MOLECULAR BIOLOGY OF THE CELL, SIXTH EDITION
CHAPTER 2: CELL CHEMISTRY AND BIOENERGETICS

1. Which of the following elements is not normally found in cells?
   A. Copper
   B. Iron
   C. Silver
   D. Cobalt
   E. Zinc

2. A hydrophobic molecule is typically …
   A. able to form hydrogen bonds with itself but not with water.
   B. able to form hydrogen bonds with water.
   C. charged.
   D. hard to dissolve in a solvent.
   E. incapable of interacting favorably with water.

3. For each of the following pairs, indicate whether they interact via hydrogen bonds (H) or ionic bonds (I), or do not favorably interact (N). Your answer would be a four-letter string composed of letters H, I, and N only, e.g. HNNI.
   ( ) ATP and Mg^{2+}
   ( ) Urea and water
   ( ) Glucose and the enzyme hexokinase (which uses glucose as a substrate)
   ( ) A phospholipid tail and inorganic phosphate

4. Which of the following chemicals do you NOT expect to be readily dissolved in water?
   A. Uric acid
   B. Hexane
   C. Glycerol
   D. Ethanol

E. Potassium chloride

5. Weak noncovalent attractions in the cell can be very strong in a nonaqueous environment. Some of these attractions are as strong as covalent interactions in a vacuum (their bond energy is approximately 340 kJ/mole), but become more than twenty-five times weaker (their bond energy becomes approximately 13 kJ/mole) in water. What type of attraction shows this phenomenon?

A. Electrostatic attractions
B. Hydrogen bonds
C. van der Waals attractions
D. Hydrophobic force
E. All of the above

6. The bond energies associated with noncovalent attractions in the cell are too weak to resist disruption by thermal motion. However, cellular macromolecules can interact specifically AND strongly with each other (or fold by themselves) merely via such interactions. How is this possible?

A. The bond energies increase radically when two interacting molecules approach each other.
B. The interacting molecules also fortify their binding via covalent bonds to keep them from dissociation.
C. Many weak bonds together in a complementary geometry can afford a strong binding.
D. The cell lowers its internal temperature to reduce thermal motion of molecules and enhance the weak attractions.

7. What is the pH of a 10^{-8} M solution of hydrochloric acid? Round the pH value to the nearest integer, e.g. 10.

A. 8
B. 7
C. 6
D. 5
E. 4

8. The cell can change the pH of its internal compartments using membrane transport proteins that pump protons into or out of a compartment. How many protons should be pumped into an endocytic vesicle that is 10^{-15} liters in volume and has a neutral pH in order to change the

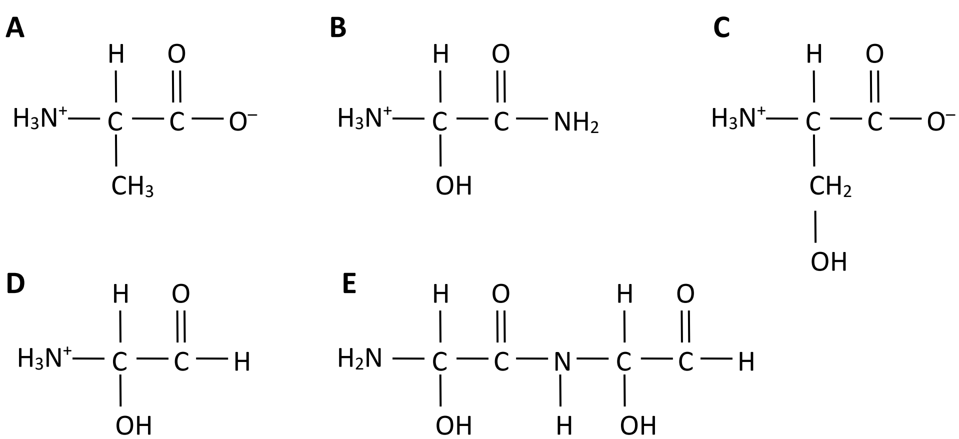
pH to 5? Avogadro's number is 6×10^{23}. Omit complications such as the membrane potential, buffers, and other cellular components.

A. 6000
B. 60,000
C. 120,000
D. 600,000
E. 6,000,000

9. Which of the following is true regarding a fatty acid molecule in water?

A. It is positively charged at physiological pH, but can become neutral when the pH is high enough.
B. It is positively charged at physiological pH, but can become neutral when the pH is low enough.
C. It is negatively charged at physiological pH, but can become neutral when the pH is high enough.
D. It is negatively charged at physiological pH, but can become neutral when the pH is low enough.
E. It is not charged at physiological pH.

10. The amino acid serine has an amino group, a carboxyl group, and a hydroxyl group. Which of the following better represents the structure of this amino acid at neutral pH?



11. The three families of cellular macromolecules are polymerized and depolymerized by a general mechanism involving water. Each of them has a set of monomers whose polymerization

changes the total free energy of the system. Which of the following statements is true regarding these macromolecules?

A. Each polymerization step requires free-energy input and proceeds by the consumption of one water molecule.
B. Each depolymerization step requires free-energy input and proceeds by the consumption of one water molecule.
C. Each polymerization step requires free-energy input and proceeds by the release of one water molecule.
D. Each depolymerization step requires free-energy input and proceeds by the release of one water molecule.

12. Sort the following from a low to a high contribution to the total mass of an *E. coli* bacterium. Your answer would be a four-letter string composed of letters A to D only, e.g. DCBA.

(A) Water
(B) Sugars
(C) Proteins
(D) Nucleic acids

13. Which of the following statements is true regarding cellular metabolism?

A. A living organism decreases the entropy in its surroundings.
B. During catabolism, heat is generated, and the cell uses this heat to perform work during anabolism.
C. The heat released by an animal cell as part of its metabolic processes comes from the bond energies in the foodstuffs that are consumed by the animal.
D. Living organisms defy the second law of thermodynamics, but still obey the first law.

14. The folding of proteins can be considered a simple conversion from the unfolded to the natively folded state. At about 27°C (or 300 K), the free-energy change of folding for a particular protein is measured to be –40 kJ/mole. If the enthalpy change (ΔH) of folding is –640 kJ/mole, what is the entropy change (ΔS) of folding for this protein? Write down your answer with the appropriate sign (+ or –) and in kJ/mole/K, e.g. –1000 kJ/mole/K.

15. Which of the following correctly summarizes the overall process of photosynthesis?

A. $CO_2 + O_2 \rightarrow H_2O$ + sugars
B. $CH_2O + CO_2 + O_2 \rightarrow H_2O$ + sugars

C. $CO_2 + H_2O \rightarrow H_2 + CO_2$
D. $CO_2 + H_2O \rightarrow O_2$ + sugars

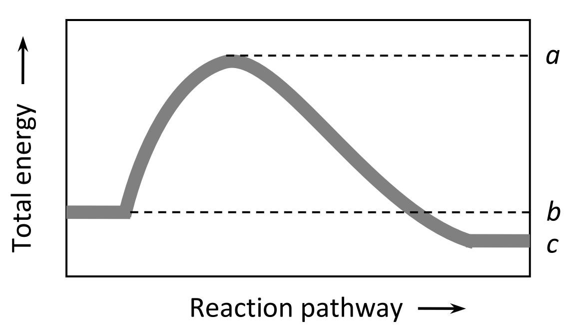
16. Which of the following statements is true regarding reactions involving oxidation and reduction?

