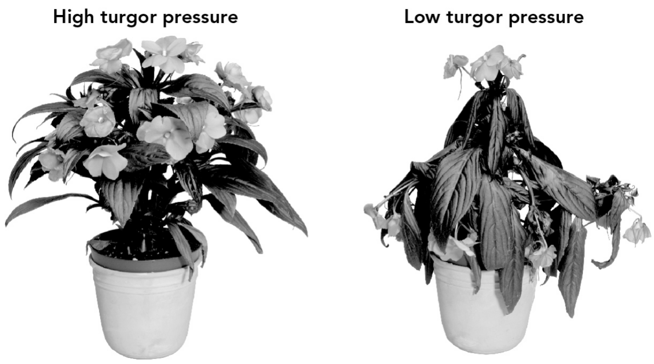
48. Osmosis occurs when water diffuses through a
   a. semipermeable membrane from high water to low water concentration.
   b. nonpermeable membrane from high water to low water concentration.
   c. semipermeable membrane from low water to high water concentration.
   d. semipermeable membrane from high solute to low solute concentration.

   ANS: A DIF: Easy REF: 2.2
   OBJ: 2.2.e. Explain the impacts of hypotonic, isotonic, and hypertonic solutions on cells.
   MSC: Remembering

49. Red blood cells are placed into a solution of unknown solute concentration. After an hour they have all burst open. The best explanation is that the solution
   a. had no solutes.
   b. had a very high concentration of solutes.
   c. had a very high concentration of solvent
   d. was at equilibrium.

   ANS: A DIF: Difficult REF: 2.2
   OBJ: 2.2.e. Explain the impacts of hypotonic, isotonic, and hypertonic solutions on cells.
   MSC: Analyzing

50. What is the expected osmotic pressure around the cells for the plant with low turgor pressure shown below?



   a. hypotonic
   b. hypertonic
   c. isotonic
   d. equilibrium

   ANS: B DIF: Difficult REF: 2.2
   OBJ: 2.2.f. Identify the important aspects of plant, fungi, and bacterial cells that allow them to survive in a hypotonic environment. MSC: Analyzing

51. How do plants, fungi, and bacteria avoid the damaging effects of a hypotonic environment?
   a. flexible cells walls
   b. rigid cells walls
   c. semipermeable cell walls
   d. photosynthesis

   ANS: B DIF: Easy REF: 2.2
   OBJ: 2.2.f. Identify the important aspects of plant, fungi, and bacterial cells that allow them to survive in a hypotonic environment. MSC: Applying

52. Which of the following is true?
   a. A neutral solution contains $[H_2O] = [H^+]$.
   b. A neutral solution does not contain any H^+ or OH^-.
   c. An acidic solution has $[H^+] > [OH^-]$.
   d. A basic solution does not contain H^+.

   ANS: C DIF: Easy REF: 2.2
   OBJ: 2.2.g. Calculate the concentration of H+ or OH– given the OH– or H+ concentration.
   MSC: Applying

53. What is the concentration of OH^- in a solution that contains 3.9×10^{-4} M H^+?
a. 2.6×10^{-11} M
b. 3.9×10^{-4} M
c. 2.7×10^{-2} M
d. 1.0×10^{-14} M

ANS: A DIF: Medium REF: 2.2
OBJ: 2.2.g. Calculate the concentration of H+ or OH– given the OH– or H+ concentration.
MSC: Applying

54. What is the concentration of H^+ in a solution of 0.05 M NaOH?
a. 5×10^{-16} M
b. 2×10^{-13} M
c. 5×10^{12} M
d. 140 M

ANS: B DIF: Medium REF: 2.2
OBJ: 2.2.g. Calculate the concentration of H+ or OH– given the OH– or H+ concentration.
MSC: Applying

55. Which of the following is the K_w value for pure water at 25°C?
a. 1×10^{14}
b. 1×10^{-14}
c. 7
d. 14

ANS: B DIF: Medium REF: 2.2
OBJ: 2.2.g. Calculate the concentration of H+ or OH– given the OH– or H+ concentration.
MSC: Applying

