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Biology

Today and Tomorrow

Without Physiology

6e

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Biology

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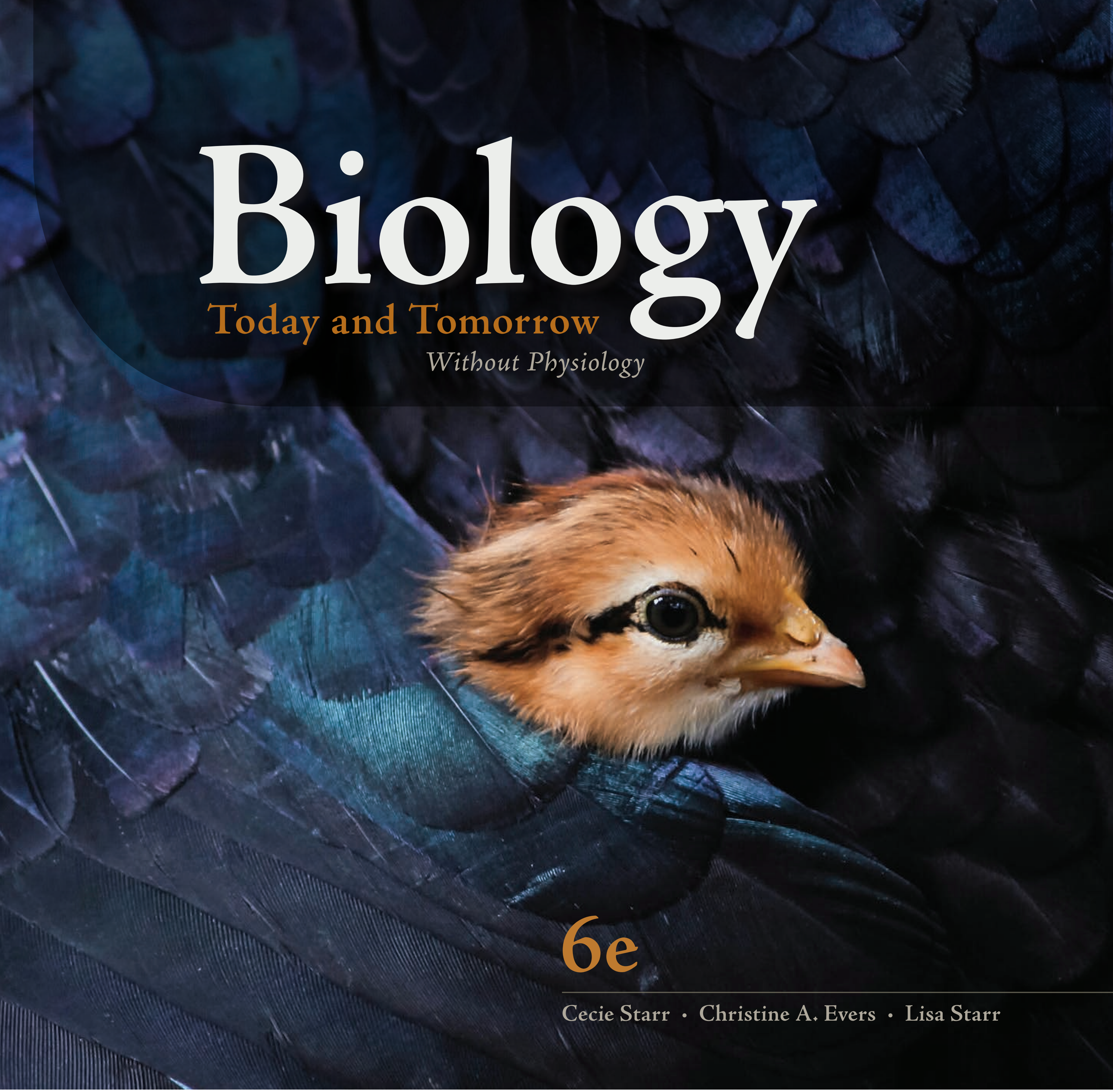

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Today and Tomorrow
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Cecie Starr • Christine A. Evers • Lisa Starr

CENGAGE

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Biology Today & Tomorrow Without Physiology,
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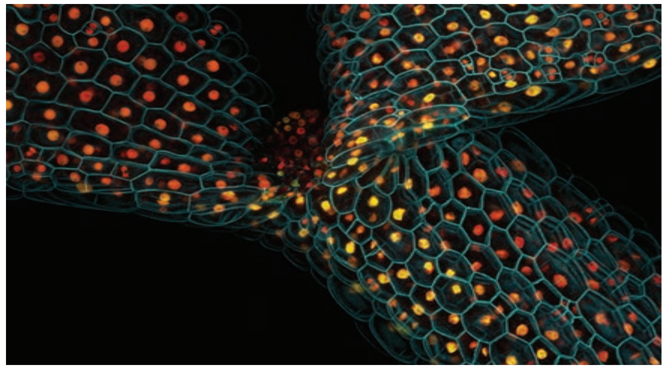

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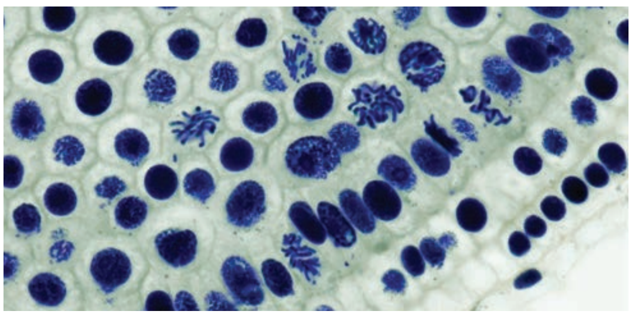

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PREFACE

The easy, instant availability of information on a global scale is both facilitating and complicating science education. Biology in particular is a huge field, with a wealth of new discoveries being made daily, and biology-related issues such as climate change, gene editing, and the global spread of diseases making headlines all the time. In an age when anyone can post anything, distinguishing fact from opinion is more challenging—and more important—than ever.

Biology: Today and Tomorrow Without Physiology presents accurate, up-to-date content in accessible language, with stunning images and beautiful art that bring the narrative to life. This book fosters scientific literacy skills by prioritizing active learning about the process of science, and it engages students with a host of real-world applications that illuminate the relevance of biology in everyday life.