A. The carbon atom is more oxidized in formaldehyde (CH_2O) than in methanol (CH_3OH).
B. Oxidation of food in all organisms requires oxygen.
C. A molecule is oxidized if it gains an electron (plus a proton) in a reaction.
D. A dehydrogenation reaction is a reduction.
E. In an organic molecule, the number of C–H bonds increases as a result of oxidation.

17. Enzymes are the cell's catalyst crew. They make the life of the cell possible by carrying out various reactions with astounding performance. Which of the following is NOT true regarding cellular enzymes?

A. Enzymes lower the activation energy of the reactions that they catalyze.
B. Enzymes can specifically drive substrate along certain reaction pathways.
C. Enzymes can push energetically unfavorable reactions forward by coupling them to energetically favorable reactions.
D. Enzymes are proteins, but RNA catalysts, called ribozymes, also exist.
E. Enzymes can change the equilibrium point for reactions that they catalyze.

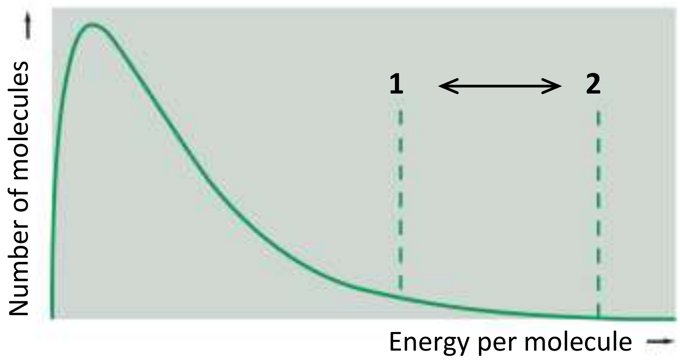
18. In the following diagram showing the reaction pathway for a simple single-substrate enzymatic reaction, which of the quantities corresponds to the activation energy of the forward reaction?



A. $(a - b)$

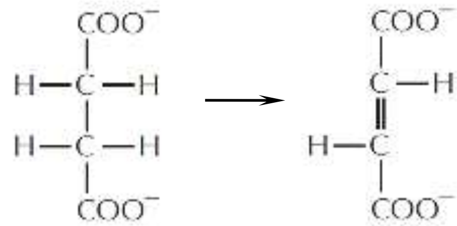
B. $(a + b)$
C. $(a - c)$
D. $(a + c)$
E. $(b - c)$

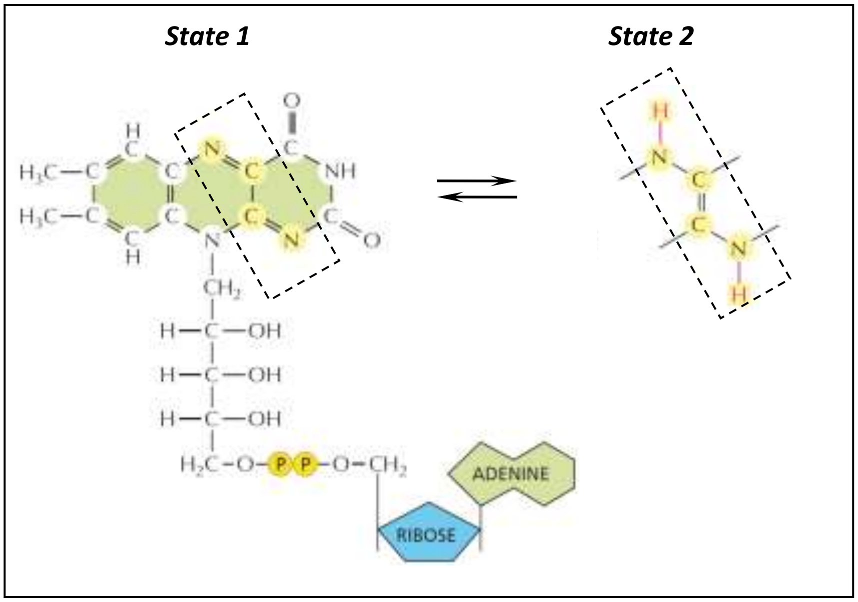
19. In the following diagram showing the distribution of thermal energy in a population of substrate molecules, the energy thresholds indicated by numbers represent ...



A. the activation energy at high and low temperature.
B. the reaction rate at high and low pH.
C. the activation energy with and without an enzyme.
D. the reaction rate at high and low substrate concentrations.
E. the activation energy at high and low substrate concentrations.

20. A cellular enzyme catalyzes the catabolic reaction shown below. Its coenzyme is shown in the box. Which of the following is correct regarding this reaction?





A. The substrate is reduced in this reaction and the coenzyme is converted from state 1 to state 2.
B. The substrate is oxidized in this reaction and the coenzyme is converted from state 1 to state 2.
C. The substrate is reduced in this reaction and the coenzyme is converted from state 2 to state 1.
D. The substrate is oxidized in this reaction and the coenzyme is converted from state 2 to state 1.

21. The molecules inside the cell constantly collide with other molecules and diffuse through the cytoplasm in a random walk. The average net distance traveled by such a molecule after a certain time period t is proportional to the square root of t, i.e. $(t)^{0.5}$, as well as to its diffusion coefficient. If, on average, it takes a molecule 100 milliseconds to travel a net distance of 0.5 µm from its starting point, how long would it normally take for the same molecule to travel a net distance of 5 µm from the same starting point?

A. 0.2 second

B. 0.3 second
C. 1 second
D. 10 seconds
E. 0.32 seconds

22. Sort the following molecules from a low to high rate of diffusion inside the cytosol. Your answer would be a four-letter string composed of letters A to D only, e.g. ADCB.
(A) Myoglobin (a protein)
(B) Glycine (an amino acid)
(C) Ribosome (a protein–RNA complex)
(D) CO_2

23. The equilibrium constant for the reaction that breaks down each molecule of substrate A to one molecule of B and one molecule of C is equal to 0.5. Starting with a mixture containing only molecules A at 1 M concentration, what will be the concentration of molecule A after reaching equilibrium under these conditions?
A. 0.5 M
B. 0.25 M
C. 0.125 M
D. 0.333 M
E. 0.667 M

24. The free-energy change (ΔG) for a simple reaction, A → B, is 0 kJ/mole at 37°C when the concentrations of A and B are 10 M and 0.1 M, respectively. What is the free-energy change for the reaction when the concentrations of A and B are instead 0.01 M and 1 M, respectively? Recall that $\Delta G° = -5.9 \times \log(K_{eq})$. Write down your answer as a number with the appropriate sign (+ or –) and in kJ/mole, e.g. +11.8 kJ/mole.

