Cecie Starr • Beverly McMillan

Human BIOLOGY

11e

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Eleventh Edition

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Cecie Starr

Beverly McMillan

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***Human Biology*, Eleventh Edition**
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Preface

This new edition of *Human Biology* continues our dedication to providing an accessible, relevant, and appealing introduction to the study of the human body. Although most students who use this book will not become scientists, all can benefit from a better understanding of body structures and their functions and from the real-world application of basic biological concepts and principles. Knowing how cells, tissues, organs, and organ systems work will help students make informed choices about lifestyle and nutrition, while having a deeper understanding of common diseases and disorders will help them navigate issues related to health care. In addition, some background in ecology will help them grasp why human activities such as adding greenhouse gases to the atmosphere put us and other species at risk. In this way, as they progress through this text, students will learn both the core concepts of human biology and how they apply to everyday situations, preparing them to make well-informed decision in their lives.

Features of This Edition

Each chapter opens with a concise real-life story and an engaging—and often dramatic—photograph. More than half of the streamlined opening stories are new to this edition. A brief *Links to Earlier Concepts* summary reminds students of relevant information that has been covered in previous chapters, and *Key Concepts* statements preview the current chapter's content. An eye-catching photograph or graphic that appears in icon form next to each key concept also occurs within a relevant section, as part of a visual message that threads through the chapter.

Sections The content of every chapter is organized as a series of Concepts, each explored in a numbered section that is two pages or less. A section's title reflects its concept, and sentence-style subsection headers guide students through the discussion. Bulleted sentences in the *Take-Home Message* summarize and reinforce the Concept and the section's supporting information.

Focus on Human Impact Our new *Focus on Human Impact* feature enriches the chapter's relevance to students' lives by exploring the impacts of our collective activities and individual choices on real-world concerns. For example, in Chapter 8, the *Focus on Human Impact* feature examines the challenges and benefits of blood donation efforts. In Chapter 16 it explores the growing commerce in human eggs used in assisted reproduction technologies.

On-Page Glossary As in the previous edition, an on-page glossary presents boldface key terms introduced in each section. This section-by-section glossary offers definitions in alternate wording and can also be used as a quick study and review aid. All terms are available in the end-matter glossary as well.

Self-Assessment Tools As with the previous edition, each text section closes with a focused *Take-Home Message* that allows students to check their grasp of the section contents before moving on. At the end of each chapter, Review, Self-Quiz, and Critical Thinking questions provide students with the opportunity to assess their understanding of the chapter's concepts. A graphic "thumbnail" from chapter sections serves as a visual reminder of each section's main content.

Enhancement Features As with the previous edition, *Think Outside the Book* features point students to opportunities to use library or online resources to learn more about a "real-world" subject related to a chapter's content. Concise *Explore on Your Own* exercises allow students to delve deeper into a selected chapter topic. At the close of each chapter a brief, timely, illustrated *Your Future* paragraph gives students a glimpse of promising developments on the frontiers of medical or genetic research.

Chapter-Specific Changes

Chapter 1 illustrates scientific methodology with a University of Missouri case study of how the protein content of breakfast influenced hunger and appetite in female college students. *Focus on Health*, which introduces coverage of infectious disease threats, adds a graphic on hand washing and other practices that can help prevent disease spread.

Chapter 2 introduces basic chemistry with a new opening vignette on phytochemicals in common foods. New graphics illustrate the shell model of atomic structure and ionic and covalent bonding. Updated photographs illustrate protein denaturation by heat and acids.

Chapter 3 illustrates different types of microscopy with new photographs and a new feature on microbiomes in the human body. A *Focus on Human Impact* feature focuses on the spread of cholera in Haiti in the aftermath of the 2010 earthquake.

Chapter 4 begins with an updated vignette on applications of stem cell technology. The chapter contains new photographs and improved graphics throughout.

Chapter 5 has updated illustrations and explores current ideas on vitamin D's physiological role in a new *Think Outside the Book*.

Chapter 6 introduces the muscular system with a new vignette on lab testing of oxygen use by working skeletal muscles. Several vivid new graphics and images enhance text discussions of the structure and functioning of whole skeletal muscles.

Chapter 7 uses new and reorganized graphics to show the heart's basic anatomy and location in the chest. An improved table and new illustration enhance Section 7.5 on blood pressure. Section 7.8 updates the chapter's coverage of cardiovascular disorders and treatment options for them.

Chapter 8 launches with a new vignette on blood typing, illustrated by a photograph of heart surgery underway. Revisions to Section 8.7, which covers hemostasis and blood clotting, include improved graphics to illustrate both topics. A *Focus on Human Impact* feature discusses the ongoing need for blood donors and procedures for becoming a donor.

Chapter 9 has new art to illustrate the workings of the complement system, antibody binding, and both cell-mediated and antibody-mediated immunity. Fresh art also appears in the reworked subsection on allergies.

Chapter 10's discussion of ventilation is illustrated by an improved graphic showing the related muscle movements. We also reworked the graphic illustrating the Heimlich maneuver. Updates include discussions of sleep apnea and the current controversy over electronic cigarettes in Section 10.7 on respiratory system disorders, with corresponding new photographs.

In **Chapter 11**, new micrographs help illustrate the structure of the small intestine's absorptive surface, and new artwork clearly shows the steps by which various types of nutrients are digested and absorbed. The updated section on human nutritional requirements presents the latest government guidelines for healthy eating. The discussion of vitamins and minerals includes up-to-date thinking on the nutritional importance of phytochemicals. Following the chapter's discussion of eating disorders, a *Focus on Human Impact* feature discusses efforts to reduce food waste in the United States and elsewhere.

Chapter 12 has a new diagram of kidney nephrons and the arterioles and capillaries associated with them.