FEATURES OF THIS EDITION

As always, the text has been updated with new discoveries and current research. This edition has been aligned with "Vision and Change" recommendations: Core concepts emphasized and explored in every chapter facilitate learning from every perspective (molecular, cellular, ecological, organismal, and so on), and several new and enhanced features encourage active learning.

Setting the Stage Each chapter opens with an eye-catching photo and a brief **CONCEPTS CONNECTIONS** feature that links the chapter's content with concepts in previous and future chapters. The opening **APPLICATION** section explores an interesting current event or social issue related to the chapter's topic. For example, a discussion of binge drinking on college campuses introduces the concept of metabolism in Chapter 4. This Application section links the function of enzymes in the body's main alcohol-breakdown pathway to hangovers and cirrhosis. Open-ended **DISCUSSION QUESTIONS** at the end of each Application section are intended to facilitate classroom discussions and critical thinking about the Application's topic.

Emphasis on Relevance An expanded focus on applications that distinguishes this book allows students to understand the relevance of a topic while learning about it. At every opportunity, opening Application topics are revisited in section content, and in end-of-chapter assessments. For example, Section 4.4 (Enzymes and Metabolic Pathways) includes a paragraph about the role of the coenzyme NADH in the mechanism by which heavy drinking causes fatty liver; in Section 4.5 (Diffusion across Membranes), a discussion about osmotic pressure includes the mechanism by which body tissues swell with fluid in cirrhosis; and an end-of-chapter Critical Thinking question asks students to connect the alcohol flushing reaction with genetically based differences in the alcohol-breakdown pathway. (Discussions related to health and the environment are marked in the index with red and blue squares, respectively.)

Section-Based Learning Objectives **LEARNING OBJECTIVES** associated with each section are phrased as activities that students should be able to carry out after reading the text.

Chunked Content To decrease student cognitive load and facilitate chapter review, concepts have been titled in the core narrative of each section.

Take-Home Message At the end of each section, a **TAKE-HOME MESSAGE** box that provides a brief summary of section concepts is useful for study review.

Highly Visual Learning Beautiful art with extended callouts enhances visual learning of complex mechanisms in the new chapter-based **CLOSER LOOK** feature. The feature includes one or more **FIGURE IT OUT** questions designed to engage students in an active learning process; an upside-down answer allows a quick check of understanding.

On-Page Glossary An **ON-PAGE GLOSSARY** includes boldface key terms introduced in each two-page spread. This spread-based glossary can be used as a quick study aid. All glossary terms also appear in boldface in the Chapter Summary.

SELF-ASSESSMENT TOOLS

Many figure captions include a **FIGURE IT OUT** question. At the end of each chapter, **SELF-QUIZ** and **CRITICAL THINKING QUESTIONS** provide additional self-assessment material. Another active-learning feature, the in-text **DIGGING INTO DATA** activity, sharpens analytical skills by asking students to interpret data presented in graphic or tabular form. The data presented are relevant to the chapter and are from published scientific studies.

HIGHLIGHTS OF REVISION UPDATES

1 **Invitation to Biology** Much-expanded material in a new section, "The Nature of Science," includes detailed coverage of pseudoscience and how it differs from science. New Critical Thinking questions about cherry-picking climate change data and MMR vaccine pseudoscience.

2 **Molecules of Life** Application section updated with new FDA ban of PHOs. New content includes current research on pathogenesis of amyloid diseases. New figures: bond polarity;

patterns of protein secondary structure; prion structure changes. New Critical Thinking question about how using palm oil as a substitute for PHOs is exacerbating deforestation. Closer Look feature: How protein structure arises.

3 **Cell Structure** New content includes theory of living systems; discussion of nuclear pores, tau tangles, and Alzheimer's disease. New tables: eukaryotic organelles; collective properties of living systems. New photographs: micrographs of gut microbiota, nuclear membrane, and basement membrane. New Critical Thinking question about why some meat contaminated with toxic strains of bacteria is not safe to eat even after cooking. Closer Look features (2): Some interactions among components of the endomembrane system; cell junctions in animal tissues.

4 **Energy and Metabolism** New content: how heavy drinking causes fatty liver; fluid balance in the body. New figures: feed conversion ratio; comparing activation energy in energy-releasing and energy-requiring reactions; enzymes lower activation energy; firefly luciferase. New Critical Thinking question about the alcohol flushing reaction and alcohol metabolism. Closer Look feature: Examples of membrane-crossing mechanisms.

5 **Photosynthesis** For this edition, expanded material on photosynthesis and respiration has been separated into two chapters. New overview section includes discussion of autotrophs, heterotrophs, and stomata function. Other new content: special pairs; bacteria that carry out infrared photosynthesis; increased efficiency of the Calvin–Benson cycle in engineered plants. New Digging Into Data activity about CO_2 emissions from fossil fuels. New figures include atmospheric CO_2 level over the last 800,000 years; correlation between atmospheric CO_2 content and temperature since 1880; how photosynthesis sustains life; correlation between light wavelength and energy; red algae (photosynthetic pigment adaptation). New research correlating wildfire severity with rising global temperatures is included with a stunning photo of the 2018 Mendocino complex wildfire. Closer Look feature: Light-dependent reactions of photosynthesis, noncyclic pathway.

6 **Respiration** New content includes Application about mitochondrial diseases, cellular respiration, and oxidative stress; introductory section comparing aerobic respiration with fermentation; glycolysis reactions; ketogenic diet mechanism. New figures: glycolysis reactions, alcoholic fermentation reactions; lactate fermentation reactions. New Digging Into Data activity about the reprogramming of brown fat mitochondria by dietary fat overload. Closer Look features (2): Aerobic respiration continues in mitochondria; food to energy.

7 **DNA Structure and Function** New content includes introduction to PCR; expanded material on mutations includes dose-dependent DNA damage by ionizing radiation, and cancer-causing chemicals in foods and industrial/household products. New figures: components of a nucleotide; micrographs of DNA packing; mutated flowers from Chernobyl. Closer Look feature: DNA packing in eukaryotic chromosomes.

8 **From DNA to Protein** New content includes concepts of coding and noncoding strands; a beneficial hemoglobin mutation (HbC); and expanded material on epigenetics. New art: how transcription copies a gene into RNA form; comparison of uracil/thymine and ribose/deoxyribose; how transcription produces an RNA copy of a gene; RNA polymerase binding to promoter; alternative splicing; surface renders of ribosome subunits; effect of a mutation in a regulatory site; points of control over gene expression; replication of methylated DNA. New table compares features of DNA and RNA. Closer Look feature: Translation.

