47. Evolutionary foundations
Page: 35 Difficulty: 2
What is meant by endosymbiotic association? How can this concept explain the evolution of eukaryotic cells that are capable of carrying out photosynthesis and/or aerobic metabolism?

Ans: An endosymbiotic association is the envelopment of one organism by another to form a relationship that is beneficial to both organisms. It is believed that primitive eukaryotic cells, which were incapable of photosynthesis or aerobic metabolism, formed endosymbiotic associations with photosynthetic and/or aerobic bacteria. The aerobic bacteria then evolved into the mitochondria found in modern eukaryotic cells, and the photosynthetic bacteria evolved into the chloroplasts found in plant cells. (See Fig. 1-36, p. 35.)

Short Answer Questions

23. Weak interactions in aqueous systems
Pages: 43–51 Difficulty: 2
Name and briefly define four types of noncovalent interactions that occur between biological molecules.

Ans: (1) Hydrogen bonds: weak electrostatic attractions between one electronegative atom (such as oxygen or nitrogen) and a hydrogen atom covalently linked to a second electronegative atom; (2) electrostatic interactions: relatively weak charge-charge interactions (attractions of opposite charges, repulsions of like charges) between two ionized groups; (3) hydrophobic interactions: the forces that tend to bring two hydrophobic groups together, reducing the total area of the two groups that is exposed to surrounding molecules of the polar solvent (water); (4) van der Waals interactions: weak interactions between the electric dipoles that two close-spaced atoms induce in each other.

24. Weak interactions in aqueous systems
Pages: 46–48 Difficulty: 3
Explain the fact that ethanol (CH_3CH_2OH) is more soluble in water than is ethane (CH_3CH_3).

Ans: Ethanol can form hydrogen bonds with water molecules, but ethane cannot. When ethanol dissolves, the decrease in the system's entropy that results from formation of ordered arrays of water around the $CH_3CH_2^-$ group is partly compensated by the favorable interactions (hydrogen bonds) of the hydroxyl group of ethanol with water molecules. Ethane cannot form such hydrogen bonds.

25. Weak interactions in aqueous systems
Pages: 46–48 Difficulty: 3
Explain the fact that triethylammonium chloride ($(CH_3CH_2)_3N$•HCl) is more soluble in water than is triethylamine ($(CH_3CH_2)_3N$).

Ans: The positive charge on the N atom in triethylammonium chloride is more polar than the uncharged N atom in triethylamine. This increased polarity leads to stronger interactions with water, leading to increased solubility.

26. Weak interactions in aqueous systems
Page: 48 Difficulty: 3
Explain with an appropriate diagram why amphipathic molecules tend to form micelles in water. What force drives micelle formation?

Ans: Micelle formation minimizes the area of the hydrophobic part of amphipathic molecules that contacts the polar solvent, water. Hydrophobic interactions between hydrophobic moieties are the driving force for micelle formation. When amphipathic molecules form micelles in water, the entropy decrease due to the formation of ordered arrays of water molecules around the hydrophobic moieties is minimized. (See Fig. 2-7, p. 48.)

22. Peptides and proteins
Page: 88 Difficulty: 1 Ans: D
Which of the following describes the overall three-dimensional folding of a polypeptide?

A) Primary structure
B) Secondary structure
C) Tertiary structure
D) Quaternary structure
E) None of the above

23. Working with proteins
Page: 89 Difficulty: 1 Ans: E
For the study of a protein in detail, an effort is usually made to first:

A) conjugate the protein to a known molecule.
B) determine its amino acid composition.
C) determine its amino acid sequence.
D) determine its molecular weight.
E) purify the protein.

24. Working with proteins
Page: 91 Difficulty: 2 Ans: B
In a mixture of the five proteins listed below, which should elute second in size-exclusion (gel-filtration) chromatography?

A) cytochrome c $M_r = 13,000$
B) immunoglobulin G $M_r = 145,000$
C) ribonuclease A $M_r = 13,700$
D) RNA polymerase $M_r = 450,000$
E) serum albumin $M_r = 68,500$

25. Working with proteins
Page: 92 Difficulty: 2 Ans: E
By adding SDS (sodium dodecyl sulfate) during the electrophoresis of proteins, it is possible to:

A) determine a protein's isoelectric point.
B) determine an enzyme's specific activity.
C) determine the amino acid composition of the protein.
D) preserve a protein's native structure and biological activity.
E) separate proteins exclusively on the basis of molecular weight.

26. Working with proteins
Page: 93 Difficulty: 2 Ans: B
To determine the isoelectric point of a protein, first establish that a gel:

A) contains a denaturing detergent that can distribute uniform negative charges over the protein's surface.
B) exhibits a stable pH gradient when ampholytes become distributed in an electric field.
C) is washed with an antibody specific to the protein of interest.

31. The covalent structure of proteins
Page: 100 Difficulty: 3 Ans: C
A nonapeptide was determined to have the following amino acid composition: $(Lys)_2$, $(Gly)_2$, $(Phe)_2$, His, Leu, Met. The native peptide was incubated with 1- fluoro-2,4-dinitrobenzene (FDNB) and then hydrolyzed; 2,4-dinitrophenylhistidine was identified by HPLC. When the native peptide was exposed to cyanogen bromide (CNBr), an octapeptide and free glycine were recovered. Incubation of the native peptide with trypsin gave a pentapeptide, a tripeptide, and free Lys. 2,4-Dinitrophenyl-histidine was recovered from the pentapeptide, and 2,4 -dinitrophenylphenylalanine was recovered from the tripeptide. Digestion with the enzyme pepsin produced a dipeptide, a tripeptide, and a tetrapeptide. The tetrapeptide was composed of $(Lys)_2$, Phe, and Gly. The native sequence was determined to be:

A) Gly–Phe–Lys–Lys–Gly–Leu–Met–Phe–His.
B) His–Leu–Gly–Lys–Lys–Phe–Phe–Gly–Met.
C) His–Leu–Phe–Gly–Lys–Lys–Phe–Met–Gly.
D) His–Phe–Leu–Gly–Lys–Lys–Phe–Met–Gly.
E) Met–Leu–Phe–Lys–Phe–Gly–Gly–Lys–His.

32. The covalent structure of proteins
Page: 100 Difficulty: 1 Ans: C
Even when a gene is available and its sequence of nucleotides is known, chemical studies of the protein are still required to determine:

A) molecular weight of the protein.
B) the amino-terminal amino acid.
C) the location of disulfide bonds.
D) the number of amino acids in the protein.
E) whether the protein has the amino acid methionine in its sequence.

33. The covalent structure of proteins
Page: 101 Difficulty: 1 Ans: C
The term “proteome” has been used to describe:

A) regions (domains) within proteins.
B) regularities in protein structures.
C) the complement of proteins encoded by an organism’s DNA.
D) the structure of a protein-synthesizing ribosome.
E) the tertiary structure of a protein.

34. The covalent structure of proteins
Pages: 102–103 Difficulty: 2 Ans: C
A major advance in the application of mass spectrometry to macromolecules came with the development of techniques to overcome which of the following problems?

A) Macromolecules were insoluble in the solvents used in mass spectrometry.
B) Mass spectrometric analyses of macromolecules were too complex to interpret.
C) Mass spectrometric analysis involved molecules in the gas phase.
D) Most macromolecules could not be purified to the degree required for mass spectrometric

analysis.
E) The specialized instruments required were prohibitively expensive.

35. Protein sequences and evolution
Pages: 107–109 Difficulty: 3 Ans: A
Compare the following sequences taken from four different proteins, and select the answer that best characterizes their relationships.

	A	B	C
1	DVEKGKKIDIMKCS	HTVEKGGKHKTGPNLH	GLFGRKTGQAPGYSYT
2	DVQRALKIDNNLGQ	HTVEKGAKHKTAPNVH	GLADRIAYQAKATNEE
3	LVTRPLYIFPNEGQ	HTLEKAAKHKTGPNLH	ALKSSKDLMFTVINDD
4	FFMNEDALVARSSN	HQFAASSIHKNAPQFH	NLKDSKTYLKPVISET

A) Based only on sequences in column B, protein 4 reveals the greatest evolutionary divergence.
B) Comparing proteins 1 and 2 in column A reveals that these two proteins have diverged the most throughout evolution.
C) Protein 4 is the protein that shows the greatest overall homology to protein 1.
D) Proteins 2 and 3 show a greater evolutionary distance than proteins 1 and 4.
E) The portions of amino acid sequence shown suggest that these proteins are completely unrelated.

Short Answer Questions

36. Amino acids
Page: 76 Difficulty: 1
What are the structural characteristics common to all amino acids found in naturally occurring proteins?

Ans: All amino acids found in naturally occurring proteins have an α carbon to which are attached a carboxylic acid, an amine, a hydrogen, and a variable side chain. All the amino acids are also in the L configuration.

37. Amino acids
Page: 79 Difficulty: 1
Only one of the common amino acids has no free α-amino group. Name this amino acid and draw its structure.

Ans: The amino acid L-proline has no free α-amino group, but rather has an imino group formed by cyclization of the R-group aliphatic chain with the amino group (see Fig. 3-5, p. 79).

38. Amino acids
Pages: 78–79 Difficulty: 2
Briefly describe the five major groupings of amino acids.

Ans: Amino acids may be categorized by the chemistry of their R groups: (1) nonpolar aliphatics; (2) polar, uncharged; (3) aromatic; (4) positively charged; (5) negatively charged. (See Fig. 3-5, p. 79.)

48. Amino acids
Page: 84 Difficulty: 2
The amino acid histidine has a side chain for which the pK_a is 6.0. Calculate what fraction of the histidine side chains will carry a positive charge at pH 5.4. Be sure to show your work.

Ans: $$\mathrm{pH} = \mathrm{p}K_a + \log \frac{[\text{conjugate base}]}{[\text{acid}]}$$

$$\mathrm{p}K_a - \mathrm{pH} = \log \frac{[\text{acid}]}{[\text{conjugate base}]}$$

$$\text{antilog}\ (\mathrm{p}K_a - \mathrm{pH}) = \frac{[\text{acid}]}{[\text{conjugate base}]}$$

$$\text{antilog}\ (6.0 - 5.4) = \frac{[\text{acid}]}{[\text{conjugate base}]}$$

4 = [acid]/[conjugate base], or
4[conjugate base] = [acid]

Therefore, at pH 5.4, 4/5 (80%) of the histidine will be in the protonated form.

49. Amino acids
Page: 84 Difficulty: 2
The amino acid histidine has three ionizable groups, with pK_a values of 1.8, 6.0, and 9.2. (a) Which pK_a corresponds to the histidine side chain? (b) In a solution at pH 5.4, what percentage of the histidine side chains will carry a positive charge?

Ans: (a) 6.0; (b) 80%. (See the previous problem for expanded solution to this problem.)

50. Amino acids
Page: 85 Difficulty: 2
What is the uniquely important acid-base characteristic of the histidine R group?

Ans: Only the imidazole ring of the histidine R group has a pK_a near physiological pH (pK_a = 6.0), which suggests that histidine may provide buffering power in intercellular and intracellular fluids.

51. Peptides and proteins
Page: 86 Difficulty: 1
How can a polypeptide have only one free amino group and one free carboxyl group?

Ans: This is possible only if the peptide has no side chains with carboxyl or amino groups. Then, with the exception of the single amino-terminal amino acid and the single carboxyl-terminal amino acid, all the other α-amino and carboxyl groups are covalently condensed into peptide bonds.

Ans: The primary structure of a protein is its unique sequence of amino acids and any disulfide bridges present in the native structure, that is, its covalent bond structure.

58. Working with proteins

Pages: 90-91 Difficulty: 2

Why do smaller molecules elute after large molecules when a mixture of proteins is passed through a size-exclusion (gel filtration) column?

Ans: The column matrix is composed of cross-linked polymers with pores of selected sizes. Smaller molecules can enter pores in the polymer beads from which larger molecules would be excluded. Smaller molecules therefore have a larger three-dimensional space in which to diffuse, making their path through the column longer. Larger molecules migrate faster because they pass directly through the column, unhindered by the bead pores.

59. Working with proteins

Pages: 90-91 Difficulty: 2

For each of these methods of separating proteins, describe the principle of the method, and tell what property of proteins allows their separation by this technique.

(a) ion-exchange chromatography
(b) size-exclusion (gel filtration) chromatography
(c) affinity chromatography

Ans: (a) Ion-exchange chromatography separates proteins on the basis of their charges. (b) Size-exclusion or gel filtration chromatography separates on the basis of size (c) Affinity chromatography separates proteins with specific high affinity for some ligand (attached to an inert support) from other proteins with no such affinity. (See Fig. 3-18, p. 91.)

60. Working with proteins

Pages: 90-93 Difficulty: 2

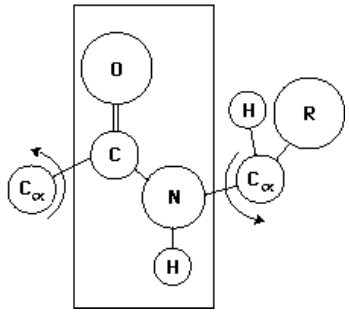
A biochemist is attempting to separate a DNA -binding protein (protein X) from other proteins in a solution. Only three other proteins (A, B, and C) are present. The proteins have the following properties:

	pI (isoelectric point)	Size M_r	Bind to DNA?
protein A	7.4	82,000	yes
protein B	3.8	21,500	yes
protein C	7.9	23,000	no
protein X	7.8	22,000	yes

What type of protein separation techniques might she use to separate
(a) protein X from protein A?
(b) protein X from protein B?
(c) protein X from protein C?

Ans: (a) size-exclusion (gel filtration) chromatography to separate on the basis of size; (b) ion-exchange chromatography or isoelectric focusing to separate on the basis of charge; (c) specific affinity chromatography, using immobilized DNA.

Page: 119 Difficulty: 3 Ans: A
In the diagram below, the plane drawn behind the peptide bond indicates the:



A) absence of rotation around the C—N bond because of its partial double-bond character.
B) plane of rotation around the C_α—N bond.
C) region of steric hindrance determined by the large C=O group.
D) region of the peptide bond that contributes to a Ramachandran plot.
E) theoretical space between –180 and +180 degrees that can be occupied by the ϕ and ψ angles in the peptide bond.

