CHAPTER

2 Chemistry Comes Alive

Objectives

Part 1: Basic Chemistry

Definition of Concepts: Matter and Energy

1. Differentiate between matter and energy and between potential energy and kinetic energy.
2. Describe the major energy forms.

Composition of Matter: Atoms and Elements

3. Define chemical element and list the four elements that form the bulk of body matter.
4. Define atom. List the subatomic particles, and describe their relative masses, charges, and positions in the atom.
5. Define atomic number, atomic mass, atomic weight, isotope, and radioisotope.

How Matter Is Combined: Molecules and Mixtures

6. Define molecule, and distinguish between a compound and a mixture.
7. Compare solutions, colloids, and suspensions.

Chemical Bonds

8. Explain the role of electrons in chemical bonding and in relation to the octet rule.
9. Differentiate among ionic, covalent, and hydrogen bonds.
10. Compare and contrast polar and nonpolar compounds.

Chemical Reactions

11. Define the three major types of chemical reactions: synthesis, decomposition, and exchange. Comment on the nature of oxidation-reduction reactions and their importance.
12. Explain why chemical reactions in the body are often irreversible.
13. Describe factors that affect chemical reaction rates.

Part 2: Biochemistry

Inorganic Compounds

14. Explain the importance of water and salts to body homeostasis.
15. Define acid and base, and explain the concept of pH.

Organic Compounds

16. Describe and compare the building blocks, general structures, and biological functions of carbohydrates and lipids.
17. Explain the role of dehydration synthesis and hydrolysis in forming and breaking down organic molecules.
18. Describe the four levels of protein structure.
19. Indicate the function of molecular chaperones.
20. Describe enzyme action.
21. Compare and contrast DNA and RNA.
22. Explain the role of ATP in cell metabolism.

Suggested Lecture Outline

Part 1: Basic Chemistry

I. Definition of Concepts: Matter and Energy (pp. 23–25)

A. Matter is anything that occupies space and has mass (p. 24).

1. Mass is equal to the amount of matter in the object.

2. Mass remains constant regardless of gravity.

B. States of Matter (p. 24)

1. Matter exists in one of three states: solid, liquid, or gas.

C. Energy (pp. 24–25)

1. Energy is the capacity to do work, and it exists in two forms.

a. Kinetic energy is the energy of motion.

b. Potential energy is stored energy.

2. Forms of Energy

a. Chemical energy is energy stored in chemical bonds.

b. Electrical energy results from the movement of charged particles.

c. Mechanical energy is energy directly involved with moving matter.

d. Radiant energy is energy that travels in waves.

3. Energy is easily converted from one form to another.

II. Composition of Matter: Atoms and Elements (pp. 25–28; Figs. 2.1–2.3; Table 2.1)

A. Basic Terms (p. 25; Table 2.1)

1. Elements are unique substances that cannot be broken down into simpler substances by ordinary chemical means.

2. Four elements—carbon, hydrogen, oxygen, and nitrogen—make up roughly 96% of body weight.

3. Atoms are the smallest particles of an element that retain the characteristics of that element.

4. Elements are designated by a one- or two-letter abbreviation called the atomic symbol.

B. Atomic Structure (pp. 25–27; Figs. 2.1–2.2)

1. Each atom has a central nucleus with tightly packed protons and neutrons.
   - **a.** Protons have a positive charge and weigh 1 atomic mass unit (amu).
   - **b.** Neutrons do not have a charge and weigh 1amu.
2. Electrons are found moving around the nucleus, have a negative charge, and are weightless (0 amu).
3. Atoms are electrically neutral and the number of electrons is equal to the number of protons.
4. The planetary model is a simplified, two-dimensional model of atomic structure.
5. The orbital model is a more accurate three-dimensional model talking about orbital regions instead of set orbital patterns.

C. Identifying Elements (pp. 27–28; Fig. 2.3)

1. Elements are identified based on their number of protons, neutrons, and electrons.
2. The atomic number of an element is equal to the number of protons of an element.
   - **a.** Because the number of protons is equal to the number of electrons, the atomic number indirectly tells us the number of electrons.
3. The mass number of an element is equal to the number of protons plus the number of neutrons.
   - **a.** The electron is weightless, and is ignored in calculating the mass number.
4. Isotopes are structural variations of an atom that have the same number of protons, but differ in the number of neutrons.
5. The atomic weight is an average of the relative weights of all known isotopes of an element, taking into account their relative abundance in nature.
6. Radioisotopes are heavier, unstable isotopes of an element that spontaneously decompose into more stable forms.
   - **a.** The time for a radioisotope to lose one-half of its radioactivity is called the half-life.

III. How Matter Is Combined: Molecules and Mixtures (pp. 28–30; Fig. 2.4)

A. Molecules and Compounds (pp. 28–29)

1. A combination of two or more atoms is called a molecule.
2. If two or more atoms of the same element combine it is called a molecule of that element.
3. If two or more atoms of different elements combine it is called a molecule of a compound.

B. Mixtures (pp. 29–30; Fig. 2.4)

1. Mixtures are substances made of two or more components mixed physically.
2. Solutions are homogeneous mixtures of compounds that may be gases, liquids, or solids.
   - **a.** The substance present in the greatest amount is called the solvent.
   - **b.** Substances present in smaller amounts are called solutes.
   - **c.** Solutions may be described by their concentrations. These may be expressed as a percent or in terms of molarity.
3. Colloids or emulsions are heterogeneous mixtures that often appear milky, and have larger solute particles that do not settle out of solution.

4. Suspensions are heterogeneous mixtures with large, often visible solutes that tend to settle out.

C. Distinguishing Mixtures from Compounds (p. 30)

1. The main difference between mixtures and compounds is that no chemical bonding occurs between molecules of a mixture.
2. Mixtures can be separated into their chemical components by physical means; separation of compounds is done by chemical means.
3. Some mixtures are homogeneous, while others are heterogeneous.

IV. Chemical Bonds (pp. 30–35; Figs. 2.5–2.10)

A. A chemical bond is an energy relationship between the electrons of the reacting atoms (p. 30; Fig. 2.5).

1. The Role of Electrons in Chemical Bonding (p. 31)
   a. Electrons occupy regions of space called electron shells that surround the nucleus in layers.
   b. Each electron shell represents a different energy level.
   c. Each electron shell holds a specific number of electrons, and shells tend to fill consecutively from the closest to the nucleus to the furthest away.
   d. The octet rule, or rule of eights, states that except for the first energy shell (stable with two electrons), atoms are stable with eight electrons in their outermost (valence) shell.

