Anatomy and Physiology An Integrative Approach 4th edition McKinley Solutions Manual

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McKinley/O'Loughlin/Bidle
***Anatomy and Physiology: An Integrative Approach*, 4/e**
Instructor Answer Key to In-chapter and End-of-chapter Questions

Chapter 1
Answers to "What Did You Learn?"

1. Anatomy is the study of structure and form, while physiology is the study of function.

2. If a health-care worker must perform CPR, the worker uses surface anatomy to palpate and locate the xiphoid process of the sternum, and then move the hands slightly superiorly to start CPR chest compressions.

3. Cardiovascular physiology examines how the heart, blood vessels and blood function.

4. Anatomists focus on the form and structure of the small intestine. They examine the cells and tissues that form the small intestine, and describe the layers of the small intestinal wall. Physiologists focus on the function of the small intestine. They examine how the muscle of the smooth intestine propels food through the digestive tract and describe the process by which nutrients are broken down and absorbed. Both anatomists and physiologists know that form and function of the small intestine are interrelated.

5. When you study with a partner, you each can help the other identify gaps in your knowledge, keep study sessions focused and on track, and serve as a sounding board when explaining a concept.

6. The ability of organisms to respond to stimuli such as changes in either their external or internal environment provides them with a mechanism for maintaining a constant internal environment, even as the environment around them changes.

7.

Level of organization	Structural Unit	Example in the body	Simple or complex?
Chemical	Atoms and molecules	DNA	Most simple
Cellular	cell	Skeletal muscle cell	More complex that chemical
Tissue	Tissues	Epithelial tissue	More complex than cellular
Organ	Organ	stomach	More complex than tissue
Organ system	Multiple organs	Digestive system	More complex than organ
Organismal	Organism	Human	Most complex

8. The urinary system is responsible for filtering and removing waste products from the blood.

9. A transverse plane, also called a horizontal or cross-sectional plane, would divide the mouth into superior and inferior sections.

10. Proximal.

11. A student's drawing and labeling should look similar to figure 1.7.

12. The lungs are located within the thoracic cavity. The serous membranes surrounding them consist of the parietal pleura, lining the inside of the body wall, and the visceral pleura, lining the individual lungs.

13. Epigastric

14. A homeostatic system consists of a receptor, such as a sensory neuron in the skin or a stretch receptor within a muscle, that detects either an internal or external stimulus; a control system that integrates the input from the receptor, such as the brain or an endocrine gland; and an effector, such as a muscle or a gland, that causes changes in response to the stimulus.

15. Receptors in the skin, and the hypothalamus, both act as receptors to detect changes in body temperature. (The skin receptors detect skin temperature changes, while the hypothalamus detects temperature changes in the blood). The hypothalamus also acts as the control center, as it signals the effectors to respond to bring the body temperature back to a set point. The effectors are blood vessels, skeletal muscle, and smooth muscle (when the body is trying to conserve heat), whereas the effectors are blood vessels and sweat glands (when the body is trying to release heat).

16. Negative feedback systems involve responses that are in opposition to the stimulus, thereby maintaining the environment near the set point or normal level. Conversely, positive feedback systems entail a series of responses, each increasing in intensity, until a climax event is reached, at which point the system will return to homeostasis.

17. Diabetes, an inability of the body to maintain blood sugar levels, may result in damage to anatomical structures throughout the body due to high levels of glucose.

Answers to "Do You Know the Basics?"

1. B
Feedback: *Surface anatomy* correlates superficial markings on the surface of the body and skin to deeper anatomical features.

2. C
Feedback: *Organs* are often composed of several tissue types working in concert to perform a common function.

3. A
Feedback: An organism's *metabolism* is the sum of all of its biochemical reactions.

4. C
Feedback: A midsagittal or median plane separates the body into equal *right and left halves* as compared to simply a sagittal section, which separates the body into unequal right and left portions. There can be numerous sagittal planes but only one possible midsagittal section along the midline of the body.

5. D
Feedback: The term *proximal* is used to describe the position of a structure on an appendage closest to the point of attachment to the trunk. Although in standard anatomical position a structure that is proximal is often also superior, proximal is the correct term for describing the position along an appendage. The term superior may be used to describe positions along the axis of the body, closer to the head.

6. A
Feedback: The *patellar* region is the anterior portion of the knee. The popliteal region is the posterior portion of the knee.

7. A
Feedback: The diaphragm comprises the barrier between the superior thoracic cavity and the inferior *abdominal cavity*. The pelvic cavity is located inferior to the superior edges of the pelvic bones.

8. D
Feedback: The pleural cavity surrounding the lungs consists of the parietal pleura, lining the internal walls of the thoracic cavity, and the *visceral pleura,* lining the surface of the lungs.

9. B
Feedback: *Homeostasis* is an automated process for maintaining a constant internal environment.

10. D
Feedback: The *effector* increasing the stimulus is an example of positive feedback. In a negative feedback system, the response moves the system in opposition to the stimulus, back toward the set point.

11. Anatomy is the study of structure and form, whereas physiology is the study of how the structures function. It is important to understand the anatomy of a structure in order to understand how it performs its function. Conversely, understanding the function of an anatomical feature helps to put into perspective the significance of its arrangement.

12. The simplest level of organization within an organism is found at the chemical level and is composed of atoms and molecules. At the cellular level of organization, molecules are organized into cells and subcellular components, forming the basic units of life. Groupings of similar cells performing similar functions are referred to as tissues, and groups of tissues may be found working in concert, forming organs at the organ level of organization. Related groups of organs working together in order to coordinate activities within the organism are called organ systems.

13. A hierarchical organization, metabolism, growth and development, responsiveness, regulation, and reproduction are characteristics common to all living organisms. All living things are arranged in a hierarchical manner with increasing levels of complexity from molecules to cells. They are capable of metabolism, growth and development, and responsiveness to stimuli. They are also able to regulate their internal environment in order to maintain homeostasis, ultimately surviving long enough to reproduce.

14. The human body consists of eleven organ systems. They are the integumentary, skeletal, muscular, nervous, endocrine, cardiovascular, lymphatic, respiratory, urinary, digestive, and reproductive systems.

15. A body in anatomical position is standing upright with the feet flat on the floor. The upper limbs are at the side of the body with palms facing anteriorly. The head is level and the eyes are looking forward. The anatomic position is the point of common reference used by anatomists and physiologists for accuracy and clarity. It provides an initial point of reference, from which all anatomic parts are described.

16. The forearm is the antebrachial region, the wrist is the carpal region, the chest is the thoracic region, the armpit is the axillary region, the thigh is the femoral region, and the entire foot is the pes.

17. The cranial cavity and vertebral canal are located within the posterior aspect of the body. The cranial cavity houses the brain and the vertebral canal contains the spinal cord.

18. The serous membranes are found lining the compartments of the ventral cavity of the body. They consist of a parietal layer lining the inside of the body wall and a visceral layer covering internal organs. In between the two membranes is a potential space, the serous cavity, which contains serous fluid.

19. A homeostatic system consists of a receptor that detects an internal or external stimulus, a control system that integrates the input from the receptor, and an effector, such as a muscle or a gland, that causes changes in response to the stimulus.

20. Negative feedback systems involve responses that are in opposition to the stimulus, thereby maintaining the environment near the set point or normal level. Conversely, positive feedback systems entail a series of responses, each increasing in intensity until a climax event is reached, at which point the system will return to homeostasis.

Answers to "Can You Apply What You've Learned?"

1. B
Feedback: The pain is coming from a region below the umbilicus, hence it is in the lower portion of the abdomen and it is located on the right side. It is therefore in the *right lower quadrant*.

2. D
Feedback: The *right iliac region* is located just medial to the pelvic bones.

3. B
Feedback: X-rays are not absorbed by soft tissue such as the appendix. They are usually used to visualize dense structures.

4. B
Feedback: Sweat glands release sweat at the surface of the skin.

5. B
Feedback: Serotonin is a neurotransmitter responsible for regulating both pathways associated with depression in the brain and gastric motility in the stomach. Drugs such as SSRIs are used to treat depression in individuals with low levels of serotonin in the brain by inhibiting its reuptake by neurons. Because the SSRI drugs cannot specifically target the brain, they also have an effect within the digestive system, causing nausea and diarrhea.

Answers to "Can You Synthesize What You've Learned?"

1. Lynn has broken the bones within her forearm, the radius and ulna. She has an abrasion on her chin as well as bruising on her buttocks and thigh.

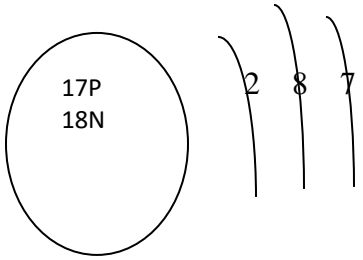
2. The epinephrine counteracted the effect of the bee sting, acting in opposition to the stimulus; it was therefore an example of negative feedback.

3. X-rays and CT scans are optimal for visualizing dense tissues, such as tumors. An MRI or ultrasound would be better suited for examining soft tissues.

Chapter 2
Answers to "What Did You Learn?"

1. The mass of an atom is determined by the combined number of protons and neutrons within its nucleus. The charge of an atom is determined by the number of positively charged protons and negatively charged electrons.

2. The nucleus of a chlorine atom consists of 17 protons and 18 neutrons. The electrons are arranged into three separate shells; the first shell closest to the nucleus contains two electrons, the second shell contains eight electrons, and the third outer shell contains seven electrons, for a total of 17 electrons.



3. Isotopes are atoms of the same element. They only differ in their number of neutrons, thus they differ in their atomic mass. A radioisotope is unstable because of extra neutrons. Stability can ultimately be reached through the loss of nuclear components in the form of high-energy radiation (e.g., alpha particles, beta particles). Thus, the radioisotope will decay as radiation is released.

4. The octet rule is the tendency for atoms to lose, gain, or share electrons to obtain a complete outer shell and thus become chemically stable.

5. Common cations (positively charged ions) of the human body include: sodium ions (Na^+), potassium ions (K^+), calcium ions (Ca^{2+}), magnesium ions (Mg^{2+}), and hydrogen ions (H^+). Common anions (negatively charged ions) include: chloride ions (Cl^-), bicarbonate ions (HCO_3^-), and phosphate ions (PO_4^{3-}).

6. Sodium (atomic number 11), potassium (atomic number 19), calcium (atomic number 20), magnesium (atomic number 12), hydrogen (atomic number 1), and chlorine (atomic number 17) should be highlighted.

7. In order to satisfy the octet rule, atoms may either lose or gain electrons to become chemically stable (have a complete outer shell of electrons). However, a charge is developed because the number of positively charged protons is no longer equal to the number of negatively charged electrons. For example, atoms with only one electron in their outer shell may give up the electron, resulting in a positive cation, now with a full outer shell. Conversely, atoms with seven electrons in their outer shell may accept an electron from another atom, becoming a negative anion, but now with a full outer shell.

8. Ionic bonds are formed due to an attraction between ions with different charges. Therefore, an ionic bond cannot be formed between two cations, nor can it be formed between two anions.

9. The structural formula exhibits the type and number of atoms in a molecule, and their arrangement within the molecule. In comparison, the molecular formula provides information only for the type and number of atoms in a molecule (but not how the atoms are arranged within the molecule).

10. Isomers are molecules composed of the same type and number of elements, but are arranged differently (i.e., they have the same molecular formula, but a different structural formula).

11. A covalent bond is formed when atoms share electrons in their outer orbitals in order to satisfy the octet rule.

12. Nitrogen is more electronegative that hydrogen, thus it is designated with a partial negative charge, whereas hydrogen is less electronegative than nitrogen and is designated with a partial positive charge.

13. A covalent bond between atoms of the same element (with both atoms equally electronegative) will result in electrons being shared equally between the two atoms. Thus, the resulting bond is a nonpolar bond. A covalent bond formed between two different atoms (with one atom more electronegative than the other) will result in electrons being shared unequally between the two atoms. Thus, the resulting bond is a polar bond. The more electronegative atom will have a slightly negative charge and the less electronegative atom will have a slightly positive charge. Note: Because carbon and hydrogen atoms are nearly equal in terms of electronegativity, atoms of these two different elements essentially share electrons equally and form a nonpolar covalent bond between them.

14. Both O_2 and CO_2 are nonpolar molecules. O_2 is nonpolar because it is composed of the same type of atoms (elements) and CO_2 is a nonpolar molecules because the oxygen atoms with their partial negative charge are positioned in opposing direction and cancel one another. (Note that both respiratory gases, both O_2 and CO_2 are nonpolar molecules.

15. A hydrogen bond is a weak attraction between a partially positive hydrogen atom within a polar molecule and a partially negative atom within a polar molecule (usually oxygen, but sometimes nitrogen).

16. A student's drawing of hydrogen bonding between water molecules should look similar to figure 2.12b.

17. Surfactant is required to decrease surface tension (the cohesive attraction between water molecules) in the alveoli of the lungs. Body temperature is regulated through sweating because of water's high heat of vaporization. Sweating is less effective on a humid day because of the increased water in the environment that impedes additional water evaporating from the skin.

18. Nonelectrolyte molecules such as glucose dissolve but do not dissociate in water. Electrolytes such as sodium chloride (NaCl) both dissolve and disassociate into constituent ions in water, forming a solution capable of conducting electricity.

19. A student's drawing of hydrogen bonding between water molecules should look similar to figure 2.13c upper right image of phospholipid bilayer

20. Each water molecule can disassociate into one positively charged hydrogen ion and one negatively charged hydroxyl ion. It is considered neutral since it has an equal distribution of positive and negative charges.

21. An acid dissociates in water and releases hydrogen ions.

22. pH is a measure of the relative amounts of H^+ in a solution. The relationship between $[H^+]$ and pH is inverse. As $[H^+]$ increases, pH decreases, whereas as $[H^+]$ decreases, pH increases.

23. A buffer helps prevent pH changes if either excess acid or base is added. It acts either to accept H^+ from excess acid or donate H^+ to neutralize excess base. (Buffers act as H^+ sponges, absorbing H^+ if acid is added and releasing H^+ if base is added.)