6. **Overview of protein structure**
Page: 119 Difficulty: 2 Ans: D
Which of the following best represents the backbone arrangement of two peptide bonds?

A) C_α—N—C_α—C—C_α—N—C_α—C
B) C_α—N—C—C—N—C_α
C) C—N—C_α—C_α—C—N
D) C_α—C—N—C_α—C—N
E) C_α—C_α—C—N—C_α—C_α—C

7. **Overview of protein structure**
Page: 119 Difficulty: 2 Ans: A
Which of the following pairs of bonds within a peptide backbone show free rotation around both bonds?

A) C_α—C and N—C_α
B) C=O and N—C
C) C=O and N—C_α
D) N—C and C_α—C
E) N—C_α and N—C

8. **Protein secondary structure**
Pages: 120–121 Difficulty: 2 Ans: A
In the α helix the hydrogen bonds:

A) are roughly parallel to the axis of the helix.
B) are roughly perpendicular to the axis of the helix.
C) occur mainly between electronegative atoms of the R groups.
D) occur only between some of the amino acids of the helix.
E) occur only near the amino and carboxyl termini of the helix.

9. **Protein secondary structure**

39. Protein secondary structure
Page: 119 Difficulty: 1
Draw the hydrogen bonding typically found between two residues in an α helix.

Ans: Hydrogen bonds occur between every carbonyl oxygen in the polypeptide backbone and the peptide —NH of the fourth amino acid residue toward the amino terminus of the chain. (See Fig. 4-2, p. 119.)

40. Protein secondary structure
Page: 120 Difficulty: 2
Describe three of the important features of the α-helical polypeptide structure predicted by Pauling and Corey. Provide one or two sentences for each feature.

Ans: The α-helical structure of a polypeptide is tightly wound around a long central axis; each turn of the right-handed helix contains 3.6 residues and stretches 5.4 Å along the axis. The peptide NH is hydrogen-bonded to the carbonyl oxygen of the fourth amino acid along the sequence toward the amino terminus. The R groups of the amino acid residues protrude outward from the helical backbone.

41. Protein secondary structure
Page: 123 Difficulty: 2
Describe three of the important features of a β sheet polypeptide structure. Provide one or two sentences for each feature.

Ans: In the β sheet structure, several extended polypeptides, or two regions of the same polypeptide, lie side by side and are stabilized by hydrogen bonding between adjacent chains. Adjacent chains may be either parallel (with a repeat distance of about 6.5 Å) or antiparallel (7 Å repeat). The R groups are often small and alternately protrude from opposite faces of the β sheet.

42. Protein secondary structure
Page: 123 Difficulty: 2
Why are glycine and proline often found within a β turn?

Ans: A β turn results in a tight 180° reversal in the direction of the polypeptide chain. Glycine is the smallest and thus most flexible amino acid, and proline can readily assume the cis configuration, which facilitates a tight turn.

43. Protein tertiary and quaternary structures
Pages: 127–128 Difficulty: 2
In superhelical proteins, such as collagen, several polypeptide helices are intertwined. What is the function of this superhelical twisting?

Ans: The superhelical twisting of multiple polypeptide helices makes the overall structure more compact and increases its overall strength.

44. Protein tertiary and quaternary structures
Page: 129 Difficulty: 2
Why is silk fibroin so strong, but at the same time so soft and flexible?

Ans: Unlike collagen and keratin, silk fibroin has no covalent crosslinks between adjacent strands, or stabilize the arrangement through hydrophobic interactions. (See Fig. 4-20, p. 140.)

50. Protein tertiary and quaternary structures
Page: 144 Difficulty: 1
Describe the quaternary structure of hemoglobin.

Ans: Each protein molecule is composed of two copies each of two different subunits α and β. The two $\alpha\beta$ protomers are arranged with C_2 symmetry.

51. Protein tertiary and quaternary structures
Pages: 145–146 Difficulty: 2
Describe briefly the two major types of symmetry found in oligomeric proteins and give an example of each.

Ans: 1) Rotational: In rotational symmetry, subunits are superimposable after rotation about one or more of the axes. Some examples are hemoglobin and thepoliovirus capsid. 2) Helical: In helical symmetry, subunits are superimposable after a helical rotation. Some examples are actin filaments and the tobacco mosaic virus capsid.

52. Protein tertiary and quaternary structures
Page: 146 Difficulty: 2
What is the rationale for many large proteins containing multiple copies of a polypeptide subunit?

Ans: Each different polypeptide requires a separate gene that must be replicated and transcribed. It is therefore more efficient to have fewer genes, encoding shorter polypeptides that can be used to construct many large proteins.

53. Protein denaturation and folding
Page: 148 Difficulty: 2
Explain (succinctly) the theoretical and/or experimental arguments in support of this statement: "The primary sequence of a protein determines its three-dimensional shape and thus its function."

Ans: Anfinsen showed that a completely denatured enzyme (ribonuclease) could fold spontaneously into its native, enzymatically active form with only the primary sequence to guide it.

54. Protein denaturation and folding
Page: 147 Difficulty: 2
Each of the following reagents or conditions will denature a protein. For each, describe in one or two sentences what the reagent/condition does to destroy native protein structure.

(a) urea
(b) high temperature
(c) detergent
(d) low pH

Ans: (a) Urea acts primarily by disrupting hydrophobic interactions. (b) High temperature provides thermal energy greater than the strength of the weak interactions (hydrogen bonds, electrostatic interactions, hydrophobic interactions, and van der Waals forces, breaking these interactions. (c) Detergents bind to hydrophobic regions of the protein, preventing hydrophobic interactions among several hydrophobic patches on the native protein. (d) Low pH causes protonation of the side chains of Asp, Glu, and His, preventing electrostatic interactions.

55. Protein denaturation and folding
Page: 147 Difficulty: 2
How can changes in pH alter the conformation of a protein?

Ans: Changes in pH can influence the extent to which certain amino acid side chains (or the amino and carboxyl termini) are protonated. The result is a change in net charge on the protein, which can lead to electrostatic attractions or repulsions between different regions of the protein. The final effect is a change in the protein's three-dimensional shape or even complete denaturation.

56. Protein denaturation and folding
Pages: 148–149 Difficulty: 2
Once a protein has been denatured, how can it be renatured? If renaturation does not occur, what might be the explanation?

Ans: Because a protein may be denatured through the disruption of hydrogen bonds and hydrophobic interactions by salts or organic solvents, removal of those conditions will reestablish the original aqueous environment, often permitting the protein to fold once again into its native conformation. If the protein does not renature, it may be because the denaturing treatment removed a required prosthetic group, or because the normal folding pathway requires the presence of a polypeptide chain binding protein or molecular chaperone. The normal folding pathway could also be mediated by a larger polypeptide, which is then cleaved (e.g., insulin). Denatured insulin would not refold easily.

57. Protein denaturation and folding
Pages: 151–153 Difficulty: 2
What are two mechanisms by which "chaperone" proteins assist in the correct folding of polypeptides?

Ans: Chaperonins protect unfolded polypeptides from aggregation by binding to hydrophobic regions. They can also provide a microenvironment that promotes correct folding.

25. Enzyme kinetics as an approach to understanding mechanism
Pages: 209-210 Difficulty: 3 Ans: B
In a plot of $1/V$ against 1/[S] for an enzyme-catalyzed reaction, the presence of a competitive inhibitor will alter the:

A) curvature of the plot.
B) intercept on the 1/[S] axis.
C) intercept on the $1/V$ axis.
D) pK of the plot.
E) V_{max}.

26. Enzyme kinetics as an approach to understanding mechanism
Pages: 209-210 Difficulty: 1 Ans: D
In competitive inhibition, an inhibitor:

A) binds at several different sites on an enzyme.
B) binds covalently to the enzyme.
C) binds *only* to the ES complex.
D) binds reversibly at the active site.
E) lowers the characteristic V_{max} of the enzyme.

27. Enzyme kinetics as an approach to understanding mechanism
Pages: 209-212 Difficulty: 2 Ans: D
V_{max} for an enzyme-catalyzed reaction:

A) generally increases when pH increases.
B) increases in the presence of a competitive inhibitor.
C) is limited only by the amount of substrate supplied.
D) is twice the rate observed when the concentration of substrate is equal to the K_m.
E) is unchanged in the presence of a uncompetitive inhibitor.

28. Enzyme kinetics as an approach to understanding mechanism
Page: 212 Difficulty: 2 Ans: B
Enzyme X exhibits maximum activity at pH = 6.9. X shows a fairly sharp decrease in its activity when the pH goes much lower than 6.4. One likely interpretation of this pH activity is that:

A) a Glu residue on the enzyme is involved in the reaction.
B) a His residue on the enzyme is involved in the reaction.
C) the enzyme has a metallic cofactor.
D) the enzyme is found in gastric secretions.
E) the reaction relies on specific acid-base catalysis.

respectively, of the ES complex and k_2 is the rate constant for the breakdown of ES to form E + P. K_m can be determined graphically on a plot of V_0 vs. [S] by finding the [S] at which $V_0 = 1/2\ V_{max}$. More conveniently, on a double-reciprocal plot, the x-axis intercept = $-1/K_m$.

51. Enzyme kinetics as an approach to understanding mechanism
Pages: 204-205 Difficulty: 3
An enzyme catalyzes a reaction at a velocity of 20 μmol/min when the concentration of substrate (S) is 0.01 M. The K_m for this substrate is 1×10^{-5} M. Assuming that Michaelis-Menten kinetics are followed, what will the reaction velocity be when the concentration of S is (a) 1×10^{-5} M and (b) 1×10^{-6} M?

Ans: The velocity of 20 μmol/min is essentially V_{max} because it is measured at [S] >> K_m. (a) When $[S] = 10^{-5}$ M $= K_m$, $V = 1/2\ V_{max}$, or 10 μmol/min. (b) When [S] is 10^{-6} M, velocity can be calculated from the Michaelis-Menten equation:

$$V_0 = V_{max}[S]/(K_m + [S]) = (20\ \mu\text{mol/min})(10^{-6}\ \text{M})/(10^{-5} + 10^{-6}) = 1.8\ \mu\text{mol/min}.$$

52. Enzyme kinetics as an approach to understanding mechanism
Pages: 204, 227 Difficulty: 2
Give the Michaelis-Menten equation and define each term in it. Does this equation apply to all enzymes? If not, to which kind does it not apply?

Ans: The Michaelis-Menten equation is: $V_0 = V_{max}[S]/(K_m + [S])$, in which V_0 is the initial velocity at any given concentration of S, V_{max} is the velocity when all enzyme molecules are saturated with S, [S] is the concentration of S, and K_m is a constant characteristic for the enzyme. This equation does not apply to enzymes that display sigmoidal V_0 vs. [S] curves, but only to those giving hyperbolic kinetic plots.

53. Enzyme kinetics as an approach to understanding mechanism
Page: 205 Difficulty: 2
A biochemist obtains the following set of data for an enzyme that is known to follow Michaelis-Menten kinetics.

Substrate concentration (μM)	Initial velocity (μmol/min)
1	49
2	96
8	349
50	621
100	676
1,000	698
5,000	699

(a) V_{max} for the enzyme is __________. Explain in one sentence how you determined V_{max}.
(b) K_m for the enzyme is __________. Explain in one sentence how you determined K_m.

Ans: (a) V_{max} is about 700. In a plot of V vs. [S], the asymptote is V_{max}. Simple inspection of the data shows the approach to V_{max}—the rate increases by only 1 unit when [S] increases fivefold.

5. **Monosaccharides and disaccharides**
Pages: 240-241 Difficulty: 2 Ans: B
Which of the following is an epimeric pair?

A) D-glucose and D-glucosamine
B) D-glucose and D-mannose
C) D-glucose and L-glucose
D) D-lactose and D-sucrose
E) L-mannose and L-fructose

6. **Monosaccharides and disaccharides**
Page: 242 Difficulty: 2 Ans: D
Which of following is an anomeric pair?

A) D-glucose and D-fructose
B) D-glucose and L-fructose
C) D-glucose and L-glucose
D) α-D-glucose and β-D-glucose
E) α-D-glucose and β-L-glucose

7. **Monosaccharides and disaccharides**
Page: 242 Difficulty: 2 Ans: C
When the linear form of glucose cyclizes, the product is a(n):

A) anhydride.
B) glycoside.
C) hemiacetal.
D) lactone.
E) oligosaccharide.

8. **Monosaccharides and disaccharides**
Page: 242 Difficulty: 2 Ans: E
Which of the following pairs is interconverted in the process of mutarotation?

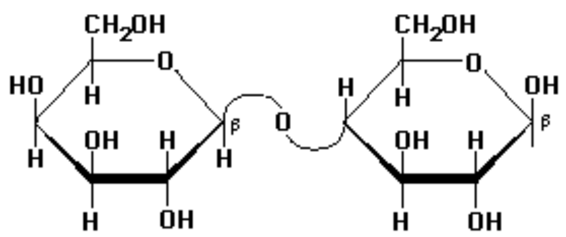
A) D-glucose and D-fructose
B) D-glucose and D-galactose
C) D-glucose and D-glucosamine
D) D-glucose and L-glucose
E) α-D-glucose and β-D-glucose

9. **Monosaccharides and disaccharides**
Pages: 243-246 Difficulty: 2 Ans: E
Which of the following is *not* a reducing sugar?

A) Fructose
B) Glucose
C) Glyceraldehyde
D) Ribose
E) Sucrose

structure should be identical to the first, except that the hydroxyl group at C-1 should point up if it pointed down in your first structure, and vice versa. (c) The number of chiral centers is 5; all are carbons except C-6. (d) The number of possible stereoisomers for a compound with *n* chiral centers is 2^n; in this case, 2^5, or 32 possible isomers.

24. Monosaccharides and disaccharides
Pages: 243-246 Difficulty: 2
In the following structure:



(a) How many of the monosaccharide units are furanoses and how may are pyranoses? (b) What is the linkage between the two monosaccharide units? (c) Is this a reducing sugar? Explain.