56. Calculate the pH of a solution that contains 3.9×10^{-4}M H^+.
a. 4.59
b. 10.59
c. 3.41
d. 9.41

ANS: C DIF: Easy REF: 2.2
OBJ: 2.2.h. Relate pH to the concentration of H+ or OH–. MSC: Applying

57. Calculate the concentration of pH of a 0.023 M HCl solution.
a. 12.36
b. 3.68
c. 1.64
d. 2.30

ANS: C DIF: Medium REF: 2.2
OBJ: 2.2.g. Calculate the concentration of H+ or OH– given the OH– or H+ concentration.
MSC: Applying

58. Calculate the pH of a solution that contains 7.8×10^{-6} M OH^-.
a. 1.28
b. 5.11
c. 12.72
d. 8.89

ANS: D DIF: Medium REF: 2.2
OBJ: 2.2.g. Calculate the concentration of H+ or OH– given the OH– or H+ concentration.
MSC: Applying

59. Which of the following acids is the strongest given their Ka values?
a. HF (3.5×10^{-4})
b. $HClO_2$ (1.1×10^{-2})
c. HCN (4.9×10^{-10})
d. HNO_2 (4.6×10^{-4})

ANS: B DIF: Medium REF: 2.2
OBJ: 2.2.i. Differentiate between weak acids and strong acids and between weak bases and strong bases. MSC: Analyzing

60. If an unknown solution has low pKa value, it can be said with certainty that it is
a. a weak acid.
b. a strong acid.
c. pure water.
d. a nonpolar solution.

ANS: B DIF: Easy REF: 2.2
OBJ: 2.2.i. Differentiate between weak acids and strong acids and between weak bases and strong bases. MSC: Applying

61. Weak acids have a high pKa because the
a. HA concentration is high.
b. H^+ concentration is high.
c. A^- concentration is high.
d. HA concentration is low.

ANS: A DIF: Easy REF: 2.2
OBJ: 2.2.i. Differentiate between weak acids and strong acids and between weak bases and strong bases. MSC: Applying

62. You wish to prepare a solution with a pH of 5.44. If the pKa of the weak acid is 4.74, what ratio of weak base to weak acid should you use?
a. 0.70
b. 0.20
c. 1.4
d. 5.0

ANS: D DIF: Medium REF: 2.2
OBJ: 2.2.j. Relate pH to pKa using the Henderson-Hasselbalch equation.
MSC: Applying

63. Calculate the pH of a solution containing 0.105 M HA and 0.146 M A^-. The Ka for the weak acid is 1.8×10^{-5}.
a. 4.88
b. 9.11
c. 4.74
d. 7.00

ANS: A DIF: Medium REF: 2.2
OBJ: 2.2.j. Relate pH to pKa using the Henderson-Hasselbalch equation.
MSC: Applying

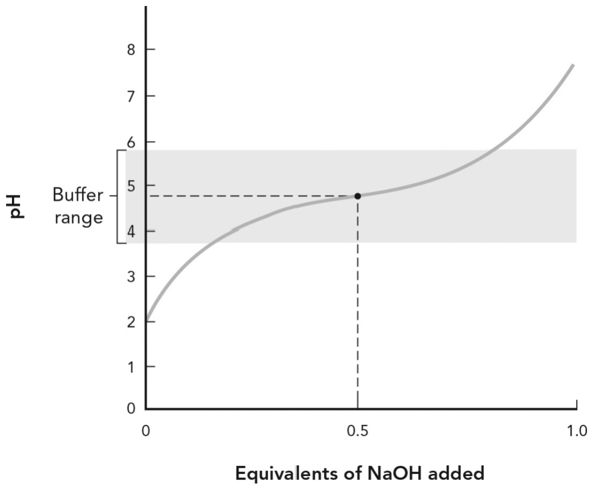
64. Given a solution with pH > pKa, what are the relative concentrations of A^- and HA?
a. $[HA] > [A^-]$
b. $[HA] < [A^-]$
c. $[HA] = [A^-]$
d. $[HA] = [A^-] = 1$

ANS: B DIF: Difficult REF: 2.2
OBJ: 2.2.j. Relate pH to pKa using the Henderson-Hasselbalch equation.
MSC: Analyzing

65. Which of the following are true about buffers?
a. An effective buffer is made from a strong acid and strong base.
b. A buffer is most resistant to changes in pH when $[HA] = [A^-]$.
c. A buffer is only resistant to changes in pH when acid is added.
d. The pH range of a buffering system is 0 to 14.