9 **How Cells Reproduce** New content includes current research and paradigms on cytoplasmic division and senescence; concept of polygenic inheritance; Mary Claire-King's discovery of *BRCA1*. New figures: micrograph showing mitosis in a human embryo; micrograph of mitotic spindle; fluorescence micrographs of checkpoint proteins; different modes of reproduction; meiosis halves the chromosome number, and fertilization restores it. New table comparing asexual and sexual reproduction. New Critical Thinking question about HPV and cancer. Closer Look features (2): Mitosis; meiosis.

10 **Patterns of Inheritance** New content includes current paradigms for CF, Huntington's, progeria, Tay–Sachs, and DMD; and concept of developmental flexibility in plant phenotype. New photos: cells lining trachea; seasonal changes in plants; albino iris; IVF. Closer Look feature: Breeding experiments with the garden pea.

11 **Biotechnology** New content includes forensic genealogy case; AquAdvantage Salmon; mechanism, applications, and social implications of CRISPR gene editing. New figures: Exponential amplification of DNA by PCR; photo of Golden Rice; example of CRISPR gene editing. New table lists human genome statistics. Closer Look feature: An example of cloning.

12 **Evidence of Evolution** Cetacean evolutionary sequence updated to reflect currently accepted narrative. New art: photo of *Dorudon atrox* fossil; stem reptile; plate tectonics; paleogeography Mercatur projections. Closer Look feature: Geologic time scale correlated with sedimentary rock in the Grand Canyon.

13 **Processes of Evolution** New content includes updated material on antibiotic resistance and overuse of antibiotics in livestock; forensic phylogenetics case; phylogeny of ST131 superbug. New figures: photos of variation in earlobe attachment; genetic drift, bottleneck, and the founder effect; evolution of ST131. Art updates to reflect current research: *HbS* allele frequency vs. incidence of malaria; sympatric speciation in wheat. New Critical Thinking question about the EPA's 2019 approval of medically important antibiotics in the treatment of citrus greening disease. Closer Look feature: How reproductive isolation prevents interbreeding.

14 **Prokaryotes, Protists, and Viruses** Updated information about the role of the human microbiome in health and disease and the

proposed fossil evidence of early life. Increased emphasis on the ecological importance of bacteria. Updated figures illustrating binary fission and bacteriophage replication. New information about antibiotic mechanisms. Discussion of protists now organized around ecology, rather than phylogeny. New Critical Thinking questions about the human virome, and the effects of pesticides on pollinator microbiomes. Closer Look feature: Replication of HIV.

15 **Plants and Fungi** Updated figures depicting plant and fungal life cycles. New table compares plant, fungal, and animal traits. New figure illustrating the hyphae in a mushroom. New photo of peat bog. Updated information about white-nose syndrome in bats. New Critical Thinking question about plant defenses against wheat stem rust. Closer Look features (2): Moss life cycle; fern life cycle.

16 **Animal Evolution** New content about and photo of the oldest known fossil animal. New graphic of sea star anatomy. Updated discussion of early *H. sapiens* migrations. New Critical Thinking question about medicinal compounds derived from spider venom. Closer Look feature: One model of human evolution.

17 **Population Ecology** New content about human overharvesting of horseshoe crabs lowering the carrying capacity of the environment for migratory red knot sandpipers. Updated nation-based age structure diagrams. New Critical Thinking questions, estimating size of a Canada goose population, predation on horseshoe crabs, effect of house sparrow introduction on bluebird populations, factors affecting human population growth. Closer Look feature: Logistic growth.

18 **Communities and Ecosystems** Revised table better depicts the variety of interspecific interactions. New content includes biological pest control, biological accumulation and magnification of toxins, nutrient pollution and algal blooms, and ocean acidification. Updated coverage of the rise in atmospheric carbon dioxide and added information about the data that indicate this increase is a result of fossil fuel use. New Critical Thinking questions about studying the history of the atmosphere and pollutant accumulation in marine mammals. Closer Look feature: The nitrogen cycle.

19 **The Biosphere and Human Effects** New opening Application about the decline of monarch butterflies. Content reorganized: Deforestation discussed with forest biomes, desertification with desert biomes. New content includes current threats to Brazilian rainforest. Updated coverage of acid rain, ozone depletion, and biodiversity hot spots. New Digging Into Data activity about marine plastic pollution. New Critical Thinking questions about preserving monarch butterflies, effects of ozone depletion on phytoplankton, and how Brazilian deforestation alters local climate.

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Learn It Supplement textbook learning with multimedia instruction. **LEARN ITS** feature chunked instruction that covers the most important concepts in each chapter. **LEARN ITS** serve to reinforce instruction from the textbook. Assign **LEARN ITS** to ensure that your students have read and understand the key concepts before class.

Chapter Homework Assign chapter homework that encourages students to apply what they have learned.

Chapter Quiz Assign chapter quizzes to assess student performance and inform class learning needs.

Chapter Case Study Build real-world data analysis and critical thinking skills with short chapter-level cases.

Tom McHugh/Science Source

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Writing, revising, and illustrating a biology textbook is a major undertaking for two full-time authors, but our efforts constitute only a small part of what is required to produce and distribute this one. We are truly fortunate to be part of a huge team of very talented people who are as committed as we are to creating and disseminating an exceptional science education product.

Biology is not dogma; paradigm shifts are a common outcome of the fantastic amount of research in the field. Ideas about what material should be taught and how best to present that material to students changes from one year to the next. It is only with the ongoing input of our many academic reviewers and advisors (previous page) that we can continue to tailor this book to the needs of instructors and students while integrating new information and models. We continue to learn from and be inspired by these dedicated educators.

On the production side of our team, the indispensable Lori Hazzard orchestrated a continuous flow of files, photos, and illustrations while managing schedules, budgets, and whatever else happened to be on fire at the time. Lori, thank you for your patience and dedication. Thank you also to Ragav Seshadri, Kelli Besse, and Christine Myaskovsky for your help with photoresearch. Copyeditor Heather McElwain and proofreader Heather Mann, your valuable suggestions kept our text clear and concise.

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Lisa Starr and Christine Evers

Cengage acknowledges and appreciates Lisa Starr's contribution of more than 300 pieces of art to this edition.