Ans: (a) 2 pyranoses; (b) β1 → 4; (c) Yes. There is a free anomeric carbon on one of the monosaccharide units that can undergo oxidation.

25. Monosaccharides and disaccharides
Pages: 244-246 Difficulty: 3
(a) Define "reducing sugar." (b) Sucrose is a disaccharide composed of glucose and fructose (Glc(α1 → 2)Fru). Explain why sucrose is not a reducing sugar, even though both glucose and fructose are.

Ans: (a) A reducing sugar is one with a free carbonyl carbon that can be oxidized by Cu^{2+} or Fe^{3+}. (b) The carbonyl carbon is C-1 of glucose and C-2 of fructose. When the carbonyl carbon is involved in a glycosidic linkage, it is no longer accessible to oxidizing agents. In sucrose (Glc(α1 → 2)Fru), both oxidizable carbons are involved in the glycosidic linkage.

26. Polysaccharides
Pages: 245-255 Difficulty: 2
Match these molecules with their biological roles.

(a) glycogen	__ viscosity, lubrication of extracellular secretions
(b) starch	__ carbohydrate storage in plants
(c) trehalose	__ transport/storage in insects
(d) chitin	__ exoskeleton of insects
(e) cellulose	__ structural component of bacterial cell wall
(f) peptidoglycan	__ structural component of plant cell walls
(g) hyaluronate	__ extracellular matrix of animal tissues
(h) proteoglycan	__ carbohydrate storage in animal liver

Ans: g; b; c; d; f; e; h; a

27. Polysaccharides
Pages: 248-249 Difficulty: 2
The number of structurally different polysaccharides that can be made with 20 different monosaccharides is far greater than the number of different polypeptides that can be made with 20 different amino acids, if both polymers contain an equal number (say 100) of total residues. Explain why.

Ans: Because virtually all peptides are linear (i.e., are formed with peptide bonds between the α-carboxyl and α-amino groups), the variability of peptides is limited by the number of different subunits. Polysaccharides can be linear or branched, can be α- or β-linked, and can be joined 1 → 4, 1 → 3, 1 → 6, etc. The number of different ways to arrange 20 different sugars in a branched oligosaccharide is therefore much larger than the number of different ways a peptide could be made with an equal number of residues.

28. Polysaccharides
Page: 248 Difficulty: 2
Describe one biological advantage of storing glucose units in *branched* polymers (glycogen, amylopectin) rather than in linear polymers.

Ans: The enzymes that act on these polymers to mobilize glucose for metabolism act only on their nonreducing ends. With extensive branching, there are more such ends for enzymatic attack than would be present in the same quantity of glucose stored in a linear polymer. In effect, branched polymers increase the substrate concentration for these enzymes.

29. Polysaccharides
Pages: 248-249 Difficulty: 2
Explain how it is possible that a polysaccharide molecule, such as glycogen, may have only one reducing end, and yet have many nonreducing ends.

Ans: The molecule is branched, with each branch ending in a nonreducing end. (See Fig. 9-15c, p. 305.)

30. Polysaccharides
Page: 248 Difficulty: 2
What is the biological advantage to an organism that stores its carbohydrate reserves as starch or glycogen rather than as an equivalent amount of free glucose?

Ans: The polymers are essentially insoluble and contribute little to the osmolarity of the cell, thereby avoiding the influx of water that would occur with the glucose in solution. They also make the uptake of glucose energetically more feasible than it would be with free glucose in the cell.

31. Polysaccharides
Page: 249 Difficulty: 3
Draw the structure of the repeating basic unit of (a) amylose and (b) cellulose.

Ans: (a) For the structure of amylose, see Fig. 9-15a, p. 305. The repeating unit is α-D-glucose linked to α-D-glucose; the glycosidic bond is therefore (α1 → 4). (b) Cellulose has the same structure as amylose, except that the repeating units are β-D-glucose and the glycosidic bond is (β1 → 4). (See Fig. 9-17a, p. 307.)

32. Polysaccharides
Page: 250 Difficulty: 2
Explain in molecular terms why humans cannot use cellulose as a nutrient, but goats and cattle can.

Ans: The ruminant animals have in their rumens microorganisms that produce the enzyme cellulase, which splits the ($\beta 1 \rightarrow 4$) linkages in cellulose, releasing glucose. Humans do not produce an enzyme with this activity; the human digestive enzyme α-amylase can split only ($\alpha 1 \rightarrow 4$) linkages (such as those in glycogen and starch).

33. Polysaccharides
Page: 253 Difficulty: 2
The glycosaminoglycans are negatively charged at neutral pH. What components of these polymers confer the negative charge?

Ans: Uronic acids such as glucuronic acid, and sulfated hydroxyl groups, such as $GalNAc4SO_3^-$ and $GlcNAc6SO_3^-$. (See Fig. 7-24, p. 253.)

34. Glycoconjugates: proteoglycans, glycoproteins, and glycolipids
Page: 256 Difficulty: 3
Sketch the principal components of a typical proteoglycan, showing their relationships and connections to one another.

Ans: A typical proteoglycan consists of a core protein with covalently attached glycosaminoglycan polysaccharides, such as chondroitin sulfate and keratin sulfate. The polysaccharides generally attach to a serine residue in the protein via a trisaccharide (gal–gal–xyl). (See Fig. 7-26, p. 256.)

35. Glycoconjugates: proteoglycans, glycoproteins, and glycolipids
Page: 256 Difficulty: 3
Describe the differences between a proteoglycan and a glycoprotein.

Ans: Both are made up of proteins and polysaccharides. In proteoglycans, the carbohydrate moiety dominates, constituting 95% or more of the mass of the complex. In glycoproteins, the protein constitutes a larger fraction, generally 50% or more of the total mass.

36. Glycoconjugates: proteoglycans, glycoproteins, and glycolipids
Pages: 257-258 Difficulty: 2
Describe the structure of a proteoglycan aggregate such as is found in the extracellular matrix.

Ans: A proteoglycan aggregate is a supramolecular assembly of proteoglycan monomers. Each monomer consists of a core protein with multiple, covalently linked polysaccharide chains. Hundreds of these monomers can bind noncovalently to a single extended molecule of hyaluronic acid to form large structures.

37. Glycoconjugates: proteoglycans, glycoproteins, and glycolipids
Page: 259 Difficulty: 2
What are some of the biochemical effects of the oligosaccharide portions of glycoproteins?

Ans: Hydrophilic carbohydrates can alter the polarity and solubility of the proteins. Steric and charge interactions may influence the conformation of regions of the polypeptide and protect it from proteolysis.

18. Nucleic acid structure
Pages: 281-283 Difficulty: 2 Ans: C
Which of the following is *not* true of all naturally occurring DNA?

A) Deoxyribose units are connected by 3′,5′-phosphodiester bonds.
B) The amount of A always equals the amount of T.
C) The ratio A+T/G+C is constant for all natural DNAs.
D) The two complementary strands are antiparallel.
E) Two hydrogen bonds form between A and T.

19. Nucleic acid structure
Pages: 282-283 Difficulty: 2 Ans: E
In the Watson-Crick model of DNA structure (now called B-form DNA):

A) a purine in one strand always hydrogen bonds with a purine in the other strand.
B) A–T pairs share three hydrogen bonds.
C) G–C pairs share two hydrogen bonds.
D) the 5′ ends of both strands are at one end of the helix.
E) the bases occupy the interior of the helix.

20. Nucleic acid structure
Page: 283 Difficulty: 2 Ans: D
The double helix of DNA in the B form is stabilized by:

A) covalent bonds between the 3′ end of one strand and the 5′ end of the other.
B) hydrogen bonding between the phosphate groups of two side-by-side strands.
C) hydrogen bonds between the riboses of each strand.
D) nonspecific base-stacking interaction between two adjacent bases in the same strand.
E) ribose interactions with the planar base pairs.

21. Nucleic acid structure
Page: 284 Difficulty: 2 Ans: C
In nucleotides and nucleic acids, syn and anti conformations relate to:

A) base stereoisomers.
B) rotation around the phosphodiester bond.
C) rotation around the sugar-base bond.
D) sugar pucker.
E) sugar stereoisomers.

22. Nucleic acid structure
Page: 284 Difficulty: 2 Ans: D
B-form DNA in vivo is a ________-handed helix, _____ Å in diameter, with a rise of ____ Å per base pair.

A) left; 20; 3.9
B) right; 18; 3.4

27. Nucleic acid chemistry
Page: 291 Difficulty: 2 Ans: B
When double-stranded DNA is heated at neutral pH, which change does *not* occur?

A) The absorption of ultraviolet (260 nm) light increases.
B) The covalent N-glycosidic bond between the base and the pentose breaks.
C) The helical structure unwinds.
D) The hydrogen bonds between A and T break.
E) The viscosity of the solution decreases.

28. Nucleic acid chemistry
Page: 291 Difficulty: 2 Ans: B
Which of the following deoxyoligonucleotides will hybridize with a DNA containing the sequence (5′)AGACTGGTC(3′)?

A) (5′)CTCATTGAG(3′)
B) (5′)GACCAGTCT(3′)
C) (5′)GAGTCAACT(3′)
D) (5′)TCTGACCAG(3′)
E) (5′)TCTGGATCT(3′)

29. Nucleic acid chemistry
Page: 291 Difficulty: 2 Ans: D
The ribonucleotide polymer (5′)GTGATCAAGC(3′) could only form a double-stranded structure with:

A) (5′)CACTAGTTCG(3′).
B) (5′)CACUAGUUCG(3′).
C) (5′)CACUTTCGCCC(3′).
D) (5′)GCTTGATCAC(3′).
E) (5′)GCCTAGTTUG(3′).

30. Nucleic acid chemistry
Page: 292 Difficulty: 2 Ans: E
In comparison with DNA-DNA double helices, the stability of DNA-RNA and RNA-RNA helices is:

A) DNA-DNA > DNA-RNA > RNA-RNA.
B) DNA-DNA > RNA-RNA > DNA-RNA.
C) RNA-DNA > RNA-RNA > DNA-DNA.
D) RNA-RNA > DNA-DNA > DNA-RNA.
E) RNA-RNA > DNA-RNA > DNA-DNA.

31. Nucleic acid chemistry
Page: 294 Difficulty: 1 Ans: E
In the laboratory, several factors are known to cause alteration of the chemical structure of DNA. The factor(s) likely to be important in a *living* cell is (are):

A) heat.
B) low pH.
C) oxygen.
D) UV light.
E) both C and D.

32. Nucleic acid chemistry
Page: 295 Difficulty: 2 Ans: B
Compounds that generate nitrous acid (such as nitrites, nitrates, and nitrosamines) change DNA molecules by:

A) breakage of phosphodiester bonds.
B) deamination of bases.
C) depurination.
D) formation of thymine dimers.
E) transformation of A → T.

33. Nucleic acid chemistry
Pages: 296-297 Difficulty: 2 Ans: D
In DNA sequencing by the Sanger (dideoxy) method:

A) radioactive dideoxy ATP is included in each of four reaction mixtures before enzymatic synthesis of complementary strands.
B) specific enzymes are used to cut the newly synthesized DNA into small pieces, which are then separated by electrophoresis.
C) the dideoxynucleotides must be present at high levels to obtain long stretches of DNA sequence.
D) the role of the dideoxy CTP is to occasionally terminate enzymatic synthesis of DNA where Gs occur in the template strand.
E) the template DNA strand is radioactive.

34. Nucleic acid chemistry
Page: 299 Difficulty: 3 Ans: D
In the chemical synthesis of DNA:

A) the dimethoxytrityl (DMT) group catalyzes formation of the phosphodiester bond.
B) the direction of synthesis is 5′ to 3′.
C) the maximum length of oligonucleotide that can be synthesized is 8-10 nucleotides.
D) the nucleotide initially attached to the silica gel support will become the 3′ end of the finished product.
E) the protecting cyanoethyl groups are removed after each step.

35. Other functions of nucleotides
Pages: 300-302 Difficulty: 1 Ans: E
In living cells, nucleotides and their derivatives can serve as:

A) carriers of metabolic energy.
B) enzyme cofactors.
C) intracellular signals.
D) precursors for nucleic acid synthesis.
E) all of the above.

41. Nucleic acid structure
Page: 280 Difficulty: 3
Briefly describe the experimental evidence of Avery, MacLeod, and McCarty that DNA is the genetic material.

Ans: Avery et al. showed that DNA isolated from a virulent (disease-causing) bacterium (*Streptococcus pneumoniae*), when mixed with living cells of a nonvirulent strain of this bacterium, provided the genetic instructions for transforming the nonvirulent strain to a virulent strain. (See Fig. 10-12, p. 333.)

42. Nucleic acid structure
Page: 281 Difficulty: 3
Briefly describe the Hershey-Chase experiment, which showed that DNA is the genetic material.

Ans: Hershey and Chase showed that when the bacteriophage (virus) T2 infected the bacterium *E. coli*, new genetic instructions appeared in the infected cells. Because only the DNA and not the proteins of T2 entered the infected cell, DNA must carry the new genetic instructions. (See Fig. 10-13, p. 334.)

43. Nucleic acid structure
Pages: 281-282 Difficulty: 3
The composition (mole fraction) of *one* of the strands of a double-helical DNA is [A] = 0.3, and [G] = 0.24. Calculate the following, if possible. If impossible, write "I."

For the *same* strand:
[T] = (a) ____
[C] = (b) ____
[T] + [C] = (c) ____
For the *other* strand:
[A] = (d) ____
[T] = (e) ____
[A] + [T] = (f) ____
[G] = (g) ____
[C] = (h) ____
[G] + [C] = (i) ____

Ans: (a) I; (b) I; (c) 0.46; (d) I; (e) 0.3; (f) I; (g) I; (h) 0.24; (i) I

44. Nucleic acid structure
Page: 282 Difficulty: 2
What is the approximate length of a DNA molecule (in the B form) containing 10,000 base pairs?

