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Scott Fong

BODY STRUCTURES and **FUNCTIONS**

13th EDITION

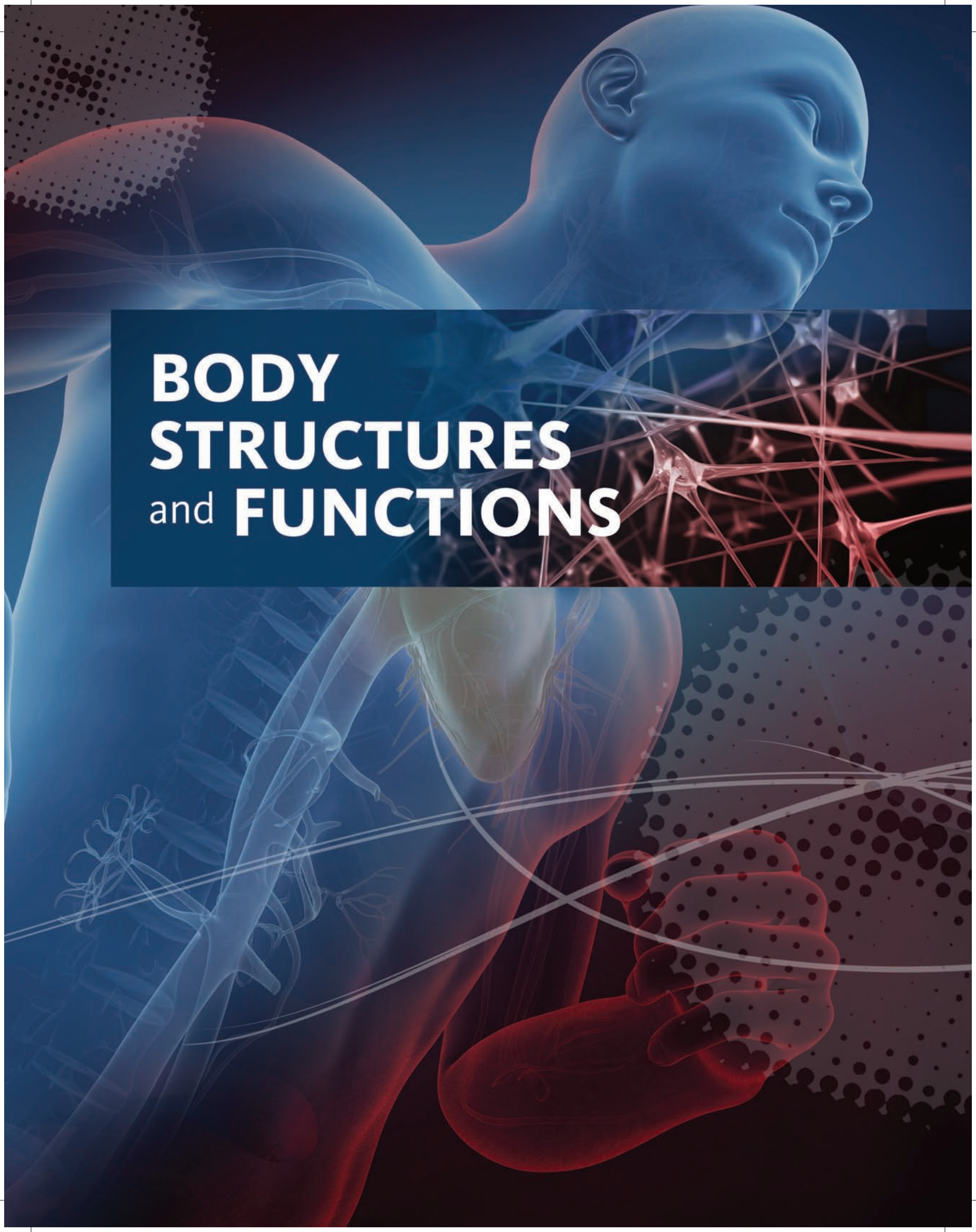
CENGAGE

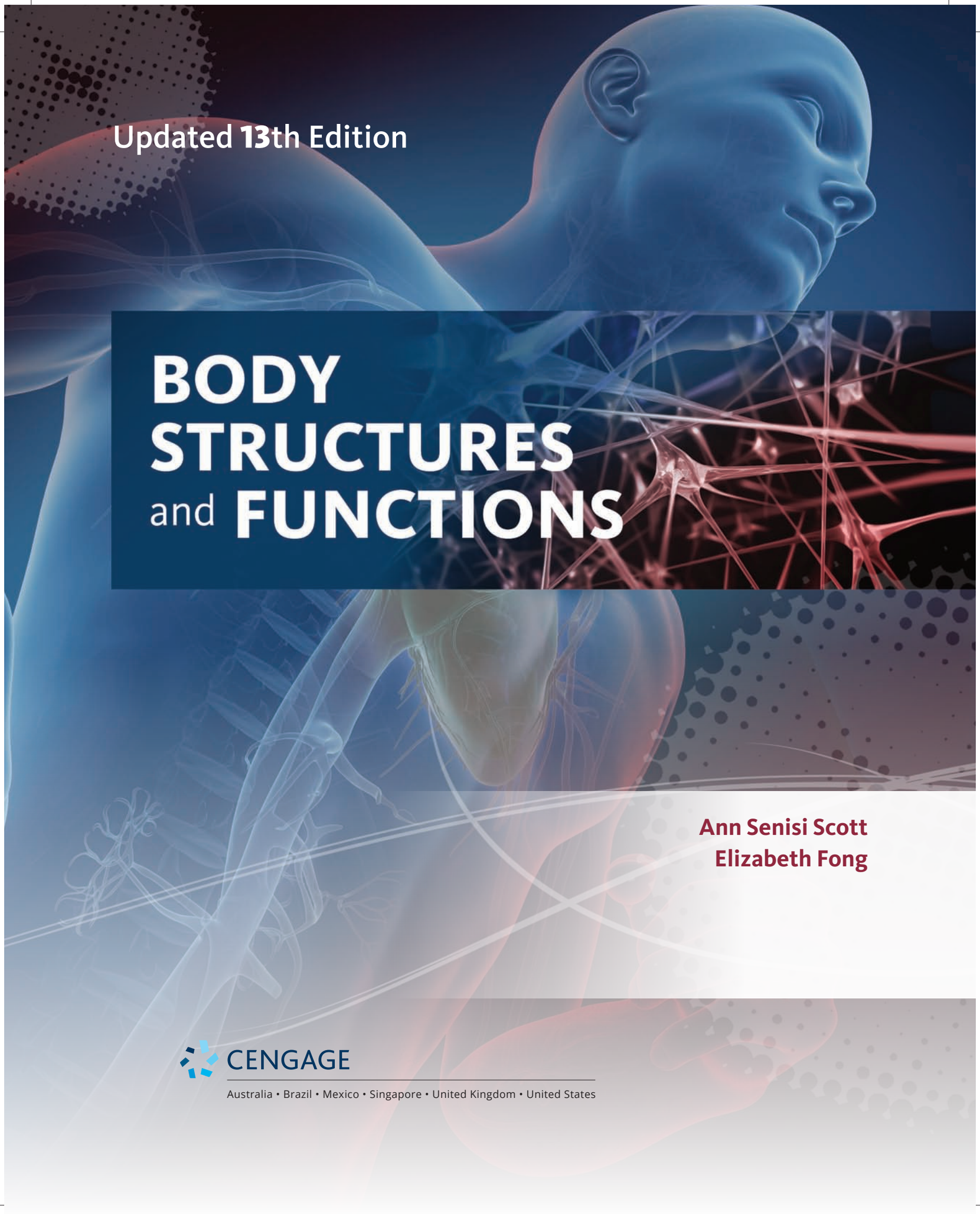
UPDATED
13th EDITION

BODY STRUCTURES and FUNCTIONS

Ann Senisi **Scott**
Elizabeth **Fong**

Aligned with PRECISION EXAMS and NCHSE National Consortium for Health Science Education





Body Structures and Functions, Updated 13th Edition

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PREFACE

Introduction

The thirteenth edition of *Body Structures and Functions* has been revised to reflect the many changes that are occurring in today's health science and medical fields. The multiskilled health practitioner (MSHP) of today must know the structure and function of each body system as well as the common diseases. All disease and disorder content is integrated within each chapter as appropriate.

This book and the accompanying teaching materials are designed to facilitate learning. Review the introductory section "How to Study Using *Body Structures and Functions*."

Key Features

Key features retained in the Thirteenth Edition include the following:

- Phonetic pronunciations of key words are included in each chapter.
- The feature **One Body** outlines how each body system interacts with other body systems.
- The feature **Study Tools** directs learners to additional resources to enhance learning and assess mastery of the material.

Phonetic Pronunciations of Key Words

Phonetic pronunciations of key words are included in each chapter in parentheses following the key word. Pronounce the word by saying each syllable, placing more emphasis on the syllable in boldface capital letters. In the following example, the syllable *NAT* would receive more emphasis than the rest of the syllables would: anatomy (ah-**NAT**-oh-mee).

Most key word pronunciations contain only one syllable in boldface; however, some key words contain more than one. When a pronunciation contains more than one syllable in boldface, place *some* emphasis on the syllable in boldface *lowercase* letters and the *most* emphasis on the syllable in boldface *capital* letters. In the following example, the syllable *em* would receive some emphasis and the syllable *OL* would receive the most emphasis: embryology (**em**-bree-**OL**-oh-jee).

Precision Exams

This edition of Body Structures and Functions is aligned to Precision Exams' Health Science Career Cluster. The Health Science pathway connects industry with skills taught in the classroom to help students successfully transition from high school to college and/or career. To access a corresponding correlation

guide, visit the accompanying Instructor Companion Website for this title. For more information on how to administer the Medical Anatomy and Physiology exam or any of the 170+ exams available to your students, contact your local Sales Consultant.

Major Changes to the Updated Thirteenth Edition

- Chapter 1: Introduction to the Structural Units—includes new information on positive feedback.
- Chapter 2: Chemistry of Living Things—provides expanded information on water, and new information on dehydration synthesis and hydrolysis.
- Chapter 3: Cells—provides guidelines from the National Institutes of Health on stem cell research.
- Chapter 5: Integumentary System—includes new information on moles, and a change in treatment of first-degree burns.
- Chapter 6: Skeletal System—includes new information on stress, Colles', spiral, and impacted fractures. Information on microfracture procedure is included in the Medical Highlights feature.
- Chapter 8: Central Nervous System—provides an expanded discussion on glial cells, astrocytes, oligodendrocytes, and Schwann cells, and additional information on Alzheimer's disease.
- Chapter 10: Special Senses—provides additional information on general sensory receptors, and new information on hearing aids in the Medical Highlights feature. A new "Did You Know?" feature regarding eyes has been added.
- Chapter 11: Endocrine System—includes new information on pheochromocytoma and values for fasting blood sugar (FBS) and HbA1C.
- Chapter 14: Circulation and Blood Vessels—provides additional information on factors that influence blood pressure, and new information on venipuncture, including an image showing the cephalic, basilic, and median cubital veins.
- Chapter 15: The Lymphatic and Immune Systems—includes updated schedules for immunizations for children 0 to 18 years old and catch-up immunizations. Information on Guillain-Barré syndrome and preexposure treatment for AIDS has been added.
- Chapter 16: Infection Control and Standard Precautions—provides information on the Ebola virus, whooping cough, and measles in the Medical Highlights feature.
- Chapter 17: Respiratory System—provides information on nitrogen and breathing, H1N1, epistaxis, respiratory syncytial virus, and safety precautions to be taken when someone is using oxygen.
- Chapter 18: Digestive System—provides a discussion on nerve cells in the stomach. Information on common symptoms of digestive disorders, including nausea and vomiting, and celiac disease has been added. New material on cleft lip and cleft palate and a new "Did You Know?" feature about butterflies in the stomach have also been added.
- Chapter 19: Nutrition–provides information on antioxidants in Medical Highlights, and new material on trans fat and weight loss surgery.
- Chapter 20: Urinary System—provides new material on overactive bladder.
- Chapter 21: Reproductive System—includes new information on the hormone relaxin, cervical cancer testing, testicular cancer, and additional information on menorrhagia. In the Medical Highlights for Treatment for BPH, expanded information on types of treatment is provided. Two new Medical Highlights (breast self-examination and testicular self-examination) have also been added.
- Chapter 22: Genetics and Genetically Linked Diseases—provides updated information on cystic fibrosis.

Medical Highlights

- Biotechnology and Nanotechnology (Chapter 1)
- Medical Imaging (Chapter 2)
- Stem Cells (Chapter 3)
- Tissue and Organ Transplant (Chapter 4)
- Hazards of the Sun (Chapter 5)
- RICE Treatment (Chapter 6)
- Surgical Joint Procedures (Chapter 6)
- Massage Therapy and Health (Chapter 7)

- Specialized Brain Cells: Mirror Neurons (Chapter 8)
- Headaches (Chapter 8)
- Parkinson's Disease and Deep Brain Stimulation (Chapter 8)
- Types of Anesthesia (Chapter 9)
- Lasers (Chapter 10)
- Eye Surgery (Chapter 10)
- Hearing Aids (Chapter 10)
- Taste: Umami (Chapter 10)
- Hormone Imbalance: Mental Health (Chapter 11)
- Bone Marrow Transplant (Chapter 12)
- Diagnostic Tests for the Heart (Chapter 13)
- Pacemakers, Defibrillators, and Heart Pumps (Chapter 13)
- Mucosa-Associated Lymphoid Tissue (MALT) (Chapter 15)
- Changes Occurring in Infectious Diseases (Chapter 16)
- Sleep Apnea (Chapter 17)
- Pulmonary Function Tests (Chapter 17)
- Minimally Invasive Surgery: Laparoscopy (Chapter 18)
- Antioxidants (Chapter 19)
- Kidney Stone Removal (Chapter 20)
- Breast Self-Examination (Chapter 21)
- Testicular Self-Examination (Chapter 21)
- Treatment for Benign Prostatic Hypertrophy and Prostate Cancer (Chapter 21)
- Human Papillomavirus Vaccine (Chapter 21)

Career Profiles

- Audiologists (Chapter 10)
- Cardiovascular Technologists and Technicians/EKG Technicians (Chapter 13)
- Certified Patient Care Technician (Chapter 15)
- Chiropractors (Chapter 7)
- Clinical Medical Laboratory Technicians and Clinical Medical Laboratory Technologists (Chapter 12)
- Dental Hygienists, Dental Assistants, and Dental Laboratory Technicians (Chapter 18)
- Dentists (Chapter 18)
- Dietitians and Nutritionists (Chapter 19)
- Electroneurodiagnostic Technicians/EEG Technicians (Chapter 8)
- Emergency Medical Technicians and Paramedics (Chapter 13)
- Home Health Aides (Chapter 15)
- Licensed Practical Nurses (Chapter 14)
- Massage Therapists (Chapter 7)
- Medical Assistants (Chapter 21)
- Nursing Aides and Psychiatric Aides (Chapter 15)
- Optometrists and Dispensing Opticians (Chapter 10)
- Orthotists and Prosthetists (Chapter 6)
- Physical Therapists and Physical Therapist Assistants (Chapter 6)
- Physicians (Chapter 5)
- Radiologic Technologists (Chapter 2)
- Registered Nurses and Nurse Practitioners (Chapter 14)
- Respiratory Therapists (Chapter 17)
- Sports Medicine/Athletic Training (Chapter 7)

Student Workbook

The student workbook includes activities that focus on applied academics through a variety of practical application exercises, including multiple choice, fill in the blanks, matching, labeling, word puzzles, basic skill problems, application of theory to practice, and a Surf-the-Net feature.

Online Resources

Online resources are available to accompany this new textbook that includes slide presentations in PowerPoint and 3D animations.

How to Access the Online Resources

1. GO TO http://www.CengageBrain.com
2. REGISTER as a new user or LOG IN as an existing user if you already have an account with Cengage Learning or CengageBrain.com

About the Author

Ann Senisi Scott, RN, BS, MA, is the author of the thirteenth edition of *Body Structures and Functions*. Ann was previously the Coordinator of Health Occupations and Practical Nursing at Nassau Tech Board of Cooperative Education Services, Westbury, New York. As the Health Occupations Coordinator, she worked to establish a career ladder program from health care worker to practical nurse. Before becoming the administrator of these programs, she taught practical nursing for more than 12 years.

Acknowledgments

To complete this revision of the textbook, I have had the assistance of many people at Cengage Learning. I want to extend my thanks to all the personnel in the Health Sciences area. To Debra Myette-Flis: You have generated so much encouragement and enthusiasm as you guided me through this revision and other revisions—a very heartfelt thank you. Thanks to the reviewers who highlighted areas that needed additional information and corrections; your comments were invaluable. Thanks to Dr. Bryan Senisi, who assisted with some valuable insight into disease conditions.

Special thanks to Wayne Scott, my personal reviewer and mentor, and to my family cheering section: Vincent, Margaret, Carolyn, Daniel, Michael, Kenneth, Leslie, Scotty, and their spouses.

To my grandchildren and future students: Have a love for learning because it will bring much knowledge and rewards as you journey through life.

To the health care professionals of tomorrow: Your knowledge will be an asset in the art of caring for the people entrusted to your care.

Reviewers

We are particularly grateful to the reviewers who continue to be a valuable resource in guiding this book as it evolves. Their insights, comments, suggestions, and attention to detail were very important in guiding the development of this textbook.

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Technical Reviewer

We would like to acknowledge and include a special thank you for the keen eye and thoroughness of our technical reviewer:

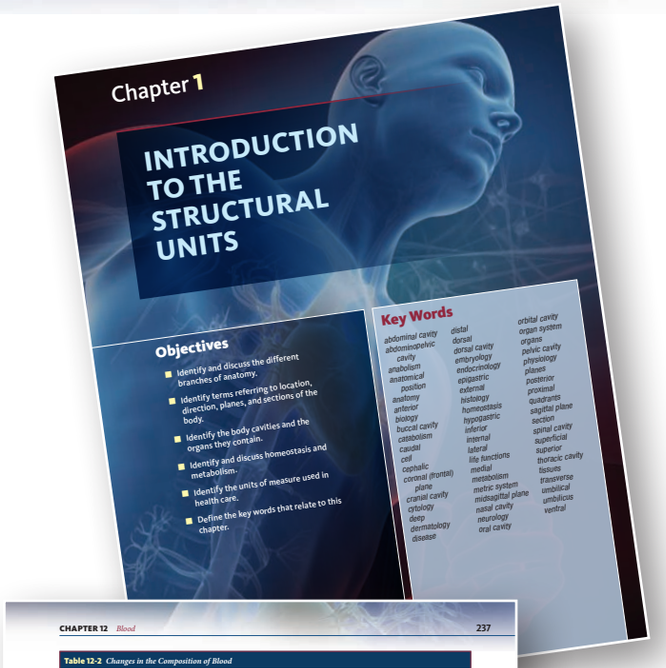
Caryl Tickner
Associate Professor of Biology
President Emeritus Human Anatomy & Physiology Society
Stark State College

How to Study Using BODY STRUCTURES AND FUNCTIONS

Preview the text before attempting to study the material covered in the individual chapters. By reviewing each section of this textbook, you will better understand its organization and purpose. Reading comprehension and long-term memory levels improve dramatically when you take the time to review the text and discover how it can help you learn.

To get the most from this course, take an active role in your learning by integrating your senses to increase your retention. You may want to

- *Visually* highlight important material.
- *Read* critically—turn headings, subheadings, and sentences into questions.
- *Recite* important material aloud to stimulate your auditory memory.
- *Draw* your own illustrations of anatomy or function processes and check them for accuracy.
- *Answer* (in writing or verbally) the review questions at the end of the chapter.


Chapter 1

INTRODUCTION TO THE STRUCTURAL UNITS

Objectives

- Identify and discuss the different branches of anatomy.
- Identify terms referring to location, direction, planes, and sections of the body.
- Identify the body cavities and the organs they contain.
- Identify and discuss homeostasis and metabolism.
- Identify the units of measure used in health care.
- Define the key words that relate to this chapter.