24. Blood would be characterized as a suspension because blood cells settle to the bottom of a tube when left standing.

25. Blood is a **suspension** of formed elements that includes erythrocytes (red blood cells), leukocytes (white blood cells), and platelets within plasma. If blood is withdrawn from the body, the formed elements will settle out from the plasma. Blood is also a **colloid** of proteins dissolved in plasma, and it is a **solution** of ions and molecules dissolved in plasma.

26. The concentration of a solution may be expressed as (1) mass of solute per volume of solution [mass/volume], (2) grams of solute per 100 milliliters (mL) of solution [mass/volume percent], (3) moles of solute per liter of solution [molarity], and (4) moles of solute per kilogram of solvent [molality].

27. The six common elements that form biological macromolecules include: carbon (C), hydrogen (H), and oxygen (O), and in some cases may also contain nitrogen (N), phosphorus (P), and sulfur (S). Hydrogen is the element that both (a) forms a common ion and (b) is a common element in biomolecules.

28. Carboxylic acids and phosphates are capable of acting as acids.

29. A polymer is composed of repeating monomer subunits. Proteins are composed of amino acid monomers, carbohydrates contain sugar monomers, and nucleic acids have nucleotide monomers.

30. Lipids are fatty, water-insoluble, hydrophobic molecules and do not typically dissolve in water.

31. Phospholipids are amphipathic molecules that form chemical barriers of cell membranes. They contain both a hydrophilic head group (that dissolves in water) and a pair of hydrophobic fatty acid tails (that do not dissolve in water), making them ideally suited for forming cellular membranes.

32. Glycogen is composed of repeating glucose monomers or subunits and is stored by animals within the liver and skeletal muscle cells.

33. Fructose, galactose, and glucose are monosaccharides. Sucrose, maltose, and lactose are disaccharides. Glycogen and starch are polysaccharides.

34. Nucleic acids store and transfer genetic information within cells. They ultimately determine the types of proteins synthesized within cells.

35. RNA molecules contain a ribose sugar in their nucleotides rather than the deoxyribose sugar that is within the nucleotides of DNA. The nucleotides of both RNA and DNA may contain the nitrogenous bases of adenine, guanine, and cytosine. The base uracil is present within nucleotides of RNA. In comparison, the base thymine is present in the nucleotides composing DNA. RNA is a single strand, whereas DNA is a double strand (double helix).

36. Amino acids are the monomers of a protein and they are covalently linked by peptide bonds.

37. A dipeptide consists of 2 amino acids, an oligopeptide contains 3 to 20 amino acids, a polypeptide contains 21 to 199 amino acids, and a protein consists of 200 or more amino acids. The term *protein* is generally used to refer to oligopeptide, polypeptide, and protein.

38. The R group of leucine is a nonpolar hydrocarbon, making it a nonpolar amino acid.

39. The tertiary structure refers to the three-dimensional shape exhibited by *one* completed polypeptide chain. The quaternary structure refers to the three-dimensional shape of *two or more* polypeptide chains that form the functional protein.

40. Denaturing a protein changes its conformation and affects its activity. Exposure of a protein to higher than normal concentration of hydrogen ions (a decrease in pH) results in the positively charged H^+ binding with negatively charged structures that were participating in electrostatic interactions that were holding the protein in its final shape. The loss of these electrostatic interactions between the amino acids that compose the protein results in its unfolding (or denaturation).

Answers to "Do You Know the Basics?"

1. C

Feedback: *Isotopes* are atoms of the same element that have the same number of protons and electrons, but differ in the number of neutrons.

2. A

Feedback: *Lipids* are hydrophobic molecules and are not soluble (do not dissolve) in water.

3. C
Feedback: Water has a high *specific heat,* allowing it to absorb and release energy without changing temperature. In addition, the high *heat of vaporization* for water allows it to dissipate a large amount of energy during evaporative cooling of the skin.

4. D
Feedback: A pH less than 7.0 is acidic and a pH greater than 7.0 is basic.

5. D
Feedback: The formed elements of blood act as a suspension. Dissolved proteins in the plasma act as a colloid. The numerous dissolved solutes also make blood a solution.

6. A
Feedback: *Triglycerides* are not considered polymers because they are not composed of repeating monomer subunits.

7. C
Feedback: Glucose is stored in animal tissues as *glycogen*.

8. B
Feedback: Although phosphates which contain phosphorus are common ions in the body, phosphorus itself is not a common ion.

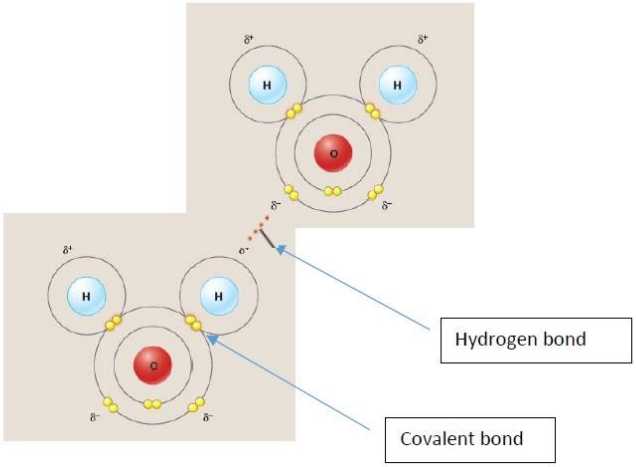
9. B
Feedback: A *hydrogen bond* is an intermolecular attraction between a slightly positive hydrogen atom within a polar molecule and a slightly negative atom (e.g., oxygen, nitrogen) in a polar molecule.

10. B
Feedback: *Denaturing* a protein changes its conformation. Excessive denaturation can permanently affect protein structure and possibly its function as well.

11. Common cations of the human body include sodium ions (Na^+), potassium ions (K^+), calcium ions (Ca^{2+}), magnesium ions (Mg^{2+}), and hydrogen ions (H^+). Common anions include chloride ions (Cl^-), bicarbonate ions (HCO^{3-}), and phosphate ions (PO_4^{3-}).

12. Polar bonds have varying degrees of unequal electron sharing between two different atoms, except for C-H, an oxygen atom bonded to a hydrogen atom. Oxygen, the more electronegative of the atoms, will have a stronger pull on the electrons and will thus have a slightly more negative charge around it, while the hydrogen atom will be relatively more positive (or less negative). A polar molecule is a molecule that contains a prevalence of polar bonds between the atoms that compose it. For example, water is a polar molecule composed of two polar covalent bonds between the oxygen atom and each hydrogen atom.

13.



14. Polar molecules (e.g., glucose) will dissolve in water because hydrogen bonds are formed between the water and the polar molecules. The polar molecule does not dissociate, remaining intact as in this example of a glucose molecule. In comparison, ionic compounds both dissolve and dissociate. Ionic compounds such as sodium chloride (NaCl) will disassociate in water because the polar water molecules will disrupt the electrostatic interactions between sodium and chloride ions, thereby separating them.

15. An acid contributes hydrogen ions to a solution, making it more acidic (having a lower pH). A base binds hydrogen ions from a solution, making it more basic (having a higher pH). pH is the measure of hydrogen ions in a solution. A buffer is capable of either absorbing or releasing hydrogen ions, thereby helping to prevent pH changes when acids or bases are added.

16. The concentration of a solution may be expressed as either the ratio of the mass of solute compared to the volume of the solution (mass/volume), as the percent of mass of solute in 100 milliliters of solution (mass/volume %), as the number of moles of solute per liter of solution (molarity), or the number of moles of solute per kilogram of solvent (molality).

17. Proteins are composed of amino acids (repeating units); carbohydrates are composed of simple sugars (repeating units); nucleic acids are composed of nucleotides (repeating units); but lipids are **not** composed of repeating units. There are four primary types of lipids: *triglycerides* (composed of glycerol and fatty acids); *phospholipids* (composed of glycerol, two fatty acids, a phosphate, and various organic groups); *steroids* (cholesterol, steroid hormones, and bile salts—composed predominantly of hydrocarbons that differ in the side chains extending from the rings); and *eicosanoids* (prostaglandins, thromboxanes, and leukotrienes—composed of modified 20-carbon fatty acids synthesized from arachidonic acid).

18. Nucleotides (composed of a sugar, phosphate, and a nitrogenous) that compose DNA and RNA contain nitrogen that forms a nitrogenous waste called uric acid. Amino acids contain an amine functional group, —NH_2, that is converted to a nitrogenous waste called urea. Both uric acid and urea must be effectively eliminated by the kidney for an individual to remain healthy.

19. In an aqueous environment, amphipathic molecules such as phospholipids will orient themselves so that their hydrophobic domains face each other while the hydrophilic domains are exposed to water. This is the basis behind the arrangement of phospholipids within a phospholipid bilayer of the plasma membrane of a cell.

20. A protein's function is dependent upon the retention of its normal 3-dimensional shape. Denaturation is a change in the conformation of a protein that changes/affects its activity. Exposure of a protein to either an increase in temperature or a pH outside of its normal environment can denature the protein by disrupting electrostatic interactions such as ionic bonds within the molecule.

An increase in temperature can weaken the intramolecular attractions between the amino acids in the primary structure of the protein strand, causing the protein to unfold or denature such that it can no longer function normally.

Changes in H^+ concentration that are associated with changes in pH interfere with the electrostatic interactions within the protein that hold it in its 3-dimensional shape. Exposure of a protein to higher than normal concentration of hydrogen ions (a decrease in pH) results in the positively charged H^+ binding with negatively charged structures that were participating in electrostatic interactions that were holding the protein in its final shape. Exposure of a protein to lower than normal concentration of hydrogen ions (an increase in pH) results in the positively charged H^+ that were participating in electrostatic interactions and holding the protein in its final shape being removed. The loss of these electrostatic interactions between the amino acids that compose the protein results in its unfolding (or denaturation).

Answers to "Can You Apply What You've Learned?"

1. C
Feedback: Surface tension is high within the air sacs in the lungs of premature infants that are not producing sufficient surfactant. Surfactant is a detergent-like substance that prevents hydrostatic interactions between water molecules, thereby preventing the lungs from collapsing and the alveolar walls from sticking together. Premature babies often lack the ability to produce surfactant and are at risk for respiratory problems.

2. D
Feedback: Electrolytes such as sodium ions, potassium ions, and chloride ions are capable of conducting electricity.

3. B
Feedback: Radioisotopes emit high-energy radiation.

4. D
Feedback: Calcium (Ca^{2+}) ions are an important structural component of bone tissue.

5. C
Feedback: *Proteins* consist of covalently bonded amino acids held together by peptide bonds. If insulin is administered orally, the peptide bonds are broken by enzymes of the digestive system (to form individual amino acids).

Answers to "Can You Synthesize What You've Learned?"

1. High-energy radiation can cause mutations within DNA.

2. The number of hydrogen ions in the blood increases, resulting in a lower pH (a condition called acidosis). The increasing number of hydrogen ions may interfere with the hydrostatic interactions holding proteins together, thus denaturing the proteins.

3. The drug would regulate the levels of the monosaccharide glucose within the blood.

CHAPTER 1: The Sciences of Anatomy and Physiology

CHAPTER OVERVIEW

This chapter provides students with an initial introduction to the disciplines of human anatomy and physiology. The chapter focuses on anatomy and physiology equally—showing the confluent interrelationship between the two. It shows that form and function are inseparable, with function dictating form.

In an exciting way, Chapter 1 introduces students to new terminology and new concepts concerning the wonderful human organism. Students will gain knowledge on the levels of organization, homeostasis, introductory physiological principles, and anatomical terms, along with some cursory understandings of human diseases.

KEY POINTS TO EMPHASIZE WHEN TEACHING HUMAN ANATOMY AND PHYSIOLOGY

An instructional understanding: An instructor must keep three important facts in mind when teaching an introductory human anatomy and physiology course. One is that many students do not have any significant biological/chemical background prior to taking the course. Second, the great majority of students taking A&P courses are already in or applying to clinical programs. Third, physiology is generally the most difficult for students to understand. Considering these facts, it is best for an instructor to relate A&P concepts to everyday life situations. Clinically relevant scenarios should be interwoven in order to show the student that the concepts discussed do clinically apply. Difficult physiological concepts should be initially explained using simple everyday terms until the student has begun to master scientific terminology.

1. Start the course by explaining to the student that an introductory course in anatomy and physiology is not easy. However, the text is written in an easy reading manner that maximally facilitates students learning. Explain that your instruction will attempt to use real-life situations along with clinically relevant scenarios. Let the student know that they will be exposed to an entirely new vocabulary that must be understood and utilized in the various clinical professions.
2. Define anatomy and physiology and compare and contrast the two.
   a. As often as possible, show word origins along with Latin and Greek prefixes and suffixes. This helps clinical students on standardized entrance and licensure examinations. Refer students to the inside back cover of this textbook for a listing of the most common roots, prefixes, and suffixes in anatomy and physiology.
   b. Discuss how anatomy integrates with physiology. Give examples of how function dictates form, like the megaphone's similarity to the human ear.
   c. Discuss the importance of composite courses in both anatomy and physiology, in contrast to independent courses in each discipline.
3. Discuss the scientific method as it relates to explaining and understanding the workings of the body. When discussing the scientific method, explain the process.
   a. Explain that the first step in examining natural events is through observation.
   b. Discuss the second step: the development of a hypothesis.
   c. Discuss why and how data are collected to support, reject, or modify the hypothesis.

