VISUALIZING
Human Biology

FIFTH EDITION

KATHLEEN A. IRELAND

WILEY

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Visualizing Human Biology

Fifth Edition

KATHLEEN ANNE IRELAND, PH.D.

WILEY

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How Is Wiley Visualizing Different?

Wiley Visualizing differs from competing textbooks by uniquely combining three powerful elements: a visual pedagogy integrated with comprehensive text, the use of authentic situations and issues, and the inclusion of interactive multimedia in *WileyPLUS*. Together these elements deliver a level of rigor in ways that maximize student learning and involvement. Each key concept and its supporting details have been analyzed and carefully crafted to maximize student learning and engagement.

1. **Visual Pedagogy.** Wiley Visualizing is based on decades of research on the use of visuals in learning.[1] Using the cognitive theory of multimedia learning, which is backed up by hundreds of empirical research studies, Wiley's authors select visualizations for their texts that specifically support students' thinking and learning—for example, the selection of relevant materials, the organization of the new information, or the integration of the new knowledge with prior knowledge. Visuals and text are conceived and planned together in ways that clarify and reinforce major concepts while allowing students to understand the details. This commitment to distinctive and consistent visual pedagogy sets Wiley Visualizing apart from other textbooks.
2. **Authentic Situations and Problems.** *Visualizing Human Biology, Fifth Edition* offers an array of remarkable photographs, maps, media, and videos. These authentic materials immerse the student in real-life issues in environmental science, thereby enhancing motivation, learning, and retention. These authentic situations are unique to Wiley Visualizing.
3. **Interactive Multimedia.** Wiley Visualizing is based on the understanding that learning is an active process of knowledge construction. *Visualizing Human Biology, Fifth Edition* is therefore tightly integrated with multimedia activities provided in *WileyPLUS*.

Visualizing Human Biology and *WileyPLUS* Learning Environment are designed as a natural extension of how we learn

Visuals, comprehensive text, and learning aids are integrated to display facts, concepts, processes, and principles more effectively than words alone can. To understand why the visualizing approach is effective, it is first helpful to understand how we learn.

1. Our brain processes information using two channels: visual and verbal. *Our working memory* holds information that our minds process as we learn. In working memory we begin to make sense of words and pictures, and build verbal and visual models of the information.
2. When the verbal and visual models of corresponding information are connected in working memory, we form more comprehensive, or integrated, mental models.
3. When we link these integrated mental models to our prior knowledge, which is stored in our long-term memory, we build even stronger mental models. When an integrated mental model is formed and stored in long-term memory, real learning begins.

The effort our brains put forth to make sense of instructional information is called cognitive load. There are two kinds of cognitive load: productive cognitive load, such as when we're engaged in learning or exert positive effort to create mental models; and unproductive cognitive load, which occurs when the brain is trying to make sense of needlessly complex content or when information is not presented well. The learning process can be impaired when the amount of information to be processed exceeds the capacity of working memory. Well-designed visuals and text with effective pedagogical guidance can reduce the unproductive cognitive load in our working memory.

[1] Mayer, R.E. (Ed) (2005). The Cambridge Handbook of Multimedia Learning. Cambridge University Press.

What Is the Organization of Visualizing Human Biology?

Any course in human biology must introduce the student to science through a focus on the human being; Visualizing Human Biology achieves this by stressing the role of the human in the environment. This theme links together the broad-ranging information in human biology, providing an organizing principle that relates human biology to the students' daily experience, and gives them the stories behind the biology. Each chapter begins with an intriguing vignette designed to stimulate a desire for more information. Throughout the chapter, students are further involved in the topics with the striking and stimulating photos and illustrations that demonstrate the concepts, questions, and stories behind the science in the *Health, Wellness, and Disease; Ethics and Issues*; and *I Wonder*... features. Tools and resources throughout the chapter help students check their understanding and focus on the most essential information. *Visualizing Human Biology, Fifth Edition* is further divided into five units to help students relate to this material.

- **Unit 1** Introduction to the Study of Life, Chapters 1 through 5, lays the groundwork for creating understanding by focusing on the basic building blocks of human biology.
- **Unit 2** Moving Through the Environment, Chapters 6, 7, and 8, investigates the human systems involved in movement: the skeletal, muscular, and nervous systems.
- **Unit 3** Protection from the Environment, Chapters 9, 10, 11 and 12 describes how the body is protected against injury and invasion, and explains both cancer and the role of the microbiome.
- **Unit 4** Thriving within the Environment, Chapters 13, 14, 15, 16 and 17, explores how the cardiovascular and respiratory systems transport nutrients and oxygen to the tissues and how food is digested and wastes are eliminated.
- **Unit 5** Populating the Environment, Chapters 18, 19, 20, and 21, covers the action of the endocrine system, and the reproductive system. The final chapter on inheritance, DNA, and biotechnology complete the student's understanding of human biology.

New to this Edition

The main focus of the fifth edition has been to make this text more student-focused. This is done through the chapter pedagogy, the engaging writing style, *WileyPLUS*, and an entirely new chapter based on current findings related to our microbiome. *Visualizing Human Biology, Fifth Edition* focuses students on what's most important for them with integrated visuals and visual pedagogy, helping to teach students the key concepts of human biology and connect the science to their own lives.

- **Chapter 11**—The Human Microbiome – An entirely new chapter has been added to cover the importance of our microbiome. Outlining current research and the findings highlighted by the Human Microbiome Project, this chapter explains the shift in scientific thinking as it relates to Human Biology and our health.
- **Key Processes**—Key Processes have been added to more figures in this edition. A reminder of the basic process underlying new concepts, the key processes, will be found at the end of the figure caption. This allows students to quickly break down seemingly complicated processes into the simple ones underlying them.
- **Chapter Openers**—Many of the photographs and opening vignettes have been updated, engaging students from the very beginning of the chapter.
- **Boxed Features**—Many of the Health, Wellness and Disease, Ethics and Issues, What a Scientist Sees, and I Wonder… boxes have been updated to reflect current topics that relate to students' lives.

