Instructor's Guide to Text and Media

Human Anatomy & Physiology

Seventh Edition

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PREFACE

This Instructor's Guide to Text and Media has been updated and revised to accompany *Human Anatomy & Physiology,* Seventh Edition, by Elaine N. Marieb and Katja Hoehn. Each chapter has been outlined in a way that we hope benefits you in your use of the text and instruction of your classes. At the beginning of each chapter is a list of Objectives to guide you in deciding how to focus your teaching. A detailed Suggested Lecture Outline is provided for each chapter to aid you in developing your own course outline. Additionally, there are Cross References that point you to concepts in other chapters of the text to facilitate integration of other information. Each chapter contains Lecture Hints and Activities/Demonstrations that may be beneficial in presenting material in a way that makes it more meaningful for students. There are also Critical Thinking/Discussion Topics, as well as Library Research Topics, to be used in class discussion or as outside assignments that may help your students further understand the lectured material.

A number of resources are listed in the chapters of this instructor's guide that may be useful in making your presentations more engaging or effective. Histology Slides for the Life Sciences, Laboratory Correlations, Multimedia in the Classroom and Lab (including descriptive listings of videos and software as well as online resources for students), and Lecture Enhancement Materials (transparency acetates and Media Manager images) are available to coordinate with your lecture. A Suggested Reading list includes articles relevant to the system covered by the chapter. In addition, Answers to End-of-Chapter Short Essay Questions and Critical Thinking and Clinical Application Questions are provided with page references pointing to the main text.

New to this edition is a list of Online Resources for Students that shows the organization of the Chapter Guide page in both the Anatomy & Physiology Place (www.anatomyandphysiology.com) and MyA&P™ (www.myaandp.com). Each Chapter Guide organizes all the online media resources in one convenient location, with e-book links to each section of *Human Anatomy & Physiology,* Seventh Edition. Both sites provide access to other resources, such as *InterActive Physiology*®, PhysioEx 6.0™, Anatomy 360°, self-study quizzes, anatomy labeling activities, flashcards, a glossary, a new Histology Tutorial, and other study tools to help enhance students' understanding of A&P. For more information, please refer to the media preview section at the very front of your textbook.

Appendix A is a guide to audio-visual distributors and their contact information. Appendix B provides thumbnails of all the textbook images, including art, photos, and tables, organized by chapter. Appendix C contains InterActive Physiology® Exercise Sheets, created by Dr. Shirley Whitescarver and Brian Witz, for use with the *InterActive Physiology*® 9-System Suite. Answers to these Exercise Sheet questions can be found in Appendix D. Finally, Appendix E includes a Correlation Guide between selected review questions from the main text and the A.D.A.M.® Interactive Anatomy (AIA) CD-ROM, version 4.0. This helps students find the most relevant view to help them answer questions that require critical reasoning.

An electronic version of this guide and other instructor supplements are available to download at the Addison Wesley/Benjamin Cummings catalog page. Visit www.aw-bc.com and select instructor resources for *Human Anatomy & Physiology,* Seventh Edition, by Elaine Marieb and Katja Hoehn.

The Internet is a tremendous resource for you and your students to find additional information on A&P topics. For a general listing of A&P websites, search for "anatomy" or "physiology" on search engines such as Google or Yahoo. Here are a few websites that you might find useful, but keep in mind that we cannot guarantee that these links will remain active.

www.medtropolis.com The Virtual Body includes interactive presentations on various body systems, including animations, narrations, and quizzes.

www.nlm.nih.gov The U.S. National Library of Medicine includes general health information as well as the Visible Human Project, which creates anatomical images of the male and female human body.

www.nlm.nih.gov/medlineplus Medline is a health database maintained by the National Institutes of Health's National Library of Medicine.

www.nih.gov The National Institutes of Health is an excellent resource for general health information; a good source of research topics.

www.npac.syr.edu The Northeast Parallel Architectures Center at Syracuse University has created the Visible Human Viewer (based on the Visible Human Project), which allows you to examine a cadaver layer by layer from different views.

Anatomy and physiology are fascinating disciplines that students are always enriched by. We hope that you find this guide a valuable partner in your teaching effort, and that the resources listed within allow you to present an effective and enjoyable learning experience for your students. Comments and suggestions are always welcome. They may be sent care of Benjamin Cummings, 1301 Sansome Street, San Francisco, CA, 94111.

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1 The Human Body: An Orientation

Objectives

An Overview of Anatomy and Physiology

1. Define anatomy and describe the nature of different topics in anatomy.
2. Define physiology and describe the main focus of physiology.
3. Describe the principle of complementarity of structure and function. How does it unite the disciplines of anatomy and physiology?

Levels of Structural Organization

4. Name the different levels of structural organization and describe their relationships with each other.
5. List the organ systems of the body and the major structures within each system.

Maintaining Life

6. Describe the importance of each of the necessary life functions.
7. Describe the survival needs for human life and discuss the importance of each.

Homeostasis

8. Define homeostasis and list the components of a homeostatic control mechanism.
9. Distinguish between negative and positive feedback mechanisms. Describe the mechanics of each and their importance to the maintenance of homeostasis.

The Language of Anatomy

10. Describe the body's position in anatomical position. Why is this position important?
11. Define the directional terms as they relate to the human body.
12. Define the regional terms of the body. Which regions are found within other regions?
13. Identify the body planes and how they relate to sectioning terms and techniques.
14. Describe the body cavities and their relationships to each other. Which cavities are contained within other cavities?
15. Describe the membranes of the ventral cavity and their relationships to each other, the body wall, and the organs they are associated with.
16. Define the abdominopelvic regions and quadrants and describe how they are used by professionals.

Suggested Lecture Outline

I. An Overview of Anatomy and Physiology (pp. 2–3)

A. Anatomy is the study of the structure of body parts and their relationships to each other, and physiology is the study of the function of body parts (p. 2).

B. Topics of Anatomy (pp. 2–3)
   1. Gross (macroscopic) anatomy is the study of structures large enough to be seen with the naked eye.
      a. Regional anatomy is the study of all body structures in a given body region.
      b. Systemic anatomy is the study of all structures in a body system.
      c. Surface anatomy is the study of internal body structures as they relate to the overlying skin.
   2. Microscopic anatomy is the study of structures that are too small to be seen with the naked eye.
      a. Cytology is the study of individual cells.
      b. Histology is the study of tissues.
   3. Developmental anatomy is the study of the change in body structures over the course of a lifetime.
   4. Specialized Branches of Anatomy
      a. Pathological anatomy is the study of structural changes associated with disease.
      b. Radiographic anatomy is the study of internal structures using specialized visualization techniques.
      c. Molecular biology is the study of biological molecules.

C. Topics of Physiology (p. 3)
   1. Physiology has several topics, most of which consider the function of specific organ systems.
   2. Physiology often focuses on cellular and molecular events.

D. Complementarity of Structure and Function (p. 3)
   1. The principle of complementarity of structure and function states that function is dependent on structure, and that the form of a structure relates to its function.

II. Levels of Structural Organization (pp. 3–4)

A. The chemical level is the simplest level of organization (Fig. 1.1).
   1. Atoms, tiny building blocks of matter, combine to form molecules.
   2. Molecules combine in specific ways to form organelles, which are the basic unit of living cells.

B. The cellular level is the smallest unit of life, and varies widely in size and shape according to the cells' function.

C. The tissue level is groups of cells having a common function.

D. The organ level is made up of discrete structures that are composed of at least two groups of tissues that work together to perform a specific function in the body.

E. The organ system level is a group of organs that work closely together to accomplish a specific purpose (Fig. 1.3).

F. The organismal level is the total of all structures working together to promote life.

III. Maintaining Life (pp. 4–8)

A. Necessary Life Functions (pp. 4–8; Fig. 1.2)
   1. Maintaining boundaries allows an organism to maintain separate internal and external environments, or separate internal chemical environments.
   2. Movement allows the organism to travel through the environment, and allows transport of molecules within the organism.
   3. Responsiveness, or irritability, is the ability to detect changes in the internal or external environment and respond to them.
   4. Digestion is the process of breaking down food into molecules that are usable by the body.
   5. Metabolism includes all chemical reactions that occur in the body.
   6. Excretion is the process of removing wastes.
   7. Reproduction is the process of producing more cells or organisms.
   8. Growth is an increase in size in body parts or the whole organism.