Ans: 3.4 Å × 10,000 = 34,000 Å = 3.4 µm. (See p. 338.)

45. Nucleic acid structure
Page: 283 Difficulty: 2
Describe briefly what is meant by saying that two DNA strands are complementary.

Ans: The nucleotide sequences of complementary strands are such that wherever an A occurs in one strand, there is a T in the other strand with which it can form a hydrogen-bonded base pair. Wherever a C occurs in one strand, a G occurs in the other. A is the base complementary to T, and C is the base complementary to G.

46. Nucleic acid structure
Pages: 284-285 Difficulty: 2
In one sentence, identify the most obvious structural difference between A-form (Watson-Crick) DNA and Z-form DNA.
Ans: A-form DNA is a right-handed helix; Z-form DNA is a left-handed helix. (See Fig. 10-19, page 338.)

47. Nucleic acid structure
Page: 285 Difficulty: 2
Write a double-stranded DNA sequence containing a six-nucleotide palindrome.

Ans: Any double-stranded sequence that has the form:
1-2-3-4-5-6-6′-5′-4′-3′-2′-1′
1′-2′-3′-4′-5′-6′-6-5-4-3-2-1
where each number and its prime represent correctly paired bases (A with T, C with G) all along the double-stranded molecule.

48. Nucleic acid structure
Pages: 288-289 Difficulty: 3
Describe briefly how noncovalent interactions contribute to the three-dimensional shapes of RNA molecules.

Ans: Hydrogen-bonding in regions of complementarity within an RNA chain can result in regions of double helix that are stabilized by base-stacking. Breaks in complementary regions can result in loops and bulges that together with the helical regions, can generate a precise three-dimensional structure.

49. Nucleic acid chemistry
Page: 292 Difficulty: 3
Why does lowering the ionic strength of a solution of double-stranded DNA permit the DNA to denature more readily (for example, to denature at a lower temperature than at a higher ionic strength)?

Ans: Lower ionic strength reduces the screening of the negative charges on the phosphate groups by positive ions in the medium. The result is stronger charge-charge repulsion between the phosphate, which favors strand separation.

50. Nucleic acid chemistry
Page: 292 Difficulty: 2

Ans: Reverse transcriptase is used to make first a single-stranded DNA complementary to mRNA, then a double-stranded DNA.

30. From genes to genomes
Pages: 319-320 Difficulty: 2
A DNA sequence that may be present as only a single copy in a large mammalian genome can be amplified and cloned using the polymerase chain reaction (PCR). Describe the steps and reaction components required in a PCR experiment. Illustrate the steps in just one round.

Ans: DNA with the desired sequence is heated to convert it to single strands and cooled in the presence of an excess of oligonucleotide primers that flank the sequence to be amplified. A heat-stable DNA polymerase extends the primers, replicating the desired sequence. (See Fig. 9-16.)

31. From genes to genomes
Page: 320 Difficulty: 1
Why must the DNA polymerase used in the polymerase chain reaction (PCR) be heat stable?

Ans: The PCR involves repeated heating of the reaction mixture (to denature the double-stranded DNA) and cooling (to allow hybridization of DNA with oligonucleotide primers). A heat-sensitive enzyme would be denatured by this procedure.

32. From genes to genomes
Page: 322 Difficulty: 2
What are RFLPs and how are they used in forensic DNA fingerprinting technology?

Ans: RFLPs (restriction fragment length polymorphisms) are minor variations among individuals in DNA base sequence that can be detected by variation in the patterns of fragments that are produced upon cleavage with restriction endonucleases. When several DNA regions are examined, these patterns are distinctive for an individual and can be used to determine the identity (or nonidentity) of two samples of DNA. One of these samples can be from a crime scene, the other from a known individual.

33. From genomes to proteomes
Page: 325 Difficulty: 2
Distinguish between protein function at the molecular, cellular, and phenotypic level.

Ans: Molecular function describes the precise biochemical activity of the protein (such as enzymatic reaction or ligand binding), cellular function depends on the network ofinteractions engaged in by the protein within a cell, and phenotypic function refers to the effects of the protein on the entire organism.

34. From genomes to proteomes
Pages: 326-327 Difficulty: 2
What is a DNA microarray? How does it resemble and how does it differ from a DNA library?

Ans: A DNA microarray is a solid surface upon which are placed DNA fragments from many thousands of genes. It is in essence a form of DNA library that is arranged physically to allow rapid simultaneous screening of many thousands of genes.

Chapter 10 Lipids

Multiple Choice Questions

1. **Structural lipids in membranes**
   Pages: 343-345 Difficulty: 2 Ans: A
   Which of the following statements concerning fatty acids is correct?

   A) One is the precursor of prostaglandins.
   B) Phosphatidic acid is a common one.
   C) They all contain one or more double bonds.
   D) They are a constituent of sterols.
   E) They are strongly hydrophilic.

2. **Storage Lipids**
   Pages: 346-358 Difficulty: 2 Ans: E
   Which of the following molecules or substances contain, or are derived from, fatty acids?

   A) Beeswax
   B) Prostaglandins
   C) Sphingolipids
   D) Triacylglycerols
   E) All of the above contain or are derived from fatty acids.

3. **Storage Lipids**
   Page: 349 Difficulty: 2 Ans: B
   Biological waxes are all:

   A) trimesters of glycerol and palmitic acid.
   B) esters of single fatty acids with long-chain alcohols.
   C) trimesters of glycerol and three long-chain saturated fatty acids.
   D) sphingolipids.
   E) none of the above.

4. **Storage Lipids**
   Pages: 346-358 Difficulty: 2 Ans: B
   Which of the following statements is true of lipids?

   A) Many contain fatty acids in ester or amide linkage.
   B) Most are simply polymers of isoprene.
   C) Testosterone is an important sphingolipid found in myelin.
   D) They are more soluble in water than in chloroform.
   E) They play only passive roles as energy-storage molecules.

5. Structural lipids in membranes
Pages: 351-352 Difficulty: 2 Ans: D
Which of the following contains an ether-linked alkyl group?

A) Cerebrosides
B) Gangliosides
C) Phosphatidyl serine
D) Platelet-activating factor
E) Sphingomyelin

6. Structural lipids in membranes
Pages: 352-353 Difficulty: 2 Ans: A
Sphingosine is *not* a component of:

A) cardiolipin.
B) ceramide.
C) cerebrosides.
D) gangliosides.
E) sphingomyelin.

7. Structural lipids in membranes
Page: 352 Difficulty: 2 Ans: D
Which of the following statements about membrane lipids is true?

A) Glycerophospholipids are found only in the membranes of plant cells.
B) Glycerophospholipids contain fatty acids linked to glycerol through amide bonds.
C) Lecithin (phosphatidylcholine), which is used as an emulsifier in margarine and chocolate, is a sphingolipid.
D) Some sphingolipids include oligosaccharides in their structure.
E) Triacylglycerols are the principal components of erythrocyte membranes.

8. Structural lipids in membranes
Page: 352 Difficulty: 2 Ans: A
Which of the following is true of sphingolipids?

A) Cerebrosides and gangliosides are sphingolipids.
B) Phosphatidylcholine is a typical sphingolipid.
C) They always contain glycerol and fatty acids.
D) They contain two esterified fatty acids.
E) They may be charged, but are never amphipathic.

9. Structural lipids in membranes
Pages: 352-354 Difficulty: 2 Ans: B
A compound containing *N*-acetylneuraminic acid (sialic acid) is:

A) cardiolipin.
B) ganglioside GM2.
C) phosphatidylcholine.
D) platelet-activating factor.
E) sphingomyelin.

24. Storage lipids
Pages: 345-350 Difficulty: 2
What is the most significant chemical difference between triacylglycerols and glycerophospholipids that leads to their different functions?

Ans: Triacylglycerols are nonpolar hydrophobic molecules that can be stored in specialized nonaqueous cellular compartments. Glycerophospholipids are amphipathic molecules that can serve as structural components of membranes, which have hydrophilic and hydrophobic regions.

25. Storage lipids
Pages: 346-347 Difficulty: 2
Describe three functions of triacylglycerols in mammals and one function in higher plants.

Ans: Triacylglycerols provide mammals with (1) stored fuel, (2) insulation, and (3) a source of metabolic water. In some animals, such as camels and desert rats, the oxidation of stored lipids provides water; in hibernating animals, oxidation of stored lipids generates heat to maintain body temperature. In plants, oxidation of the triacylglycerols stored in seeds provides the energy and precursors for biosynthetic processes during germination, before photosynthetic mechanisms become functional.

26. Structural lipids in membranes
Page: 348 Difficulty: 2
What are the chemical components of a biological wax, and what is their general structure?

Ans: A wax consists of a long-chain fatty acid in ester linkage with a long-chain fatty alcohol. (See Fig. 10-6, p. 349.)

27. Structural lipids in membranes
Page: 351 Difficulty: 2
Draw the structure of phosphatidylserine in the ionic form it would have at pH 7.

Ans: For this structure, see Fig. 10-10, p. 351. At neutral pH, there is a charge on the phosphate group, and serine is in the zwitterionic form; it has a protonated amino group and an ionized carboxyl group.

28. Structural lipids in membranes
Page: 351 Difficulty: 3
Give the structure of phosphatidylethanolamine containing one palmitate and one oleate. Show the ionic form expected at pH 7. How many ester bonds are there in this compound?

Ans: See Fig. 10-10, p. 351 for the phospholipid structure and Table 10-1, p. 344 for the structures of the fatty acids. There are two carboxylate esters and two phosphate esters (one phosphodiester) in the molecule.

29. Structural lipids in membranes
Page: 351 Difficulty: 2
Draw the structure of phosphatidylcholine. Circle the part of the molecule that is polar and draw an arrow to the part that is nonpolar.

Ans: For this structure, see Fig. 10-10, p. 351. At neutral pH, there is a negative charge on the phosphate group, and the quaternary amino group of choline carries a fixed positive charge; this entire phosphorylcholine moiety is polar. The acyl chains attached to glycerol are the nonpolar part of the molecule.

30. Structural lipids in membranes
Page: 351 Difficulty: 2
Show the basic structure of all glycerophospholipids.

Ans: All glycerophospholipids have two fatty acids in ester linkage with C-1 and C-2 of glycerol; often the fatty acid at C-1 is saturated, and that at C-2 is unsaturated. C-3 of glycerol is joined to an alcohol-containing head group through a phosphodiester linkage, which is negatively charged at neutral pH. (See Fig. 10-10, p. 351.)

31. Structural lipids in membranes
Page: 351 Difficulty: 3
What chemical features distinguish a plasmalogen from a common glycerophospholipid?

Ans: (1) The long-chain acyl group attached to C-1 of glycerol is ether-linked in a plasmalogen, but is an ester-linked fatty acyl group in typical glycerophospholipids. (2) There is a double bond between C-1 and C-2 of this fatty acyl chain in plasmalogens, but not in other phospholipids. (See Fig. 10-10, p. 351.)

32. Structural lipids in membranes
Page: 353 Difficulty: 2
Show the structure of sphingosine and indicate the relationship between sphingosine and ceramide.

Ans: The structure of sphingosine is shown in Fig. 10-13, p. 353, which also shows that the attachment of a fatty acyl group to sphingosine in amide linkage converts it to ceramide.

33. Structural lipids in membranes
Page: 353 Difficulty: 3
What chemical features distinguish a cerebroside from a ganglioside?

Ans: A cerebroside has a single sugar residue joined to ceramide; a ganglioside has an oligosaccharide joined to ceramide. (See Fig. 10-13, p. 353.)

34. Lipids as signals, cofactors, and pigments
Pages: 353-361 Difficulty: 2
Match the compounds on the left with the important roles they play listed on the right. (Answers are used only once.)

(a) prostaglandins	___ blood clotting
(b) sphingolipids	___ necessary for sight
(c) thromboxanes	___ mediates pain and inflammation
(d) vitamin A	___ important component of myelin membranes

Ans: c; d; a; b

35. Lipids as signals, cofactors, and pigments
Page: 355 Difficulty: 3
Describe the differences between the glycosphingolipids corresponding to the A, B, and O human blood group antigens.

Ans: The type O structure is found in all three glycosphingolipids. In both type A and type B, there is an added sugar; this sugar differs between type A and B.

47. Membrane dynamics

Page: 387 Difficulty: 2 Ans: D

According to the current model for HIV infection, which of the following is *not* involved in the process of membrane fusion?

A) A cell surface co-receptor protein
B) A cell surface receptor protein
C) A viral glycoprotein complex
D) The viral chromosome
E) The viral envelope

48. Solute transport across membranes

Page: 391 Difficulty: 2 Ans: A

Which of these statements about facilitated diffusion across a membrane is true?

A) A specific membrane protein lowers the activation energy for movement of the solute through the membrane.
B) It can increase the size of a transmembrane concentration gradient of the diffusing solute.
C) It is impeded by the solubility of the transported solute in the nonpolar interior of the lipid bilayer.
D) It is responsible for the transport of gases such as O_2, N_2, and CH_4 across biological membranes.
E) The rate is not saturable by the transported substrate.

49. Solute transport across membranes

Page: 390 Difficulty: 2 Ans: A

Facilitated diffusion through a biological membrane is:

A) driven by a difference of solute concentration.
B) driven by ATP.
C) endergonic.
D) generally irreversible.
E) not specific with respect to the substrate.

50. Solute transport across membranes

Pages: 391-392 Difficulty: 1 Ans: D

Glucose transport into erythrocytes is an example of:

A) active transport.
B) antiport.
C) electrogenic uniport
D) facilitated diffusion.
E) symport.

19. Regulation of transcription by steroid hormones

Pages: 456-457 Difficulty: 3 Ans: E

Steroid hormone response elements (HREs) are __________ , which, when bound to _____________, alter gene expression at the level of ________________.

A) intron sequences; activated hormone receptor; translation
B) nuclear proteins; hormone; transcription
C) plasma membrane proteins; hormone; transcription
D) sequences in DNA; receptor-hormone complex; replication
E) sequences in DNA; receptor-hormone complex; transcription

20. Signaling in microorganisms and plants

Pages: 457-458 Difficulty: 2 Ans: D

Which one of the following signaling mechanisms is used most predominantly in plants?

