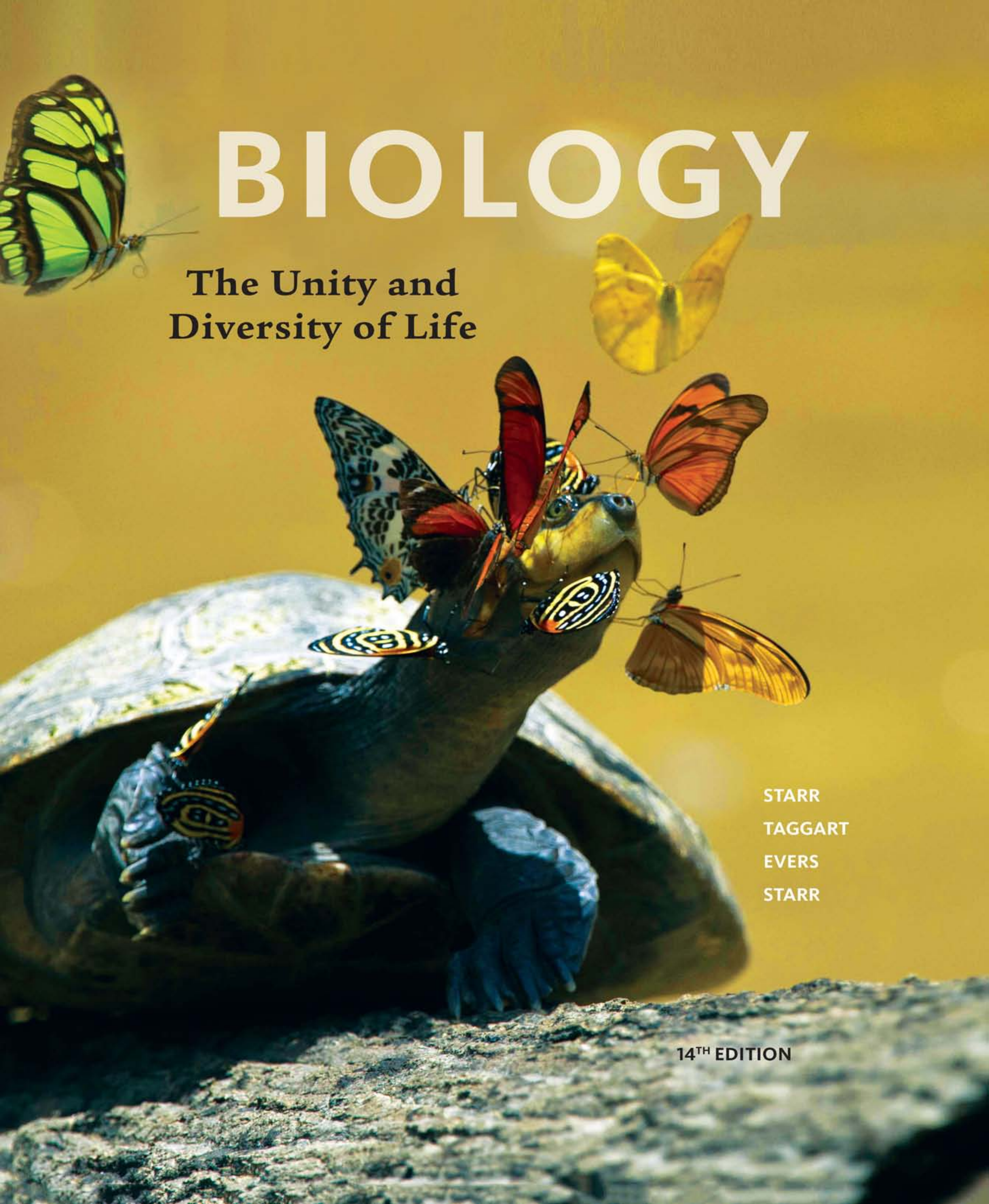

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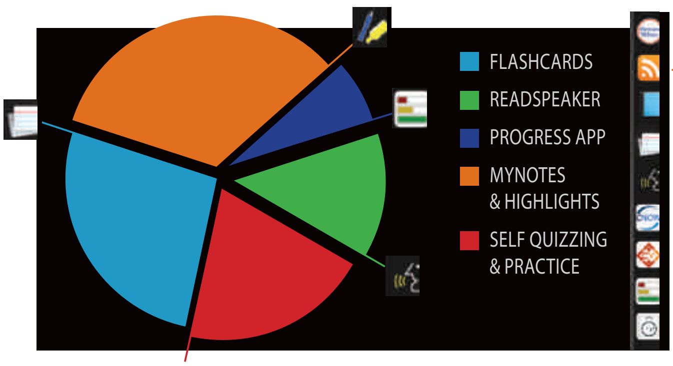

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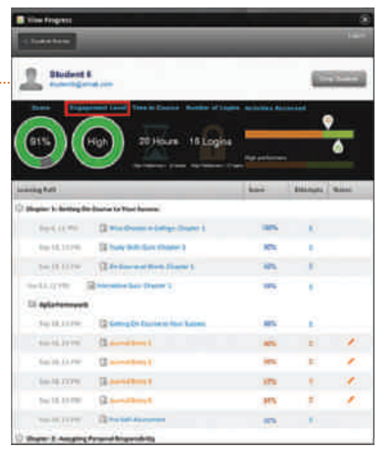