25. Imagine the reaction A → B with a negative ΔG value under experimental conditions. Which of the following statements is true about this reaction?
A. The reaction is energetically unfavorable.
B. The reaction proceeds spontaneously and rapidly under these conditions.
C. Increasing the concentration of B molecules would increase the ΔG value (toward more positive values).
D. The reaction would result in a net decrease in the entropy (disorder) of the universe.

E. The reaction cannot proceed unless it is coupled to another reaction with a positive value of ΔG.

26. In the first reaction of the glycolytic pathway, the enzyme hexokinase uses ATP to catalyze the phosphorylation of glucose, yielding glucose 6-phosphate and ADP. The $\Delta G°$ value for this reaction is –17 kJ/mole. The enzyme glucose 6-phosphatase catalyzes a "reverse" reaction, in which glucose 6-phosphate is converted back to glucose, and a phosphate is released. The $\Delta G°$ value for this reaction is –14 kJ/mole. What is the $\Delta G°$ value for the following reaction?

$ATP + H_2O \rightarrow ADP + P_i$

A. –3 kJ/mole
B. +3 kJ/mole
C. –31 kJ/mole
D. +31 kJ/mole
E. –15.5 kJ/mole

27. The enzyme phosphoglucose isomerase converts glucose 6-phosphate to its isomer fructose 6-phosphate in the second step of glycolysis. The equilibrium constant for the reaction is 0.36. Evaluating the $\Delta G°$ of the reaction ($\Delta G° = –5.9 \times \log K_{eq}$), decide which of the following conclusions is true.

A. The $\Delta G°$ is negative, therefore the reaction proceeds in the forward direction.
B. The $\Delta G°$ is negative, but whether or not the reaction proceeds would depend on ΔG, not $\Delta G°$.
C. The $\Delta G°$ is positive, but in a cell that is active in glycolysis, the reaction can still proceed in the forward direction.
D. The $\Delta G°$ is positive, therefore the reaction proceeds in the reverse direction.

28. Which of the following represents an "activated" carrier molecule?

A. AMP
B. NADH
C. NAD^+
D. $NADP^+$
E. CoA

29. ATP is the main energy currency in cells, and it can especially be used to drive condensation reactions that produce macromolecular polymers. How does ATP normally catalyze the condensation reaction, which by itself is energetically unfavorable?

A. It transfers its terminal phosphate to an enzyme and is released as ADP.
B. It transfers its two terminal phosphates to an enzyme, and is released as AMP.
C. It covalently attaches to both of the substrates.
D. It transfers either one or two terminal phosphate(s) to one of the substrates and is released as either ADP or AMP.
E. It covalently attaches to the enzyme, forming an enzyme–AMP adduct.

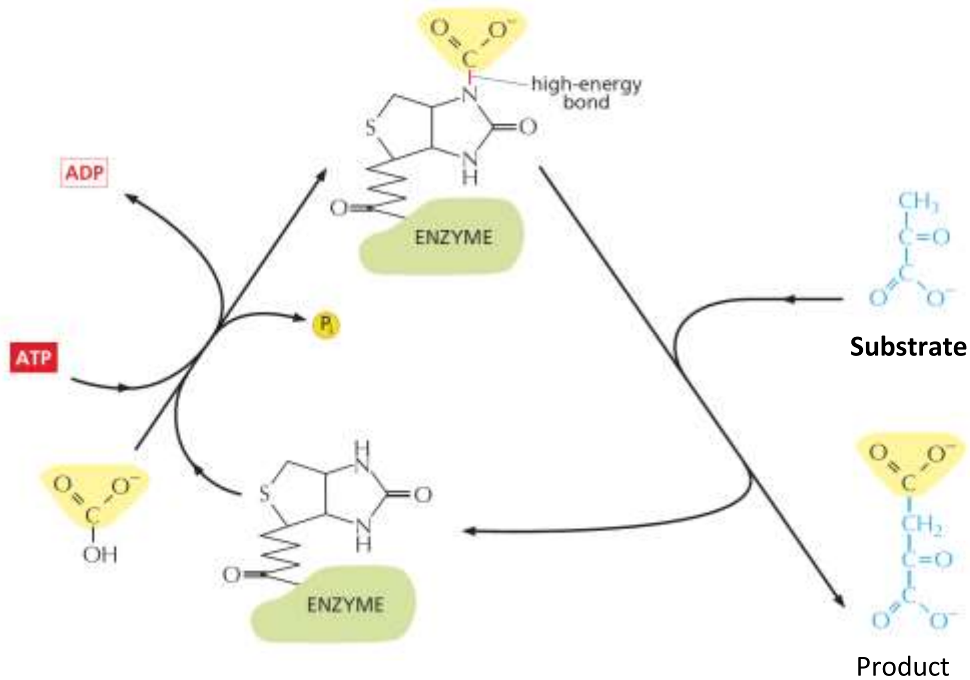
30. Despite their overall similarity, NADH and NADPH are not used indiscriminately by the cell. What are the distinctive features of these two carrier molecules?

A. NADPH has an extra phosphate near its nicotinamide ring, giving it distinct electron-transfer properties.
B. In the cell, NADH is usually in excess over NAD^+, but $NADP^+$ is usually in excess over NADPH.
C. NADH is normally involved in anabolic reactions, whereas NADPH is normally involved in catabolism.
D. Both NADPH and NADH are recognized by the same enzymes with similar affinities, since the extra phosphate group in NADPH is not involved in such recognition.
E. In the cell, NADH is found mostly in the form that acts as an oxidizing agent, whereas NADPH is found mostly in the form that acts as a reducing agent.

31. In an enzymatic reaction involving NADH or NADPH, reduction of a substrate accompanies the oxidation of these carrier molecules to NAD^+ or $NADP^+$, respectively. What else typically happens in such a reaction?

A. A molecule of water is released to the solution upon completion of the reaction.
B. A proton is released during the oxidation of the carriers.
C. A proton is taken up by the substrate that is being reduced.
D. A proton is taken up by the carrier molecule that is being oxidized.
E. A phosphate group is transferred to the substrate.

32. What is the reaction performed on the molecule labeled as substrate in the following diagram? What is the name of the activated carrier?



A. This is a methylation reaction and the activated carrier is ATP.
B. This is a methylation reaction and the activated carrier is *S*-adenosylmethionine.
C. This is a carboxylation reaction and the activated carrier is ATP.
D. This is a carboxylation reaction and the activated carrier is carboxylated biotin.
E. This is an acetylation reaction and the activated carrier is acetyl CoA.