Key Words

abdominal cavity, abdominopelvic cavity, anabolism, anatomical position, anatomy, anterior, biology, buccal cavity, catabolism, caudal, cell, cephalic, coronal (frontal) plane, cranial cavity, cytology, deep, dermatology, disease, distal, dorsal, dorsal cavity, embryology, endocrinology, epigastric, external, histology, homeostasis, hypogastric, inferior, internal, lateral, life functions, medial, metabolism, metric system, midsagittal plane, nasal cavity, neurology, oral cavity, orbital cavity, organ system, organs, pelvic cavity, physiology, planes, posterior, proximal, quadrants, sagittal plane, section, spinal cavity, superficial, superior, thoracic cavity, tissues, transverse, umbilical, umbilicus, ventral

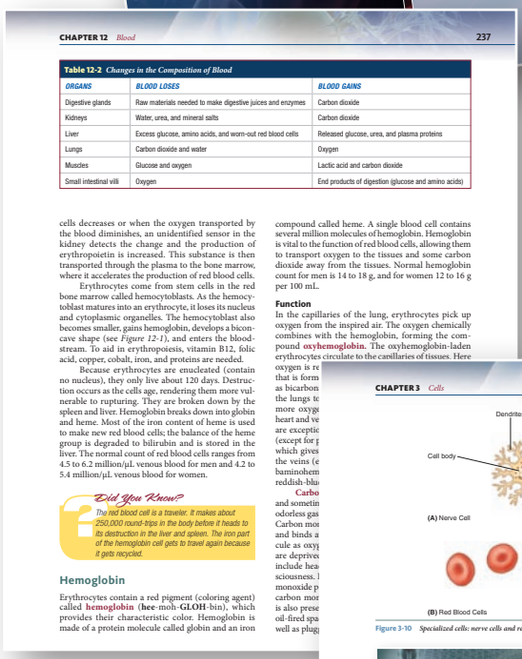

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Table 12-2 *Changes in the Composition of Blood*

ORGANS	BLOOD LOSES	BLOOD GAINS
Digestive glands	Raw materials needed to make digestive juices and enzymes	Carbon dioxide
Kidneys	Water, urea, and mineral salts	Carbon dioxide
Liver	Excess glucose, amino acids, and worn-out red blood cells	Released glucose, urea, and plasma proteins
Lungs	Carbon dioxide and water	Oxygen
Muscles	Glucose and oxygen	Lactic acid and carbon dioxide
Small intestinal villi	Oxygen	End products of digestion (glucose and amino acids)

cells decreases or when the oxygen transported by the blood diminishes, an unidentified sensor in the kidney detects the change and the production of erythropoietin is increased. This substance is then transported through the plasma to the bone marrow, where it accelerates the production of red blood cells.

Erythrocytes come from stem cells in the red bone marrow called hemocytoblasts. As the hemocytoblast matures into an erythrocyte, it loses its nucleus and cytoplasmic organelles. The hemocytoblast also becomes smaller, gains hemoglobin, develops a biconcave shape (see *Figure 12-1*), and enters the bloodstream. To aid in erythropoiesis, vitamin B12, folic acid, copper, cobalt, iron, and proteins are needed.

Because erythrocytes are enucleated (contain no nucleus), they only live about 120 days. Destruction occurs as the cells age, rendering them more vulnerable to rupturing. They are broken down by the spleen and liver. Hemoglobin breaks down into globin and heme. Most of the iron content of heme is used to make new red blood cells; the balance of the heme group is degraded to bilirubin and is stored in the liver. The normal count of red blood cells ranges from 4.5 to 6.2 million/μL venous blood for men and 4.2 to 5.4 million/μL venous blood for women.

Did You Know?

The red blood cell is a traveler. It makes about 250,000 round-trips in the body before it heads to its destruction in the liver and spleen. The iron part of the hemoglobin cell gets to travel again because it gets recycled.

Hemoglobin

Erythrocytes contain a red pigment (coloring agent) called **hemoglobin** (**hee**-moh-**GLOH**-bin), which provides their characteristic color. Hemoglobin is made of a protein molecule called globin and an iron compound called heme. A single blood cell contains several million molecules of hemoglobin. Hemoglobin is vital to the function of red blood cells, allowing them to transport oxygen to the tissues and some carbon dioxide away from the tissues. Normal hemoglobin count for men is 14 to 18 g, and for women 12 to 16 g per 100 mL.

Function

In the capillaries of the lung, erythrocytes pick up oxygen from the inspired air. The oxygen chemically combines with the hemoglobin, forming the compound **oxyhemoglobin.** The oxyhemoglobin-laden erythrocytes circulate to the cardiac tissues. Here oxygen is re
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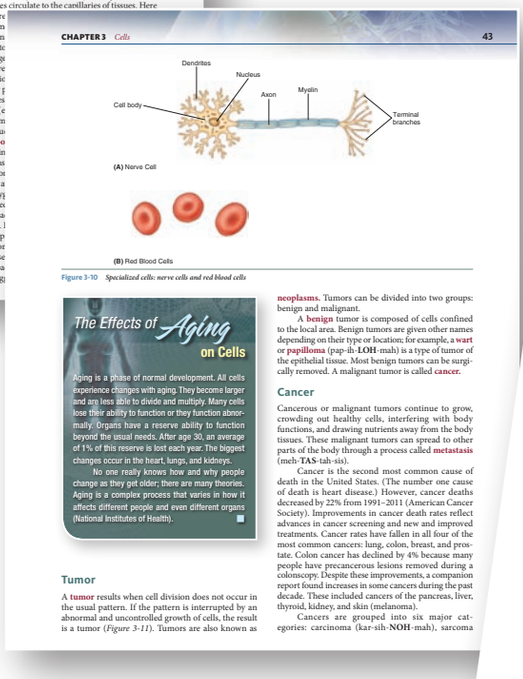

CHAPTER 3 *Cells* 43

Figure 3-10 *Specialized cells: nerve cells and red blood cells*

The Effects of Aging on Cells

Aging is a phase of normal development. All cells experience changes with aging. They become larger and are less able to divide and multiply. Many cells lose their ability to function or they function abnormally. Organs have a reserve ability to function beyond the usual needs. After age 30, an average of 1% of this reserve is lost each year. The biggest changes occur in the heart, lungs, and kidneys.

No one really knows how and why people change as they get older; there are many theories. Aging is a complex process that varies in how it affects different people and even different organs (National Institutes of Health).

Tumor

A **tumor** results when cell division does not occur in the usual pattern. If the pattern is interrupted by an abnormal and uncontrolled growth of cells, the result is a tumor (*Figure 3-11*). Tumors are also known as **neoplasms.** Tumors can be divided into two groups: benign and malignant.

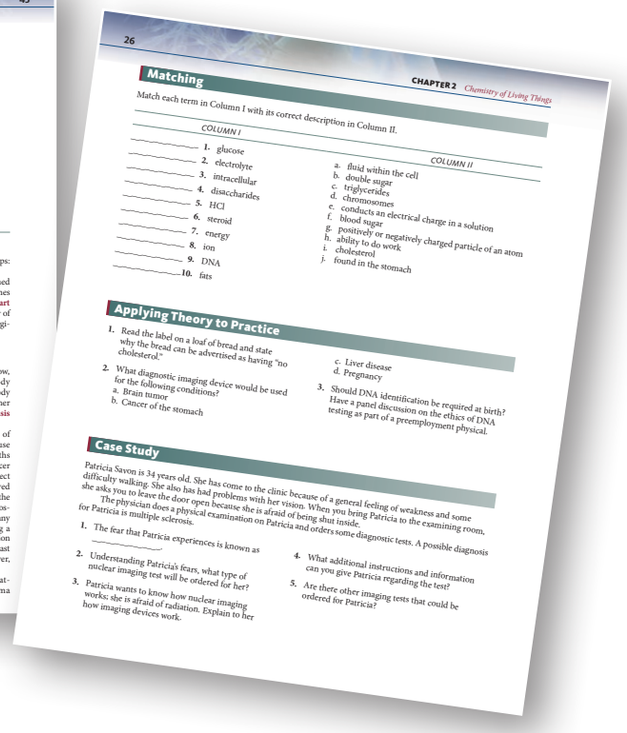
A **benign** tumor is composed of cells confined to the local area. Benign tumors are given other names depending on their type or location; for example, a **wart** or **papilloma** (pap-ih-**LOH**-mah) is a type of tumor of the epithelial tissue. Most benign tumors can be surgically removed. A malignant tumor is called **cancer.**

Cancer

Cancerous or malignant tumors continue to grow, crowding out healthy cells, interfering with body functions, and drawing nutrients away from the body tissues. These malignant tumors can spread to other parts of the body through a process called **metastasis** (meh-**TAS**-tah-sis).

Cancer is the second most common cause of death in the United States. (The number one cause of death is heart disease.) However, cancer deaths decreased by 22% from 1991–2011 (American Cancer Society). Improvements in cancer death rates reflect advances in cancer screening and new and improved treatments. Cancer rates have fallen in all four of the most common cancers: lung, colon, breast, and prostate. Colon cancer has declined by 4% because many people have precancerous lesions removed during a colonoscopy. Despite these improvements, a companion report found increases in some cancers during the past decade. These included cancers of the pancreas, liver, thyroid, kidney, and skin (melanoma).

Cancers are grouped into six major categories: carcinoma (kar-sih-**NOH**-mah), sarcoma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CHAPTER 2 *Chemistry of Living Things*

Matching

Match each term in Column I with its correct description in Column II.

COLUMN I	COLUMN II
1. glucose	a. fluid within the cell
2. electrolyte	b. double sugar
3. intracellular	c. triglycerides
4. disaccharides	d. chromosomes
5. HCl	e. conducts an electrical charge in a solution
6. steroid	f. blood sugar
7. energy	g. positively or negatively charged particle of an atom
8. ion	h. ability to do work
9. DNA	i. cholesterol
10. fats	j. found in the stomach

Applying Theory to Practice

1. Read the label on a loaf of bread and state why the bread can be advertised as having "no cholesterol."
2. What diagnostic imaging device would be used for the following conditions?
   a. Brain tumor
   b. Cancer of the stomach
   c. Liver disease
   d. Pregnancy
3. Should DNA identification be required at birth? Have a panel discussion on the ethics of DNA testing as part of a preemployment physical.

Case Study

Patricia Savon is 34 years old. She has come to the clinic because of a general feeling of weakness and some difficulty walking. She also has had problems with her vision. When you bring Patricia to the examining room, she asks you to leave the door open because she is afraid of being shut inside.

The physician does a physical examination on Patricia and orders some diagnostic tests. A possible diagnosis for Patricia is multiple sclerosis.

1. The fear that Patricia experiences is known as _____.
2. Understanding Patricia's fears, what type of nuclear imaging test will be ordered for her?
3. Patricia wants to know how nuclear imaging works; she is afraid of radiation. Explain to her how imaging devices work.
4. What additional instructions and information can you give Patricia regarding the test?
5. Are there other imaging tests that could be ordered for Patricia?

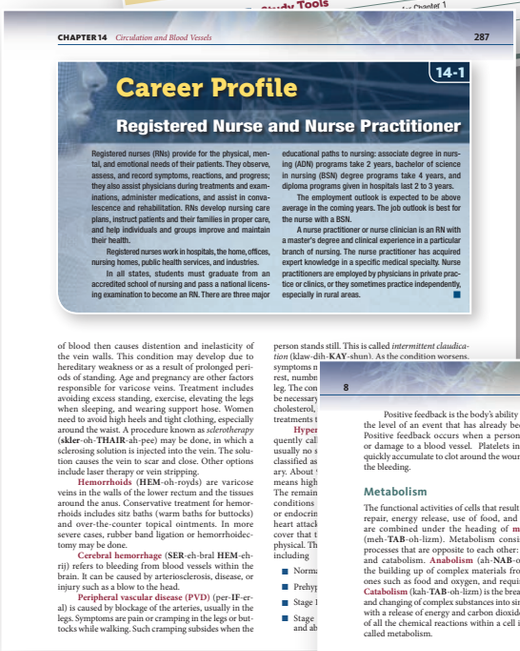
Each time you encounter a new chapter, preview it first to understand its overall structure. Review the **Objectives** presented at the beginning of each chapter to easily identify the key facts *before* you read the chapter. These objectives are also useful to review *after* you have completed a chapter. After reading a chapter, test yourself to see whether you can answer each objective. If you cannot, you will know exactly which areas to study again. The **Key Words** are listed at the beginning of each chapter, are highlighted in ***red*** within the chapter, and are also defined in the glossary.

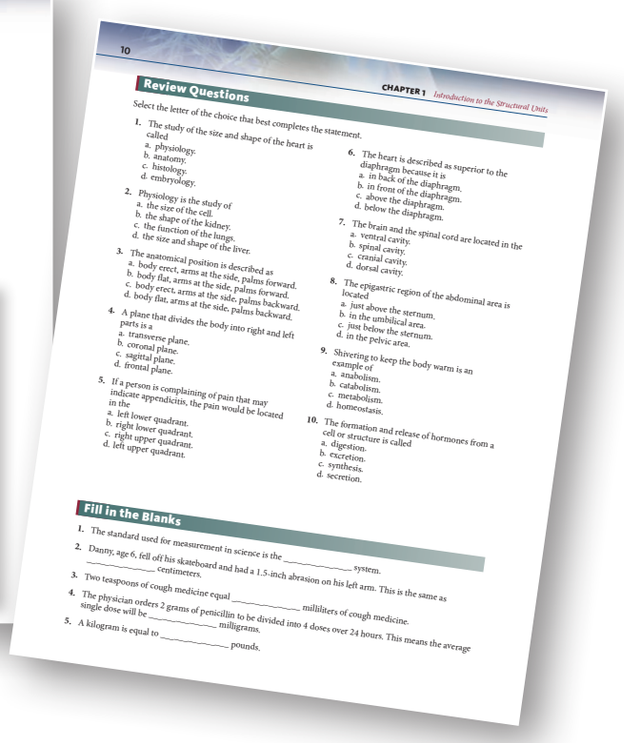
Read the **main headings, subheadings,** and first sentence of each paragraph—these elements serve as the outline for the whole chapter. Be careful not to overlook the **illustrations, photographs,** and **tables,** which can help you comprehend difficult material.

Did You Know? boxes feature fun, interesting, trivialike facts to engage the learner.

Effects of Aging boxes are integrated within the chapters to highlight the changes that are associated with the body systems as we age.

Case Studies promote a real-world view of medical careers and encourage critical thinking.





Medical Terminology boxes introduce you to common medical prefixes and suffixes and how they work to form medical terms.

Career Profiles provide descriptions of many health professions in today's dynamic health and medical environment. These profiles describe the role of each professional, and may even provide you with insight into possible future career paths.

Medical Highlights provide information on technology, innovations, discoveries, and bioethical issues in research and medicine. These topics are based on current information obtained from research on various medical websites.

Review Questions will help you measure whether you have mastered the material you have covered. Questions in a variety of formats are presented to reinforce important information within each chapter. Also integrated here and in the workbook are applied academic activities for math, spelling, communication, and legal-ethical issues.

CHAPTER 2 *Chemistry of Living Things* 27

2-1

Lab Activity

Acid or Base

■ *Objective:* To identify the difference between an acidic (containing an acid), a basic (containing a base), and a neutral substance using litmus paper and pH-indicator scale paper

■ *Materials needed:* litmus paper, pH-indicator scale paper, tap water, vinegar, liquid soap, paper cups, red or blue litmus paper, pH-indicator scale paper, tap water, vinegar, liquid soap, tomato juice, nail polish remover, baking soda solution, milk, lemon juice, a list of the solutions

Step 1: Place the solutions into separate paper cups and label the contents.

Step 2: Using **litmus** paper, indicate if the solution is an acid or a base and record your results on the list.

Step 3: Using pH-indicator scale paper, mark the pH of each solution.

Step 4: Which solution is the strongest acid?

Step 5: What is the pH of water?

2-2

Lab Activity

Effects of Antacid on an Acidic Stomach

■ *Objective:* To determine the effectiveness of various antacid preparations or household remedies on an acidic stomach; the stomach under normal conditions has a pH of about 2

■ *Materials needed:* measuring cup, vinegar, water, paper cups, Tums, Rolaids, Pepcid AC, Alka-Seltzer, baking soda solution, pH-indicator paper, pencil, paper on which to record your results

Step 1: Mix 1 oz of vinegar with 8 oz of water to make a solution that represents an acidic stomach.

Step 2: Use pH-indicator paper to test the pH of the acidic stomach preparation. Record your result.

Step 3: Place approximately 1.5 oz of the acidic stomach solution into each of the different paper cups.

Step 4: Add one type of antacid preparation or 1 tablespoon of the baking soda solution to

Step 6: After the tablets and baking soda solutions have dissolved, retest each of the solutions with pH-indicator paper to measure any changes in the pH of the solution. Record your results.

Step 7: Did the antacid preparation raise the pH of the acidic stomach solution?

Step 8: Which preparation was most effective as an antacid?

Step 9: Obtain the prices of the various antacids. Which preparation is most cost-effective (least expensive to produce the desired result)?

30 CHAPTER 3 *Cells*

The body of a plant or animal seems to be a single entity, but when any portion is examined under a microscope it is found to be made up of many small, discrete parts. These tiny parts, or units, are called cells. (*Note:* These units were first discovered in the 1600s by Robert Hook. When examining a piece of cork under a crude microscope, the units reminded him of a monk's room, which was called a cell.) All living things—whether plant or animal, unicellular or multicellular, large or small—are composed of cells. A cell is microscopic in size. Our bodies are made up of trillions of cells that live mostly for a few weeks or months, die, and are replaced by new cells. Even the bone cells of our skeleton are replaced. *The cell is the basic unit of structure and function of all living things.*

Protoplasm

Cells are composed of **protoplasm** (pro-toh-**PLAZM**), an aqueous solution of carbohydrates, proteins, lipids, nucleic acids, and inorganic salts surrounded by a cell membrane. These components are organized into structures that have a specific function in the cell and are called organelles. **Organelles** (or-guh-**NELZ**) common to human cells include the nucleus, **ribosomes** (**RYE**-boh-sohmz), **centrosomes** (**SEN**-troh-sohmz), **centrioles** (**SEN**-tree-olz), **endoplasmic reticulum** (en-doh-**PLAZ**-mik re-**TICK**-you-lum), **mitochondria** (my-toh-**KON**-dree-ah), **lysosomes** (**LIGH**-soh-sohmz), **peroxisomes** (peh-**ROKS**-ih-sohmz), the **Golgi apparatus** (**GOHL**-jee), and a **cytoskeleton.**

Protoplasm inside the nucleus of a cell is called **nucleoplasm** (**NOO**-klee-oh-plazm), and outside the nucleus it is called **cytoplasm** (**SIGH**-toh-plazm).

Because cells are microscopic, a special unit of measurement is used to determine their size. This is the micrometer (µm), or micron (µ). It is used to describe both the size of cells and their cellular components. To see or study a cell in fine detail, an electron microscope must be used.

To better understand the structure of a cell, let us compare a living entity—such as a human being—to a house. The many individual cells of this living organism are comparable to the many rooms of a house. Just as each room is bounded by four walls, a floor, and a ceiling, a cell is bounded by a specialized cell membrane with many openings. Cells, like rooms, come in a variety of shapes and sizes. Every kind of room or cell has its own unique function. A house can be made up of a single room or many. In much the same fashion, a living thing can be made up of only one cell (unicellular) or many cells (multicellular). *Figure 3-1* shows the structure of a typical animal cell.

Did You Know?

Fifty thousand cells in your body will die and be replaced with new cells while you read this sentence.

Cell/Plasma Membrane

Every cell is surrounded by a **cell membrane,** sometimes called a plasma membrane. The membrane separates the cell from its external environment and from the neighboring cells. It also regulates the passage or transport of certain molecules into and out of the cell, while preventing the passage of others. This is why the cell membrane is often called a selective semipermeable membrane. The cell membrane is composed of a double phospholipid layer, with proteins embedded in the layer. The phospholipid looks like a balloon with tails. The round balloonlike part is hydrophilic (attracts water) and the double tails are hydrophobic (repels water). This arrangement allows for the easy passage of water molecules through the cell membrane by osmosis. The proteins embedded in the double phospholipid layer allow for the passage of molecules and ions across the cell membrane (*Figure 3-2*).

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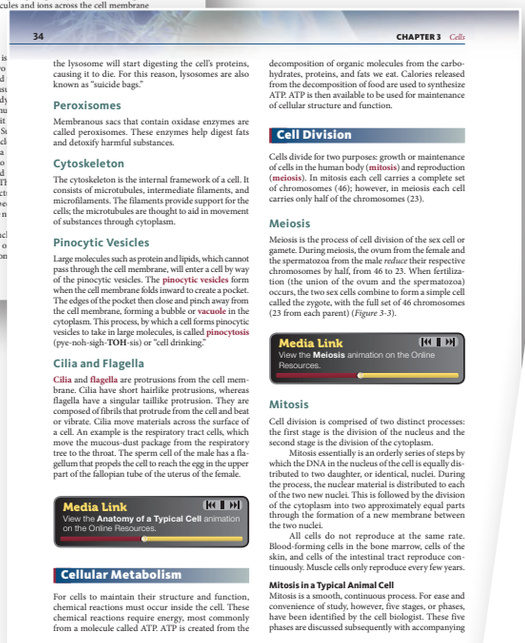


34 CHAPTER 3 *Cells*

the lysosome will start digesting the cell's proteins, causing it to die. For this reason, lysosomes are also known as "suicide bags."