Instructor's Support

Wiley Visualizing Site

Wiley Visualizing The Wiley Visualizing site hosts a wealth of information for instructors using Wiley Visualizing, including ways to maximize the visual approach in the classroom and a white paper titled 'How Visuals Can Help Students Learn' by Matt Leavitt, instructional design consultant. Visit Wiley Visualizing at **www.wiley.com/college/visualizing**

Instructor's Manual

(Available in *WileyPLUS* and on the book companion site)

A Teaching Tips with Illustrations instructor's manual created by Joel Piperberg at Millersville University is available for each chapter and helps instructors create lectures based on the visuals in the textbook. The instructor's manual also includes in-depth discussion questions to accompany each chapter.

Test Bank

(Available in *WileyPLUS* and on the book companion site)

Many visuals from the textbook are also included in the Test Bank by Alicia Steinhart at West Valley College. The Test Bank has approximately 1,600 test items, with at least 25% of them incorporating visuals from the book. The test items include multiple choice, true/false, text entry, and essay questions which test a variety of comprehension levels. The test bank is available online in MS Word files, as a computerized Test Bank, and within *WileyPLUS*. The easy-to-use test-generation program fully supports graphics, print tests, student answer sheets, and answer keys. The software's advanced features allow you to produce an exam to your exact specifications.

Lecture PowerPoints and Image PowerPoints

(Available in *WileyPLUS* and on the book companion site)

A complete set of highly visual PowerPoint presentations—one per chapter—by Jill Feinstein at Richland Community College is available online and in *WileyPLUS* to enhance classroom presentations. Tailored to the text's topical coverage and learning objectives, these presentations are designed to convey key text concepts, illustrated by embedded text art.

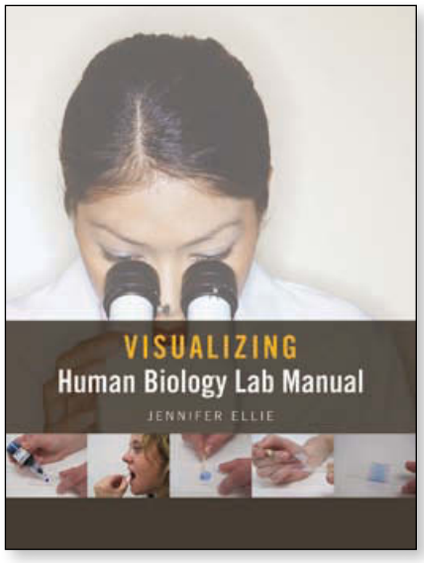
All photographs, figures, maps, and tables from the text are available as JPEGs and PowerPoints, and can be used as you wish in the class room. These electronic files allow you to easily incorporate images into your own PowerPoint presentations as you choose, or to create your own handouts.

Clicker Questions

(Available in *WileyPLUS* and on the book companion site)

Clicker questions, written by Keith Hench at Kirkwood Community College are available in PowerPoint, and can be converted to various clicker formats.

Also Available



Visualizing Human Biology Lab Manual by Jennifer Ellie of Wichita State University provides instructors and students with a lab book that focuses on engaging students in the study of human biology. Each lab includes **Active Learning Questions**, **Introductions**, **Exercises**, **Review Questions**, and **Visualizing the Lab**, a unique exercise that contains step-by-step instructions with accompanying pictures to help students successfully complete each lab assignment.

Visualizing Human Biology Lab Manual is available as a standalone or in a customizable package with *Visualizing Human Biology* and your own materials, through the Wiley Custom Select program (www.customselect.wiley.com). Please contact your Wiley representative for more information.

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Book Companion Site

All instructor resources (the Test Bank, Instructor's Manual, PowerPoint presentations, and all textbook illustrations and photos) are housed on the book companion site (www.wiley.com/college/ireland).

Special Thanks

I am extremely grateful to the many members of the editorial and production staff at John Wiley and Sons who guided us through the challenging steps of developing this text. Their tireless enthusiasm, professional assistance, and endless patience smoothed the path as I found my way. I thank in particular Alan Halfen, Senior Editor, who expertly launched and directed the revision; Melissa Edwards Whelan, Development Editor, for coordinating the development and revision process; Kristine Ruff, Market Development Manager, for a superior marketing effort, and MaryAlice Skidmore and Alden Ferrar, Editorial Assistants, for their constant attention to detail. I also thank Trish McFadden, Senior Production Editor, and Jeanine Furino of Furino Production for expertly helping me through the production process. I thank Mary Ann Price, Photo Editor, for her unflagging, always swift work in researching and obtaining many of our text images. I thank Wendy Lai for the stunning new cover. Thank you to Petra Recter, Vice President and Director for providing guidance and support to the rest of the team throughout the revision.

Dedication

This edition is dedicated to Betty Ireland, whose legacy of strength, determination, and intellectual curiosity I now strive to carry forward with loving support from my husband Jeff, and my sons Greg and Marc.

About the Author

Aloha! I was born and raised on the East Coast of the US, where I began my education at Lehigh University. I went on to graduate with a BS and MS from the University of Alabama, and then later obtained my PhD from Iowa State. I spent many years on Maui, where I taught, learned to surf and competed in triathlons. My work experience has been broad, including both applied and basic research in genetics, cell biology, and human physiology. I have taught at colleges (Iowa State University, University of Hawaii, Maui, and Arkansas State University) as well as both private and public high schools. Like all professors I have a long list of societies and awards to my name; however I prefer to focus on teaching. My favorite teaching experiences revolve around making a difficult concept accessible to a struggling student. When that light shines from the student's eyes, I know I have done my job! This book is an extension of those moments. I have included tested and proven ways to make this material both interesting and memorable. When I am not teaching, I can be found riding my bike, stand up paddling, or hanging out with my husband Jeff and my grown sons, Greg and Marc.