A) Cyclic-nucleotide dependent protein kinases
B) DNA-binding nuclear steroid receptors
C) G protein-coupled receptors
D) Protein serine/threonine kinases
E) Protein tyrosine kinases

21. Signaling in microorganisms and plants

Pages: 460-461 Difficulty: 2 Ans: E

In the plant signaling pathways employing receptor-like kinases (RLKs), which one of the following does *not* occur?

A) Activation of a MAPK cascade
B) Autophosphorylation of receptor
C) Dimerization of receptor
D) Ligand binding to receptor
E) Phosphorylation of key proteins on Tyr residues

22. Sensory transduction in vision, olfaction, and gustation

Page: 462 Difficulty: 1 Ans: B

Most transduction systems for hormones and sensory stimuli that involve trimeric G proteins have in common all of the following *except:*

A) cyclic nucleotides.
B) nuclear receptors.
C) receptors that interact with a G protein.
D) receptors with multiple transmembrane segments.
E) self-inactivation.

55. Oncogenes, tumor suppressor genes and programmed cell death
Page: 474 Difficulty: 3
The product of the *erb*B oncogene closely resembles the cellular receptor for epidermal growth factor (EGF). How do the two proteins differ, and how does this difference account for the oncogenic action of the ErbB protein?

Ans: The EGF receptor is a transmembrane receptor with tyrosine kinase activity that is stimulated by EGF bound to the extracellular domain of the protein. The ErbB protein is a truncated version of the EGF receptor, in which the tyrosine kinase activity is always active, even in the absence of EGF, because the protein lacks the EGF-binding domain. The kinase activity gives the cell the signal for continuous growth and cell division, producing the unregulated growth that characterizes tumors. (See Fig. 12-49, p. 474.)

56. Oncogenes, tumor suppressor genes and programmed cell death
Pages: 435-442, 472-473 Difficulty: 3
Explain how mutations in the following proteins might result in either loss of responsiveness to a given hormone or production of a continuous signal even in the absence of the hormone: (a) a mutation in the regulatory (R) subunit of cAMP-dependent protein kinase, making R incapable of binding to the catalytic (C) subunit; (b) a mutation in a growth factor receptor with protein kinase activity; (c) a defect in a G protein that renders the GTPase activity inactive.

Ans: (a) When a mutation in the R subunit of cAMP-dependent protein kinase prevents R-C interaction, the inhibitory effect of R is lost, and the catalytic subunit continues to phosphorylate target proteins regardless of cAMP concentration. (b) A mutation in a receptor that acts via tyrosine kinase (the EGF receptor, for example) may lead to production of a receptor molecule in which tyrosine kinase is always active, even in the absence of the growth factor. (c) When a mutation in a G protein destroys its GTPase activity, it can no longer inactivate itself by converting bound GTP to GDP. Once activated, the mutant G protein continues to send its unregulated signal.

Chapter 13 Principles of Bioenergetics

Multiple Choice Questions

1. Bioenergetics and thermodynamics
Page: 492 Difficulty: 1 Ans: E
If the $\Delta G'^\circ$ of the reaction A → B is –40 kJ/mol, under standard conditions the reaction:

A) is at equilibrium.
B) will never reach equilibrium.
C) will not occur spontaneously.
D) will proceed at a rapid rate.
E) will proceed spontaneously from left to right.

2. Bioenergetics and thermodynamics
Page: 492 Difficulty: 1 Ans: C
For the reaction A → B, $\Delta G'^\circ$ = –60 kJ/mol. The reaction is started with 10 mmol of A; no B is initially present. After 24 hours, analysis reveals the presence of 2 mmol of B, 8 mmol of A. Which is the most likely explanation?

A) A and B have reached equilibrium concentrations.
B) An enzyme has shifted the equilibrium toward A.
C) B formation is kinetically slow; equilibrium has not been reached by 24 hours.
D) Formation of B is thermodynamically unfavorable.
E) The result described is impossible, given the fact that $\Delta G'^\circ$ is –60 kJ/mol.

3. Bioenergetics and thermodynamics
Page: 492 Difficulty: 2 Ans: A
When a mixture of 3-phosphoglycerate and 2-phosphoglycerate is incubated at 25°C with phosphoglycerate mutase until equilibrium is reached, the final mixture contains six times as much 2-phosphoglycerate as 3-phosphoglycerate. Which one of the following statements is most nearly correct, when applied to the reaction as written? (R = 8.315 J/mol·K; T = 298 K)

3-Phosphoglycerate → 2-phosphoglycerate

A) $\Delta G'^\circ$ is –4.44 kJ/mol.
B) $\Delta G'^\circ$ is zero.
C) $\Delta G'^\circ$ is +12.7 kJ/mol.
D) $\Delta G'^\circ$ is incalculably large and positive.
E) $\Delta G'^\circ$ cannot be calculated from the information given.

Short Answer Questions

26. Bioenergetics and thermodynamics
Pages: 490-491 Difficulty: 2
Explain the relationships among the change in the degree of order, the change in entropy, and the change in free energy that occur during a chemical reaction.

Ans: Entropy is a measure of disorder. Thus, if there is an increase in order there is a decrease in entropy. The greater the entropy of a system, the smaller is its free nergy. Thus, an increase in entropy during a reaction will result in a decrease in free nergy.

27. Bioenergetics and thermodynamics
Pages: 491-492 Difficulty: 2
Consider the reaction: A + B → C + D. If the equilibrium constant for this reaction is a large number (say, 10,000), what do we know about the standard free-energy change ($\Delta G'^{\circ}$) for the reaction? Describe the relationship between K_{eq}' and $\Delta G'^{\circ}$.

Ans: $\Delta G'^{\circ} = -RT \ln K_{eq}'$. If K_{eq}' is a large (positive) number, the term $-RT \ln K_{eq}'$ (and therefore $\Delta G'^{\circ}$) has a relatively large, negative value.

28. Bioenergetics and thermodynamics
Page: 492 Difficulty: 2
The standard free-energy change ($\Delta G'^{\circ}$) for ATP hydrolysis is –30.5 kJ/mol. ATP, ADP, and P_i are mixed together at initial concentrations of 1 M of each, then left alone until the reaction ADP + P_i → ATP has come to equilibrium. For each species (in other words, ATP, ADP, and P_i) indicate whether the concentration will be equal to 1 M, less than 1 M, or greater than 1 M.

Ans: At equilibrium, ATP < 1 M; ADP > 1 M; P_i > 1 M.

29. Bioenergetics and thermodynamics
Page: 492 Difficulty: 3
If a 0.1 M solution of glucose 1-phosphate is incubated with a catalytic amount of phosphoglucomutase, the glucose 1-phosphate is transformed to glucose 6-phosphate until equilibrium is reached. At equilibrium, the concentration of glucose 1-phosphate is 4.5×10^{-3} M and that of glucose 6-phosphate is 8.6×10^{-2} M. Set up the expressions for the calculation of K_{eq}' and $\Delta G'^{\circ}$ for this reaction (in the direction of glucose 6-phosphate formation). (R = 8.315 J/mol·K; T = 298 K)

Ans: $$K_{eq}' = \frac{[\text{glucose 6-phosphate}]}{[\text{glucose 1-phosphate}]} = \frac{0.086\text{ M}}{0.0045\text{ M}} = 19$$

$$\Delta G'^{\circ} = -RT \ln K_{eq}' = -(8.315\text{ J/mol·K})(298\text{ K})(\ln 19) = -7.3\text{ kJ/mol}$$

Chapter 14 Glycolysis, Gluconeogenesis, and the Pentose Phosphate Pathway

Multiple Choice Questions

91. Glycolysis
Page: 528 Difficulty: 2 Ans: D
Glycolysis is the name given to a metabolic pathway occurring in many different cell types. It consists of 11 enzymatic steps that convert glucose to lactic acid. Glycolysis is an example of:

A) aerobic metabolism.
B) anabolic metabolism.
C) a net reductive process.
D) fermentation.
E) oxidative phosphorylation.

92. Glycolysis
Pages: 528-531 Difficulty: 1 Ans: C
The anaerobic conversion of 1 mol of glucose to 2 mol of lactate by fermentation is accompanied by a net gain of:

A) 1 mol of ATP.
B) 1 mol of NADH.
C) 2 mol of ATP.
D) 2 mol of NADH.
E) none of the above.

93. Fates of pyruvate under anaerobic conditions: fermentation
Page: 530 Difficulty: 1 Ans: E
During strenuous exercise, the NADH formed in the glyceraldehyde 3-phosphate dehydrogenase reaction in skeletal muscle must be reoxidized to NAD^+ if glycolysis is to continue. The most important reaction involved in the reoxidation of NADH is:

A) dihydroxyacetone phosphate $\rightarrow$ glycerol 3-phosphate
B) glucose 6-phosphate $\rightarrow$ fructose 6-phosphate
C) isocitrate $\rightarrow$ α-ketoglutarate
D) oxaloacetate $\rightarrow$ malate
E) pyruvate $\rightarrow$ lactate

98. Glycolysis
Pages: 530-531 Difficulty: 2 Ans: E
When a muscle is stimulated to contract aerobically, less lactic acid is formed than when it contracts anaerobically because:

A) glycolysis does not occur to significant extent under aerobic conditions.
B) muscle is metabolically less active under aerobic than anaerobic conditions.
C) the lactic acid generated is rapidly incorporated into lipids under aerobic conditions.
D) under aerobic conditions in muscle, the major energy-yielding pathway is the pentose phosphate pathway, which does not produce lactate.
E) under aerobic conditions, most of the pyruvate generated as a result of glycolysis is oxidized by the citric acid cycle rather than reduced to lactate.

99. Glycolysis
Pages: 530-531 Difficulty: 1 Ans: E
Glycolysis in the erythrocyte produces pyruvate that is further metabolized to:

A) CO_2.
B) ethanol.
C) glucose.
D) hemoglobin.
E) lactate.

100. Glycolysis
Page: 532 Difficulty: 2 Ans: A
When a mixture of glucose 6-phosphate and fructose 6-phosphate is incubated with the enzyme phosphohexose isomerase, the final mixture contains twice as much glucose 6-phosphate as fructose 6-phosphate. Which one of the following statements is most nearly correct, when applied to the reaction below? (R = 8.315 J/mol·K and T = 298 K)

Glucose 6-phosphate ↔ fructose 6-phosphate

A) $\Delta G'^\circ$ is +1.7 kJ/mol.
B) $\Delta G'^\circ$ is –1.7 kJ/mol.
C) $\Delta G'^\circ$ is incalculably large and negative.
D) $\Delta G'^\circ$ is incalculably large and positive.
E) $\Delta G'^\circ$ is zero.

101. Glycolysis
Page: 534 Difficulty: 2 Ans: D
In glycolysis, fructose 1,6-bisphosphate is converted to two products with a standard free-energy change ($\Delta G'^{\circ}$) of 23.8 kJ/mol. Under what conditions (encountered in a normal cell) will the free-energy change (ΔG) be negative, enabling the reaction to proceed to the right?

A) If the concentrations of the two products are high relative to that of fructose 1,6-bisphosphate.
B) The reaction will not go to the right spontaneously under any conditions because the $\Delta G'^{\circ}$ is positive.
C) Under standard conditions, enough energy is released to drive the reaction to the right.
D) When there is a high concentration of fructose 1,6-bisphosphate relative to the concentration of products.
E) When there is a high concentration of products relative to the concentration of fructose 1,6-bisphosphate.

102. Glycolysis
Page: 535 Difficulty: 3 Ans: E
Glucose labeled with ^{14}C in C-1 and C-6 gives rise in glycolysis to pyruvate labeled in:

A) A and C.
B) all three carbons.
C) its carbonyl carbon.
D) its carboxyl carbon.
E) its methyl carbon.

103. Glycolysis
Page: 535 Difficulty: 2 Ans: E
If glucose labeled with ^{14}C at C-1 (the aldehyde carbon) were metabolized in the liver, the first radioactive pyruvate formed would be labeled in:

A) all three carbons.
B) both A and C.
C) its carbonyl carbon.
D) its carboxyl carbon.
E) its methyl carbon.

104. Fates of pyruvate under anaerobic conditions: fermentation
Page: 535 Difficulty: 2 Ans: B
In an anaerobic muscle preparation, lactate formed from glucose labeled in C-2 would be labeled in:

A) all three carbon atoms.
B) only the carbon atom carrying the OH.
C) only the carboxyl carbon atom.
D) only the methyl carbon atom.
E) the methyl and carboxyl carbon atoms.

105. Fates of pyruvate under anaerobic conditions: fermentation
Page: 535 Difficulty: 2 Ans: C
If glucose labeled with ^{14}C in C-3 is metabolized to lactate via fermentation, the lactate will contain ^{14}C in:

A) all three carbon atoms.
B) only the carbon atom carrying the OH.
C) only the carboxyl carbon atom.
D) only the methyl carbon atom.
E) the methyl and carboxyl carbon atoms.

106. Fates of pyruvate under anaerobic conditions: fermentation
Page: 535 Difficulty: 2 Ans: E
Which of these cofactors participates directly in most of the oxidation-reduction reactions in the fermentation of glucose to lactate?

A) ADP
B) ATP
C) $FAD/FADH_2$
D) Glyceraldehyde 3-phosphate
E) $NAD^+/NADH$

107. Fates of pyruvate under anaerobic conditions: fermentation
Page: 535 Difficulty: 1 Ans: B
In comparison with the resting state, actively contracting human muscle tissue has a:

A) higher concentration of ATP.
B) higher rate of lactate formation.
C) lower consumption of glucose.
D) lower rate of consumption of oxygen
E) lower ratio of NADH to NAD^+.

108. Glycolysis
Pages: 535-538 Difficulty: 2 Ans: C
The steps of glycolysis between glyceraldehyde 3-phosphate and 3-phosphoglycerate involve all of the following *except:*

A) ATP synthesis.
B) catalysis by phosphoglycerate kinase.
C) oxidation of NADH to NAD^+.
D) the formation of 1,3-bisphosphoglycerate.
E) utilization of P_i.