In **Chapter 13**, reworked graphics provide an overview of information flow in the nervous system and show the structure of motor neurons. *Think Outside the Book* points interested students to the Human Connectome Project's efforts to map the brain's neural wiring. A new *Science Comes to Life* feature explores the use of technologies such as functional magnetic resonance imaging to study brain function and disorders. An updated *Focus on Health* includes the substances known as "bath salts," "Spice," and K2 in the discussion of psychotropic drugs.

Chapter 14 on sensory systems begins with a new opening vignette on the biology of itching. A simplified introduction to sensory receptors outlines the three main forms of receptors: free nerve endings, encapsulated receptors, and receptors that synapse directly with sensory neurons.

Chapter 15 has a fresh beginning with the story of Sultan Kosen, whose (now treated) pituitary tumor made him famous as possibly being the tallest man alive. The chapter also considers the suspected endocrine disrupting effects of phthalates in a new *Focus on Our Environment* feature.

For **Chapter 16**, a new opening vignette on the increasing use of assisted reproductive technologies (ART) introduces the chapter's discussion of reproductive systems. New graphics illustrate the ovarian cycle and the most common options for ART. Striking new images show pathogens responsible for a range of STDs. The section of reproductive cancers has an expanded discussion of prostate cancer. A *Focus on Human Impact* feature discusses the lucrative commerce in "donated" oocytes for use in assisted reproduction.

Chapter 17 has more explanatory and streamlined graphics to illustrate cleavage, early embryonic development, and development of extraembryonic membranes. It also provides an expanded discussion of lactation.

Chapter 18 revisions include new photographs to illustrate cytokinesis in animal cells and how events in meiosis produce the genetic and phenotypic diversity we observe in human populations.

Chapter 19 has a new opening vignette that uses the example of freckling to introduce concepts of heredity. Inheritance patterns of this and other familiar traits are used throughout the chapter in streamlined discussions of the role of probability in determining genetic outcomes, independent assortment, and other basic genetic concepts. In keeping with current research in human genetics, the chapter section on gene interactions (19.5) emphasizes the polygenic basis of traits such as eye color and skin color.

Chapter 20's discussions of chromosomes and human genetics includes general updating, a new example to illustrate the use of pedigree analysis, and numerous new photographs.

Chapter 21 uses a new opening vignette on the buccal (cheek) swab technique of obtaining cells for DNA analysis. A new example, spinal muscular dystrophy, illustrates the topic of expansion mutations as causes of human genetic disorders. Graphic improvements clarify the diagram of mRNA translation. Updates include outcomes of the Human Genome Project (HGP), the current status of gene therapy efforts, and recent uses of biotechnology in plant genetic engineering and animal cloning. *Your Future* alerts students to the discoveries of the 1,000 Genomes Project, which is rapidly adding to the knowledge gained from HGP analysis.

Chapter 22 has updated information on the sites and types of major cancers in males and females and updated text and graphics related to cancer diagnosis, treatment, and prevention.

Chapter 23 revisions include new graphics depicting *Homo habilis* and comparing the skeletal organization of modern primates (gorillas and humans). Updates on the emergence of early humans reflect recent interpretations of fossil evidence for the divergence of *Homo sapiens* and *H. erectus*, and interpretation of DNA evidence for interactions between modern non-African humans and Neanderthals.

Chapter 24 revisions include an updated opening vignette on wildfires in the western United States and striking new photographs to illustrate the food web concept.

Chapter 25 includes updates to the graphic on human population growth to reflect current estimates and streamlines the discussion of total fertility rate. Updating of sections on air pollution, climate change, solid waste management, and renewable energy sources includes numerous new photographs.

Student and Instructor Resources

MindTap for *Human Biology* 11e MindTap is a fully online, highly customizable learning experience built upon Cengage Learning content. MindTap combines student learning tools—readings, multimedia, activities, and assessments—into a singular Learning Path that guides students through their course. Instructors personalize the experience by customizing authoritative Cengage Learning content and learning tools, including the ability to add their own content in the Learning Path via apps that integrate into the MindTap framework seamlessly with Learning Management Systems. New to this edition are assignable problems and a digital Study Guide.

Cognero for *Human Biology* 11e Cengage Learning Testing Powered by Cognero is a flexible, online system that allows you to:

- author, edit, and manage test bank content from multiple Cengage Learning solutions
- create multiple test versions in an instant
- deliver tests from your LMS, your classroom, or wherever you want

Instructor's Companion Site for *Human Biology* 11e Everything you need for your course in one place! This collection of book-specific lecture and class tools is available online via www.cengage.com/login. Access and download PowerPoint® presentations, images, an instructor's manual, videos, and more.

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LEARNING ABOUT HUMAN BIOLOGY

1

LINKS TO EARLIER CONCEPTS

In this textbook, be on the lookout for a basic theme in biology: Complex structures and functions often emerge from the interactions of simpler ones.

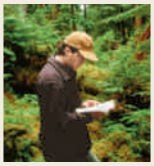
KEY CONCEPTS

Shared Features of Life

Living things have features that are not found in nonliving objects. These shared features include DNA, the genetic material, and the need to maintain a state of internal stability called homeostasis.

Life's Organization and Diversity

Nature is organized from simple to complex. The broadest level of life's organization is the biosphere—the whole living world. Sections 1.2–1.3



Studying Life

Critical thinking is the foundation for science. It also is valuable in many life decisions. Sections 1.4–1.7

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Even if you have never "officially" studied biology, you already know a lot about one living thing: yourself. You also have learned a lot about the natural world simply by experiencing it—from nonliving things like water and rocks to living ones like plants, bugs, and a trusty pet. We can study nature, including ourselves, in ways that may help us better understand the natural world and our place in it. That's what this book is for—to give you a fuller understanding of how your body works and where we humans fit in the larger world.

This first chapter of our survey of human biology starts with basic features shared by all forms of life. It sets the stage for a deeper journey into human biology, including a brief introduction to the chemical foundations of life, how our body cells are built and operate, and how the body's tissues, organs, and organ systems function.