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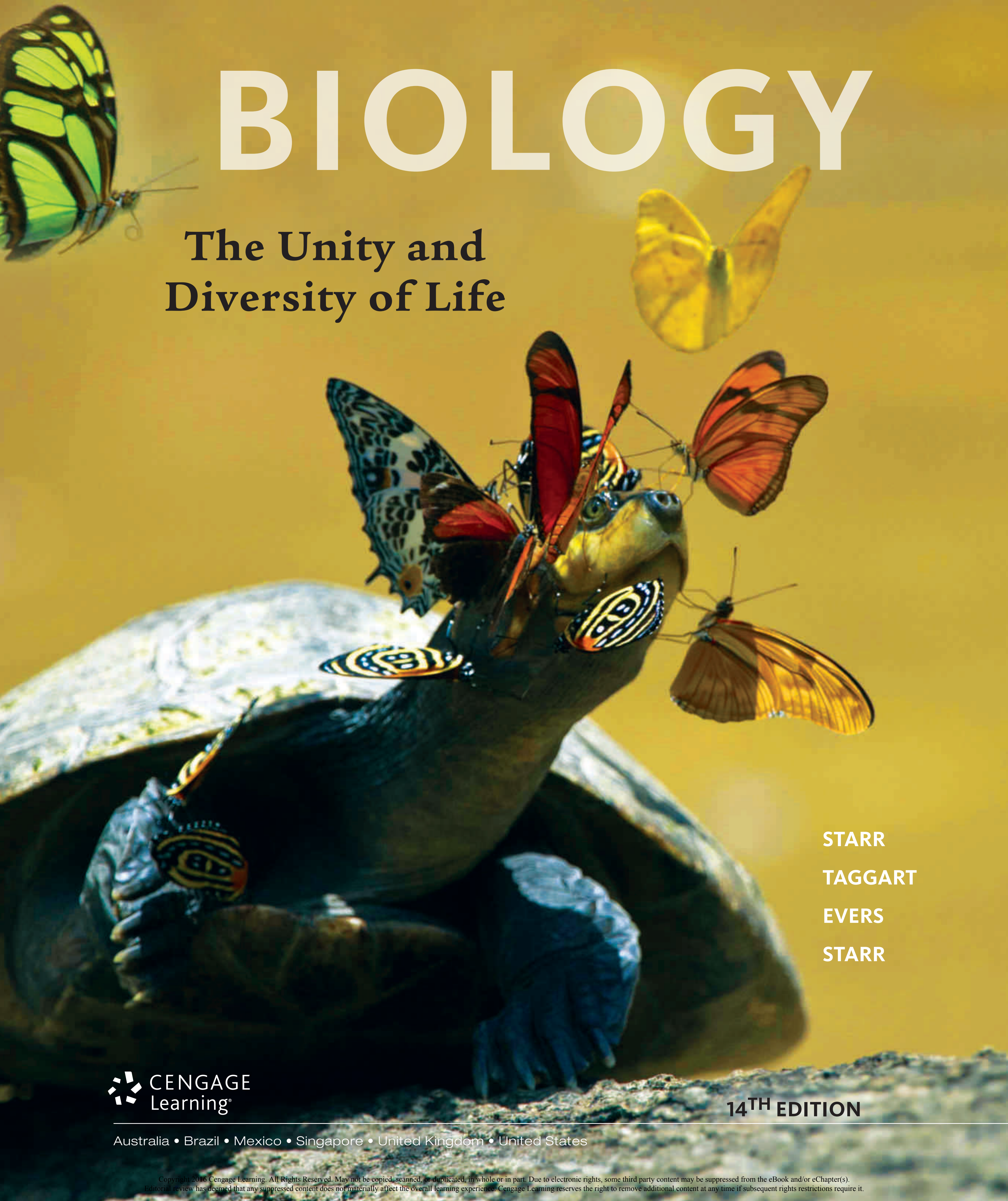

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Butterflies sip the tears of a yellow-spotted river turtle sunning itself in Yasuní National Park, Ecuador. Turtle tears supply the butterflies with sodium, an essential nutrient missing from their flower nectar diet in the Amazon rainforest. Butterflies are almost never observed sipping turtle tears outside of this small region, which is famous for having one of the most diverse assortments of species in the world. Currently, oil drilling operations are destroying the forest and wildlife in the park.

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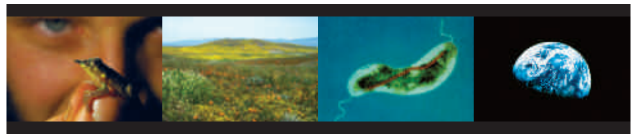

UNIT I PRINCIPLES OF CELLULAR LIFE

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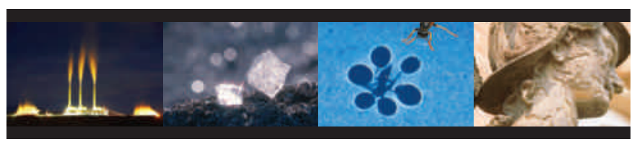

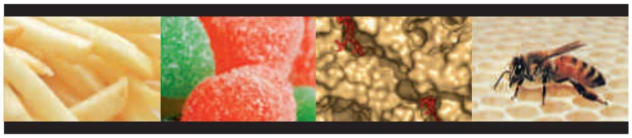

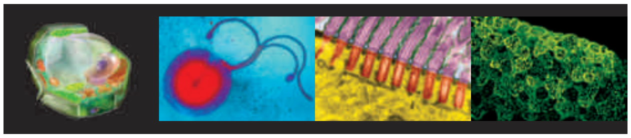

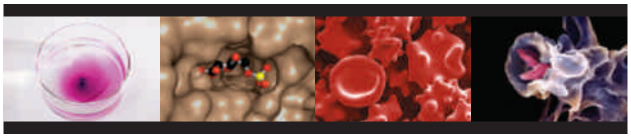

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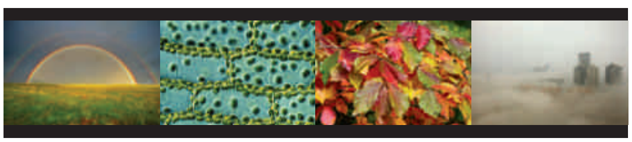