33. Under anaerobic conditions, glycolysis provides most of the ATP that the cell needs. In animal cells, pyruvate, the end product of glycolysis, is converted to lactic acid by lactate dehydrogenase, as shown below:

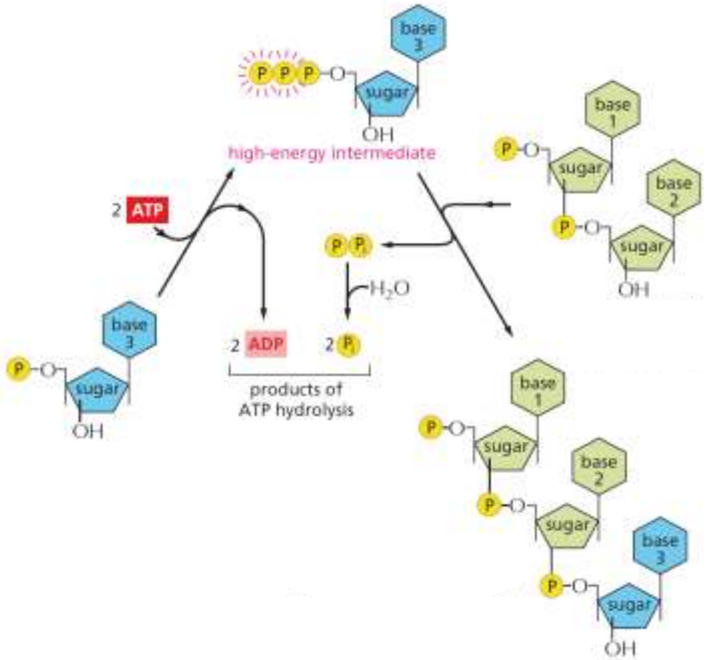
$$CH_3(CO)COO^- + X \rightarrow CH_3(CHOH)COO^- + Y$$

What is the correct carrier pair (in place of X and Y) in this reaction?

A. X is (ADP + P_i), and Y is (ATP)
B. X is ($NADP^+$), and Y is (NADPH + H^+)
C. X is (NAD^+), and Y is (NADH + H^+)
D. X is (NADH + H^+), and Y is (NAD^+)
E. X is ($NADP^+$+ H^+), and Y is (NADPH)

34. Macromolecules in the cell can be made from their monomers using one of two polymerization schemes. One is called *head polymerization*, in which the reactive bond required for polymerization is carried on the end of the growing polymer. In contrast, in *tail*

polymerization, the reactive bond is carried by each monomer for its own incorporation. In the figure, indicate the polymerization scheme and the type of macromolecule.



A. Head polymerization of a protein
B. Tail polymerization of a protein
C. Head polymerization of a polysaccharide
D. Head polymerization of a nucleic acid
E. Tail polymerization of a nucleic acid

35. What is the end product of glycolysis in the cytoplasm of eukaryotic cells? How many carbon atoms does the molecule have?

A. Acetyl CoA; it has two carbon atoms attached to coenzyme A
B. Phosphoenolpyruvate; it has three carbon atoms
C. Glucose 6-phosphate; it has six carbon atoms
D. Pyruvate; it has three carbon atoms
E. Glyceraldehyde 3-phosphate; it has three carbon atoms

36. The substrate for the glycolytic enzyme glyceraldehyde 3-phosphate dehydrogenase is glyceraldehyde 3-phosphate (with one phosphate group) while its product is 1,3-bisphosphoglycerate (with two phosphate groups). Where does the extra phosphate group come from?

A. From combining two molecules of the substrate

B. ATP
C. Fructose 1,6-bisphosphate
D. P_i
E. NADH

37. Steps 6 and 7 of glycolysis are catalyzed by the enzymes glyceraldehyde 3-phosphate dehydrogenase and phosphoglycerate kinase, respectively. Together, they ...

A. result in the oxidation of an aldehyde to a carboxylic acid.
B. produce both ATP and NADH.
C. couple the oxidation of a C–H bond to the activation of carrier molecules.
D. catalyze the only glycolytic reactions that create a high-energy phosphate linkage directly from inorganic phosphate.
E. All of the above.

38. Arsenate is a toxic ion that can interfere with both glycolysis and oxidative phosphorylation. Arsenate resembles P_i (inorganic phosphate) and can replace it in many enzymatic reactions. One such reaction is catalyzed by glyceraldehyde 3-phosphate dehydrogenase in step 6 of glycolysis. Upon completion of the reaction, instead of the normal product, 1,3-bisphosphoglycerate, the mixed anhydride 1-arsenato-3-phosphoglycerate is formed; this undergoes rapid spontaneous hydrolysis into arsenate plus 3-phosphoglycerate, the latter being a normal product of step 7 in glycolysis. What would be the effect of arsenate poisoning in glycolysis?

A. It results in more ATP and NADH molecules generated for every glucose molecule.
B. It results in fewer ATP molecules generated per glucose molecule, but NADH generation is not directly affected.
C. It brings glycolysis to an abrupt stop.
D. It results in fewer ATP and NADH molecules generated per glucose molecule.
E. It does not affect the number of ATP or NADH molecules generated per glucose molecule.

39. Which of the following is true regarding energy production and storage in plants and animals?

A. Plant and animal cells make starch for long-term energy storage.
B. Most of the ATP in a plant cell has been generated in the chloroplast and transported to other parts of the cell.

C. Oxidation of one gram of starch releases more energy than oxidation of fat, but since starch absorbs a lot of water, it is not as efficient as fat in energy storage.
D. Animals, but not plants, can store fats in the form of triacylglycerol (triglyceride).
E. Plant seeds often contain large amounts of fats and starch.

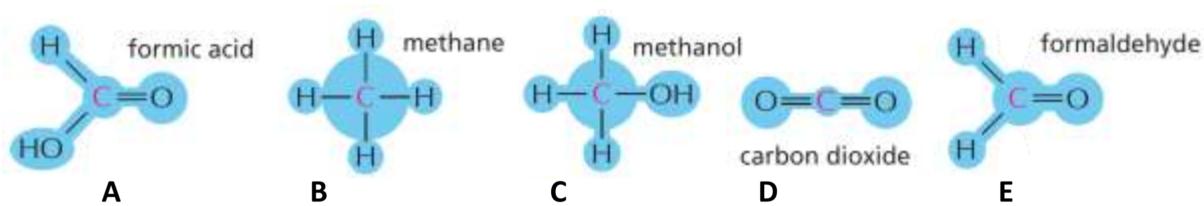
40. What are the molecules that normally supply carbon and oxygen atoms, respectively, for the citric acid cycle?

A. Oxaloacetate, oxaloacetate
B. Acetyl CoA, O_2
C. Oxaloacetate, O_2
D. Acetyl CoA, H_2O
E. Pyruvate, pyruvate

41. Indicate if each of the following descriptions matches lipids (1), nucleic acids (2), polysaccharides (3), or proteins (4). Your answer would be a four-digit number composed of digits 1 to 4 only, e.g. 1332.

( ) Their monomers contain phosphorus and nitrogen.
( ) They constitute almost half of the cell's dry mass.
( ) They are the main constituent of all cellular membranes.
( ) They are largely hydrophobic and can store energy.