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1.1 Shared Features of Life

■ **Several basic characteristics allow us to distinguish between living things and nonliving objects.**

cell An organized unit that can survive and reproduce by itself, using energy, necessary raw materials, and DNA instructions.

homeostasis A state of overall internal chemical and physical stability that is required for survival of cells and the body as a whole.

Living and nonliving things are all alike in some ways. For instance, both are made up of nature's fundamental substances, the elements (examples are carbon and hydrogen), which we will discuss in Chapter 2. On the other hand, all living things share some features that nonliving ones don't have. There are five basic characteristics of life.

1. **Living things consist of one or more cells.** A **cell** is an organized unit that can live and reproduce by itself, using energy, the required raw materials, and instructions in the genetic material DNA. Figure 1.1 shows a living bone cell. Cells are the smallest units that can be alive.
2. **Living things take in and use energy and materials.** Like other animals, and many other kinds of organisms, we humans take in energy and materials by consuming food (Figure 1.2). Our cells use the energy and raw materials in food to build and operate in ways that keep us alive. The energy for all cell activities comes from another special chemical found only in living things, ATP.
3. **Living things sense and respond to changes in the environment.** For example, a plant wilts when the soil around its roots dries out, and you might put on a sweater on a chilly afternoon.

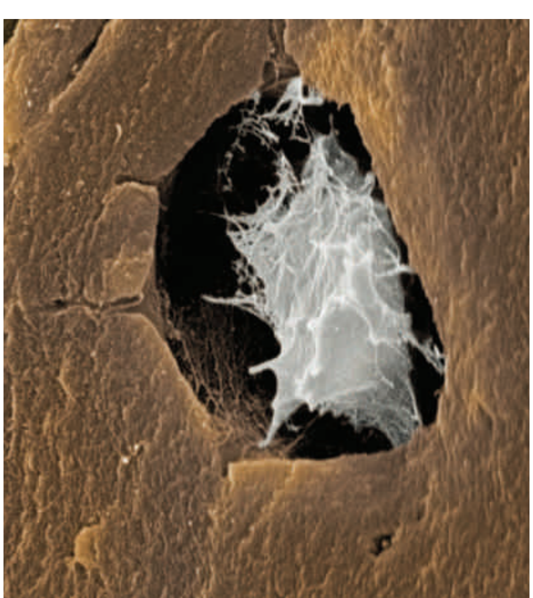

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Figure 1.1 Cells are the basic units of life. This is a picture of a bone cell.

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Figure 1.2 Humans take in energy by eating food. This girl's body will extract energy and raw materials from the raspberries perched on her fingers and use them for processes that are required to keep each of her cells, and her body as a whole, alive.

4. **Living things maintain homeostasis.** Changes inside and outside of organisms affect the ability of cells to carry out their activities. Mechanisms that maintain an overall internal state of chemical and physical stability compensate for these changes. This overall internal stability, called **homeostasis** (hoe-me-oh-STAY-sis, "staying the same"), is necessary for the survival of cells and, ultimately, for the survival of the body as a whole. How the human body's organ systems contribute to homeostasis is a major theme of this textbook.
5. **Living things reproduce and grow.** Organisms can make more of their own kind, based on instructions in DNA. Guided by DNA instructions, most organisms develop through a series of life stages. For us humans, the basic life stages are infancy, childhood, adolescence, and adulthood.

TAKE-HOME MESSAGE

WHAT CHARACTERISTICS SET LIVING ORGANISMS APART FROM NONLIVING OBJECTS?

- Living things are built of one or more cells, take in and use energy and materials, and sense and can respond to changes in their environment.
- Living things can reproduce and grow, based on instructions in DNA.
- The cell is the smallest unit that can be alive.
- Organisms maintain homeostasis by way of mechanisms that keep conditions inside the body within life-supporting limits.

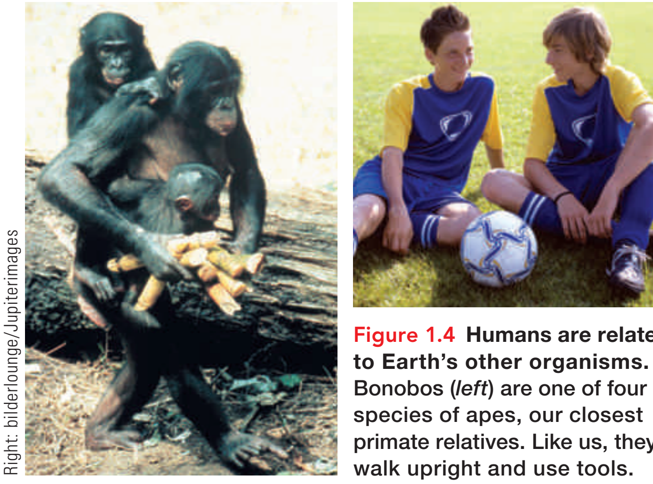
1.2 Our Place in the Natural World

■ **Human beings arose as a distinct group of animals during an evolutionary journey that began billions of years ago.**

Humans have evolved over time

The term "evolution" means change over time. Chapter 23 explains how populations of organisms may evolve by way of changes in DNA. This biological evolution is a process that began billions of years ago on the Earth and continues today. In the course of evolution, major groups of life forms have come into being.

Figure 1.3 provides a snapshot of how we fit into the natural world. Humans, apes, and some other closely related animals are **primates** (PRY-mates). Primates are mammals, and mammals make up one group of **vertebrates** (VER-tuh-braytes), "animals with backbones." Of course, we share our planet with millions of other animal species, as well as with plants, fungi, countless bacteria, and other life forms. Biologists classify living things according to their characteristics, which in turn reflect their evolutionary heritage. Notice that Figure 1.3 shows three domains of life. Animals, plants, fungi, and microscopic organisms called protists are assigned to kingdoms in a domain called Eukarya (you-KARE-ee-uh). The other two domains are reserved for bacteria and some other single-celled life forms. Some biologists prefer different schemes. For example, for many years all living things were simply organized into five kingdoms—animals, plants, fungi, protists, and bacteria. The key point is that despite the basic features all life forms share, evolution has produced a living world of incredible diversity.