B. Survival Needs (p. 8)
   1. Nutrients are consumed chemical substances that are used for energy and cell building.
   2. Oxygen is required by the chemical reactions that release energy from foods.
   3. Water, the most abundant chemical substance in the body, provides an environment for chemical reactions and a fluid medium for secretions and excretions.
   4. Normal body temperature is required for the chemical reactions of the body to occur at the proper rate.
   5. Atmospheric pressure must be within an appropriate range so that proper gas exchange occurs in the lungs.

IV. Homeostasis (pp. 8–12)

A. Homeostasis is the ability of the body to maintain a relatively constant internal environment, regardless of environmental changes (p. 9).

B. Homeostatic Control Mechanisms (pp. 9–12; Figs. 1.4–1.6)
   1. Components
      a. Variable: the regulated factor or event.
      b. Receptor: structure that monitors changes in the environment and sends information to the control center.
      c. Control center: structure that determines the set point for a variable, analyzes input, and coordinates an appropriate response.
      d. Effector: struture that carries out the response directed by the control center.
   2. Negative Feedback Mechanisms
      a. Most homeostatic control mechanisms are negative feedback mechanisms.
      b. A negative feedback mechanism causes the variable to change in a way that opposes the initial change.
      c. Both the nervous system and the endocrine system are important to the maintenance of homeostasis.

d. The goal of negative feedback mechanisms is to prevent sudden, severe changes in the body.

3. Positive Feedback Mechanisms
   a. A positive feedback mechanism causes the variable to change in the same direction as the original change, resulting in a greater deviation from the set point.
   b. Positive feedback mechanisms typically activate events that are self-perpetuating.
   c. Most positive feedback mechanisms are not related to the maintenance of homeostasis.
4. Homeostatic imbalance often results in disease.

V. The Language of Anatomy (pp. 12–22)

A. Anatomical Position and Directional Terms (p. 12; Table 1.1; Fig. 1.7)
   1. Anatomical position is a position in which the body is erect, palms face forward, and thumbs point away from the body.
      a. In anatomical position, right and left refer to the right and left sides of the person viewed.
      b. In anatomy, anatomical position is always assumed, regardless of the actual position of the body.
   2. Directional terms are used to explain exactly where one body part is in relation to another.

B. Regional Terms (pp. 12–14)
   1. There are two fundamental divisions of the body.
      a. The axial region includes the head, neck, and trunk.
      b. The appendicular region consists of the upper and lower limbs.
   2. Regional terms designate specific areas within the axial and appendicular divisions.

C. Body Planes and Sections (p. 15; Fig. 1.8)
   1. Body planes are flat surfaces that lie at right angles to each other.
      a. Sagittal plane: a vertical plane that separates the body into right and left parts.
         i. Median, or midsagittal plane: lies exactly along the body's midline.
         ii. Parasagittal plane: lies offset from the midline.
      b. Frontal plane: a vertical plane that separates the body into anterior and posterior parts.
      c. Transverse, or horizontal, plane: a plane that runs horizontally from right to left, and divides the body into superior and inferior parts.
   2. Sections are cuts made along specific planes.
      a. Transverse section, or cross section, is a cut made along the transverse plane.
      b. Oblique sections are cuts made at angles between the horizontal and vertical planes.

D. Body Cavities and Membranes (pp. 15–19; Figs. 1.9–1.13)
   1. Body cavities are spaces within the body that are closed to the outside and contain the internal organs.

2. The dorsal body cavity is the space that houses the central nervous system, and has two subdivisions: the cranial cavity and the vertebral cavity.
   a. The cranial cavity is within the skull, and houses the brain.
   b. The vertebral, or spinal, cavity is within the vertebral column, and houses the spinal cord.
3. The ventral body cavity is anterior to and larger than the dorsal cavity and has two main subdivisions: the thoracic cavity, and the abdominopelvic cavity.
   a. The thoracic cavity is a superior division of the ventral cavity that is further subdivided into the lateral pleural cavities that surround the lungs.
   b. The thoracic cavity also contains the medial mediastinum, which includes the pericardial cavity surrounding the heart and the space surrounding the other thoracic structures.
4. The ventral body cavity houses the body organs, or viscera.
5. Membranes in the Ventral Body Cavity
   a. Serous membranes, or serosae, cover the inner walls of the ventral cavity and the outer surfaces of organs.
   b. The parietal serosa lines the body cavity walls, and is named for the specific cavities it is associated with.
   c. The visceral serosa covers the outer surfaces of organs, and is named for the specific organs it is associated with.
   d. Serous membranes secrete and are separated by a thin layer of lubrication fluid called serous fluid, which allows organs to slide without friction along cavity walls and between each other.
6. Abdominopelvic Regions and Quadrants
   a. There are nine abdominopelvic regions used primarily by anatomists.
   b. There are four quadrants used primarily by medical personnel.
7. Other Body Cavities
   a. Oral and digestive cavities are continuous cavities that extend from the mouth through the digestive system to the anus.
   b. The nasal cavity is within and posterior to the nose.
   c. The orbital cavities house the eyes.
   d. The middle ear cavities are within the skull just medial to the eardrums, and house the bones that transmit sound vibrations to the inner ears.
   e. Synovial cavities are joint cavities lined with a lubricating fluid-secreting membrane associated with all movable joints.

Cross References

Additional information on the topics covered in Chapter 1 can be found in the chapters listed below.

1. Chapter 2: Basic chemical and physical principles
2. Chapter 3: Cellular level of structural organization
3. Chapter 4: Tissue level of structural organization
4. Chapter 16: Hormonal control as an example of feedback regulation
5. Chapter 22: Organs of the mediastinum
6. Chapter 23: Serous membranes of the abdominal cavity
7. Chapter 28: Example of positive feedback (see Fig. 28.16)

Laboratory Correlations

1. Marieb, E. N. *Human Anatomy & Physiology Laboratory Manual: Cat and Fetal Pig Versions*. Eighth Edition Updates. Benjamin Cummings, 2006.
   Exercise 1: The Language of Anatomy
   Exercise 2: Organ Systems Overview
2. Marieb, E. N. *Human Anatomy & Physiology Laboratory Manual: Main Version.* Seventh Edition Update. Benjamin Cummings, 2006.
   Exercise 1: The Language of Anatomy
   Exercise 2: Organ Systems Overview

Lecture Hints

1. *The Incredible Human Machine* is an excellent videotape that offers an exciting overview of many physiological functions. With the help of sophisticated photographic techniques, the wonders of the body's internal world are revealed. The videotape is inexpensive and available from numerous vendors, including Carolina Biological. Listed below are alternate methods for using the tape.
   a. Show the entire video during lecture or lab (60 minutes).
   b. Show selected sections of video during an introductory lecture or lab.
   c. Show selected sections as an introduction to each body system.
   d. Place the videotape on reserve in the library or video center and have students view it on their own. This could be required or optional (if optional, encourage viewing by adding bonus points).
2. In order to illustrate the principle of complementarity of structure and function, ask the students to consider the relatively similar structure of the human arm and a bird wing. Then ask them to consider the functional constraints placed on the limbs by their form, as well as the adaptive value of each form. Manual dexterity vs. flight is an excellent compare-and-contrast example.
3. Many students have a very poor concept of the dynamics of the human body and how it functions in the environment. Try to stress throughout this chapter the adaptive nature of the body and the interrelationship between environmental variables and system response.
4. The body organ systems are actually an artificial grouping of structures that work toward a common goal. Stress the interrelationship between organs and systems that make the body "work" as an entire unit.
5. At times, students might substitute the term *circulatory system* for *cardiovascular system*. Explain the difference and the relationship to the lymphatic system.
6. The role of negative and positive feedback systems in maintaining or disrupting homeostasis is basic to understanding many of the physiological processes covered throughout the text. Stress the importance of feedback systems throughout the course.
7. Students often equate the term *negative* in feedback systems to something disruptive. This misunderstanding is compounded by the term *positive* also used in feedback systems. Stress the differences and give an example; for example, describe how a thermostat controls house temperature.
8. To illustrate the different degrees of protection in the dorsal and ventral cavities, ask the questions:
   a. Why do you suppose that a dog instinctively curls up to protect its abdomen?

   b. Two people have rapidly growing tumors: one in the dorsal cavity, the other in the ventral. Which one would develop symptoms first?
9. To encourage understanding of structure/function relationships, ask students to comment on the relationship between muscle and bone, and between the respiratory and circulatory systems.