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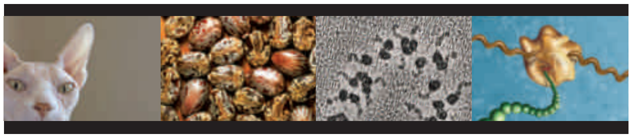

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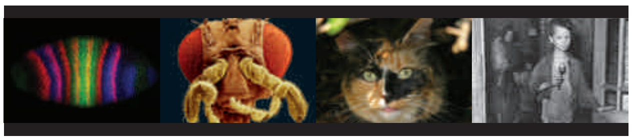

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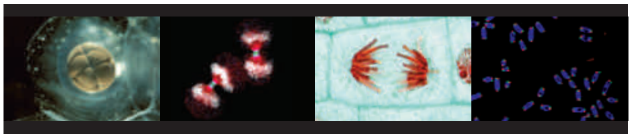

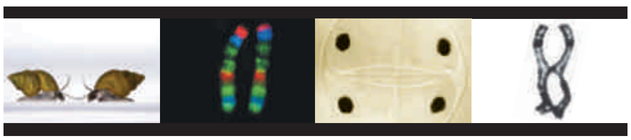

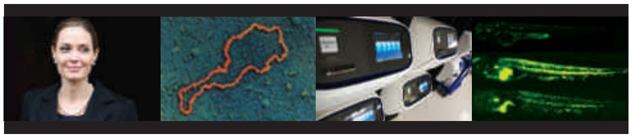

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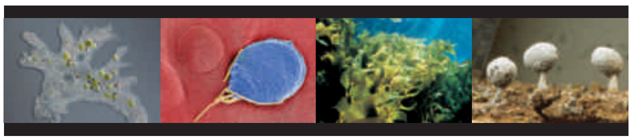

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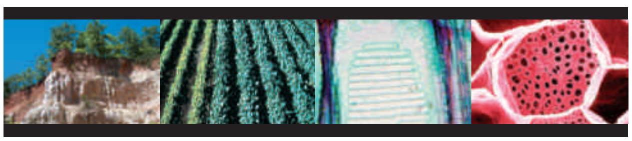

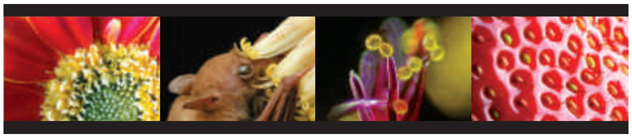

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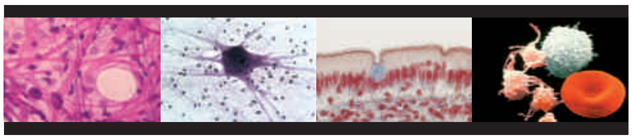

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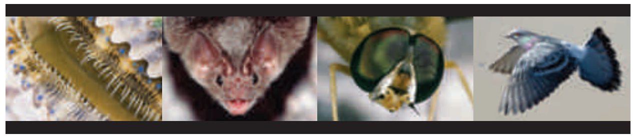

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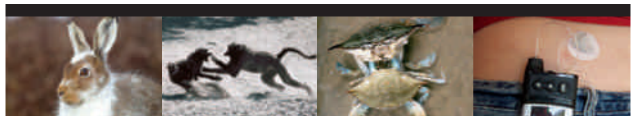

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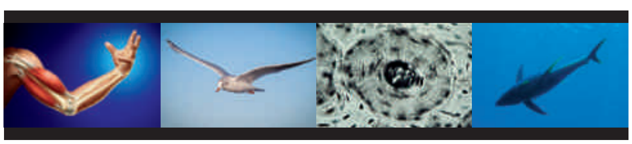

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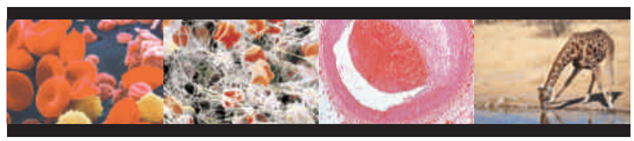

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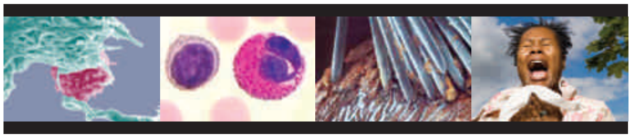

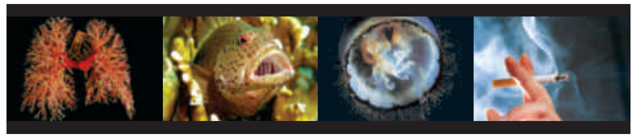

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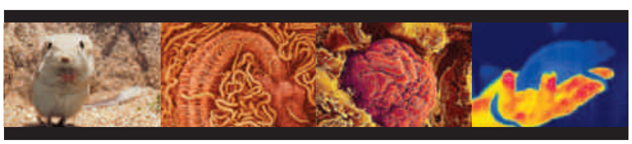