4. When discussing various methods of studying anatomy, give some clinically relevant reasoning.
    a. Use, for example, that systemic anatomy is used in medical fields. The cardiovascular system is shared by the cardiologist (subspecialty of internal medicine) and the cardiothoracic surgeon (subspecialty of surgery). The gastrointestinal system is shared by the gastroenterologist (internal medicine) and the general or colorectal surgeon. Surgeons can operate, and internal medicine specialists use nonsurgical treatments.
    b. Discuss that gross anatomy is a course in itself. The dissection method used in the course is generally a regional approach rather than a systemic approach. A systemic approach dissection requires several specimens to be used by the same group of students.
    c. Discuss that cytology, histology, and embryology are complete courses by themselves. Inform the student that this course presents an in-depth yet introductory-type presentation of these topics. For some students, this introductory presentation sparks interest to take additional courses.
    d. Define and discuss embryology. Define the embryonic period in a human.
    e. Discuss that in the clinical setting, topical anatomy terms are important. For example, a nurse or medical doctor would not say, “Put the IV on the inside surface of the elbow.” Instead he/she would say, “Place it in the antecubital fossa.”
5. When discussing various methods of studying physiology, give some clinically relevant reasoning.
    a. It is important to mention that physiology will be discussed mainly using a systemic approach, such as cardiovascular physiology and neurophysiology. However, though it will be discussed on the systemic approach, much of modern-day physiology is discussed on the cellular and chemical level basis. It is important for the student to know that diagnosis and treatment is fast moving to the cellular level.
    b. Students sometimes have difficulty comparing physiology to pathophysiology. It is best to use homeostatic imbalance as an explanatory method. For example, if resting heart rate is in the 60–100 beats per minute range, the discussion is physiologic, but in most cases when it deviates outside this range, it is pathologic.
    c. Some students have difficulty understanding the difference between pathology and pathophysiology. One is more anatomical and the other more physiological.
6. Discuss the living processes (properties) and levels of organization, using several examples.
    a. Students have difficulty understanding life processes and how they interrelate with one another.
    b. Define metabolism and its subsumed components of anabolism and catabolism.
    c. Discuss the dynamic cycle of anabolism and catabolism in terms of biochemical compounds.
    d. Discuss growth. Use related media to compare and contrast growth by hyperplasia (increase in the number of cells) versus hypertrophy (increase in the size of cells).
    e. Use supportive resources to discuss why most growth is by hyperplasia rather than hypertrophy as a result of the surface-to-volume relationship of cells.
    f. Discuss development in terms of differentiation. Use related media to discuss that though human cells undergo differentiation (cell specialization), those with a nucleus have the same genetic information (genomic equivalence).

g. Define responsiveness and how it interrelates with homeostasis. One must be able to perceive a stimulus in order to react to it.
h. Discuss body regulation in terms of homeostasis. Use good examples that are clinically relevant.
i. Give a cursory explanation of mitosis versus meiosis as it relates to somatic cells and gametes, respectively.
j. Explain that the reproductive process attributed to the sex cells (development of a new living organism) is the least vitally important homeostatic process in a stressful situation. Use the example that a female's menstrual period is discontinued during extreme times of stress and/or severe weight loss.
k. Show how the levels of organization integrate with one another.
l. Explain how the whole is greater than the sum of its parts in a living organism.
m. Explain how, though the levels of organization have defined levels such as the chemical and cellular levels, some emphasis must be placed on describing the in-between structures like organelles.
n. Since most students are seeking clinical careers, one may emphasize that an organism is an individual entity. However, humans interact with the living and nonliving, and all of this impacts our wellness. Thus, mention and define population, biological community, and ecosystem. Use related resources to explain this.

7. Most students who have taken a chemistry or physics course have been presented with the term "system" as defined in those disciplines.
   a. Note the difference between a system in chemistry and physics and that of an organ system.
   b. Describe all of the organ systems.
8. Describe the anatomical position and how it relates to the various body planes.
   a. Define a body plane.
   b. Give examples of all the body planes using examples of cutting the body along those planes.
   c. Explain the importance of the anatomical position in terms of relative anatomical terminology. However, the person does not have to actually be positioned that way to discuss the anatomical terminology. For example, if an individual is removed by paramedics from the interior of their vehicle in a car accident, the paramedics will use anatomical terms to describe the various injured body areas. However, they obviously would not rearrange the accident victim into the anatomical position to describe the injuries. They would imagine the person is in that position for point of reference.
   d. Explain why a sagittal plane utilizes two descriptive terms, "midsagittal" and "sagittal" (some use the term "parasagittal" instead of "sagittal"). The other anatomical planes have only one descriptive term. The reason is that the human body is intended to be bilaterally symmetrical.
   e. Explain that some synonymous anatomic terms in a human (two-legged organism) differ in their synonymous meaning in a four-legged organism. For example, in a two-legged organism, anterior and ventral are the same and posterior and dorsal are the same. However, in a dog, his head (cephalic) is anterior and his caudal region is posterior.
   f. Explain that anatomical directional terms are relative (need at least two terms for comparison). Thus "medial" means a structure closer to the midline, not necessarily at the

midline. But in order to use it, reference must be made to something further out from the midline ('lateral').

9. Describe all the body cavities.
    a. Discuss the lines of demarcation that delineate the various body cavities.
    b. Discuss the fact that there are really no freely open spaces in the human body, due to the surface tension of water closing the spaces. However, the space can be easily opened without trauma to a delineating surface. Body cavities are therefore potential spaces.
    c. Discuss the lack of body cavities in the arms and legs.
    d. Discuss the false and true pelvic body cavities. Use outside resources to do this.
    e. Use the visceral and parietal serous membranes to describe the body cavities.
    f. Define and describe a serous membrane, along with the type of fluid it produces and the membrane's purpose.
    g. Discuss the contents of some body cavities.
10. Describe the abdominopelvic regions and quadrants.
    a. Present the terms used in the nine-region description.
    b. Present the terms used in the quadrant system.
    c. Inform the students that the quadrant system is used in the clinical professions. The nine-region system is too confining when making a diagnosis using the physical exam. The quadrant system provides more diagnostic latitude. More of an organ is in a quadrant than a nine-section region.
    d. Use a clinical scenario in describing the quadrant system as it relates to diagnosis. For example, have the students state what possible structures could be injured if one had a stab wound injury to a certain quadrant.
11. Students have difficulty understanding homeostasis in terms of (a) its dynamic fluctuating nature, (b) the internal environment, and (c) its normal homeostatic range, and the set point within the range.
    a. Define homeostasis explaining its dynamic nature.
    b. Describe the body fluids considered to comprise the internal environment.
    c. Discuss that all body processes and chemicals have a normal range. The range was determined by examining a statistically significant population of healthy individuals.
    d. Discuss that the dynamic nature of homeostatic actions involves oscillating fluctuations around a central value in the homeostatic range, known as the "set point." The set point is the optimal point for homeostatic control, with the rest of the range being a buffer zone.
    e. Discuss that when an individual moves out of the homeostatic range, particularly in an unexplained manner, it generally is no longer a discussion of physiology but rather pathophysiology. For example, if a person's resting heart rate is above 100 beats per minute, it could point to a pathological condition.
    f. Discuss the major mechanism used in homeostasis: feedback.
    g. Define feedback and the two types (negative and positive). Use good examples to compare and contrast both types.
    h. Discuss how negative feedback is the most common mechanism used in homeostasis and why.
    i. Discuss that positive feedback is occasionally used as a control method in homeostasis. Describe when and why it is used.
    j. Discuss each component of the feedback loop and how they integrate.

k. Use specific examples of feedback loop operation.
l. Give an example of a disease state that occurred when the feedback loop malfunctioned.

12. Discuss homeostatic imbalance as it relates to disease states.
    a. Mention deviations from homeostatic ranges and diseases.
    b. Discuss signs versus symptoms of disease. Use outside resources to do this.
    c. Discuss the difference between a diagnostic maneuver versus a therapeutic one. Give good clinical examples of each. Use outside resources to do this.
    d. Use external sources to inform students of the techniques used in a physical exam (palpation, auscultation, percussion, and visualization). Use outside resources to do this.
    e. Discuss the role of some of the various laboratory tests in the clinical diagnostic process. Laboratory tests are ordered after a good history and physical exam has been performed. The specific laboratory tests to be ordered are determined by the findings from the history and physical examination.
13. Discuss the fact that not only anatomists and physiologists use the scientific method to gain an understanding of the normal workings of the human body, clinicians also use this method to explain the abnormal (disease) workings of the human body. Use examples of clinical scenarios to explain the process.
14. Students are very interested in the wide array of radiologic tests, particularly the newer fascinating ones. Use external-related media to show examples of the various radiographic techniques and images.
    a. Discuss the advantages and disadvantages of the standard X-ray.
    b. Discuss what a contrast media is and its advantages in radiographic imaging. Use outside resources to do this.
    c. Discuss the CT scan, noting its benefits and limitations.
    d. Discuss the MRI, noting its benefits and limitations.
    e. Discuss the reason to do a CT scan versus an MRI, and vice versa. MRI allows a better view of soft tissue since it avoids bone. Bone does not have much water. Water is a main factor in the operation of the MRI device.
    f. Discuss the ultrasound in terms of benefit.
    g. Briefly discuss the DSA and PET scan in terms of their advantages.

SUGGESTED CHAPTER OUTLINE

1.1 Anatomy and Physiology Compared: Anatomy is the study of structure and form. Physiology is the study of function of the body parts. (pp. 2–3)

A. Scientific Method (p. 2)
    1. A systematic and rigorous process that scientists use to study a problem.
    2. They use **observation** to examine natural events.
    3. Then develop a **hypothesis** or a possible explanation for their observations.
    4. They devise an **experiment** to test the validity of their hypothesis.
    5. The data are then closely examined to see whether the hypothesis is supported, rejected, or needs to be modified.

B. Anatomy: Details of Structure and Form (p. 2)
    1. **Microscopic anatomy** cannot be seen with the unaided eye. It includes cytology and histology.
    2. **Cytology** is the study of body cells and their internal structure.
    3. **Histology** is the study of tissues.

4. **Neurophysiology** examines how nerve impulses are propagated throughout the nervous system.
5. **Gross anatomy,** also called **macroscopic anatomy,** investigates the structure and relationships of body parts that are visible to the unaided eye, such as the intestines, stomach, brain, heart, and kidneys. It includes systemic anatomy, regional anatomy, surface anatomy, comparative anatomy, and embryology.
6. **Systemic anatomy** studies the anatomy of each functional body system.
7. **Regional anatomy** examines all of the structures in a particular region of the body as a complete unit.
8. **Surface anatomy** focuses on both superficial anatomic markings and the internal body structures that relate to the skin covering them.
9. **Comparative anatomy** examines similarities and the differences in the anatomy of different species.
10. **Embryology** is the discipline concerned with the developmental changes occurring from conception until birth.
11. Specialized branches of anatomy focus on the diagnosis of medical conditions or the advancement of basic scientific research. These branches include pathologic anatomy and radiographic anatomy.
12. **Pathologic anatomy** examines all anatomic changes resulting from disease.
13. **Radiographic anatomy** investigates the relationships among internal structures that may be visualized by specific scanning procedures such as the ultrasound, magnetic resonance imaging (MRI), or X-ray.

C. Physiology: Details of Function (p. 3)

1. Physiologists examine the function of various organ systems and typically focus on the molecular or cellular level to gain a complete understanding of the system's workings.
2. The discipline parallels anatomy because it also is very broad and may be divided into smaller groups. These groups include cardiovascular physiology, neurophysiology, respiratory physiology, reproductive physiology, and pathophysiology.
3. **Cardiovascular physiology** examines the functioning of the heart, blood vessels, and blood.
4. **Neurophysiology** examines how nerve impulses are propagated throughout the nervous system.
5. **Respiratory physiology** studies how respiratory gases are transferred by gas exchange between the lungs and the blood vessels, supplying the lungs among other things.
6. **Reproductive physiology** explores how the regulation of reproductive hormones can drive the reproductive cycle and influence sex cell production and maturation.
7. **Pathophysiology** investigates the relationship between the functioning of an organ system and disease or injury to that organ system.

1.2 Anatomy and Physiology Integrated: Physiologic function dictates structure's anatomic form. (p. 3 and Figure. 1.1 on pp. 4–5)

A. Anatomy and physiology initially may appear to be different sciences, but further reflection reveals that these two sciences are integrated, because form (anatomy) and function (physiology) are interrelated.
B. Structure (anatomy) determines the function (physiology) and the function dictates the structure.
C. Anatomists cannot gain a full appreciation of anatomic form without also understanding a structure's function.
D. Physiologists cannot fully appreciate body functions without learning the form of the structures involved.

1.3 How to Study Anatomy and Physiology Effectively (pp. 3–7)

A. Do not wait until the last minute to study.
B. Do not study for long periods of time without breaks.
C. Do not study with multiple distractions.
D. Do not simply passively read over your notes.
E. Do not study by yourself only.
F. Do schedule regular daily study sessions well before the upcoming exam.
G. Do study for multiple, short periods of time.
H. Do minimize your distractions.
I. Do utilize active learning methods when you study, which include making your own tables to organize materials, drawing and labeling anatomic structures, making flow charts, quizzing yourself repeatedly, and explaining/teaching a concept to a partner.
J. Study with a partner or group.
K. Utilize all the resources available in the textbook, which includes learning strategies boxes, concept connection boxes, concept overview figures, multiple assessments in each chapter, LearnSmart, and Anatomy and Physiology Revealed.

1.4 The Body's Levels of Organization: Scientists group the body's components into an organized hierarchy of form and function. (pp. 7–9)

A. Characteristics that Describe Living Things (pp. 7–8)
1. Several properties are common to all organisms, including organization, metabolism, growth, development, responsiveness, regulation, and reproduction.
2. **Organization** is the complex hierarchical structuring of the body.
3. **Metabolism** is the sum of all chemical reactions in the body. Metabolism is subsumed into two interrelated processes, anabolism and catabolism.
4. **Anabolism** is a biochemical building process where small molecules are joined to make larger ones.
5. **Catabolism** is a biochemical breaking down process where large molecules are broken down into smaller ones.
6. **Growth** is the enlargement in the size of an organism.
7. **Development** (differentiation) is the process whereby cells specialize to become more sophisticated for specific functioning, like nerve cells.
8. **Responsiveness** is the ability to sense and react to stimuli.
9. **Regulation** is based in homeostasis. The ability to maintain a constant internal environment in the face of a changing external environment.
10. **Reproduction** is a process that produces new cells for growth, maintenance, and repair. The sex cells are responsible for developing a new living organism.