Activities/Demonstrations

1. Audio-visual materials listed under Multimedia in the Classroom and Lab.
2. Ask the students to explain how scratching an itch can be considered an example of negative feedback.
3. Assume the anatomical position and ask why this particular position is important to the study of anatomy. Then relate that any position would be acceptable as long as it was the standard for anatomical description.
4. Place a chair center stage. Ask a student to indicate how the chair would be cut in the different planes of section. The answer should include why the other options were not selected.
5. Have students identify body regions on themselves or a lab partner. Stress the usage of directional terms in describing their positions relative to each other.
6. Arrange for the class to attend an autopsy (after the material in Chapter 1 has been covered).
7. Use a balloon to illustrate the two layers of a serous membrane.
8. Use a torso model and/or dissected animal model to exhibit body cavities, organs, and system relationships.
9. Use the thermostat found in the classroom (or one found in a home) to illustrate how a negative feedback system works.

Critical Thinking/Discussion Topics

1. Discuss how our intercellular environment can be described as the "sea within us."
2. List several embryonic features that form early in the developmental stages but are "lost" or converted to entirely new structures such as our "tail" (coccyx).
3. If an object were found on Mars that appeared to move and react to external stimuli, what other characteristics would be necessary to classify it as "live" and why?
4. Contrast the type of imagery obtained with X-ray machines, CT scans, DSR scans, and ultrasonics.
5. What differences are there between a free-living, single-celled organism such as a paramecium and a single human cell such as a ciliated cell of the respiratory tract?

Library Research Topics

1. Research the historical development of anatomy and physiology.
2. Review the current definitions of death and life.
3. Develop a rationale for the chemical basis of stress and how it can affect homeostasis.
4. Explore the current research on aging and describe the effect of aging on the genetic material of the cell.

Multimedia in the Classroom and Lab

Online Resources for Students

The Anatomy & Physiology Place
www.anatomyandphysiology.com

MyA&P
www.myaandp.com

The following shows the organization of the Chapter Guide page in both the Anatomy & Physiology Place and MyA&P™. The Chapter Guide organizes all the chapter-specific online media resources for Chapter 1 in one convenient location, with e-book links to each section of the textbook. Please note that both sites also give you access to other general A&P resources, like InterActive Physiology®*, PhysioEx 6.0™, Anatomy 360°, Flashcards, a Glossary, a Histology Tutorial, and much more.*

Objectives
Section 1.1 An Overview of Anatomy and Physiology (pp. 2–3)
Section 1.2 Levels of Structural Organization (pp. 3–4)
Section 1.3 Maintaining Life (pp. 4–8)
Memory: Major Systems of the Body
Section 1.4 Homeostasis (pp. 8–12)
Art Labeling Activity: The Elements of a Homeostatic Control System (Fig. 1.4, p. 9)
Section 1.5 The Language of Anatomy (pp. 12–19)
Art Labeling Activity: Regional Terms Used to Designate Specific Body Areas (Fig. 1.7a, p. 14)
Art Labeling Activity: Regional Terms Used to Designate Specific Body Areas (Fig. 1.7b, p. 14)
Art Labeling Activity: Dorsal and Ventral Body Cavities (Fig. 1.9, p. 17)
Memory: Major Cavities of the Body
Chapter Summary
Self-Study Quizzes
Art Labeling Quiz
Matching Quiz
Multiple-Choice Quiz (Level I)
Multiple-Choice Quiz (Level II)
True-False Quiz
Crossword Puzzles
Crossword Puzzle 1.1
Crossword Puzzle 1.2

Media

See Guide to Audio-Visual Resources in Appendix A for key to AV distributors.

Video

1. *Systems Working Together* (WNS; 15 min., 1993). Animation, X rays, motion pictures, and micrographs help explain the workings of the human body. Students learn that some organs belong to more than one system, and that all of the systems must work together to support all of their activities.
2. *The Incredible Human Machine* (CBS; 60 min., 1992). Sophisticated photographic techniques show the wonders of the body's internal world.

3. *The Universe Within* (CBS; 60 min., 1995). NOVA takes viewers on an incredible voyage into the microworld of the human body. The coordination of muscles, bones, heart, and circulatory systems is revealed by microphotography.

Software

1. *A.D.A.M.® InterActive Anatomy® 4.0* (ADAM, BC; Win/Mac). Comprehensive, precise, and anatomically correct database of the human body gives the student an opportunity to explore human systems and structures within the context of the whole body.
2. *A.D.A.M.® MediaPro* (ADAM, BC; Win/Mac). Provides clinical illustrations for classroom curriculum and presentations. Contains more than 2000 images in JPEG format.
3. *Bodyworks* (WNS; Windows). An economical CD of anatomy and physiology, which includes lesson plans and quizzes that can be printed.
4. *Explorations in Human Biology* (WNS; Win/Mac). This CD contains a set of 15 animated, interactive lessons. It features clearly written topic information, colorful graphics, and animated illustrations.
5. *The Ultimate Human Body* (ED; Win/Mac). A blend of high-quality 3-D images, animation, sounds, and text. Students can explore the body through three search paths: "The Body Machine," "The Body Organs," and "The Body Systems."
6. *WARD's Radiographic Anatomy: A Gallery of Images CD-ROM* (WNS; Windows). This CD contains an extensive collection of images ideal for college-level study. Includes X rays, angiograms, CT scans, MRIs, and urograms. Each image is accompanied by descriptive text and identifying labels. The CD also includes a variety of testing methods.

Lecture Enhancement Material

To view thumbnails of all of the illustrations for Chapter 1, see Appendix B.

Transparencies Index/Media Manager

Figure 1.1	Levels of structural organization.
Figure 1.2	Examples of selected interrelationships among body organ systems.
Figure 1.3	Summary of the body's organ systems.
Figure 1.4	The elements of a homeostatic control system.
Figure 1.5	Regulation of room temperature by a negative feedback mechanism.
Figure 1.6	Summary of the positive feedback mechanism regulating blood clotting.
Figure 1.7	Regional terms used to designate specific body areas.
Figure 1.8	Planes of the body—frontal, transverse, and median (midsagittal) with corresponding magnetic resonance imaging (MRI) scans.
Figure 1.9	Dorsal and ventral body cavities and their subdivisions.
Figure 1.10	Serous membrane relationships.
Figure 1.11	The nine abdominopelvic regions.
Figure 1.12	The four abdominopelvic quadrants.
Figure 1.13	Other body cavities.
Table 1.1	Orientation and Directional Terms
A Closer Look	Medical Imaging: Illuminating the Body*

**Indicates images that are on the Media Manager only.*

Answers to End-of-Chapter Questions

Multiple Choice and Matching Question answers appear in Appendix G of the main text.

Short Answer Essay Questions

11. Since function (physiology) reflects structure, structure will determine and/or influence function. (p. 3)
12. See Fig. 1.3, which provides a summary of all the organ systems of the body.
13. Nutrients—the chemical substances used for energy and cell building; oxygen—used in the reactions that produce cellular energy; water—the liquid environment necessary for all chemical reactions; body temperature—to maintain the proper temperature for chemical reactions to proceed; and atmospheric pressure—to allow gas exchange to occur. (p. 8)
14. It is the ability to maintain relatively stable internal conditions even in the face of continuous change in the outside world. (p. 9)
15. Negative feedback mechanisms operate in the opposite direction to decrease the original stimulus and/or reduce its effects, thus returning the system back to normal. Examples include regulation of body temperature and blood sugar levels. (p. 10)

    Positive feedback mechanisms operate in the same direction to enhance the original stimulus such that the activity is accelerated. Examples include regulations of blood clotting and enhancement of labor contractions. (pp. 10–11)
16. The anatomical position requires the body being erect, the arms hanging at the sides, the palms forward, the thumbs pointing away from the body, and the feet flat to the ground. It is necessary to use this standard position because most directional terms refer to the body in this position, regardless of its actual position. The use of anatomical terms saves a great deal of description and is less ambiguous. (p. 12)
17. A plane refers to an imaginary line, and a section refers to a cut along that imaginary line. (p. 15)
18. a. arm—brachial
    b. thigh—femoral
    c. chest—thoracic
    d. fingers/toes—digits
    e. anterior aspect of knee—patellar (p. 14)
19. The elbow's olecranal region is proximal (superior) and posterior (dorsal) to the palm. (pp. 13–14)
20. See Figs. 1.11 and 1.12. The figures illustrate the regions and quadrants and list several organs for each.