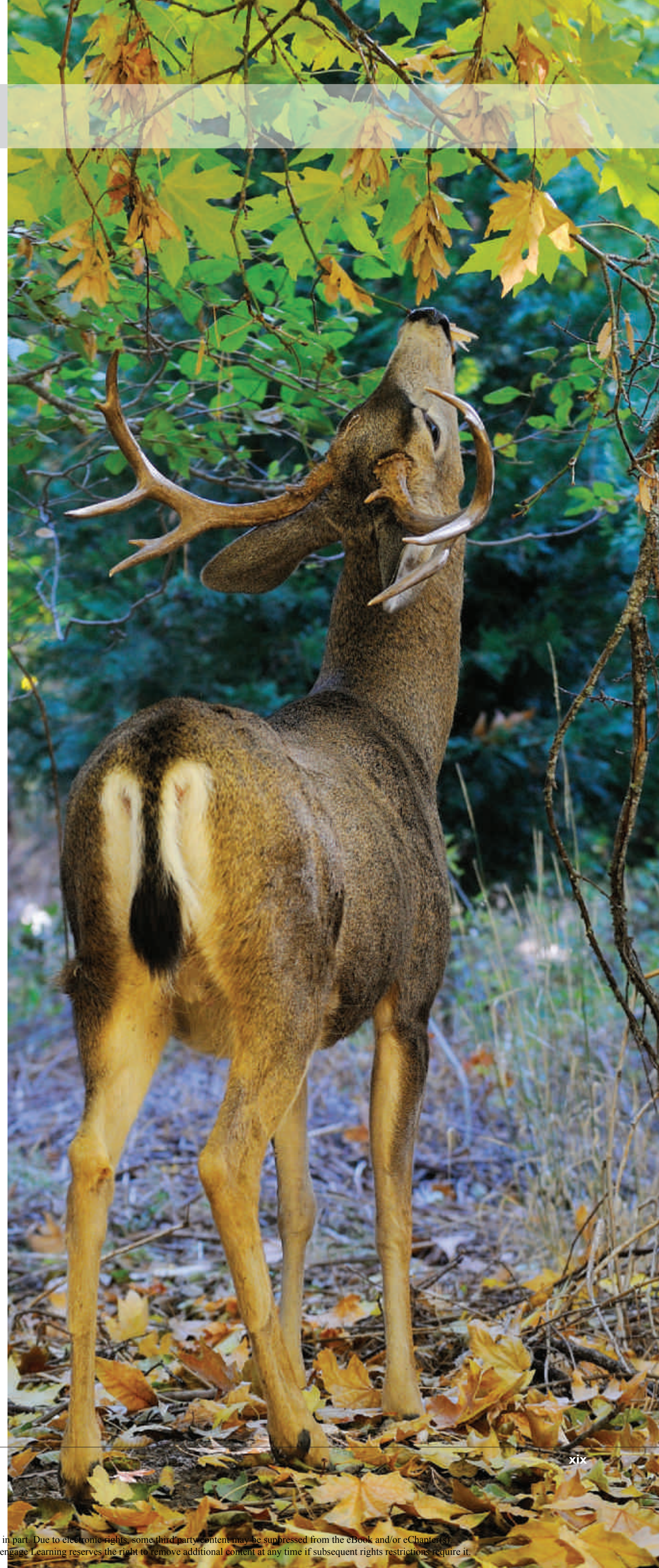

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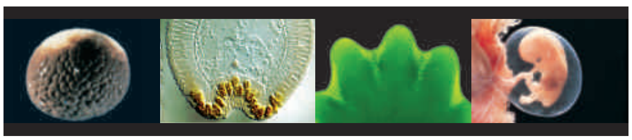

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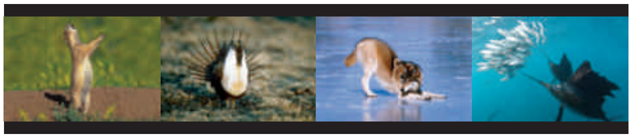

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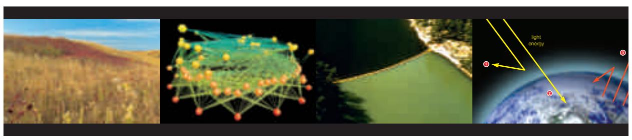

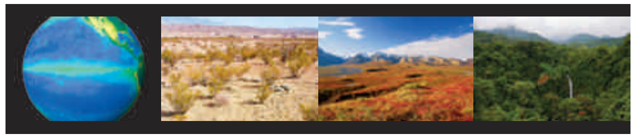

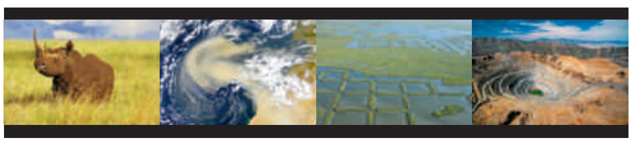

Preface

This edition of *Biology: The Unity and Diversity of Life* includes a wealth of new information reflecting recent discoveries in biology (details can be found in the *Power Bibliography*, which lists journal articles and other references used in the revision process; available upon request). Descriptions of current research, along with photos and videos of scientists who carry it out, underscore the concept that science is an ongoing endeavor carried out by a diverse community of people. Discussions include not only what was discovered, but also how the discoveries were made, how our understanding has changed over time, and what remains to be discovered. These discussions are provided in the context of a thorough, accessible introduction to well-established concepts and principles that underpin modern biology. Every topic is examined from an evolutionary perspective, emphasizing the connections between all forms of life.

Throughout the book, text and art have been revised to help students grasp difficult concepts. This edition also continues to focus on real world applications pertaining to the field of biology, including social issues arising from new research and developments. This edition covers in detail the many ways in which human activities are continuing to alter the environment and threaten both human health and Earth's biodiversity.