Left: Rich Buzzelli/Tom Stack & Associates
Right: bilderlounge/Jupiterimages

Figure 1.4 Humans are related to Earth's other organisms. Bonobos (*left*) are one of four species of apes, our closest primate relatives. Like us, they walk upright and use tools.

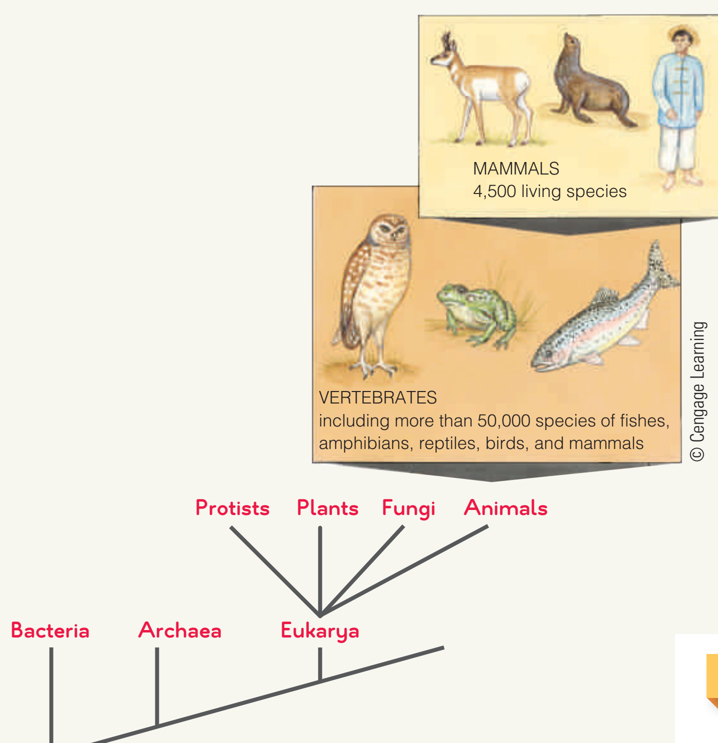


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Figure 1.3 Animated! **Organisms are classified into groups according to their characteristics.** Humans are one of more than a million species in the animal kingdom, which is part of the domain Eukarya. Plants, fungi, and some other life forms make up other kingdoms in Eukarya. The domains Bacteria and Archaea contain vast numbers of single-celled organisms.

Humans are related to all other living things—but we have some distinctive characteristics

Due to evolution, humans are related to every other life form and share characteristics with many of them. For instance, we and other mammals are the only vertebrates that have body hair. We share the most features with apes, our closest primate relatives (Figure 1.4). We humans also have some distinctive features that appeared as evolution modified traits of our primate ancestor. For example, we have great manual dexterity due to the way muscles and bones in our hands are arranged and how our nervous system has become wired to operate them. Even more astonishing is the human brain. This extraordinarily complex organ gives us the capacity for sophisticated language and analysis, for developing advanced technology, and for a huge variety of social behaviors.

primates Distinct group of mammals that includes humans, apes, and their close relatives.

vertebrate Animal that has a backbone.

TAKE-HOME MESSAGE

WHY IS EVOLUTION A BASIC CONCEPT IN HUMAN BIOLOGY?

- Like all life forms, humans arose through evolution.
- Evolution has produced the features that set humans apart from other complex animals. These characteristics include sophisticated verbal skills, analytical abilities, and extremely complex social behavior.

1.3 Life's Organization

- **Nature is organized on many levels, from nonliving materials to the entire living world.**

Nature is organized on many levels

Nature is organized on eleven general levels, which you see summarized in Figure 1.5. At the most basic level are atoms, the smallest units of elements. Next come molecules, which are combinations of atoms. Atoms and molecules are the nonliving components from which cells are built. In humans and other multicellular organisms, cells are organized into tissues—muscle, bone tissue, and so forth. Different kinds of tissues make up organs, and systems of organs make up whole complex organisms.

We can study the living world on any of its levels. Many courses in human biology focus on organ systems, and a good deal of this textbook explores their structure and how they function.

Nature's organization doesn't end with individuals. Each organism is part of a population, such as the Earth's whole human population. In turn, populations of different organisms interact in communities of species occupying the same area. The example in Figure 1.5I is a community that includes trees, grasses, humans, and other organisms. Communities interact in ecosystems. The most inclusive level of organization is the **biosphere**. This term refers to all parts of the Earth's waters, crust, and atmosphere in which organisms live.

biosphere Parts of the Earth's waters, crust, and atmosphere where organisms live.

Organisms are connected through the flow of energy and cycling of materials

Organisms take in energy and materials to keep their life processes going. Where do these essentials come from? Energy flows into the biosphere from the sun (Figure 1.6). This solar energy is captured by "self-feeding" life forms such as plants, which use a sunlight-powered process called photosynthesis to make fuel for building tissues, such as a grain of wheat. Raw materials such as carbon that are needed to build the wheat plant come from air, soil, and water. Thus self-feeding organisms are the living world's basic food producers.

Animals, including humans, are the consumers: When we eat plant parts, or feed on animals that have done so, we take in materials and energy to fuel our body functions. You tap directly into stored energy when you eat bread made from grain, and you tap into it indirectly when you eat the meat of an animal that fed on grain. Organisms such as bacteria and fungi obtain energy and materials when they decompose tissues, breaking them down to substances that can be recycled back to producers. This one-way flow of energy through organisms, and the cycling of materials among them, means that all parts of the living world are connected.