Peroxisomes

Membranous sacs that contain oxidase enzymes are called peroxisomes. These enzymes help digest fats and detoxify harmful substances.

Cytoskeleton

The cytoskeleton is the internal framework of a cell. It consists of microtubules, intermediate filaments, and microfilaments. The filaments provide support for the cells; the microtubules are thought to aid in movement of substances through cytoplasm.

Pinocytic Vesicles

Large molecules such as protein and lipids, which cannot pass through the cell membrane, will enter a cell by way of the pinocytic vesicles. The **pinocytic vesicles** form when the cell membrane folds inward to create a pocket. The edges of the pocket then close and pinch away from the cell membrane, forming a bubble or **vacuole** in the cytoplasm. This process, by which a cell forms pinocytic vesicles to take in large molecules, is called **pinocytosis** (pye-noh-sigh-**TOH**-sis) or "cell drinking."

Cilia and Flagella

Cilia and **flagella** are protrusions from the cell membrane. Cilia have short hairlike protrusions, whereas flagella have a singular taillike protrusion. They are composed of fibrils that protrude from the cell and beat or vibrate. Cilia move materials across the surface of a cell. An example is the respiratory tract cells, which move the mucous-dust package from the respiratory tree to the throat. The sperm cell of the male has a flagellum that propels the cell to reach the egg in the upper part of the fallopian tube of the uterus of the female.

Media Link
View the **Anatomy of a Typical Cell** animation on the Online Resources.

Cellular Metabolism

For cells to maintain their structure and function, chemical reactions must occur inside the cell. These chemical reactions require energy, most commonly from a molecule called ATP. ATP is created from the decomposition of organic molecules from the carbohydrates, proteins, and fats we eat. Calories released from the decomposition of food are used to synthesize ATP. ATP is then available to be used for maintenance of cellular structure and function.

Cell Division

Cells divide for two purposes: growth or maintenance of cells in the human body (**mitosis**) and reproduction (**meiosis**). In mitosis each cell carries a complete set of chromosomes (46); however, in meiosis each cell carries only half of the chromosomes (23).

Meiosis

Meiosis is the process of cell division of the sex cell or gamete. During meiosis, the ovum from the female and the spermatozoa from the male *reduce* their respective chromosomes by half, from 46 to 23. When fertilization (the union of the ovum and the spermatozoa) occurs, the two sex cells combine to form a simple cell called the zygote, with the full set of 46 chromosomes (23 from each parent) (*Figure 3-3*).

Media Link
View the **Meiosis** animation on the Online Resources.

Mitosis

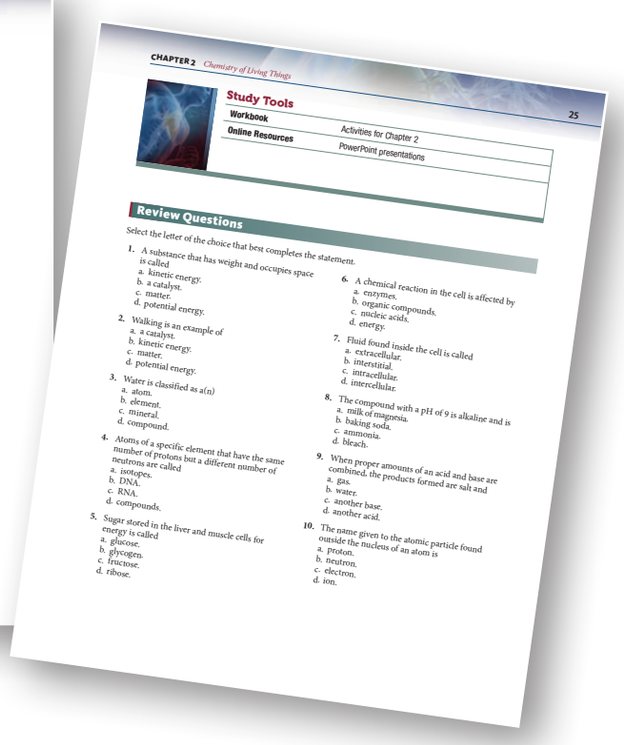
Cell division is comprised of two distinct processes: the first stage is the division of the nucleus and the second stage is the division of the cytoplasm.

Mitosis essentially is an orderly series of steps by which the DNA in the nucleus of the cell is equally distributed to two daughter, or identical, nuclei. During the process, the nuclear material is distributed to each of the two new nuclei. This is followed by the division of the cytoplasm into two approximately equal parts through the formation of a new membrane between the two nuclei.

All cells do not reproduce at the same rate. Blood-forming cells in the bone marrow, cells of the skin, and cells of the intestinal tract reproduce continuously. Muscle cells only reproduce every few years.

Mitosis in a Typical Animal Cell

Mitosis is a smooth, continuous process. For ease and convenience of study, however, five stages, or phases, have been identified by the cell biologist. These five phases are discussed subsequently with accompanying



CHAPTER 2 *Chemistry of Living Things* 25

Study Tools

Workbook	Activities for Chapter 2
Online Resources	PowerPoint presentations

Review Questions

Select the letter of the choice that best completes the statement.

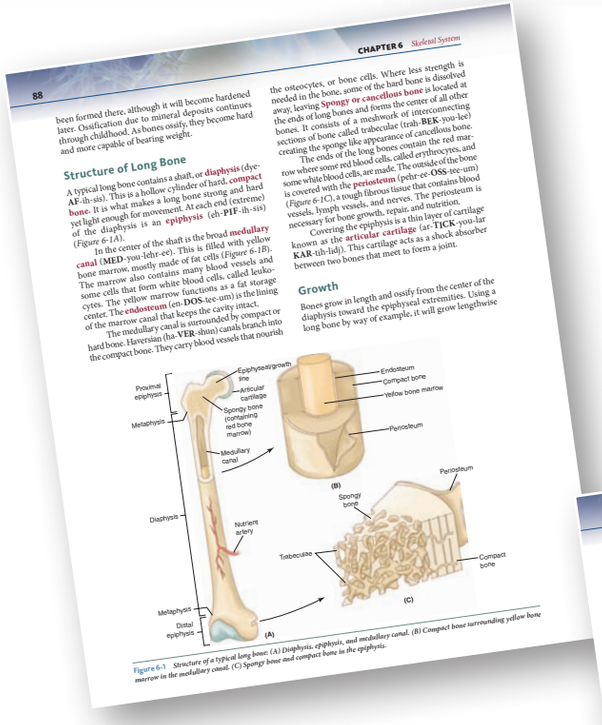
1. A substance that has weight and occupies space is called
   a. kinetic energy.
   b. a catalyst.
   c. matter.
   d. potential energy.
2. Walking is an example of
   a. a catalyst.
   b. kinetic energy.
   c. matter.
   d. potential energy.
3. Water is classified as a(n)
   a. atom.
   b. element.
   c. mineral.
   d. compound.
4. Atoms of a specific element that have the same number of protons but a different number of neutrons are called
   a. isotopes.
   b. DNA.
   c. RNA.
   d. compounds.
5. Sugar stored in the liver and muscle cells for energy is called
   a. glucose.
   b. glycogen.
   c. fructose.
   d. ribose.
6. A chemical reaction in the cell is affected by
   a. enzymes.
   b. organic compounds.
   c. nucleic acids.
   d. energy.
7. Fluid found inside the cell is called
   a. extracellular.
   b. interstitial.
   c. intracellular.
   d. intercellular.
8. The compound with a pH of 9 is alkaline and is
   a. milk of magnesia.
   b. baking soda.
   c. ammonia.
   d. bleach.
9. When proper amounts of an acid and base are combined, the products formed are salt and
   a. gas.
   b. water.
   c. another base.
   d. another acid.
10. The name given to the atomic particle found outside the nucleus of an atom is
    a. proton.
    b. neutron.
    c. electron.
    d. ion.

Lab Activities incorporate an element of interactivity to the content, further enhancing comprehension.

Phonetic pronunciations of key words in each chapter are in parentheses following the key word. Pronounce the word by saying each syllable, placing more emphasis on the syllable in boldface capital letters.

Media Links direct you to Online Resources that include PowerPoint presentations and 3D animations.

Study Tools alert you to additional resources to help you understand the material.



88 CHAPTER 6 Skeletal System

been formed there, although it will become hardened later. Ossification due to mineral deposits continues through childhood. As bones ossify, they become hard and more capable of bearing weight.

Structure of Long Bone

A typical long bone contains a shaft, or **diaphysis** (dye-**AF**-ih-sis). This is a hollow cylinder of hard, **compact bone**. It is what makes a long bone strong and hard yet light enough for movement. At each end (extreme) of the diaphysis is an **epiphysis** (eh-**PIF**-ih-sis) (*Figure 6-1A*).

In the center of the shaft is the broad **medullary canal** (**MED**-you-lehr-ee). This is filled with yellow bone marrow, mostly made of fat cells (*Figure 6-1B*). The marrow also contains many blood vessels and some cells that form white blood cells, called leukocytes. The yellow marrow functions as a fat storage center. The **endosteum** (en-**DOS**-tee-um) is the lining of the marrow canal that keeps the cavity intact.

The medullary canal is surrounded by compact or hard bone. Haversian (ha-**VER**-shun) canals branch into the compact bone. They carry blood vessels that nourish the osteocytes, or bone cells. Where less strength is needed in the bone, some of the hard bone is dissolved away, leaving **Spongy or cancellous bone** is located at the ends of long bones and forms the center of all other bones. It consists of a meshwork of interconnecting sections of bone called trabeculae (trah-**BEK**-you-lee) creating the sponge like appearance of cancellous bone.

The ends of the long bones contain the red marrow where some red blood cells, called erythrocytes, and some white blood cells, are made. The outside of the bone is covered with the **periosteum** (peh-ree-**OSS**-tee-um) (*Figure 6-1C*), a tough fibrous tissue that contains blood vessels, lymph vessels, and nerves. The periosteum is necessary for bone growth, repair, and nutrition.

Covering the epiphysis is a thin layer of cartilage known as the **articular cartilage** (ar-**TICK**-you-lar **KAR**-tih-lidj). This cartilage acts as a shock absorber between two bones that meet to form a joint.

Growth

Bones grow in length and ossify from the center of the diaphysis toward the epiphyseal extremities. Using a long bone by way of example, it will grow lengthwise

Figure 6-1 *Structure of a typical long bone: (A) Diaphysis, epiphysis, and medullary canal. (B) Compact bone surrounding yellow bone marrow in the medullary canal. (C) Spongy bone and compact bone in the epiphysis.*

The **Glossary of Terms** provides you with a concise definition for all the *key words* in the textbook. The **Index** serves as an alphabetical listing of topics, terms, concepts, and important names for easy reference. Note that figure page numbers are listed in **boldface** in the index.

482 GLOSSARY

anemia blood disorder characterized by reduction in red blood cells or hemoglobin
aneurysm a widening, or sac, formed by dilation of a blood vessel
angina pectoris severe chest pain caused by lack of blood supply to heart
angioplasty balloon surgery to open blocked blood vessels
anorexia nervosa an illness in which a person refuses to eat
anoxia a lack of oxygen to cellular structures
antagonist a muscle whose action opposes the action of another muscle
anterior from or ventral
anterior chamber space between cornea and iris
anterior nares external portion of the nostrils
anterior pituitary lobe area of the pituitary gland that is responsible for the secretion of growth hormones
anthrax a disease-causing organism that has three forms: cutaneous, intestinal, and inhalation; the last of which is the most deadly form
antibody substance produced by the body that inactivates a specific foreign substance that has entered the body; formed as a reaction to an antigen
anticoagulant chemical substance that prevents or slows blood clotting (e.g., heparin)
anticonvulsant therapeutic agent that stops or prevents convulsions
antidiuretic hormone (ADH) hormone secreted by the posterior pituitary gland that prevents or suppresses urine excretion
antigen substance stimulating formation of antibodies against itself
antipyretic/pyrexia chemical substance, such as heparin, that directly or indirectly reduces or retards the action of prothrombin
antithromboplastin chemical substance that inhibits the clot-accelerating effect of thromboplastins
anuria absence of urine
anus outlet from rectum
anvil (incus) middle ear bone, or ossicle, in a chain of three ossicles of the middle ear
aorta largest artery in body, rising from the left ventricle of the heart
aortic semilunar valve made up of three half-moon-shaped cups, located between the junction of the aorta and the left ventricle of the heart
aphasia loss of ability to speak; may be accompanied by loss of verbal comprehension
aplastic anemia anemia caused by a suppression of the bone marrow
apnea temporary stoppage of breathing movements
aponeurosis flattened sheet of white, fibrous connective tissue; holds one muscle to another or to the periosteum
apoptosis an orderly process by which cells intentionally die. The term is used interchangeably with the term *programmed cell death (PCD)*
appendicitis inflammation of the appendix; *see* vermiform appendix
appendicular skeleton part of skeleton consisting of pectoral and pelvic girdles, and limbs
aqueous humor watery fluid found in anterior chamber of the eye
arachnoid mater weblike middle membrane of meninges
areola pigmented ring around nipple; any small space in tissue
areolar tissue a type of connective tissue that surrounds various organs and supports both nerve and blood vessels
arrector pili muscle a smooth muscle on the side of each hair follicle; when cold, it stimulates the skin to pucker around the hair
arrhythmia absence of a normal heartbeat rhythm
arterioles small branches of an artery
arteriosclerosis hardening of arteries, resulting in thickening of walls and loss of elasticity
artery blood vessel that carries blood away from the heart
arthritis inflammation of a joint
articular cartilage thin layer of cartilage over the ends of long bones
artificial acquired immunity type of immunity acquired as a result of an injection of vaccine, antigen, or toxoid
artificial insemination procedure in which semen is placed in vagina by means of cannula or syringe
artificial pacemaker is a surgically implanted device that sends electrical impulses to regulate the rhythm of the heart.
asbestosis a respiratory disease caused by inhaling asbestos fibers
ascending colon portion of the colon that travels up the right side of the abdominal cavity
ascites accumulation of fluid in the peritoneal cavity
asepsis being free of living Pathogenic microorganisms
association neuron carries messages from sensory neuron to motor neuron; also called *interneuron*
asthma condition in which the airways are obstructed as a result of an inflammatory reaction to a stimulus
astigmatism irregular curvature of cornea or lens
atelectasis condition in which the lungs fail to expand normally
atherosclerosis hardening of arteries due to deposits of fatlike material in the lining of the arteries
athlete's foot fungal infection of the foot
atlas first cervical vertebra; articulates with the axis and occipital skull bone
atom smallest piece of an element
atrial fibrillation occurs when abnormal impulses from the atria bombard the AV node. This action causes the ventricles to beat faster and a person can experience tachycardia
atrioventricular bundle conducting fibers in the septum; also known as the *bundle of His*
atrioventricular (AV) node small mass of interwoven conducting tissue located between the atria and ventricles
atrium upper chamber of the heart
atrophy wasting away of tissue
auricle (1) pinna, or ear flap, of external ear; (2) atrium of the heart
autoimmune disorder a condition that causes destruction of the body's own tissues
autoimmunity action of antibodies against one's own body
autonomic nervous system collection of nerves, ganglia, and plexuses through which visceral organs, heart, blood vessels, glands, and smooth (involuntary) muscles receive stimulation
avascular without blood vessels
axial skeleton skeleton of head and trunk
axilla armpit
axillary nodes lymph nodes found under the arms and near the breast
axis second cervical vertebra
axon nerve cell structure that carries impulses away from cell bodies to dendrites

B

B lymphocytes white blood cells synthesized in the bone marrow; help form antibodies
bacteria agents capable of causing disease or infection
bactericidal causing the death of bacteria
ball-and-socket joint diarthrosis joint that allows the greatest freedom of movement

PROLOGUE

The History of Anatomical Science and Scientists

Much of the early study of gross anatomy and physiology comes from Aristotle, a Greek philosopher. Aristotle believed that every organ has a specific function and that function is based on the organ's structure. Most of Aristotle's ideas were based on the dissection of plants and animals. He never dissected a human body.

In the third century BC, Herophilus founded the first school of anatomy and encouraged the dissection of the human body. He is credited with demonstrating that the brain is the center of the nervous system. It was a Greek physician, Galen, however, who is credited with the creation of the first standard medical text expanding on Aristotle's ideas. Galen was the first to discover many muscles and the first to find the value in monitoring an individual's pulse. Galen never performed human dissections and many of his theories were later proven wrong.

The first medical schools were founded in the Middle Ages; however, instructors at this time were hesitant to question the theories and beliefs founded by the early Greeks such as Aristotle and Galen. As a result, very few ideas or discoveries were made in the medical field in the Middle Ages.

During the Renaissance, however, interest in anatomy was renewed due in part to the work of artist Leonardo da Vinci, who studied the form and function of the human body. It was during this period in history that the first systematic study of the structure of the human body was made. Many of these early scientists were hindered in their pursuit of knowledge of the human body because it was believed by many that human dissections were immoral and illegal. For example, Andreas Vesalius, a founder of modern anatomy, was sentenced to death because of his anatomical dissections of humans.

In the seventeenth century, the invention of the microscope aided in new anatomical discoveries and research. Scientists could now see structures that were invisible to the naked eye. Robert Hooke's investigation of cork under the microscope was the foundation of the theory that the cell is the basic unit of life. This theory was later proved and expanded on by other scientists in the eighteenth century as technological advances continued to improve.

Advances in technology have continued into today and new anatomical and physiological discoveries are still being made. With the mapping of the human genome, completed in 2003, the complete genetic code has been documented. It is hoped that this knowledge will enable discoveries into disease processes and the development of cures for many of the diseases that continue to plague our society.

The use of new types of medical imaging, such as computerized scanning and digitalized photography, has helped researchers make new discoveries about the body.

Use key words to search the Internet for new discoveries related to a particular body system and the scientists who made those discoveries.

Chapter 1

INTRODUCTION TO THE STRUCTURAL UNITS

Objectives

- Identify and discuss the different branches of anatomy.
- Identify terms referring to location, direction, planes, and sections of the body.
- Identify the body cavities and the organs they contain.
- Identify and discuss homeostasis and metabolism.
- Identify the units of measure used in health care.
- Define the key words that relate to this chapter.

Key Words

abdominal cavity
abdominopelvic cavity
anabolism
anatomical position
anatomy
anterior
biology
buccal cavity
catabolism
caudal
cell
cephalic
coronal (frontal) plane
cranial cavity
cytology
deep
dermatology
disease
distal
dorsal
dorsal cavity
embryology
endocrinology
epigastric
external
histology
homeostasis
hypogastric
inferior
internal
lateral
life functions
medial
metabolism
metric system
midsagittal plane
nasal cavity
neurology
oral cavity
orbital cavity
organ system
organs
pelvic cavity
physiology
planes
posterior
proximal
quadrants
sagittal plane
section
spinal cavity
superficial
superior
thoracic cavity
tissues
transverse
umbilical
umbilicus
ventral

Anatomy and Physiology

Anatomy and physiology are branches of a much larger science called **biology** (bye-**OL**-oh-jee). Biology is the study of all forms of life. Biology studies microscopic one-celled organisms, multicelled organisms, plants, animals, and humans.

Anatomy (ah-**NAT**-oh-mee) studies the shape and structure of an organism's body and the relationship of one body part to another. The word *anatomy* comes from the Greek *ana*, meaning "apart," and *temuein*, "to cut"; thus, the acquisition of knowledge on human anatomy comes basically from dissection. However, one cannot fully appreciate and understand anatomy without the study of its sister science, **physiology** (fiz-ee-**OL**-oh-jee). Physiology studies the function of each body part and how the functions of the various body parts coordinate to form a complete living organism. Any abnormal change in a structure or function that produces symptoms is considered a **disease** (diz-**EASE**).

Branches of Anatomy

Anatomy is subdivided into many branches based on the investigative techniques used, the type of knowledge desired, or the parts of the body under study.