Changes to this Edition

Here are a few highlights of the revisions to this edition.

1 Invitation to Biology Renewed and updated emphasis on the relevance of new species discovery and the process of science.

2 Life's Chemical Basis New graphics illustrate elements and radioactive decay.

3 Molecules of Life New figure illustrates protein domains.

4 Cell Structure and Function New table summarizing cell theory; new photos of prokaryotes. Comparison of microscopy techniques updated using *Paramecium*. New figure shows food vacuoles in *Nassula*.

5 Ground Rules of Metabolism Temperature-dependent enzyme activity now illustrated with polymerases. New art and photos illustrate coenzymes, adhesion proteins, membrane trafficking, and energy transfer in redox reactions.

6 Where It Starts—Photosynthesis New photos illustrate phycobilins, stomata, adaptations of C4 plants, ice core sampling, smog in China. Light-dependent reactions art simplified.

7 How Cells Release Chemical Energy New photos illustrate mitochondrial disease and aerobic respiration.

8 DNA Structure and Function Concepts and illustrations of DNA hybridization and primers added to replication section. New photo of mutations caused by radiation at Chernobyl; new illustration of mutation.

9 From DNA to Protein Expanded material on the effects of mutation includes discussion of hairlessness in cats and a new micrograph of a sickled blood cell.

10 Gene Control New photos show transcription factors, X chromosome inactivation; new material explains evolution of lactose tolerance. New critical thinking question requires understanding of the effects of floral identity gene mutations.

11 How Cells Reproduce New photos illustrate mitosis, the mitotic spindle, and telomeres.

12 Meiosis and Sexual Reproduction New material on asexuality in mud snails and bdelloid rotifers. New micrograph shows multiple crossovers.

13 Observing Patterns in Inherited Traits New material about environmental effects on hemoglobin gene expression in *Daphnia*. New photos illustrate continuous variation.

14 Chromosomes and Human Inheritance Material on Tay-Sachs has been moved to this chapter as an illustration of autosomal recessive inheritance.

15 Studying and Manipulating Genomes Coverage of personal genetic testing updated with new medical applications, including the social impact of Angelina Jolie's response to her test. New photos of genetically modified animals. New "who's the daddy" critical thinking question offers students an opportunity to analyze a paternity test based on SNPs.

16 Evidence of Evolution New MRI showing coccyx illustrates a vestigial structure. Photos of 19th century naturalists added to emphasize the process of science that led to natural selection theory. Expanded coverage of fossil formation includes how banded iron formations provide evidence of the evolution of photosynthesis.

17 Processes of Evolution New opening essay on resistance to antibiotics as an outcome of agricultural overuse (warfarin material moved to illustrate directional selection). New art illustrates founder effect, and hypothetical example in text replaced with reduced diversity of *ABO* alleles in Native Americans. New art illustrates stasis in coelacanths.

18 Organizing Information About Species New material on DNA barcoding added to biochemical comparisons section. Data analysis activity revised to incorporate new data on honeycreeper ancestry.

19 Life's Origin and Early Evolution Added material about new discovery of 3.4-billion-year old fossil bacteria. New graphic illustrates endosymbiotic origin of mitochondria and chloroplasts.

20 Viruses, Bacteria, and Archaea Added information about Ebola and West Nile viruses, and newly discovered giant viruses.

21 Protists—The Simplest Eukaryotes New graphic depicts primary and secondary endosymbiosis. Added information about diatoms as a source of oil.

22 The Land Plants New essay about seed banks and the importance of sustain plant biodiversity.

23 Fungi More extensive coverage of fungal ecology; added information about white nose syndrome, a fungal disease of bats.

24 Animal Evolution—Invertebrates Updated information of medicines from invertebrates. New photos of terrestrial flatworm, plant-infecting roundworm.

25 Animal Evolution—Vertebrates Improved discussion of transition to land, with new illustration. Reorganized coverage of mammal evolution and diversity.

26 Human Evolution Updated to include latest discoveries about *Australopithecus sediba*, Denisovans, and Neanderthals.

27 Plant Tissues Carbon sequestration essay revised to include new data on wood production by old-growth redwoods. Reorganized to consolidate primary growth into its own section. Many new photos illustrate stem, leaf, and root structure. Material on fire scars added to section on dendroclimatology.

28 Plant Nutrition and Transport Illustration of Casparian strip integrated with new micrograph. Revisited section discusses phytoremediation at Ford's Rouge Center.

29 Life Cycles of Flowering Plants Updated material reflects current research on bee pollination behavior and colony collapse. New photos illustrate pollinators, fruit classification, asexual reproduction.

30 Communication Strategies in Plants Updates reflect ongoing major breakthroughs in the field of plant hormone function. New photos show apical dominance, effect of gibberellin, and abscission.

31 Animal Tissues and Organ Systems Added information about tissue regeneration in nonhuman animals; updated information about use of human and embryonic stem cells. Added information about blubber as a specialized adipose tissue.

32 Neural Control New opening essay about the effects of concussion on the brain. Reorganized coverage of psychoactive drugs. Added information about epidural anesthesia. Updated, improved coverage of memory.

33 Sensory Perception New opening essay about cochlear implants; revisited section discusses retinal implants, artificial limbs. Updated information about human sense of taste.

34 Endocrine Control Updated discussion of endocrine disruptors. New examples of pituitary gigantisms, dwarfism. Added information about role of melatonin in seasonal coat color changes.