Critical Thinking and Clinical Application Questions

1. a. Parietal and/or visceral pleural membranes.
   b. The membranes allow the organs to slide easily across the cavity walls and one another without friction.
   c. The organs and membranes stick together and grate against one another, creating friction, heat, and pain. (p. 17)
2. a. anterior aspect of elbow
   b. took off his shirt
   c. buttock (p. 14)

3. Of the procedures listed, MRI would be the best choice because dense structures (e.g., the skull) do not impair the view with this technique, and it is best at producing a high-resolution view of soft tissues, particularly neural tissue. Furthermore, MRI can provide information about chemical conditions in a tissue. Thus, once the suspected tumor is localized, MRI can perform a "metabolic biopsy" to determine if it is cancerous . . . all of this without surgery. (p. 20)
4. When we take a drink, body hydration increases and thirst declines—an example of a typical negative feedback system. If it were a positive feedback system, the body's need for water (and thirst) would increase after taking a drink. (pp. 10–11)
5. The carpal region is found at the wrist. (p. 14)

Suggested Readings

Lester, David S. and Olds, James L. "Biomedical Imaging: 2001 and Beyond." *The Anatomical Record* 265 (2001): 35–36.

Morris, D. *The Naked Ape: A Zoologist's Study of the Human Animal*. New York: Dell Publishing Co., 1999.

Raichle, M.E. "Visualizing the Mind." *Scientific American* 270 (April 1994): 58.

Sivitz, Laura B. "Beyond Imaging." *Science News* 159 (Jan. 2001): 12–13.

Weiss, Peter. "Magnetic Whispers." *Science News* 159 (Jan. 2001): 42–44.

Yonas, H., D.W. Johnson, and R. R. Pindzola. "Xenon-enhanced CT of Cerebral Blood Flow." *Scientific American* (Sept./Oct. 1995).

2 Chemistry Comes Alive

Objectives

PART 1: BASIC CHEMISTRY

Definition of Concepts: Matter and Energy

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

Composition of Matter: Atoms and Elements

3. Define element. What four elements are responsible for the bulk of body matter?
4. Define atom. List the subatomic particles, their charges, relative sizes, and location in the atom.
5. Identify atomic number, atomic mass, atomic weight, isotope, and radioisotope.

How Matter Is Combined: Molecules and Mixtures

6. Define molecule. Differentiate between a molecule of an element and a molecule of a compound. Distinguish between a compound and a mixture.
7. Compare solutions, colloids, and suspensions.

Chemical Bonds

8. Define a chemical bond. Explain the role of electrons in chemical bonding and their importance in the octet rule.
9. Differentiate between ionic bonds, covalent bonds, and hydrogen bonds. Differentiate between a polar and a nonpolar molecule.

Chemical Reactions

10. Explain what happens in a chemical reaction and discuss the four patterns of chemical reactions.
11. Define exergonic and endergonic reactions.
12. Discuss the factors that influence the rate of chemical reactions.

PART 2: BIOCHEMISTRY

Inorganic Compounds

13. Discuss the importance of water and its special properties.
14. Describe salts.
15. Define acid, base, neutralization, and buffers. Explain the concept of pH.

Organic Compounds

16. Describe the building blocks, general structures, and functions of carbohydrates, lipids, and proteins.
17. Describe the four levels of protein structure.
18. Identify the role and function of enzymes.
19. Describe the function of molecular chaperones.
20. Describe, compare, and contrast DNA and RNA.
21. Explain the role of ATP in the body.

Suggested Lecture Outline

PART 1: BASIC CHEMISTRY

I. Definition of Concepts: Matter and Energy (pp. 25–27)

A. Matter is anything that occupies space and has mass (p. 25).
   1. Mass is equal to the amount of matter in the object.
   2. Mass remains constant regardless of gravity.

B. States of Matter (p. 25)
   1. Matter exists in one of three states: solid, liquid, or gas.

C. Energy (pp. 25–27)
   1. Energy is the capacity to do work, and it exists in two forms.
      a. Kinetic energy is the energy of motion.
      b. Potential energy is stored energy.
   2. Forms of Energy
      a. Chemical energy is energy stored in chemical bonds.
      b. Electrical energy results from the movement of charged particles.
      c. Mechanical energy is energy directly involved with moving matter.
      d. Radiant energy is energy that travels in waves.
   3. Energy is easily converted from one form to another.

II. Composition of Matter: Atoms and Elements (pp. 27–30)

A. Basic Terms (p. 27; Table 2.1)
   1. Elements are unique substances that cannot be broken down into simpler substances by ordinary chemical means.
   2. Four elements: carbon, hydrogen, oxygen, and nitrogen make up roughly 96% of body weight.
   3. Atoms are the smallest particles of an element that retain the characteristics of that element.
   4. Elements are designated by a one- or two-letter abbreviation called the atomic symbol.

B. Atomic Structure (pp. 27–29; Figs. 2.1–2.2)
   1. Each atom has a central nucleus with tightly packed protons and neutrons.
      a. Protons have a positive charge and weigh 1 atomic mass unit (amu).
      b. Neutrons do not have a charge and weigh 1amu.
   2. Electrons are found moving around the nucleus, have a negative charge, and are weightless (0 amu).
   3. Atoms are electrically neutral and the number of electrons is equal to the number of protons.
   4. The planetary model is a simplified, two-dimensional model of atomic structure.
   5. The orbital model is a more accurate three-dimensional model talking about orbital regions instead of set orbital patterns.

C. Identifying Elements (pp. 28–29)
   1. Elements are identified based on their number of protons, neutrons, and electrons.

D. Atomic Number (pp. 28–29)
   1. The atomic number of an element is equal to the number of protons of an element.
   2. Since the number of protons is equal to the number of electrons, the atomic number indirectly tells us the number of electrons.

E. Mass Number and Isotopes (p. 29; Fig. 2.3)
   1. The mass number of an element is equal to the number of protons plus the number of neutrons.
   2. The electron is weightless and is ignored in calculating the mass number.
   3. Isotopes are structural variations of an atom. They have the same number of protons and neutrons of all other atoms of the element but differ in the number of neutrons the atom has.

F. Atomic Weight (p. 29)
   1. The atomic weight is an average of the relative weights of all isotopes of an element, taking into account their relative abundance in nature.

G. Radioisotopes are heavier, unstable isotopes of an element that spontaneously decompose into more stable forms (pp. 29–30).
   1. The time required for a radioactive isotope to lose one-half of its radioactivity is called the half-life.

III. How Matter Is Combined: Molecules and Mixtures (pp. 30–31)

A. Molecules and Compounds (p. 30)
   1. A combination of two or more atoms is called a molecule.
   2. If two or more atoms of the same element combine it is called a molecule of that element.
   3. If two or more atoms of different elements combine it is called a molecule of a compound.

B. Mixtures (pp. 30–31)
   1. Mixtures are substances made of two or more components mixed physically.
   2. Solutions are homogeneous mixtures of compounds that may be gases, liquids, or solids.
      a. The substance present in the greatest amounts is called the solvent.
      b. Substances present in smaller amounts are called solutes.
      c. Solutions may be described by their concentrations. These may be expressed as a percent or in terms of its molarity.
   3. Colloids or emulsions are heterogeneous mixtures.
   4. Suspensions are heterogeneous mixtures with large, often visible solutes that tend to settle out.

C. Distinguishing Mixtures and Compounds (p. 31)
   1. The main difference between mixtures and compounds is that no chemical bonding occurs between molecules of a mixture.
   2. Mixtures can be separated into their chemical components by physical means; separation of compounds is done by chemical means.
   3. Some mixtures are homogeneous, while others are heterogeneous.

IV. Chemical Bonds (pp. 31–36)

A. A chemical bond is an energy relationship between the electrons of the reacting atoms (p. 31).
   1. The Role of Electrons in Chemical Bonding (Fig. 2.4)
      a. Electrons occupy regions of space called electron shells that surround the nucleus in layers.
      b. Each electron shell represents a different energy level.
      c. Each electron shell holds a specific number of electrons, and shells tend to fill consecutively from the closest to the nucleus to the furthest away.
      d. The octet rule, or rule of eights, states that except for the first energy shell (stable with two electrons), atoms are stable with eight electrons in their outermost (valence) shell.