Biology

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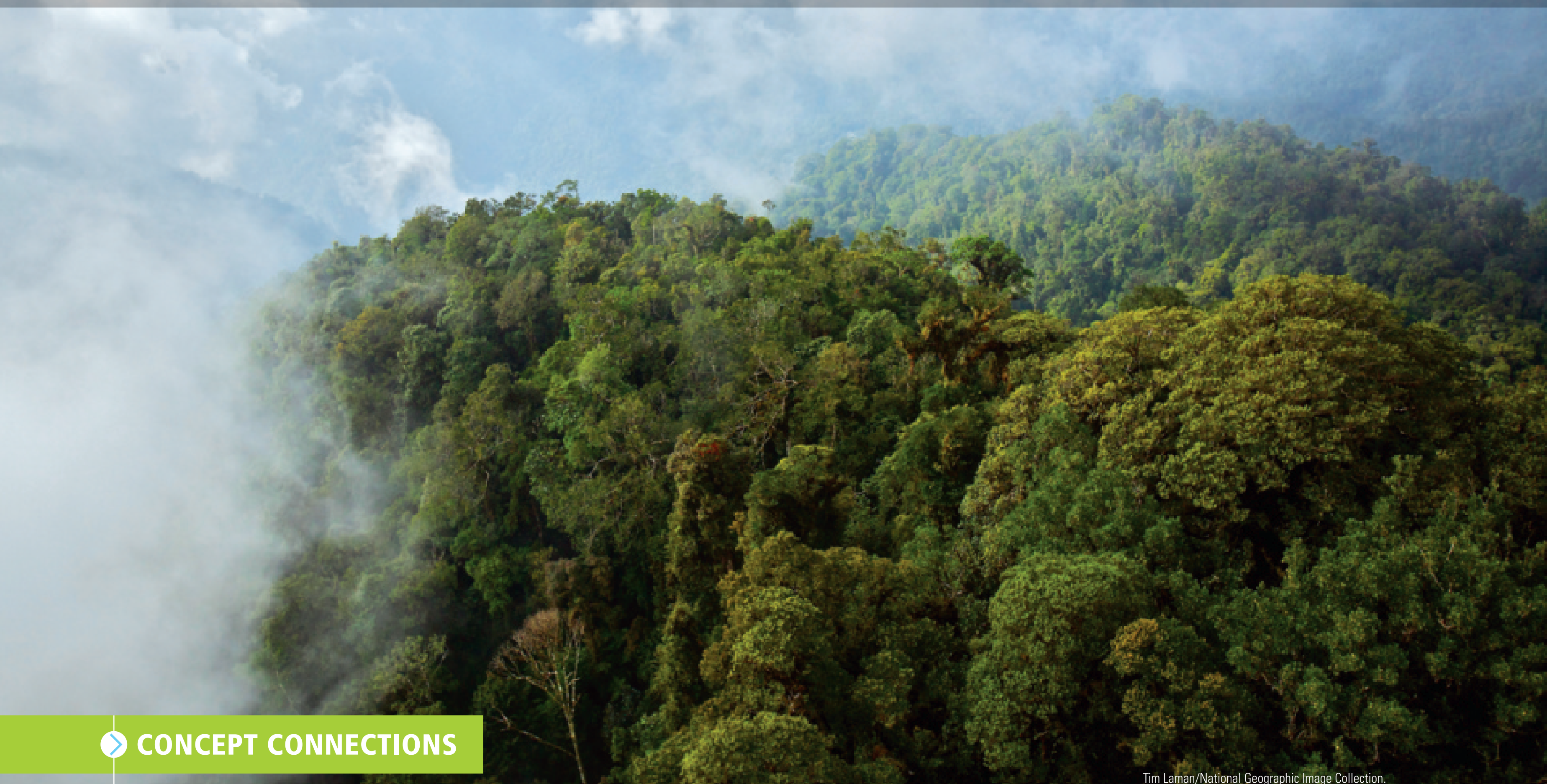
1

Invitation to Biology

The cloud forest that covers about 2 million acres of New Guinea's Foja Mountains is extremely remote and difficult to access, even for native people of the region. Explorers are still discovering new species in it.



Tim Laman/National Geographic Image Collection.

CONCEPT CONNECTIONS

Whether or not you have studied biology, you already have an intuitive understanding of life on Earth because you are part of it. Every one of your experiences with the natural world—from the warmth of the sun on your skin to the love of your pet—has contributed to that understanding.

The organization of this book parallels nature's levels of organization, from atoms to the biosphere. Learning about the structure and function of atoms and molecules will prime you to understand how living cells work. Learning about processes that keep a single cell alive can help you understand how multicelled organisms survive. Knowing what it takes for organisms to survive can help you see why and how they interact with one another and their environment.

APPLICATION

1.1 The Secret Life of Earth

Could there possibly be any places left on Earth that humans have not yet explored? Actually there are, and many of these places remain unexplored because they are difficult or impossible for us to access. Consider a mile-high cloud forest in the Foja Mountains of western New Guinea. This forest is huge, covering around 2 million acres of the region, but extremely rugged terrain kept it completely isolated from humans. Recently, persistent explorers found an opening in the forest large enough for a helicopter to drop them off. Since then, about forty new **species**—unique types of organisms—have been found in this forest, including a rhododendron plant with flowers the size of dinner plates, a rat the size of a cat, and a frog with an erectile nose (**Figure 1.1A**).

Today, researchers no longer need to leave their offices to find places that are untouched by humans. In 2012, conservation scientist Julian Bayliss was perusing Google Earth when he spied a curious pimple rising from a jungled plain in Mozambique, Africa. The pimple was Mount Lico, a 2,300-foot extinct volcano with a lush rain forest on top of it. Bayliss realized that Lico's smooth, vertical rock face would be extremely difficult to climb, so he suspected that the forest had remained hidden and isolated. Six years later, two professional rock climbers helped Bayliss and his team of experts make the arduous ascent up Mount Lico. Exhaustion quickly gave way to excitement when the mud-caked scientists reached the summit because, as Bayliss had suspected, the forest was pristine. Over the next ten days, the team members discovered a host of new species: snakes, frogs, fish, butterflies, crabs, flowering plants, and so on (**Figure 1.1B**).

New species are discovered all the time, even in unexpected places. In 2018, for example, a new type of tardigrade (a tiny animal) was found in the parking lot of an apartment complex. Each discovery is a reminder that we do not yet know all of the species that share our planet. We don't even know how many to look for.