1. **Gross anatomy.** Gross anatomy is the study of large and easily observable structures on an organism. This is done through dissection and visible inspection with the naked eye. In gross anatomy, the different body parts and regions are studied with regard to their general shape, external features, and main divisions.
2. **Microscopic anatomy.** Microscopic anatomy refers to the use of microscopes to enable one to see the minute details of organ parts. Ultrawave and electron microscopes provide greater magnification and resolution than optical microscopes do. Microscopic anatomy is subdivided into two branches. One branch is **cytology** (sigh-**TOL**-oh-jee), which is the study of the structure, function, and development of cells that comprise the different body parts. The other subdivision is **histology** (hiss-**TOL**-oh-jee), which studies the tissues and organs that make up the entire body of an organism.
3. **Developmental anatomy.** Developmental anatomy studies the growth and development of an organism during its lifetime. More specifically, **embryology** (**em**-bree-**OL**-oh-jee) studies the formation of an organism from fertilized egg to birth.
4. **Comparative anatomy.** Humans are some of the many animals found in the animal kingdom. The different body parts and organs of humans can be studied with regard to similarities with and differences from others in the animal kingdom.
5. **Systematic anatomy.** Systematic anatomy is the study of the structure of various organs or parts that comprise a particular organ system. Depending on the particular organ system under study, a specific term is applied; for example
   a. **Dermatology** (der-mah-**TOL**-oh-jee)—study of the integumentary system (skin, hair, and nails)
   b. **Endocrinology** (**en**-doh-krin-**OL**-oh-jee)—study of the endocrine or hormonal system
   c. **Neurology** (**new**-**ROL**-oh-jee)—study of the nervous system

Anatomical Terminology

In the study of anatomy and physiology, special words are used to describe the specific location of a structure or organ, or the relative position or direction of one body part to another. The initial reference point used is the anatomical position. In the **anatomical position,** a human being is standing erect, with face forward, arms at the side, and palms forward (*Figure 1-1*).

Terms Referring to Location or Position and Direction

See *Figure 1-1* and *Figure 1-2*.

- **Anterior** or **ventral** means "front" or "in front of." For example, the knees are located on the anterior surface of the human body. A ventral hernia may protrude from the front or belly of the abdomen.
- **Posterior** or **dorsal** means "back" or "in back of." For example, human shoulder blades are found on the posterior surface of the body.
- **Cephalic** (seh-**FAL**-ick) and **caudal** (**KAWD**-al) refer to direction: Cephalic means "skull" or "head end" of the body; caudal means "tail end." For example, a blow to the skull may increase cranial pressure and cause headaches. Caudal anesthesia is injected in the lower spine.
- **Superior** means "upper" or "above another" and **inferior** refers to "lower" or "below another." For

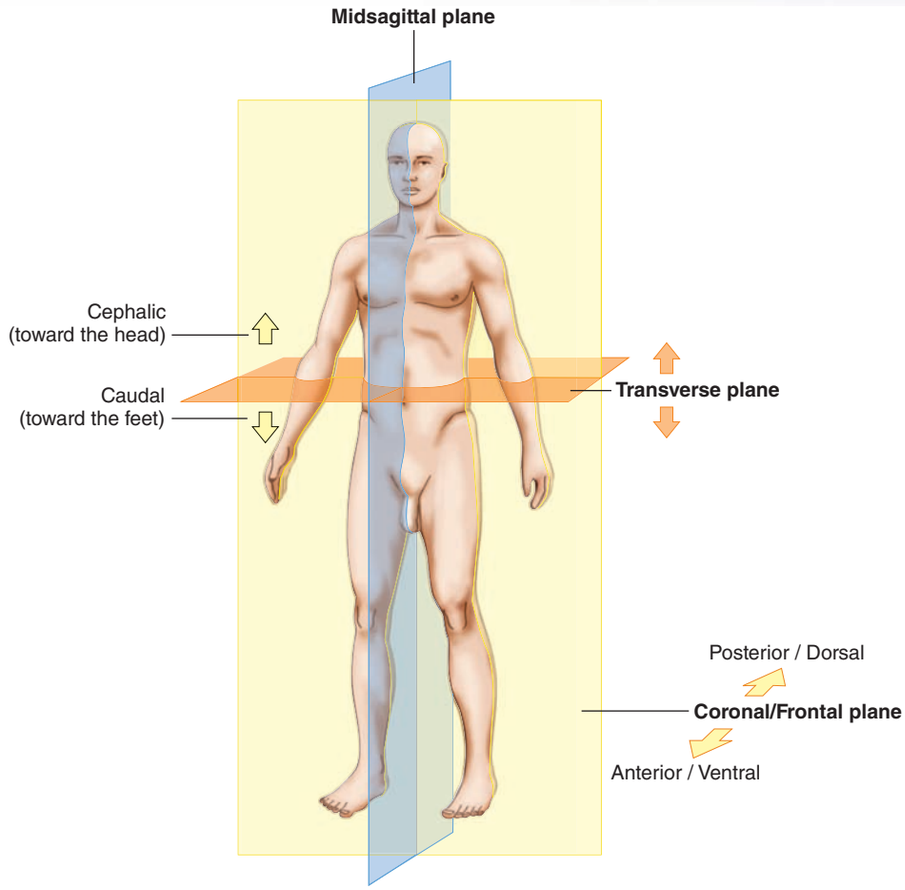


Figure 1-1 *Body directions: Cephalic refers to the skull or head end of the body, and caudal refers to the tail end. Anterior (or ventral) means "front" or "in front of." Posterior (or dorsal) means "back" or "in back of."*

example, the heart and lungs are situated superior to the diaphragm, while the intestines are inferior to the diaphragm.

- **Medial** signifies "toward the midline or median plane of the body," while **lateral** means "away" or "toward the side of the body." For example, the nose is medial to the eyes and the ears are lateral to the nose.
- **Proximal** means "toward the point of attachment to the body" or "toward the trunk of the body"; **distal** means "away from the point of attachment or origin" or "farthest from the trunk." For example, the wrist is proximal to the hand; the elbow is distal to the shoulder. *Note:* these two words are used primarily to describe the appendages or extremities.
- **Superficial** or **external** and **deep** or **internal**—superficial implies "on or near the surface of the body." For example, a superficial wound involves an injury to the outer skin. A deep injury involves damage to an internal organ such as the stomach. The terms *external* and *internal* are specifically used to refer to body cavities and hollow organs.

Terms Referring to Body Planes and Sections

Planes are imaginary anatomical dividing lines that are useful in separating body structures (*Figure 1-3*). A **section** is a cut made through the body in the direction of a certain plane.

The **sagittal plane** (**SAJ**-ih-tal) divides the body into right and left parts. If the plane started in the middle of the skull and proceeded down, bisecting the sternum and the vertebral column, the body would be divided equally into right and left halves. This would be known as the **midsagittal plane.**

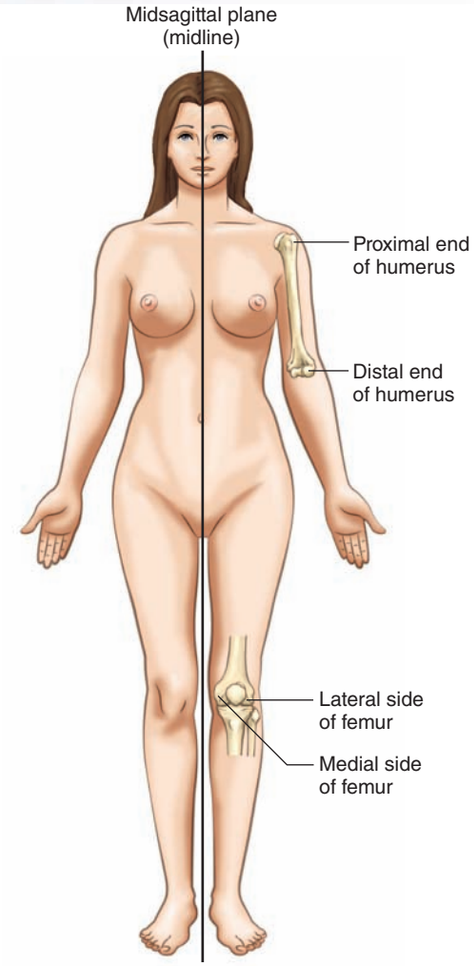


Figure 1-2 *Body directions: Proximal means "toward the point of attachment to the body" or "toward the trunk of the body." Distal means "away from the point of attachment or origin" or "farthest from the trunk." Medial means "toward the midline or median plane of the body," and lateral means "away or toward the side of the body."*

A **coronal (frontal) plane** is a vertical cut at right angles to the sagittal plane, dividing the body into anterior and posterior portions. The term *coronal* comes from the coronal suture, which runs perpendicular (at a right angle) to the sagittal suture. A **transverse** or cross section is a horizontal cut that divides the body into upper and lower portions.

Media Link
View the **Body Planes** animation on the Online Resources.

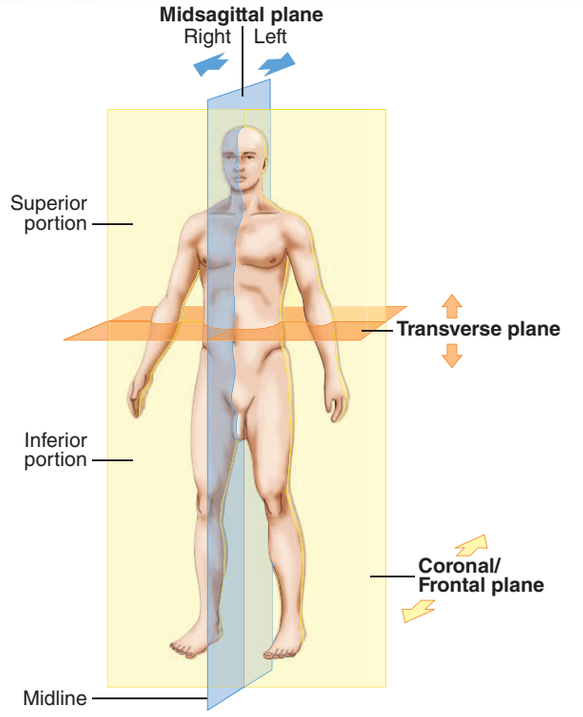


Figure 1-3 *Body planes: The midsagittal plane divides the body equally into right and left halves. The transverse plane divides the body into upper and lower portions. The coronal (or frontal) plane divides the body into anterior and posterior portions.*

Terms Referring to Cavities of the Body

The organs that comprise most of the body systems are located in four major cavities: cranial, spinal, thoracic, and abdominopelvic (*Figure 1-4*). The cranial and spinal cavities are within a larger region known as the posterior (dorsal) cavity. The thoracic and abdominopelvic cavities are found in the anterior (ventral) cavity.

The **dorsal cavity** contains the brain and spinal cord: the brain is in the **cranial cavity** and the spinal cord is in the **spinal cavity** (*Figure 1-4*). The diaphragm divides the ventral cavity into two parts: the upper thoracic and lower abdominopelvic cavities.

The central area of the **thoracic cavity** (tho-**RASS**-ik) is called the mediastinum. It lies between the lungs and extends from the sternum (breastbone) to the vertebrae of the back. The esophagus, bronchi, lungs, trachea, thymus gland, and heart are located in the thoracic cavity. The heart itself is contained within a smaller cavity called the pericardial cavity.

The thoracic cavity is further subdivided into two pleural cavities. The left lung is in the left cavity; the right lung is in the right cavity. Each lung is covered with a thin membrane called the pleura.

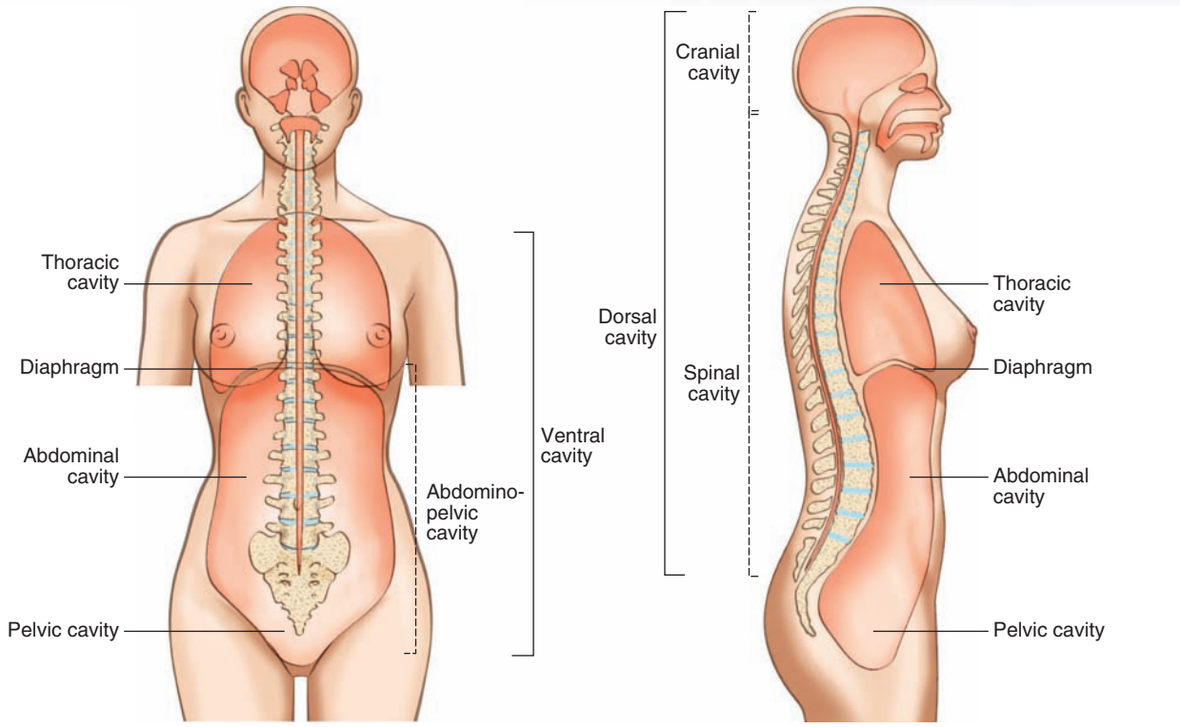


Figure 1-4 *The major body cavities*

The **abdominopelvic cavity** (ab-**dom**-ih-noh-**PEL**-vick) is actually one large cavity with no separation between the abdomen and pelvis. To avoid confusion, this cavity is usually referred to separately as the abdominal cavity and the pelvic cavity. The **abdominal cavity** contains the stomach, liver, gallbladder, pancreas, spleen, small intestine, appendix, and part of the large intestine. The kidneys are close to but behind the abdominal cavity. The urinary bladder, reproductive organs, rectum, and remainder of the large intestine are in the **pelvic cavity.**

Terms Referring to Regions in the Abdominopelvic Cavity

To locate the abdominal and pelvic organs more easily, the abdominopelvic cavity is divided into nine regions (*Figure 1-5*).

The nine regions are located in the upper, middle, and lower parts of the abdomen:

- The upper or **epigastric** (ep-ih-**GAS**-trick) region is located just below the sternum (breastbone). The right and left **hypochondriac** (**high**-poh-**KON**-dree-ack) regions are located below the ribs.
- The middle or **umbilical** area is located around the navel or **umbilicus** (um-**BILL**-ih-kus), and the right and left lumbar regions extend from anterior to posterior. (A person will complain of back pain or lumbar pain.)
- The lower or **hypogastric** (**high**-poh-**GAS**-trick) region may also be referred to as the pubic area; the left and right iliac may also be called the left and right inguinal areas.

Smaller Cavities

In addition to the cranial cavity, the skull contains several smaller cavities. The eyes, eyeball muscles, optic nerves, and lacrimal (tear) ducts are within the **orbital cavity.** The **nasal cavity** contains the parts that form the nose. The **oral cavity** or **buccal cavity** (**BUCK**-ull) encloses the teeth and tongue.

Terms Referring to Quadrants in the Abdominal Area

Another method for referencing the abdominal area is to divide the area into **quadrants.** This method uses one median sagittal plane and one transverse plane that passes through the umbilicus at right angles. The four

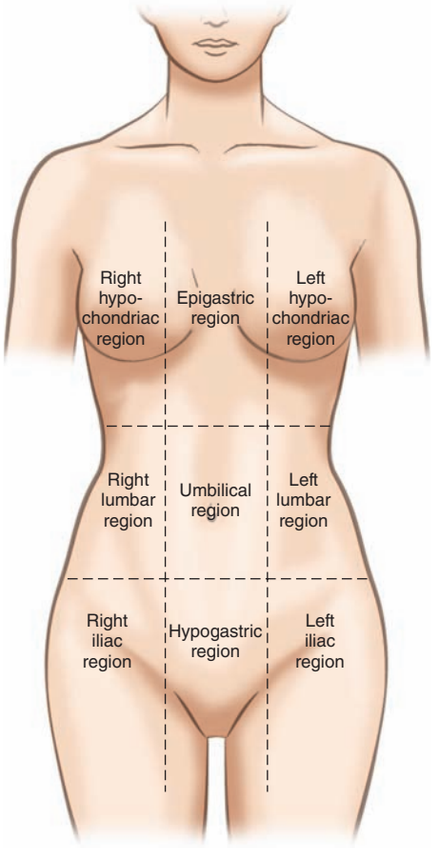


Figure 1-5 *Regions of the thorax and abdomen*

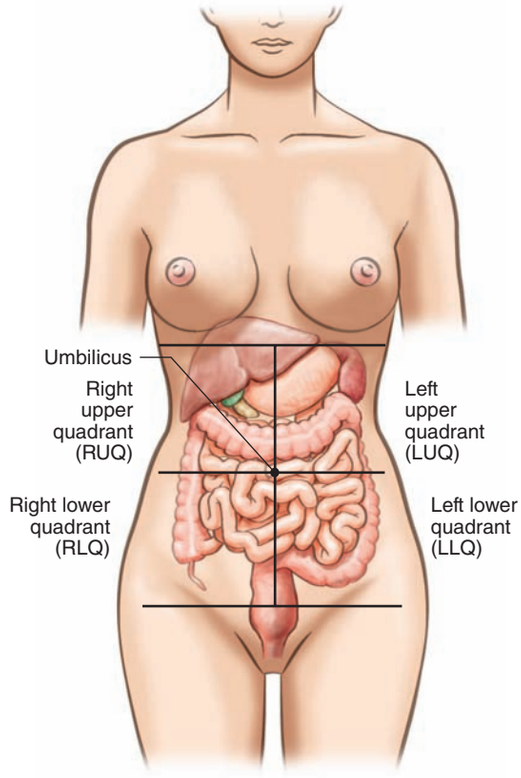


Figure 1-6 *Division of the abdomen into quadrants*

resulting quadrants are named according to their positions: right upper quadrant (RUQ), left upper quadrant (LUQ), right lower quadrant (RLQ), and left lower quadrant (LLQ) (*Figure 1-6*).

Did You Know?

McBurney's point is not at the top of a mountain but midway between the umbilicus and the iliac crest (the prominent area on the hip bone) and the right lower quadrant or right inguinal area. This area is painful when a person has appendicitis.

Life Functions

When we examine humans, plants, one-celled organisms, or multicelled organisms, we recognize that all of them have one thing in common: they are alive.

All living organisms are capable of carrying on life functions. **Life functions** are a series of highly organized and related activities that allow living organisms to live, grow, and maintain themselves.

These vital life functions include movement, ingestion, digestion, transport, respiration, synthesis, assimilation, growth, secretion, excretion, regulation (sensitivity), and reproduction (*Table 1-1*).

Human Development

During our lifetime, the body carries on numerous functions that keep us alive and active. Living depends on the constant release of energy in every cell of the body. Powered by the energy released from food, cells are able to maintain their own living condition and, thus, the life of a human being.

A complex life-form like a human being consists of more than 50 trillion cells. The **cell** is the basic unit of structure and function of all living things. Early in human development, certain groups of cells become highly specialized for specific functions, such as movement or growth.

Table 1-1 *Review of the Life Functions and Body Systems*

LIFE FUNCTIONS/ BODY SYSTEMS	DEFINITION
Movement / Muscle System	The ability of the whole organism—or a part of it—to move
Ingestion	The process by which an organism takes in food
Assimilation	The breakdown of complex food molecules into simpler food molecules
Digestion / Digestive System	The transformation of digested food molecules into living tissue for growth and self-repair
Transport / Circulatory System	The movement of necessary substances to, into, and around cells, and of cellular products and wastes out of and away from cells
Respiration / Respiratory System	The burning or oxidation of food molecules in a cell to release energy, water, and carbon dioxide
Immunity / Lymphatic System	The filtering out of harmful bacteria and production of white blood cells (lymphocytes)
Protection / Integumentary System	The waterproof covering of the body
Growth / Skeletal System	The enlargement of an organism due to synthesis and assimilation, resulting in an increase in the number and size of its cells
Secretion / Endocrine System	The formation and release of hormones from a cell or structure
Excretion / Urinary System	The removal of metabolic waste products from an organism
Regulation (Sensitivity) / Nervous System	The ability of an organism to respond to its environment so as to maintain a balanced state (homeostasis)
Reproduction / Reproductive System	The ability of an organism to produce offspring with similar characteristics (This is *essential* for species survival as opposed to individual survival.)

Special cells—grouped according to function, shape, size, and structure—are called **tissues.** Tissues, in turn, form larger functional and structural units known as **organs.** For example, human skin is an organ of epithelial, connective, muscular, and nervous tissue. In much the same way, kidneys consist of highly specialized connective and epithelial tissue.