B. The View from Simplest to Most Complex (p. 8) and Figure 1.2 (p. 9)
   1. Anatomists and physiologists recognize several levels of increasing complex organization in humans. In increasing hierarchical order, these levels include the chemical level, cellular level, tissue level, organ level, organ system level, and organism level.
   2. The **chemical level** is the simplest level, involving atoms and molecules. Atoms are the smallest intact chemical units and molecules are combinations of atoms.
   3. The **cellular level** consists of cells, which are the smallest living structures and serve as the basic units of structure and function. Interfaced between the chemical level and cellular level are the biochemical macromolecules (carbohydrates, lipids, proteins, and nucleic acids) and the cellular substructures these macromolecules form, which are the organelles.
   4. The **tissue level** is comprised of groups of similar cells (similar embryonic origin) that collectively form common functions.
   5. The **organ level** is composed of human organs that are composed of two or more tissue types that perform specific, complex functions.
   6. The **organ system level** contains organs that work together to coordinate activities and achieve a common function.
   7. The **organism** is the highest level human structural organization, comprised of all of the organ systems working in an integrated functional manner.

C. Introduction to Organ Systems (p. 8); Figure 1.3 (pp. 10–12)
   1. Complex multicellular organisms, like the human, perform a myriad of complex metabolic processes.
   2. The complexity of these processes requires a sophisticated division of physiological labor. Each organ system is assigned a certain major physiological task; its name reflects that major task.
   3. Since a living entity is not merely the sum of its parts, each organ system multitasks. No organ system performs only one task. It is named in accordance with its major task, but its other tasks are also vital to life.
   4. Some tasks are shared by more than one organ system, as exemplified by the control of acid/base balance. This homeostatic control is shared by two organ systems, the respiratory system and the renal system. This sharing of tasks enhances physiological organization.
   5. Due to their primary and secondary functions, some organs are included in more than one organ system.

D. Clinical View: The Human Microbiome: Another Human Organ? (p. 9)
   1. The human microbiome is the total collection of microorganisms living on and within the body, which equals the number of human cells present in the body (about 30-40 trillion)
   2. These unique microorganisms with their own genes, metabolic pathways, and products are deeply woven into our physiology and can have profound effects on our health.
   3. The Human Microbiome Project has given us a great deal of information about the composition and range of this microbial world.

4. These bacteria flourish in all parts of the body that are exposed to the external environment with some body areas more hospitable than others.
5. The large intestine contains 70% of the entire human microbiome.
6. The microbiome interacts with our body systems and can influence the nervous system; protect us from infection; assist with digestion, energy harvest, and energy utilization; and influence the development of the immune system.
7. Our microbiome is essential to our health and well-being as are the rest of our body organs.

1.5 The Precise Language of Anatomy and Physiology: Clinicians and researchers in anatomy and physiology require a precise language to ensure that they are discussing the same features and functions. (pp. 9–19)

A. Anatomic Position (p. 13); Figure 1.4 (p. 13)
1. **Anatomic position** is a common agreed upon point of reference used when describing the position of certain anatomical structures in the human body. It is very important when discussing relative anatomical terms.
2. In order to assume the position, the person stands erect and upright with their limbs at their sides, their palms facing anteriorly, and feet held together but positioned in a 45° angle from one another.

B. Sections and Planes (pp. 13−14); Figure 1.4 (p. 13); Figure 1.5 (p. 14)
1. The term **section** implies an actual cut or slice to expose the internal anatomy.
2. A **plane** is an imaginary flat surface passing through the body.
3. The planes of the body include the coronal, transverse, sagittal, and oblique planes.
4. A **coronal plane,** also termed a frontal plane, is a vertical plane that divides the body into front (anterior) and back (posterior) parts.
5. A **transverse plane,** also termed a horizontal plane, divides the body into top (superior) and bottom (inferior) parts.
6. A **sagittal plane** divides the body into right and left halves. Since the body is intended to be bilaterally symmetrical, a cut down the middle of the head continuing down through the midline of the trunk (through the umbilicus) will divide the body into equal right and left sections, thus termed a midsagittal plane. If the body is divided into unequal right and left parts, it is simply termed a sagittal plane.
7. The coronal, transverse, and sagittal planes are at perfect 90° angles from one another. If a plane is cut at another angle, it is termed an oblique plane.

C. Anatomic Directions (p. 14); Figure 1.6 (p. 15); Table 1.1 (p. 14)
1. Once the body is positioned in the anatomic position, the researcher or clinician can discuss anatomical structures in terms of relative directional terms. Examples of these terms are anterior, posterior, dorsal, ventral, proximal, and distal.
2. **Anterior** is toward the front surface.
3. **Posterior** is toward the back surface.
4. **Dorsal** is at the back side of the human body.
5. **Ventral** is at the belly side of the human body.
6. **Proximal** refers to a structure on the appendages. It is the structure closest to the point of attachment to the body trunk.
7. **Distal** refers to a structure on the appendages. It is the structure farthest away from the point of attachment to the body trunk.

D. Regional Anatomy (p. 15) Figure 1.7 (p. 15); Table 1.2 (p. 16)
1. The human body is partitioned into two main regions, the axial and appendicular regions.
2. The **axial region** includes the head, neck, and trunk.
3. The **appendicular region** is composed of the upper and lower limbs, which attach to the axial region.
4. Several more specific regions are located within the two main regions, and they are identified by proper anatomic terminology as noted in Table 1.2: Human Body Regions (p. 16).

E. Body Cavities and Membranes (pp. 16–18); Figure 1.8 (p. 17); Figure 1.9 (p. 18)
1. Internal organs and organ systems are housed within enclosed spaces, or cavities. These body cavities are named either according to the bones that surround them or the organs they contain. The main two body cavities are the posterior cavity and ventral cavity. These two body cavities are subdivided into smaller body cavities according to certain anatomical structures.
2. The posterior body cavity is different from the ventral cavity in that the posterior aspect contains cavities that are completely encased in bone and are physically and developmentally different from the ventral cavity. It is subdivided into two enclosed cavities, the cranial and vertebral cavities.
3. The **cranial cavity** is formed by the bones of the cranium, and so it goes by the name endocranium.
4. The **vertebral cavity** is formed by the bones of the vertebral column and houses the spinal cord.
5. The **ventral cavity** is the large, anteriorly placed cavity in the body. Unlike the posterior cavity, the ventral cavity and its subdivisions do not completely encase their organs. This cavity contains the thoracic and **abdominopelvic cavities.**
6. Ventral body cavities are lined by serous membranes, unlike the posterior cavities.
7. A serous membrane is a continuous layer of cells, as compared to the plasma membrane, which surrounds a single cell.
8. **Serous membranes** are composed of two layers, a parietal layer and a visceral layer.
9. The **parietal layer** lines the internal surface of the body wall.
10. The **visceral layer** covers the external surface of the organ in the cavity.
11. Between the parietal layer and visceral layer of serous membranes is a potential space, called the serous cavity.
12. **Serous membranes** secrete a serous fluid that has an oily consistency. Its purpose is to serve as a lubricant that prevents friction when organs rub against one another in the ventral cavities.
13. The **thoracic cavity,** a subdivision of the ventral cavity, contains three cavities itself. These cavities are the mediastinum cavity, pericardial cavity, and the pleural cavity.
14. The **mediastinum cavity** is located in the median space in the thoracic cavity. It contains the heart, thymus, esophagus, trachea, and major blood vessels that connect to the heart.
15. The **pericardial cavity** is located within the mediastinum, and it encloses the heart in a two-layered serous membrane, called the pericardium.

16. The **parietal pericardium** is the outermost layer of the serous membrane and forms the sac around the heart, while the visceral pericardium forms the heart's external surface.
17. The pericardial cavity is the potential space between the parietal and visceral pericardium.
18. The pleural cavities are located in the right and left sides of the thoracic cavity; they surround the two lungs.
19. Just like the pericardial cavity, the pleural cavities have two layers of serous membranes. One is the parietal layer and the other is the visceral layer.
20. The parietal layer is the outer layer that surrounds the internal surface of the thoracic wall and the visceral layer covers the external surface of the lungs.
21. The **abdominopelvic cavity** is a subdivision of the ventral body cavity and is separated from the thoracic cavity by a flat dome-shaped muscle, known as the diaphragm.
22. The abdominopelvic cavity is subdivided into two smaller cavities, the abdominal cavity and pelvic cavity, by a horizontal plane at the level of the superior aspects of the hip bones.
23. The abdominal cavity lies superior to this horizontal plane, at the level of the superior aspects of the hip bones. It contains most of the digestive organs along with the kidneys and most of the ureters.
24. The **pelvic cavity** lies inferior to the horizontal plane, at the level of the superior aspects of the hip bones. It contains the distal part of the large intestine, the remainder of the ureter, the urinary bladder, and the internal reproductive organs.
25. Just like the pericardial and pleural membranes, the peritoneum is a two-layered serous membrane that lines the abdominopelvic cavity. It also has a parietal layer and visceral layer.
26. The **parietal peritoneum** is the outermost layer of this serous membrane, lining the internal walls of the abdominopelvic cavity.
27. The **visceral peritoneum** is the inner layer of this serous membrane, covering the external surfaces of most of the abdominopelvic organs.
28. The **peritoneal cavity** is the potential space between the visceral and parietal peritoneum, containing a lubricating fluid: serous fluid.

F. Abdominopelvic Regions and Quadrants (pp. 18−19) Figure 1.10 (p. 19)

1. In order to accurately describe organ location, anatomists and clinicians commonly partition the large abdominopelvic cavity into smaller compartments. Two partitioning methods are used, the nine compartment method and the quadrant method.
2. The nine compartment method divides the abdominopelvic cavity into an **umbilical region, epigastric region, hypogastric region, right hypochondriac region, left hypochondriac region, right lumbar region, left lumbar region, right iliac region,** and **left iliac region.**
3. Some health care professionals prefer to partition the abdomen into four quadrants, using the umbilicus as the central point and having imaginary transverse and midsagittal planes pass through the umbilicus.

4. The quadrant system divides the abdominal cavity into a **right upper quadrant, right lower quadrant, left upper quadrant,** and **left lower quadrant.**

1.6 Homeostasis: Keeping Internal Conditions Stable: Homeostasis refers to the body's ability to maintain a relatively stable internal environment in response to changing internal or external conditions. (pp. 19–24)

A. Components of Homeostatic Systems (pp. 19–21); Figure 1.11 (p. 20)

1. The body maintains homeostasis by utilizing homeostatic control systems. Three components are associated with each homeostatic system: receptor, control center, and effector.
2. The **receptor** is the body structure that detects changes in a variable, which is either the substance or process that is regulated.
3. The change in the variable is the **stimulus.**
4. The control center is the structure that interprets input from the receptor and initiates changes through the effector. It serves as the go between, integrating the other two components of the homeostatic system.
5. The **effector** is the structure that brings about the change to alter the stimulus. Its action attempts to bring the variable back into optimal homeostatic range, as dictated by the control unit.
6. The components of the homeostatic system form a dynamic control system, known as the feedback loop.
7. The **feedback loop** operates in the following manner: A stimulus is received by the receptor. The receptor information is sent to the control center. The control unit integrates the incoming input and dictates a change utilizing the effectors. The effectors receive input from the control unit, effecting return of the body to homeostasis.
8. Homeostatic control systems are separated into two broad categories based on whether the system maintains the variable within a normal range by moving the stimulus in the opposite direction, or amplifies the stimulus in the same direction.
9. Negative feedback moves the variable in the opposite direction.
10. Positive feedback moves the variable in the same direction.

B. Homeostatic Systems Regulated by Negative Feedback (pp. 21–23); Figure 1.12 (p. 21); Figure 1.13 (pp. 22–23)

1. Most body processes are controlled by **negative feedback.**
2. Negative feedback involves moving the stimulus in the opposite direction. The variable is maintained with a normal level, termed the "set point." Temperature regulation is one example of negative feedback homeostatic control.
3. Human body temperature is monitored by temperature receptors in the skin and by blood passing through a certain area of the brain, known as the hypothalamus.
4. The skin temperature receptors send a signal to the hypothalamus, which is the human body temperature control unit.
5. The hypothalamus sends a signal to the thermal effectors, which are blood vessels in the skin, sweat glands, skeletal muscles, and in some cases smooth muscles associated with hair follicles.
6. In a cold environment, surface blood vessels decrease lumen diameter, thus decreasing blood flow to the skin, leading to decreased heat loss from the body.

Skeletal muscles increase motion: shivering. In some cases, smooth muscle associated with hair follicles increase contraction: goose bumps.

7. The opposite actions occur in a hot environment for the opposite reasons. Skin blood vessels increase lumen diameter, skeletal muscles decrease motion, and sweat glands increase action.

C. Homeostatic Systems Regulated by Positive Feedback (p. 24); Figure 1.14 (p. 24); Figure 1.15 (p. 24)

1. A homeostatic system may also be controlled by **positive feedback**. In such a case, the stimulus is reinforced to continue in the same direction until a climatic event occurs. Following the climatic event, the body returns to homeostasis.
2. One example of positive feedback, as used in homeostasis, is the breast-feeding process.
3. The baby's suckling of the breast is the initial stimulus, which is detected by the sensory receptors in the skin of the nipple. The receptors send a signal to the control center in the hypothalamus. A signal is sent from the hypothalamus to the anterior pituitary gland, where oxytocin, a hormone, is produced and secreted. The oxytocin travels in the bloodstream to the mammary glands, which are the effectors, causing them to secrete milk.
4. The intensity of suckling force governs the amount milk secretion; the stimulus intensifies the response in the same direction.
5. Once the baby stops suckling (and thus the initial stimulus is removed), then the cycle will stop.
6. Other homeostatic examples of positive feedback are blood coagulation and labor contractions, subsequently leading to childbirth.