How do we know what species a particular organism belongs to? What is a species, anyway, and why should discovering a new one matter to anyone other than biologists? You will find the answers to such questions in this book. They are part of the scientific study of life, **biology**, which is one of many ways we humans try to make sense of the world around us.

Trying to understand the immense scope of life on Earth gives us some perspective on where we fit into it. Ironically, the more we learn about the natural world, the more we realize we have yet to learn. Whether or not we are aware of it, humans are intimately connected with the world around us. Our activities are profoundly changing the entire fabric of life on Earth. These changes are, in turn, affecting us in ways we are only beginning to understand.

biology The scientific study of life.
species A unique type of organism.

A. Paul Oliver discovered this tiny tree frog perched on a sack of rice during the first survey of a cloud forest in the Foja Mountains of New Guinea. It was named the Pinocchio frog because the male's long nose inflates and points upward during times of excitement.

B. Ana Gledis da Conceição Miranda discovered an as-yet unidentified mouse during the first survey of the rain forest atop Mount Lico, in Mozambique.

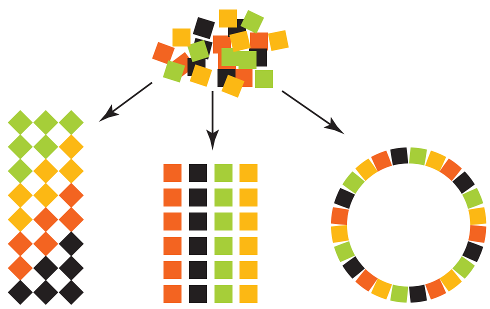
Figure 1.1 Discovering new species in unexplored places.

(A) Tim Laman/National Geographic Image Collection; (B) Jeffrey Barbee/Allianceearth.org.

DISCUSSION QUESTIONS

1. Hundreds of new species are discovered every year, but about 20 species become extinct every minute in rain forests alone—and those are only the ones we know about. Human activities are responsible for a massive acceleration in the rate of extinctions. Unless this trend is reversed, we will never know about most of the species that are alive on Earth today. Why does that matter?
2. How could the discovery of a new species of plant or animal impact humans beyond adding to our knowledge of the world?
3. Explain the statement "the more we learn about the natural world, the more we realize we have yet to learn."

Figure 1.2 The same materials, assembled in different ways, form objects with different properties.
The property of "roundness" emerges when these squares are assembled in a certain way.



1.2 Life Is More Than the Sum of Its Parts

LEARNING OBJECTIVES

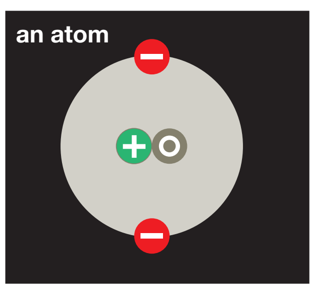
- Describe the successive levels of life's organization.
- Use examples to explain how complex properties can emerge from interactions among simpler components.

Biologists study life. What, exactly, is "life"? We may never actually come up with a satisfying definition, because living things are too diverse, and they consist of the same basic components as nonliving things. When we try to define life, we end up with a long list of properties that differentiate living from nonliving things. These properties often emerge from the arrangements or interactions of basic components (**Figure 1.2**).

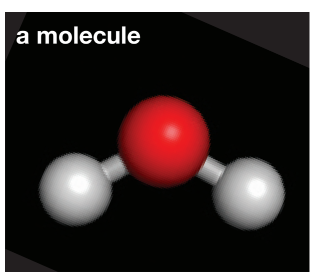
Consider a complex behavior called swarming that is characteristic of honeybees. When the bees swarm, they fly en masse to establish a hive in a new location. Each bee is autonomous, but the new hive's location is decided collectively based on an integration of signals from hive mates. A swarm's collective intelligence is a property that does not appear in the swarm's components (individual bees).

Life's Organization

Biologists view life in increasingly inclusive levels of organization. Interacting components of one level compose larger, more complex structures and systems of the next. The interactions give rise to new properties that emerge at each level. Later chapters detail these systems; here, we give a preview.

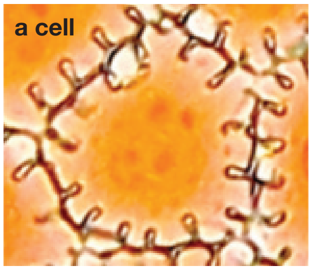


Atoms An **atom** is the smallest unit of matter. All matter consists of atoms and the fundamental particles that compose them. No atoms are unique to living things.

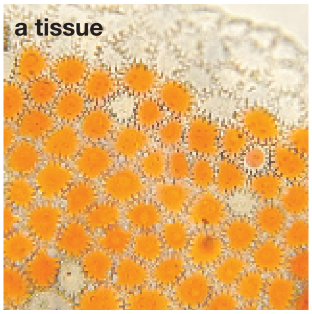


Molecules A **molecule** consists of atoms that are bonded together. Some molecules are unique to life, and these are more complex than the water molecule depicted here.

atom The smallest unit of matter.
biosphere All regions of Earth where organisms live.
cell Smallest unit of life.
community All populations of all species in a defined area.
ecosystem A community interacting with its environment.
molecule Two or more atoms bonded together.
organ In multicelled organisms, a structure that consists of tissues engaged in a collective task.
organ system In multicelled organisms, a set of interacting organs and tissues that carry out one or more body functions.
organism An individual that consists of one or more cells.
population A group of interbreeding individuals of the same species living in a defined area.
tissue In multicelled organisms, specialized cells organized in a pattern that allows them to perform a collective function.

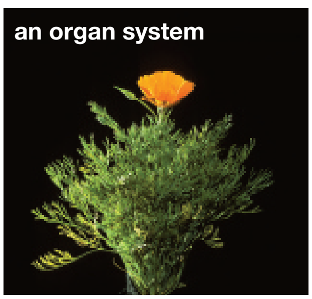


Cells The property we call "life" emerges as molecules organize to form cells. The **cell** is the smallest unit of life. Some, like this plant cell, live and reproduce as part of a multicelled organism; others do so on their own.



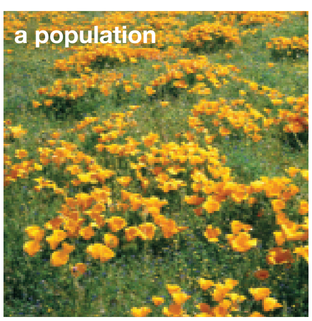
Tissues A **tissue** consists of specific types of cells organized in a particular pattern. The arrangement allows the cells to collectively perform a special function. This is dermal tissue on the outer surface of a flower petal.