The organs of the human body do not operate independently; they function interdependently with one another to form a live, functioning organism. Some organs are grouped together because more than one is needed to perform a function. Such a grouping is called an **organ system.** One example is the digestive system, composed of the teeth, esophagus, stomach, small intestine, and large intestine. In this textbook you will study the various body systems and the organs that comprise them.

Homeostasis

Homeostasis (**hoe**-mee-oh-**STAY**-sis) is the ability of the body to regulate its internal environment within narrow limits through negative and positive feedback. Maintaining homeostasis is essential to survival; imbalance results in disease. All organ systems contribute to homeostasis. Examples of homeostasis controls are blood sugar levels, body temperature, heart rate, and the fluid environment of cells. Aging cells no longer respond as quickly, which makes it harder to maintain homeostasis.

Most of homeostasis control works on a **negative feedback loop.** Feedback responses reverse disturbances to our body's condition. An example of how a negative feedback loop operates is seen in maintaining our body temperature. Our normal body temperature is 37°C (98.6°F). Outside, on a hot summer day, our body temperature rises. The hypothalamus in the brain detects this and sends signals to various organs, and we start to sweat (sweating is a cooling process). As water is excreted by the sweat glands on the skin, it evaporates (evaporation is a cooling mechanism). In addition, our blood vessels dilate to bring blood near the skin's surface to dissipate body heat. If we go outside on a cold day and our body temperature falls below 37°C (98.6°F), the hypothalamus of the brain detects this and sends signals to the muscles, causing us to shiver, which raises the body temperature (increased muscle activity produces heat). In addition, the hypothalamus sends signals to the blood vessels, causing them to constrict, which reduces blood flow near the surface, conserving body heat.

Positive feedback is the body's ability to increase the level of an event that has already been started. Positive feedback occurs when a person has a cut or damage to a blood vessel. Platelets in the blood quickly accumulate to clot around the wound and stop the bleeding.

Metabolism

The functional activities of cells that result in growth, repair, energy release, use of food, and secretions are combined under the heading of **metabolism** (meh-**TAB**-oh-lizm). Metabolism consists of two processes that are opposite to each other: anabolism and catabolism. **Anabolism** (ah-**NAB**-oh-lizm) is the building up of complex materials from simpler ones such as food and oxygen, and requires energy. **Catabolism** (kah-**TAB**-oh-lizm) is the breaking down and changing of complex substances into simpler ones, with a release of energy and carbon dioxide. The sum of all the chemical reactions within a cell is therefore called metabolism.

Metric System

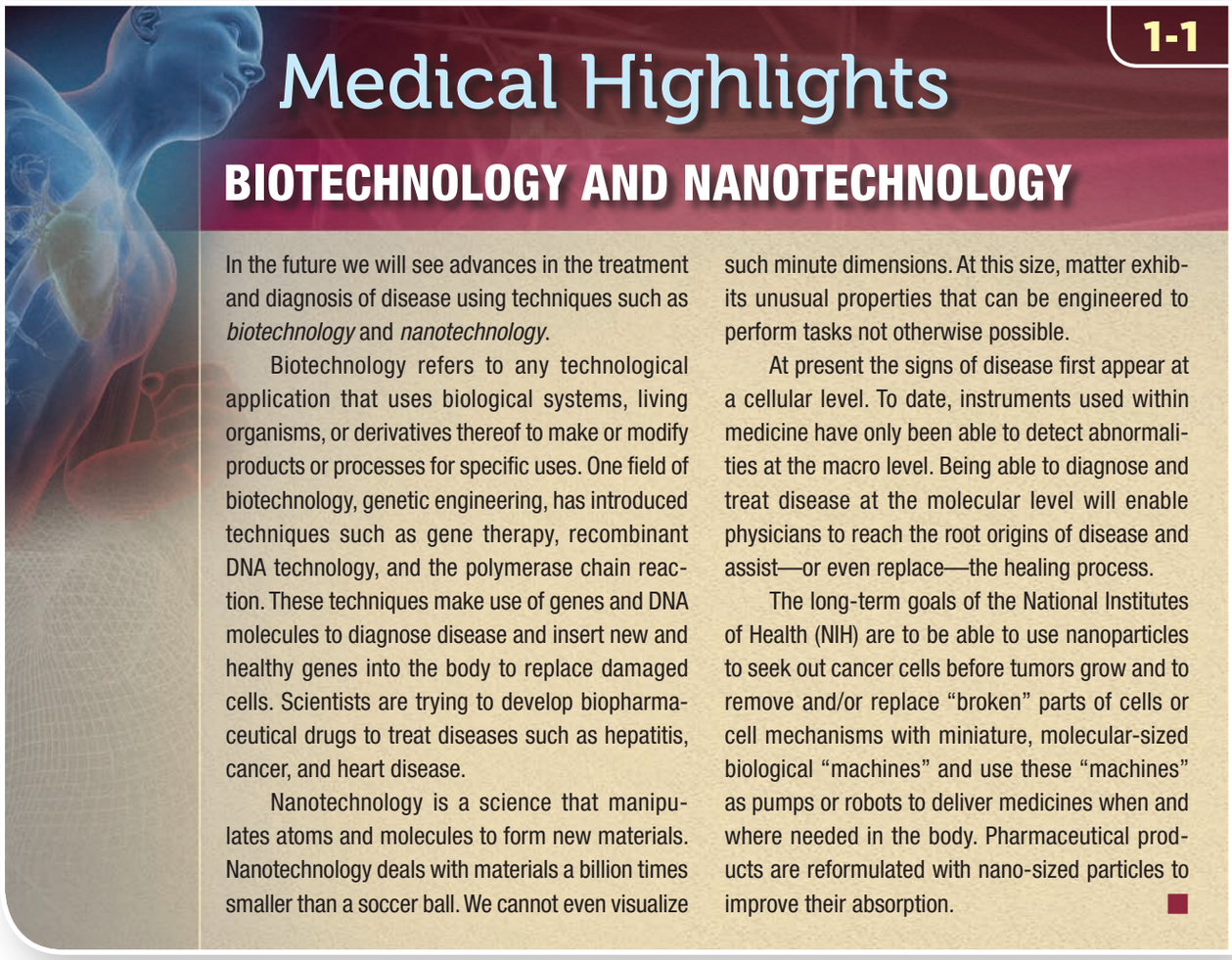
To understand the language used in *Body Structures and Functions*, you must be familiar with the metric system. The medical community measures length, weight, and volume using this system. The **metric system** is a decimal system based on the power of 10. Just as there are 100 cents in a dollar, there are 100 centimeters in a meter (see Appendix A).

Some of the prefixes used in the metric system are

centi = 1/100 (one/one-hundredth)
milli = 1/1000 (one/one-thousandth)
micro = 1/1,000,000 (one/one-millionth)

Length is measured using meters instead of inches and feet.

1 centimeter (cm) = 0.4 inch
2.5 cm = 1 inch



1-1

Medical Highlights

BIOTECHNOLOGY AND NANOTECHNOLOGY

In the future we will see advances in the treatment and diagnosis of disease using techniques such as *biotechnology* and *nanotechnology*.

Biotechnology refers to any technological application that uses biological systems, living organisms, or derivatives thereof to make or modify products or processes for specific uses. One field of biotechnology, genetic engineering, has introduced techniques such as gene therapy, recombinant DNA technology, and the polymerase chain reaction. These techniques make use of genes and DNA molecules to diagnose disease and insert new and healthy genes into the body to replace damaged cells. Scientists are trying to develop biopharmaceutical drugs to treat diseases such as hepatitis, cancer, and heart disease.

Nanotechnology is a science that manipulates atoms and molecules to form new materials. Nanotechnology deals with materials a billion times smaller than a soccer ball. We cannot even visualize such minute dimensions. At this size, matter exhibits unusual properties that can be engineered to perform tasks not otherwise possible.

At present the signs of disease first appear at a cellular level. To date, instruments used within medicine have only been able to detect abnormalities at the macro level. Being able to diagnose and treat disease at the molecular level will enable physicians to reach the root origins of disease and assist—or even replace—the healing process.

The long-term goals of the National Institutes of Health (NIH) are to be able to use nanoparticles to seek out cancer cells before tumors grow and to remove and/or replace "broken" parts of cells or cell mechanisms with miniature, molecular-sized biological "machines" and use these "machines" as pumps or robots to deliver medicines when and where needed in the body. Pharmaceutical products are reformulated with nano-sized particles to improve their absorption. ■

Weight is measured using grams instead of ounces and pounds.

1 gram (g) = 1 ounce
1 kilogram (kg) = 2.2 pounds
1000 g = 1 kg

In drug dosage, the most familiar unit used is the gram or milligram (mg).

500 mg = 0.5 g

Volume is measured using liters or milliliters instead of quarts, pints, ounces, teaspoons, and tablespoons.

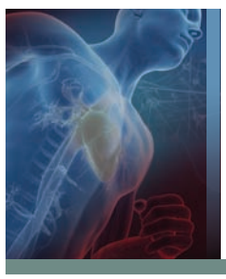
1 liter (L) = 1.06 quarts (a liter is slightly larger than a quart)
1 L = 1000 milliliters (ml)

For liquid drug dosage, milliliters are used.

5 ml = 1 teaspoon
15 ml = 1 tablespoon
30 ml = 1 ounce

Medical Terminology

ana	apart
-tom	cutting
-y	process of
ana/tom/y	process of cutting apart; study of body parts by dissection
-ology	study of
bio	life
bio/logy	study of life
physio	nature
physi/ology	study of nature or natural function of body
ante	in front of
anter/ior	in the front
poster	behind
poster/ior	in back of
super	above
super/ior	above a part
infer	below
infer/ior	below a part
-al	pertaining to
caud	tail
caud/al	pertaining to the tail
crani	skull
crani/al	pertaining to the skull
dist	distant
dist/al	pertaining to a distant part
dors	back
dors/al	pertaining to the back
later	side
later/al	pertaining to the side
medi	middle
medi/al	pertaining to the middle
proxim	near
proxim/al	pertaining to nearness or closeness
ventr	belly, front side
ventr/al	pertaining to the belly or front side



Study Tools

Workbook	Activities for Chapter 1
Online Resources	PowerPoint presentations

Review Questions

Select the letter of the choice that best completes the statement.

1. The study of the size and shape of the heart is called
a. physiology.
b. anatomy.
c. histology.
d. embryology.

2. Physiology is the study of
a. the size of the cell.
b. the shape of the kidney.
c. the function of the lungs.
d. the size and shape of the liver.

3. The anatomical position is described as
a. body erect, arms at the side, palms forward.
b. body flat, arms at the side, palms forward.
c. body erect, arms at the side, palms backward.
d. body flat, arms at the side, palms backward.

4. A plane that divides the body into right and left parts is a
a. transverse plane.
b. coronal plane.
c. sagittal plane.
d. frontal plane.

5. If a person is complaining of pain that may indicate appendicitis, the pain would be located in the
a. left lower quadrant.
b. right lower quadrant.
c. right upper quadrant.
d. left upper quadrant.

6. The heart is described as superior to the diaphragm because it is
a. in back of the diaphragm.
b. in front of the diaphragm.
c. above the diaphragm.
d. below the diaphragm.

7. The brain and the spinal cord are located in the
a. ventral cavity.
b. spinal cavity.
c. cranial cavity.
d. dorsal cavity.

8. The epigastric region of the abdominal area is located
a. just above the sternum.
b. in the umbilical area.
c. just below the sternum.
d. in the pelvic area.

9. Shivering to keep the body warm is an example of
a. anabolism.
b. catabolism.
c. metabolism.
d. homeostasis.

10. The formation and release of hormones from a cell or structure is called
a. digestion.
b. excretion.
c. synthesis.
d. secretion.

Fill in the Blanks

1. The standard used for measurement in science is the _____ system.

2. Danny, age 6, fell off his skateboard and had a 1.5-inch abrasion on his left arm. This is the same as _____ centimeters.

3. Two teaspoons of cough medicine equal _____ milliliters of cough medicine.

4. The physician orders 2 grams of penicillin to be divided into 4 doses over 24 hours. This means the average single dose will be _____ milligrams.

5. A kilogram is equal to _____ pounds.

Matching

Match each term in Column I with its correct description in Column II.

COLUMN I	COLUMN II
_____ **1.** catabolism	a. balanced cellular environment
_____ **2.** pelvic cavity	b. constructive chemical processes that use food to build the complex materials of the body
_____ **3.** pericardial cavity	c. useful breakdown of food materials resulting in the release of energy
_____ **4.** anabolism	d. contained within the oral cavity
_____ **5.** abdominal cavity	e. cavity in which the reproductive organs, urinary bladder, and lower part of the large intestine are located
_____ **6.** diaphragm	f. cavity in which the stomach, liver, gallbladder, pancreas, spleen, small intestine, appendix, and part of the large intestine are located
_____ **7.** homeostasis	g. cavity containing the heart
_____ **8.** tissue	h. a group of cells that together perform a particular job
_____ **9.** kidneys	i. portion of the dorsal cavity containing the brain
_____ **10.** teeth and tongue	j. divides the ventral cavity into two regions
_____ **11.** cranial cavity	k. structure located behind the abdominal cavity
_____ **12.** organ system	l. organs grouped together because they have a related function
_____ **13.** life function	m. an activity that a living thing performs to help it live and grow

Applying Theory to Practice

1. In each of the following examples, choose the term that correctly describes the human body according to anatomical position.
   a. In the anatomical position, the palms are forward or backward.
   b. The liver is superior or inferior to the diaphragm.
   c. The hand is proximal or distal to the elbow.
   d. The shoulder blade is on the anterior or posterior part of the body.
   e. Cranial refers to the head or tail end of the body.
   f. The coronal plane divides the body into front and back or right and left sections.
   g. The arms are located on the medial or lateral side of the body.
   h. The transverse plane divides the body into superior and inferior or anterior and posterior parts.

2. Describe the following to a physician using the correct anatomical term.
   a. The location of an appendectomy scar
   b. A wound that is on the front of the leg
   c. The end of the spine
   d. A pain near the breastbone

3. Think about what your body does within a 24-hour period and name the life functions that take place.

Case Study

An Emergency Medical Technician (EMT) responds to a call about a fall out of a tree. On arrival, the EMT sees a young boy lying at the bottom of the tree; his right arm is visibly deformed. The EMT suspects the arm may be broken.

1. Describe the anatomical terms the EMT will use to describe the injury to the emergency department physician.
2. What life function will be affected by the fall?
3. The boy is right-handed; describe other life functions that may be affected by his injury.

1-1

Lab Activity

Anatomical Directions

- *Objective:* To properly use directional terms to reference anatomical regions
- *Materials needed:* pencil, paper

Step 1: You may work individually or with a lab partner. Each student will assume the anatomical position. Is it comfortable? Why is the anatomical position used in health care? Record your response.

Step 2: Ask your lab partner if he or she is comfortable in the anatomical position. Record your partner's response.

Step 3: State the reason why you think this position is comfortable or uncomfortable. Record your response.

Step 4: Locate your own anterior, posterior, lateral, medial, superior, and inferior body surfaces; repeat this step with your partner. ■

1-2

Lab Activity

Anatomical Planes

- *Objective:* To identify the types of planes used to describe anatomy and what those planes indicate about the anatomical region
- *Materials needed:* modeling clay, tongue depressors, pencil, paper

Step 1: Form the clay into a kidney shape.

Step 2: Using the tongue depressor, make a transverse cut of the kidney. What does this type of cut demonstrate? Record your answer.

Step 3: Make a sagittal cut. What does this type of cut demonstrate? Record your answer.

Step 4: Make a coronal cut. What does this type of cut demonstrate? Record your answer. ■

1-3

Lab Activity

Anatomical Abdominal Regions

- *Objective:* To identify each of the cavities of the abdomen and the organs that can be found in those regions
- *Materials needed:* anatomical model of a torso; models of a gallbladder, liver, stomach, colon, and pancreas; pencil and paper

Step 1: Place the organs correctly into the anatomical model.

Step 2: Record the name of the abdominal region in which each of the organs is located. ■

Chapter 2

CHEMISTRY OF LIVING THINGS

Objectives

- Relate the importance of chemistry and biochemistry to health care.
- Define matter and energy.
- Explain the structure of an atom, an element, and a compound.
- Explain the importance of water to our body.
- Describe the four main groups of organic compounds: carbohydrates, fats, proteins, and nucleic acids.
- Explain the difference between the DNA molecule and the RNA molecule.
- Explain the difference between an acid, a base, and salt.
- Explain the acid-base balance.
- Describe why homeostasis is necessary for good health.
- Define the key words that relate to this chapter.

Key Words

acid
alkali
amino acids
atom
base
buffer
carbohydrate
chemical bond
chemistry
cholesterol
compounds
covalent bond
dehydrated
dehydration synthesis
deoxyribonucleic acid (DNA)
disaccharide
electrolytes
electron
element
energy
enzymes
extracellular fluid
fat
glycogen
hydrogen bond
hydrolysis
hydroxide
interstitial fluid
intracellular fluid
ion
ionic bond
isotopes
kinetic energy
lipid
matter
molecule
monosaccharide
multicellular
neutralization
neutron
nucleic acid
organic catalyst
organic compound
pH scale
phospholipids
polysaccharide
potential energy
protein
protein synthesis
proton
radioactive
ribonucleic acid (RNA)
steroids
triglycerides
unicellular

To be an effective health care professional, an individual must have a thorough understanding of the normal and abnormal functioning of the human body and a knowledge of basic chemistry and biochemistry.

Chemistry

Chemistry is the study of the structure of matter and the composition of substances, their properties, and their chemical reactions. Many chemical reactions occur in the human body. These reactions can range from the digestion of a piece of meat in the stomach to the formation of urine in the kidneys to the manufacture of proteins in a microscopic human cell. The chemical reactions necessary to sustain life occur in the cells. Thus, the study of the chemical reactions of living things is called *biochemistry*.

Matter and Energy

Matter is anything that has weight (mass) and occupies space. Matter exists in solid, liquid, and gas forms. An example in our bodies of solid matter is bone; liquid matter is blood; gas is oxygen.

Matter is neither created nor destroyed, but it can change form through physical or chemical means. A physical change occurs when we chew a piece of food and it breaks into smaller pieces. A chemical change occurs when the food is acted on by various chemicals in the body to change its composition. For example, imagine a piece of buttered toast that becomes molecules of fat and glucose to be used by the body for energy.

Energy is the ability to do work or to put matter into motion. Energy exists in our body as **potential energy** and **kinetic energy** (kih-**NET**-ik). Potential energy is energy stored in cells waiting to be released, whereas kinetic energy is work resulting in motion. Lying in bed is an example of potential energy; getting out of bed is an example of kinetic energy.

Atoms

An **atom** is the smallest piece of an element. Atoms are invisible to the human eye, yet they surround us and are part of our human structure. Hydrogen is an example of an atom.

The normal atom is made up of subatomic particles: **protons, neutrons,** and **electrons.** Protons have a positive (+) electric charge; neutrons have no electric charge. Protons and neutrons make up the nucleus of an atom (which differs from the nucleus of a cell) (*Figure 2-1*). Electrons have a negative (−) electric charge and are arranged around the nucleus in orbital zones or *electron shells*. Atoms usually have more than one electron shell. The number and arrangement of the subatomic particles dictate how the atoms of one element differ from atoms of another element; for example, the structure of the hydrogen atom is different from the structure of the oxygen atom.

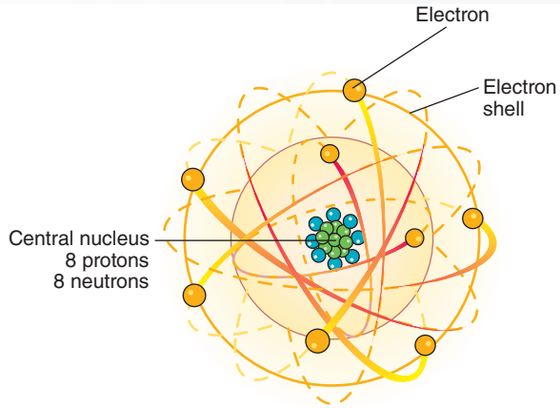


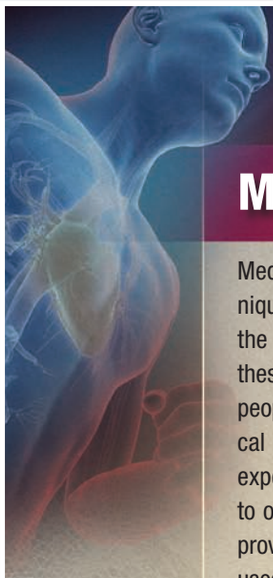
Figure 2-1 *Structure of an atom. Eight protons and eight neutrons are tightly bound in the central nucleus, around which the eight electrons revolve.*

The number of protons of an atom is equal to the number of electrons; atoms are electrically neutral—neither negative nor positive.