B. Types of Chemical Bonds (pp. 31–35; Figs. 2.6–2.10)

1. Ionic bonds are chemical bonds that form between two atoms that transfer one or more electrons from one atom to the other.
   a. Ions are charged particles.
   b. An anion is an electron acceptor carrying a net negative charge due to the extra electron.
   c. A cation is an electron donor carrying a net positive charge due to the loss of an electron.
   d. Crystals are large structures of cations and anions held together by ionic bonds.
2. Covalent bonds form when electrons are shared between two atoms.
   a. Some atoms are capable of sharing two or three electrons between them, resulting in double covalent or triple covalent bonds.
   b. Nonpolar molecules share their electrons evenly between two atoms.
   c. In polar molecules, electrons spend more time around one atom thus providing that atom with a partial negative charge, while the other atom takes on a partial positive charge.
   d. A polar molecule is often referred to as a dipole due to the two poles of charges contained in the molecule.
3. Hydrogen bonds are weak attractions that form between partially charged atoms found in polar molecules.
   a. Surface tension is due to hydrogen bonds between water molecules.
   b. Intramolecular bonds may form between partially charged atoms in a large molecule and are important in maintaining the shape of that molecule.

V. Chemical Reactions (pp. 35–38; Fig. 2.11)

A. Chemical Equations (pp. 35–36)

1. Chemical reactions occur whenever bonds are formed, rearranged, or broken.

2. Chemical Equations

a. A chemical equation describes what happens in a reaction.

b. Chemical reactions denote the kinds and number of reacting substances, called reactants; the chemical composition of the products; and the relative proportion of each reactant and product, if balanced.

B. Patterns of Chemical Reactions (pp. 36–37; Fig. 2.11)

1. In a synthesis (combination) reaction, larger molecules are formed from smaller molecules.

2. In a decomposition reaction a molecule is broken down into smaller molecules.

3. Exchange (displacement) reactions involve both synthesis and decomposition reactions.

4. Oxidation-reduction reactions are special exchange reactions in which electrons are exchanged between reactants.

C. Energy Flow in Chemical Reactions (p. 37)

1. Exergonic reactions release energy as a product, while endergonic reactions absorb energy.

D. Reversibility of Chemical Reactions (p. 37)

1. All chemical reactions are theoretically reversible.

2. When the rate of the forward reaction equals the rate of the reverse reaction, the reactions have reached a chemical equilibrium.

E. Factors Influencing the Rate of Chemical Reactions (pp. 37–38)

1. Chemicals react when they collide with enough force to overcome the repulsion by their electrons.

2. An increase in temperature increases the rate of a chemical reaction.

3. Smaller particle size results in a faster rate of reaction.

4. Higher concentration of reactants results in a faster rate of reaction.

5. Catalysts increase the rate of a chemical reaction without taking part in the reaction.

Part 2: Biochemistry

VI. Inorganic Compounds (pp. 38–41; Figs. 2.12–2.13)

A. Water (pp. 38–39)

1. Water is the most important inorganic molecule, and makes up 60–80% of the volume of most living cells.

2. Water has a high heat capacity, meaning that it absorbs and releases a great deal of heat before it changes temperature.

3. Water has a high heat of vaporization, meaning that it takes a great deal of energy (heat) to break the bonds between water molecules.

4. Water is a polar molecule and is called the universal solvent.

5. Water is an important reactant in many chemical reactions.

6. Water forms a protective cushion around organs of the body.

B. Salts (p. 39; Fig. 2.12)

1. Salts are ionic compounds containing cations other than H^+ and anions other than the hydroxyl (OH^-) ion.

2. When salts are dissolved in water they dissociate into their component ions.

C. Acids and Bases (pp. 39–41; Fig. 2.13)

1. Acids are also known as proton donors and dissociate in water to yield hydrogen ions and anions.

2. Bases are also called proton acceptors and absorb hydrogen ions.

3. The relative concentration of hydrogen ions is measured in concentration units called pH units.

a. The greater the concentration of hydrogen ions in a solution, the more acidic the solution is.

b. The greater the concentration of hydroxyl ions, the more basic, or alkaline, the solution is.

c. The pH scale extends from 0–14. A pH of 7 is neutral; a pH below 7 is acidic; a pH above 7 is basic or alkaline.

4. Neutralization occurs when an acid and a base are mixed together. They react with each other in displacement reactions to form a salt and water.

5. Buffers resist large fluctuations in pH that would be damaging to living tissues.

VII. Organic Compounds (pp. 41–56; Figs. 2.14–2.24; Tables 2.2–2.4)

A. Carbohydrates, lipids, proteins, and nucleic acids are molecules unique to living systems, and all contain carbon, making them organic compounds (pp. 41–43).

B. Carbohydrates (p. 43; Fig. 2.15)

1. Carbohydrates are a group of molecules including sugars and starches.

2. Carbohydrates contain carbon, hydrogen, and oxygen.

3. The major function of carbohydrates in the body is to provide cellular fuel.

4. Monosaccharides are simple sugars that are single-chain or single-ring structures.

5. Disaccharides are formed when two monosaccharides are joined by dehydration synthesis.

6. Polysaccharides are long chains of monosaccharides linked together by dehydration synthesis.

C. Lipids (pp. 43–47; Fig. 2.16; Table 2.2)

1. Lipids are insoluble in water, but dissolve readily in nonpolar solvents.

2. Triglycerides (neutral fats) are commonly known as fats when solid and oils when liquid.

3. Phospholipids are diglycerides with a phosphorus-containing group and two fatty acid chains.

4. Steroids are flat molecules made up of four interlocking hydrocarbon rings.

5. Eicosanoids are a group of diverse lipids derived from arachidonic acid.

D. Proteins (pp. 47–53; Figs. 2.17–2.21; Table 2.3)

1. Proteins compose 10–30% of cell mass.

a. They are the basic structural material of the body.

b. They also play vital roles in cell function.

2. Proteins are long chains of amino acids connected by peptide bonds.
3. Proteins can be described in terms of four structural levels.
   a. The linear sequence of amino acids is the primary structure.
   b. Proteins twist and turn on themselves to form a more complex secondary structure.
   c. A more complex structure is tertiary structure, resulting from protein folding upon itself to form a ball-like structure.
   d. Quaternary structure results from two or more polypeptide chains grouped together to form a complex protein.
4. Fibrous and Globular Proteins
   a. Fibrous proteins are extended and strandlike. They are known as structural proteins and most have only secondary structure.
   b. Globular proteins are compact, spherical structures. They are water-soluble, chemically active molecules and play an important role in vital body functions.
   c. Fibrous proteins are stable, but globular proteins are susceptible to denaturing, losing their shape due to breaking of their hydrogen bonds.
5. Protein denaturation is a loss of the specific three-dimensional structure of a protein. It may occur when globular proteins are subjected to a variety of chemical and physical changes in their environment.
6. Molecular chaperones, or chaperonins, are a type of globular protein that help proteins achieve their three-dimensional shape.
7. Enzymes and Enzyme Activity
   a. Enzymes are globular proteins that act as biological catalysts.
   b. Enzymes may be purely protein or may consist of two parts that are collectively called a holoenzyme.
   c. Each enzyme is chemically specific.
   d. Enzymes work by lowering the activation energy of a reaction.