Brief Contents

Contents

InSight Features

These multipart visual presentations focus on a key concept or topic in the chapter.

Process Diagram

These series or combinations of figures and photos describe and depict a complex process.

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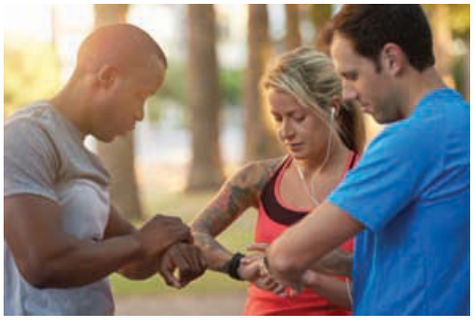
CHAPTER 1

Halfpoint / Shutterstock.com

What Is Life?

Every day there is a new report on how to maintain or improve your health. These reports are changing the way we think about our health. As proof of this, look at the rise in popularity of personal fitness tracking devices. Between Fitbit's launch in 2009 and the introduction of four new devices in 2016, Fitbit has become a multi-billion dollar industry. Obviously people are interested. Does a monitoring device that tracks your every movement really help you improve your overall health? That remains to be seen, with current research indicating that activity trackers do little to motivate otherwise non-athletic people to take up any form of exercise. Perhaps the largest benefit of these devices is the interest they have generated in personal health.

It is a great idea to try to monitor and improve your fitness, but wading through the incredible amount of literature and propaganda on health-related issues can be daunting. To really understand what is being presented, you must be able to scientifically evaluate advertising claims, medical breakthroughs, and social media hype. Taking advantage of the critical thinking guides throughout this book will help you practice the skills needed to become a knowledgeable consumer!



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CHAPTER OUTLINE

1.1 Living Organisms Display Nine Specific Characteristics

LEARNING OBJECTIVES

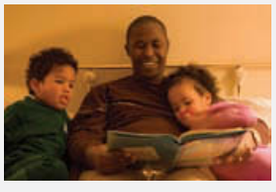
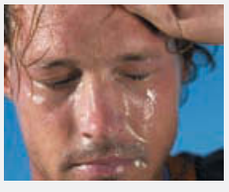
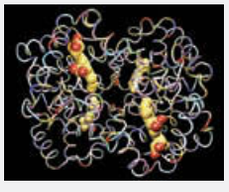
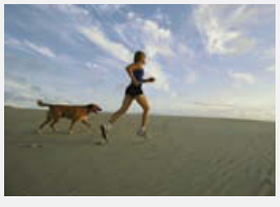
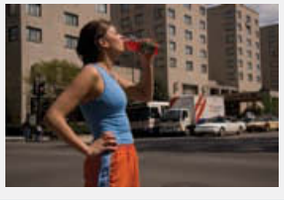
1. **List** the characteristics of life.
2. **Define** homeostasis and relate it to the study of life.
3. **Describe** how homeostasis plays a role in everyday activities.
4. **Contrast** negative and positive feedback systems.

Reflect on the start of your day. It has demonstrated many of the characteristics of life (**Table 1.1**). Several of these characteristics appeared during your first minutes of awakening. Life is defined by the ability to **respond to external stimuli** (remember waking to the alarm?). Objects that are alive can **alter their environment**, as you did by silencing the dreadful noise. You **sensed your environment** when you felt the chill of the morning, then you **adapted to your environment** by covering yourself with clothes to maintain your internal temperature. Living things **require energy**, which plants get by synthesizing compounds using solar power and which animals get by ingesting nutrients, aka breakfast. All of us are proof that living organisms **reproduce**. On the average foggy-headed morning, you undoubtedly failed to notice three other characteristics of life: (1) Life is composed of **materials found only in living objects** (your body contains proteins, lipids, carbohydrates, and nucleic acids—DNA and RNA); (2) living organisms maintain a stable internal environment, a property called **homeostasis**; and (3) life exhibits a **high degree of organization**, which extends from microscopic units, called **cells**, in increasingly complex **tissues**, **organs**, **organ systems**, and individual organisms.

Living Things Must Maintain Homeostasis

One key element of life is **homeostasis**, a word that means "staying the same" (*homeo* = unchanging; *stasis* = standing). Humans,

TABLE 1.1 Characteristics of life

Respond to external stimuli  Joel Sartore / NG Image Collection	Adapt to the environment  Masterfile	Contain materials found only in living organisms  Dr. Tim Evans / Science Source
Alter the environment  Image Source / John Harper / Getty Images, Inc.	Use energy  Skip Brown / NG Image Collection	Maintain a constant internal environment (homeostasis)  Stacy Gold / NG Image Collection
Sense the environment  Joel Sartore / NG Image Collection	Reproduce  Richard Lord / The Image Works	Have a high degree of organization  Photodisc / Rubberball / Getty Images

cell The smallest unit of life, contained in a membrane or cell wall.

tissue A cohesive group of similar cells performing a specific function.

organ A structure composed of more than one tissue having one or more specific functions.

organ system A group of organs that perform a broad biological function, such as respiration or reproduction.