B. Types of Chemical Bonds (pp. 33–36; Figs. 2.5–2.10)
   1. Ionic bonds are chemical bonds that form between two atoms that transfer one or more electrons from one atom to the other.
      a. Ions are charged particles.
      b. An anion is an electron acceptor carrying a net negative charge due to the extra electron.
      c. A cation is an electron donor carrying a net positive charge due to the loss of an electron.
      d. Crystals are large structures of cations and anions held together by ionic bonds.
   2. Covalent bonds form when electrons are shared between two atoms.
      a. Some atoms are capable of sharing two or three electrons between them, resulting in double covalent or triple covalent bonds.
      b. Nonpolar molecules share their electrons evenly between two atoms.
      c. In polar molecules, electrons spend more time around one atom thus providing that atom with a partial negative charge, while the other atom takes on a partial positive charge.
      d. A polar molecule is often referred to as a dipole due to the two poles of charges contained in the molecule.
   3. Hydrogen bonds are weak attractions that form between partially charged atoms found in polar molecules.
      a. Surface tension is due to hydrogen bonds between water molecules.
      b. Intramolecular bonds may form between partially charged atoms in a large molecule, and are important in maintaining the shape of that molecule.

V. Chemical Reactions (pp. 36–40)

A. Chemical Reactions (pp. 36–37)
   1. Chemical reactions occur whenever bonds are formed, rearranged, or broken.
   2. Chemical Equations
      a. A chemical equation describes what happens in a reaction.
      b. Chemical reactions denote the kinds and number of reacting substances, called reactants; the chemical composition of the products; and the relative proportion of each reactant and product, if balanced.

B. Patterns of Chemical Reactions (pp. 37–38; Fig. 2.11)
   1. In a synthesis (combination) reaction, larger molecules are formed from smaller molecules.
   2. In a decomposition reaction a molecule is broken down into smaller molecules.
   3. Exchange (displacement) reactions involve both synthesis and decomposition reactions.
   4. Oxidation-reduction reactions are special exchange reactions in which electrons are exchanged between reactants.

C. Energy Flow in Chemical Reactions (pp. 38–39)
   1. Exergonic reactions release energy as a product, while endergonic reactions absorb energy.

D. Reversibility of Chemical Reactions (p. 39)
   1. All chemical reactions are theoretically reversible.
   2. When the rate of the forward reaction equals the rate of the reverse reaction, the reactions have reached a chemical equilibrium.

E. Factors Influencing the Rate of Chemical Reactions (pp. 39–40)
   1. Chemicals react when they collide with enough force to overcome the repulsion by their electrons.
   2. An increase in temperature increases the rate of a chemical reaction.
   3. Smaller particle size results in a faster rate of reaction.
   4. Higher concentration of reactants results in a faster rate of reaction.
   5. Catalysts increase the rate of a chemical reaction without taking part in the reaction.

PART 2: BIOCHEMISTRY

I. Inorganic Compounds (pp. 40–43)

A. Water (pp. 40–41)
   1. Water is the most important inorganic molecule, and makes up 60–80% of the volume of most living cells.
   2. Water has a high heat capacity, meaning that it absorbs and releases a great deal of heat before it changes temperature.
   3. Water has a high heat of vaporization, meaning that it takes a great deal of energy (heat) to break the bonds between water molecules.
   4. Water is a polar molecule and is called the universal solvent.
   5. Water is an important reactant in many chemical reactions.
   6. Water forms a protective cushion around organs of the body.

B. Salts (p. 41; Fig. 2.12)
   1. Salts are ionic compounds containing cations other than H^+ and anions other than the hydroxyl (OH^-) ion.
   2. When salts are dissolved in water they dissociate into their component ions.

C. Acids and Bases (pp. 41–43; Fig. 2.13)
   1. Acids are also known as proton donors, and dissociate in water to yield hydrogen ions and anions.
   2. Bases are also called proton acceptors, and absorb hydrogen ions.

3. The relative concentration of hydrogen ions is measured in concentration units called pH units.
   a. The greater the concentration of hydrogen ions in a solution, the more acidic the solution is.
   b. The greater the concentration of hydroxyl ions, the more basic, or alkaline, the solution is.
   c. The pH scale extends from 0–14. A pH of 7 is neutral; a pH below 7 is acidic; a pH above 7 is basic or alkaline.
4. Neutralization occurs when an acid and a base are mixed together. They react with each other in displacement reactions to form a salt and water.
5. Buffers resist large fluctuations in pH that would be damaging to living tissues.

II. Organic Compounds (pp. 43–59)

A. Carbohydrates (pp. 44–46; Fig. 2.14)
   1. Carbohydrates are a group of molecules including sugars and starches.
   2. Carbohydrates contain carbon, hydrogen, and oxygen.
   3. The major function of carbohydrates in the body is to provide cellular fuel.
   4. Monosaccharides are simple sugars that are single-chain or single-ring structures.
   5. Disaccharides are formed when two monosaccharides are joined by a dehydration synthesis.
   6. Polysaccharides are long chains of monosaccharides linked together by dehydration synthesis.

B. Lipids (pp. 46–48; Table 2.2; Fig. 2.15)
   1. Lipids are insoluble in water but dissolve readily in nonpolar solvents.
   2. Triglycerides (neutral fats) are commonly known as fats when solid and oils when liquid.
   3. Phospholipids are diglycerides with a phosphorus-containing group and two fatty acid chains.
   4. Steroids are flat molecules made up of four interlocking hydrocarbon rings.
   5. Eicosanoids are a group of diverse lipids derived from arachidonic acid.

C. Proteins (pp. 48–54; Table 2.3; Figs. 2.16–2.21)
   1. Proteins compose 10–30% of cell mass.
      a. They are the basic structural material of the body.
      b. They also play vital roles in cell function.
   2. Proteins are long chains of amino acids connected by peptide bonds.
   3. Proteins can be described in terms of four structural levels.
      a. The linear sequence of amino acids is the primary structure.
      b. Proteins twist and turn on themselves to form a more complex secondary structure.
      c. A more complex structure is tertiary structure, resulting from protein folding upon itself to form a ball-like structure.
      d. Quaternary structure results from two or more polypeptide chains grouped together to form a complex protein.

4. Fibrous and Globular Proteins
    a. Fibrous proteins are extended and strandlike. They are known as structural proteins and most have only secondary structure.
    b. Globular proteins are compact, spherical structures. They are water soluble, chemically active molecules, and play an important role in vital body functions.
    c. Fibrous proteins are stable but globular proteins are susceptible to denaturing, losing their shape due to breaking of their hydrogen bonds.
5. Protein denaturation is a loss of the specific three-dimensional structure of a protein. It may occur when globular proteins are subjected to a variety of chemical and physical changes in their environment.
6. Molecular chaperones, or chaperonins, are a type of globular protein that help proteins achieve their three-dimensional shape.
7. Enzymes and Enzyme Activity
    a. Enzymes are globular proteins that act as biological catalysts.
    b. Enzymes may be purely protein, or may consist of two parts which are collectively called a holoenzyme.
    c. Each enzyme is chemically specific.
    d. Enzymes work by lowering the activation energy of a reaction.

D. Nucleic Acids (DNA and RNA) (pp. 54–57; Table 2.4; Fig. 2.22)
1. Nucleic acids composed of carbon, oxygen, hydrogen, nitrogen, and phosphorus are the largest molecules in the body.
2. Nucleotides are the structural units of nuleic acids.
3. Each nucleotide consists of three components: a pentose sugar, phosphate group, and a nitrogen-containing base.
4. There are five nitrogenous bases used in nucleic acids: Adenine (A), Guanine (G), Cytosine (C), Uracil (U), and Thymine (T).
5. DNA, or Deoxyribonucleic Acid
    a. DNA is the genetic material of the cell, and is found within the nucleus.
    b. DNA replicates itself before cell division and provides instructions for making all of the proteins found in the body.
    c. The structure of DNA is a double-stranded polymer containing the nitrogenous bases A, T, G, and C, and the sugar deoxyribose.
    d. Bonding of the nitrogenous bases in DNA is very specific; A bonds to T, and G bonds to C.
    e. The bases that always bind together are known as complementary bases.
6. RNA, or Ribonucleic Acid
    a. RNA is located outside the nucleus, and is used to make proteins using the instructions provided by the DNA.
    b. The structure of RNA is a single-stranded polymer containing the nitrogenous bases A, G, C, and U, and the sugar ribose.
    c. In RNA, G bonds with C, and A bonds with U.