E. Nucleic Acids (DNA and RNA) (pp. 53–55; Fig. 2.22; Table 2.4)

1. Nucleic acids composed of carbon, oxygen, hydrogen, nitrogen, and phosphorus are the largest molecules in the body.
2. Nucleotides are the structural units of nucleic acids.
3. Each nucleotide consists of three components: a pentose sugar, a phosphate group, and a nitrogen-containing base.
4. There are five nitrogenous bases used in nucleic acids: Adenine (A), Guanine (G), Cytosine (C), Uracil (U), and Thymine (T).
5. DNA, or Deoxyribonucleic Acid
   a. DNA is the genetic material of the cell and is found within the nucleus.
   b. DNA replicates itself before cell division and provides instructions for making all of the proteins found in the body.
   c. The structure of DNA is a double-stranded polymer containing the nitrogenous bases A, T, G, and C, and the sugar deoxyribose.
   d. Bonding of the nitrogenous bases in DNA is very specific; A bonds to T, and G bonds to C.
   e. The bases that always bind together are known as complementary bases.

6. RNA, or Ribonucleic Acid
   a. RNA is located outside the nucleus and is used to make proteins using the instructions provided by the DNA.
   b. The structure of RNA is a single-stranded polymer containing the nitrogenous bases A, G, C, and U, and the sugar ribose.
   c. In RNA, G bonds with C, and A bonds with U.

F. Adenosine Triphosphate (ATP) (pp. 55–56; Figs. 2.23–2.24)

1. ATP is the energy currency used by the cell.
2. ATP is an adenine-containing RNA nucleotide that has two additional phosphate groups attached.
3. The additional phosphate groups are connected by high-energy bonds.
4. Breaking the high-energy bonds releases energy the cell can use to do work.

Bozeman Biology
Biological Molecules video
http://bit.ly/QEZZg0

1. Where can we find DNA? _____
2. Four categories of four macro molecules are
   i. _____
   ii. _____
   iii. _____
   iv. _____

3. What is a monomer?

_____
__

4. What is unique about lipids?

_____
__

5. What are the main functions of lipids?

_____
__
_____
__

6. Lipids are polar? T/F

7. Nucleic acid monomers are -> _____and are made up of _____.

8. Functions of nucleic acids are-

_____
_____
____

9. Proteins monomers are

_____

10. What differentiates one amino acid from another?

_____

_____

11. Carbohydrate monomers are _____

12. What helps make different types of carbohydrates?

_____

_____

_____

13. What are generic functions of each?

_____

_____

_____

14. What is the significance of directionality of the monomers in a polymer?

_____

_____

_____

15. The process of "putting monomers together" is called

_____

_____

_____

16. Draw an example of this process

17. What is lost during the process?

_____

_____

18 What kind of bond is formed? Is it a strong or weak bond?

_____

_____

_____

_____

19 Can this process be used in the creation of other polymers?

_____

_____

20 How can we break these apart?

_____

_____

21. What is the name of the process?

_____

_____

Nucleic Acids:

22. The two different types of Nucleic acids are

i. _____

ii. _____

23. What is a nucleotide? and what are the three parts of a nucleotide?

_____

_____

i. _____
ii. _____
iii. _____

24. What are the differences between a DNA nucleotide and an RNA nucleotide?

_____

_____

_____

_____

25. How are these nucleotides arranged in the DNA/ RNA strand?

_____

_____

26. What are the four nucleotides in DNA?

i. _____
ii. _____
iii._____
iv._____

27 What are the four nucleotides in RNA?

i. _____
ii. _____
iii._____
iv._____

28. Draw a diagram to demonstrate how the directionality of the DNA/RNA molecule is determined.

29. What does the 3' and 5' stand for?

_____

_____

30 What makes DNA anti parallel?

_____

_____

Proteins:

31. Proteins monomer is _____

32. How many amino acids are there and how do we get them?

_____

_____

33. Draw a basic amino acid.

34. What part of the amino acid makes it different? Label it in your diagram above.

_____

_____

_____

_____

35. What gives the structure to proteins?

_____

36. What is the directionality of a protein?

_____

_____

37. What is the significance of the directionality of proteins?

_____

_____

Lipids:

38. Lipids have different types
    1. _____
    2. _____
    3. _____
    4. _____

39. What are the common factors between the different lipids?

_____

_____

40. What is significant about hydrocarbons found in lipids?

_____

41. What is unique about phospholipids?

42. What does amphipathic mean?

43. What is the difference between saturated and unsaturated fatty acids?

44. Why do unsat fats bend?

45. Why is margarine solid?

46. Is butter saturated or unsaturated? Solid? or liquid?

<u>Carbohydrates</u>:

47. Carbohydrates monomers?

48. What are the two categories of carbohydrates?

49. What are the different types of glucose?

50. What are the differences between amylose and glycogen?

Human Anatomy & Physiology, 9e **(Marieb/Hoehn)**
Chapter 2 Chemistry Comes Alive

2.1 Matching Questions

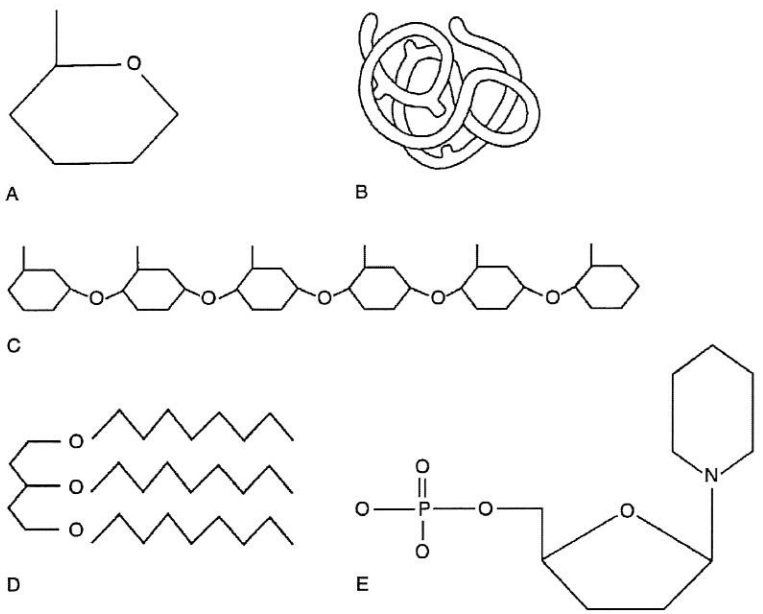

Figure 2.1

Using Figure 2.1, match the following:

1) Lipid

2) Functional protein

3) Nucleotide

4) Polysaccharide.