Atoms of a specific element that have the same number of protons but a different number of neutrons are called **isotopes** (eye-so-**TOWPS**). All isotopes of a specific element have the same number of electrons. Certain isotopes are called **radioactive** isotopes because they are unstable and decay (come apart). As they decay they give off (emit) energy in the form of radiation, which can be picked up by a detector. The detector not only detects the emission from a radioactive isotope, but, with the aid of a computer, also forms the image of its distribution within the body. Radioactive isotopes can be used to study the structure and function of particular tissues. Nuclear medicine is a branch of medicine that uses radioactive isotopes to prevent, diagnose (see *Medical Highlights 2-1—Medical Imaging*), and treat disease. The most common uses of isotopes are for the treatment of thyroid conditions, prostate cancer, and cancer bone pain. Radioactive isotopes enable the physician to point the selected isotopes directly at the disease and destroy the diseased tissue.

Elements

Atoms that are alike combine to form the next stage of matter, which is an **element.** An element is a substance that can neither be created nor destroyed by ordinary



2-1

Medical Highlights

MEDICAL IMAGING

Medical imaging refers to the noninvasive techniques and processes used to create images of the human body for clinical purposes. Some of these techniques use radioactive isotopes. Many people fear overexposure to radiation from medical imaging processes, but the risk of radiation exposure must be weighed against other risks to one's health. Scientists have not been able to prove satisfactorily that low doses of radiation as used in medical settings increase cancer risks.

A ***computed axial tomography (CAT or CT) scan*** is a painless diagnostic X-ray procedure that uses ionizing radiation to produce cross-section images of the body. The computer detects the pattern of the radiation absorption and the variations in tissue density. From the detection of radiation absorption, a series of anatomical pictures is produced. The resulting scan is an analysis of a three-dimensional view of the tissue being evaluated. CT scans are most useful in evaluating the brain, detecting internal injuries or bleeding, and detecting cancer.

Magnetic resonance imaging (MRI) is a scanning procedure that provides visualization of fluids, soft tissue, and bony structures without the use of radiation. The person is placed inside a large electromagnetic tubelike chamber where specific frequencies of radio signals are generated that change the alignment of hydrogen atoms in the body. The computer analyzes the absorbed radio-frequency energy. Strong magnetic fields are used, causing the radio-frequency waves to produce images, which are projected on a screen. Persons with implanted metal devices such as pacemakers, prosthetic knees, and such cannot undergo an MRI, because the strong magnetic fields could damage them. An open MRI, which is open on all four sides and does not require placement inside a chamber, can be used for those who are claustrophobic (a pathological fear of confinement).

A ***positron emission tomography (PET) scan*** is a procedure in which the patient is given a short-lived radioactive isotope, either inhaled or injected, and placed in a scanner. The metabolic activity of the brain and numerous other body structures is shown through computerized color-coded images that indicate the degree and intensity of the metabolic processes. The patient may be asked questions to see how the brain activity changes by reasoning or remembering. PET scans are most useful for diagnosing brain tumors, cerebral palsy, stroke, and heart disease.

Bone scans, liver scans, brain scans, and ***spleen scans*** are procedures that scan various body parts with a gamma camera after an intravenous injection of a radionuclide material and its absorption by the body. The camera's recording of the concentration or collection of the radioactive substance specifically drawn to that area discloses the image of the area.

Ultrasound or ***sonography*** uses high-frequency sound waves that are directed through a transducer. Those sound waves bounce off the spot just below the transducer and generate an image that can be seen on the ultrasound screen. The screen image changes as the transducer is slowly moved from one location to another. This imaging choice is used for rotator cuff disorders and musculoskeletal disorders, and in obstetrics for visualizing the embryo, fetus, and placenta.

Doppler ultrasound is a variation of sonography in which returning sound waves are transformed into audible sounds that can be detected by earphones. The Doppler method measures blood flow by moving the transducer along the path of a blood vessel.

Mammograms (see Chapter 21)

After having a diagnostic test done using radioactive material, patients are advised to drink lots of water to flush out radioactive material. ■

chemical means. Elements can exist in more than one phase in our bodies. Our bones are solid and contain the element calcium. The air we take into our lungs contains the element oxygen, which is a gas. Our cells are bathed in fluids that contain the elements of hydrogen and oxygen.

Ninety-two elements are found naturally in our world; additional elements have been created by scientists. Each of the elements is represented by a chemical symbol or an abbreviation. *Table 2-1* shows a sampling of elements and their chemical symbols.

Compounds

Various elements can combine in a *definite proportion by weight* to form **compounds.** A compound has different characteristics or properties depending on its elements. For example, the compound water (H_2O) is made of two parts hydrogen and one part oxygen. Separately, hydrogen and oxygen are gaseous elements, but when combined the resulting compound is a liquid (water). Common table salt is a compound made from the two elements sodium (Na) and chlorine (Cl), chemically called sodium chloride (NaCl). Separately, sodium is a metallic element. It is light, silver-white, and shiny when freshly cut, but rapidly becomes dull and gray when exposed to air. Chlorine, on the other hand, is an irritating, greenish-yellow poisonous gas with a suffocating odor. However, the chemical combination of both sodium and chlorine results in sodium chloride, which is a crystalline powder that can be dissolved in water.

Table 2-1 *Sample Elements and Their Symbols*

ELEMENT	SYMBOL
Calcium	Ca
Carbon	C
Chlorine	Cl
Hydrogen	H
Iodine	I
Iron	Fe
Magnesium	Mg
Nitrogen	N
Oxygen	O
Phosphorus	P
Potassium	K
Sodium	Na
Zinc	Zn

Just as elements are represented by symbols, compounds are represented by something called a *formula*. A formula shows the types of elements present and the proportion of each element present by weight. Some common formulas are H_2O (water), NaCl (common table salt), HCl (hydrogen chloride or hydrochloric acid), $NaHCO_3$ (sodium bicarbonate or baking powder), NaOH (sodium hydroxide or lye), $C_6H_{12}O_6$ (glucose or grape sugar), $C_{12}H_{22}O_{11}$ (sucrose or common table sugar), CO_2 (carbon dioxide), and CO (carbon monoxide).

A living organism, whether it is a **unicellular** (yoo-nih-**SELL**-yoo-lar) or one-celled microbe or a **multicellular** (mull-tye-**SELL**-yoo-lar) or many-celled animal or plant, can be compared with a chemical factory. Most living organisms will take the 20 essential elements and change them into needed compounds for the maintenance of the organism. In many living organisms, the elements carbon, hydrogen, and oxygen are united to form **organic compounds** (or-**GAN**-ik). Compounds found in living things contain the element carbon.

Molecules

The smallest unit of a compound that still has the properties of the compound and the ability to lead its own stable and independent existence is called a **molecule** (**MOL**-eh-kyool). For example, the common compound water can be broken down into smaller and smaller droplets. The absolutely smallest unit is a molecule of water (H_2O).

Chemical Bonds

In addition to combining to form elements, atoms can share or combine their electrons with atoms of other elements to form **chemical bonds.** One type of bond is called an **ionic bond** (*Figure 2-2*). If one atom gives up an electron to another atom to form an ionic bond, that atom will now have more protons than electrons and will have a positive (+) charge. The atom that took the extra electron will now have more electrons than protons and thus have a negative (−) charge. The positively or negatively charged particle is now called an **ion.** Ionically bonded atoms disassociate when immersed in water (H_2O); an example is sodium chloride (Na^+Cl^-).

A second type of bond is the **covalent bond** (*Figure 2-3*). In this type of bond the atoms share electrons to fill their outermost levels or shells. Molecules containing covalent bonds do not form ionic bonds and do not disassociate when immersed in water.

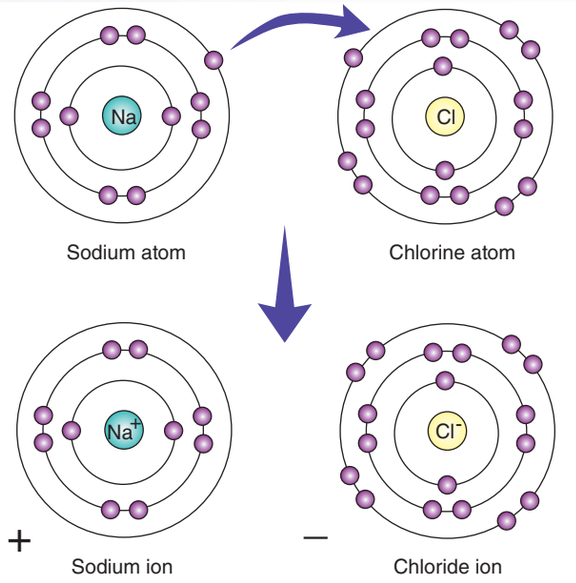


Figure 2-2 *Ionic bond. In this figure the* Na^+ *atom gives up an electron to the* Cl^- *atom to form an ionic bond.*

Four of the most important elements found in cells form this type of bond. They are carbon, oxygen, hydrogen, and nitrogen.

A third type of bond is the **hydrogen bond.** Hydrogen bonds are very weak bonds. They help hold water molecules together by forming a bridge between the negative oxygen atom of one water molecule and the positive hydrogen atoms of another water molecule.

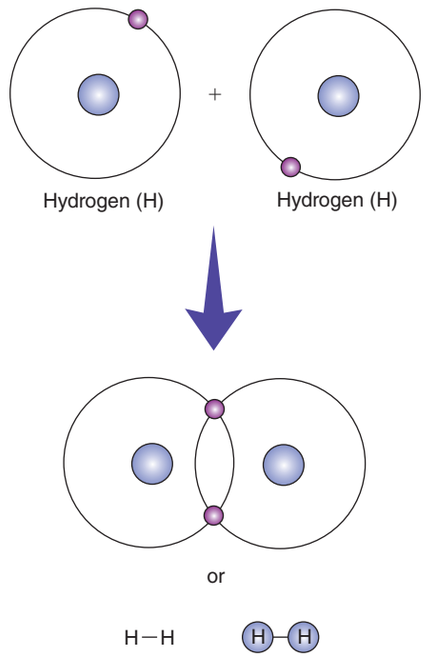


Figure 2-3 *Covalent bond. In this figure each hydrogen atom will share an electron to form a compound.*

Electrolytes

When compounds are in solution and act as if they have broken into individual pieces (ions), the elements of the compound are called **electrolytes** (ee-**LEK**-troh-lights). For example, in water a salt solution consists of sodium (Na^+) ions with a positive charge and chlorine (Cl^-) ions with a negative charge.

In the cells and tissue fluids of the body, ions make it possible for materials to be altered, broken down, and recombined to form new substances or compounds. Electrolytes are responsible for the acidity or alkalinity of solutions and can conduct an electrical charge. The ability to record electric charges within the tissue is invaluable for diagnostic tools such as an *electrocardiogram*, which measures the electrical conduction of the heart.

Types of Compounds

The various elements can combine to form a great number of compounds. All known compounds, whether natural or synthetic, can be classified into two groups: inorganic compounds and organic compounds.

Inorganic Compounds

Inorganic compounds are made of molecules that do not contain the element carbon (C) (e.g., salt [NaCl]). Exceptions include carbon dioxide (CO_2) and calcium carbonate ($CaCO_3$).

Water

Water is the most important inorganic compound to living organisms. Water makes up 55% to 65% of our body weight. It is considered the universal solvent because more substances dissolve in water than in any other fluid. Most of the body's cellular processes take place in the presence of water. In anabolic reactions, water may be removed from the molecule **(dehydration synthesis),** the molecules fuse together, and a new substance is formed. In catobolic reactions, water is added to the molecule **(hydrolysis)** to break down larger molecules. Water regulates body temperature, takes nutrients to cells, and takes away the waste products. Water is necessary for homeostasis. Water is essential to life; if we do not have enough water our bodies become **dehydrated** (dee-**HYE**-dray-ted), which is a life-threatening condition.

Organic Compounds

Organic compounds are found in living things and the products they make. These compounds always contain the element carbon, combined with hydrogen and

other elements. Carbon has the ability to combine with other elements to form a large number of organic compounds. There are more than a million known organic compounds. Their molecules are comparatively large and complex; inorganic molecules are much smaller. The four main groups of organic compounds are carbohydrates, lipids, proteins, and nucleic acids.

Carbohydrates

All **carbohydrates** are compounds of the elements carbon (C), hydrogen (H), and oxygen (O). These compounds have twice as many hydrogen atoms as oxygen and carbon atoms. Carbohydrates are divided into three groups: monosaccharides, disaccharides, and polysaccharides.

MONOSACCHARIDES. **Monosaccharides** (mon-oh-**SAK**-ah-rides) are sugars that cannot be broken down any further. Hence, they are also called single or simple sugars. The types of monosaccharide sugars are glucose, fructose, galactose, ribose, and deoxyribose.

Glucose is an important sugar. It is the main source of energy in cells. Glucose, sometimes referred to as blood sugar, is carried by the bloodstream to individual cells, and is stored in the form of **glycogen** in the liver and muscle cells. Glucose combines with oxygen in a chemical reaction called oxidation, which produces energy.

Fructose is the sweetest of the monosaccharides and is found in fruit and honey. Galactose is found in mother's milk and nursing infants need it for development. Deoxyribose sugar is found in **deoxyribonucleic acid (DNA)** (dee-ock-see-rye-boh-new-**KLEE**-ik) and ribose sugar is found in **ribonucleic acid (RNA)** (**rye**-boh-new-**KLEE**-ik) .

DISACCHARIDES. A **disaccharide** (dye-**SAK**-ih-ride) is known as a double sugar because it is formed from two monosaccharide molecules by a chemical reaction called dehydration synthesis. This reaction involves the synthesis of a large molecule from small ones by the loss of a molecule of water. *Table 2-2* illustrates the process of dehydration synthesis.

The opposite of dehydration synthesis is hydrolysis. In this reaction, a large molecule is broken down into smaller molecules by the addition of water. Examples of disaccharides are sucrose (table sugar), maltose (malt sugar), and lactose (milk sugar).

Disaccharides must first be broken down by the process of digestion (hydrolysis) into monosaccharides to be absorbed and used by the body.

2-1

Career Profile

Radiologic Technologists

Medical uses of radiation go far beyond the diagnosis of broken bones by X-ray. Radiation is used to produce images of the interior of the body and to treat cancer. The term *diagnostic imaging* not only involves X-ray technique but also ultrasound and MRI scans.

Radiographers produce X-ray films for use in diagnosing disease. They prepare the patient for the procedure by explaining the process, positioning the patient, removing jewelry and other articles through which X-rays cannot penetrate, shielding the patient to prevent unnecessary radiation exposure, and taking the picture. Experienced radiographers may also perform more complex imaging tests such as mammography and fluoroscopy or operate CT scanners and MRI machines.

Radiation therapy technologists prepare cancer patients for treatment and administer prescribed doses of ionizing radiation to specific body parts. They check for radiation side effects.

Sonographers project nonionizing, high-frequency sound waves into specific areas of the patient's body; the machine then collects the reflected echoes to form an image.

Education for these positions is offered in hospitals, colleges, and vocational-technical institutes. The course of study includes class and clinical practice. The Joint Review Committee on Education in Radiologic Technology accredits most formal training programs in this field. Specialty areas in radiology include MRI technology, nuclear medicine technology, diagnostic technology, ultrasound technology, and mammography technology. Most specialty areas require additional education and certification. The job outlook in this field is expected to grow faster than average. ■

Table 2-2 *The Monosaccharide Composition of Sucrose, Maltose, and Lactose*

MONOSACCHARIDE + MONOSACCHARIDE − H_2O (DEHYDRATION SYNTHESIS)	FORMS	DISACCHARIDE
Glucose + fructose − H_2O	→	Sucrose
Glucose + glucose − H_2O	→	Maltose
Glucose + galactose − H_2O	→	Lactose

POLYSACCHARIDES. A large number of carbohydrates found in or made by living organisms are **polysaccharides** (pol-ee-**SAK**-ah-rides). These are large, complex molecules of hundreds to thousands of glucose molecules bonded together in one long, chain-like molecule. Examples of polysaccharides are starch, cellulose, and glycogen. Under the proper conditions, polysaccharides can be broken down into disaccharides and then, finally, into monosaccharides.

Starch is a polysaccharide found in grain products and root vegetables such as potatoes.

Lipids

Lipids are molecules containing the elements carbon, hydrogen, and oxygen. Lipids are different from carbohydrates because they have proportionately much less oxygen in relation to hydrogen. Examples of lipids are fats, phospholipids, and steroids.

CHARACTERISTICS OF LIPIDS. Lipids are referred to as "fats." Though "fat-free" foods have become popular, lipids or fats are essential to health. Lipids are an important source of stored energy. They make up the essential steroid hormones and help insulate our bodies. It is when the intake of lipids in the form of fat becomes excessive that a health problem may occur.

Fats, also called **triglycerides,** consist of glycerol and fatty acids and make up 95% of fats in the human body.

Phospholipids contain carbon, hydrogen, oxygen, and phosphorus. This type of lipid may be found in the cell membranes, the brain, and nervous tissue.

Steroids are lipids that contain **cholesterol** (koh-**LES**-ter-ol). Cholesterol is essential in the structure of the semipermeable membrane of the cell. It is necessary in the manufacture of vitamin D and in the production of male and female hormones. Cholesterol is needed to make the adrenal hormone cortisol. In certain people, however, cholesterol can accumulate in the arteries, becoming problematic.

Proteins

Proteins are organic compounds containing the elements carbon, hydrogen, oxygen, nitrogen, and usually phosphorus and sulfur. Proteins are among the most diverse and essential organic compounds found in all living organisms. They are found in every part of a living cell; they are also an important part of the outer protein coat of all viruses. Proteins also serve as binding and structural components of all living things. For example, large amounts of protein are found in fingernails, hair, cartilage, ligaments, tendons, and muscle.

Amino acids are small molecular units that work together to build proteins in the body. They are vital for proper body function. Twenty different amino acids are combined in any number and sequence to make up all the types of protein. They are classified as essential and nonessential. Essential amino acids must be obtained from dietary sources and cannot be made up by the body. Nonessential amino acids are those that the body can manufacture. *Table 2-3* lists the essential and nonessential amino acids.

Large protein molecules are constructed from any number and sequence of these amino acids. The number of amino acids in any given protein molecule can range from 300 to several thousand. Therefore, the structure of proteins is quite complicated.

ENZYMES. **Enzymes** are specialized protein molecules found in all living cells. They help control the various chemical reactions occurring in a cell, so each reaction occurs at just the right moment and at the right speed. Enzymes help provide energy for the cell, assist in the making of new cell parts, and control almost every process in a cell. Because enzymes are capable of such activity, they are known as **organic catalysts.** An enzyme or

Table 2-3 *Essential and Nonessential Amino Acids*

ESSENTIAL AMINO ACIDS	NONESSENTIAL AMINO ACIDS
Arginine	Alanine
Histidine	Asparagine
Isoleucine	Aspartate
Leucine	Cysteine
Lysine	Glutamate
Methionine	Glutamine
Phenylalanine	Glycine
Threonine	Proline
Tryptophan	Serine
Valine	Tyrosine

organic catalyst affects the rate or speed of a chemical reaction without being changed itself. Enzymes can also be used over and over again. An enzyme molecule is highly specific in its action. Enzymes are made up of all protein or part protein (apoenzyme) attached to a nonprotein part (coenzyme).

Nucleic Acids

Nucleic acids (new-**KLEE**-ik) are important organic compounds containing the elements carbon, oxygen, hydrogen, nitrogen, and phosphorus. The two major types of nucleic acids are deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).

STRUCTURE OF NUCLEIC ACIDS. Nucleic acids are the largest known organic molecules. They are made from thousands of smaller, repeating subunits called *nucleotides*. A nucleotide is a complex molecule composed of three different molecular groups. *Figure 2-4* shows a typical nucleotide. Group 1 is a phosphate or phosphoric acid group (H_3PO_4); group 2 represents a five-carbon sugar. Depending on the nucleotide, the sugar could be either a ribose or a deoxyribose sugar. Group 3 represents a nitrogenous base. The two groups of nitrogenous bases are the purines and the pyrimidines. The purines are either adenine (A) or guanine (G); the pyrimidines are cytosine (C) and thymine (T).

DNA STRUCTURE AND FUNCTION. DNA is a double-stranded molecule referred to as a double helix. This structure resembles a twisted ladder. The sides of the ladder are formed by alternating bands of a sugar (deoxyribose) unit and a phosphate unit. The rungs of the ladder are formed by nitrogenous bases that always pair in very specific ways: thymine (T) pairs with adenine (A), and cytosine (C) pairs with guanine (G) (*Figure 2-5*).