Health, Wellness, and Disease

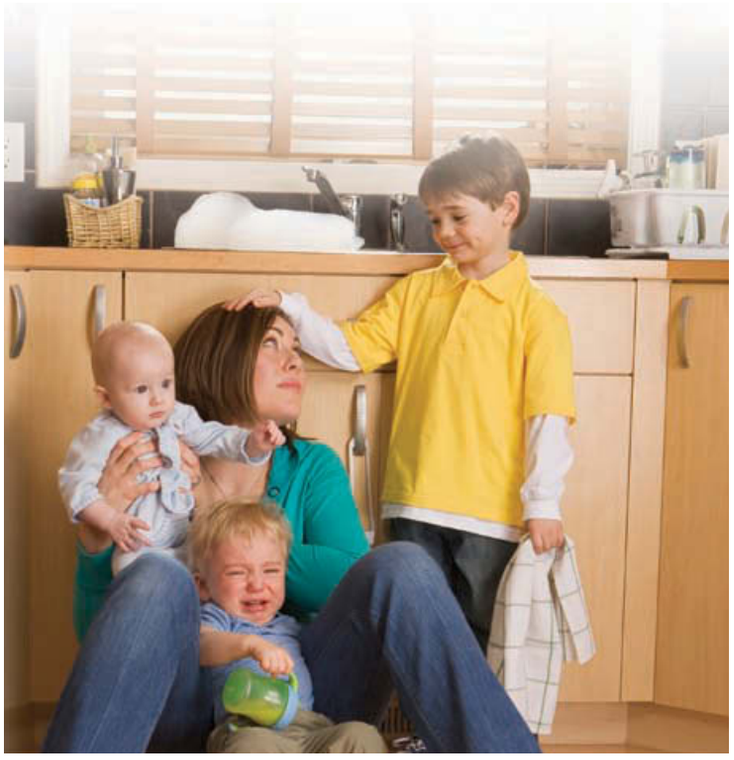
Homeostasis Is a Way of Life!

We have all felt tired or "out of sorts" at one time or another. Often, when we experience these episodes, we are functioning under a slight homeostatic imbalance. One accepted definition of disease is, in fact, a homeostatic imbalance with distinct signs and symptoms. Symptoms are the series of complaints we generate when we begin to feel ill. They include headache, nausea, fatigue, and muscle aches. Signs are the changes in bodily function that can be detected by a medical professional. Signs of homeostatic imbalance usually include a full description of the blood chemistry of the individual as well as tests of hormone levels and function.

There are many examples of subtle homeostatic imbalances that, if left unchecked, can lead to serious complications. For example, feeling tired may be due to a lack of oxygen-carrying capacity in the blood, a condition known as anemia. Adding iron to your diet might be all that is needed to reduce chronic fatigue.

Some people require regular food intake to maintain their homeostatic sugar balance. If they wait too long between meals, they may experience nervousness, sweating, trembling, and inability to concentrate, all caused by low blood sugar. Hypoglycemia is the clinical diagnosis for this. The brain responds very strongly to the lack of sugar, and will intensify feelings of hunger so that blood sugar does not reach critical levels. If there is no food immediately available, blood sugar may drop below 50 mg/dl causing more serious complications such as confusion, drowsiness, coma, or seizure.

Recent studies show that the onset of Alzheimer's disease may be heightened by an imbalance of the copper, iron, and zinc ions in the brain. Treatment for early signs of Alzheimer's disease includes restoring metal homeostasis. Patients whose metal balance is regulated experience a slower progression of the disease.



Design Pics / SuperStock

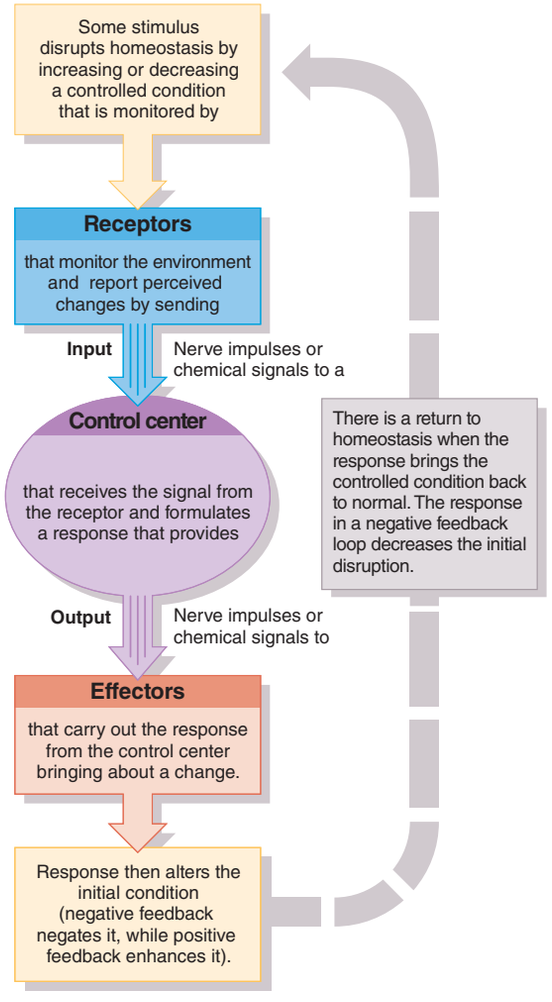
along with other organisms, can function properly only if they stay within narrow ranges of temperature and chemistry. Homeostasis allows you to respond to changes in your internal environment by modifying some aspect of your behavior, either consciously or unconsciously. When you are chilled, you consciously look for ways to warm yourself. This morning, you clothed yourself in an attempt to remain warm. If your clothing was not enough, your body would begin to shiver to generate internal heat through chemical reactions. Blood vessels near the surface of your skin would constrict and carry less blood, thereby reducing heat loss through **radiation**. These changes are attempts to maintain homeostasis. Each response to the chill is designed to remove or negate that feeling, in a typical negative feedback loop. (See *Health, Wellness, and Disease: Homeostasis Is a Way of Life!*)

Homeostasis Helps an Organism Stay Alive

Homeostasis helps an organism stay alive, often through the use of **feedback systems**, or loops, as shown in **Figure 1.1**. The most common type of feedback system in the human is **negative feedback**. Negative feedback systems operate to reduce or eliminate the changes detected by the stimulus receptor. Negative feedback prevents you from breathing fast enough to pass out or from drinking so much water that your blood chemistry becomes dangerously unbalanced. Positive feedback systems are rare in the body and include childbirth and blood clotting. The response in a positive feedback system serves to amplify the original stimulus. Feedback is so important that we will return to it when we discuss each organ system.

radiation The transfer of heat from a warm body to the surrounding atmosphere.