5) Monosaccharide

6) Polymer

7) Tertiary (protein) structure

2.2 True/False Questions

2) It is the difference in the R group that makes each amino acid chemically unique.

6) About 60% to 80% of the volume of most living cells consists of organic compounds.

7) Lipids are a poor source of stored energy.

8) Current information suggests that omega-3 fatty acids decrease the risk of heart disease.

9) Glucose is an example of a monosaccharide.

10) Glycogen, the storage form of glucose, is primarily stored in muscle tissue only.

11) The lower the pH, the higher the hydrogen ion concentration.

17) All organic compounds contain carbon.

18) A dipeptide can be broken into two amino acids by dehydration synthesis.

19) The pH of body fluids must remain fairly constant for the body to maintain homeostasis.

21) Buffers resist abrupt and large changes in the pH of the body by releasing or binding ions.

2.3 Multiple-Choice Questions

1) Which of the following elements is necessary for proper conduction of nervous impulses?
A) Fe
B) I
C) P
D) Na

2) The basic structural material of the body consists of _____.
A) Carbohydrates
B) Lipids.
C) Proteins.
D) Nucleic acids.

3) In general, the lipids that we refer to as oils have _____.
A) a high water content
B) long fatty acid chains
C) a high degree of saturated bonds
D) a high degree of unsaturated bonds

4) The genetic information is coded in DNA by the _____.
A) regular alteration of sugar and phosphate molecules
B) sequence of the nucleotides
C) three-dimensional structure of the double helix
D) arrangement of the histones

5) Which of the following is not true of proteins?
A) They may be denatured or coagulated by heat or acidity.
B) They have both functional and structural roles in the body..
C) They appear to be the molecular carriers of coded hereditary information.
D) Their function depends on their three-dimensional shape.

6) The single most abundant protein in the body is _____.
A) DNA
B) hemoglobin
C) collagen
D) glucose

7) Carbohydrates are stored in the liver and muscles in the form of _____.
A) glucose
B) triglycerides
C) glycogen
D) cholesterol

8) Which of the following does NOT describe enzymes?
A) Some enzymes are purely protein.
B) Some enzymes are protein plus a cofactor.
C) Each enzyme is chemically specific.
D) Enzymes work by raising the energy of activation.

14) Which of the following is the major positive ion outside cells?
A) magnesium
B) hydrogen
C) potassium
D) sodium

16) What is a chain of more than 50 amino acids called?
A) polypeptide
B) polysaccharide
C) protein
D) nucleic acid

17) What level of protein synthesis is represented by the coiling of the protein chain backbone into an alpha helix?
A) primary structure
B) secondary structure
C) tertiary structure
D) quaternary structure

18) Carbohydrates and proteins are built up from their basic building blocks by the _____.
A) addition of a water molecule between each two units
B) addition of a carbon atom between each two units
C) removal of a water molecule between each two units
D) removal of a carbon atom between each two units

25) Which of the following does not describe uses for the ATP molecule?
A) chemical work
B) mechanical work
C) transport across membranes
D) pigment structure

29) The four elements that make up about 96% of body matter are _____.
A) carbon, oxygen, phosphorus, calcium
B) nitrogen, hydrogen, calcium, sodium
C) carbon, oxygen, hydrogen, nitrogen
D) sodium, potassium, hydrogen, oxygen

30) _____ is fat soluble, produced in the skin on exposure to UV radiation, and necessary for normal bone growth and function.
A) Vitamin K
B) Cortisol
C) Vitamin A
D) Vitamin D

41) Amino acids joining together to make a peptide is a good example of a(n) _____ reaction.
A) synthesis
B) decomposition
C) exchange
D) reversible

43) Which property of water is demonstrated when we sweat?
A) high heat capacity
B) high heat of vaporization
C) polar solvent properties
D) reactivity
E) cushioning

44) Sucrose is a _____.
A) monosaccharide
B) disaccharide
C) polysaccharide
D) triglyceride

2.4 Fill-in-the-Blank/Short Answer Questions

5) _____ have a bitter taste, feel slippery, and are proton acceptors.

8) The _____ molecule directly provides energy for cellular work.

11) Starch is the stored carbohydrate in plants, while _____ is the stored carbohydrate in animals.

16) What happens when globular proteins are denatured?

19) What properties does water have that make it a very versatile fluid?

2.5 Clinical Questions
1) Mrs. Mulligan goes to her dentist and, after having a couple of cavities filled, her dentist strongly suggests that she reduce her intake of sodas and increase her intake of calcium phosphates in the foods she eats. Why?

5) A 65-year-old patient came to the emergency room with complaints of severe heartburn unrelieved by taking a "large handful" of antacids. Would you expect the pH to be high or low? Explain why.

6) A 23-year-old male was riding his road bike in 100-degree heat, when he suddenly became nauseated and weak. He called 911 from his cell phone. When the ambulance came, the paramedics started intravenous therapy for severe dehydration. Explain the critical role of water to maintain homeostasis.

CHAPTER

3 Cells: The Living Units

Objectives

The Cellular Basis of Life

1. Define cell.
2. List the three major regions of a generalized cell and their functions.

The Plasma Membrane: Structure

3. Describe the chemical composition of the plasma membrane and relate it to membrane functions.
4. Compare the structure and function of tight junctions, desmosomes, and gap junctions.

The Plasma Membrane: Membrane Transport

5. Relate plasma membrane structure to active and passive transport processes.
6. Compare and contrast simple diffusion, facilitated diffusion, and osmosis relative to substances transported, direction, and mechanism.
7. Differentiate between primary and secondary active transport.
8. Compare and contrast endocytosis and exocytosis in terms of function and direction.
9. Compare and contrast pinocytosis, phagocytosis, and receptor-mediated endocytosis.

The Plasma Membrane: Generation of a Resting Membrane Potential

10. Define membrane potential and explain how the resting membrane potential is established and maintained.

The Plasma Membrane: Cell-Environment Interactions

11. Describe the role of the glycocalyx when cells interact with their environment.
12. List several roles of membrane receptors and that of voltage-gated membrane channel proteins.