Organs An **organ** is a structure composed of tissues that collectively carry out a particular task or set of tasks. Flowers are the reproductive organs of some plants.

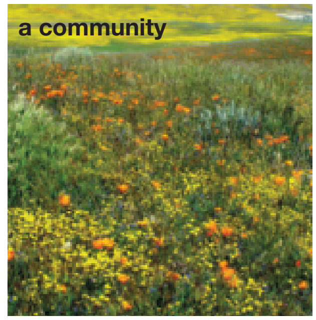


Organ Systems An **organ system** is a set of interacting organs and tissues that fulfill one or more body functions. Leaves, stems, flowers, and fruits form the shoot system of this plant. A plant's body consists of two organ systems: shoots and roots.

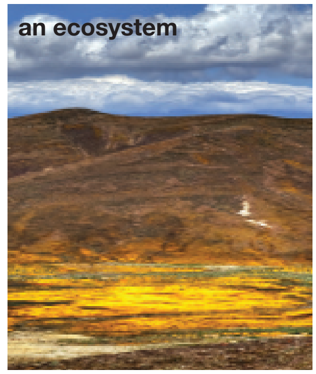
Organisms An **organism** is an individual that consists of one or more cells. Humans consist of many cells, as do other organisms such as this California poppy plant.



Populations A **population** is a group of interbreeding individuals of the same species living in a given area. This population of California poppy plants is in the Antelope Valley California Poppy Reserve.



Communities Populations interact in communities. A **community** consists of all populations of all species in a given area. This one includes all of the populations of plants, animals, microorganisms, and so on living in the Antelope Valley California Poppy Reserve.



Ecosystems An **ecosystem** is a community interacting with its physical and chemical environment through the transfer of energy and materials. Sunlight and water sustain the community in the Antelope Valley.

The Biosphere The **biosphere** is the sum of all ecosystems, and it encompasses all regions of Earth's crust, waters, and atmosphere in which organisms live.

Top to bottom (left): Umberto Salvagnin; Umberto Salvagnin; California Poppy, © 2009, Christine M. Welter; Lady Bird Johnson Wildflower Center; SPL/Science Source; James Randklev/Exactostock-1672/SuperStock. Top to bottom (right): © Sergei Krupnov, www.flickr.com/photos/7969319@N03; © Mark Koberg Photography; Source: NASA.

TAKE-HOME MESSAGE 1.2

- Biologists study life by thinking about it at successive levels of organization. Interactions among the components of each level give rise to complex properties that emerge at the next.
- All matter consists of atoms and the fundamental particles that compose them.
- Molecules consist of atoms that are bonded together. The property we call "life" emerges as molecules unique to life become organized into cells.
- An organism is an individual that consists of one or more cells. Many multicelled organisms have tissues that are organized as organs and organ systems.
- Interacting individuals compose populations, and interacting populations form communities.
- A community interacting with its environment constitutes an ecosystem. All ecosystems on Earth form the biosphere.

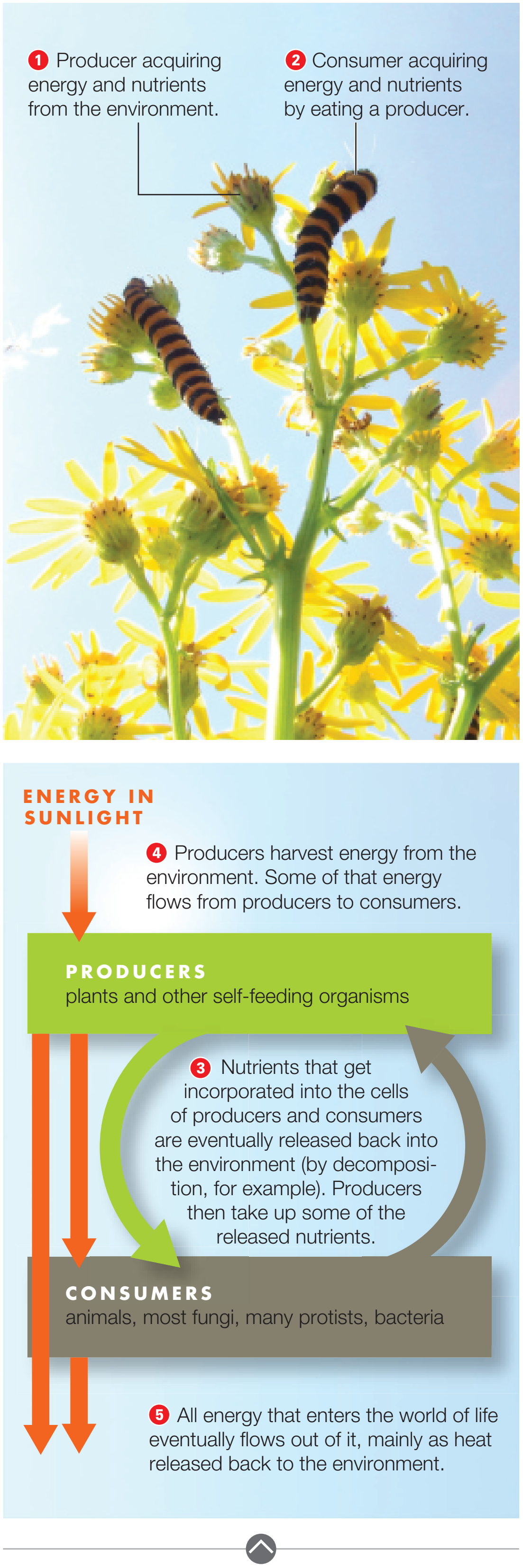


Figure 1.3 The one-way flow of energy and the cycling of materials in the world of life.

Top, © Victoria Pinder, http://www.flickr.com/photos/vixstarplus.

1.3 How Living Things Are Alike

LEARNING OBJECTIVES

- Distinguish producers from consumers.
- Describe the movement of nutrients and energy through the world of life.
- Explain why homeostasis is important for sustaining life.

All living things share a particular set of key features. You already know one of these features: Because the cell is the smallest unit of life, all organisms consist of at least one cell. For now, we introduce three more: All living things require ongoing inputs of energy and raw materials; all sense and respond to change; and all use DNA as the carrier of genetic information (Table 1.1).