E. ATP, or Adenosine Triphosphate (pp. 57–59; Figs. 2.23–2.24)
1. ATP is the energy currency used by the cell.
2. ATP is an adenine-containing RNA nucleotide that has two additional phosphate groups attached.
3. The additional phosphate groups are connected by high energy bonds.
4. Breaking the high energy bonds releases energy the cell can use to do work.

Cross References

Additional information on topics covered in Chapter 2 can be found in the chapters listed below.

1. Chapter 3: Phospholipids in the composition and construction of membranes; DNA replication and roles of DNA and RNA in protein synthesis; cellular ions; enzymes and proteins in cellular structure and function; hydrogen bonding
2. Chapter 9: Function of ATP in muscle contraction; role of ions in generating muscle cell contraction
3. Chapter 11: ATP, ions, and enzymes in the nervous impulse
4. Chapter 16: Steroid- and amino-acid based hormones
5. Chapter 22: Acid-base balance
6. Chapter 23: Digestive enzyme function; acid function of the digestive system; digestion of proteins, carbohydrates, and lipids
7. Chapter 24: Oxidation-reduction reaction; importance of ions (minerals) in life processes; metabolism of carbohydrates, lipids, and proteins; basic chemistry of life examples
8. Chapter 25: Renal control of electrolytes
9. Chapter 26: Acid-base balance, electrolytes, and buffers; sodium and sodium-potassium pump
10. Appendix E: Periodic table of the elements

Lecture Hints

1. *Introduction to Chemistry for Biology Students*, by George Sackheim, is an excellent aid for students who need a quick brushup in chemistry or for those that need extra help. The book is designed as a self-paced learning guide. Most students should be able to finish a review of the essentials for Marieb Chapter 2 in about 2 to 6 hours.
2. As an alternative to presenting the chemistry in Chapter 2 as a distinct block of material, you could provide the absolute minimum coverage of the topics at this time and expand topics later as areas of application are discussed.
3. Students often find the concept of isotopes confusing. A clear distinction between atomic mass and atomic weight will help clarify the topic.
4. In discussing radioisotopes it might be helpful to refer the students back to the discussion of PET scans in *A Closer Look* in Chapter 1.
5. Oxidation-reduction reactions involve the loss and gain of electrons. The reactant oxidized will lose electrons while the reactant reduced will gain electrons. One easy way to remember this is by using the phrase "Leo the lion goes ger." Leo stands for "loss of electrons is oxidation," and ger for "gain of electrons is reduction."
6. In biological oxidation-reduction reactions the loss and gain of electrons is often associated with the loss and gain of hydrogen atoms. Electrons are still being transferred since the hydrogen atom contains an electron.
7. The relationship between the terms *catalyst* and *enzyme* can be clarified by asking the students if all enzymes are catalysts and if all catalysts are enzymes.
8. Table 2.4 is an excellent summary of the differences between DNA and RNA. This information will be important when discussing protein synthesis.

9. The notion that ATP is the "energy currency" of the cell should be emphasized. Students should realize that without ATP, molecules cannot be synthesized or degraded, cells cannot maintain boundaries, and life processes cease.
10. The cycling back and forth between ATP and ADP is a simple but important concept often overlooked by students.

Activities/Demonstrations

1. Audio-visual materials listed under Multimedia in the Classroom and Lab.
2. Obtain and/or construct 3-D models of various types of biological molecules such as glucose, DNA, protein, and lipids.
3. Bring in materials or objects that are composed of common elements, e.g., a gold chain, coal, copper pipe, cast iron. Also provide examples of common compounds such as water, table salt, vinegar, and sodium bicarbonate. Solicit definitions of *atom, element*, and *compound,* and an explanation of how an atom and a molecule of a compound differ.
4. Ask students to name all the foods containing saturated fats and all those containing unsaturated fats that they have eaten in the past 24 hours.
5. Obtain a two-foot-long piece of thick string or cord. Slowly twist to exhibit primary, secondary, and tertiary levels of protein organization.
6. Obtain a Thompson-style vacuum tube with an internal frosted plate (to exhibit electrons), a direct current generator (Tesla coil), and bar magnet. Turn off room lights and charge one end of the tube to start an electron beam. Use a magnet to move the electron beam up and down. This experiment helps to illustrate electrons as particles.
7. Obtain an electrolyte testing system (light bulb setup connected to electrodes) and prepare a series of solutions such as salt, acid, base, glucose, etc. Place the electrodes into the solutions to illustrate the concept of electrolytes.
8. Prepare two true solutions (1% sodium chloride; 1% glucose) and two colloidal solutions (1% boiled starch, sol state; Jell-O, gel state). Turn off the room lights and pass a beam of light through each to demonstrate the Tyndall effect of colloids.
9. Obtain two strings of dissimilar "pop-it" beads. Put the beads together to demonstrate a synthesis reaction, and take them apart to demonstrate a decomposition reaction. Take a bead from each different chain and put them together to illustrate an exchange reaction.
10. Use a slinky to demonstrate denaturation of an enzyme. Tie colored yarn on the slinky at two sites that are widely separated, and then coil and twist the slinky upon itself to bring the two pieces of yarn next to each other. Identify the site where the yarn pieces are as the active site. Then remind students that when the hydrogen bonds holding the enzyme (or structural protein) in its specific 3-D structure are broken, the active site (or structural framework) is destroyed. Uncoil the slinky to illustrate this point.

Critical Thinking/Discussion Topics

1. Discuss how two polysaccharides, starch and cellulose, each having the same subunit (glucose), have completely different properties. Why can we digest starch but not cellulose?
2. How and why can virtually all organisms—plant, animal, and bacteria—use the exact same energy molecule, ATP?

3. How could a substance such as alcohol be a solvent under one condition and a solute under another? Provide examples of solid, liquid, and gaseous solutions.
4. Describe how weak bonds can hold large macromolecules together.
5. Why can we state that most of the volume of matter, such as the tabletop you are writing on, is actually empty space?
6. When you drive up your driveway at night you see the light from the headlights on the garage door, but not in the air between the car and the door. Why? What would be observed if the night were foggy?
7. Why are water molecules at the surface of a drop of water closer together than those in the interior?

Library Research Topics

1. Explore the use of radioisotopes in the treatment of cancers.
2. Study the mechanisms by which DNA can repair itself.
3. Locate the studies of Niels Bohr concerning the structure of atoms and the location of electrons. Determine why his work with hydrogen gas provided the foundation of our knowledge about matter.
4. How can a donut provide us with so much "energy"? Find out exactly where this energy is coming from.
5. Phospholipids have been used for cell membrane construction by all members of the "cellular" world. What special properties do these molecules have to explain this phenomenon?
6. Virtually every time an amino acid chain consisting of all 20 amino acids is formed in the cell, it twists into an alpha helix, then folds upon itself into a glob. Why?
7. What is the current status of the Human Genome Project? Who is directing the project? What are the expected benefits from the study?
8. What is DNA fingerprinting? Explore the applications of this technology.

Multimedia in the Classroom and Lab

Online Resources for Students

The Anatomy & Physiology Place
www.anatomyandphysiology.com

MyA&P
www.myaandp.com

The following shows the organization of the Chapter Guide page in both the Anatomy & Physiology Place and MyA&P™. The Chapter Guide organizes all the chapter-specific online media resources for Chapter 2 in one convenient location, with e-book links to each section of the textbook. Please note that both sites also give you access to other general A&P resources, like InterActive Physiology®*, PhysioEx 6.0™, Anatomy 360°, Flashcards, a Glossary, a Histology Tutorial, and much more.*

Objectives

PART ONE: BASIC CHEMISTRY

Section 2.1 Definition of Concepts: Matter and Energy (pp. 25–26)

Animation: Energy Concepts

Section 2.2 Composition of Matter: Atoms and Elements (pp. 27–30)

Animation: The Structure of Atoms

Section 2.3 How Matter Is Combined: Molecules and Mixtures (pp. 30–31)
Section 2.4 Chemical Bonds (pp. 31–36)
Section 2.5 Chemical Reactions (pp. 36–40)

PART TWO: BIOCHEMISTRY

Section 2.6 Inorganic Compounds (pp. 40–43)
InterActive Physiology®: Introduction to Body Fluids
Section 2.7 Organic Compounds (pp. 43–59)
Animations: Disaccharides | Polysaccharides | Fats
Art Labeling Activity: Lipids (Fig. 2.15, p. 47)
Animations: Structure of Proteins | Primary and Secondary Structure | Tertiary and Quaternary Structure
Animation: How Enzymes Work
Art Labeling Activity: Mechanisms of Enzyme Action (Fig. 2.21, p. 55)
Art Labeling Activity: Structure of DNA (Fig. 2.22, p. 56)
Memory: Important Molecules
Chapter Summary
Self-Study Quizzes
Art Labeling Quiz
Matching Quiz
Multiple-Choice Quiz (Level I)
Multiple-Choice Quiz (Level II)
True-False Quiz
Crossword Puzzles
Crossword Puzzle 2.1
Crossword Puzzle 2.2

Media

See Guide to Audio-Visual Resources in Appendix A for key to AV distributors.