1.7 Homeostasis, Health, and Disease: Disease is a result of homeostatic imbalance. (p. 25)

A. Disease occurs when the body is unable to maintain a relatively stable internal environment: homeostatic imbalance.

1. Homeostatic imbalance may sometimes occur due to a normal process, such as aging.
2. Normal homeostatic ranges may be altered as a result of aging.
3. In order to treat a patient, a diagnosis must be made.
4. A **diagnosis** is a finding of the specific cause of the homeostatic imbalance.
5. Some drugs are intended to produce a homeostatic imbalance in order to treat a certain disease, such as when a serotonin reuptake inhibitor (SSRI) is given to raise the level of serotonin out of homeostatic range in an attempt to treat human depression.
6. Some medications adversely alter body processes and chemical levels. These are known as drug side effects.
7. Clinical View: Medical Imaging (pp. 26–27)
    a. **Radiography** is the primary method of obtaining an image of a body part for diagnostic purposes.
    b. **Ultrasound** is an imaging method that transmits high-frequency ultrasonic waves into the body and then receives reflected signals in order to produce an image of internal organs.
    c. **Computerized Tomography,** CT scan, is a more sophisticated application of X-rays, producing multiple axial images of a body organ or region. The

multiple images are processed and analyzed by a computer, thus producing a three-dimensional image of a thin slice of the body region.

d. **Digital Subtraction Angiography (DSA)** is a modified three-dimensional X-ray technique used primarily to observe blood vessels.
e. **Magnetic Resonance Imaging, MRI,** provides noninvasive images of soft body tissues, using a strong magnetic field and radio waves that alters the energy of protons in the nuclei of hydrogen atoms. Since hydrogen atoms are a main component of water molecules, soft tissues possessing higher water contents are viewed better than hard tissues, such as bone, having lower water contents.
f. **Positron Emission Tomography (PET scan)** uses radioactively labeled glucose molecules to analyze the metabolic state of a tissue at a given moment in time, thus determining which tissues are most metabolically active.

VISUALS, IN-CLASS DEMONSTRATIONS, AND DISCUSSIONS

1. Discuss some of the early discoveries that led to our current understanding of the human body.
2. Models of the early stages of human development (cleavage through gastrula) are good visuals and students can see the changes in sizes of cells and movements during the gastrula stage. Models of later stages of development (fetal) are useful for showing the orientation of the fetus in the female body.
3. Explain how anatomy and physiology are related to one another. Help students visualize the correlation between anatomy and physiology by showing models of the various organ systems and discuss how a structure determines function.
4. Using a SMART Board, discuss PowerPoint slides of the body cavities and internal structures to help students visualize regions of the body.
5. Charts of body cavities and their contents are useful for review.
6. Students enjoy dissectible mannequins and models of the adult body, and they are good visuals.
7. Discuss the differences between microscopic and macroscopic (gross) anatomy. It is important that students understand that dissections are aimed at helping us to understand the functions of each level of organization but that the body works as a whole and is more complex than the sum of its parts.
8. Have the students outline the ways in which the body compensates for the variations in temperature and identify these mechanisms as homeostasis at work when an individual is working outside on a 100°F day, and compare that to being outside on a day that is below freezing.
9. Discuss the thermostat in the classroom with students to demonstrate negative feedback. Students can easily understand the negative feedback system of the HVAC system at work.
10. Discuss the process of childbirth with students to demonstrate positive feedback. There are some childbirth models on the market.

11. Using a human model, present directional terms as opposites. Discuss how the terms anterior/posterior and superior/inferior refer to different areas for bipeds and quadrupeds. Also, discuss that words are often combined to more accurately identify the relative position of a single structure.
12. Give definitions of word roots, prefixes, and suffixes to help students begin to build a language of biomedical terminology.
13. Using a balloon or plastic bag, show that body cavities lined by serous membranes are generally potential spaces. They are filled with a serous fluid that exhibits a surface tension, thus closing the space. Use water in the balloon or plastic bag to show that surface tension of the fluid creates a potential space that can be easily opened without destruction of the two layers of the balloon or paper bag.
14. Have students work in small groups to practice the human body regional terms with each other or with models.

Related Media

Insight Media. *The last Neanderthal: Competing theories of human origins*.
Winston, Robert M. L. *Interactive universe: The human body*.
Cambridge Educational (Firm). *The human body systems at work*.
Chantilly, VA Teaching Company. *Understanding the human body: An introduction to anatomy and physiology*.
Films for the Humanities and Sciences. *The virtual body*.
Warner Home Video. *The incredible human body*.
Cambridge Educational (Firm). *Human body systems at work*.
Cerebellum Corporation. *The anatomically correct world of anatomy*.
Films for the Humanities (Firm). *The new living body*.
HSTN. *Basic human anatomy*.
Macpherson, Peter. *The body atlas*.
Goldcrest Films and Television. *The living body*.
Interactive Physiology 9-system suite.
Cerebellum Corporation. *Anatomy*.
Karen Goodman. *The incredible human body*.
Marshall, E. G. *National geographic: The incredible human machine*.
www.you.tube for many short videos on the human body.

Related Animations Found in APR—Module 1—Body Orientation

Homeostasis: Thermoregulation

Related Animations Found Under Presentation Tools

Blood sugar regulation
Homeostasis: Introduction
Homeostasis: Digestion blood glucose
Homeostasis: Hypoglycemic condition
Homeostasis: Homeostasis of blood glucose
Positive and negative feedback

CHAPTER 2: Atoms, Ions, and Molecules

CHAPTER OVERVIEW

This chapter is designed to help students understand the chemical level of organization. Atoms and molecules form the basis of human anatomical structures and physiologic processes; thus, an understanding of this level of organization is very important. The chapter presents certain concepts in both inorganic chemistry and organic chemistry. It describes the chemical level of organization, all the way from the atom to the macromolecule.

The atom is discussed in terms of its construct. Various types of chemical bonds are introduced along with certain chemical properties associated with each type. The water molecule is presented along with water's properties. An introduction to acids, bases, pH, and buffers is given in this chapter. Macromolecular structure and properties of carbohydrates, lipids, proteins, and nucleic acids are presented and discussed. All these chemical structures are presented in a confluent manner, allowing students to see interrelationships.

KEY POINTS TO EMPHASIZE WHEN TEACHING BIOLOGICAL CHEMISTRY

An instructional understanding: Most students taking an introductory course in human anatomy and physiology have difficulty understanding the chemical level of organization, particularly those who have not taken a good previous general biology or chemistry course. A basic understanding of atoms and their subatomic particles is important to an understanding of molecules and macromolecules found in the human body. Many students taking human anatomy and physiology are entering health care fields. It is important for these students and the others to understand the function and structure of the four basic macromolecules: carbohydrates, lipids, proteins, and nucleic acids. Some of the students will have to take additional courses in biology such as microbiology, nutrition, and pathophysiology; thus, it is particularly important for them to obtain a firm foundation in biochemistry.

1. Explain to the student that **biological chemistry** is sometimes difficult to understand unless the student has taken a previous course that has a chemistry component.
2. As often as possible, show practical applications of biological chemistry to the human body, particularly in respect to physiological processes and disease processes.
3. Define **chemistry** and how it relates to matter. For example, chemistry is the scientific study of matter.
4. Define **matter.**
    a. Define and discuss **mass** and its relationship to matter.
    b. Discuss how **weight** differs from mass.
5. Discuss the **atom** and how matter is related to it.
6. Define and discuss an **element** and how the atom relates to it.
    a. Discuss the number of naturally occurring elements.
    b. Discuss the major, lesser, and trace elements in the human body.

c. Show and discuss the **periodic table.**

7. Examine the structure and components of an atom.
   a. Discuss the size, charge, and location of the **neutrons, protons,** and **electrons** in an atom.
   b. Discuss **"atomic mass unit"** and its relationship to a **"Dalton."**
   c. Discuss the **chemical symbol.**
   d. Explain the **atomic mass** and **atomic number.**
   e. Explain how to determine the number of protons, neutrons, and electrons in an atom.
   f. Show and explain the atomic structure in terms of the nucleus components (neutrons and protons) and the electron shells.
8. Define and discuss an **isotope.**
   a. Discuss alterations in neutron number and atomic mass in an isotope.
   b. Explain the isotope in terms of radiation.
   c. Define and discuss a **radioisotope.**
   d. Explain the **physical half-life** of a radioisotope.
   e. Explain the **biological half-life** of a radioisotope.
   f. Discuss the radioisotope's importance in medical imaging.
9. Define and discuss an **ion.**
   a. Explain some of the physiological roles of ions in the body.
   b. Discuss ions in terms of electron number and charge.
   c. Define a **cation** and **anion.**
   d. Discuss **polyatomic ions.**
   e. Discuss how to use the periodic chart to predict the charge on an ion.
   f. Give examples of some of the ions in the body.
   g. Explain how an ion relates to an electrolyte.
10. Define and discuss the **ionic chemical bond.**
    a. Discuss why an ionic chemical bond can form between certain atoms.
    b. Discuss the electron's role in chemical bonding.
    c. Discuss a **salt** in terms of ionic bonding.
    d. Discuss **ionic compounds.**
11. Show and discuss types of chemical formulas.
    a. Discuss and show examples of a **molecular formula.**
    b. Discuss and show examples of a **structural formula** and how it differs from a molecular formula.
    c. Explain how a molecule can have the same molecular formula but differ in the structural formula, thus forming an **isotope**.
    d. Discuss the physiological importance of the various types of **isomers.**
12. Define and discuss the **covalent bond.**
    a. Discuss why a covalent bond can form between certain atoms.
    b. Explain the difference between an **ionic bond** and a covalent bond.
    c. Explain the electron's role in a covalent bond and how this role differs in an ionic bond.
    d. Discuss the number **(single, double, triple) of covalent bonds** that can form between atoms and why.
    e. Explain how carbon forms covalently bonded chains, termed the carbon skeleton.
    f. Explain nonpolar covalent bonding and polar covalent bonding.

g. Discuss the properties and chemical behavior of polar covalent molecules and nonpolar covalent molecules.
h. Explain the structure of an **amphipathic molecule.**
i. Give examples of the physiologic roles of amphipathic molecules in the human body.
j. Define and the discuss **electronegativity,** in terms of chemical bonding.

13. Discuss intermolecular attractions.
    a. Compare and contrast the ionic chemical bond and covalent bond in regard to intermolecular attractions.
    b. Define and discuss **hydrogen bonding,** especially in terms of its importance to water.
    c. Define and discuss **hydrophobic interactions.**
    d. Define **van der Waals forces.**
14. Discuss water in terms of why is it so important to biological systems.
    a. Show and discuss the molecular structure of water.
    b. Repeat the discussion on the polar covalent bonding in water molecules, in terms of its importance to the chemical behavior of water.
    c. Repeat the discussion on the hydrogen bonding between water molecules, in terms of its importance to the chemical behavior of water.
    d. Discuss the importance of these two types of bonds in relation to the properties of water.
    e. Discuss the liquid, gas, and solid phase of water and how water can transform between the three phases.
    f. Discuss the transport, lubricant, cushioning, and excretion functions of water and how the two types of chemical bonds enable water to perform these functions.
    g. Explain how hydrogen bonding results in **water's adhesive** and **cohesive nature.**
    h. Explain the physiological importance of water's cohesive and adhesive nature.
    i. Define temperature, specific heat, and heat of vaporization and how it relates to water.
    j. Discuss the reason for the tremendous solvent ability of water.
    k. Discuss the types of substances that dissolve in water and the substances that do not dissolve, explaining the rationale for both actions.
    l. Discuss the concept of a **"hydration shell."**
    m. Discuss and define dissociation of molecules in water.
    n. Define **electrolytes** and **nonelectrolytes** and how water relates to these substances.
    o. Repeat the discussion of nonpolar molecules, but this time in reference to nonsolubility in water.
    p. Repeat the discussion of amphipathic molecules, but this time in terms of partial solubility in water.
15. Discuss acidic and basic solutions.
    a. Define an **acid** and **base.**
    b. Explain how the formation of an acid and base relates to the spontaneous dissociation of water.
    c. Explain how acids and bases are formed.
    d. Discuss **pH** in terms of its mathematical concept.
    e. Discuss how pH measures acidity and basicity.
    f. Show and discuss the pH scale in terms of acidic values, basic values, and neutral values.
    g. Discuss the pH of certain foods and human body fluids.
    h. Use outside sources to discuss the Henderson-Hasselbach pH equation used in biochemistry.
    i. Define a **pH buffer** and how it is formed.
    j. Discuss the role of pH buffers in the body.
16. Discuss the three types of **chemical mixtures.**
    a. Define and discuss the properties of a **suspension.**

b. Define and discuss the properties of a **colloid.**
c. Define and discuss the properties of a **solution.**
d. Give examples of all three mixtures in the human body.
e. Discuss the homogenous nature of a solution.