TABLE 1.1 Some Key Features of Life

Cellular basis	All living things consist of one or more cells.
Requirement for energy and nutrients	Life is sustained by ongoing inputs of energy and nutrients.
Homeostasis	Living things sense and respond to change.
DNA is hereditary material	Genetic information in the form of DNA is passed to offspring.

Organisms Require Nutrients and Energy

Not all living things eat, but all require raw materials—nutrients—and energy on an ongoing basis. A **nutrient** is a substance that an organism needs for growth and survival but cannot make for itself.

Producers and Consumers Both nutrients and energy are essential to maintain life, so organisms spend a lot of time acquiring them. However, the source of energy and the type of nutrients required differ among organisms. These differences allow us to classify all living things into two broad categories: producers and consumers (Figure 1.3). A **producer** makes its own food using energy and simple raw materials it obtains from nonbiological sources (1). Typical plants are producers. By a process called **photosynthesis**, plants use the energy of sunlight to make sugars from carbon dioxide (a gas in air) and water. Consumers, by contrast, cannot make their own food. A **consumer** obtains energy and nutrients by feeding on other organisms (2). Animals are consumers. So are decomposers, which feed on the wastes or remains of other organisms. Nutrients released from decomposing consumers return to the environment, where they are taken up by producers. Said another way, nutrients cycle between producers and consumers (3).

The One-Way Flow of Energy Unlike nutrients, energy is not cycled. It flows through the world of life in one direction: from the environment (4), through organisms, and to the environment (5). This flow maintains the organization of every living cell and body, and it also influences how individuals interact with one another and their environment. The energy flow is one-way, because with each transfer, some energy escapes as heat, and cells cannot use heat as an energy source. Thus, energy that enters the world of life eventually leaves it (Chapter 4 returns to this topic).

Organisms Sense and Respond to Change

An organism cannot survive for very long unless it responds appropriately to specific stimuli inside and outside of itself. Consider how humans and some other animals perspire (sweat) when the body's internal temperature rises above a certain point (**Figure 1.4**). The moisture cools the skin, which in turn helps cool the body.

All of the internal fluids that bathe the cells in your body are collectively called your internal environment. Temperature and many other conditions in that environment must be kept within certain ranges, or your cells will die (and so will you). By sensing and adjusting to change, all organisms keep conditions in their internal environment within ranges that favor cell survival. **Homeostasis** is the name for this process, and it is one of the defining features of life.

Figure 1.4 Living things sense and respond to their environment.

Sweating is a physiological response to an internal body temperature that exceeds the normal set point. The response cools the skin, which in turn helps return the internal temperature to the set point.

iStock.com/gvillani.

DNA Is Hereditary Material

Inheritance and Reproduction With little variation, the same types of molecules perform the same basic functions in every organism. For example, information in an organism's **DNA** (a molecule called deoxyribonucleic acid) guides ongoing cellular activities that sustain the individual through its lifetime. These activities include **growth**: increases in cell number, size, and volume; **reproduction**: processes by which individuals produce offspring; and **development**: in multicelled species, the process by which the first cell of a new individual gives rise to an adult. **Inheritance**, the transmission of DNA to offspring, occurs during reproduction. All organisms inherit their DNA from one or two parents.

DNA Is the Basis of Life's Unity and Diversity Individuals of every natural population are alike in most aspects of body form and behavior because their DNA is very similar: Humans look and act like humans and not like poppy plants because they inherited human DNA, which differs from poppy plant DNA in the information it carries. Individuals of almost every natural population also vary—just a bit—from one another: One human has blue eyes, the next has brown eyes, and so on. Such variation arises from small differences in the details of DNA molecules, and herein lies the source of life's diversity. As you will see in later chapters, differences among individuals of a species are the raw material of evolutionary processes.

TAKE-HOME MESSAGE 1.3

- Energy and nutrients are required to maintain life. Energy flows from the environment, through organisms, and back to the environment. Nutrients cycle between producers and consumers.
- Organisms sense and respond to conditions inside and outside themselves. They make adjustments that keep conditions in their internal environment within ranges that favor cell survival, a process called homeostasis.
- All organisms use information in the DNA they inherited from parents to guide activities such as growth, reproduction, and (in multicelled organisms) development. DNA is the basis of similarities and differences among organisms.

consumer Organism that acquires energy and nutrients by feeding on the tissues, wastes, or remains of other organisms.

development In multicelled species, the process by which the first cell of a new individual gives rise to an adult.

DNA Deoxyribonucleic acid. Molecule that carries hereditary information. That information guides growth, reproduction, and other cellular activities.

growth Increases in the number, size, and volume of cells.

homeostasis Process in which organisms keep their internal conditions within tolerable ranges by sensing and responding appropriately to change.

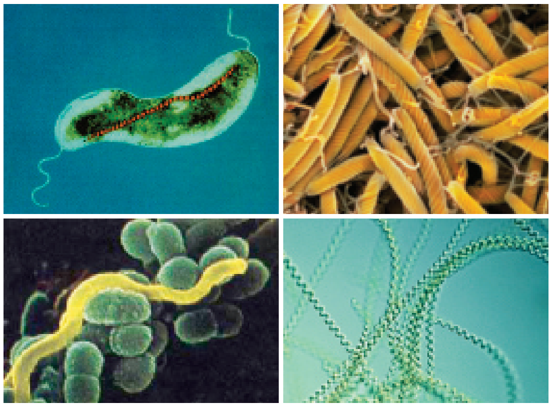
inheritance Transmission of DNA to offspring.

nutrient A substance that an organism must acquire from the environment to support growth and survival.

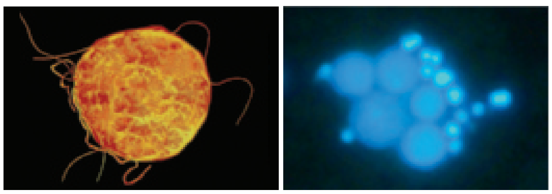
photosynthesis Process by which producers use light energy to make sugars from carbon dioxide and water.

producer An organism that makes its own food using energy and nonbiological raw materials from the environment.

reproduction Processes by which individuals produce offspring.



A. Bacteria are the most numerous organisms on Earth. Clockwise from upper left, a bacterium with a row of iron crystals that serves as a tiny compass; a common bacterial resident of mouse stomachs; photosynthetic bacteria; bacteria found in dental plaque.