Video

1. *Basic Chemistry for Biology Students* (HRM; 21 min., 1993). Introduces students to the chemical concepts important to understanding life processes.
2. *Double Helix* (FHS; 107 min., 1998). Exceptional Hollywood-style film (starring Jeff Goldblum) that captures all the drama of the discovery of DNA.
3. *The Molecular Building Blocks of Life* (WNS; 19 min.). Nine modules explore life's molecular architecture—carbohydrates, fats, proteins, and an overview of nucleic acids.

Software

1. *Cell Biology* (CBS; Win/Mac). Provides the information necessary to cover the cell, presents the structure and function of organelles, and examines systems of cell motility.
2. *Cellular Respiration* (CBS; Win/Mac). Topics include Energy, Structure of ATP and ADP, the Krebs Cycle, and the Role of Food in the Production of Energy.
3. *The Chemistry of Life* (BC; Win/Mac). This tutorial aims at teaching chemistry through animation and interactive learning activities. Includes diagnostic quizzes and illustrated glossary.

4. *Inside the Cell* (CE, WNS; Win/Mac). Cells and their processes are detailed in three-dimensional illustrations, animation sequences, and electron micrographs.

Lecture Enhancement Material

To view thumbnails of all of the illustrations in Chapter 2, see Appendix B.

Transparencies Index/Media Manager

Figure 2.1	The structure of an atom.
Figure 2.2	Atomic structure of the three smallest atoms.
Figure 2.3	Isotopes of hydrogen.
Figure 2.4	Chemically inert and reactive elements.
Figure 2.5	Formation of an ionic bond.
Figure 2.6	Properties of a compound differ from those of its atoms.
Figure 2.7	Formation of covalent bonds.
Figure 2.8	Molecular models of carbon dioxide and water molecules.
Figure 2.9	Comparison of ionic, polar covalent, and nonpolar covalent bonds.
Figure 2.10	Hydrogen bonding between polar water molecules.
Figure 2.11	Patterns of chemical reactions.
Figure 2.12	Dissociation of a salt in water.
Figure 2.13	The pH scale and pH values of representative substances.
Figure 2.14	Carbohydrate molecules.
Figure 2.15	Lipids.
Figure 2.16	Amino acid structures.
Figure 2.17	Amino acids are linked together by dehydration synthesis.
Figure 2.18	Levels of protein structure.
Figure 2.19	Denaturation of a globular protein such as an enzyme.
Figure 2.20	Enzymes lower the energy barrier for a reaction.
Figure 2.21	Mechanism of enzyme action.
Figure 2.22	Structure of DNA.
Figure 2.23	Structure of ATP (adenosine triphosphate).
Figure 2.24	Three examples of how ATP drives cellular work.
Table 2.1	Common Elements Composing the Human Body
Table 2.2	Representative Lipids Found in the Body
Table 2.3	Representative Types of Proteins in the Body
Table 2.4	Comparison of DNA and RNA
A Closer Look	DNA Fingerprinting: Cracking Our Genetic "Barcode"*

**Indicates images that are on the Media Manager only.*

Answers to End-of-Chapter Questions

Multiple Choice and Matching Question answers appear in Appendix G of the main text.

Short Answer Essay Questions

23. Energy is defined as the capacity to do work, or to put matter into motion. Energy has no mass, takes up no space, and can be measured only by its effects on matter. Potential energy is the energy an object has because of its position in relation to other objects. Kinetic energy is energy associated with a moving object. (p. 25)

24. According to the First Law of Thermodynamics, energy cannot be created or destroyed. Therefore, energy is not really lost, but may be released in another form such as heat or light. In this form, the energy may be partly unusable. (p. 27)
25. a. Ca, b. C, c. H, d. Fe, e. N, f. O, g. K, h. Na (Appendix E)
26. a. All three are carbon with six protons. (p. 29)
    b. All possess different numbers of neutrons and therefore have different atomic masses. (p. 29)
    c. Isotopes. (p. 29)
    d. See Fig 2.4b, which provides a drawing of a planetary model.
27. a. Add molecular weight of all atoms: 9×12 (C) + 8×1 (H) + 4×16 (O) = 180 g.
    b. Total molecular weight equals the number of grams in one mole, in this case 180.
    c. Divide the number of grams in the bottle by the number of grams in one mole of aspirin. This equals the total number of moles in the bottle.
    d. Answer = 2.5 moles (p. 31)
28. a. Covalent
    b. Covalent
    c. Ionic (pp. 33–34)
29. Hydrogen bonds are weak bonds that form when a hydrogen atom, already covalently linked to an electronegative atom, is attracted by another electronegative atom. Hydrogen bonding is common between water molecules, and in binding large molecules such as DNA and protein into specific three-dimensional shapes. (p. 36)
30. a. The reversibility of the reaction can be indicated by double reaction arrows pointed in opposing directions.
    b. When arrows are of equal length the reaction is at equilibrium.
    c. Chemical equilibrium is reached when, for each molecule of product formed, one product molecule breaks down, releasing the same reactants. (p. 39)
31. a. Primary structure—linear molecule formed by peptide bonds; second structure—coiling of primary structure into alpha helix or ß-pleated sheet; tertiary structure—folding of helical coils.
    b. Secondary level.
    c. Globular (functional) proteins achieve the tertiary level and tend to operate independently rather than in combination with others such as with structural proteins. (p. 50)
32. Dehydration refers to the joining together of two molecules by the removal of water. Monosaccharides are joined to form disaccharides and amino acids are joined to form dipeptides (and proteins) by this process. Hydrolysis refers to the breakdown of a larger molecule such as a disaccharide into small molecules or monosaccharides by the addition of water at the bond that joins them. (pp. 44, 49)
33. Enzymes are highly specific biological catalysts that help to increase the rate of reactions. The exact mechanism of how enzymes decrease activation energy is not known; however, they decrease the randomness of reactions by binding specifically and temporarily to the reacting molecules and, perhaps, holding them in the proper position(s) to interact. (p. 53)
34. Proteins that aid the folding of other proteins into their functional three-dimensional structures. They also inhibit incorrect folding. They are produced in great amounts when cells are damaged and proteins are denatured and must be replaced. (pp. 52–53)

35. The surface tension of water tends to pull water molecules into a spherical shape, and since the glass does not completely overcome this attractive force, water can elevate slightly above the rim of the glass. (p. 36)
36. Seawater is significantly hypertonic to our own body fluids. Drinking quantities of seawater raises the blood plasma osmolarity, leading to fluid imbalances between our intracellular and extracellular fluids. (p. 41)

Critical Thinking and Clinical Application Questions

1. In a freshwater lake, there are comparatively few electrolytes (salts) to carry a current away from a swimmer's body. Hence, the body would be a better conductor of the current and the chance of a severe electrical shock if lightning hit the water is real. (p. 41)
2. a. Some antibiotics compete with the substrate at the active site of the enzyme. This would tend to reduce the effectiveness of the reaction.
   b. Since the bacteria would be unable to catalyze the essential chemical reactions normally brought about by the "blocked" enzymes, the anticipated effect would be the inhibition of its metabolic activities. This would allow white blood cells to remove them from the system. However, some human cells would also be affected and this could cause them to cease their functions, hopefully only temporarily. (p. 54)
3. a. pH is defined as the measurement of the hydrogen ion concentration in a solution. The normal blood pH is 7.4.
   b. Severe acidosis is critical because blood comes in contact with nearly every body cell and can adversely affect the cell membranes, the function of the kidneys, muscle contraction, and neural activity. (pp. 42–43)
4. The blood pH is rising, thus becoming more basic or alkaline. This is due to the carbonic acid-bicarbonate buffer system that is at work within the blood. Changes in respiratory rate will cause a change in blood pH by altering the amount of carbonic acid in the blood. (pp. 42–43)

Suggested Readings

Ballew, et al. "Folding Proteins Caught in the Act." *Science* 273 (July 1996): 29–30.