17. Discuss measurements of solute concentrations.
    a. Discuss the **mass/volume** measurement of solutes, giving examples like that of the concentration of glucose in the blood.
    b. Define and discuss a **mole.**
    c. Define and discuss **molecular mass.**
    d. Discuss how the mole concept is important in the determination of solute concentrations.
    e. Define and discuss **molarity.**
    f. Define and discuss **molality.**
    g. Compare and contrast molarity and molality.
    h. Define and discuss an **osmole.**
    i. Define and discuss **osmolarity.**
    j. Define and discuss **osmolality.**
    k. Compare and contrast osmolality and osmolarity.
18. Discuss general concepts concerning biological macromolecules.
    a. Define **organic chemistry** and discuss how it differs from **inorganic chemistry.**
    b. Repeat the discussion of why carbon is the basis of organic chemistry, again mentioning the carbon skeleton.
    c. Explain the fact that all organic compounds contain carbon, but the compound must also contain hydrogen, thus a hydrocarbon. Carbon dioxide can be used as an example, since it contains carbon but not hydrogen, thus it is not organic.
    d. Discuss certain commonalities among biological macromolecules such as the monomer to polymer relationship, dehydration synthesis, and hydrolysis decomposition.
    e. Discuss the different types of functional groups found in biological macromolecules, explaining their respective chemical properties.
19. Discuss **lipids.**
    a. Discuss the difference between a **saturated** fatty acid and an **unsaturated** one.
    b. Define and show the structure of a triglyceride.
    c. Discuss how **triglycerides** are formed in the human body.
    d. Explain the anatomical and physiological functions of triglycerides in the human body.
    e. Define and show the structure of a **phospholipid.**
    f. Explain the physiological functions of phospholipids in the human body.
    g. Define and show the structure of a **steroid.**
    h. Explain the physiological functions of steroids in the human body.
    i. Define and show the structure of an **eicosanoid.**
    j. Explain the physiological functions of eicosanoids in the human body.
    k. Discuss some of the other lipids, like **glycolipids** and the fat soluble vitamins.
20. Discuss **carbohydrates.**
    a. Discuss the reason for the carbohydrate name: a hydrated carbon.
    b. Define and show the structure of a **monosaccharide.**
    c. Discuss the physiological importance of certain monosaccharides.

d. Discuss some of the **hexose monosaccharide isomers** such as **glucose, fructose,** and **galactose.**
e. Discuss the two main **pentose monosaccharides: ribose and deoxyribose**.
f. Define and show the structure of a **disaccharide.**
g. Discuss the physiological importance of certain disaccharides such as **lactose, sucrose,** and **maltose.**
h. Define and show the structure of a **polysaccharide.**
i. Discuss the physiological importance of certain polysaccharides, especially that of **glycogen.**
j. Discuss **glycogenesis** and **glycogenolysis.**

21. Discuss the nucleic acids.
    a. Define a **nucleic acid.**
    b. Define and show the composition and structure of the **monomeric unit** of the nucleic acids, the nucleotide.
    c. Discuss the structure of the two general classes of nitrogenous bases: **purine** and **pyrimidine.**
    d. Discuss and show the structure of the two purine nitrogenous bases: **adenine** and **guanine.**
    e. Discuss and show the structure of the three pyrimidine nitrogenous bases: **cytosine, uracil,** and **thymine.**
    f. Discuss and show how nucleotides covalently bond to form the nucleic acid polymers: **deoxyribonucleic acid (DNA)** and **ribonucleic acid (RNA).**
    g. Discuss and show the structure of DNA.
    h. Discuss and show the structure of RNA.
    i. Discuss the function and show the structure of another nucleotide, **adenosine triphosphate,** termed **ATP.**
    j. Discuss the function and show the structures of the nucleotides: **nicotinamide adenine dinucleotide (NAD)** and **flavin adenine dinucleotide (FAD).**
22. Discuss the proteins.
    a. Define a **protein.**
    b. Discuss seven functions of proteins: enzyme, defense, transport, support, movement, regulation, and storage.
    c. Define and show the structure of the monomeric unit of a protein, the **amino acid**.
    d. Discuss and show the structure of the 20 naturally occurring amino acids.
    e. Explain the role of the **carboxyl group** in an amino acid.
    f. Explain the role of the **amine group** in an amino acid.
    g. Explain that the differences in both structure and chemical behavior among the amino acids are based on the types of **R groups**.
    h. Discuss and show structures of nonpolar amino acids, polar amino acids, charged amino acids, and amino acids with special functions.
    i. Explain how amino acids use **dehydration synthesis** to form covalent bonds, known as peptide bonds, to form a polymer.
    j. Define the various polymer terms used when amino acids covalently bond together: dipeptide, oligopeptide, polypeptide, and protein.
    k. Define the term **glycoprotein.**

l. Discuss the fact that protein molecular shape is paramount to its functioning.
m. Discuss the conditions that cause a protein to bend out of shape, termed **denaturation.**
n. Define and discuss the **primary structure** of a protein.
o. Discuss how the primary structure, linear sequence of amino acids, determines the three-dimensional **conformation** of a protein.
p. Define and discuss the **secondary structure** of a protein, reiterating how the primary structure is primarily responsible for determining the secondary structure.
q. Define and discuss the **tertiary structure** of a protein, reiterating how the primary structure is primarily responsible for determining the tertiary structure.
r. Define and discuss the **quaternary structure** of a protein, reiterating how the primary structure is primarily responsible for determining the quaternary structure.
s. Discuss the role of **chaperone proteins** in the folding of a protein.

ADDITIONAL TOPICS FOR DISCUSSION

1. Explain and discuss the various types of formulas and models: empirical formula, molecular formula, structural formula, and molecular models.
2. Explain and discuss optical isomerism, in terms of cis and trans, noting its importance in nutrition.
3. Explain and discuss the types of covalent bonding.
4. Discuss why carbon is the basic element in biological systems.
5. Discuss the relative strengths of acids and bases.
6. Discuss pH using the Henderson-Hesselbach equation.
7. Discuss the nutritional and physiological importance of certain plant polysaccharides such as cellulose and amylose.
8. Discuss the structure of various fatty acids.
9. Discuss the nutritional and physiologic importance of the omega fatty acids.
10. Discuss some of the problems encountered when there are errors in the primary structure of a protein.

SUGGESTED CHAPTER OUTLINE

2.1 Atomic Structure: The simplest level of organization is composed of atoms, ions, and molecules. (pp. 32–35)

A. Matter, Atoms, Elements, and the Periodic Table (p. 33)
   1. The human body is composed of matter, defined as a substance that has mass and occupies space.
   2. Matter is present in the human body in three forms: solid, liquid, and gas.
   3. All matter is composed of atoms.
   4. An atom is the smallest particle that exhibits the chemical properties of an element.
   5. There are 92 naturally occurring elements, with hydrogen being the smallest and uranium the largest and heaviest.

6. Technical advances in chemistry and physics have resulted in the ability to produce "ultraheavy" elements that are larger than uranium.
7. All elements are organized into a chart form in the periodic table of elements. (Figure 2.1a, p. 33)
8. Elements are grouped into major, lesser, and trace elements based on the percentage each composes by weight in the human body.
9. Major elements comprise almost 99% and minor elements less than 1%.
10. Only 12 elements occur in living organisms in greater than trace amounts: oxygen, carbon, hydrogen, nitrogen, calcium, phosphorus, sulfur, potassium, sodium, chlorine, magnesium, and iron. (Figure 2.1b, p. 33
11. Atoms are composed of three subatomic particles: protons, neutrons, and electrons. (Figure 2.2, p. 33)
12. Two major criteria differentiate subatomic particles—namely, mass and charge.
13. The mass of an atom is expressed as the atomic mass unit (amu) of dalton.
14. Neutrons are uncharged, having a mass of 1 amu.
15. Protons have a positive charge, also having a mass of 1 amu.
16. Neutrons and protons are located in the atomic nucleus.
17. The electrons have a negative charge, having a mass of 1/800th the mass of a proton or neutron.
18. Electrons are located at varying distances from the nucleus in regions called orbitals or shells, often depicted as either an electron cloud or discrete energy levels (shell model).
19. Elements differ in subatomic particles, and the periodic table can be used to determine the number of these subatomic particles.
20. The periodic table shows an element's symbol, atomic number, and average atomic mass.
21. A unique chemical symbol is assigned to each element.
22. The atomic number of an element indicates the number of protons in an atom.
23. The average atomic mass indicates the mass of both protons and neutrons in the atomic nucleus, and it reflects the "heaviness" of an element's atoms relative to atoms of other elements.
24. The number of protons in an atom is the atomic number.
25. The number of neutrons can be determined by subtracting the atomic number from the atomic mass.
26. The number of electrons is the same as the atomic number because all atoms are neutral.
27. Shells of electrons surround the atomic nucleus, and each shell has a given energy level.
28. Each shell can only hold a limited number of electrons, with the innermost shell holding up to two electrons, and the second shell holding up to eight electrons.
29. All subsequent shells also house eight electrons, but some subsequent shells hold more than eight.
30. Electrons fill the shells from the shells closest to the nucleus first and then move outward, shell by shell.

B. Isotopes (p. 34); Figure 2.3 (p. 34)

1. Isotopes are different atoms of the same element that have the same number of protons and electrons but differ in the number of neutrons.
2. Isotopes exhibit essentially identical chemical characteristics but have a different atomic mass.
3. Carbon exists in three isotopes: carbon-12, carbon-13, and carbon-14.
4. All the carbon isotopes have six protons in their nuclei; however, carbon-12 has six neutrons, carbon-13 has seven neutrons, and carbon-14 has eight neutrons.
5. Some isotopes are referred to as radioisotopes, in that they are unstable due to having an excess number of neutrons.
6. Radioisotopes usually lose nuclear components in the form of high-energy radiation that includes alpha particles, beta particles, or gamma rays as they decay or break down to a more stable isotope.
7. The time it takes for 50% of the radioisotope to become stable is its physical half-life.
8. The time it takes for half of the radioactive material (e.g., from a medical test using radioactive contrast material) to be eliminated from the body is the biological half-life.
9. Clinical View—Medical Imaging of the Thyroid Gland (p. 35)—radioisotopes can be used for diagnosis as well as treatment of certain diseases such as thyroid disease. Scintigraphy is the nuclear medicine imaging technique used to assess metabolic activity using radioactive tracers.

C. Chemical Stability and the Octet Rule (pp. 34−35); Figure 2.4 (p. 35)

1. The periodic table is organized into horizontally across the table based on atomic number, and it is organized into columns based on electrons in the outer shell, or what is referred to as the valence shell.
2. Each consecutive column, IA–VIIIA, has the same number of electrons in its valence shell, as represented by the numeral at the top of the column.
3. For example, in Column IIA, all the elements in the column have two electrons in their valence shells.
4. Atoms that have a completely filled valence shell of either two or eight electrons are stable or inert and thus do not typically combine with other elements.
5. Elements that do not have a filled valence shell tend to lose, gain, or share electrons to obtain a complete outer shell and are chemically active.
6. The tendency to fill the valence shell is termed the octet rule.

2.2 Ions and Ionic Compounds: The body is composed mostly of compounds. (pp. 36–38)

A. Ions (pp. 36–37)

1. Ions are atoms or groups of atoms with either a positive charge or a negative charge and are produced from the loss or gain of an electron or electrons.
2. Whether an atom will lose or gain electrons depends on which action will provide it with a complete valence shell.
3. When an atom loses one or more electrons, it becomes positively charged and called a cation.
4. When an atom gains one or more electrons, it becomes negatively charged and called an anion.

5. When two or more atoms complex together and become ions, they are termed polyatomic ion.
6. The periodic table can be used to predict whether an atom will become a cation or an anion and how many electrons will be lost or gained to attain the octet.
7. Usually, elements on the left side of the periodic chart lose electrons, thus becoming cations, and elements on the right side of the chart gain electrons, thus becoming anions.
8. Certain ions have important physiological functions in the body. (Table 2.1, p. 36)
9. Ions, including the common ones found in the body, function as electrolytes, which are substances that conduct an electric current when dissolved in water.
10. Optimal health requires electrolyte balance, which is maintaining homeostatic blood levels of the different ions.
11. An electrolyte imbalance occurs when blood concentrations are either too high or too low. This can lead to disease and even death.

B. Ionic Bonds (pp. 37−38)

1. Positively charged cations and negatively charged anions may bind together by electrostatic interactions called ionic bonds.
2. The structures formed are salts.
3. A classic example is when table salt is formed from the bonding of metallic atoms of sodium with nonmetallic atoms of chlorine. (Figure 2.5, p. 37)
4. In this example, the sodium atom donates one outer shell electron to a chlorine atom.
5. After donating the electron, the sodium atom becomes a cation (Na^+) and the chlorine atom becomes an anion (Cl^-).
6. The positively and negatively charged ions then attract each other in amounts so that the salt is neutral.
7. The chemical formula for an ionic compound represents the atoms present and how many are needed for electrical neutrality. Examples NaCl (1:1 ratio), $MgCl_2$ (1:2 ratio), $Ca_3(PO_4)_2$ (3:2 ratio).

2.3 Covalent Bonding, Molecules, and Molecular Compounds: Instead of donating or gaining electrons to form ionic compounds, atoms also have the possibility of reaching stability by sharing electrons. (pp. 38–42)

A. Chemical Formulas: Molecular and Structural (pp. 38–39)

1. The sharing of electrons between atoms results in a covalently bonded molecule.
2. Most molecules are composed of two or more different elements and are called molecular compounds.
3. The chemical constituents of a molecule and their actual numbers are represented using a molecular formula.
4. The structural formula of a molecule is complementary to its molecular formula and exhibits not only the number and types of atoms but also their arrangements within the molecule.
5. Structural formulas provide a means for differentiating isomers, which are molecules composed of the same number and kind of elements but arranged differently in space.
6. Isomers may have very different properties from one another—therefore, structural formulas are an important piece of chemical information. (Figure 2.6, p. 38)

B. Covalent Bonds (pp. 39–41)

1. The bond that is formed when atoms share electrons is a covalent bond.
2. Covalent bonding occurs when both atoms require electrons to become stable.
3. This bonding takes place when the participating atoms that form the chemical bond have four, five, six, or seven electrons in the outer shell.
4. The most common elements of the human body that form covalent bonds are oxygen, carbon, hydrogen, and nitrogen.
5. The number of covalent bonds formed by an atom may be determined by examining the number of electrons needed to complete the outer shell.
6. Atoms of elements that can form more than one covalent bond may do so through combinations of single, double, or triple covalent bonds.
7. A single covalent bond is one pair of electrons shared between two atoms. (Figure 2.7a, p. 39)
8. A double covalent bond is two pairs of electrons shared between two atoms. (Figure 2.7b, p. 39)
9. A triple covalent bond is three pairs of electrons shared between two atoms. (Figure 2.7c, p. 39)
10. Numerous carbon atoms are sometimes bonded together to form a "carbon skeleton."
11. Three possible arrangements of the carbon skeleton may occur: a straight chain, branched chain, or a ring. (Figure 2.9, p. 40)
12. Atoms share electrons in a covalent bond either equally or unequally between the atoms.
13. How the atoms share the electrons between them is determined by the relative attraction each atom has for electrons, a concept referred to as electronegativity.
14. Different types of atoms have varying degrees of electronegativity, or attraction for electrons, and thus may share the electrons unequally, resulting in what is termed a polar covalent bond.
15. If the atoms are the same or have very close electronegativities, they share the electrons equally, a nonpolar covalent bond is formed.
16. As a general rule, electronegativity increases both from left to right across a row of the periodic table and from bottom to the top of a column.
17. The more protons in the nucleus of an atom, the greater the pull on shared electrons, while more electron shells will decrease the pull.
18. For the four most common elements in the body, the order of electronegativity from least to greatest is hydrogen, carbon, nitrogen, and oxygen.
19. When a bond is nonpolar, the shared electrons spend equal amounts of time around each atom.
20. When a bond is polar, the shared electrons are more strongly attracted to the more electronegative atom and spend more time circulating around that atom. This causes the more electronegative atom to develop a partial negative charge (δ-).
21. The atom that is more electropositive develops a partial positive charge (δ+) because the shared electrons spend less time in orbit around that atom.
22. These polar covalent bonds act like magnets with opposite poles.