FIGURE 1.1 Feedback loop A simple homeostatic feedback loop has three main components that function as a whole to manipulate the environment.



Concept Check

1. **How** do you display characteristics that indicate you are living?
2. **Why** might a biologist want to understand the normal homeostatic ranges of her study subject?
3. **How** does homeostasis play a role in everyday activities?
4. **What** type of feedback is exemplified by the maintenance of blood calcium levels within a small range?

1.2 Human Biology Is Structured and Logical

LEARNING OBJECTIVES

1. **Explain** how atoms, and therefore the entire field of chemistry, relate to the study of life.
2. **Describe** the organizational pattern of all biology and the logic of taxonomy.
3. **Relate** taxonomy to human biology.
4. **List** the five processes that are most helpful in studying human physiology.

One of the oldest techniques for dealing with our world is to categorize it and divide it into manageable chunks. Imagine trying to understand this paragraph if the sentences were not divided into words through the use of spaces. Similarly, the natural world seems overwhelming and chaotic until we organize it. Biology is organized in steps, from microscopic to macroscopic: Small units make up larger units, which in turn form still larger units. We see this in both artificial and natural organization in biology. In artificial classification (taxonomy), a system of names is used to identify organisms and show their genetic relationship.

These names identify individual species and also group organisms, based on similar characteristics. The categories from species through genus, family, order, class, phylum, kingdom, and domain indicate groups of similar organisms, with each category broader than the last.

Organisms Are Structured

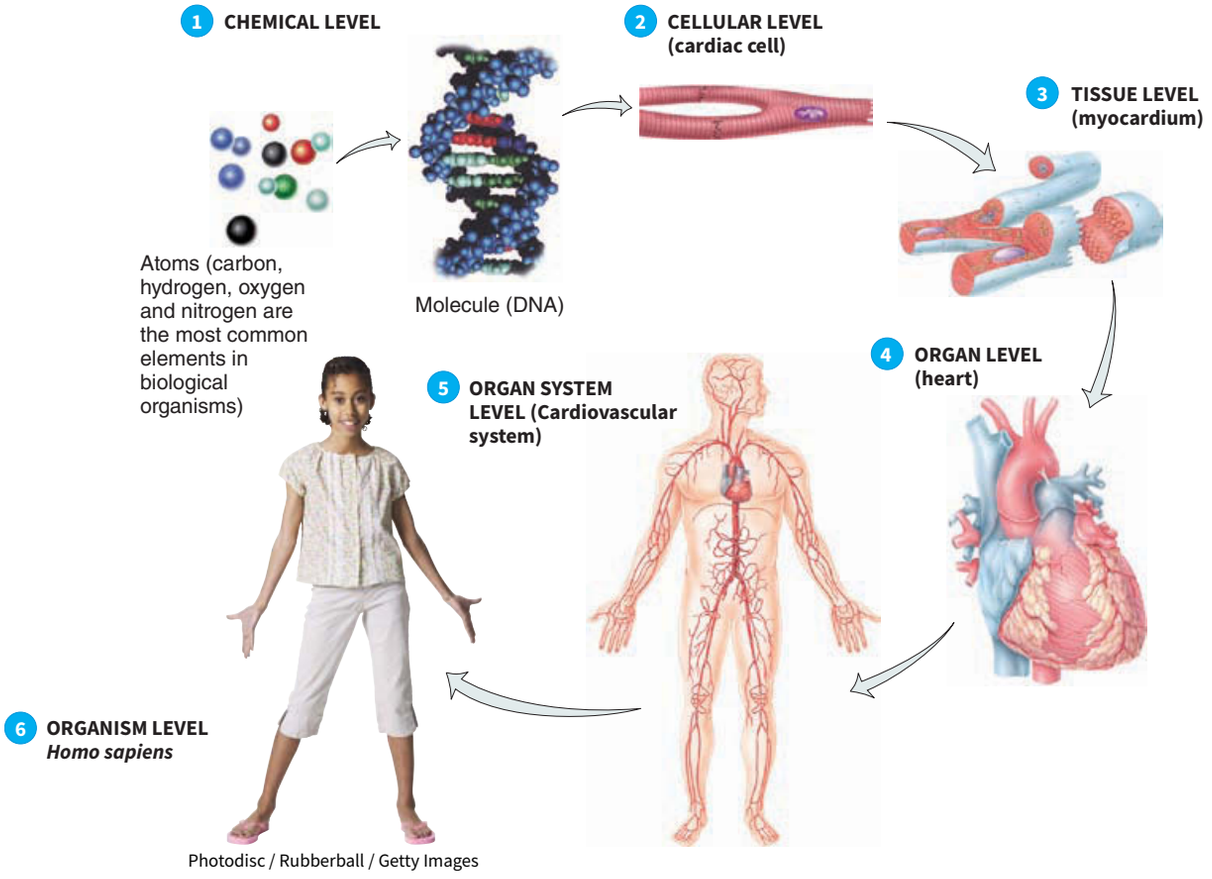
Natural organization emerges from the structure of organisms. Both natural and artificial organization help us make sense of the living world. Natural organization appears in the human body as it does in the rest of the living realm. Natural organization is based on a system of increasing complexity. Each level in the hierarchy is composed of

groups of simpler units from the previous level, arranged to perform a specific function. The smallest particles that usually matter in biology are atoms, as shown in **Figure 1.2**. An atom is defined as the smallest unit of an element that has the properties of that element. Atoms combine to form molecules–larger units that can have entirely different properties than the atoms they contain. You already know some of the molecules we will discuss, such as water, glucose, and DNA. Molecules combine to form **cells**, which are the smallest unit of life. We will take a closer look at cells in Chapter 4. Groups of similar cells with similar function combine to form **tissues**.