144. Glycolysis
Page: 529 Difficulty: 3
Describe the part of the glycolytic pathway from fructose 6-phosphate to glyceraldehyde 3-phosphate. Show structures of intermediates, enzyme names, and indicate where any cofactors participate.

Ans: This part of the pathway involves the reactions catalyzed by phosphofructokinase-1, aldolase, and triose phosphate isomerase. (See the figures from pp. 532-535.)

145. Glycolysis
Page: 529 Difficulty: 2
Describe the glycolytic pathway from fructose 1,6-bisphosphate to 1,3-bisphospho-glycerate, showing structures of intermediates and names of enzymes. Indicate where any cofactors participate.

Ans: The answer should show the reactions catalyzed by aldolase, triose phosphate isomerase, and glyceraldehyde 3-phosphate dehydrogenase. (See figures from pp. 534-536.)

146. Feeder pathways for glycolysis
Page: 529 Difficulty: 3
Yeast can metabolize D-mannose to ethanol and CO_2. In addition to the glycolytic enzymes, the only other enzyme needed is phosphomannose isomerase, which converts mannose 6-phosphate to fructose 6-phosphate. If mannose is converted to ethanol and CO_2 by the most direct pathway, which of the compounds and cofactors in this list are involved?

A. Lactate
B. Acetaldehyde
C. Acetyl-CoA
D. FAD
E. Glucose 6-phosphate
F. Fructose 1-phosphate
G. Pyruvate
H. Lipoic acid
I. Thiamine pyrophosphate
J. Dihydroxyacetone phosphate

Ans: B, G, I, J

147. The pentose phosphate pathway of glucose oxidation
Page: 529 Difficulty: 2
Rat liver is able to metabolize glucose by both the glycolytic and the pentose phosphate pathways. Indicate in the blanks if the following are properties of glycolytic (G), pentose phosphate (P), both (G + P), or neither (0):

_____ NAD^+ is involved.
_____ CO_2 is liberated.
_____ Phosphate esters are intermediates.
_____ Glyceraldehyde 3-phosphate is an intermediate.
_____ Fructose 6-phosphate is an intermediate.

Ans: G; P; G + P; G; G

148. Glycolysis

Page: 529 Difficulty: 2

In the conversion of glucose to pyruvate via glycolysis, all of the following enzymes participate. Indicate the order in which they function by numbering them.

_1_ hexokinase
_4__ triose phosphate isomerase
_2__ phosphohexose isomerase
_6__ enolase
_5__ glyceraldehyde 3-phosphate dehydrogenase
_7__ pyruvate kinase
_3__ phosphofructokinase-1

Which of the enzymes represents a major regulation point in glycolysis?
Which catalyzes a reaction in which ATP is produced?
Which catalyzes a reaction in which NADH is produced?

Ans: 4; 2; 6; 5; 7; 3; phosphofructokinase-1; pyruvate kinase; glyceraldehyde 3-phosphate dehydrogenase

149. Glycolysis

Page: 532 Difficulty: 2 Ans: C

The conversion of glucose into glucose 6-phosphate, which must occur in the breakdown of glucose, is thermodynamically unfavorable (endergonic). How do cells overcome this problem?

Ans: Cells often drive a thermodynamically unfavorable reaction in the forward direction by coupling it to a highly exergonic reaction through a common intermediate. In this example, to make glucose 6-phosphate formation thermodynamically favorable, cells transfer phosphoryl groups from ATP to glucose. ATP "hydrolysis" is highly exergonic, making the overall reaction exergonic. (Numerical solution below not required.)

	Glucose + P_i →	glucose 6-phosphate + H_2O	$\Delta G'^{\circ} = +13.8$ kJ/mol
	ATP + H_2O →	ADP + P_i	$\Delta G'^{\circ} = -30.5$ kJ/mol
Sum:	ATP + glucose →	ADP + glucose 6-phosphate	$\Delta G'^{\circ} = -16.7$ kJ/mol

150. Glycolysis

Page: 534 Difficulty: 3

The conversion of glyceraldehyde 3-phosphate to dihydroxyacetone phosphate is catalyzed by triose phosphate isomerase. The standard free-energy change ($\Delta G'^{\circ}$) for this reaction is –7.5 kJ/mol. Draw the two structures. Define the equilibrium constant for the reaction and calculate it using only the data given here. Be sure to show your work. (R = 8.315 J/mol·K; T = 298 K)

9. Regulation of metabolic pathways
Pages: 574-575 Difficulty: 2 Ans: A
Which one of the following types of mechanisms is *not* known to play a role in the reversible alteration of enzyme activity?

A) Activation by cleavage of an inactive zymogen
B) Allosteric response to a regulatory molecule
C) Alteration of the synthesis or degradation rate of an enzyme
D) Covalent modification of the enzyme
E) Interactions between catalytic and regulatory subunits

10. Coordinated regulation of glycolysis and gluconeogenesis
Pages: 575-576 Difficulty: 2 Ans: D
Gluconeogenesis must use "bypass reactions" to circumvent three reactions in the glycolytic pathway that are highly exergonic and essentially irreversible. Reactions carried out by which three of the enzymes listed must be bypassed in the gluconeogenic pathway?

1) Hexokinase
2) Phosphoglycerate kinase
3) Phosphofructokinase-1
4) Pyruvate kinase
5) Triosephosphate isomerase

A) 1, 2, 3
B) 1, 2, 4
C) 1, 4, 5
D) 1, 3, 4
E) 2, 3, 4

11. Coordinated regulation of glycolysis and gluconeogenesis
Pages: 579-580 Difficulty: 2 Ans: B
Cellular isozymes of pyruvate kinase are allosterically inhibited by:

A) high concentrations of AMP.
B) high concentrations of ATP.
C) high concentrations of citrate.
D) low concentrations of acetyl-CoA.
E) low concentrations of ATP.

16. Coordinated regulation of glycogen synthesis and breakdown
Page: 584 Difficulty: 2 Ans: E
Glycogen phosphorylase *a* can be inhibited at an allosteric site by:

A) AMP.
B) calcium.
C) GDP.
D) glucagon.
E) glucose.

17. Coordinated regulation of glycogen synthesis and breakdown
Page: 586 Difficulty: 2 Ans: B
Which one of the following directly results in the activation of glycogen synthase?

A) Binding of glucose-6-phosphate
B) Dephosphorylation of multiple residues by phosphoprotein phosphorylase-1 (PP1)
C) Phosphorylation of specific residues by casein kinase II (CKII)
D) Phosphorylation of specific residues by glycogen synthase kinase-3 (GSK-3)
E) The presence of insulin

18. Coordinated regulation of glycogen synthesis and breakdown
Pages: 586-588 Difficulty: 2 Ans: E
Which one of the following is *not* a characteristic of phosphoprotein phosphorylase-1 (PP1)?

A) PP1 can be phosphorylated by protein kinase A (PKA).
B) PP1 can dephosphorylate glycogen phosphorylase, glycogen synthase, and phosphorylase kinase.
C) PP1 is allosterically activated by glucose-6-phosphate.
D) PP1 is inhibited by activated glycogen phosphorylase
E) PP1 is phosphorylated by glycogen synthase kinase-3 (GSK3).

19. Analysis of metabolic control
Pages: 592-595 Difficulty: 2 Ans: E
The flux control coefficient for an enzyme in a multistep pathway depends on:

A) the concentration of the enzyme itself.
B) the concentration of other enzymes in the pathway.
C) the levels of regulatory molecules.
D) the amounts of substrate molecules present at each step.
E) all of the above.

20. Analysis of metabolic control
Pages: 593, 595 Difficulty: 2 Ans: E
The elasticity coefficient for an enzyme in a multistep pathway depends on:

A) the concentration of the enzyme itself.
B) the levels of regulatory molecules.
C) the amounts of substrate molecules present at each step.
D) both A and C.

189. Reactions of the citric acid cycle
Page: 614 Difficulty: 3 Ans: A
Which of the following intermediates of the citric acid cycle is prochiral?

A) Citrate
B) Isocitrate
C) Malate
D) Oxaloacetate
E) Succinate

190. Reactions of the citric acid cycle
Page: 615 Difficulty: 2 Ans: D
The conversion of 1 mol of pyruvate to 3 mol of CO_2 via pyruvate dehydrogenase and the citric acid cycle also yields _____ mol of NADH, _____ mol of $FADH_2$, and _____ mol of ATP (or GTP).

A) 2; 2; 2
B) 3; 1; 1
C) 3; 2; 0
D) 4; 1; 1
E) 4; 2; 1

191. Regulation of the citric acid cycle
Page: 621 Difficulty: 3 Ans: D
Entry of acetyl-CoA into the citric acid cycle is *decreased* when:

A) [AMP] is high.
B) NADH is rapidly oxidized through the respiratory chain.
C) the ratio of [ATP]/[ADP] is low.
D) the ratio of [ATP]/[ADP] is high.
E) the ratio of $[NAD^+]/[NADH]$ is high.

192. Regulation of the citric acid cycle
Page: 621 Difficulty: 3 Ans: E
Citrate synthase and the NAD^+-specific isocitrate dehydrogenase are two key regulatory enzymes of the citric acid cycle. These enzymes are inhibited by:

A) acetyl-CoA and fructose 6-phosphate.
B) AMP and/or NAD^+.
C) AMP and/or NADH.
D) ATP and/or NAD^+.
E) ATP and/or NADH.

Chapter 17 Fatty Acid Catabolism

Multiple Choice Questions

1. **Digestion, mobilization, and transport of fats**
Page: 632 Difficulty: 2 Ans: A
Lipoprotein lipase acts in:

A) hydrolysis of triacylglycerols of plasma lipoproteins to supply fatty acids to various tissues.
B) intestinal uptake of dietary fat.
C) intracellular lipid breakdown of lipoproteins.
D) lipoprotein breakdown to supply needed amino acids.
E) none of the above.

2. **Digestion, mobilization, and transport of fats**
Page: 634 Difficulty: 2 Ans: B
Free fatty acids in the bloodstream are:

A) bound to hemoglobin.
B) carried by the protein serum albumin.
C) freely soluble in the aqueous phase of the blood.
D) nonexistent; the blood does not contain free fatty acids.
E) present at levels that are independent of epinephrine.

3. **Digestion, mobilization, and transport of fats**
Page: 634 Difficulty: 2 Ans: C
The role of hormone-sensitive triacylglycerol lipase is to:

A) hydrolyze lipids stored in the liver.
B) hydrolyze membrane phospholipids in hormone-producing cells.
C) hydrolyze triacylglycerols stored in adipose tissue.
D) synthesize lipids in adipose tissue.
E) synthesize triacylglycerols in the liver.

4. **Digestion, mobilization, and transport of fats**
Pages: 635-636 Difficulty: 1 Ans: A
Transport of fatty acids from the cytoplasm to the mitochondrial matrix requires:

A) ATP, carnitine, and coenzyme A.
B) ATP, carnitine, and pyruvate dehydrogenase.
C) ATP, coenzyme A, and hexokinase.
D) ATP, coenzyme A, and pyruvate dehydrogenase.
E) carnitine, coenzyme A, and hexokinase.

30. Oxidation of fatty acids
Page: 638 Difficulty: 2
The β oxidation of fatty acids begins with this activation reaction:

$R–CH_2–CH_2–CH_2–COOH + ATP + CoA–SH \rightarrow$

$R–CH_2–CH_2–CH_2–CO–S–CoA + AMP + PP_i$

What are the next two steps (after transport into the mitochondria)? Show structures and indicate where any cofactors participate.

Ans: The reactions are those catalyzed by fatty acyl–CoA dehydrogenase and enoyl hydratase. See Fig. 17-8a, p. 638.

31. Oxidation of fatty acids
Page: 638 Difficulty: 3
Draw the four basic steps in the oxidation of a saturated fatty acid (the β-oxidation pathway). Show structures, name enzymes, and indicate where any cofactors participate.

Ans: See Fig. 17-8a, p. 638.

32. Oxidation of fatty acids
Page: 638 Difficulty: 2
Show the last step in the sequence of the four reactions in the β-oxidation pathway for fatty acid degradation. Include the structures of reactant and product, the enzyme name, and indicate where any cofactors participate.

Ans: See the thiolase reaction, Fig. 17-8a, p. 638.

33. Oxidation of fatty acids
Page: 638 Difficulty: 3
One of the steps in fatty acid oxidation in mitochondria involves the addition of water across a double bond. What is the next step in the process? Show structures and indicate where any cofactor(s) participate(s).

Ans: The reaction is that catalyzed by β-hydroxyacyl-CoA dehydrogenase, for which NAD^+ is cofactor. See Fig. 17-8a, p. 638.

34. Oxidation of fatty acids
Page: 638 Difficulty: 2
In the citric acid cycle, a double bond is introduced into a four-carbon compound containing the —CH_2—CH_2— group, producing fumarate. Show a similar reaction that occurs in the β-oxidation pathway.

Ans: See Fig. 17-8a, p. 638.

35. Oxidation of fatty acids
Page: 639 Difficulty: 3
Write a balanced equation for the β oxidation of palmitoyl-CoA, a 16-carbon, fully saturated fatty acid, and indicate how much of each product is formed.

44. Pathways of amino acid degradation
Page: 671 Difficulty: 1
Name four amino acids that can be converted directly (in one step) into pyruvate or a citric acid cycle intermediate, and name the intermediate formed from each.

Ans: (1) aspartate; oxaloacetate; (2) glutamate; α-ketoglutarate; (3) alanine; pyruvate; (4) serine; pyruvate. (Order is not important.)

45. Pathways of amino acid degradation
Page: 671 Difficulty: 2
Name one amino acid whose oxidation proceeds via the intermediate shown: (a) pyruvate; (b) oxaloacetate; (c) α-ketoglutarate; (d) succinyl-CoA; (e) fumarate.

Ans: Possible answers are: (a) alanine, tryptophan, glycine, serine, cysteine; (b) aspartate, asparagine; (c) glutamate, glutamine, arginine, histidine, proline; (d) isoleucine, threonine, methionine, valine; (e) phenylalanine, tyrosine.