Because of the interconnections among organisms, it makes sense to think of ecosystems as webs of life. With this perspective, we can see that the effects of events in one part of the web will eventually ripple through the whole and may even affect the entire biosphere. For example, we see evidence of large-scale impacts of human activities in the loss of biodiversity in many parts of the world, as well as in acid rain, climate change, and other concerns.

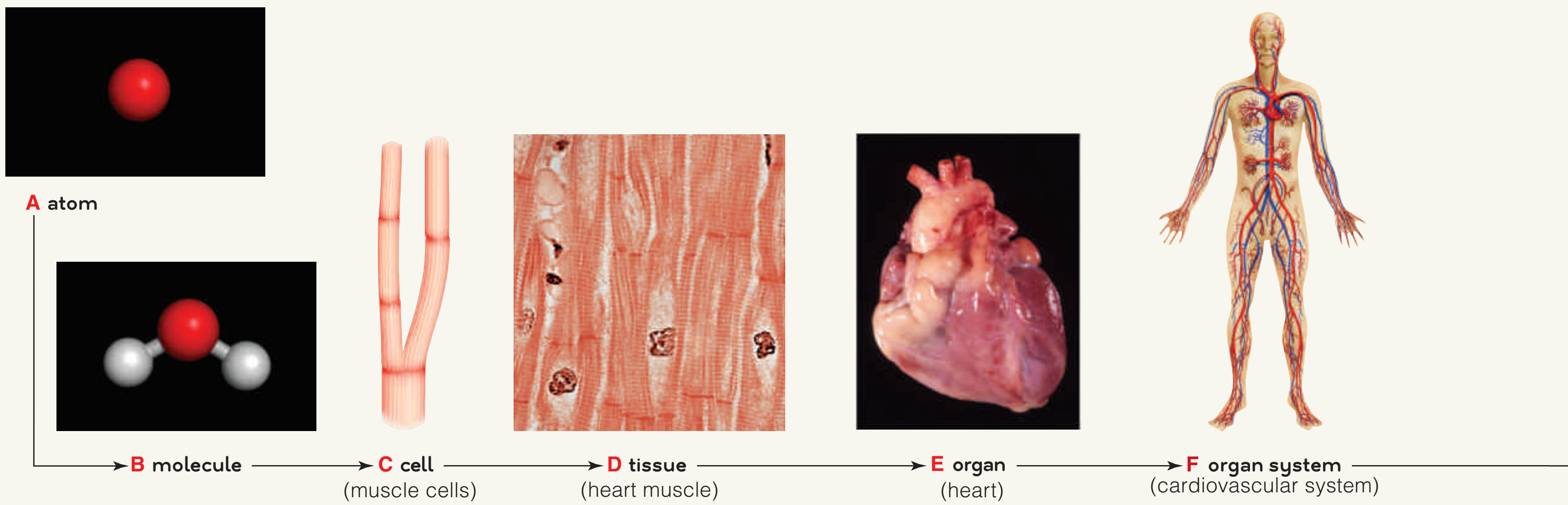
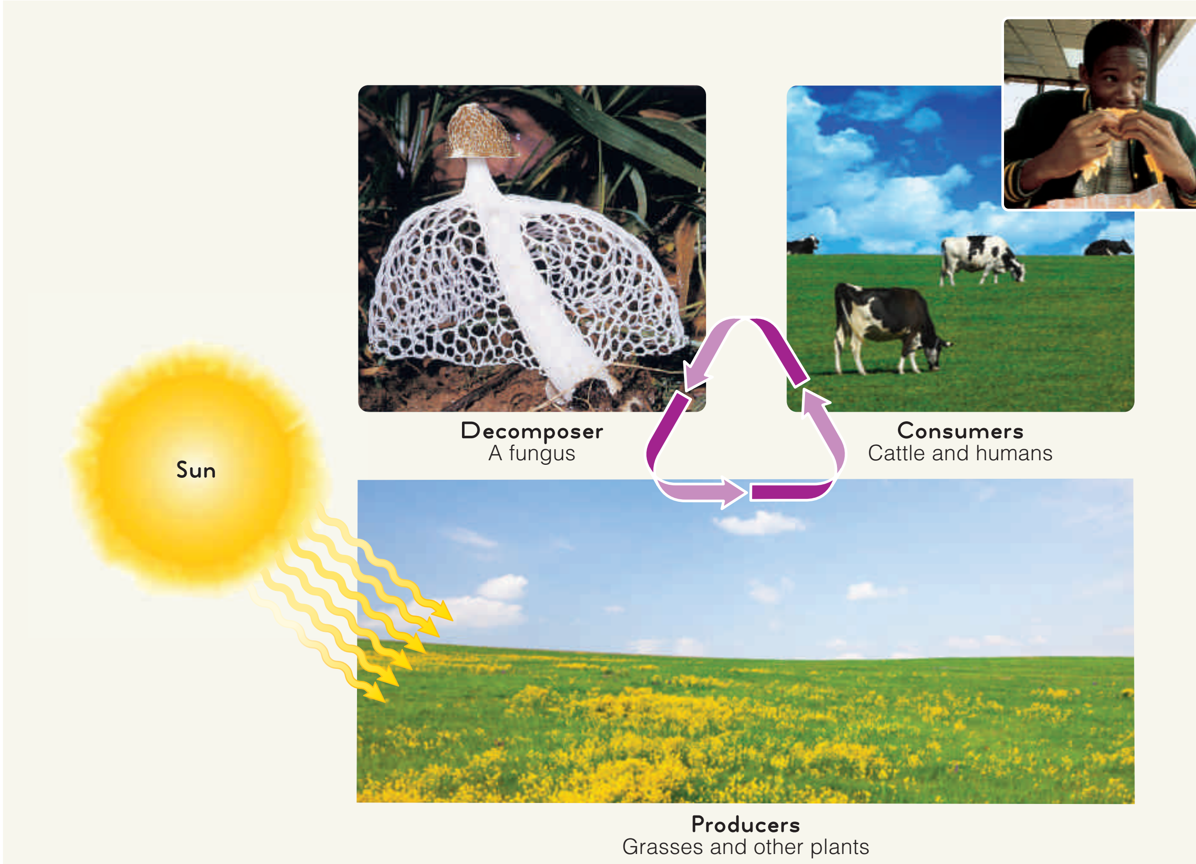