The human body has four major tissue types: muscular, nervous, epithelial, and connective. Tissues working together form organs, such as the kidney, stomach, liver, and heart. **Organs** with the same general function combine to form **organ systems**. For example, the respiratory system includes organs that work together to exchange gas between cells and the atmosphere; organs in the skeletal system support the body and protect the soft internal organs. A suite of organ systems combine to form the human **organism**. Notice that each layer of complexity involves a group of related units from the preceding layer. This type of hierarchy is found throughout biology and the natural world.

Taking a global view of the organization found in the natural world, we see that the concept of hierarchy does not stop at the individual. The individual human organism lives in groups of humans called **populations**, as shown in **Figure 1.3**. Beyond populations are larger and more inclusive groups called communities, ecosystems, biomes and the biosphere.

FIGURE 1.2 **Hierarchy of organization of life** In the hierarchy of biology, each level gains in complexity, and demonstrates new properties. These emergent properties arise as smaller units interact, with consequences unattainable by the previous level.



Natural organization: from atom to organism

1. Chemical level: the chemical "components" that are arranged into cells (atoms to molecules)
2. Cellular level: the smallest unit of life; a component bounded by a membrane or cell wall; in multicellular organisms, cells are usually specialized to perform specific functions (for example, cardiac muscle cell)
3. Tissue level: an assemblage of similar cells (for example, cardiac muscle tissue, myocardium)
4. Organ level: an assemblage of tissues that often have several functions (for example, heart)
5. Organ system level: the group of organs that carries out a more generalized set of functions (for example, cardiovascular system)
6. Organism level: Homo sapiens

population All representatives of a specific organism found in a defined area.

FIGURE 1.3 Hierarchy of life beyond the individual Living organisms are grouped beyond the individual, to include populations, communities, ecosystems, and the all-inclusive biosphere.

James L. Stanfield / NG Image Collection

a. Individual or species

Raga Jose Fuste / Prisma / SuperStock

b. Human Population
Populations are composed of all individuals of a given species in a specified area.

Dugald Bremner Studio / NG Image Collection

c. Biological Community
Human populations live in concert with populations of other organisms, interacting in a larger concept called the community.

Raymond Gehman / NG Image Collection

d. Ecosystem
Communities are united in geographic areas, interacting with one another and the physical environment in a biome. Earth has many biomes, such as the open ocean, high sierra, desert, and tropical rain forest.

Todd Gipstein / NG Image Collection

e. Biosphere
Finally, all Earth's biomes comprise the biosphere.

Biological Classification Is Logical

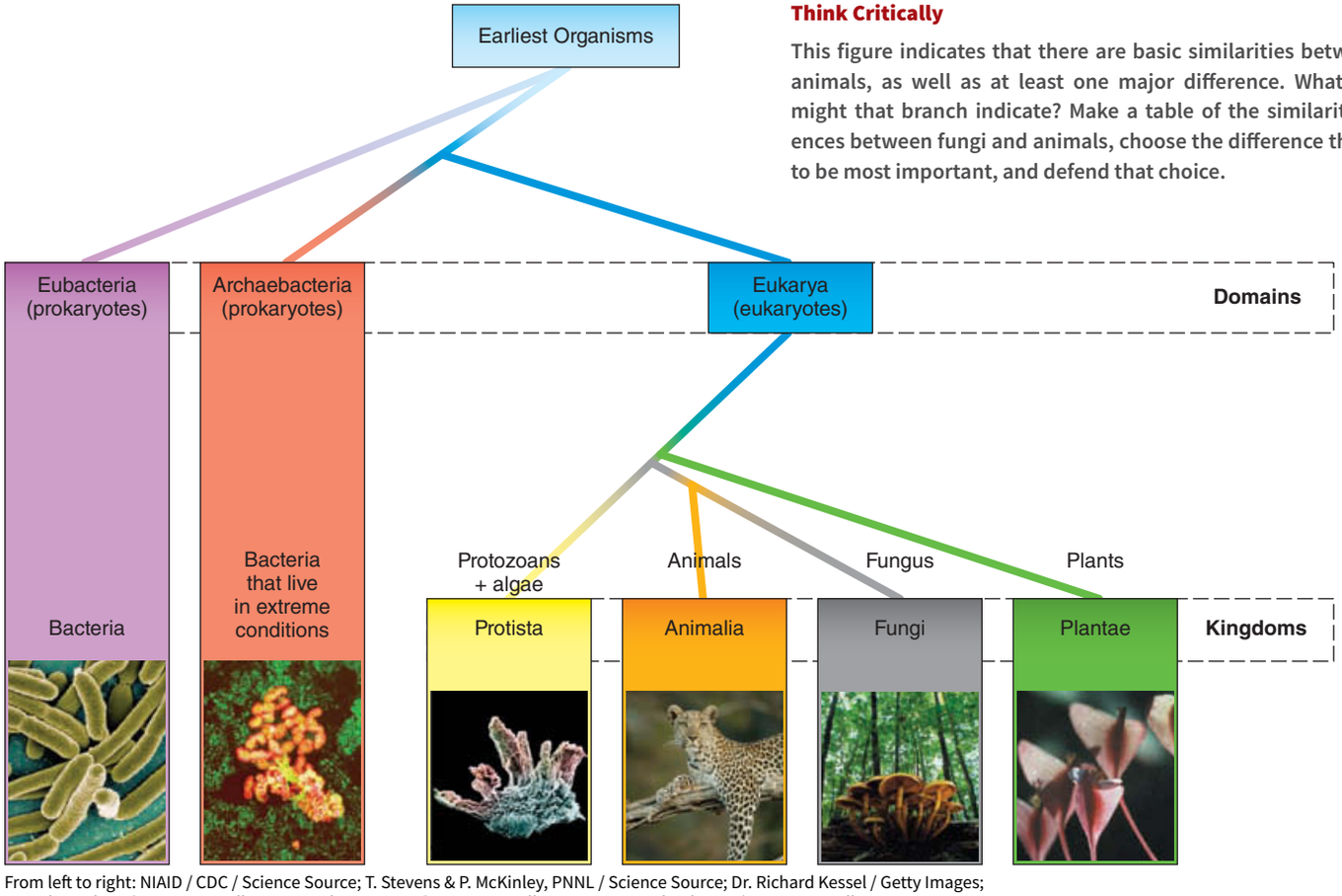
Biology tries to make sense of myriad observations of the biosphere by classifying organisms into groups with similar characteristics. The branch of science that deals with this organizational scheme is called **taxonomy**. One of the best-accepted taxonomic schemes starts from the most inclusive, with three domains and six **kingdoms** (see **Figure 1.4**). The domain Eukarya includes organisms whose cells contain nuclei and internal membranes. The four kingdoms in Eukarya are **Animalia** (the animals), **Plantae** (the plants), **Fungi** (the fungi), and **Protista** (the one-celled organisms that possess nuclei). The two remaining kingdoms are the prokaryotic **Eubacteria** and **Archaebacteria** (the bacteria and other one-celled organisms without nuclei). It is worth noting that unlike bacteria, viruses are not classified as living–see *I Wonder… Are Viruses Considered Living Organisms?* on the next page.