46. Pathways of amino acid degradation
Pages: 671-672 Difficulty: 2
Degradation of amino acids yields compounds that are common intermediates in the major metabolic pathways. Explain the distinction between glucogenic and ketogenic amino acids in terms of their metabolic fates.

Ans: The glucogenic amino acids are those that are catabolized to intermediates that can serve as substrates for gluconeogenesis: pyruvate and any of the four- or five-carbon intermediates of the citric acid cycle. Ketogenic amino acids are catabolized to yield acetyl-CoA or acetoacetyl-CoA, the precursors for ketone body formation.

15. ATP synthesis

Page: 709 Difficulty: 2 Ans: D

When the $\Delta G'^{\circ}$ of the ATP synthesis reaction is measured on the surface of the ATP synthase enzyme, it is found to be close to zero. This is thought to be due to:

A) a very low energy of activation.
B) enzyme-induced oxygen exchange.
C) stabilization of ADP relative to ATP by enzyme binding.
D) stabilization of ATP relative to ADP by enzyme binding.
E) none of the above.

16. ATP synthesis

Page: 712 Difficulty: 2 Ans: C

During oxidative phosphorylation, the proton motive force that is generated by electron transport is used to:

A) create a pore in the inner mitochondrial membrane.
B) generate the substrates (ADP and P_i) for the ATP synthase.
C) induce a conformational change in the ATP synthase.
D) oxidize NADH to NAD^+.
E) reduce O_2 to H_2O.

17. ATP synthesis

Page: 713 Difficulty: 2 Ans: C

The oxidation of a particular hydroxy substrate to a keto product by mitochondria has a P/O ratio of less than 2. The initial oxidation step is very likely directly coupled to the:

A) oxidation of a flavoprotein.
B) oxidation of a pyridine nucleotide.
C) reduction of a flavoprotein.
D) reduction of a pyridine nucleotide.
E) reduction of cytochrome a_3.

18. General features of photophosphorylation

Page: 724 Difficulty: 2 Ans: B

Which of the following statements about the light reactions in photosynthetic plants is *false*?

A) A membrane-bound ATPase couples ATP synthesis to electron transfer.
B) No CO_2 is fixed in the light reactions.
C) The ultimate electron acceptor is O_2.
D) The ultimate source of electrons for the process is H_2O.
E) There are two distinct photosystems, linked together by an electron transfer chain.

in mitochondria. For each electron carrier, indicate whether only electrons, or both electrons and protons, are accepted/donated by that carrier. Indicate with an arrow where electrons from succinate oxidation enter the chain of carriers.

Ans: NADH (both) → FP (both) → Q (both) → cyt *b* (e^- only) → cyt c_1 (e^- only) → cyt *c* (e^- only) → cyt ($a + a_3$) (e^- only) → O_2 (both)

Electrons from succinate enter at Q.

37. Electron-transfer reactions in mitochondria

Pages: 695, 701 Difficulty: 3

A recently discovered bacterium carries out ATP synthesis coupled to the flow of electrons through a chain of carriers to some electron acceptor. The components of its electron transfer chain differ from those found in mitochondria; they are listed below with their standard reduction potentials.

Electron carriers in the newly discovered bacterium:

Oxidant	Reductant	Electrons transferred	$E'°$ (V)
NAD^+ NADH	2 –0.32		
flavoprotein *b* (FP_b) (oxidized)	flavoprotein *b* (reduced)	2	–0.62
cytochrome *c* (Fe^{3+})	cytochrome *c* (Fe^{2+})		+0.22
Fe-S protein (oxidized)	Fe-S protein (reduced)	2	+0.89
flavoprotein *a* (FP_a) (oxidized)	flavoprotein *a* (reduced)	2	+0.77

(a) Place the electron carriers in the order in which they are most likely to act in carrying electrons. (b) Is it likely that O_2 (for which $E'° = 0.82$ V) is the final electron acceptor in this organism? Why or why not? (c) How would you calculate the maximum number of ATP molecules that could theoretically be synthesized, under standard conditions, per pair of electrons transfered through this chain of carriers? (The Faraday constant, $\mathfrak{I}$, is 96.48 kJ/V·mol.) $\Delta G'°$ for ATP synthesis is +30.5 kJ/mol.

Ans: (a) $FP_b \rightarrow NAD^+ \rightarrow$ cyt *c* $\rightarrow FP_a \rightarrow$ Fe-S

(b) No; Fe-S has a larger $E'°$, so will probably be the terminal acceptor.

(c) First calculate $\Delta G'°$ for e^- flow from FP_b to Fe-S:

$\Delta E'° = E'°(\text{oxidant}) - E'°(\text{reductant}) = +0.89 - (-0.62) = +1.51$ V

$\Delta G'° = -n\mathfrak{I}\Delta E'° = (-2)(96.48 \text{ kJ/V·mol})(1.51 \text{ V}) = -291 \text{ kJ}/2e^-$

Theoretically, the flow of two electrons from FP_b to Fe-S could drive the synthesis of 291 kJ/30.5 kJ/mol = 9.5 mol ATP. Because only whole numbers of molecules can be made, the correct answer is 9 mol ATP per electron pair.

38. Electron-transfer reactions in mitochondria

Page: 701 Difficulty: 2

During electron transfer through the mitochondrial respiratory chain, the overall reaction is: $NADH + 1/2\ O_2 + H^+ \rightarrow NAD^+ + H_2O$. The difference in reduction potentials for the two half-

28. Photosynthetic carbohydrate synthesis
Page: 764 Difficulty: 2
How does glyceraldehyde 3-phosphate formed in the chloroplast stroma by the Calvin cycle reactions enter the cytosol?
Ans: It is converted to dihydroxyacetone phosphate or to 3-phosphoglycerate and carried into the cytosol by the P_i-triose phosphate antiporter, a specific transporter in the inner chloroplast membrane. (See Fig. 20-16, p. 764.)

29. Photosynthetic carbohydrate synthesis
Pages: 764-765 Difficulty: 3
Describe how thioredoxin participates in the regulation of several chloroplast enzymes by light.

Ans: Thioredoxin is an electron-carrying protein that is reduced by electrons from ferredoxin during illumination. Electrons from thioredoxin reduce critical disulfide bonds in key enzymes of the Calvin cycle, activating those enzymes. (See Fig. 20-19, p. 765.)

30. Photorespiration and the C_4 and CAM pathways
Pages: 766-768 Difficulty: 3
Describe the oxygenase activity of ribulose 1,5-bisphosphate carboxylase/oxygenase (rubisco) and explain why this reaction is undesirable from the point of view of a plant.

Ans: The condensation of molecular oxygen with ribulose 1,5-bisphosphate yields 3-phosphoglycerate and the two-carbon compound phosphoglycolate. Phosphoglycolate has no known metabolic role; its carbon is salvaged by a series of reactions that consume O_2 and produce CO_2 – the "photorespiration" process. The salvage pathway requires energy, and therefore the oxygenase reaction of rubisco represents a net energy cost to the plant cell in which it occurs.

31. Photorespiration and the C_4 and CAM pathways
Page: 767 Difficulty: 1
Describe the reaction sequence by which 2-phosphoglycolate (produced when O_2 replaces CO_2 as substrate for rubisco) is converted to serine. Name each enzyme and any cofactors required and indicate the subcellular compartment in which the reaction takes place.

Ans: 2-phosphoglycolate is converted to glycolate by a phosphatase in the chloroplast. Glycolate is transported to the peroxisome and converted to glyoxylate by glycolate oxidase. The glyoxylate is then converted in the peroxisome to glycine by a transaminase that requires pyridoxal phosphate. Finally, two molecules of glycine are converted to serine + NH_3 + CO_2 by the enzyme glycine decarboxylase, which is located in the mitochondrion.

32. Photorespiration and the C_4 and CAM pathways
Page: 770 Difficulty: 1
CAM plants, such as cactus and pineapple, are native to very hot and dry environments. Briefly describe the biochemical events that allow CAM plants to minimize water loss by closing their stroma during daylight hours.

Ans: CAM plants fix CO_2 into malate in the dark when the stroma are open. The resulting malate is stored in vacuoles. During daylight hours, the CO_2 is released from malate by the action of the NADP-linked malic enzyme, and the CO_2 serves as substrate for rubisco.

45. Biosynthesis of fatty acids and eicosanoids
Page: 797 Difficulty: 2 Ans: E
Which of the following is *not* true of the fatty acid elongation system of vertebrate cells?

A) It involves the same four-step sequence seen in the fatty acid synthase complex.
B) It is located in the smooth endoplasmic reticulum.
C) It produces stearoyl-CoA by the extension of palmitoyl-CoA.
D) It uses malonyl-CoA as a substrate.
E) The immediate precursor of the added carbons is acetyl-CoA.

46. Biosynthesis of fatty acids and eicosanoids
Page: 797 Difficulty: 2 Ans: A
Which of these can be synthesized by plants but *not* by humans?

A) Linoleate [18:2($\Delta^{9,12}$)]
B) Palmitate (16:0)
C) Phosphatidylcholine
D) Pyruvate
E) Stearate (18:0)

47. Biosynthesis of fatty acids and eicosanoids
Page: 798 Difficulty: 3 Ans: B
The enzyme system for adding double bonds to saturated fatty acids requires all of the following *except:*

A) a mixed-function oxidase.
B) ATP.
C) cytochrome b_5.
D) molecular oxygen (O_2).
E) NADPH.

48. Biosynthesis of fatty acids and eicosanoids
Pages: 800-801 Difficulty: 3 Ans: A
Which of these statements about eicosanoid synthesis is true?

A) An early step in the path to thromboxanes is blocked by ibuprofen.
B) Arachidonate is derived mainly by hydrolysis of triacylglycerols.
C) Aspirin acts by blocking the synthesis of arachidonate.
D) Plants can synthesize leukotrienes, but humans cannot.
E) Thromboxanes are produced from arachidonate via the “linear” path.

49. Biosynthesis of triacylglycerols
Page: 804 Difficulty: 2 Ans: B
The biosynthesis of triacylglycerols from acetate occurs mainly in:

A) animals but not in plants.
B) humans after ingestion of excess carbohydrate.
C) humans with low carbohydrate intake.
D) plants but not in animals.
E) none of the above.

50. Biosynthesis of triacylglycerols
Page: 805 Difficulty: 2 Ans: D
The synthesis of both glycerophospholipids and triacylglycerols involves:

A) CDP-choline.
B) CDP-diacylglycerol.
C) phosphatidate phosphatase.
D) phosphatidic acid.
E) phosphoethanolamine.

51. Biosynthesis of triacylglycerols
Page: 806 Difficulty: 2 Ans: B
Which of these statements about triacylglycerol synthesis is correct?

A) Humans can store more energy in glycogen than in triacylglycerols.
B) Insulin stimulates conversion of dietary carbohydrate into triacylglycerols.
C) It is not a hormone-sensitive process.
D) Mammals are unable to convert carbohydrates into triacylglycerols.
E) Phosphatidate is not on the pathway of triacylglycerol synthesis.

52. Biosynthesis of membrane phospholipids
Pages: 808-813 Difficulty: 2 Ans: C
A strategy that is *not* employed in the synthesis of phospholipids is:

A) condensation of CDP-alcohol with diacylglycerol.
B) condensation of CDP-diacylglycerol with alcohol.
C) condensation of CDP-diacylglycerol with CDP-alcohol.
D) exchange of free alcohol with head group alcohol of phospholipid.
E) remodeling of head group alcohols by chemical modification

53. Biosynthesis of membrane phospholipids
Pages: 810-811 Difficulty: 2 Ans: E
All glycerol-containing phospholipids are synthesized from:

A) cardiolipin
B) ceramide.

mediated endocytosis the cholestrol in LDL; the resulting high level of LDL in the blood is characteristic of familial hypercholesterolemia. 2) Mutations in the ABC1 protein of HDL result in a failure of the HDL to take up cholesterol and remove it from the blood.

87. Biosynthesis of cholesterol, steroids, and isoprenoids
Page: 827 Difficulty: 1
The synthetic compound mevinolinic acid, also called lovastatin, is a potent competitive inhibitor of HMG-CoA reductase (hydroxymethylglutaryl-CoA reductase). Predict and explain the effect of this drug on serum cholesterol levels in humans.

Ans: HMG-CoA reductase catalyzes the rate-limiting step in cholesterol biosynthesis. By inhibiting this step, lovastatin reduces the endogenous production of cholesterol and lowers the level of cholesterol in the blood.

5. Biosynthesis of amino acids
Pages: 860-861 Difficulty: 2 Ans: D
Nonessential amino acids:

A) are amino acids other than those required for protein synthesis.
B) are not utilized in mammalian proteins.
C) are synthesized by plants and bacteria, but not by humans.
D) can be synthesized in humans as well as in bacteria.
E) may be substituted with other amino acids in proteins.

6. Biosynthesis of amino acids
Page: 861 Difficulty: 3 Ans: E
An amino acid that does *not* derive its carbon skeleton, at least in part, from α-ketoglutarate is:

A) arginine.
B) glutamate.
C) glutamine.
D) proline.
E) threonine.

7. Biosynthesis of amino acids
Page: 861 Difficulty: 3 Ans: B
Glutamine, arginine, and proline:

A) do not have a common precursor.
B) may all be derived from a citric acid cycle intermediate.
C) may all be derived from a Cori cycle intermediate.
D) may all be derived from a glycolytic intermediate.
E) may all be derived from a urea cycle intermediate.

8. Biosynthesis of amino acids
Page: 862 Difficulty: 2 Ans: E
In which group are all the amino acids closely interrelated metabolically?

A) Arginine, hydroxyproline, and histidine
B) Arginine, tyrosine, and glutamate
C) Glycine, valine, glutamine, and aspartate
D) Ornithine, alanine, glycine, and valine
E) Ornithine, proline, arginine, and glutamate

9. Biosynthesis of amino acids
Page: 863 Difficulty: 2 Ans: D
If glucose labeled with ^{14}C at C-1 were the starting material for amino acid biosynthesis, the product(s) that would be readily formed is (are):

A) serine labeled at the carboxyl carbon.
B) serine labeled at alpha carbon.
C) serine labeled at the R-group carbon.
D) all of the above.