Figure 1.5 Animated! An overview of the levels of organization in nature. (A, B, C, F: © Cengage Learning; D: Ed Reschke/Peter Arnold; E: CMSP/Custom Medical Stock)



Clockwise from top left: Edward S. Ross; © iStockphoto.com/shaunl; Nancy J. Pierce/Science Source; © Ozerov Alexander/Shutterstock.com

Figure 1.6 Animated! The flow of energy and the cycling of materials maintain nature's organization. The bottom photograph shows producers—grasses and other plants. The plants obtained the energy to make their roots, seeds, and other parts from the sun. They obtained nutrients for their growth from soil and air. Consumers include animals, such as insects, birds, and humans, and decomposers include organisms such as fungi and bacteria. (© Cengage Learning)

TAKE-HOME MESSAGE

HOW IS NATURE ORGANIZED?

- Nature is organized in levels that are sustained by a flow of energy and cycling of materials.
- Energy flows into the biosphere from the sun. Raw materials cycle within the biosphere as consumers obtain food from producers, and decomposers break down tissues to substances that help nourish producers.
- Because living things are interconnected, ecosystems are webs of life in which all the parts are linked.

G: © Lavaria Ferreri Liotti/Shutterstock.com; H: © Rafael Ramirez Lee/Shutterstock.com; I: © Robert J. Beyers II/Shutterstock.com; J: © Sebastien Burel/Shutterstock.com; K: NASA

1.4 Using Science to Explain Natural Events

- **Scientists try to explain natural phenomena by making and testing predictions. They search for evidence that may disprove or support the explanation they have proposed.**

Scientific studies are systematic

In your human biology course, you will be learning a great deal of science-based information about the human body. Sometimes scientists gather information about natural processes and events by doing experiments in a laboratory or in the field (Figure 1.7). An alternative is to record detailed observations of a phenomenon. Regardless, doing science requires a systematic approach that is sometimes called the **scientific method**. The following steps are common.

hypothesis Proposed explanation for an observation or how a natural process works.

scientific method Any systematic way of obtaining information about the natural world.

1. **Observe some natural phenomenon.** For example, nutritionists have documented a correlation between the amount of protein eaten at breakfast and the amount of calories consumed later in the day.
2. **Identify a question or problem to explore.** As you'll read later in this book, appetite—the desire to eat—is governed by hormones and certain parts of the brain. Does the amount of protein in your breakfast affect these control messages—and accordingly, how much you eat later on? Nutrition researchers at the University of Missouri decided to explore this question.
3. **Develop a scientifically testable hypothesis.** A **hypothesis** is a proposed explanation for an observation. The University of Missouri team hypothesized that for their subjects, eating breakfast, and particularly one rich in protein, would be more effective in tamping down appetite than eating a "normal protein" breakfast that had the same calorie content.
4. **Make a specific prediction.** The researchers predicted that young adult females who consumed a 350-calorie breakfast that contained 35 grams of protein (as in a plate of eggs) would want to eat less later in the day than subjects who received a 350-calorie meal that had 15 grams of protein (cereal and milk). As in this example, a prediction states what you should observe about the question or problem if the hypothesis is valid.
5. **Test the prediction.** The team recruited twenty volunteers—all females between the ages of 18 and 20, all clinically overweight but not currently dieting. The restrictions were important to avoid skewing results due to differences in bodily energy use related to dieting, gender, and age. The subjects also shared the habit of skipping breakfast—which they would be asked to do as an important part of the study.

The study was divided into three seven-day periods. During week one, subjects skipped breakfast as usual. During the second week, they received a 350-calorie breakfast of cereal and milk. For the third week the women ate a high-protein breakfast. The calorie content of lunches, dinners, and any snacks the subjects ate also were recorded. All the subjects filled out questionnaires rating their desire to eat on test days. They also underwent blood tests and brain scans to determine whether these subjective feelings correlated with any shifts in bodily controls. They did. Together, the findings clearly supported the hypothesis that eating breakfast, especially one high in protein, reduces the desire to eat during the remainder of the day.

The Missouri team reported its findings in the *American Journal of Clinical Nutrition* so others

Figure 1.7 Scientists do research in the laboratory and in the field. A Examining heart tissue from a deceased person to determine the cause of death. **B** Making field observations in an old-growth forest. **C** Weighing a polar bear in Alaska.