42. Sort the following molecules (A to E) based on the oxidation of the carbon atom, from higher to lower oxidation states. Your answer would be a five-letter string composed of letters A to E only, e.g. ADCBE. Put the letter corresponding to the highest oxidation level on the left.



43. Indicate true (T) and false (F) statements below regarding glycolysis. Your answer would be a four-letter string composed of letters T and F only, e.g. TTTT.

( ) Molecular oxygen is used in glycolysis to oxidize glucose.
( ) Along the glycolytic pathway, ATP is both consumed and generated.

( ) In the course of glycolysis, one molecule of NADH is formed per molecule of glucose.

( ) Following the production of one molecule of fructose 1,6-bisphosphate, the rest of the glycolytic pathway generates four molecules of ATP.

44. Fill in the blank in the following paragraph.

> "During intense 'anaerobic' physical exercise, the high energy demand in the muscle cells leads to an accumulation of lactic acid in these cells and their surrounding tissues. Similarly, the yeast *Saccharomyces cerevisiae* can produce ethanol when grown anaerobically. The lactate or ethanol production takes place in a process called ..."

45. Sort the following molecules based on the amount of energy that is released when their phosphate bond is hydrolyzed as indicated. Your answer would be a four-letter string composed of letters A to D only, e.g. ADCB. Put the molecule with the highest amount of hydrolysis energy on the left.

(A) ATP when hydrolyzed to ADP

(B) Glucose 6-phosphate when hydrolyzed to glucose

(C) 1,3-bisphosphoglycerate when hydrolyzed to 3-phosphoglycerate

(D) Phosphoenolpyruvate when hydrolyzed to pyruvate

46. Indicate true (T) and false (F) statements below regarding fatty acid metabolism. Your answer would be a four-letter string composed of letters T and F only, e.g. TTTT.

( ) Most animals derive their energy from fatty acids between meals.

( ) Fatty acids are converted to acetyl CoA in the cytosol, which is then transported into mitochondria for further oxidation.

( ) Fatty acids are stored in fat droplets in the form of triacylglycerols.

( ) The breakdown of fatty acids into each acetyl CoA unit requires the hydrolysis of two ATP molecules.

47. Indicate whether each of the following descriptions matches glycolysis (G) or the Krebs cycle (K). Your answer would be a four-letter string composed of letters G and K only, e.g. GGGK.

( ) It oxidizes acetyl CoA to CO_2.

( ) In eukaryotic cells, it is carried out in the cytosol.

( ) It produces $FADH_2$.

( ) α-Ketoglutarate, one of its intermediates, is used to synthesize the amino acid glutamic acid.

48. Indicate whether each of the following molecules is an intermediate in glycolysis (G) or in the tricarboxylic acid cycle (T). Your answer would be a four-letter string composed of letters G and T only, e.g. GGTT.

( ) Fumarate

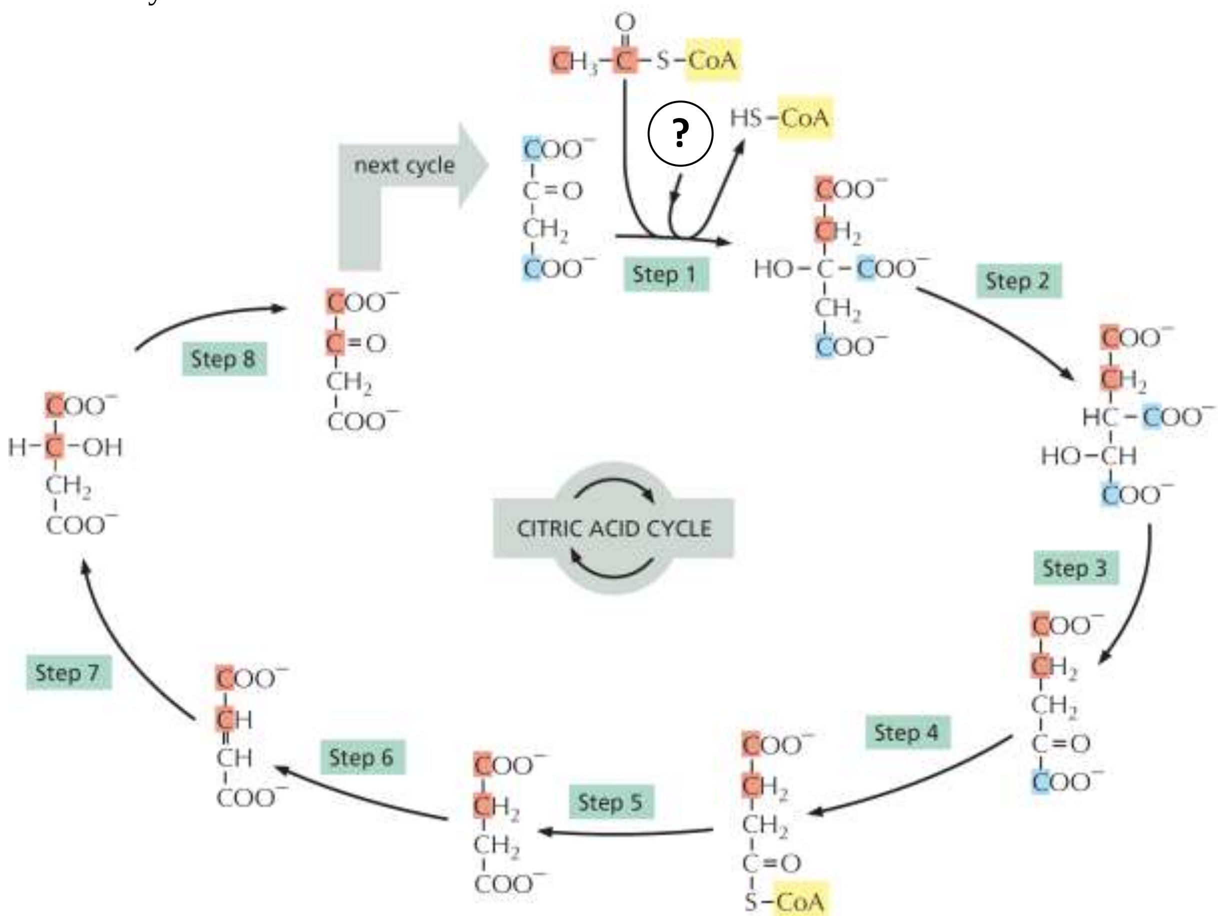
( ) Malate

( ) Phosphoenolpyruvate

( ) Succinate

The Citric Acid Cycle: Questions 49-52

The citric acid cycle is summarized in the following figure. Answer the following question(s) about this cycle.



49. In step 1 of the citric acid cycle drawn above, what is the molecule indicated with a question mark?

A. O_2
B. ATP
C. H_2O
D. H^+
E. Pyruvate

50. In the citric acid cycle shown above, which steps produce CO_2 as a by-product? List all such steps by their number, from the smallest number to the largest. Your answer would be a number composed of digits 1 to 8 only, e.g. 258.