29. Biosynthesis and degradation of nucleotides
Page: 886 Difficulty: 2 Ans: E
Orotic aciduria is an inherited metabolic disease in which orotic acid (orotate) accumulates in the tissues, blood, and urine. The metabolic pathway in which the enzyme defect occurs is:

A) epinephrine synthesis.
B) purine breakdown.
C) purine synthesis.
D) pyrimidine breakdown.
E) pyrimidine synthesis.

30. Biosynthesis and degradation of nucleotides
Page: 886 Difficulty: 2 Ans: A
Precursors for the biosynthesis of the pyrimidine ring system include:

A) carbamoyl phosphate and aspartate.
B) glutamate, NH_3, and CO_2.
C) glycine and succinyl-CoA.
D) glycine, glutamine, CO_2, and aspartate.
E) inosine and aspartate.

31. Biosynthesis and degradation of nucleotides
Page: 886 Difficulty: 2 Ans: A
The most direct precursors of the nitrogens of UMP are:

A) aspartate and carbamoyl phosphate.
B) glutamate and aspartate.
C) glutamate and carbamoyl phosphate.
D) glutamine and aspartate.
E) glutamine and carbamoyl phosphate.

32. Biosynthesis and degradation of nucleotides
Pages: 886-887 Difficulty: 2 Ans: B
CMP, UMP, and TMP all have ________________ as a common precursor.

A) adenosine
B) aspartate
C) glutamine
D) inosine
E) *S*-adenosyl methionine

33. Biosynthesis and degradation of nucleotides
Pages: 888-890 Difficulty: 2 Ans: D
Which of the following is *not* true of the reaction catalyzed by ribonucleotide reductase?

A) Glutathione is part of the path of electron transfer.
B) It acts on nucleoside diphosphates.
C) Its mechanism involves formation of a free radical.
D) There is a separate enzyme for each nucleotide (ADP, CDP, GDP, UDP).

5. **Hormones: diverse structures for diverse functions**
Page: 888 Difficulty: 1 Ans: A
Epinephrine is an example of a(n) ____________ hormone.

A) catecholamine
B) eicosanoid
C) paracrine
D) peptide
E) steroid

6. **Hormones: diverse structures for diverse functions**
Page: 888 Difficulty: 2 Ans: D
An example of an eicosanoid hormone is:

A) epinephrine.
B) retinoic acid.
C) testosterone.
D) thromboxane.
E) thyroxine.

7. **Hormones: diverse structures for diverse functions**
Page: 888 Difficulty: 2 Ans: C
An example of a steroid hormone is:

A) epinephrine.
B) retinoic acid.
C) testosterone.
D) thromboxane.
E) thyroxine.

8. **Hormones: diverse structures for diverse functions**
Page: 890 Difficulty: 2 Ans: A
The tropic hormones (such as thyrotropin, somatotropin, and luteinizing hormone) are produced and released by the:

A) anterior pituitary.
B) hypothalamus.
C) ovaries.
D) pancreas.
E) posterior pituitary.

9. **Hormones: diverse structures for diverse functions**
Page: 890 Difficulty: 2 Ans: E
The normal sequence of action of these components of the hormonal hierarchy is:

A) adrenal cortex → hypothalamus → anterior pituitary
B) anterior pituitary → adrenal cortex → hypothalamus
C) anterior pituitary → hypothalamus → adrenal cortex
D) hypothalamus → adrenal cortex → anterior pituitary

14. Tissue-specific metabolism: the division of labor
Page: 899 Difficulty: 2 Ans: C
The Cori cycle is:

A) the conversion of lactate to pyruvate in skeletal muscle to drive glycogen synthesis.
B) the interconversion between glycogen and glucose l-phosphate.
C) the production of lactate from glucose in peripheral tissues with the resynthesis of glucose from lactate in liver.
D) the synthesis of alanine from pyruvate in skeletal muscle and the synthesis of pyruvate from alanine in liver.
E) the synthesis of urea in liver and degradation of urea to carbon dioxide and ammonia by bacteria in the gut.

15. Tissue-specific metabolism: the division of labor
Page: 900 Difficulty: 2 Ans: A
Which one of the following statements is true?

A) The brain prefers glucose as an energy source, but can use ketone bodies.
B) Muscle cannot use fatty acids as an energy source.
C) In a well-fed human, about equal amounts of energy are stored as glycogen and as triacylglycerol.
D) Fatty acids cannot be used as an energy source in humans because humans lack the enzymes of the glyoxylate cycle.
E) Amino acids are a preferable energy source over fatty acids.

16. Hormonal regulation of fuel metabolism
Page: 902 Difficulty: 1 Ans: D
When blood glucose is abnormally high, the pancreas releases:

A) epinephrine.
B) glucagon.
C) glucose.
D) insulin.
E) trypsin.

17. Hormonal regulation of fuel metabolism
Page: 904 Difficulty: 2 Ans: B
When blood glucose is abnormally low, the pancreas releases:

A) epinephrine.
B) glucagon.
C) glucose.
D) insulin.
E) trypsin.

40. DNA replication

Page: 989 Difficulty: 2

List two proteins or enzymes, other than DNA polymerase III, that are found at the replication fork in *E. coli.* Describe each of their functions with no more than one sentence.

Ans: The proteins are listed in Table 25-4, p. 989. They include (a) DNA polymerase I, which fills gaps and excises RNA primers; (b) primase (the DnaG protein), which synthesizes short RNA primers; (c) DNA ligase, which seals nicks; and (d) proteins that aid in DNA unwinding and supercoiling.

41. DNA replication

Pages: 989-990 Difficulty: 2

In the bacterial cell, what are catenated chromosomes, when do they arise, and how does the cell resolve the problem posed by their structure?

Ans: Catenanes are topologically interlinked circular chromosomes, which are the normal end result of DNA replication of the parental circular genome when the bidirectional replication forks meet. They are unlinked by the bacterial topoisomerase IV (a type II enzyme), and thus become free to segregate into daughter cells upon cell division. (See Fig. 25-19, p. 990.)

42. DNA replication

Page: 992 Difficulty: 2

Why is the drug acyclovir effective against the herpes simplex virus?

Ans: Acyclovir is a guanine nucleoside with an incomplete ribose ring, which can be phosphorylated much more efficiently by the viral thymidine kinase than the host enzyme. Further conversion forms acyclo-GTP, which competitively inhibits the viral DNA polymerase more strongly than the host enzyme, and when incorporated into DNA is a chain terminator, because it lacks a 3' hydroxyl group.

43. DNA repair

Pages: 993-994 Difficulty: 2

The high fidelity of DNA replication is due primarily to immediate error correction by the 3' —> 5' exonuclease (proofreading) activity of the DNA polymerase. Some incorrectly paired bases escape this proofreading, and further errors can arise from challenges to the chemical integrity of the DNA. List the four classes of repair mechanisms that the cell can use to help correct such errors.

Ans: The four classes are listed in Table 25-5 (p. 994), and consist of (1) mismatch repair; (2) base-excision repair; (3) nucleotide-excision repair; and (4) direct repair.

44. DNA repair

Page: 993 Difficulty: 2

List three types of DNA damage that require repair.

Ans: The defects in DNA that require repair include (a) mismatches that occur during replication; (b) abnormal bases; and (c) pyrimidine dimers produced by UV irradiation. Other answers are possible.

45. DNA repair

Pages: 993-1000 Difficulty: 2

Match the damage type or repair step at the left with a related enzyme at right. Only one answer will be the most direct for each.

___ cytosine deamination	(a) hypoxanthine-*N*-glycosylase
___ base loss	(b) AP endonuclease
___ adenine deamination	(c) mutH protein
___ binds to GATC sequences	(d) DNA polymerase I
___ binds to mismatch in DNA	(e) uracil *N*-glycosylase
___ DNA synthesis in gaps	(f) mutS-mutL complex
___ seals nicks	(g) ABC excinuclease
___ O^6-methylguanine	(h) DNA photolyase
___ direct chemical reversal of pyrimidine dimer formation	(i) O^6-methylguanine methyltransferase
___ double-strand break	(j) DNA ligase
___ excision of a lesion-containing oligonucleotide	(k) λ integrase
	(l) RecA protein
	(m) restriction endonuclease

Ans: e; b; a; c; f; d; j; i; h; m; g

46. DNA repair

Pages: 996-997 Difficulty: 3

Explain the role of DNA glycosylases in DNA repair.

Ans: When spontaneous deamination converts cytosine in DNA to uracil, or adenine to hypoxanthine, DNA glycosylase breaks the *N*-glycosidic bond to the defective base, creating an "abasic" or "AP" site. The region containing the AP site is then excised by AP endonuclease, and the resulting gap is closed by DNA polymerase I and sealed by DNA ligase. (See Fig. 25-25, p. 997.) Other DNA glycosylases recognize other types of modified or damaged bases.

47. DNA repair

Page: 996-998 Difficulty: 2

Briefly explain the difference between base-excision repair and nucleotide-excision repair.

Ans: Base excision involves removing only the defective base from the DNA by cleavage of the *N*-glycosidic linkage of the base to deoxyribose. This leaves an apurinic or apyrimidinic site, which must then undergo additional repair processes. Nucleotide excision involves removing the defective base together with its deoxyribose and phosphate (as well as some neighboring nucleotides) by cleavage of phosphodiester bonds in the DNA chain.

48. DNA repair

Page: 996-998 Difficulty: 2

Describe the process of nucleotide-excision repair of lesions like pyrimidine dimers in *E. coli*.

Ans: DNA lesions such as pyrimidine dimers are repaired by the excision of a 12- or 13-nucleotide fragment of the defective strand. The ABC excinuclease makes single-strand cuts on both sides of the defect. The fragment between the cuts is removed by the UvrD helicase. This leaves a gap in the DNA, which is filled in by DNA polymerase I and sealed by DNA ligase. (See Fig. 25-26, p. 998.)

Page: 1042 Difficulty: 2
Transfer RNAs have several bases in addition to the normal four found in RNA. How are these rare bases incorporated into the tRNA molecule?

Ans: The unusual bases in tRNA are made by first incorporating the usual four bases into a tRNA precursor, then enzymatically modifying specific nucleotide residues in the pre-tRNA molecule.

49. RNA processing
Pages: 1045-1048 Difficulty: 2
Define ribozymes and briefly describe the structure and function of two ribozymes.

Ans: Ribozymes are enzymes that consist in part or entirely of RNA. RNase P, which contains both protein and RNA, cleaves extra nucleotides from the 5′ end of tRNA molecules. The enzymatic activity is contained entirely in the RNA portion. Group I introns are RNA sequences in primary transcripts that catalyze their own excision, without any involvement of catalytic proteins. Small RNAs associated with certain RNA viruses of plants also contain self-splicing RNA sequences. The enzyme peptidyl transferase (see Chapter 27), which forms peptide bonds during protein synthesis on ribosomes, is a ribozyme in which the essential catalytic component is RNA.

50. RNA-dependent synthesis of RNA and DNA
Pages: 1022, 1050-1051 Difficulty: 2
Compare transcription and reverse transcription in terms of the following characteristics:

(a) direction of polynucleotide synthesis
(b) nature of template
(c) nature of primer
(d) incorporated nucleotides

Ans:

	Reverse Transcription	Transcription
(a) direction of polynucleotide synthesis	5′ → 3′	5′ → 3′
(b) nature of template	RNA or DNA	DNA
(c) nature of primer	tRNA	none
(d) incorporated nucleotides	dNTPs	NTPs

51. RNA-dependent synthesis of RNA and DNA
Page: 1051 Difficulty: 2
Describe all of the known catalytic activities of reverse transcriptase.

Ans: Reverse transcriptase can (1) synthesize DNA complementary to an RNA template; (2) degrade the RNA strand of the resulting RNA-DNA hybrid; and (3) synthesize DNA complementary to the resulting single-stranded DNA.

52. RNA-dependent synthesis of RNA and DNA
Pages: 1053-1056 Difficulty: 2
What is a telomere? Describe the key features of its structure. What is unusual about the structure and/or mechanism of action of telomerase?

Chapter 28 Regulation of Gene Expression

Multiple Choice Questions

1. Principles of gene regulation
Page: 1116 Difficulty: 2 Ans: B
"Housekeeping genes" in bacteria are commonly expressed constitutively, but not all of these genes are expressed at the same level (the same number of molecules per cell). The primary mechanism responsible for variations in the level of constitutive enzymes from different genes is that:

A) all constitutive enzymes are synthesized at the same rate, but are not degraded equally.
B) their promoters have different affinities for RNA polymerase holoenzyme.
C) some constitutively expressed genes are more inducible than others.
D) some constitutively expressed genes are more repressible than others.
E) the same number of mRNA copies are made from each gene, but are translated at different rates.

2. Principles of gene regulation
Pages: 1116-1117 Difficulty: 2 Ans: D
Which of the following statements correctly describes promoters in *E. coli*?

A) A promoter may be present on either side of a gene or in the middle of it.
B) All promoters have the same sequence that is recognized by RNA polymerase holoenzyme.
C) Every promoter has a different sequence, with little or no resemblance to other promoters.
D) Many promoters are similar and resemble a consensus sequence, which has the highest affinity for RNA polymerase holoenzyme.
E) Promoters are not essential for gene transcription, but can increase its rate by two- to three-fold.

3. Principles of gene regulation
Pages: 1117-1118 Difficulty: 2 Ans: D
The operator region normally can be bound by:

A) attenuator.
B) inducer.
C) mRNA.
D) repressor.
E) suppressor tRNA.

4. Principles of gene regulation
Pages: 1117-1118 Difficulty: 2 Ans: C
Small signal molecules that regulate transcription are *not* known to:

A) cause activator proteins to bind to DNA sites.
B) cause repressor proteins to bind to DNA sites.
C) directly bind to DNA sites.
D) prevent activator proteins from binding to DNA sites.
E) release repressor proteins from DNA sites.