35 Structural Support and Movement Added information about myostatin polymorphism in race horses to opening essay. New section discusses principles of animal location. Added information about boneless muscular organs such as the tongue.

36 Circulation More extensive coverage of plasma components. Discussion of genetics of blood types deleted. Improved coverage of and illustration of capillary exchange. Added information about blood pressure and jugular vein valves in giraffes.

37 Immunity Updated material on HIV/AIDS treatment strategies. New photos show T cell/APC interaction, skin as a surface barrier, a cytotoxic T cell killing a cancer cell, contact allergy, and victims of HIV.

38 Respiration Improved comparison of water and air as respiratory media with accompanying figure. Revised figure depicting first aid for choking victims to reflect latest guidelines. Discussion of human adaptation to high altitude now compares mechanisms in Tibetan and Andean populations.

39 Digestion and Nutrition New graphic depicting functional variations in animal dentition. New figure showing arrangement of organs that empty into the small intestine. Improved discussion of vitamin and mineral functions. New MRI illustrates how abdominal fat compresses internal organs. Added information about basal metabolic rate.

40 Maintaining the Internal Environment New subsection about climate-related adaptations in human populations.

41 Animal Reproductive Systems Coverage of intersex conditions dropped. Opening essay now discusses reproductive technology (IVF, egg banking); Revisited section discusses sperm banks. New section discusses location of animal gonads and the general mechanism of gamete formation. Reproductive function of human females now discussed before that of males; improved figure depicting the ovarian cycle.

42 Animal Development New opening essay about human birth defects, with a focus on cleft lip and palate. Improved photos illustrating apoptosis in digit development. Reorganized coverage of early human development. Added information about surgical delivery (cesarean section).

43 Animal Behavior Opening essay about effects of noise pollution on animal communication moved here and updated to reflect recent research. Revised discussion of the possible benefits of grouping.

44 Population Ecology Improved presentation of effects of predation on guppy life history. Revised, updated graphics.

45 Community Ecology Added information about and a photo of a brood parasite of ants. Added photo of the keystone species Pisaster.

46 Ecosystems More extensive discussion of aquifer depletion, salination; added information about ecological effects of over-allocation of river water. Updated discussion of the rise in atmospheric CO_2.

47 The Biosphere New opening essay about how winds and ocean currents distributed and are distributing material from the 2011 earthquake and tidal wave that affected Japan. Discussion of El Nino now a subsection within the chapter.

48 Human Impacts on the Biosphere New graphics of extinct animals: mastadon and dodo. Added information about and photo of endangered Florida lichen; added information about the Great Pacific Garbage Patch. Updated coverage of ozone depletion and effects of global climate change.

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Cooperative Learning Cooperative Learning: Making Connections in General Biology, 2nd Edition, authored by Mimi Bres and Arnold Weisshaar, is a collection of separate, ready-to-use, short cooperative activities that have broad application for first year biology courses. They fit perfectly with any style of instruction, whether in large lecture halls or flipped classrooms. The activities are designed to address a range of learning objectives such as reinforcing basic concepts, making connections between various chapters and topics, data analysis and graphing, developing problem solving skills, and mastering terminology. Since each activity is designed to stand alone, this collection can be used in a variety of courses and with any text.

MindTap A personalized, fully online digital learning platform of authoritative content, assignments, and services that engages students with interactivity while also offering instructors their choice in the configuration of coursework and enhancement of the curriculum via web-apps known as MindApps. MindApps range from ReadSpeaker (which reads the text out loud to students), to Kaltura (allowing you to insert inline video and audio into your curriculum). MindTap is well beyond an eBook, a homework solution or digital supplement, a resource center website, a course delivery platform, or a Learning Management System. It is the first in a new category —the Personal Learning Experience.

New for this edition! MindTap has an integrated Study Guide, expanded quizzing and application activities, and an integrated Test Bank.

Aplia for Biology The Aplia system helps students learn key concepts via Aplia's focused assignments and active learning opportunities that include randomized, automatically graded questions, exceptional text/art integration, and immediate feedback. Aplia has a full course management system that can be used independently or in conjunction with other course management systems such as MindTap, D2L, or Blackboard.

Acknowledgments

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 even from one year to the next. It is only with the ongoing input of our many academic reviewers and advisors (see opposite 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. A special thanks goes to Jose Panero for his extensive and detailed review for this edition.

On the production side of our team, the indispensable Grace Davidson orchestrated a continuous flow of files, photos, and illustrations while managing schedules, budgets, and whatever else happened to be on fire at the time. Grace, thank you as always for your patience and dedication. Thank you also to Cheryl DuBois, John Sarantakis, and Christine Myaskovsky for your help with photoresearch. Copyeditor Anita Hueftle and proofreader Kathy Dragolich, your valuable suggestions kept our text clear and concise.

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Lisa Starr and Christine Evers, May 2014

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1 Invitation to Biology

LEARNING ROADMAP

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—contributes to that understanding.

THE SCIENCE OF NATURE

We can understand life by studying it at many levels, starting with atoms that are components of all matter, and extending to interactions of organisms with their environment.

LIFE'S UNITY

All living things require ongoing inputs of energy and raw materials; all sense and respond to change; and all have DNA that guides their functioning.

LIFE'S DIVERSITY

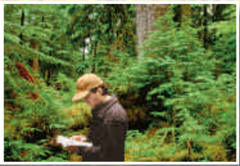
Observable characteristics vary tremendously among organisms. Various classification systems help us keep track of the differences.

THE NATURE OF SCIENCE

Carefully designing experiments helps researchers unravel cause-and-effect relationships in complex natural systems.