ANS: B DIF: Medium REF: 2.2
OBJ: 2.2.j. Relate pH to pKa using the Henderson-Hasselbalch equation.
MSC: Remembering

66. Using the figure below, which of the following best describes the titration curve?



a. The equivalence point for the titration is pH = 7.
b. The midpoint of the titration is pH = 7.
c. The pKa for this weak acid is 4.76.
d. This is a titration of a weak base by NaOH.

ANS: C DIF: Easy REF: 2.2
OBJ: 2.2.j. Relate pH to pKa using the Henderson-Hasselbalch equation.
MSC: Understanding

67. A solution of which of the following would be a good buffer system?
a. HCl and NaOH
b. HCl and H_2O
c. CH_3COOH and $NaCH_3COO$
d. NaOH and KOH

ANS: C DIF: Easy REF: 2.2
OBJ: 2.2.j. Relate pH to pKa using the Henderson-Hasselbalch equation.
MSC: Understanding

68. A molecule with hydrophobic and hydrophilic properties is best described as
a. a zwitterion.
b. amphipathic.
c. polar.
d. nonpolar.

ANS: B DIF: Easy REF: 2.3
OBJ: 2.3.a. Identify the characteristics of a phospholipid that contribute to membrane formation. MSC: Remembering

69. The characteristic(s) of a phospholipid is/are that they
a. are overall nonpolar.
b. have a polar charged head group and nonpolar hydrocarbon tails.
c. have a nonpolar head group and polar hydrocarbon tails.
d. are overall polar.

ANS: B DIF: Easy REF: 2.3
OBJ: 2.3.a. Identify the characteristics of a phospholipid that contribute to membrane formation. MSC: Understanding

70. The fluidity of a membrane depends on
a. the degree of saturation of the phospholipids.
b. the number of phospholipids in the membrane.
c. the size of the polar head group.
d. osmotic pressure.

ANS: A DIF: Easy REF: 2.3
OBJ: 2.3.a. Identify the characteristics of a phospholipid that contribute to membrane formation. MSC: Understanding

71. The lateral mobility of lipids with membrane depends on temperature as well as other factors. What would be expected to happen to the lateral mobility if the temperature was decreased?
a. Mobility would be unaffected.
b. Mobility would increase.
c. Mobility would decrease.
d. The membrane would decompose.

ANS: C DIF: Medium REF: 2.3
OBJ: 2.3.c. Explain the various ways cholesterol affects membrane structure.
MSC: Applying

72. How are polar molecules like glucose transported across a membrane?
   a. There are holes in the membrane.
   b. There are proteins that allow the transportation of polar molecules across the membrane.
   c. Polar molecules cannot ever enter the cell.
   d. Polar molecules diffuse across the hydrophobic barrier.

   ANS: B DIF: Easy REF: 2.3
   OBJ: 2.3.c. Explain the various ways cholesterol affects membrane structure.
   MSC: Applying

73. The endomembrane system encompasses which part of the cell?
   a. organelles
   b. nucleus
   c. cytoplasmic membrane structures
   d. entire cell

   ANS: C DIF: Easy REF: 2.3
   OBJ: 2.3.d. Differentiate among the different types of membranes found in a eukaryotic cell.
   MSC: Remembering

74. The endomembrane system is/are
   a. an intracellular network of lipid bilayers.
   b. energy converting organelles.
   c. a membrane surrounding the cell.
   d. nucleotide-containing membranes.

   ANS: A DIF: Easy REF: 2.3
   OBJ: 2.3.d. Differentiate among the different types of membranes found in a eukaryotic cell.
   MSC: Remembering

75. The main function of the chloroplast is
   a. protein biosynthesis.
   b. to attach carbohydrates to lipids.
   c. to convert light energy into chemical energy.
   d. RNA synthesis.

   ANS: C DIF: Easy REF: 2.3
   OBJ: 2.3.d. Differentiate among the different types of membranes found in a eukaryotic cell.
   MSC: Remembering

SHORT ANSWER

1. Justify the following sentence: The conversion of carbon dioxide and water into glucose and oxygen is a decrease of entropy.