Each kingdom is further classified, based on similar characteristics, into divisions that get ever more narrow: **phylum**, **class**, **order**, **family**, **genus**, and **species**. Each category defines the organisms more tightly, resulting in a hierarchy of similarity. The final category, species, implies reproductive isolation, meaning (with very few exceptions) that members of a particular species can produce **viable** and fertile offspring only if they breed with each other.

Taxonomists capitalize the first letter of all classification terms except species (*Homo sapiens*). The species name is always preceded by the entire genus name, unless you have just mentioned the genus; then you can abbreviate it: "In regard to *Homo sapiens*, we must note that *H. sapiens* . . ." Genus and species names are either underlined or written in italics, as shown in **Figure 1.5**.

Each successive category refines the characteristics of "human" to the point where only humans are classified in the final category, *Homo sapiens*. Despite the amazingly complex and pervasive cultural

FIGURE 1.4 Domains and kingdoms There are three Domains into which all living organisms are classified.



From left to right: NIAID / CDC / Science Source; T. Stevens & P. McKinley, PNNL / Science Source; Dr. Richard Kessel / Getty Images; Beverly Joubert / NG Image Collection; Norbert Rosing / NG Image Collection; Raymond Gehman / NG Image Collection

Think Critically

This figure indicates that there are basic similarities between fungi and animals, as well as at least one major difference. What characteristic might that branch indicate? Make a table of the similarities and differences between fungi and animals, choose the difference that you believe to be most important, and defend that choice.

taxonomy The study of classification, based on structural similarities and common ancestry.

kingdom A high-level taxonomic classification.

species A precise taxonomic classification, consisting of organisms that can breed and produce offspring capable of breeding.

viable Capable of remaining alive.

I Wonder . . .

Are Viruses Considered Living Organisms?

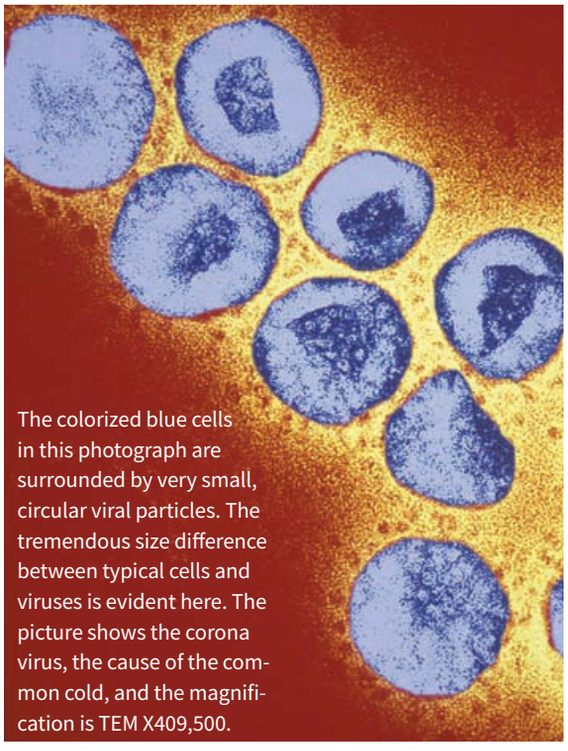
Viruses are among the smallest agents that can cause disease, and they cause some of the worst diseases around. Scientists think that smallpox, caused by the variola virus, killed more people in the past few centuries than all wars combined. HIV, human immunodeficiency virus, is thought to cause AIDS, whose death toll continues to mount year after year.

Because viruses are less than 1 micron (millionth of a meter) across, they were not discovered until early in the 19th century. Viruses are much smaller than bacteria, which are single-celled organisms that are truly alive.

We know viruses can kill. To determine whether they are alive, we refer to the required characteristics of life, and we observe that viruses lack many of them, such as:

- Cells (a virus is basically a protein coat surrounding a few genes, made of either DNA or RNA);
- The ability to reproduce;
- The ability to metabolize or respire; and
- A mechanism to store or process energy.

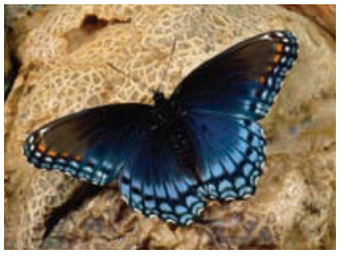
Viruses can reproduce but only if they can slip inside a host cell and seize control of its internal machinery. Viruses are more complex than prions, the distorted proteins that cause bovine spongiform encephalopathy—mad cow disease. However, viruses are far simpler than even a bacterial cell. So although viruses are not alive, they are the ultimate parasite.