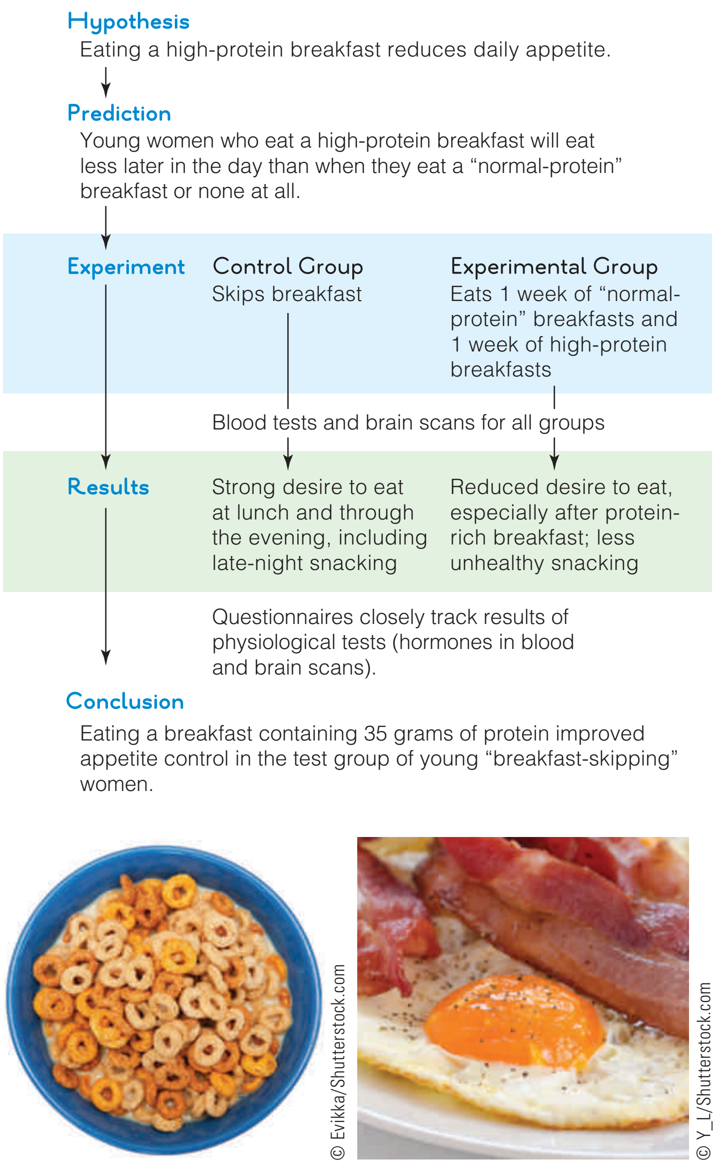


Figure 1.8 The Missouri protein breakfast study followed steps used in many scientific experiments. A key finding was that eating a protein-rich breakfast such as eggs staved off hunger longer that a relatively low-protein breakfast such as cereal and milk—even when the calorie count was the same.

interested in the same topic could accurately repeat the work. Hypotheses that are supported by the results of repeated testing are more likely to be correct.

Doing experiments is a common way to test a scientific prediction

An **experiment** is a test that is carried out under conditions that the researcher can control. Figure 1.8 shows the typical steps, using the Missouri study as an example. To get meaningful test results, as those researchers did, experimenters start by reviewing information and previous studies that may bear on their project. Then they design an experiment that will test any and all predictions of a hypothesis separately.

Most phenomena that we observe in the natural world are the result of interacting variables. A **variable** is a factor that can change with time or in different circumstances. Researchers design experiments to test one variable at a time. They also perform the test in a **control group** so that they can compare results between the control and experimental tests. In the protein breakfast study, the volunteers served as a control group during the week they skipped breakfast. It's important for a control group to be identical to the experimental one except for the variable being studied—in this case, how eating a high-protein breakfast affects appetite. Eliminating unwanted variables is crucial for obtaining reliable experimental results. For instance, if any of the participants in the breakfast food study were taking protein supplements on the side, the experimenters wouldn't have been able to determine if any reported changes in appetite were due to the nature of the food subjects ate.

Scientists usually can't study all the individuals in a group of interest. Results obtained from a subset of test subjects—especially a small one like twenty of the potentially millions of breakfast-skippers around the world—may differ from results obtained from the whole group. This sort of distortion is called **sampling error**. It's most likely to occur when a sample size is too small. To avoid such errors, researchers may try to assemble a test group that is large enough to be representative of the whole. If that's not feasible, only more experiments will clarify whether the original results are reliable. You can learn firsthand about sampling error in the *Explore on Your Own* exercise at the end of this chapter.

control group Group to which one or more experimental groups can be compared.

experiment Test carried out under controlled conditions that the researcher can manipulate.

sampling error Distortion of experimental results, often because the sample size is too small.

variable A factor that can change over time or under different circumstances.

In science, logic rules!

The conclusion a scientist draws from research can't be at odds with the findings used to support it. It has to be based on logic. In the Missouri breakfast study, the researchers couldn't conclude that eating a high-protein breakfast helps people lose weight. Their results did support the hypothesis that in young women, eating breakfast, especially ones high in protein, may help curb the desire to eat more later in the day.

TAKE-HOME MESSAGE

HOW DO SCIENTISTS STUDY THE NATURAL WORLD?

- Scientists begin by observing a natural event. They then pose a question about it.
- Next they propose a possible explanation, make a testable prediction about this hypothesis, and do one or more tests.
- In controlled experiments researchers study a single variable and compare the results to those obtained with a control group.

1.5 Critical Thinking in Science and Life

■ **To think critically, it is important to evaluate information before accepting it.**

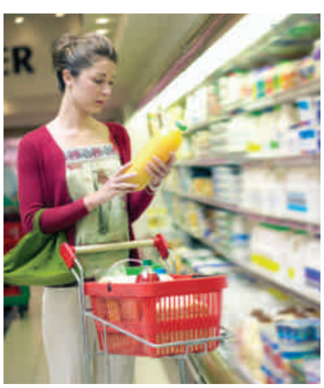
Have you ever tried a new or "improved" product and been disappointed when it didn't work as expected? Everyone learns, sometimes the hard way, how useful it can be to cast a skeptical eye on advertising claims or get an unbiased evaluation of, say, a used car you are considering buying. This objective evaluation of information is called *evidence-based* or **critical thinking**.

critical thinking Using systematic, objective strategies to judge the quality of information; evidence-based thinking.

fact Verifiable information, not opinion or speculation.

opinion A subjective judgment.

Scientists use critical thinking in their own work and to review findings reported by others. Anyone can make a mistake, and there is always a chance that pride or bias will creep in. Critical thinking is a smart practice in everyday life, too, because so many decisions we face involve scientific information. Will an herbal food supplement really boost your immune system? Is it safe to eat irradiated food? Table 1.1 gives guidelines for evidence-based critical thinking.