WHAT SCIENCE IS (AND WHAT IT IS NOT)

Science addresses only testable ideas about observable events and processes. It does not address the untestable, including beliefs and opinions.



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.

1.1 The Secret Life of Earth

In this era of detailed satellite imagery and cell phone global positioning systems, could there possibly be any places left on Earth that humans have not yet explored? Actually, there are plenty of them. In 2005, for example, helicopters dropped a team of scientists into the middle of a vast and otherwise inaccessible cloud forest atop New Guinea's Foja Mountains. Within a few minutes, the explorers realized that their landing site, a dripping, moss-covered swamp, had been untouched by humans. Team member Bruce Beehler remarked, "Everywhere we looked, we saw amazing things we had never seen before. I was shouting. This trip was a once-in-a-lifetime series of shouting experiences."

How did the explorers know they had landed in uncharted territory? For one thing, the forest was filled with plants and animals previously unknown even to native peoples that have long inhabited other parts of the region. During the next month, the team members discovered many new species, including a rhododendron plant with flowers the size of a plate and a frog the size of a pea. They also came across hundreds of species that are on the brink of extinction in other parts of the world, and some that supposedly had been extinct for decades. The animals had never learned to be afraid of humans, so they could easily be approached. A few were discovered as they casually wandered through campsites (**FIGURE 1.1**).

New species are discovered all the time, often in places much more mundane than Indonesian cloud forests. 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 a scientist? 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. For example, 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. The current rate of extinctions is about 1,000 times faster than normal, and human activities are responsible for the acceleration. At this rate, we will never know about most of the species that are alive on Earth today. Does that matter? Biologists think so. 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.

Ironically, the more we learn about the natural world, the more we realize we have yet to learn. But don't take our word for it. Find out what biologists know, and what they do not, and you will have a solid foundation upon which to base your own opinions about how humans fit into this world. By reading this book, you are choosing to learn about the human connection—your connection—with all life on Earth.

biology The scientific study of life.

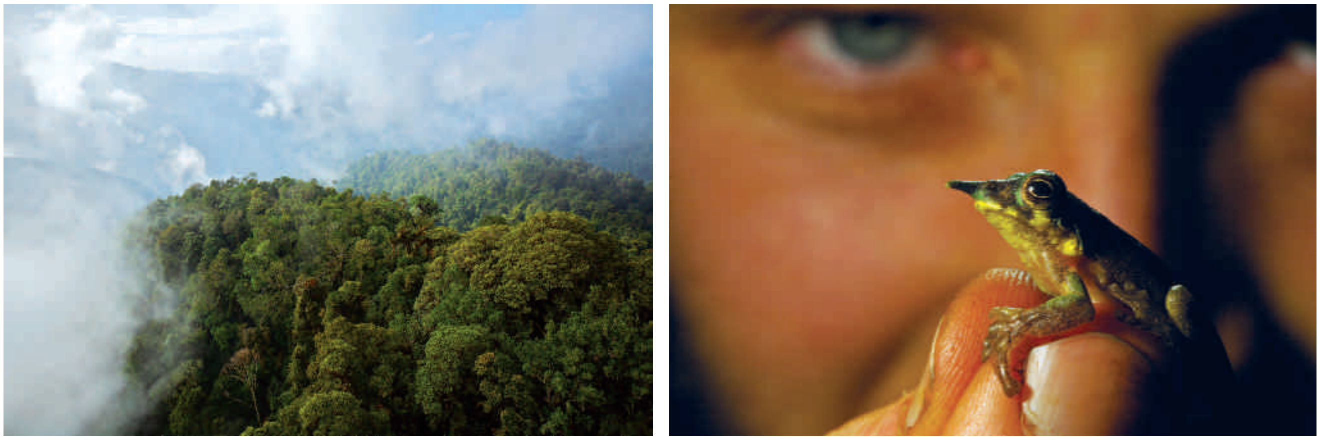


FIGURE 1.1 Explorers found hundreds of rare species and dozens of new ones during recent survey expeditions to the Foja Mountain cloud forest (left). Right, Paul Oliver discovered this tree frog (*Litoria*) perched on a sack of rice during a particularly rainy campsite lunch. The explorers dubbed the new species "Pinocchio frog" after the Disney character because the male frog's long nose inflates and points upward during times of excitement.

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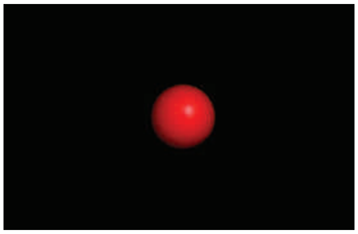
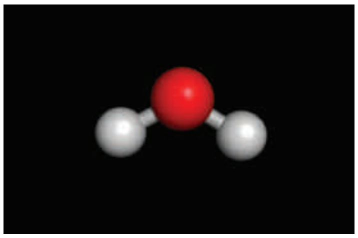
1.2 Life Is More Than the Sum of Its Parts

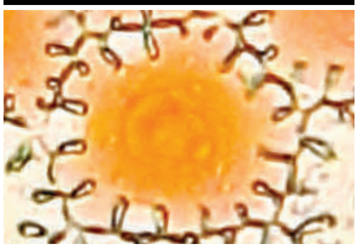
- ✔ Biologists study life by thinking about it at different levels of organization.
- ✔ The quality of life emerges at the level of the cell.



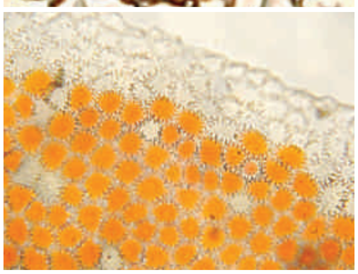
1 Atoms
Atoms are fundamental units of all substances, living or not. This image shows a model of a single atom.