The Cytoplasm

13. Describe the composition of the cytosol.
14. Discuss the structure and function of mitochondria.
15. Discuss the structure and function of ribosomes, the endoplasmic reticulum, and the Golgi apparatus, including functional interrelationships among these organelles.
16. Compare the functions of lysosomes and peroxisomes.
17. Name and describe the structure and function of cytoskeletal elements.

18. Describe the roles of centrioles in cell division and in formation of cilia and flagella.
19. Describe how the two main types of cell extensions, cilia and microvilli, differ in structure and function.

The Nucleus

20. Outline the structure and function of the nuclear envelope, nucleolus, and chromatin.

Cell Growth and Reproduction

21. List the phases of the cell cycle and describe the key events of each phase.
22. Describe the process of DNA replication.
23. Define gene and genetic code and explain the function of genes.
24. Name the two phases of protein synthesis and describe the roles of DNA, mRNA, tRNA, and rRNA in each phase.
25. Contrast triplets, codons, and anticodons.
26. Define autophagy and indicate its major cellular function.
27. Describe the importance of ubiquitin-dependent degradation of soluble proteins.

Extracellular Materials

28. Name and describe the composition of extracellular materials.

Developmental Aspects of Cells

29. Discuss some theories of cell differentiation and aging.
30. Indicate the value of apoptosis to the body.

Suggested Lecture Outline

I. The Cellular Basis of Life (p. 62; Figs. 3.1–3.2)

A. The four concepts of the cell theory state (p. 62; Figs. 3.1–3.2):

1. Cells are the basic structural and functional units of life.
2. The activity of an organism depends on the activities of its cells.
3. The biochemical activities of a cell are dictated by their sub-cellular structures.
4. The continuity of life has a cellular basis.

B. Cells have several basic characteristics (p. 62; Figs. 3.1–3.2):

1. Cells vary greatly in their size, shape, and function.
2. All cells are composed primarily of carbon, hydrogen, nitrogen, and oxygen.
3. All cells have the same basic parts and some common functions.
4. A generalized human cell contains the plasma membrane, the cytoplasm, and the nucleus.

II. The Plasma Membrane: Structure (pp. 63–67; Figs. 3.3–3.5)

A. The Fluid Mosaic Model (pp. 63–65; Figs. 3.3–3.4)

1. The plasma membrane is composed of a double layer of lipid molecules, in which proteins are embedded.

2. The lipid bilayer is composed of two layers of phospholipids with small amounts of glycolipids, cholesterol, and lipid rafts.

a. Phospholipid heads are hydrophilic and line up to face the inner and outer surfaces of the membrane.

b. Phopholipid tails are hydrophobic and line up facing each other in the interior of the bilayer.

c. Lipid rafts make up about 20% of the membrane and serve as platforms for receptors.

3. There are two distinct populations of membrane proteins:

a. Integral proteins are transmembrane proteins that span the entire width of the membrane and are involved with transport as channels or carriers.

b. Peripheral proteins are not embedded in the plasma membrane, but attach to integral proteins or to phospholipids, and may function as enzymes or in mechanical functions of the cell.

B. The glycocalyx is the fuzzy, sticky, carbohydrate-rich area at a cell's surface that acts as a biological marker allowing cells to identify each other (pp. 65–66).

C. Cell Junctions (pp. 66–67; Fig. 3.5)

1. Most body cells are bound together using glycoproteins, specialized interlocking regions, or specialized cell junctions.

2. Tight junctions are integral proteins between adjacent cells, forming an impermeable junction that prevents molecules from passing through the extracellular space between cells.

3. Desmosomes are mechanical couplings that are scattered along the sides of adjoining cells that prevent their separation and reduce the chance of tearing when a tissue is stressed.

4. Gap junctions are hollow cylinders of protein between cells that allow selected small molecules to pass between adjacent cells.

a. Gap junctions are often used in the conduction of action potentials between cells.

III. The Plasma Membrane: Membrane Transport (pp. 67–79; Figs. 3.6–3.14; Tables 3.1–3.2)

A. The cell membrane is selectively permeable: it allows nutrients to enter the cell and waste to leave, but restricts movement of other substances in or out of the cell (p. 68).

B. Passive processes do not use energy (ATP) to move substances down their concentration gradient (pp. 68–72; Figs. 3.7–3.9; Table 3.1).

1. Diffusion is the movement of molecules down their concentration gradient. The rate of diffusion is influenced by the size of the molecule and the temperature.

2. Simple diffusion is diffusion through the plasma membrane, without using a channel or carrier, and is restricted to the movement of very small molecules, or lipids.

3. In facilitated diffusion, sugars, amino acids, or ions are moved through the plasma membrane by binding to protein carriers in the membrane or by moving through channels.
4. Osmosis is the diffusion of water through a selectively permeable membrane.
   a. Water will move into areas where the osmolarity, the total concentration of particles in solution, is greater.
   b. A solution that has a solute concentration equal to cellular fluid is an isotonic solution, and cells show no net gain or loss of water if exposed to this type of solution.
   c. Solutions may be more concentrated than cellular fluid (hypertonic) or less concentrated than cellular fluid (hypotonic): a cell will have a net gain of water if exposed to a hypotonic solution or a net loss of water if exposed to a hypertonic solution.

C. Active transport processes use energy contained in ATP to move substances across a membrane (pp. 72–79; Figs. 3.10–3.14; Table 3.2).
1. Both primary active transport and secondary active transport uses solute pumps to move substances against a concentration gradient.
   a. In primary active transport, energy used to transport molecules is directly from ATP.
   b. In secondary active transport, energy used to transport molecules is from energy stored in ionic gradients created by primary active transport.
2. Vesicular transport uses membranous sacs, called vesicles, to transport large particles, macromolecules, and fluids across the plasma membrane, or within the cell.
3. Endocytosis, transcytosis, and vesicular trafficking are receptor-mediated vesicular transport processes that move molecules into the cell.
   a. Phagocytosis is an endocytotic process in which large, solid materials are brought into the cell.
   b. Pinocytosis is an endocytotic process aimed at taking a small volume of extracellular fluid with dissolved solutes into the cell.
4. Exocytosis is a type of vesicular transport in which substances from inside the cell are moved to the extracellular environment.

IV. The Plasma Membrane: Generation of a Resting Membrane Potential (pp. 79–80; Fig. 3.15)

A. A membrane potential is a voltage across the cell membrane that occurs due to a separation of oppositely charged particles (ions) (p. 79).