C. Nonpolar, Polar, and Amphipathic Molecules (pp. 41−42)

1. If the atoms share the electrons equally, a nonpolar covalent bond is formed. This will form a nonpolar molecule.
2. Nonpolar molecules in the body are formed predominantly by covalent bonding between the same elements and between carbon and hydrogen. (Figure 2.10a, p. 42)
3. Polar molecules are formed by polar covalent bonding between different elements. (Figure 2.10b, p. 42)
4. If a molecule has polar covalent bonds but is symmetrically arranged, the resulting molecule will be nonpolar. (Figure 2.8a and b, p. 40)
5. If the polar bonds are not symmetrically arranged, the resulting molecule will be polar.
4. Sometimes a molecule is large enough that it can have one major part that is nonpolar and another part that is polar, resulting in a molecule termed an amphipathic molecule.

D. Intermolecular Attractions (p. 41–42)
1. Molecules sometimes have weak chemical attractions to other molecules, called intermolecular attractions.
2. One important intermolecular attraction is termed a hydrogen bond, which occurs between polar molecules.
3. A hydrogen bond is a weak attraction between a partially positive hydrogen atom within a molecule and a partially negative atom (oxygen or nitrogen) within another molecule. (Figure 2.11, p. 42)
4. A second type of force occurs when electrons orbiting the nucleus of an atom of a nonpolar molecule are for a brief instant distributed unequally, causing one portion of the atom to be slightly negative and one end slightly positive.
5. Nonpolar atoms with an unequal charge distribution cause neighboring atoms to perform similarly, leading to opposition of charges that cause weak intermolecular attractions
6. Hydrophobic interactions are a type of intermolecular attraction between nonpolar molecules when placed in water.
7. When a molecule is large, intermolecular type forces can occur between different parts of that molecule and are called intramolecular attractions.
8. Intermolecular and intramolecular attractions are important in establishing the three-dimensional shapes of complex molecules like proteins and DNA, as well as temporary binding between molecules such as a hormone to its protein receptor.

2.4 Molecular Structure of Water and the Properties of Water: Water is the substance that comprises approximately two third of the human body by weight. (pp. 43–46)

A. Molecular Structure of Water (p. 43)
1. Chemist classify molecules into two broad categories: organic molecules and inorganic molecules.
2. Organic molecules are defined as molecules that contain carbon, which are (or have been) components of living organisms, such as glucose, protein, and triglycerides.
3. Inorganic molecules are all the other molecules that are not organic, such as water, salts, and others.
4. Water is a polar molecule composed of one oxygen atom bonded to two hydrogen atoms (H_2O).

5. The polar nature of water is due to the oxygen atom being more electronegative than the hydrogen atom, thus pulling the electrons unequally.
6. Every water molecule has the ability to form four hydrogen bonds with adjacent water molecules. (Figure 2.12, p. 43)

B. Properties of Water (pp. 43–44)
1. Water is present in three phases, depending upon the temperature: a gas (water vapor), a liquid (water), and a solid (ice).
2. Water has several functions in the human body: transport, lubricate, cushion, and excrete wastes.
3. Cohesion is the attraction between water molecules due to hydrogen bonding between the water molecules.
4. Surface tension is the inward pulling of cohesive forces at the surface of water due to water at the surface only being able to form three hydrogen bonds rather than the four formed by water in the internal liquid.
5. Adhesion is the attraction between water molecules and a substance other than water, as a result of water forming hydrogen bonds with molecules of the other substance.
6. Temperature is a measure of the kinetic energy, or random movement, of atoms or molecules within a substance.
7. The relationship between temperature and kinetic energy is direct—the temperature is higher when the kinetic energy is greater.
8. Specific heat is the amount of energy required to increase the temperature of 1 g of a substance 1°C.
9. Water has a very high specific heat as a result of the need to break hydrogen bonds in water to raise its temperature.
10. Heat of vaporization is the heat required for the release of molecules from a liquid phase into a gaseous phase for 1 g of a substance.
11. Water has a high heat of vaporization as a result of the need to break hydrogen bonds to release water from the liquid into the gaseous phase.
12. Concept Overview—Water's Roles in the Body, Figure 2.14 (p. 47)

C. Water as the Universal Solvent (pp. 44−46); Figure 2.13 (p. 45)
1. Water is the solvent of the body, and substances that dissolve in water are called solutes.
2. Many substances dissolve in water, but not all.
3. The chemical properties of a substance (whether it is polar, charged, nonpolar, or amphipathic) determine how it interacts with water.
4. Since water is polar, substances that can dissolve in it are either polar or charged, such as ions.
5. Substances that can dissolve in water are called hydrophilic (water loving).
6. Substances that dissolve in water are surrounded by many water molecules, known as a hydration shell.
7. Some substances dissolve in water but do not remain intact, thus they break apart: dissociate.
8. Dissociation in water occurs with substances that have ionic bonding.
9. Acids and bases dissociate in water.

10. Substances that both dissolve and dissociate in water, such as salts, acids, and bases, can readily conduct an electric current; thus, they are called electrolytes.
11. Substances that dissolve in water but do not dissociate are nonelectrolytes—do not conduct a current.
11. Hydrophobic (water fearing) substances do not dissolve in water because these substances are not charged (nonpolar).
12. The interaction between the molecules of the "excluded" nonpolar excluded substance is termed hydrophobic interaction because it appears these molecules are avoiding water.
14. Amphipathic molecules have both polar and nonpolar regions.
15. Amphipathic molecules partially dissolve in water due to the polar region seeking water and the nonpolar region avoiding water.
16. Certain molecules (phospholipids) in the cell membrane are amphipathic.

2.5 Acidic and Basic Solutions, pH, and Buffers: Acidic and basic solutions occur when an acid or base is added to water. (pp. 46–49)

A. Water: A Neutral Solvent (pp. 46–48)
   1. Water can spontaneously dissociate a result of the covalent chemical bond between oxygen and either of the two hydrogen atoms in a water molecule spontaneously breaking apart at a low rate, about 10^{-7} ions per liter.
   2. When a hydrogen ion transfers to a water molecule, giving it an extra hydrogen ion (H^+), it is represented as H_30^+ and termed the hydronium ion.
   3. When a water molecule loses a hydrogen ion, it is termed a hydroxide ion and represented as OH^-.
   4. Water is neutral in that it has as many positively charged hydronium ions as it does negatively charged hydroxide ions.

B. Acids and Bases (p. 46)
   1. An acid is a substance that dissociates in water to produce an H^+ and an anion; thus, it is also called a proton donor.
   2. Acid strength is determined by the degree of dissociation; a strong acid produces more hydrogen ions, while a weak acid produces fewer hydrogen ions in solution.
   3. A base accepts H^+ when added to a solution; thus, it is termed a proton acceptor.
   4. Strong bases dissociate to a greater extent and can accept more H^+, while a weak acid binds to fewer H^+.

C. pH, Neutralization, and the Action of Buffers (pp. 46–48)
   1. The pH of a solution is a measure of the relative amounts of H^+ and is expressed as a number between 0 and 14. (Figure 2.15, p. 48)
   2. Pure water and other solutions that have equal concentrations of H^+ and OH^- are neutral and have a pH of 7.
   3. Solutions with a pH below 7 are acidic, and solutions with a pH above 7 are basic, or alkaline.
   4. The higher the hydrogen ion concentration, the lower the pH, and the lower the hydrogen ion concentration, the higher the number.
   5. The pH scale represents a 10-fold change in H^+ concentration between two adjacent whole number pH values. A pH of 2 is 10 times more acidic than a pH of 3; a pH of 10 is 10 times less acidic than a pH of 9.

6. Neutralization occurs when a solution that is either acidic or basic is returned to neutral (pH 7).
7. A buffer is a single substance, or an associated group of substances, that functions to help prevent pH changes if either excess acid or base is added.

2.6 Water Mixtures: Mixtures are formed from the combining or "mixing" of two or more substances. (pp. 49–51)

A. Categories of Water Mixtures (pp. 49–50); Figure 2.16 (p. 49)
1. Water mixtures are placed into three categories based on the relative size of the substance mixed with water and include suspensions, colloids, and solutions.
2. A suspension, like sand in water, is formed when a material that is larger than 100 nm particulate size is mixed with water, resulting in a mixture that does not remain mixed unless it remains in motion.
3. Blood cells within the plasma (the liquid portion) form a suspension.
4. A colloid is a mixture of smaller particles within water, where the size ranges from 1 to 100 nanometers. May appear milky and scatters light.
5. Colloids in the body include semifluid cell cytosol and proteins within plasma.
6. A solution is a homogeneous mixture in which the particulate size of the substance is smaller than 1 nanometer, and it dissolves in water.
7. In a solution, the substance being dissolved is the solute and the substance doing the dissolving is the solvent.
8. In a solution, the solute is not visible, do not scatter light, and do not settle.
9. Blood plasma is an example of a solution in the body.
7. An emulsion is a type of colloid composed specifically of water and a nonpolar (hydrophobic) liquid substance such as vegetable oil in water; breast milk is an example of an emulsion.

B. Expressions of Solute Concentration (pp. 50–51), Table 2.2 (p. 50)
1. The amount of solute dissolved in a solution determines the concentration of a solution and may be expressed in several ways: mass/volume, mass/volume percent, molarity, and molality.
2. Mass/volume is grams of solute per volume of solution.
3. Mass/volume percentage is grams of solute per 100 ml of solution.
4. Molarity is a measure of number of moles per liter of solution.
5. Molality is the moles per kilogram of solvent.
6. An osmole (osm) is another means of expressing concentration, which reflects whether a substance either dissolves, or dissolves and dissociates, when placed in a solution (i.e., whether it is a nonelectrolyte or electrolyte).
7. An osmole measures the number of osmotic active particles in a solution.
8. Osmoles can be expressed as either osmolarity or osmolality.
9. Osmolarity is the number of particles in 1 l of solution, whereas osmolality is the number of particles in 1 kg of water.
10. A mole is the mass in grams that is equal to either the atomic mass of an element or the molecular mass of a compound.
11. One mole contains 6.02×10^{23} atoms, ions, or molecules.

2.7 Biological Macromolecules: Four classes of organic biological macromolecules (biomolecules) can be distinguished in living organisms: lipids, carbohydrates, nucleic acids, and proteins. (pp. 51–63)

A. General Characteristics (pp. 51–53)

1. Biological macromolecules are large organic molecules that are synthesized by the human body.
2. Biological macromolecules always contain carbon and hydrogen, and generally oxygen; some also contain nitrogen, phosphorus, and sulfur.
3. Organic biological macromolecules have several distinct features: carbon and carbon skeletons, hydrocarbons, and functional groups.
4. Carbon is the central element of biological macromolecules, existing independently, or covalently bonded into a carbon skeleton.
5. Hydrocarbons contain both carbon and hydrogen, covalently bonded together (nonpolar).
6. Functional groups are two or more atoms bonded together, attached to a carbon skeleton, displaying the same specific chemical characteristics, no matter what carbon skeleton they are attached to. Functional groups are polar. (Table 2.3, p. 52)
7. Polymers, present in biological macromolecules, are composed of repeating subunits called monomers.
8. Polymer forms are seen in carbohydrates, proteins, and nucleic acids, but not in lipids.
9. Dehydration synthesis (condensation) is a process that combines monomers to form polymers.
10. Dehydration synthesis involves the removal of a H from one monomer and an OH from another monomer, thus allowing the formation of a covalent bond between the two monomers and resulting in the formation of a water molecule when the H bonds to the OH (H_2O). (Figure 2.17, p. 53)
11. Hydrolysis is a process that splits polymers into monomers by inserting a split water molecule into the polymer, thus breaking the covalent bonding between the two monomers. (Figure 2.17, p. 53)
12. In the process of hydrolysis, water is split into a –H and –OH, the –H is added to one monomeric subunit and the OH is added to the other subunit, resulting in a split covalent bond between the two monomers.

B. Lipids (pp. 53–56)

1. Lipids are a diverse group of macromolecules that do not form polymers and are totally (nonpolar) or partially (amphipathic) insoluble in water.
2. Lipids function as stored energy, components of cell membranes, and hormones.
3. The four primary classes of lipids are triglycerides (neutral fats), phospholipids, steroids, and eicosanoids. (Table 2.4, p. 54)
4. Triglycerides (triacylglycerols) are formed from a glycerol molecule and three fatty acids bonded together.
5. Triglycerides are the most common form of lipids in living things and function in long-term energy storage (adipose tissue) and provide structural support, cushioning, and insulation of the body.