   ANS:
   The balanced chemical equation of $6\ CO_2\ (g) + 6\ H_2O\ (l) \rightarrow C_6H_{12}O_6\ (s) + 6\ O_2\ (g)$ shows that 12 molecules are being converted to 7 molecules. This is an example of decreasing the disorder of the system; therefore this reaction is a decrease in entropy.

   DIF: Difficult REF: 2.1
   OBJ: 2.1.i. Explain the concept of entropy and its role in biological systems.
   MSC: Evaluating

2. Calculate ΔG for a reaction given $\Delta H = 15.4$ kJ/mole and $\Delta S = 2.0$ J/K at 298 K. Is this reaction spontaneous in the forward direction?

ANS:
Using the equation $\Delta G = \Delta H - T\Delta S$ and converting the units of entropy to kJ, the final answer is 14.8 kJ/mole.

DIF: Medium REF: 2.1
OBJ: 2.1.k. Identify the impacts of enthalpy, entropy, and temperature on free energy.
MSC: Applying

3. Compare the reaction conditions for $\Delta G°$ and $\Delta G°'$.

ANS:
$\Delta G°$ is the standard free energy change and measured under 1 atm and 298 K, where all reactants and products are present at 1 M. $\Delta G°'$ is the biochemical standard condition where the free energy change is measured under 1 atm and 298 K, where all reactants and products are present at 1 M as well as at pH 7 and the concentration of H_2O is 55.5 M.

DIF: Medium REF: 2.1
OBJ: 2.1.l. Differentiate between standard state condition and the biochemical standard state.
MSC: Analyzing

4. Compare the reaction conditions under which you measure K_{eq} versus Q.

ANS:
K_{eq} is the equilibrium constant, so the reaction is at equilibrium at 1 atm, 298 K, and initial concentration of 1 M of all reactants and products. Q is the mass-action ratio measured at nonequilibrium concentrations.

DIF: Medium REF: 2.1
OBJ: 2.1.l. Differentiate between standard state condition and the biochemical standard state.
MSC: Analyzing

5. Calculate the $\Delta G°$ for the net reaction given the following two reactions:

Reaction 1: $A + B \rightarrow C$ $\Delta G° = 5\,\frac{\text{kJ}}{\text{mol}}$.

Reaction 2: $C + D \rightarrow E$ $\Delta G° = -12\,\frac{\text{kj}}{\text{mol}}$.

ANS:
The net reaction is the addition of reaction 1 and 2. The net $\Delta G°$ is $5 - 12 = -7$ kJ/mol.

DIF: Medium REF: 2.1
OBJ: 2.1.m. Differentiate between exergonic and endergonic reactions and explain how such reactions are coupled in biological systems. MSC: Applying

6. Differentiate between autotrophs and heterotrophs.

ANS:
Autotrophs convert solar energy to chemical energy, whereas heterotrophs cannot.

DIF: Easy REF: 2.1
OBJ: 2.1.b. Differentiate between autotrophs and heterotrophs.
MSC: Analyzing

7. How can a reaction that is endergonic occur in a biological system?

ANS:
It must be paired with an exergonic reaction for a reaction in a biological system to occur.

DIF: Easy REF: 2.1
OBJ: 2.1.m. Differentiate between exergonic and endergonic reactions and explain how such reactions are coupled in biological systems. MSC: Understanding

8. Compare a catabolic pathway versus an anabolic pathway.

ANS:
Anabolic pathways synthesize biomolecules, whereas catabolic pathways extract energy from metabolic fuels. Catabolic pathways also generate ATP and reduced coenyzmes.

DIF: Medium REF: 2.1
OBJ: 2.1.o. Describe the relationship between energy charge and concentrations of ATP, ADP, and AMP. MSC: Analyzing

9. The antifreeze proteins evolved independently through convergent evolution. What does that mean?

ANS:
Convergent evolution is the independent evolution of similar proteins for similar functions. For example, insect antifreeze proteins prevent the formation of ice crystals in the hemolymph by disrupting hydrogen bonding between H_2O molecules. The structures of antifreeze proteins from four different organisms show that although they all contain numerous threonine residues on the protein surface, the overall structure of the proteins is quite different.