DNA is involved in the process of heredity. The nucleus of every human cell contains 46 chromosomes (23 pairs), creating a long, coiled molecule of DNA. These chromosomes contain about 100,000 genes. This genetic information tells a cell what structure it will possess and what function it will have. The DNA molecule passes on the genetic information from one generation to the next.

DNA structures are unique for each person and are used as a means of identification; only a very small amount of DNA is necessary for identification.

Did You Know?

If you stretched out the strands of the DNA from a single cell end to end, it would measure 6 feet long but would be so incredibly thin (50 trillionths of an inch wide) that no one could see it.

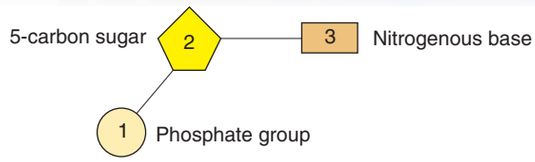


Figure 2-4 *Structure of a typical nucleotide*

RNA STRUCTURE AND FUNCTION. The RNA nucleotide consists of a phosphate group, the ribose sugar, and any one of the following nitrogenous bases: adenine, cytosine, guanine, and uracil instead of thymine. The RNA molecule is single-stranded, whereas the DNA molecule is double-stranded.

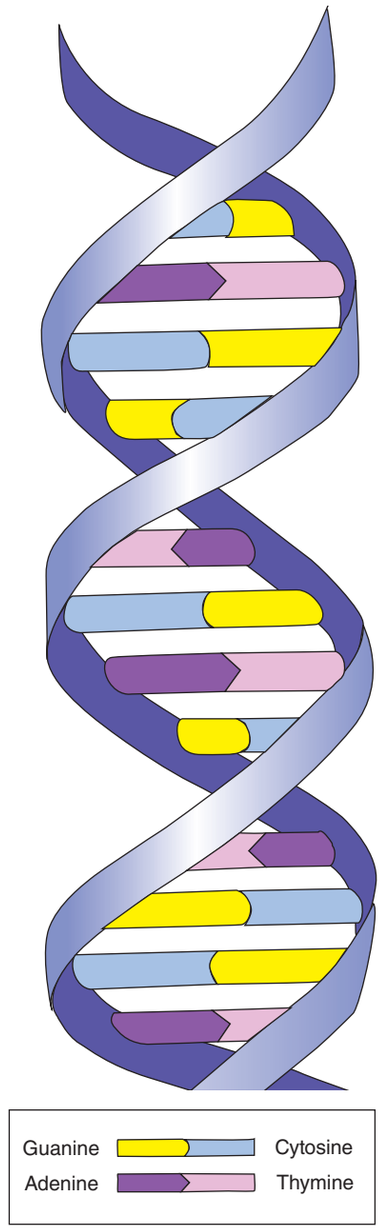


Figure 2-5 *Schematic of DNA*

Table 2-4 *Differences between DNA and RNA Molecules*

TYPE OF NUCLEIC ACID	TYPE OF SUGAR PRESENT	TYPES OF BASE PRESENT	PHOSPHATE GROUP	LOCATION	NUMBER OF STRANDS PRESENT
DNA	Deoxyribose	A, T, G, C	Same as RNA	Cell nucleus, chromosomes	2
RNA	Ribose	A, U, G, C	Same as DNA	Cytoplasm, nucleoli, ribosomes	1

The three different types of RNA in a cell are messenger RNA (m-RNA), transfer RNA (t-RNA), and ribosomal RNA (r-RNA). Messenger RNA carries the instructions for **protein synthesis** from the DNA molecule located in the nucleus of a cell to the ribosomes in the cytoplasm. The transfer RNA molecule picks up amino acid molecules in the cytoplasm and transfers them to the ribosomes. Ribosomal RNA helps in the attachment of the m-RNA to the ribosome. Protein synthesis is the process by which amino acids are linearly arranged into proteins through the involvement of messenger RNA, transfer RNA, ribosomal RNA, and various enzymes.

Table 2-4 shows the basic differences between the DNA molecule and the RNA molecule.

Acids, Bases, and Salts

Before ending the discussion of basic chemistry and biochemistry, a brief discussion of acids, bases, salts, and pH is essential.

Many inorganic and organic compounds found in living organisms are ones that we use in our daily lives. They can be classified into one of three groups: acids, bases, and salts. We are familiar with the sour taste of citrus fruits (grapefruits, lemons, and limes) and vinegar. The sour taste is due to the presence of compounds called acids. What characteristics do acids have to set them apart from bases and salts?

Acids

An **acid** is a substance that, when dissolved in water, will ionize into positively charged hydrogen ions (H^+) and negatively charged ions of some other element. Basically, an acid is a substance that yields hydrogen ions (H^+) in solution. For example, hydrogen chloride (HCl) in pure form is a gas. But when bubbled into water, it becomes hydrochloric acid. How does this happen? Simply—in a water solution, hydrogen chloride ionizes into one hydrogen ion and one negatively charged chloride ion.

$$HCl + H_2O \longrightarrow H^+ + Cl^-$$

Hydrogen chloride in solution → Hydrogen ion + Chloride ion

It is the presence of the hydrogen ions that gives hydrochloric acid its acidity and sour taste. However, one should *not* taste any substance to identify it as an acid. There are more reliable and safer methods for identification. A substance can be tested for its acidity through the use of specially treated paper called litmus. In the presence of an acid, blue litmus paper turns red. *Table 2-5* names some common acids, their formulas, and where they are found or how they are used.

Bases

A **base** or **alkali** is a substance that, when dissolved in water, ionizes into negatively charged **hydroxide** (OH^-) ions and positively charged ions of a metal. For example, sodium hydroxide (NaOH) ionizes into one

Table 2-5 *Names, Formulas, and Locations or Uses of Common Acids*

NAME OF ACID	FORMULA	LOCATION OR USE
Acetic acid	CH_3COOH	Found in vinegar
Boric acid	H_3BO_3	Weak eyewash
Carbonic acid	H_2CO_3	Found in carbonated beverages
Hydrochloric acid	HCl	Found in stomach
Nitric acid	HNO_3	Industrial oxidizing acid
Sulfuric acid	H_2SO_4	Found in batteries and industrial mineral acid

sodium ion (Na^+) and one hydroxide ion (OH^-). The reaction can be shown as follows:

$$NaOH \longrightarrow Na^+ + OH^-$$

Sodium hydroxide in solution → Sodium ion + Hydroxide ion

Bases have a bitter taste and feel slippery between the fingers. They turn red litmus paper blue. *Table 2-6* names some common bases, their formulas, and location or use.

Neutralization and Salts

When an acid and a base are combined, they form salt and water. This type of reaction is called a **neutralization** (new-tral-ih-**ZAY**-shun) or exchange reaction. In a neutralization reaction, hydrogen ions (H^+) from the acid and hydroxide ions (OH^-) from the base join to form water. At the same time, the negative ions of the acid combine with the positive ions of the base to form the compound salt. For example, hydrochloric acid and sodium hydroxide combine to form sodium chloride and water. The hydrogen ions from the acid unite with the hydroxide ions from the base to form water. The sodium ions (Na^+) combine with the chloride ions (Cl^-) to form sodium chloride (NaCl). When the water evaporates, solid salt remains. The neutralization reaction is shown in *Figure 2-6*.

Table 2-6 *Names, Formulas, and Locations or Uses of Common Bases*

NAME OF BASE	FORMULA	LOCATION OR USE
Ammonium hydroxide	NH_4OH	Household liquid cleaners
Magnesium hydroxide	$Mg(OH)_2$	Milk of magnesia
Potassium hydroxide	KOH	Caustic potash
Sodium hydroxide	NaOH	Lye

pH Scale

pH is a measure of the acidity or alkalinity (basicity) of a solution. Special pH meters determine the hydrogen or hydroxide ion concentration of a solution. The **pH scale** is used to measure the acidity or alkalinity of a solution, and it ranges from 0 to 14. A pH reading of 7 indicates that a particular solution has the same number of hydrogen ions as hydroxide ions. This is a neutral pH; distilled water is neutral with a pH value of 7. Any pH value between 0 and 6.9 indicates an acidic solution. The lower the pH number, the stronger the acid or the higher the hydrogen ion concentration. A pH value between 7.1 and 14 indicates that a solution is basic or alkaline. Thus, the greater the number above 7, the stronger the base or the greater the hydroxide ion concentration. *Figure 2-7* shows the pH values of some common acids, bases, and human body fluids.

Homeostasis of Acid-Base

Living cells and the fluids they produce are usually nearly neutral, neither strongly acidic nor strongly alkaline. Living cells are very sensitive to even a slight change in the acid-base balance. For instance, human tears have a pH of 7.4 and human blood a range of 7.35 to 7.45.

In humans and other living organisms, the maintenance of a balanced pH is achieved through a compound called a **buffer.** Sodium bicarbonate ($NaHCO_3$) acts as a buffer in many living organisms. Buffers help a living organism maintain a constant pH value, which contributes to its homeostasis, or balanced state.

Optimum cell functioning requires a stable cellular fluid environment. The fluid that bathes the cell and transports nutrients into and out of the cell is known as **extracellular fluid.** This includes the blood, lymph, and fluid between the tissues, known as **interstitial fluid** (in-ter-**STISH**-al). The fluid within the cell is called **intracellular fluid.** A state of homeostasis is required for the body to function at an optimum level of health. If a control system like the acid-base or electrolyte balance is not maintained, cells and tissue will become damaged. A moderate dysfunction causes illness; a severe dysfunction causes death.

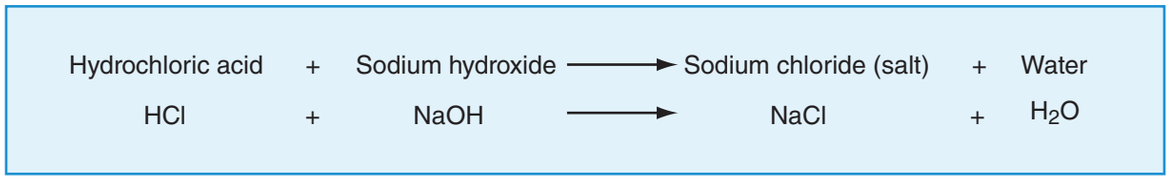


Figure 2-6 *Neutralization or exchange reaction*

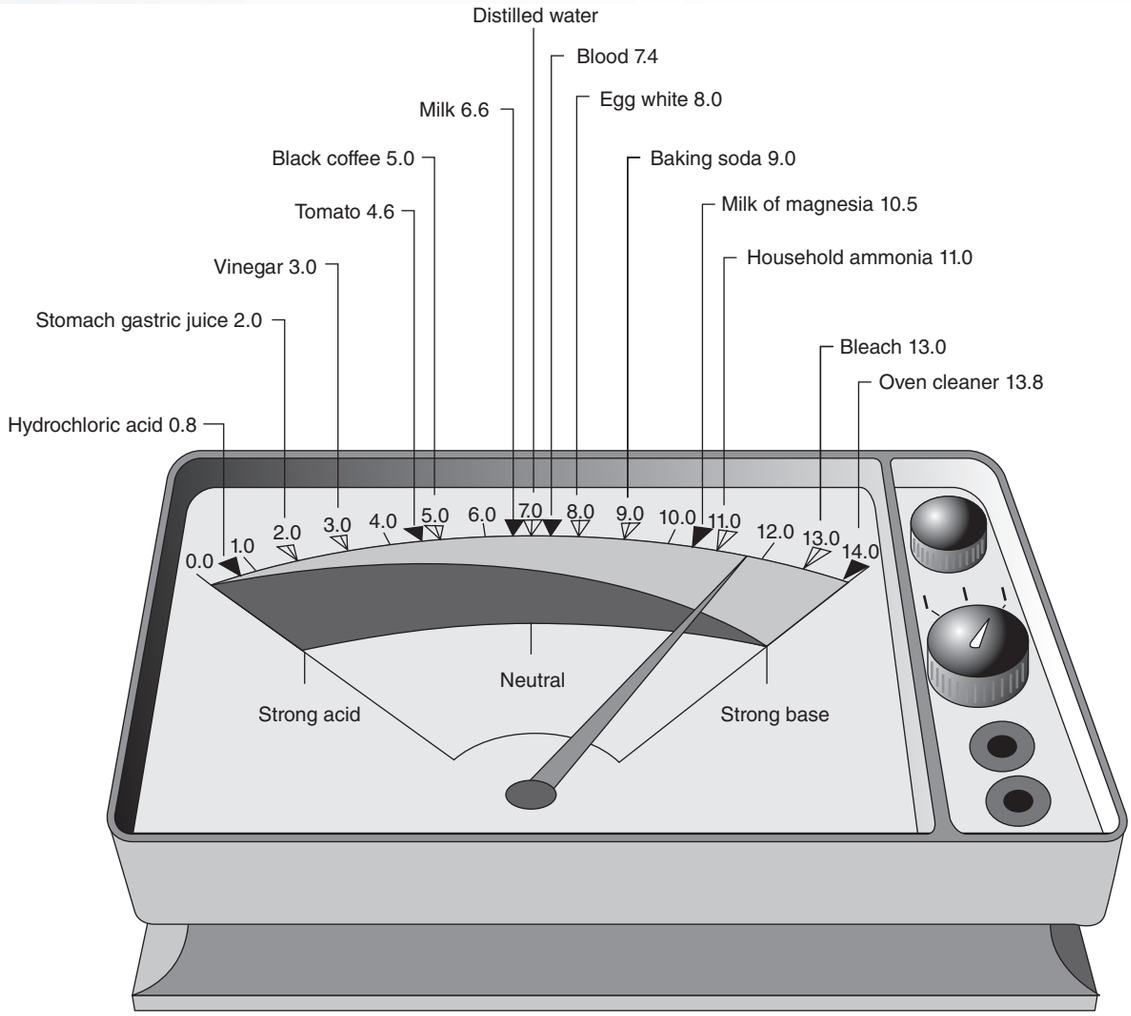
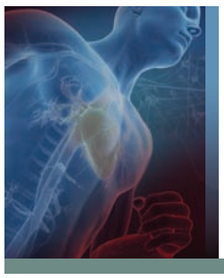


Figure 2-7 *pH values of common acids, bases, and human body fluids*

Medical Terminology

chem	chemical
chemistry	study of chemical composition of matter
di	two
-saccharide	sugar containing carbon, hydrogen, and oxygen
di/saccharide	contains two sugars
extra	outside
-cellular	pertaining to cell(s)
extra/cellular	outside the cell
intra	inside
intra/cellular	inside the cell
mono	one
mono/ saccharide	contains one sugar
multi	many
multi/cellular	many cells
poly	many
poly/ saccharide	contains many sugars
uni	one
uni/cellular	one-celled



Study Tools

Workbook	Activities for Chapter 2
Online Resources	PowerPoint presentations

Review Questions

Select the letter of the choice that best completes the statement.

1. A substance that has weight and occupies space is called
   a. kinetic energy.
   b. a catalyst.
   c. matter.
   d. potential energy.

2. Walking is an example of
   a. a catalyst.
   b. kinetic energy.
   c. matter.
   d. potential energy.

3. Water is classified as a(n)
   a. atom.
   b. element.
   c. mineral.
   d. compound.

4. Atoms of a specific element that have the same number of protons but a different number of neutrons are called
   a. isotopes.
   b. DNA.
   c. RNA.
   d. compounds.

5. Sugar stored in the liver and muscle cells for energy is called
   a. glucose.
   b. glycogen.
   c. fructose.
   d. ribose.

6. A chemical reaction in the cell is affected by
   a. enzymes.
   b. organic compounds.
   c. nucleic acids.
   d. energy.

7. Fluid found inside the cell is called
   a. extracellular.
   b. interstitial.
   c. intracellular.
   d. intercellular.

8. The compound with a pH of 9 is alkaline and is
   a. milk of magnesia.
   b. baking soda.
   c. ammonia.
   d. bleach.

9. When proper amounts of an acid and base are combined, the products formed are salt and
   a. gas.
   b. water.
   c. another base.
   d. another acid.

10. The name given to the atomic particle found outside the nucleus of an atom is
    a. proton.
    b. neutron.
    c. electron.
    d. ion.

Matching

Match each term in Column I with its correct description in Column II.

COLUMN I	COLUMN II
_____ **1.** glucose	a. fluid within the cell
_____ **2.** electrolyte	b. double sugar
_____ **3.** intracellular	c. triglycerides
_____ **4.** disaccharides	d. chromosomes
_____ **5.** HCl	e. conducts an electrical charge in a solution
_____ **6.** steroid	f. blood sugar
_____ **7.** energy	g. positively or negatively charged particle of an atom
_____ **8.** ion	h. ability to do work
_____ **9.** DNA	i. cholesterol
_____ **10.** fats	j. found in the stomach

Applying Theory to Practice

1. Read the label on a loaf of bread and state why the bread can be advertised as having "no cholesterol."

2. What diagnostic imaging device would be used for the following conditions?
   a. Brain tumor
   b. Cancer of the stomach
   c. Liver disease
   d. Pregnancy

3. Should DNA identification be required at birth? Have a panel discussion on the ethics of DNA testing as part of a preemployment physical.

Case Study

Patricia Savon is 34 years old. She has come to the clinic because of a general feeling of weakness and some difficulty walking. She also has had problems with her vision. When you bring Patricia to the examining room, she asks you to leave the door open because she is afraid of being shut inside.

The physician does a physical examination on Patricia and orders some diagnostic tests. A possible diagnosis for Patricia is multiple sclerosis.

1. The fear that Patricia experiences is known as _____.

2. Understanding Patricia's fears, what type of nuclear imaging test will be ordered for her?

3. Patricia wants to know how nuclear imaging works; she is afraid of radiation. Explain to her how imaging devices work.

4. What additional instructions and information can you give Patricia regarding the test?

5. Are there other imaging tests that could be ordered for Patricia?

2-1

Lab Activity

Acid or Base

- *Objective:* To identify the difference between an acidic (containing an acid), a basic (containing a base), and a neutral substance using litmus paper and pH-indicator scale paper
- *Materials needed:* paper cups, red or blue litmus paper, pH-indicator scale paper, tap water, vinegar, liquid soap, tomato juice, nail polish remover, baking soda solution, milk, lemon juice, a list of the solutions

Step 1: Place the solutions into separate paper cups and label the contents.

Step 2: Using **litmus** paper, indicate if the solution is an acid or a base and record your results on the list.

Step 3: Using pH-indicator scale paper, mark the pH of each solution.

Step 4: Which solution is the strongest acid?

Step 5: What is the pH of water? ■

2-2

Lab Activity

Effects of Antacid on an Acidic Stomach

- *Objective:* To determine the effectiveness of various antacid preparations or household remedies on an acidic stomach; the stomach under normal conditions has a pH of about 2
- *Materials needed:* measuring cup, vinegar, water, paper cups, Tums, Rolaids, Pepcid AC, Alka-Seltzer, baking soda solution, pH-indicator paper, pencil, paper on which to record your results

Step 1: Mix 1 oz of vinegar with 8 oz of water to make a solution that represents an acidic stomach.

Step 2: Use pH-indicator paper to test the pH of the acidic stomach preparation. Record your result.

Step 3: Place approximately 1.5 oz of the acidic stomach solution into each of five different paper cups.

Step 4: Add one type of antacid preparation or 1 tablespoon of the baking soda solution to separate cups of the acidic stomach solution.

Step 5: After adding antacid preparation, does the solution fizz? What is occurring? Record your results.

Step 6: After the tablets and baking soda solutions have dissolved, retest each of the solutions with pH-indicator paper to measure any changes in the pH of the solution. Record your results.

Step 7: Did the antacid preparation raise the pH of the acidic stomach solution?

Step 8: Which preparation was most effective as an antacid?

Step 9: Obtain the prices of the various antacids. Which preparation is most cost-effective (least expensive to produce the desired result)?

Step 10: Record your results for steps 7, 8, and 9. ■

2-3

Lab Activity

Testing Your pH Level

- *Objective:* To determine the pH of your body by testing your saliva
- *Materials needed:* bottle of pH test strips with color-coded scale, spoon, paper, pencil

Step 1: Recall what you had for breakfast or lunch. If you have not had breakfast or lunch, your instructor may give you a snack and wait until the end of the class session to do the experiment.

Step 2: Assemble pH test strips and spoon.

Step 3: Have test strip ready.

Step 4: Spit on a spoon.

Step 5: Dip the test strip into your saliva.

Step 6: Immediately compare the color on the test strip with the color-coded chart.

Step 7: Record your findings.