6. A fatty acid is a lipid molecule with generally 14–20 carbons bonded together in a chain, and terminating in an acidic carboxyl functional group. (Figure 2.18, p. 55)
7. If the fatty acid molecule contains a double bond, it is termed unsaturated, and if it does not contain a double bond, it is termed saturated.
8. If the fatty acid has one double bond, it is unsaturated, and if it has more than one, it is polyunsaturated.
9. Triglycerides are a storage form of energy located in fat (adipose) cells.
10. When cells form triglycerides for energy storage, it is termed lipogenesis, and when cells break down triglycerides to release energy, it is termed lipolysis.
11. A phospholipid is amphipathic and has a chemical structure similar to a triglyceride, except the phospholipid molecule contains a polar phosphate functional group.
12. Phospholipids are amphipathic in that they contain a polar head, where the polar phosphate group is positioned, along with two nonpolar tails, where the fatty acids are positioned.
13. Phospholipids are a main component of cell membranes.
14. Steroids are composed predominantly of hydrocarbons arranged in a distinct four multi-ringed structure, three of the rings having six carbons and one ring having five carbons.
15. Steroids differ according to the side chains extending from the rings.
16. Steroids include cholesterol, steroid hormones (e.g., testosterone, estrogen, and progesterone), and bile salts.
17. Eicosanoids are modified 20-carbon fatty acids that are synthesized from phospholipids of plasma membranes.
18. Four classes of eicosanoids are produced and include prostaglandins, thromboxanes, leukotrienes, and prostacyclins.
19. The primary functions of eiconsanoids are in the inflammatory response of the immune system and communication within the nervous system.
20. Glycolipids are lipid molecules with a carbohydrate covalently attached, having functions associated with cell membranes, such as cell binding.
21. Vitamins A, E, and K are lipids known as the fat soluble vitamins.

C. Carbohydrates (pp. 56–57)

1. The term carbohydrate is derived from the fact that a monomer of carbohydrate, termed a monosaccharide, has virtually every carbon hydrated with the equivalent of a water molecule, with a –H and –OH usually attached to each carbon.
2. One monomer of carbohydrate is termed a monosaccharide, two covalently bonded together into one molecule is termed a disaccharide, and several bonded together is a polysaccharide.
3. Glucose, fructose, and galactose are six-carbon monosaccharide isomers, termed hexose sugars. (Figure 2.20a, p. 57)
4. Ribose and deoxyribose are five-carbon monosaccharides, termed pentose sugars, and are found in RNA (ribonucleic acid) and DNA (deoxyribonucleic acid), respectively.
5. Sucrose (table sugar), lactose, and maltose are common disaccharides. (Figure 2.20b, p. 57)

6. Glycogen, the storage carbohydrate in animals, is a polysaccharide, while starch and cellulose (fiber) are plant polysaccharides.
7. Glucose is critical to life processes because it is the primary molecule that provides energy for body cells. The brain uses glucose exclusively for energy.
8. Blood glucose homeostasis is carefully maintained by several hormones and processes that either store or release glucose from storage.
9. Liver and skeletal muscle store excess glucose in the form of glycogen in a process called glycogenesis. (Figure 2.19, p. 56)
10. When blood sugar levels drop, the process of glycogenolysis breaks glycogen back down to glucose.
11. The liver can also make glucose from noncarbohydrate sources through gluconeogenesis.
12. Glycosaminoglycans (GAGs) are attached to proteins to form proteoglycans that are associated with the ground substance of connective tissue.

D. Nucleic Acids (pp. 57–59), Figure 2.21 (p. 58), Table 2.5 (p. 59)

1. Nucleic acids are macromolecules that store and transfer genetic information for protein synthesis and were initially discovered in the cell nucleus.
2. Two classes of nucleic acid are deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).
3. A nucleic acid monomer, known as a nucleotide, is composed of a nitrogenous base, pentose sugar, and phosphate group, covalently bonded together.
4. The pentose sugar in DNA is deoxyribose, and the pentose sugar in RNA is ribose.
5. There are five nitrogenous bases classified as either pyrimidines, which are single-ringed, or purines, which are double-ringed.
6. The nitrogenous bases adenine and thymine are pyrimidines, and cytosine, uracil, and guanine are purines.
7. Deoxyribonucleic acid (DNA) is a double-stranded nucleic acid; it can be found both as components of chromosomes within the cell nucleus and as a circular strand of DNA found in the mitochondria.
8. The nitrogenous bases in DNA are adenine, cytosine, guanine, and thymine; DNA contains no uracil.
9. The DNA double strands are held together by hydrogen bonds between adenine and thymine and between cytosine and guanine that formed complementary base pairs.
9. The nitrogenous bases in RNA are adenine, cytosine, guanine, and uracil; RNA contains no thymine; it is replaced by uracil.
10. RNA is a single-stranded nucleic acid located both within the cell nucleus and within the cytoplasm of the cell.
11. Adenosine triphosphate (ATP) is another nucleotide that is composed of adenine, ribose, and three phosphate groups; it provides chemical energy within the cell. (Figure 2.22, p. 59)
12. Nicotinamide adenine dinucleotide (NAD^+) and flavin adenine dinucleotide (FAD) are nucleotides that participate in the production of ATP in the cell mitochondria.

E. Proteins (pp. 59–67)

1. Proteins are polymers composed of one or more linear strands of amino acid monomers that may number in thousands. (Figure 2.23b, p. 61)

2. Proteins have many functions: enzyme, defense, transport, support, movement, regulation, and storage. (Table 2.6, p. 60)
3. Proteins are composed of 20 different amino acids.
4. An amino acid, the monomeric unit of a protein, is a molecule composed of an acidic carboxyl function group and a basic amine group. (Figure 2.23a, p. 61)
5. The differences between amino acids are due to side-chain structures, termed the R groups.
6. Amino acid chemical properties are determined by the chemical nature of the R group; some amino acids are nonpolar, some polar, some charged, and some have special functions.
7. Amino acids are covalently linked together by a peptide bond, which is a type of covalent bond, found only in amino acid polymers and formed by dehydration synthesis.
8. Two amino acids bonded together into one molecule is termed a dipeptide, 3–20 bonded together is termed an oligopeptide, 21–199 bonded together is termed a polypeptide, and 200 or more is termed a protein.
9. A protein covalently bonded to carbohydrate is termed a glycoprotein; the ABO surface marker on a red blood cell is one example of glycoprotein function.
10. The glycocalx of cells is composed of glycoproteins and glycolipids and is used for identification of "self" cells.

F. Concept Overview, Figure 2.24 (pp. 62–63) reviews the four primary biological macromolecules.

2.8 Protein Structure: Protein structure is paramount to its functioning. (pp. 64–67)

A. Categories of Amino Acids (pp. 64–66), Figure 2.25 (p. 65)

1. Amino acids are organized into four groups based on the chemical characteristics of their R group: nonpolar amino acids, polar amino acids, charged amino acids, and amino acids with special functions.
2. Nonpolar amino acids contain R groups with either hydrogen (glycine) or hydrocarbons (alanine, valine, leucine, isoleucine, phenylalanine, and tryptophan); they tend to group with other nonpolar amino acids by hydrophobic interactions in water.
3. Polar amino acids contain R groups with elements in addition to carbon and hydrogen (e.g., O, N, or S) (serine, threonine, asparagine, glutamine, and tyrosine); they form interactions with other polar molecules and with water.
4. Charged amino acids can either have a negative charge or a positive charge.
5. Negatively charged amino acids, with a negatively charged R group, include glutamic acid and aspartic acid, and those with a positively charged R group include histidine, lysine, and arginine.
6. Charged and polar amino acids are hydrophilic, and their presence increases the solubility of the protein in water.
7. Three amino acids have unique characteristics: proline, cysteine, and methionine.
8. Proline has an R group that attaches to the amino group, forming a ring that bends proteins.

9. Cysteine is an amino acid containing a sulfhydryl group, allowing it to form a disulfide covalent bond (bridge) between the sulfhydryl group of another cysteine amino acid; these disulfide bridges stabilize the construct of a protein.
10. Methionine is always the first amino acid positioned when a protein is synthesized.

B. Amino Acid Sequence and Protein Conformation (pp. 66–67)

1. The structuring of a protein is described on a hierarchical level, having four possible structural levels: primary, secondary, tertiary, and quaternary.
2. The primary structure is the linear sequence of amino acids in the protein. (Figure 2.26a, p. 66)
3. The next three structural levels are responsible for the three-dimensional shape of a protein, known as protein conformation.
4. The more complex structural organizations of a protein are dependent upon intramolecular attractions between the amino acids in the linear sequence (primary structure) for proper folding and maintaining of a protein's conformation.
5. Proteins, known as chaperone proteins, assist in proper protein folding.
6. Four main types of intermolecular and intramolecular interactions contribute to the final conformation of a protein: hydrophobic exclusion, hydrogen bonding, ionic bonding, and disulfide bonds.
7. The primary protein polymer is forced into its initial shape as hydrophobic exclusions "tuck" amino acids with nonpolar R groups into a more central location, limiting their contact with water.
8. Hydrogen bonds form between polar R groups and between amine and carboxylic acid functional groups of closely positioned amino acids.
9. Ionic bonds form between negatively charged and positively charged R groups.
10. Disulfide bonds form between the sulfhydryl groups of two cysteine amino acids.
11. The secondary structure of a protein is a series of repeating patterns within the protein. (Figure 2.26b, p. 66)
12. There are two possible secondary repeating patterns: alpha helix and beta-pleated sheet.
13. An alpha helix pattern is a spiral coiling arrangement of the protein, whereas the beta-pleated sheet is a planar arrangement.
14. The alpha helix gives some elasticity to fibrous proteins that are located in skin or hair.
15. The beta-pleated sheet gives some degree of flexibility to many globular proteins.
16. The tertiary structure of a protein is the final three-dimensional shape exhibited by a completed polypeptide chain. (Figure 2.26c, p. 66)
17. Two categories of proteins, either fibrous or globular, are distinguished by their molecular shape.
18. Globular proteins fold into a compact, often nearly spherical shape such as enzymes, antibodies, and some hormones.
19. Fibrous proteins are extended linear molecules that are constituents of ligaments, tendons, and contractile proteins within muscle cells.
20. The quaternary structure of a protein is present only in those proteins with two or more polypeptide chains; hemoglobin is an example of a protein in the quaternary structure. (Figure 2.26, p. 66)

21. The normal function of a protein may also require a prosthetic group which is a nonprotein structure covalently bonded to a protein; heme in hemoglobin is an example of a prosthetic group.
22. The biological activity of a protein is usually disturbed or terminated when its conformation is changed, termed denaturation.
23. Denaturation occurs when a protein is subjected to a nonoptimal chemical environment, such as improper pH and improper temperature. (Figure 2.27, p. 67)

VISUALS, IN-CLASS DEMONSTRATIONS, AND DISCUSSIONS

1. Using a molecular modeling kit, demonstrate the manipulation of atoms with bonds.
2. Using the VSPER Theory, have students assign geometry, molecular structure, and hybridization to five substances.
3. Using a dart, demonstrate where electrons will fall outside the nucleus. If darts are not an option in your classroom, use the split pea orbitals model.
4. Show the flame test of seven elements and have the students complete the Abigail Freiberger's Flame test demonstration worksheet.
5. Using the SMART Board, demonstrate how images produced by computed tomography (CT) and magnetic resonance imaging (MRI) can be used to estimate an individual's body fat content.
6. One of the problems with discussing the atom is that we cannot see it. To help students overcome this, use nuts and bolts as models to visualize and explain the behavior of atoms.
7. Using the SMART Board, present PowerPoint slides on atoms and molecules and how they form the basis of human anatomical structures and physiological processes.
8. Show the periodic table and discuss the trends of the periodic table.
9. Explain how molecular and structural formulas symbolize the composition of compounds. Discuss the size, charge, and location of the neutrons, protons, and electrons in an atom.
10. Using milk of magnesia, demonstrate acid and bases. Discuss the changes in pH.
11. Demonstrate surface tension of water using a dropper to see how many drops of water can be placed on a clean penny before the dome collapses.
12. Demonstrate osmosis by allowing students to observe the effects of different concentrations of salt solutions on potato cores.
13. Use a bright flashlight to show the Tyndall Effect (scattering of light) through a solution, colloid, and suspension.
14. Look at several food labels to discuss the different types of lipids in foods.
15. Use paper cutout nucleotides to show complementary pairing of A-T and C-G in DNA.
16. Demonstrate how polypeptides may become folded through interactions between the side chains of amino acids.
17. Use an egg (the egg white) to demonstrate denaturing of a protein by heat and adding drops of acid.

18. Use a telephone cord (the twisted one that connected the handheld piece to the base of old landline phones) to demonstrate primary, secondary (alpha helix), and tertiary structures of a protein.
19. Use a homemade paper fan to demonstrate a beta-pleated sheet.
20. Chart the major groups of inorganic chemicals common in cells and chart the functions of each of the chemicals.

Related Media

Museum of Science. *Physical science in action: Atoms and molecules*.
Carolina. *Diffusion and osmosis instructional* [DVD].
School Media Associates. *Overview of the periodic table*.
Museum of Science. *Chemical reaction*.
Museum of Science. *In matter: Atoms, elements, & chemistry. Squibs Vol. 5*.
Ambrose Video. *Atom*.
The University of Maryland and the Educational Film Center. *The world of chemistry*.
Museum of Science. *A matter of state*.
File Transit. *Covalent bonding*.
Museum of Science. *Chemical bonds*.
TMW Media Group. *Chemistry: Lesson 27: Strong acids and bases 1*.
Museum of Science. *Water*.
2.0 File Transit. *Atoms, bonding, and structure*.
Museum of Science. *The proton in chemistry*.
File Transit. *Ionic bonding software*.
Clearvue and SVE, Inc. *Atoms and their electrons*.
Clearvue and SVE, Inc. *Bonding between atoms*.
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TMW Media Group. *Atomic number, mass number and isotopes Part 1*.
TMW Media Group. *Atomic number, mass number and isotopes Part 2*.
TMW Media Group. *Atomic theory of matter: Part 1*.
TMW Media Group. *Atomic theory of matter: Part 2*.
TMW Media Group. *Atomic theory of matter: Part 3*.
TMW Media Group. *Atoms and elements*.
Atomic structure/bonding videos on YouTube
Properties of Water videos on YouTube
Structure and properties of lipids videos on You*Tube*
Structure and properties of carbohydrates on YouTube
Structure and properties of nucleic acids on YouTube
Structure and properties of proteins on YouTube

Related Animations Found in APR—Module 2—Cells and Chemistry

Atomic structure
Bonds
Organic molecules
Electrolytes

Enzymes

Related Animations Found Under Presentation Tools

Carbohydrates structure and function
Fatty acids and their structure
How enzymes work
Protein structure and function
Protein denaturation
What is an enzyme?