Cech, T.R. "RNA as an Enzyme." *Scientific American* 255 (Nov. 1986): 64–75.

Doolittle, R.F. "Proteins." *Scientific American* 253 (Oct. 1985): 88–99.

Dressler, D.H., and H. Potter. *Discovering Enzymes*. New York: Scientific American Library, 1991.

Gorman, Jessica. "Getting Out the Thorn: Biomaterials Become Friendlier to the Body." *Science News* 161 (1) (Jan. 2002): 13–14.

Hartl, F. U. "Molecular Chaperones in Cellular Protein Folding." *Nature* 381 (June 1996): 571–580.

Horgan, J. "In the Beginning." *Scientific American* 264 (Feb. 1991): 116–125.

Karplus, M., and J.A. McCammon. "The Dynamics of Proteins." *Scientific American* 254 (Apr. 1986): 42–51.

Russo, S., and M. Silver. *Introductory Chemistry: A Conceptual Focus*. San Francisco: Benjamin Cummings, 2000.

Ruvkun, Gary. "Glimpses of a Tiny RNA World." *Science* 294 (5543) (Oct. 2001): 797–799.

Welch, W.J. "How Cells Respond to Stress." *Scientific American* 268 (May 1993): 56.

3 Cells: The Living Units

Objectives

Overview of the Cellular Basis of Life

1. Define cell. Discuss cell diversity.
2. Discuss a generalized cell. List the three main parts of a cell and their functions.

The Plasma Membrane: Structure

3. Discuss the fluid mosaic model of membrane structure.
4. List and describe the plasma membrane specializations.

The Plasma Membrane: Functions

5. Discuss membrane transport. Differentiate between active and passive transport.
6. Compare and contrast simple diffusion, facilitated diffusion, osmosis, and filtration.
7. Compare and contrast primary and secondary active transport.
8. Discuss the differences and similarities between the vesicular transport processes.
9. Define the resting membrane potential. How is it created and maintained?
10. Identify the different ways a cell interacts with its environment. Discuss cell adhesion molecules and the roles of membrane receptors.

The Cytoplasm

11. Discuss the cytoplasm and its components.
12. Discuss the functions of the cytoplasmic organelles. What conditions lead to a greater prevalence of a specific organelle?

The Nucleus

13. Define the characteristics and functions of the nucleus, nuclear envelope, and nucleoli.
14. Discuss chromatin structure and function.

Cell Growth and Reproduction

15. Identify the phases of cell growth and division, and describe what specific events occur within each phase.
16. Name the factors that influence cell division.
17. Define protein synthesis and the processes of transcription and translation.
18. Describe the types of RNA that are used in protein synthesis and their specific roles.
19. Discuss how proteins are degraded within the cytosol.

Extracellular Material

20. Define extracellular material and list its components.

Developmental Aspects of Cells

21. Discuss how cell development progresses, and what signals stimulate these changes.
22. Discuss the various theories of cell aging.

Suggested Lecture Outline

I. Overview of the Cellular Basis of Life (pp. 65–66)

A. The four concepts of the cell theory state (p. 65):
   1. Cells are the basic structural and functional units of life.
   2. The activity of an organism depends on the activities of its cells.
   3. The biochemical activities of a cell are dictated by their organelles.
   4. The continuity of life has a cellular basis.

B. Characteristics of Cells (pp. 65–66; Figs. 3.1–3.2)
   1. Cells vary greatly in their size, shape, and function.
   2. All cells are composed primarily of carbon, hydrogen, nitrogen, and oxygen.
   3. All cells have the same basic parts and some common functions.
   4. A generalized human cell contains the plasma membrane, the cytoplasm, and the nucleus.

II. The Plasma Membrane: Structure (pp. 67–69)

A. The Fluid Mosaic Model (pp. 67–68; Figs. 3.3–3.4)
   1. The plasma membrane is composed of a double layer of phospholipids embedded with small amounts of cholesterol and proteins.
   2. The phospolipid bilayer is composed of two layers of phospholipids lying tail to tail, with their polar heads exposed to water inside and outside the cell.
   3. The inward-facing and outward-facing surfaces of the plasma membrane differ in the kinds and amounts of lipids they contain.
      a. Glycolipids are found only in the outer membrane.
      b. Lipid rafts are also found only in the outer membrane, and are assumed to function in cell signaling.
   4. Integral proteins are firmly inserted into the plasma membrane.
      a. Most integral proteins are transmembrane proteins that span the entire width of the membrane and are involved with transport as channels or carriers.
   5. Peripheral proteins are not embedded in the plasma membrane, but attach to integral proteins or to phospolipids.
      a. Peripheral proteins may function as enzymes or in mechanical functions of the cell.
   6. The glycocalyx is the fuzzy, sticky, carbohydrate-rich area surrounding the cell.

B. Specializations of the Plasma Membrane (p. 69; Fig. 3.5)
   1. Microvilli are fingerlike extensions of the plasma membrane that increase the surface area of the cell.
   2. Most body cells are bound together using glycolipids, specialized interlocking regions, or specialized membrane junctions.
      a. Tight junctions are a type of membrane junction in which integral proteins on adjacent cells fuse together to form an impermeable junction in order to prevent molecules from passing through the extracellular space between cells.

b. Desmosomes are mechanical couplings that are scattered along the sides of adjoining cells that prevent their separation and reduce the chance of tearing when a tissue is stressed.
c. Gap junctions are a communication junction between cells that allows substances to pass between adjacent cells.

III. The Plasma Membrane: Functions (pp. 70–83)

A. Membrane Transport (pp. 69–81; Tables 3.1–3.2; Figs. 3.6–3.14)
1. The plasma membrane is a selectively permeable barrier, regulating how substances pass into and out of the cell.
2. Passive processes do not use energy and move substances down a concentration gradient.
a. Diffusion is a process in which substances move directly through the plasma membrane from an area of higher concentration to an area of lower concentration.
b. In facilitated diffusion substances are moved through the plasma membrane by binding to protein carriers in the membrane or by moving through channels.
c. Osmosis is the diffusion of water through a selectively permeable membrane.
d. Filtration is a pressure-driven process that forces water and solutes through a membrane or capillary wall.
3. Active processes use energy (ATP) to move substances across a membrane.
a. Active transport uses solute pumps to move substances against a concentration gradient. The two kinds of active transport are primary active transport and secondary active transport.
b. Vesicular transport is the means by which large particles, macromolecules, and fluids are transported across the plasma membrane, or within the cell.
i. Exocytosis is a process used to move substances from inside the cell to the extracellular environment.
c. Endocytosis, transcytosis, and vesicular traffiking are vesicular transport processes that move molecules using protein-coated vesicles.
d. Clathrin-coated vesicles are the main route for endocytosis and transcytosis of bulk solids.
e. Non-clathrin-coated vesicles, or caveolae, are inpocketings of the cell membrane that capture specific molecules in vesicles lined with caveolin, not clathrin.

B. Generating and Maintaining a Resting Membrane Potential (pp. 81–83; Fig. 3.15)
1. A membrane potential is a voltage across the cell membrane that occurs due to a separation of oppositely charged particles (ions).
2. The resting membrane potential is a condition in which the inside of the cell membrane is negatively charged compared to the outside, and ranges in voltage from -5 to -100 millivolts.
a. The resting membrane potential is determined mainly by the concentration gradient of potassium (K^+).

Human physiology is the study of how the human body functions. This includes the mechanical, physical, bioelectrical, and biochemical functions of humans in good health, from organs to the cells of which they are composed. The human body consists of many interacting systems of organs.Â Human anatomy, physiology, and biochemistry are basic medical sciences, generally taught to medical students in their first year at medical school.[40][41][42]. Depiction[edit]. Figure drawing by Lovis Corinth (before 1925).