51. In the citric acid cycle shown above, which steps produce either NADH or $FADH_2$? List all such steps by their number, from the smallest number to the largest. Your answer would be a number composed of digits 1 to 8 only, e.g. 258.

52. Aconitase catalyzes an isomerization reaction in the citric acid cycle shown above, in which H_2O is first removed and then added back to the substrate. Which step is catalyzed by this enzyme? Write down the step number as your answer, e.g. 5.

53. The electron carriers NADH and $FADH_2$ donate their electrons to the electron-transport chain in the inner mitochondrial membrane, leading to ATP synthesis powered by an H^+ gradient across the membrane. If, on average, the oxidation of each NADH or $FADH_2$ molecule in this pathway results in the production of 2.5 and 1.5 molecules of ATP, respectively, how many ATP (and GTP) molecules are produced on average as a result of the complete oxidation of one molecule of acetyl CoA in the mitochondrion? Consider only the citric acid cycle and oxidative phosphorylation.

A. 10
B. 12
C. 13.5
D. 14.5
E. 15

54. Indicate true (T) and false (F) statements below regarding the cellular metabolism of nucleotides and amino acids. Your answer would be a four-letter string composed of letters T and F only, e.g. TTTT.

( ) Nitrogen fixation occurs in the mitochondria in most animal cells to generate amino acids.

( ) All 20 natural amino acids must be provided in our diet and are therefore “essential.”

( ) There are NO essential nucleotides that must be provided in the diet.

( ) Catabolism of amino acids in our body leads to the production of urea which is excreted.

Answers

1. Answer: C
   Difficulty: 1
   Section: The Chemical Components of a Cell
   Feedback: Metal ions such as copper, iron, cobalt, and zinc are used as cofactors that are necessary for the function of some enzymes.
2. Answer: E
   Difficulty: 1
   Section: The Chemical Components of a Cell
   Feedback: Hydrophobic molecules usually have no charge and form no or few hydrogen bonds, and are therefore not favored by the network of hydrogen bonds in liquid water. They do dissolve in nonpolar organic solvents.
3. Answer: IHHN
   Difficulty: 2
   Section: The Chemical Components of a Cell
   Feedback: ATP is negatively charged and can form ionic bonds with magnesium ions. Urea is highly soluble in water due to its hydrogen-bonding capacity. Similarly, interaction of a polar molecule like glucose with the active site of an enzyme can be mediated by hydrogen bonds and other noncovalent (or even covalent) bonds. In contrast, the fatty acid tails in phospholipids are hydrophobic and do not favorably interact with negatively charged phosphate molecules.
4. Answer: B
   Difficulty: 3
   Section: The Chemical Components of a Cell
   Feedback: Hexane is an alkane hydrocarbon incapable of hydrogen-bonding with water molecules, which results in an entropically unfavorable state when the two interact. All the other mentioned chemicals can be readily dissolved in water because they have polar bonds or can dissociate into ions.
5. Answer: A
   Difficulty: 2
   Section: The Chemical Components of a Cell
   Feedback: The probing of the charged ions by water molecules greatly reduces the bond energy of ionic bonds (electrostatic interactions) in aqueous solutions. Hydrogen bonds are also weakened in water, but they are not that strong in a vacuum to begin with.
6. Answer: C
   Difficulty: 1

Section: The Chemical Components of a Cell

Feedback: Although each noncovalent bond is weak, when many of them are formed simultaneously (in a complementary interface), their energies can sum to produce a tight binding.

7. Answer: B

   Difficulty: 3

   Section: The Chemical Components of a Cell

   Feedback: The concentration of hydronium ions would be the sum of those obtained from the dissociation of water and the acid: $[H_3O^+] = 10^{-7} + 10^{-8} = 1.1 \times 10^{-7}$. The pH value will then be calculated as: pH = $-\log [H_3O^+] = -\log [1.1 \times 10^{-7}] = 7 - \log (1.1) = 6.96$. This is very close to neutral pH.

8. Answer: A

   Difficulty: 3

   Section: The Chemical Components of a CellFeedback: The initial number of hydronium ions would be: $[H_3O^+]_1 = 10^{-15}$ L × 10^{-7} mole/L = 10^{-22} mole. The final number at pH 5 would be: $[H_3O^+]_2 = 10^{-15}$ L × 10^{-5} mole/L = 10^{-20} mole. The difference is: $[H_3O^+]_2 - [H_3O^+]_1 = 9.9 \times 10^{-21}$ mole. This is equivalent to approximately 6000 protons that need to be pumped in.

9. Answer: D

   Difficulty: 3

   Section: The Chemical Components of a Cell

   Feedback: Due to the presence of the carboxyl group, a fatty acid molecule carries a negative charge at neutral pH. However, lowering the pH can reverse the ionization of this group to the neutral (protonated) state.

10. Answer: C

    Difficulty: 2

    Section: The Chemical Components of a Cell

    Feedback: The amino and carboxyl groups are common to all amino acids. The serine side chain contains a hydroxyl group.

11. Answer: C

    Difficulty: 2

    Section: The Chemical Components of a Cell

    Feedback: The polymerization reaction generally requires a free-energy input. Also, the addition of each monomer to the growing polymer is a condensation reaction that is accompanied by the release of one water molecule. The opposite reaction (depolymerization) involves hydrolysis and consumes one water molecule.

12. Answer: BDCA

    Difficulty: 2

    Section: The Chemical Components of a Cell

    Feedback: Water accounts for about 70% of the total mass in a typical cell. In the remaining "dry mass," proteins constitute about half, the nucleic acids RNA and DNA are next, and polysaccharides (and their sugar monomers) are still less abundant.

13. Answer: C

    Difficulty: 2

    Section: Catalysis and the Use of Energy by Cells

    Feedback: For a living animal cell, heat-generating reactions from burning of foodstuffs are "coupled" to other reactions that increase order inside the cell. Concomitantly, there is an increase in the overall entropy of the universe (cell plus its environment), with no violation of the laws of thermodynamics for a spontaneous process.

14. Answer: –2 kJ/mole/K

    Difficulty: 3

    Section: Catalysis and the Use of Energy by Cells

    Feedback: For the folding reaction, the free-energy change can be written as:

    $$\Delta G = \Delta H - T\Delta S$$

    Therefore:

    $$\Delta S = (\Delta H - \Delta G)/T = (-640 \text{ kJ/mole} + 40 \text{ kJ/mole}) / (300 \text{ K}) = -2 \text{ kJ/mole/K}$$

    The negative value of ΔS means a decrease in entropy. This is not unexpected since folding results in the formation of a single conformation (or a limited set of conformations) out of an enormous number of possible coils.

15. Answer: D

    Difficulty: 2

    Section: Catalysis and the Use of Energy by Cells

    Feedback: Photosynthesis consumes water and atmospheric CO_2 to make simple sugars and the by-product oxygen.