Step 8: Wash the spoon and return materials. ■

Chapter 3

CELLS

Objectives

- Identify the structure of a typical cell.
- Define the function of each component of a typical cell.
- Relate the functions of cells to the functions of the body.
- Describe the processes that transport materials in and out of a cell.
- Describe a tumor and define cancer.
- Define the key words that relate to this chapter.

Key Words

active transport
adenosine triphosphate (ATP)
anaphase
anoxia
apoptosis
atrophy
benign
biomarkers
cancer
cell membrane
centrioles
centrosome
chromatid
chromatin
chromosome
cilia
cytoplasm
cytoskeleton
diffusion
dysplasia
endoplasmic reticulum
equilibrium
filtration
flagella
Golgi apparatus
hyperplasia
hypertonic solution
hypertrophy
hypotonic solution
hypoxia
interphase
isotonic solution
lysosome
meiosis
metaphase
metastasis
mitochondria
mitosis
necrosis
neoplasia
neoplasm
nuclear membrane
nucleolus
nucleoplasm
nucleus
organelle
osmosis
osmotic pressure
papilloma
passive transport
peroxisomes
phagocytosis
pinocytic vesicle
pinocytosis
prophase
protoplasm
replication
ribosome
solutes
telophase
tumor
vacuole
wart

The body of a plant or animal seems to be a single entity, but when any portion is examined under a microscope it is found to be made up of many small, discrete parts. These tiny parts, or units, are called cells. (*Note:* These units were first discovered in the 1600s by Robert Hook. When examining a piece of cork under a crude microscope, the units reminded him of a monk's room, which was called a cell.) All living things—whether plant or animal, unicellular or multicellular, large or small—are composed of cells. A cell is microscopic in size. Our bodies are made up of trillions of cells that live mostly for a few weeks or months, die, and are replaced by new cells. Even the bone cells of our skeleton are replaced. *The cell is the basic unit of structure and function of all living things.*

Protoplasm

Cells are composed of **protoplasm** (pro-toh-**PLAZM**), an aqueous solution of carbohydrates, proteins, lipids, nucleic acids, and inorganic salts surrounded by a cell membrane. These components are organized into structures that have a specific function in the cell and are called organelles. **Organelles** (or-guh-**NELZ**) common to human cells include the nucleus, **ribosomes** (**RYE**-boh-sohmz), **centrosomes** (**SEN**-troh-sohmz), **centrioles** (**SEN**-tree-olz), **endoplasmic reticulum** (en-doh-**PLAZ**-mik re-**TICK**-you-lum), **mitochondria** (my-toh-**KON**-dree-ah), **lysosomes** (**LIGH**-soh-sohmz), **peroxisomes** (peh-**ROKS**-ih-sohmz), the **Golgi apparatus** (**GOHL**-jee), and a **cytoskeleton.**

Protoplasm inside the nucleus of a cell is called **nucleoplasm** (**NOO**-klee-oh-plazm), and outside the nucleus it is called **cytoplasm** (**SIGH**-toh-plazm).

Because cells are microscopic, a special unit of measurement is used to determine their size. This is the micrometer (μm), or micron (μ). It is used to describe both the size of cells and their cellular components. To see or study a cell in fine detail, an electron microscope must be used.

To better understand the structure of a cell, let us compare a living entity—such as a human being—to a house. The many individual cells of this living organism are comparable to the many rooms of a house. Just as each room is bounded by four walls, a floor, and a ceiling, a cell is bounded by a specialized cell membrane with many openings. Cells, like rooms, come in a variety of shapes and sizes. Every kind of room or cell has its own unique function. A house can be made up of a single room or many. In much the same fashion, a living thing can be made up of only one cell (unicellular) or many cells (multicellular). *Figure 3-1* shows the structure of a typical animal cell.

Did You Know?

Fifty thousand cells in your body will die and be replaced with new cells while you read this sentence.

Cell/Plasma Membrane

Every cell is surrounded by a **cell membrane,** sometimes called a plasma membrane. The membrane separates the cell from its external environment and from the neighboring cells. It also regulates the passage or transport of certain molecules into and out of the cell, while preventing the passage of others. This is why the cell membrane is often called a selective semipermeable membrane. The cell membrane is composed of a double phospholipid layer, with proteins embedded in the layer. The phospholipid looks like a balloon with tails. The round balloonlike part is hydrophilic (attracts water) and the double tails are hydrophobic (repels water). This arrangement allows for the easy passage of water molecules through the cell membrane by osmosis. The proteins embedded in the double phospholipid layer allow for the passage of molecules and ions across the cell membrane (*Figure 3-2*).

Nucleus

The **nucleus** is the most important organelle within a cell. It has two vital functions: to control the activities of the cell and to facilitate cell division. This spherical organelle is usually located in or near the center of the cell. Various dyes or stains, such as iodine, can be used to make the nucleus stand out. The nucleus stains vividly because it contains deoxyribonucleic acid (DNA) and protein. Surrounding the nucleus is a membrane called the nuclear membrane.

When a cell reaches a certain size, it divides to form two new cells. The DNA and protein are arranged in a loose and diffuse state called **chromatin.** The chromatin condenses to form short, rodlike structures called **chromosomes.** Each species has a specific number of chromosomes in the nucleus. The number of chromosomes for the human being is 46.

The nucleus divides first by a process called mitosis. It is only during the process of mitosis that the chromosomes can be seen. Chromosomes store the

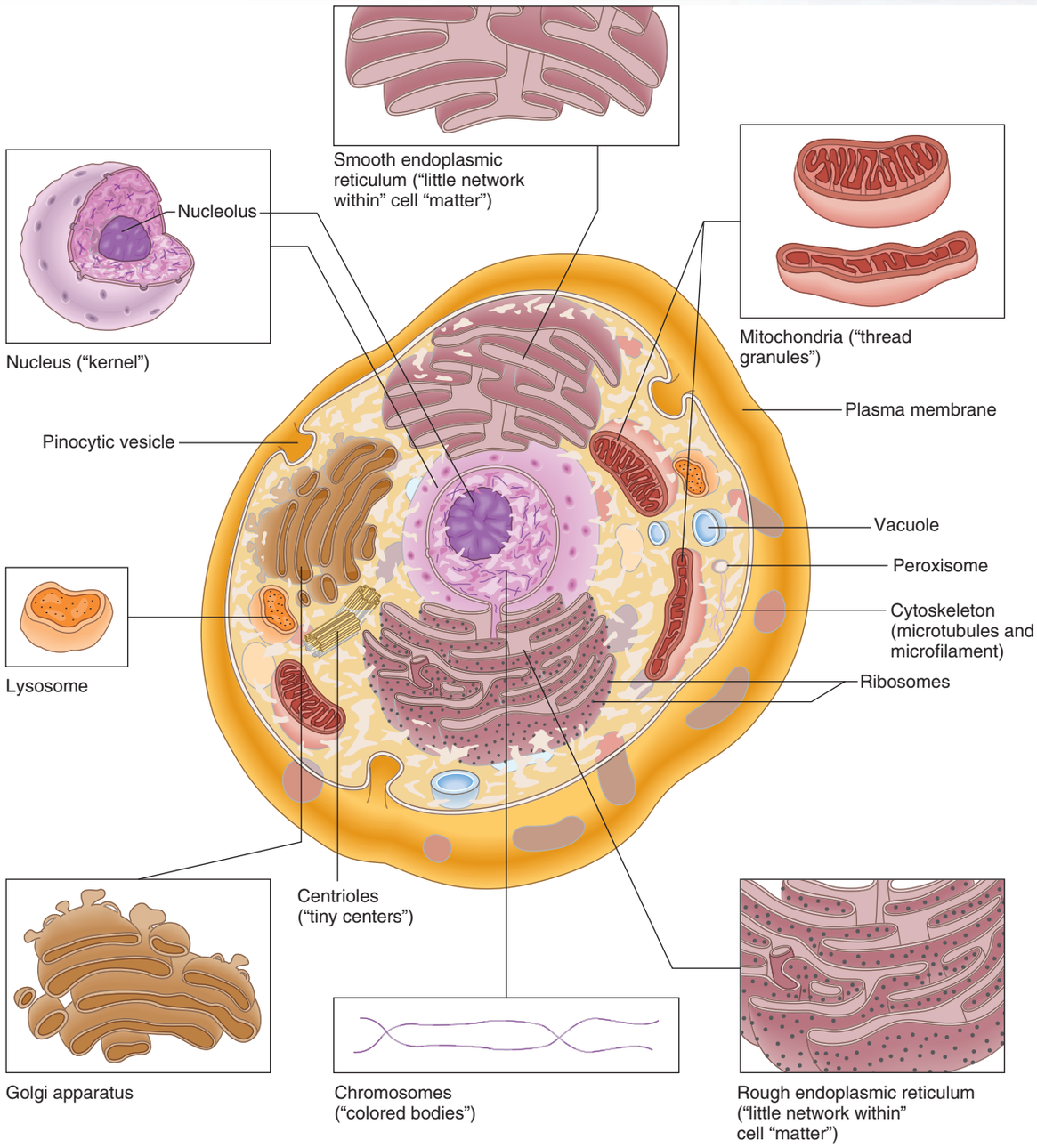


Figure 3-1 *The structure of a typical animal cell*

hereditary material DNA, which is passed on from one generation of cells to the next.

Nuclear Membrane

The nucleus of a cell is contained within a **nuclear membrane,** or nuclear envelope. This membrane is a double-layered structure that has openings (pores) at regular intervals. Materials can pass through these openings from either the nucleus to the cytoplasm (the material found between the nucleus and the plasma membrane) or the cytoplasm to the nucleus. The outer layer of the nuclear membrane is continuous with the endoplasmic reticulum of the cytoplasm and may have small round projections on it, called ribosomes.

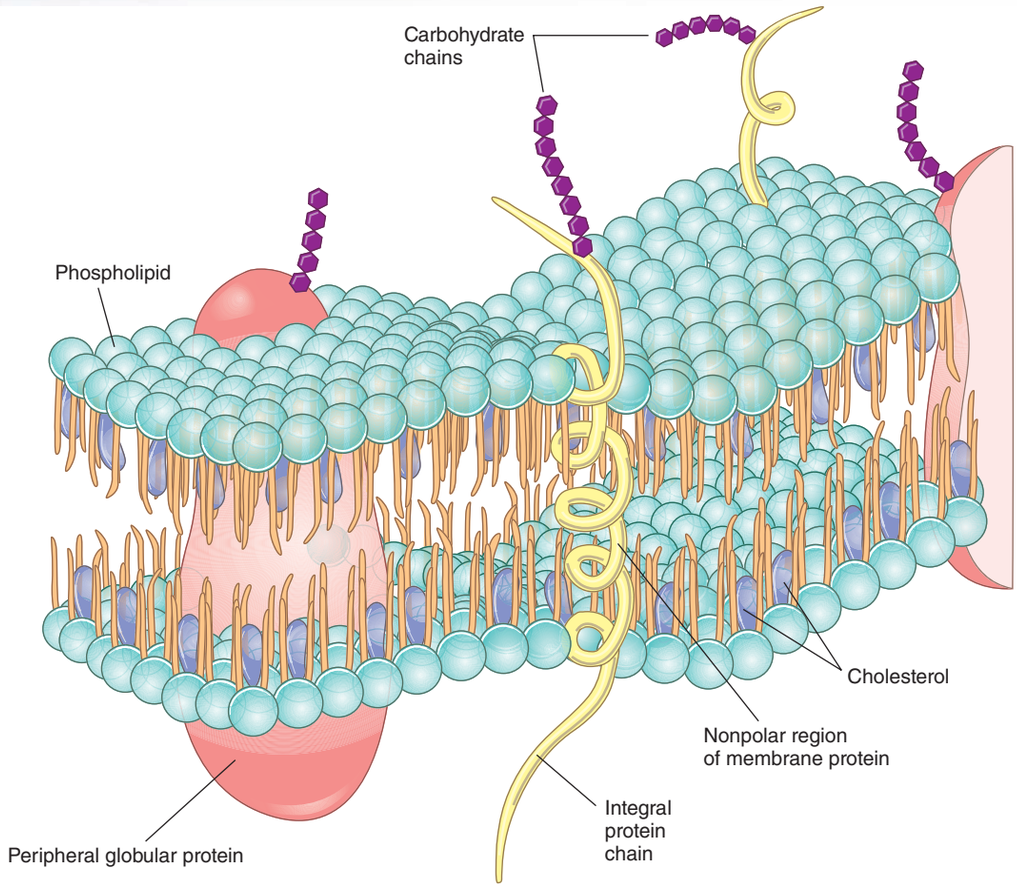


Figure 3-2 *The structure of a plasma (cell) membrane*

Nucleoplasm

Nucleoplasm is a clear, semifluid medium that fills the spaces around the chromatin and the nucleoli within the nucleus.

Nucleolus and the Ribosomes

Within the nucleus are one or more nucleoli (plural of nucleolus). Each **nucleolus** is a small round body (*Figure 3-1*). It contains ribosomes composed of ribonucleic acid and protein. The ribosomes can pass from the nucleus through the nuclear pores into the cytoplasm. There the ribosomes aid in *protein synthesis*. They may exist freely in the cytoplasm, be in clusters called polyribosomes, or be attached to the walls of the endoplasmic reticulum.

Cytoplasm

Cytoplasm is a sticky, semifluid material found between the nucleus and the cell membrane. Chemical analysis of cytoplasm shows that it consists of proteins, lipids, carbohydrates, minerals, salts, and water (70% to 90%). Each of these substances, other than water, varies greatly from one cell to the next and from one organism to the next. Cytoplasm is the background for all chemical reactions that take place in a cell, such as protein synthesis and cellular respiration. Molecules are transported about the cell by the circular motion of the cytoplasm.

Table 3-1 summarizes the cell structures and their functions.

Centrosome and Centrioles

The centrioles are two cylindrical organelles found near the nucleus in a tiny round body called the centrosome. The centrioles are perpendicular to each other; *Figure 3-1* shows two centrioles near the nucleus. During mitosis, or cell division, the two centrioles separate from each other. In the process of separation, thin cytoplasmic spindle fibers form between the two centrioles. This structure is called a spindle-fiber apparatus. The spindle fibers attach themselves to individual chromosomes to help in the equal distribution of these chromosomes to two daughter cells.

Table 3-1 *Cell Structures, Organelles, and Their Functions*

STRUCTURE AND ORGANELLE	FUNCTION
Cell membrane	Regulates transport of substances into and out of the cell
Cytoplasm	Provides an organized watery environment in which life functions take place by the activities of the organelles contained in the cytoplasm
Nucleus/organelle	Serves as the "brain" for the control of the cell's metabolic activities and cell division
Nuclear membrane	Regulates transport of substances into and out of the nucleus
Nucleoplasm	Fills the spaces around the chromatin and the nucleoli with a clear, semifluid medium
Nucleolus/organelle	Functions as a reservoir for RNA
Ribosomes/organelle	Serve as sites for protein synthesis
Endoplasmic reticulum/organelle	Provides passages through which transport of substances occurs in cytoplasm
Mitochondria/organelle	Serve as sites of cellular respiration and energy production; store ATP
Golgi apparatus/organelle	Manufactures carbohydrates and packages secretions for discharge from the cell
Lysosomes/organelle	Serve as centers for cellular digestion
Peroxisomes/organelle	Use enzymes to oxidize cell substances
Centrosome and centrioles/organelle	Are functional during animal cell division
Cytoskeleton/organelle	Forms the internal framework
Cilia and flagella	Beat and vibrate their hairlike protrusions

Endoplasmic Reticulum

Crisscrossing the cellular cytoplasm is a fine network of tubular structures called the endoplasmic reticulum (reticulum means "network"). Some of this endoplasmic reticulum connects the nuclear membrane to the cell membrane; thus, it serves as a channel for the transport of materials in and out of the nucleus. Sometimes the endoplasmic reticulum will accumulate large masses of proteins and act as a storage area.

The two types of endoplasmic reticulum are rough and smooth. Rough endoplasmic reticulum has ribosomes studding the outer membrane. The ribosomes are the sites for protein synthesis in the cell. Smooth endoplasmic reticulum has a role in cholesterol synthesis, fat metabolism, and detoxification of drugs.

Mitochondria

Most of a cell's energy comes from spherical or rod-shaped organelles called mitochondria. These mitochondria vary in shape and number. There can be as few as one in each cell or more than a thousand. Cells that need the most energy have the greatest number of mitochondria. Because they supply the cell's energy, mitochondria are also known as the "powerhouses" of the cell.

The mitochondria have a double-membrane structure that contains enzymes. These enzymes help break down carbohydrates, fats, and protein molecules into energy to be stored in the cell as **adenosine triphosphate (ATP)** (ah-**DEN**-oh-seen try-**FOS**-fate). All living cells need ATP for their activities.

Golgi Apparatus

The Golgi apparatus is also referred to as Golgi bodies or the Golgi complex. It is an arrangement of layers of membranes resembling a stack of pancakes. Scientists believe that this organelle synthesizes carbohydrates and combines them with protein molecules as they pass through the Golgi apparatus. In this way, the Golgi apparatus stores and packages secretions for discharge from the cell. These organelles are abundant in the cells of gastric glands, salivary glands, and pancreatic glands.

Lysosomes

Lysosomes are oval or spherical bodies in the cellular cytoplasm. They contain powerful enzymes that digest protein molecules. The lysosome thus helps digest old, worn-out cells, bacteria, and foreign matter. If a lysosome should rupture, as sometimes happens,

the lysosome will start digesting the cell's proteins, causing it to die. For this reason, lysosomes are also known as "suicide bags."

Peroxisomes

Membranous sacs that contain oxidase enzymes are called peroxisomes. These enzymes help digest fats and detoxify harmful substances.

Cytoskeleton

The cytoskeleton is the internal framework of a cell. It consists of microtubules, intermediate filaments, and microfilaments. The filaments provide support for the cells; the microtubules are thought to aid in movement of substances through cytoplasm.

Pinocytic Vesicles

Large molecules such as protein and lipids, which cannot pass through the cell membrane, will enter a cell by way of the pinocytic vesicles. The **pinocytic vesicles** form when the cell membrane folds inward to create a pocket. The edges of the pocket then close and pinch away from the cell membrane, forming a bubble or **vacuole** in the cytoplasm. This process, by which a cell forms pinocytic vesicles to take in large molecules, is called **pinocytosis** (pye-noh-sigh-**TOH**-sis) or "cell drinking."

Cilia and Flagella

Cilia and **flagella** are protrusions from the cell membrane. Cilia have short hairlike protrusions, whereas flagella have a singular taillike protrusion. They are composed of fibrils that protrude from the cell and beat or vibrate. Cilia move materials across the surface of a cell. An example is the respiratory tract cells, which move the mucous-dust package from the respiratory tree to the throat. The sperm cell of the male has a flagellum that propels the cell to reach the egg in the upper part of the fallopian tube of the uterus of the female.

Media Link

View the **Anatomy of a Typical Cell** animation on the Online Resources.

Cellular Metabolism

For cells to maintain their structure and function, chemical reactions must occur inside the cell. These chemical reactions require energy, most commonly from a molecule called ATP. ATP is created from the decomposition of organic molecules from the carbohydrates, proteins, and fats we eat. Calories released from the decomposition of food are used to synthesize ATP. ATP is then available to be used for maintenance of cellular structure and function.

Cell Division

Cells divide for two purposes: growth or maintenance of cells in the human body (**mitosis**) and reproduction (**meiosis**). In mitosis each cell carries a complete set of chromosomes (46); however, in meiosis each cell carries only half of the chromosomes (23).

Meiosis

Meiosis is the process of cell division of the sex cell or gamete. During meiosis, the ovum from the female and the spermatozoa from the male *reduce* their respective chromosomes by half, from 46 to 23. When fertilization (the union of the ovum and the spermatozoa) occurs, the two sex cells combine to form a simple cell called the zygote, with the full set of 46 chromosomes (23 from each parent) (*Figure 3-3*).

Media Link

View the **Meiosis** animation on the Online Resources.

Mitosis

Cell division is comprised of two distinct processes: the first stage is the division of the nucleus and the second stage is the division of the cytoplasm.

Mitosis essentially is an orderly series of steps by which the DNA in the nucleus of the cell is equally distributed to two daughter, or identical, nuclei. During the process, the nuclear material is distributed to each of the two new nuclei. This is followed by the division of the cytoplasm into two approximately equal parts through the formation of a new membrane between the two nuclei.

All cells do not reproduce at the same rate. Blood-forming cells in the bone marrow, cells of the skin, and cells of the intestinal tract reproduce continuously. Muscle cells only reproduce every few years.

Mitosis in a Typical Animal Cell

Mitosis is a smooth, continuous process. For ease and convenience of study, however, five stages, or phases, have been identified by the cell biologist. These five phases are discussed subsequently with accompanying