Cardinal/Corbis

Evaluate the source of information

An easy way to begin evaluating information is to notice where it is coming from and how it is presented. Here are two simple strategies for assessing sources.

TABLE 1.1 A Critical Thinking Guide and Checklist

To think critically about any subject:

✔	***Do*** gather information or evidence from reliable sources.
✗	***Don't*** rely on hearsay.
✔	***Do*** look for facts that can be checked independently and for signs of obvious bias (such as paid testimonials).
✗	***Don't*** confuse *cause* with *correlation*.
✔	***Do*** separate *facts* from *opinions*.

Once you have formed your opinion:

Be able to state clearly your view on a subject.

Be aware of the evidence that led you to hold this view.

Ask yourself if there are alternative ways to interpret the evidence.

Think about the kind of information that might make you reconsider your view.

If you decide that nothing can ever persuade you to alter your view, recognize that you are not being objective about this subject.

Let credible scientific evidence, not opinions or hearsay, do the convincing For instance, if you are concerned about reports that heavy use of a cell phone might cause brain cancer, information on the website of the American Cancer Society is more likely to be reliable than something cousin Fred heard at work. Informal information may be correct, but you can't know for sure without investigating further.

Question credentials and motives For example, if an advertisement is designed to look like a news story, or a product is touted on TV or a blog by someone being paid for the job, your critical thinking antennae should go up. Is the promoter simply trying to sell a product with the help of "scientific" window dressing? Can any facts presented be checked out? Responsible scientists try to be cautious and accurate in discussing their findings and are willing to supply the evidence to back up their statements.

Evaluate the content of information

Even if information seems authoritative and unbiased, it is important to be aware of the difference between the cause of an event or phenomenon and factors that may only be correlated with it. For example, studies show that recirculation of air in an airplane's passenger cabin increases travelers' exposure to germs coughed or sneezed out by others. An "airplane cold," however, is caused directly by infection by a virus.

Also keep in mind the difference between facts and opinions or speculation. A **fact** is verifiable information, such as the price of a loaf of bread. An **opinion**—whether the bread tastes good—can't be verified because it involves a subjective judgment. Likewise, a marketer's prediction that many consumers will favor a new brand of bread is speculation, at least until there are statistics to back up the claim.

THINK OUTSIDE THE BOOK

Controversy swirls around claims that an extract from berries of the acai plant can produce rapid, easy weight loss. Using reputable sources such as the National Institutes of Health, do some Web research on this topic. What is the fuss all about?

TAKE-HOME MESSAGE

WHAT IS CRITICAL THINKING?

- Critical thinking is an objective, evidence-based evaluation of information.
- Critical thinking is required for doing science. It also is a smart strategy in many aspects of daily life.

1.6 Science in Perspective

- **A scientific theory explains a large number of observations.**

We know that the practice of science can yield powerful ideas, like the theory of evolution, that explain key aspects of life. At the same time, we also know that science is only one part of human experience.

It is important to understand what the word *theory* means in science

You've probably said, "I've got a theory about that!" This expression usually means that you have an untested idea about something. A **scientific theory** is the opposite: It is an explanation of a broad range of related natural events and observations that is based on repeated, careful testing of hypotheses. Table 1.2 lists some major scientific theories related to biology. Before scientific research established one of them, the germ theory of disease, some people tried to appease malevolent spirits they blamed for outbreaks of infectious disease (Figure 1.9).

A hypothesis usually becomes accepted as a theory only after years of testing by many scientists. Then, if the hypothesis has not been disproved, scientists may feel confident about using it to explain more data or observations. The theory of evolution—a topic we will look at in Chapter 23—is a prime example of a "theory" that is supported by tens of thousands of scientific observations.

Science demands critical thinking, so a theory can be modified, and even rejected, if results of new scientific tests call it into question. It's the same with other scientific ideas. Today, for instance, advances in technology are giving us a new perspective on subjects such as the links between emotions and health. Some "facts" in this textbook one day will likely be revised as we learn more about various processes. This willingness to reconsider ideas as new information comes to light is a major strength of science.

Science has limits

Because science requires an objective mindset, scientists can only do certain kinds of studies. No experiment can explain the "meaning of life," for example, or why each of us dies at a certain moment. Such questions have *subjective* answers that are shaped by our experiences and beliefs. Every culture and society has its own standards of morality and esthetics, and there are probably thousands of different sets of religious beliefs. All guide their members in deciding what is important and morally good and what is not. By contrast, the external world, rather than internal conviction, is the only testing ground for scientific views.

Because science does not involve value judgments, it sometimes has been or can be used in controversial ways. For example, some people worry about issues such as the use of animals in scientific research and possible negative consequences of genetic modification of food plants. There has been great debate over the causes of global climate change and the use of "industrial" fishing methods on the high seas. Meanwhile, whole ecosystems are being altered by technologies that each year allow millions of a forest's trees to be cut and hundreds of millions of fishes to be taken from the sea. The scientific community alone can't resolve these issues. That responsibility also belongs to us.

TABLE 1.2 Examples of Scientific Theories

Cell theory	All organisms consist of one or more cells, the cell is the basic unit of life, and all cells arise from existing cells.
Germ theory	Germs cause infectious diseases.
Theory of evolution	Change can occur in lines of descent.

Bettmann/Corbis

Figure 1.9 In the 1300s, people tried all sorts of strategies to ward off the bubonic plague epidemic—the Black Death—that may have killed half the people in Europe.

scientific theory Thoroughly tested explanation of a broad range of natural events and observations.

TAKE-HOME MESSAGE

WHAT ARE THE STRENGTHS AND LIMITS OF SCIENTIFIC STUDY?

- Science applies to questions and problems that can be tested objectively.
- A scientific theory remains open to tests, revision, and even rejection if new evidence comes to light.
- Responsibility for the wise use of scientific information must be shared by all.