B. The resting membrane potential is a condition in which the inside of the cell membrane is negatively charged compared with the outside, and ranges in voltage from –5 to –100 millivolts (pp. 79–80; Fig. 3.15).
1. The resting membrane potential is determined mainly by the concentration gradient of potassium (K^+).
2. Active transport pumps ensure that passive ion movement does not lead to an electrochemical equilibrium across the membrane, thus maintaining the resting membrane potential.

V. The Plasma Membrane: Cell-Environment Interactions (pp. 80–81; Fig. 3.16)

A. Cells can interact directly with other cells, respond to extracellular chemicals, and interact with molecules that direct migration (p. 80).

B. Roles of Cell Adhesion Molecules (CAMs) (p. 80)

1. Cell adhesion molecules (CAMs) are glycoproteins that act as attachment sites or signals during embryonic development, wound repair, and immunity.

C. Roles of Plasma Membrane Receptors (p. 81; Fig. 3.16)

1. Contact signaling involves touch between membrane receptors of neighboring cells to facilitate recognition between cells.

2. Chemical signaling involves the binding of a chemical signal to a membrane receptor, resulting in the initiation of cellular responses.

D. Role of Voltage-Gated Membrane Channel Proteins: Electrical Signaling (p. 81)

1. In excitable tissues, such as neurons or muscle cells, certain ion channels in the cell membrane open or close in response to a change in membrane potential, allowing electrical signaling between cells.

VI. The Cytoplasm (pp. 81–91; Figs. 3.17–3.28; Table 3.3)

A. The cytoplasm is the cellular material between the cell membrane and the nucleus and is the site of most cellular activity (p. 81).

1. There are three major elements of the cytoplasm: cytosol, cytoplasmic organelles, and cytoplasmic inclusions.

B. Cytoplasmic Organelles (pp. 83–91; Figs. 3.17–3.28; Table 3.3)

1. Mitochondria are membranous organelles that produce most of the ATP for a cell, by breaking down food molecules and transferring the energy to the bonds of ATP.

2. Ribosomes are small, dark-staining granules consisting of protein and ribosomal RNA that are the site of protein synthesis.

3. The endoplasmic reticulum is an extensive system of tubes and membranes enclosing fluid-filled cavities, called cisterns, which extend throughout the cytosol.

a. The rough endoplasmic reticulum has ribosomes that manufacture all proteins that are secreted from cells.

b. Smooth ER is a continuation of rough ER, consisting of a looping network of tubules. Its enzymes catalyze reactions involved in lipid and glycogen metabolism, as well as performing detoxification processes.

4. The Golgi apparatus is a series of stacked, flattened, membranous sacs associated with groups of membranous vesicles.

a. The main function of the Golgi apparatus is to modify, concentrate, and package the proteins and lipids made at the rough ER.

b. The Golgi apparatus creates vesicles containing lipids and transmembrane proteins for incorporation into the cell membrane.

c. The Golgi apparatus packages digestive enzymes into lysosomes.

5. Lysosomes are spherical membranous organelles that contain digestive enzymes.

a. Lysosomes digest particles taken in by endocytosis, degrade worn-out organelles or nonuseful tissues, and perform glycogen breakdown and release.

6. Peroxisomes are membranous sacs containing enzymes, such as oxidases and catalases, which are used to detoxify harmful substances such as alcohol, formaldehyde, and free radicals.

7. The endomembrane system functions together to produce, store, and export biological molecules, as well as degrade potentially harmful substances.

8. The cytoskeleton is a series of rods running through the cytosol, supporting cellular structures and aiding in cell movement.
   a. There are three types of rods in the cytoskeleton: microtubules, microfilaments, and intermediate filaments.
9. Centrosome and Centrioles
   a. The centrosome is a region near the nucleus that functions to organize microtubules and organize the mitotic spindle during cell division.
   b. Centrioles are small, barrel-shaped organelles associated with the centrosome and form the bases of cilia and flagella.
10. Cellular Extensions
   a. Cilia are whiplike, motile cellular extensions on the exposed surfaces of some cells.
   b. Flagella are long cellular projections that move the cell through the environment.
   c. Microvilli are fingerlike extensions of the plasma membrane that increase surface area.

VII. The Nucleus (pp. 91–96; Figs. 3.29–3.30)

A. Basic Characteristics (p. 91; Fig. 3.29)

1. The nucleus contains the cellular DNA and determines the kinds and amounts of proteins to be synthesized within a cell.
2. All body cells except mature red blood cells have nuclei, and most cells have only one nucleus, although very large cells may be multinucleate.
3. The nucleus has three regions: the nuclear envelope, nucleoli, and chromatin.

B. The Nuclear Envelope (pp. 92–93)

1. The nuclear envelope is a double-membrane barrier surrounding the nucleus.
   a. The outer membrane is continuous with the rough ER, while the inner membrane is lined with a shape-maintaining network of protein filaments, the nuclear laminae.
   b. At various points, nuclear pores penetrate areas where the membranes of the nuclear envelope fuse and regulate passage of large particles into and out of the nucleus.
2. The nuclear envelope encloses the fluid and solutes of the nucleus, the nucleoplasm.

C. Nucleoli (p. 93)

1. Nucleoli are dark-staining spherical bodies within the nucleus that are the sites of assembly of ribosomal subunits, and are large in actively growing cells.

D. Chromatin (pp. 93–96; Fig. 3.30)

1. Chromatin is 30% DNA, the genetic material of the cell, 60% histone proteins, and 10% RNA chains.
2. Nucleosomes are the fundamental unit of chromatin, consisting of clusters of eight histone proteins connected by a DNA molecule.
3. When a cell is preparing to divide, chromatin condenses into dense, rodlike chromosomes.

VIII. Cell Growth and Reproduction (pp. 96–110; Figs. 3.31–3.40)

A. The Cell Cycle (pp. 96–99; Figs. 3.31–3.33)

1. The cell cycle is a series of changes a cell goes through from the time it is formed to the time it reproduces.

2. Interphase and cell division are the two main periods of the cell cycle.
3. Interphase is the period from cell formation to cell division and has three subphases.
   a. During the G_1, or gap 1, subphase, the cell is synthesizing proteins and actively growing.
   b. During the S phase, DNA is replicated.
   c. During the G_2, or gap 2, subphase, enzymes and other proteins are synthesized and distributed throughout the cell.
   d. DNA replication takes place when the DNA helix uncoils, and the hydrogen bonds between its base pairs are broken. Then, each nucleotide strand of the DNA acts as a template for the construction of a complementary nucleotide strand.
4. Cell division is a process necessary for growth and tissue repair. There are three main events of cell division.
   a. Mitosis is the process of nuclear division in which cells contain all genes.
   b. Cytokinesis is the process of dividing the cytoplasm.
   c. Control of cell division depends on surface-volume relationships, chemical signaling, and contact inhibition.