The colorized blue cells in this photograph are surrounded by very small, circular viral particles. The tremendous size difference between typical cells and viruses is evident here. The picture shows the corona virus, the cause of the common cold, and the magnification is TEM X409,500.

Dr. Gopal Murti / Getty Images

FIGURE 1.5 Human taxonomy Meet your human taxonomy

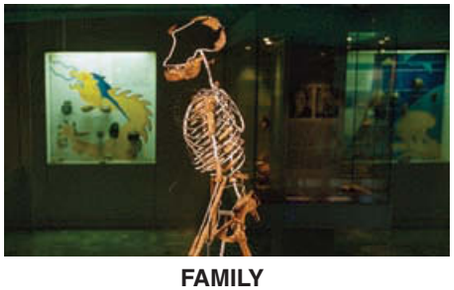


KINGDOM
Animalia
(all multicellular organisms that ingest nutrients rather than synthesize them)

PHYLUM
Vertebrata
(all animals with a vertebral column or **dorsal hollow notocord**—a structure along the back of animals—that protects their central nervous system)

CLASS
Mammalia
(all vertebrates with placental development, mammary glands, hair or fur, and a tail located past the anus)

ORDER
Primates
(mammals adapted to life in trees, with opposable thumbs)



FAMILY
Hominidae
(primates that move primarily with bipedal—two-footed—locomotion)

GENUS
Homo
(hominids with large brain cases, or skulls)

SPECIES
H. sapiens
(The only living organisms in our species, with a unique set of combined characteristics from our family [bipedal], order [opposable thumbs], and genus [large brain case])

From left to right: George Grall / NG Image Collection; Tim Laman / NG Image Collection; Joel Sartore / NG Image Collection; Karine Aigner / NG Image Collection; Kenneth Garrett / NG Image Collection; Kenneth Garrett / NG Image Collection; Mark Cosslett/ NG Image Collection

differences that exist between populations of humans, we are all members of the same species.

It is human nature to group similar ideas, processes, and organisms to make sense of the seemingly complex world in which we live. Just as there are characteristics that can be identified as common to all life forms in the domain Eukarya, there are basic processes that can be identified as common to the study of human physiology. There are arguably five basic processes on which human physiology hinges: osmosis and diffusion, energy transfer and storage, protein functioning, DNA actions, and cellular structure and function.

Osmosis and diffusion appear in Chapter 4. These processes are integral in the respiratory, digestive, urinary, and nervous systems. Energy transfer and storage are all about chemical bonds. The flow of energy through the biological world, introduced in Chapters 2 and 3, relies on this simple process. Humans are composed of both structural and functional proteins, introduced in Chapter 3. Structural proteins protect and maintain organ shape, hold our skin in place, and provide flexibility to bone. Functional proteins are the basis of digestion, oxygen transport, muscle contraction, immunology, endocrinology, and even reproduction. DNA is introduced in Chapter 3 and discussed in greater detail in Chapter 21. Molecular biology is the backbone of inheritance, evolution, and biotechnology. Cellular structure and function is the topic of Chapter 4. Understanding how organelles function and what differentiates cell types underlies every process we will study. As you go through the physiology presented in this book, the basic underlying process will be indicated. This will make it easier for you to understand the larger, more complicated processes by allowing you to relate them to their most basic components.

Concept Check

1. **How** do atoms relate to the study of life?
2. **What** is the largest taxonomic group that apes and humans share? What is the smallest taxonomic group they share?
3. **What** can you discover about an organism by comparing its full taxonomic classification to that of a human?
4. **How** will mastering protein functioning help in understanding other processes?

1.3 Scientists Approach Questions Using the Scientific Method

LEARNING OBJECTIVES

1. **List** the steps in the scientific method in order.
2. **Define** hypothesis and theory.

Science is a field with specific goals and rules. The overall goals are to provide sound theories regarding the phenomena we observe, using rules embodied by the **scientific method**. When a question arises about the natural world, the scientific method provides the accepted, logical path to the answer, as shown in **Figure 1.6**.

A scientific experiment is an exercise in logic: Our goal is to prove our hypothesis wrong. In the example below, our hypothesis is that the rooster's crow causes the sun to rise within the next 20 minutes. How could we test this hypothesis? Could we force the rooster to crow at midnight and wait 20 minutes for a glow on the eastern horizon? Could we prevent the rooster from crowing in the morning? In either case, if the sun rose as usual, our hypothesis would be disproved, and we would need to find a better hypothesis.

This silly example shows how scientists may manipulate factors that (according to the hypothesis) seem related to the observation, all in an attempt to disprove the hypothesis. We develop a hypothesis using **inductive reasoning**–creating a general statement from our observations. We design the experiment, however, with **deductive reasoning**, moving from the general hypothesis to a specific situation. An "if, then" statement is an ideal basis for a scientific experiment: "If situation A (rooster crows) occurs, then result B (sunrise) will follow." In our experiment, we changed situation A and monitored any changes in result B.

When designing and running an experiment, we must control all potential **variables**. Otherwise, we cannot draw any valid conclusions. In the rooster example, it would be a good idea to muzzle all nearby roosters. Otherwise, how would we know whether our bird or a bird in the next chicken coop had caused the sunrise? Similarly, in testing new medicines, scientists use a "double-blind" experiment: Only the scientist knows whether each research participant is getting real medicine or a fake, called a "placebo." Neither the patients nor the prescribing doctor know whether the patient is being given the drug or a placebo. This prevents expectations that the drug will work from actually causing a change in the participant's health. The placebo effect can be powerful, but the goal is to test the drug, not the research participant's expectations.

Finally, our hypothesis must be testable and falsifiable. If we cannot think of a situation where we could disprove it, there is no experiment to devise. Learning to assess situations with the scientific method takes some practice, but it's a skill that can be useful throughout life.

variable A factor that can be changed in an experiment to test whether and how it affects the outcome.