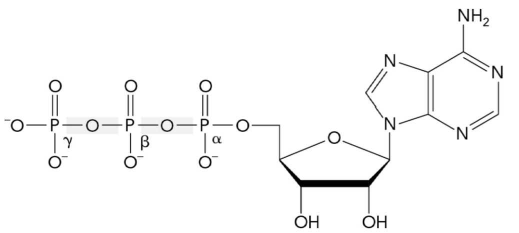
DIF: Medium REF: 2.2
OBJ: 2.2.b. Describe how an antifreeze protein functions. MSC: Remembering

10. List the three chemical properties of ATP that account for the large standard free energy change that occurs when a phosphoanhydride bond is cleaved.

ANS:
1. Electrostatic repulsion between the charged phosphoryl groups destabilizes ATP. Repulsion is reduced on hydrolysis, and therefore the products of ATP hydrolysis are more stable than ATP itself, which favors the hydrolysis reaction.
2. The released phosphate ion has more possible resonance forms than when it is covalently attached to adenylate. Entropically, this favors the free phosphate ions compared to ATP or ADP.
3. The phosphate ion and ADP have a greater degree of solvation than ATP. This means that the phosphate ion and ADP form hydration layers and are more stable than ATP.

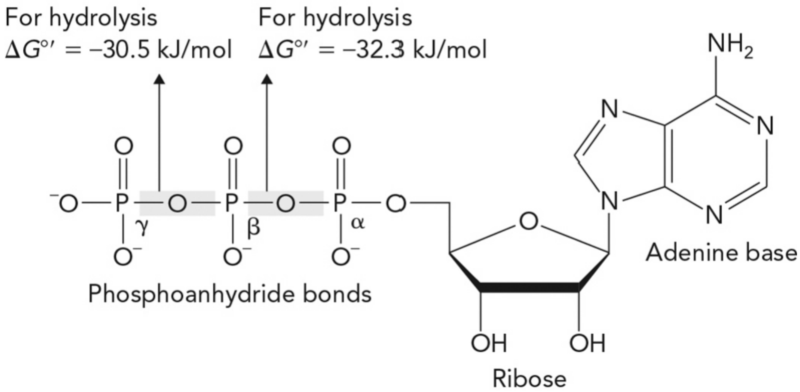
DIF: Easy REF: 2.1
OBJ: 2.1.n. Identify the characteristics of the ATP molecule that provide such a large standard free energy change for phosphoanhydride bond cleavage. MSC: Remembering

11. In the figure below, identify the adenine base, ribose, and phosphoanhydride bonds.



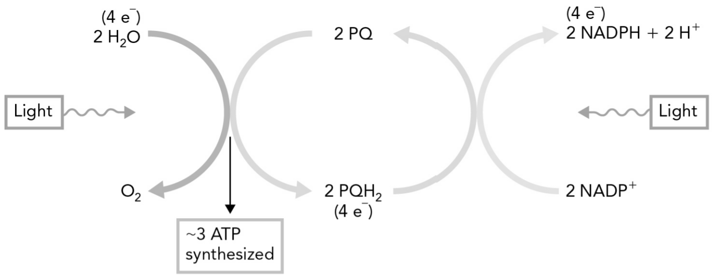
ANS:

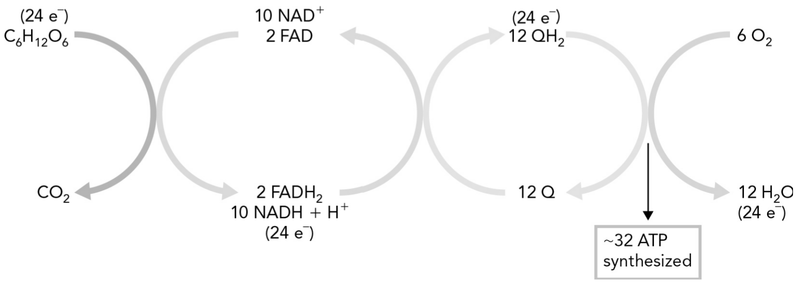
Adenosine-5′-triphosphate



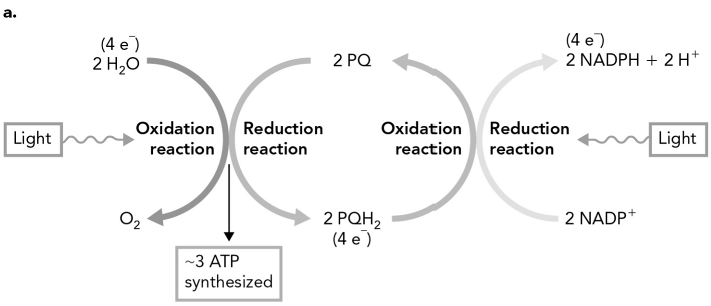
DIF: Easy REF: 2.1
OBJ: 2.1.n. Identify the characteristics of the ATP molecule that provide such a large standard free energy change for phosphoanhydride bond cleavage. MSC: Understanding

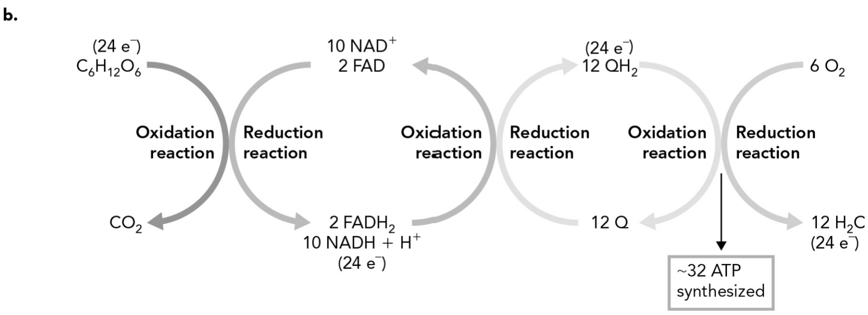
12. In the figure below, label which reactions are oxidations and which are reduction.





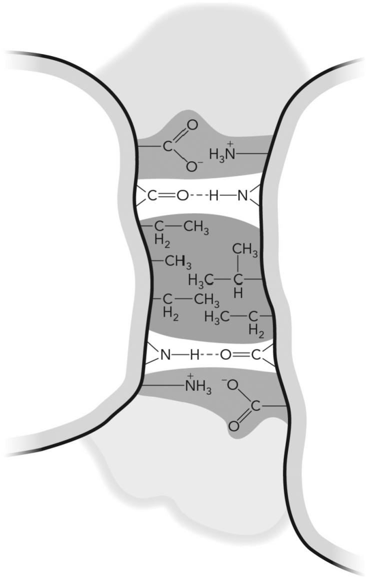
ANS:



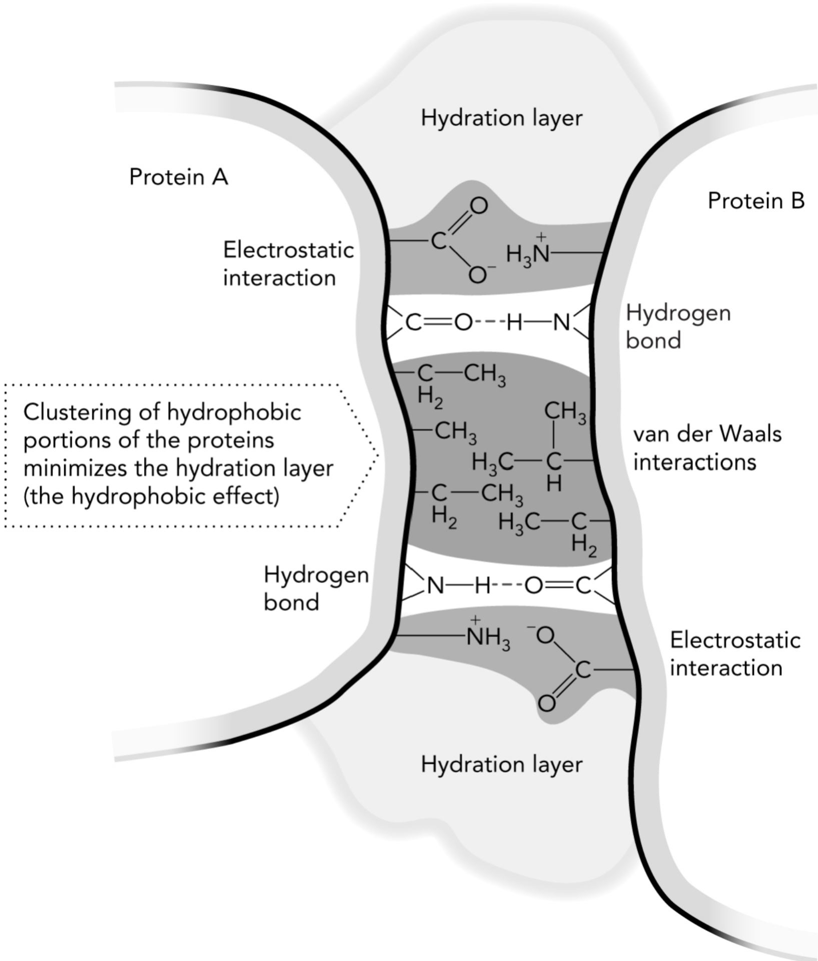


DIF: Easy REF: 2.1
OBJ: 2.1.c. Explain the role of oxidation-reduction reactions in biological systems.
MSC: Remembering

13. Given the figure below, label the following: hydration layer, electrostatic interaction, hydrogen bond, van der Waals interaction.



ANS:



DIF: Easy REF: 2.2
OBJ: 2.2.d. State the concept of the hydrophobic effect and how it impacts protein folding.
MSC: Remembering

14. If serum pH falls blow pH 7.4, a condition called acidosis, how does the body respond?

ANS:
The equilibrium of the carbonic acid–bicarbonate reaction is shifted toward H_2CO_3 formation to decrease H^+ concentration and thereby increase the pH. This is done by lowering CO_2 through hyperventilation and decreasing excretion of HCO_3^- by the kidneys.

DIF: Difficult REF: 2.2
OBJ: 2.2.j. Relate pH to pKa using the Henderson-Hasselbalch equation.
MSC: Analyzing

15. Compare the structure of a phospholipid bilayer and the structure of a micelle.

ANS:
Phospholipid bilayers are characteristic of biological membranes and create a hydrophobic barrier between two aqueous compartments. The hydrophilic polar head groups orient toward the aqueous environment, and the hydrophobic nonpolar hydrocarbon tails form a water impermeable barrier in the interior of the membrane. Micelles are structures in which the hydrophobic tails are in the center of a globular sphere and the polar head groups are facing outward toward the water.

DIF: Easy REF: 2.3
OBJ: 2.3.a. Identify the characteristics of a phospholipid that contribute to membrane formation. MSC: Analyzing

16. The inclusion of cholesterol in a membrane can change the behavior of the membrane. Compare how the membrane behaves at low cholesterol concentration compared with high cholesterol concentration.

ANS:
When small amounts of cholesterol are added to a membrane, it prevents close packing by the phospholipids and helps the membrane increase fluidity. When large amounts are added, the cell membrane fluidity decreases due to the rigid ring structure of cholesterol.

DIF: Medium REF: 2.3
OBJ: 2.3.c. Explain the various ways cholesterol affects membrane structure.
MSC: Analyzing

17. It is known that lipid molecules in a membrane are able to move throughout the membrane. Propose a method to determine which mode of motion is MOST likely to happen and justify your answer.

ANS:
Fluorescence labeling of a phospholipid to determine that rotational movement would be the most likely to happen. This requires the least energy to perform and does not require the movement of another phospholipid.

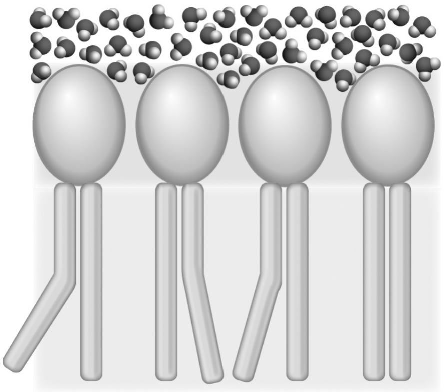
DIF: Difficult REF: 2.3
OBJ: 2.3.c. Explain the various ways cholesterol affects membrane structure.
MSC: Evaluating

18. What are the three major types of membranes?

ANS:
Plasma membrane, endomembrane, organelle membranes

DIF: Easy REF: 2.3
OBJ: 2.3.d. Differentiate among the different types of membranes found in a eukaryotic cell.
MSC: Remembering

19. Using the figure below, explain how having unsaturated fatty acid tails on phospholipids affects the fluidity of the membrane.