B. Protein Synthesis (pp. 99–105; Figs. 3.34–3.40)

1. DNA specifies the structure of protein molecules that act as structural or functional molecules.
2. Proteins are composed of polypeptide chains made up of amino acids.
3. Each gene is a segment of DNA that carries instructions for one polypetide chain.
4. There are four nucleotide bases, A, G, T, and C, that compose DNA, and each sequence of three nucleotide bases of DNA is called a triplet.
   a. Each triplet specifies a particular amino acid in the sequence of amino acids that makes up a protein.
5. The Role of RNA
   a. RNA exists in three forms that decode and carry out the instructions of DNA in protein synthesis: transfer RNA (tRNA), ribosomal RNA (rRNA), and messenger RNA (mRNA).
   b. All three types of RNA are constructed on the DNA in the nucleus, then released from the DNA to migrate to the cytoplasm while the DNA recoils to its original form.
6. There are two main steps of protein synthesis: transcription and translation.
   a. Transcription is the process of transferring information from a gene's base sequence to a complementary mRNA molecule.
      i. To make the mRNA complement, the transcription factor mediates binding of RNA polymerase, an enzyme that directs the synthesis of mRNA.
      ii. The mRNA that initially results from transcription, called primary transcript, contains introns that must be removed.
   b. Translation is the process of converting the language of nucleic acids (nucleotides) to the language of proteins (amino acids).

C. Other Roles of DNA (pp. 105, 109)

1. DNA introns code for a variety of RNAs.
   a. Antisense RNAs, made from the complementary DNA strand, can prevent mRNA from being translated.

b. Small RNAs, called microRNAs, can suppress some mRNAs.

c. Folded RNAs, called riboswitches, can turn their own protein synthesis on or off in response to environmental changes.

D. Degradation of Organelles and Cytosolic Proteins (pp. 109–110)

1. Autophagy is the process of degrading malfunctioning or obsolete organelles, to prevent excessive accumulation of these structures.

2. Proteins called ubiquitins attach to and mark unneeded proteins for degradation and recycling, to prevent excess accumulation of protein in the cell.

IX. Extracellular Materials (p. 110)

A. Extracellular materials are substances contributing to body mass that are found outside the cells (p. 110).

B. There are three classes of extracellular materials (p. 110):

1. Body fluids, consisting mainly of interstitial fluid, blood plasma, and cerebrospinal fluid, are important for transport and solute dissolution.

2. Cellular secretions including substances aiding in digestion or functioning as lubrication.

3. Extracellular matrix, a jellylike substance secreted by cells consisting of proteins and polysaccharides.

X. Developmental Aspects of Cells (pp. 110–111)

A. Embryonic cells are exposed to different chemical signals that cause them to follow different pathways in development (p. 110).

1. Chemical signals influence development by switching genes on and off.

2. Cell differentiation is the process of cells developing specific and distinctive features.

B. Apoptosis and Modified Rates of Cell Division (p. 110)

1. Apoptosis is the programmed cell death of stressed, unneeded, injured, or aged cells.

a. In response to cellular damage or some extracellular signal, chemicals are released to activate intracellular enzymes that digest cellular structures, killing the cell.

2. Most organ systems are well-formed and functional before birth, but the body continues to form new cells throughout childhood and adolescence.

3. During adulthood, cell division mostly serves to replace cells and repair wounds.

C. Cell Aging (p. 111)

1. The wear and tear theory considers the cumulative effect of slight chemical damage and the production of free radicals.

2. Cell aging may also be a result of autoimmune responses and progressive weakening of the immune response.

3. The genetic theory of cell aging suggests that cessation of mitosis and cell aging are genetically programmed.

Bozeman Science
A Tour of the Cell
http://www.bozemanscience.com/a-tour-of-the-cell

1. Why are cells so small?

2. How does Mr. Anderson describe the inner cell?

3. What allowed scientist to discover the cell?

4. The two major types of cells are _____ and _____.
    a. Describe prokaryotes:

    b. Describe eukaryotes:

5. All cells have:
    a.
    b.
    c.

The following is a table of the organelles described as the major organelles of eukaryotic cells. Use this table to fill in the descriptions during the video.

Organelle	Description	Function
Nucleolus		

Nucleus		
Ribosome		
Vesicle		
Rough ER		
Golgi		
Cytoskeleton		
Smooth ER		

Mitochrondria		
Vacuole		
Cytosol		
Lysosome		
Centriole		

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3.1 Matching Questions

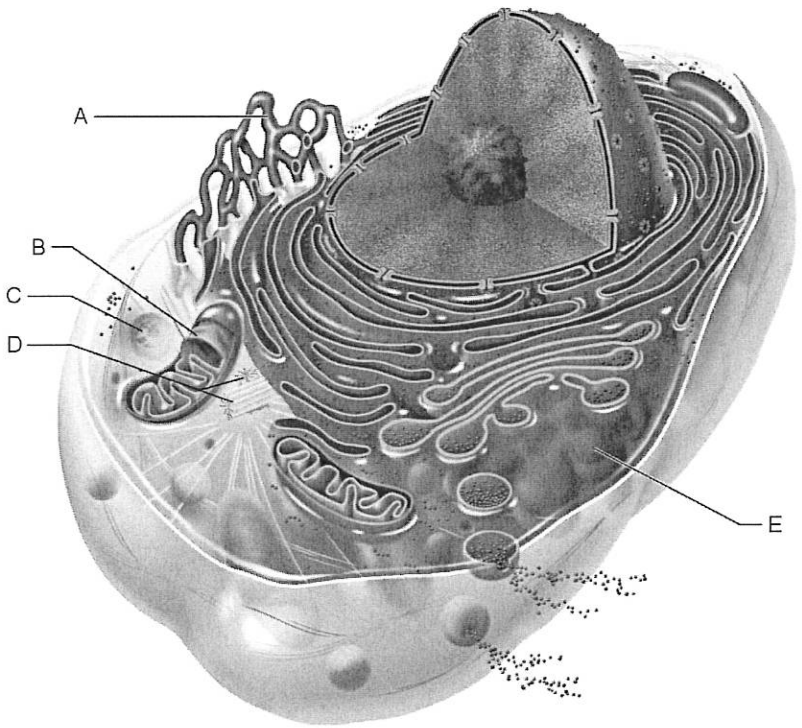

Figure 3.1

Using Figure 3.1, match the following:

1) Produces ATP aerobically.

2) Site of enzymatic breakdown of phagocytized material.

3) Packages proteins for insertion in the cell membrane or for exocytosis.

4) Site of synthesis of lipid and steroid molecules.