16. Answer: A

    Difficulty: 3

    Section: Catalysis and the Use of Energy by Cells

    Feedback: Oxidation involves the full or partial removal of electrons from an atom, and does not necessarily involve oxygen. In the cell, organic molecules usually release a proton to their surrounding when oxidized in a dehydrogenation reaction, decreasing the number of C–H bonds in the molecule.

17. Answer: E

Difficulty: 2

Section: Catalysis and the Use of Energy by Cells

Feedback: Enzymes catalyze most cellular reactions by lowering the activation energy, but they cannot change the equilibrium constant of the reactions that they catalyze; that is, both forward and reverse reactions are sped up by the same factor. However, they can selectively drive substrates along one of various cellular metabolic pathways, and can also couple unfavorable reactions to spontaneous heat-generating reactions.

18. Answer: A

    Difficulty: 2

    Section: Catalysis and the Use of Energy by Cells

    Feedback: The activation energy corresponds to the height of the energy barrier between the reactant and the product, and is the minimum amount of energy that should be provided in order for the reaction to proceed.

19. Answer: C

    Difficulty: 2

    Section: Catalysis and the Use of Energy by Cells

    Feedback: In the presence of an enzyme (line 1), the fraction of substrate molecules that have enough thermal energy to proceed through the reaction is increased compared to that in the uncatalyzed reaction (line 2).

20. Answer: B

    Difficulty: 3

    Section: Catalysis and the Use of Energy by Cells

    Feedback: This is the reaction catalyzed by the enzyme succinate dehydrogenase in the citric acid cycle. Succinate is oxidized to fumarate, and the FAD carrier is reduced to $FADH_2$. By subsequently donating its two electrons to the electron-transport chain, $FADH_2$ will be converted back to FAD for another round of the reaction.

21. Answer: D

    Difficulty: 3

    Section: Catalysis and the Use of Energy by Cells

    Feedback: The net distance of 5 μm is 10 times higher than 0.5 μm, and would on average take 10 seconds (i.e. $10^2 \times 100$ milliseconds) to reach.

22. Answer: CABD

    Difficulty: 2

    Section: Catalysis and the Use of Energy by Cells

Feedback: In general, larger molecules diffuse more slowly compared to smaller molecules. Interaction with other molecules (including the solvent) and the shape of the molecule will also affect the diffusion coefficient.

23. Answer: A

Difficulty: 3

Section: Catalysis and the Use of Energy by Cells

Feedback: The equilibrium constant for this reaction is calculated as:

$K_{eq} = 0.5 = [B]_{eq}\,[C]_{eq} / [A]_{eq}$

Since the initial mixture contains only molecule A, it follows that:

$[B]_{eq} = [C]_{eq} = 1\text{ M} – [A]_{eq}$

Combining these equations and solving for $[A]_{eq}$, we will have:

$[A]_{eq} = 0.5\text{ M}$

which means the molecules B and C will also be present at 0.5 M at equilibrium.

24. Answer: +23.6kJ/mole

Difficulty: 4

Section: Catalysis and the Use of Energy by Cells

Feedback: The free-energy change can be written as:

$$\Delta G = \Delta G° + RT \ln([B]/[A])$$

When ΔG is equal to zero, the system is at chemical equilibrium, and

$$\Delta G° = – RT \ln([B]_{eq}/[A]_{eq}) = – RT \ln(10^{–2}) = –5.9 \times \log (10^{–2}) = +11.8\text{ kJ/mole}$$

When the concentrations are changed, we have:

$\Delta G = \Delta G° + RT \ln([B]/[A]) = \Delta G° + RT \ln(10^{2}) = \Delta G° – RT \ln(10^{–2}) = 2\,\Delta G° = +23.6$ kJ/mole

25. Answer: C

Difficulty: 3

Section: Catalysis and the Use of Energy by Cells

Feedback: The negative ΔG value indicates that the reaction is favorable under these conditions and would increase the entropy of the universe. However, unless we know the steps of the reaction, the ΔG value cannot predict the reaction rate, because the latter depends on the activation-energy barrier. Finally, the ΔG value changes as the concentrations of reactants and products change. As the products accumulate, the reaction will eventually reach an equilibrium, where ΔG is equal to zero.

26. Answer: C

Difficulty: 3

Section: Catalysis and the Use of Energy by Cells

Feedback: The two reactions described in the question can be written as:

ATP + glucose → ADP + glucose 6-phosphate $\Delta G°$= –17 kJ/mole

glucose 6-phosphate + H_2O → glucose + P_i $\Delta G°$= –14 kJ/mole

Combining these reactions yields the ATP hydrolysis reaction presented in the question. Since the free-energy changes are additive, the $\Delta G°$ value for this combined reaction is the sum of the $\Delta G°$ values for the two reactions above:

(–17 kJ/mol) + (–14 kJ/mole) = –31 kJ/mole.

27. Answer: C

Difficulty: 3

Section: Catalysis and the Use of Energy by Cells

Feedback: Since the equilibrium constant is less than 1, the log K_{eq} term is negative, making the $\Delta G°$ positive, which means the reaction is unfavorable under standard conditions. But inside a cell performing glycolysis, a lower concentration of fructose 6-phosphate than of glucose 6-phosphate can drop ΔG to a negative value. The reaction thus proceeds in the forward direction, providing a continuous supply of substrate for the next step in the pathway. Note that due to “coupling” of the reactions in the glycolytic pathway, and even though some steps can have positive $\Delta G°$ values, the overall negative $\Delta G°$ of the pathway can drive the entire chain of reactions in the forward direction, even under the standard conditions.

28. Answer: B

Difficulty: 1

Section: Catalysis and the Use of Energy by Cells

Feedback: The activated carrier molecules carry chemical groups in high-energy linkages and can deliver the group or the energy (or both) to metabolic reactions when necessary. They then need to be activated again. NADH is an activated carrier, while its oxidized form NAD^+ is not.

29. Answer: D

Difficulty: 1

Section: Catalysis and the Use of Energy by Cells

Feedback: By transferring either a phosphate group or a pyrophosphate group to a hydroxyl group on one of the monomers involved in the polymerization, ATP “activates” the monomer, making the overall reaction favorable.

30. Answer: E

Difficulty: 3

Section: Catalysis and the Use of Energy by Cells

Feedback: The extra phosphate in NADPH does not affect its electron-transfer properties, but makes it different enough to be recognized by a different set of enzymes. NADPH operates chiefly with enzymes that catalyze anabolic reactions, which normally need reducing power. Accordingly, NADPH is found mostly in its reduced form (i.e. in excess over $NADP^+$) in the cell. The opposite is true for NADH, which is normally involved in catabolic reactions.