ANS:
The kink in the tails that occurs with the inclusion of a double bond prevents the tight packing of the fatty acid tails and increases the fluidity of the membrane.

DIF: Medium REF: 2.3
OBJ: 2.3.a. Identify the characteristics of a phospholipid that contribute to membrane formation. MSC: Understanding

20. Fill in the table below.

If the sign of ΔH is	and if the sign of ΔS is	then the sign of ΔG will be	Will it be spontaneous?
Negative	Positive		
Positive	Negative		
Negative	Negative		
Positive	Positive		

ANS:

If sign of ΔH is	and if the sign of ΔS is	then the sign of ΔG will be	Will it be spontaneous?
Negative	Positive	Negative	Yes at all temperatures
Positive	Negative	Positive	No at all temperatures
Negative	Negative	Negative when temperature is low Positive when temperature is high	Temperature dependent
Positive	Positive	Negative when temperature is high Positive when temperature is low	Temperature dependent

DIF: Difficult REF: 2.1
OBJ: 2.1.k. Identify the impacts of enthalpy, entropy, and temperature on free energy.
MSC: Understanding

21. Explain why a negative ΔG does not necessarily mean it will be a rapid reaction.

ANS:
ΔG tells you whether a reaction is likely to proceed to products as written. It is not a measure of the rate at which a reaction will take place. To determine rates of reactions you need to consider the kinetics of a reaction.

DIF: Difficult REF: 2.1
OBJ: 2.1.k. Identify the impacts of enthalpy, entropy, and temperature on free energy.
MSC: Understanding

22. Water is a simple molecule that has three distinct properties. What are these properties and how are they critical for life processes?

ANS:
Water is less dense as a solid than a liquid, which allows water to float. Water is a liquid over a wide range of temperatures, which allows for the existence of aquatic life and oxygen content in the atmosphere. Water is an excellent solvent that is polar and can solvate ions and polar molecules. Hydrogen bonding within water is also important as it keeps water as a solvent over a much larger temperature range then would be expected.

DIF: Difficult REF: 2.2
OBJ: 2.2.c. Differentiate among hydrogen bonds, ionic interactions, and van der Waals interactions. MSC: Understanding

23. Explain the first and second laws of thermodynamics and how they are relevant to the field of biochemistry.

ANS:
The first law of thermodynamics states that energy is neither created nor destroyed, only converted from one form to another. This is what allows energy to be taken in by plants as light and converted to chemical energy. The second law of thermodynamics states that entropy in the universe is always increasing and therefore without the input of energy to restrain entropy, the highly ordered structures of organisms would fail and the organism would die.

DIF: Difficult REF: 2.1
OBJ: 2.1.h. State the second law of thermodynamics as it applies to biological systems.
MSC: Understanding

24. Explain why adding nonpolar compounds to water is energetically unfavorable.

ANS:
The addition of nonpolar compounds to water breaks the hydrogen bonds between water molecules without replacing them and leads to the formation of ordered cagelike water structures, which is energetically unfavorable.

DIF: Medium REF: 2.2
OBJ: 2.1.h. State the second law of thermodynamics as it applies to biological systems.
MSC: Understanding

25. Name and briefly describe the four types of weaker intermolecular forces found in biochemistry.

ANS:
Hydrogen bonds: form between a hydrogen atom on an electronegative donor group and another electronegative atom that serves as a hydrogen-bond acceptor.

Ionic interactions: weak interactions between oppositely charged atoms or groups.

van der Waals: weak interactions occurring between the dipoles of nearby electrically neutral molecule.

Hydrophobic effects: weak “interaction” is due to the tendency of hydrophobic molecules to pack close together away from water.

DIF: Easy REF: 2.2
OBJ: 2.1.h. State the second law of thermodynamics as it applies to biological systems.
MSC: Understanding