B. Archaea resemble bacteria, but are more closely related to eukaryotes. Left, an archaeon that grows in sulfur hot springs. Right, two types of archaea from a seafloor hydrothermal vent.

Figure 1.5 A few representative prokaryotes.

(A) top left, Dr. Richard Frankel; top right, Dr. Kari Lounatmaa/Science Photo Library/Getty Images; bottom left, Source: www.zahnarzt-stuttgart.com; bottom right, © Susan Barnes; (B) left, Dr. Terry Beveridge/Visuals Unlimited/Corbis; right, Source: © Dr. Harald Huber, Dr. Michael Hohn, Prof. Dr. K.O. Stetter, University of Regensburg, Germany.

1.4 How Living Things Differ

LEARNING OBJECTIVES

- Name the prokaryotic groups and how they differ from eukaryotes.
- Describe the four main groups of eukaryotes.
- Discuss how and why we name species.
- Describe the way species are grouped in taxa.
- Explain why DNA can be used to determine relative relatedness.

You will see in later chapters how differences in the details of DNA molecules are the basis of a tremendous range of differences among types of organisms. Various classification schemes help us organize what we understand about this variation, which we call Earth's biodiversity.

The Prokaryotes

Organisms can be grouped on the basis of whether they have a nucleus, which is a saclike structure that contains a cell's DNA. **Bacteria** (singular, bacterium) and **archaea** (singular, archaeon) are the organisms whose DNA *is not* contained within a nucleus (**Figure 1.5**). All bacteria and archaea are single-celled, which means each individual consists of one cell. Collectively, these organisms are the most diverse representatives of life. Different kinds of bacteria and archaea are producers or consumers in nearly all regions of Earth, some inhabiting such extreme environments as frozen desert rocks, boiling acid hot springs, and nuclear reactor waste. The first cells on Earth may have faced similarly hostile conditions.

Traditionally, organisms without a nucleus have been called **prokaryotes**, but the designation is now used only informally. This is because bacteria and archaea are less related to one another than we once thought, despite their similar appearance. Archaea turned out to be more closely related to **eukaryotes**, which are organisms whose DNA is contained within a nucleus. Some eukaryotes live as individual cells; others are multicelled.

The Eukaryotes

Protists, fungi, plants, and animals are the four groups of eukaryotes (**Figure 1.6**).

Protist is the common term for a eukaryote that is not a fungus, plant, or animal. Collectively, protists vary dramatically, from single-celled consumers to giant multicelled producers.

Fungi (singular, fungus) are eukaryotic consumers that secrete substances to break down food externally, then absorb nutrients released by this process. Many are decomposers. Most fungi, including those that form mushrooms, are multicellular. Fungi that live as single cells are called yeasts.

Plants are multicelled eukaryotes, and the vast majority of them are photosynthetic producers that live on land. Besides feeding themselves, plants also serve as food for most other land-based organisms.

Animals are multicelled eukaryotic consumers that ingest other organisms or components of them. Unlike fungi, animals break down food inside their body. They also develop through a series of stages that lead to the adult form. All animals actively move about during at least part of their lives.

animal A multicelled eukaryotic consumer that develops through a series of stages and moves about during part or all of its life.

archaea Singular, archaeon. Group of prokaryotes that are more closely related to eukaryotes than to bacteria.

bacteria Singular, bacterium. Largest and most well-known group of prokaryotes.

eukaryotes Organisms whose cells characteristically have a nucleus.

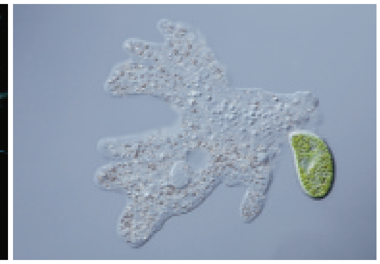
fungus Plural, fungi. A single-celled or multicelled eukaryotic consumer that breaks down material outside itself, then absorbs nutrients released from the breakdown.

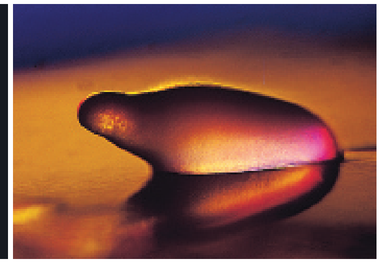
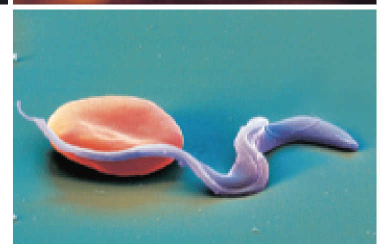
plant A multicelled eukaryotic producer; most are photosynthetic and live on land.

prokaryotes Single-celled organisms with no nucleus.

protist Common term for a eukaryote that is not a fungus, plant, or animal.





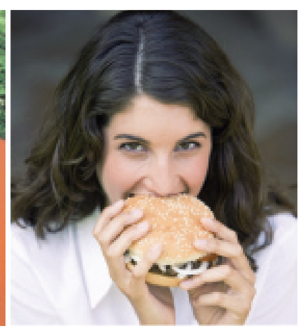



Protists are a group of extremely diverse eukaryotes that range from giant multicelled seaweeds to microscopic single cells.


Plants are multicelled eukaryotes. Almost all plants are photosynthetic producers with roots, stems, and leaves.


Fungi are eukaryotic consumers that secrete substances to break down food outside their body. Most are multicelled (left); some are single-celled (above).





Animals are multicelled eukaryotes that ingest other organisms or their parts, and they actively move about during part or all of their life cycle.

Figure 1.6 A few representative eukaryotes.

Protists: Top left, worldswildlifewonders/Shutterstock.com; Top center, Courtesy of Allen W. H. Be & David A. Caron; Emiliania huxleyi. Photograph by Vita Pariente. Scanning electron micrograph taken on a Jeol T330A instrument at the Texas A & M University Electron Microscopy Center; Top right, Lebendkulturen.de/Shutterstock.com; Carolina Biological Supply Company; Oliver Meckes/Science Source; Center left, Jag_cz/Shutterstock.com; Center, Martin Ruegner/Radius Images/Getty Images; Edward S. Ross; Center right, London Scientific Films/Exactostock-1598/Superstock; Bottom left, Shironina/Shutterstock.com; Bottom center, Martin Zimmerman, Science, 1961, 133:73–79, © AAAS; Bottom right, Pixtal/Superstock.