5) Forms the mitotic spindle.

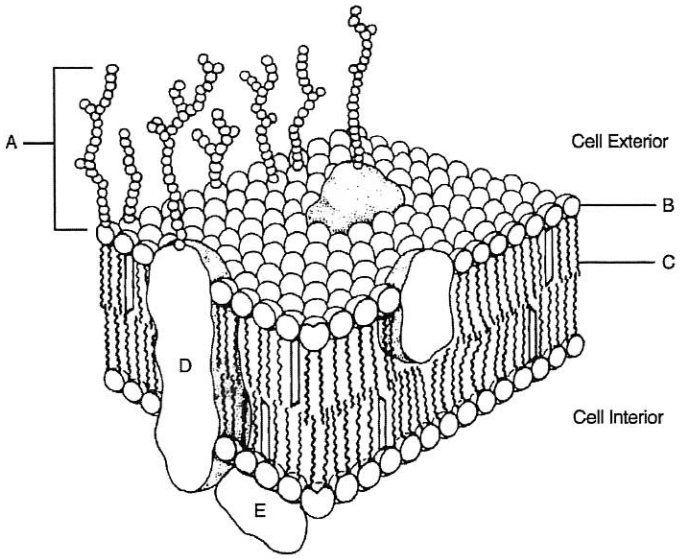

Figure 3.2

Using Figure 3.2, match the following:

8) Nonpolar region of phospholipid.

9) Glycocalyx.

10) Polar region of phospholipid.

11) Peripheral protein.

12) Integral protein.

13) Identification "tags" for the cell.

14) Hydrophilic portion of phospholipid.

Match the following:

A) Nucleus
B) Microtubules
C) Endoplasmic reticulum
D) Ribosomes
E) Nucleoli

26) Plays a role in the synthesis of steroid-based hormones and proteins.

27) The actual site of protein synthesis.

28) Hollow cytoskeletal elements that act as organizers for the cytoskeleton.

29) Dense spherical bodies in the nucleus that are the synthesis site for ribosomal RNA.

30) Houses DNA and RNA.

Match the following:

A) Gap junctions
B) Desmosomes
C) Tight junctions

31) Help prevent molecules from passing through the extracellular space between adjacent cells.

32) Type of anchoring junction.

33) Communicating junction.

35) Abundant in tissues subjected to great mechanical stress.

True/False
2) Apoptosis is programmed cell suicide; cancer cells do not undergo this process.

5) Lipid rafts, found in the cell outer membrane surface, are concentrating platforms for certain receptor molecules or for protein molecules needed for cell signaling..

8) A process by which large particles may be taken into the protection of the body by invaders like bacteria, or for disposing of old or dead cells is called phagocytosis.

13) The glycocalyx is often referred to as the "cell coat," which is somewhat fuzzy and sticky with numerous cholesterol chains sticking out from the surface of the cell membrane.

15) Microfilaments are thin strands of the contractile protein myosin.

17) Cholesterol helps to stabilize the cell membrane while decreasing the mobility of the phospholipids.

18) Aquaporins are believed to be present in red blood cells and kidney tubules, but not in any other cells in the body.

19) Most organelles are bounded by a membrane that is quite different in structure from the lipid bilayer of the plasma membrane.

20) There is only one cell type in the human body that has a flagellum.

21) Microtubules are hollow tubes made of subunits of the protein tubulin.

3.3 Multiple-Choice Questions

6) Which of the following describes the plasma membrane?
A) a single-layered membrane that surrounds the nucleus of the cell
B) a double layer of protein enclosing the plasma
C) a phospholipid bilayer surrounding the cell
D) a membrane composed of tiny shelves or cristae

7) Which of these is not a function of the plasma membrane?
A) It is selectively permeable but permits water and gases to cross.
B) It prevents potassium ions from leaking out and sodium ions from crossing into the cell.
C) It acts as a site of cell-to-cell interaction and recognition.
D) It encloses the cell contents in such a way that water I the body is divided into separate compartments.

8) Which structures are fingerlike projections that greatly increase the absorbing surface of cells?
A) stereocilia
B) microvilli
C) primary cilia
D) flagella

10) Which type of cell junction acts as anchors and distributes tension through a cellular sheet and reduces the chance of tearing when it is subjected to great mechanical stress?
A) gap junctions
B) desmosomes
C) connexons
D) tight junctions

15) Which of the following is a function of a plasma membrane protein?
A) circulating antibody
B) molecular transport through the membrane
C) forms a lipid bilayer
D) oxygen transport

17) Which of the following would not be a constituent of a plasma membrane?
A) glycolipids
B) messenger RNA
C) glycoproteins
D) phospholipids

26) Which of the following is NOT a function of the smooth endoplasmic reticulum?
A) lipid metabolism and cholesterol synthesis
B) steroid-based hormone synthesis
C) breakdown of stored glycogen to form free glucose
D) protein synthesis in conjunction with ribosomes

29) Peroxisomes _____.
A) are also called microbodies, and contain acid hydrolases
B) are able to detoxify substances by enzymatic action
C) function to digest particles ingested by endocytosis
D) sometimes function as secretory vesicles

30) Which of the following is NOT a function of lysosomes?
A) digesting particles taken in by endocytosis
B) degrading worn-out or nonfunctional organelles
C) forming acid hydrolases which are necessary to help form cell membranes
D) breaking down bone to release calcium ions into the blood

35) Which of the following is a principle of the fluid mosaic model of cell membrane structure?
A) Phospholipids form a bilayer that is largely impermeable to water-soluble molecules.
B) Phospholipids consist of a polar head and a nonpolar tail made of three fatty acid chains.
C) The lipid bilayer is a solid at body temperature, thus protecting the cell.
D) All proteins associated with the cell membrane are contained in a fluid layer on the outside of the cell.

38) The functions of centrioles include _____.
A) organizing the mitotic spindle in cell division
B) providing a whiplike beating motion to move substances along cell surfaces
C) serving as the site for ribosomal RNA synthesis
D) producing ATP

Fill-in-the-blank

6) _____ are hollow tubes made of spherical protein subunits called tubulins.

7) Aerobic cellular respiration occurs in the _____.

13) Describe two important functions of the Golgi apparatus.

17) Briefly describe the glycocalyx and its functions.

19) Why are free radicals so dangerous to cells, and how are they dealt with by the body?

22) Other than the nucleus, which organelle has its own DNA?

23) How are the products of free ribosomes different from membrane-bound ribosomes?

24) How are peroxisomes different from lysosomes?

3.5 Clinical Questions

4) Your patient has a respiratory disease that has literally paralyzed the cilia. Explain why this patient would be at an increased risk for a respiratory infection.