31. Answer: C
Difficulty: 2
Section: Catalysis and the Use of Energy by Cells
Feedback: In a reduction reaction, NADPH (or NADH) is oxidized, donating a hydride ion to the substrate. A substrate can also capture a proton from the surroundings, creating two C–H bonds. The carrier is converted to its oxidized form ($NADP^+$ or NAD^+).
32. Answer: D
Difficulty: 2
Section: Catalysis and the Use of Energy by Cells
Feedback: The reaction shown is catalyzed by the enzyme pyruvate carboxylase, which uses a covalently bound carboxylated biotin to carboxylate pyruvate and produce oxaloacetate.
33. Answer: D
Difficulty: 3
Section: Catalysis and the Use of Energy by Cells
Feedback: Under anaerobic conditions, NAD^+ can be recycled in this reaction (in which pyruvate is reduced), so that glycolysis can continue in the absence of oxidative phosphorylation.
34. Answer: E
Difficulty: 2
Section: Catalysis and the Use of Energy by Cells
Feedback: Each nucleotide monomer is activated—at the expense of hydrolysis of two ATP molecules—into an intermediate carrying a reactive phosphoanhydride bond.
35. Answer: D Difficulty: 1 Section: How Cells Obtain Energy from Food
Feedback: In glycolysis, two pyruvate molecules (each with three carbon atoms) are produced from each molecule of glucose (with six carbon atoms).
36. Answer: D
Difficulty: 2
Section: How Cells Obtain Energy from Food
Feedback: In step 6 of glycolysis, this enzyme couples the oxidation of the substrate with the production of NADH, as well as incorporation of inorganic phosphate. The P_i is then transferred to ADP to generate ATP in step 7.

37. Answer: E
    Difficulty: 2
    Section: How Cells Obtain Energy from Food
    Feedback: Please refer to Figure 2–48.
38. Answer: B
    Difficulty: 3
    Section: How Cells Obtain Energy from Food
    Feedback: Since step 7 is bypassed, the ATP molecules that are naturally generated in that step are no longer produced; however, NADH is still made as before in the first half of step 6. Arsenate also has other effects on cell metabolism that collectively make it a toxic compound. Please refer to Figure 2–48.
39. Answer: E
    Difficulty: 1
    Section: How Cells Obtain Energy from Food
    Feedback: Compared to the polysaccharides glycogen (in animals) and starch (in plants), fat is more efficient as a long-term energy storage both per gram and per volume. It can be stored as triglycerides in both plants and animals, although the types of fatty acids vary. In plant cells, chloroplasts generate sugars that can be oxidized by the mitochondria to generate ATP for the cell. The ATP produced in the chloroplast by photosynthesis cannot be transported out of that organelle.
40. Answer: D
    Difficulty: 2
    Section: How Cells Obtain Energy from Food
    Feedback: One molecule of acetyl CoA enters the cycle by combining with oxaloacetate.
41. Answer: 2411
    Difficulty: 2
    Section: The Chemical Components of a Cell
    Feedback: The nucleotides contain one to three phosphate groups and a nitrogen-containing base, and are polymerized to form long nucleic acid molecules such as DNA. Proteins are made of amino acids and make up half of the dry mass of the cell, i.e. approximately 15% of the total cell weight. Lipids have large hydrophobic fatty acid chains and, in addition to forming bilayer membranes, can store food energy and release it when necessary.
42. Answer: DAECB
    Difficulty: 3
    Section: Catalysis and the Use of Energy by Cells

Feedback: As a general rule, in organic molecules, a lower number of C–H bonds corresponds to more oxidized carbon atoms.

43. Answer: FTFT

    Difficulty: 2

    Section: How Cells Obtain Energy from Food

    Feedback: During the stepwise oxidation of glucose in the course of glycolysis, two molecules of ATP are used to make fructose 1,6-bisphosphate, which is then cleaved and eventually converted to two molecules of pyruvate, generating four molecules of ATP and two molecules of NADH.

44. Answer: fermentation

    Difficulty: 1

    Section: How Cells Obtain Energy from Food

    Feedback: Fermentation is an energy-yielding pathway and is often anaerobic.

45. Answer: DCAB

    Difficulty: 2

    Section: How Cells Obtain Energy from Food

    Feedback: Hydrolysis of phosphoenolpyruvate to pyruvate is the most exergonic (releases the highest amount of energy). ATP can be generated from ADP upon the hydrolysis of 1,3-bisphosphoglycerate to 3-phosphoglycerate. ATP hydrolysis can be used to drive the phosphorylation of glucose.

46. Answer: TFTF

    Difficulty: 2

    Section: How Cells Obtain Energy from Food

    Feedback: Between meals, fatty acids stored in the fat droplets in adipocytes in the form of triacylglycerol are released by hydrolysis and enter the bloodstream. Upon entry into other cells, they are transported to the mitochondria where they are mostly converted to acetyl CoA in a step-by-step manner, each step producing one $FADH_2$ and one NADH molecule.

47. Answer: KGKK

    Difficulty: 2

    Section: How Cells Obtain Energy from Food

    Feedback: In the citric acid cycle (Krebs cycle), which takes place in the mitochondria, the carbon atoms of acetyl CoA are oxidized and released as CO_2, while NADH, $FADH_2$, and GTP are generated in the process. Many intermediates of the citric acid cycle and glycolysis are precursors for the biosynthesis of important small molecules in the cell.

48. Answer: TTGT

Difficulty: 2

Section: How Cells Obtain Energy from Food

Feedback: Phosphoenolpyruvate is converted to pyruvate in the last step of glycolysis. Succinate, fumarate, and malate are three consecutive citric acid cycle intermediates leading to the regeneration of oxaloacetate.

49. Answer: C

Difficulty: 3

Feedback: In the first step of the citric acid cycle, CoA is hydrolyzed by water after the formation of a citryl CoA intermediate.

50. Answer: 34

Difficulty: 3

Feedback: Steps 3 and 4 are catalyzed by isocitrate dehydrogenase and the α-ketoglutarate dehydrogenase complex, respectively, and involve decarboxylation of the substrates and the release of carbon dioxide.

51. Answer: 3468

Difficulty: 3

Refer to: The Citric Acid Cycle Section: How Cells Obtain Energy from Food

Feedback: Steps 3, 4, and 8 produce NADH, while step 6 produces $FADH_2$.

52. Answer: 2

Difficulty: 2

Feedback: Aconitase converts citrate to isocitrate through an aconitate intermediate created by dehydration of the substrate.

53. Answer: A

Difficulty: 3

Section: How Cells Obtain Energy from Food

Feedback: The complete oxidation of a molecule of acetyl CoA results in the production of three NADH molecules plus one $FADH_2$ and one GTP (or ATP) molecule. Therefore, as a result of oxidative phosphorylation, a total of 10 molecules are generated:

$$(3 \times 2.5) + (1 \times 1.5) + 1 = 10$$

54. Answer: FFTT

Difficulty: 2

Section: How Cells Obtain Energy from Food

Feedback: All known nitrogen-fixing cells are prokaryotic microorganisms. Animals rely on their dietary intake of protein and nucleic acids as sources of useful nitrogen. However, only 9 of the 20 amino acids that make up proteins and none of the nucleotides that make up nucleic acids are essential; the remainder can be synthesized from other ingredients in the diet. When amino acids in our body are degraded, their nitrogen atoms eventually appear in urea molecules which are excreted.