2 Molecule
Atoms join other atoms in molecules. This is a model of a water molecule. The molecules special to life are much larger and more complex than water.



3 Cell
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.



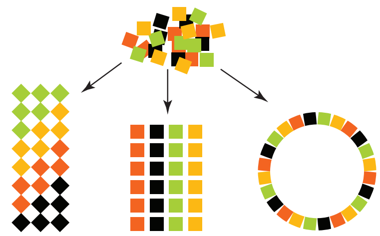
4 Tissue
Organized array of cells that interact in a collective task. This is epidermal tissue on the outer surface of a flower petal.

5 Organ
Structural unit of interacting tissues. Flowers are the reproductive organs of many plants.

6 Organ system
A set of interacting organs. The shoot system of this poppy plant includes its aboveground parts: leaves, flowers, and stems.

FIGURE 1.2 ▶**Animated** Levels of life's organization.

What, exactly, is the property we call "life"? We may never actually come up with a good 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 list of properties that differentiate living from nonliving things. These properties often emerge from the interactions of basic components. To understand how that works, take a look at these groups of squares:



The property of "roundness" emerges when the component squares are organized one way, but not other ways. Characteristics of a system that do not appear in any of the system's components are called **emergent properties**. The idea that structures with emergent properties can be assembled from the same basic building blocks is a recurring theme in our world—and also in biology.

Life has successive levels of organization, with new emergent properties appearing at each level (**FIGURE 1.2**). This organization begins with interactions between **atoms**, which are fundamental building blocks of all substances 1. Atoms bond together to form **molecules** 2. There are no atoms unique to living things, but there are unique molecules. In today's natural world, only living things make the "molecules of life," which are lipids, proteins, DNA, RNA, and complex carbohydrates. The emergent property of "life" appears at the next level, when many molecules of life become organized as a cell 3. A **cell** is the smallest unit of life. Cells survive and reproduce themselves using energy, raw materials, and information in their DNA.

Some cells live and reproduce independently. Others do so as part of a multicelled organism. An **organism** is an individual that consists of one or more cells. A poppy plant is an example of a multicelled organism 7. In most multicelled organisms, cells are organized as tissues 4. A **tissue** consists of specific types of cells organized in a particular pattern. The arrangement allows the cells to collectively perform a special function such as protection from injury (dermal tissue) or movement (muscle tissue). An **organ** is an organized array of tissues that collectively carry out a particular task or set of tasks ❺. For example, a flower is an organ of reproduction in plants; a heart, an organ that pumps blood in animals. An **organ system** is a set of organs and tissues that interact to keep the individual's body working properly ❻. Examples of organ systems include the aboveground parts of a plant (the shoot system), and the heart and blood vessels of an animal (the circulatory system).

A **population** is a group of interbreeding individuals of the same type, or species, living in a given area ❽. An example may be all California poppies living in California's Antelope Valley Poppy Reserve. At the next level, a **community** consists of all populations of all species in a given area. The Antelope Valley Reserve community includes California poppies and all other plants, animals, microorganisms, and so on ❾. Communities may be large or small, depending on the area defined.

The next level of organization is the **ecosystem**, which is a community interacting with its environment ❿. The most inclusive level, the **biosphere**, encompasses all regions of Earth's crust, waters, and atmosphere in which organisms live ⓫.

atom Fundamental building block of all matter.
biosphere All regions of Earth where organisms live.
cell Smallest unit of life.
community All populations of all species in a given area.
ecosystem A community interacting with its environment.
emergent property A characteristic of a system that does not appear in any of the system's component parts.
molecule Two or more atoms bonded together.
organ In multicelled organisms, a grouping of tissues engaged in a collective task.
organism Individual that consists of one or more cells.
organ system In multicelled organisms, set of organs engaged in a collective task that keeps the body functioning properly.
population Group of interbreeding individuals of the same species that live in a given area.
tissue In multicelled organisms, specialized cells organized in a pattern that allows them to perform a collective function.

TAKE-HOME MESSAGE 1.2

How do living things differ from nonliving things?

- ✔ All things, living or not, consist of the same building blocks: atoms. Atoms join as molecules.
- ✔ In today's natural world, only living things make lipids, proteins, DNA, RNA, and complex carbohydrates. The unique properties of life emerge as these molecules become organized into cells.
- ✔ Higher levels of life's organization include multicelled organisms, populations, communities, ecosystems, and the biosphere.
- ✔ Emergent properties occur at each successive level of life's organization.

❼ **Multicelled organism** Individual that consists of more than one cell. Cells of this California poppy plant are part of its two organ systems: aboveground shoots and belowground roots.

❽ **Population** Group of single-celled or multicelled individuals of a species in a given area. This population of California poppy plants is in California's Antelope Valley Poppy Reserve.

❾ **Community** All populations of all species in a specified area. These plants are part of the Antelope Valley Poppy Reserve community.

❿ **Ecosystem** A community interacting with its physical environment through the transfer of energy and materials. Sunlight and water sustain the natural community in the Antelope Valley.

⓫ **Biosphere** The sum of all ecosystems: every region of Earth's waters, crust, and atmosphere in which organisms live. No ecosystem in the biosphere is truly isolated from any other.

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1.3 How Living Things Are Alike

✔ Continual inputs of energy and the cycling of materials maintain life's complex organization.

✔ Organisms sense and respond to change.

✔ All organisms use information in the DNA they inherited from their parent or parents to function.

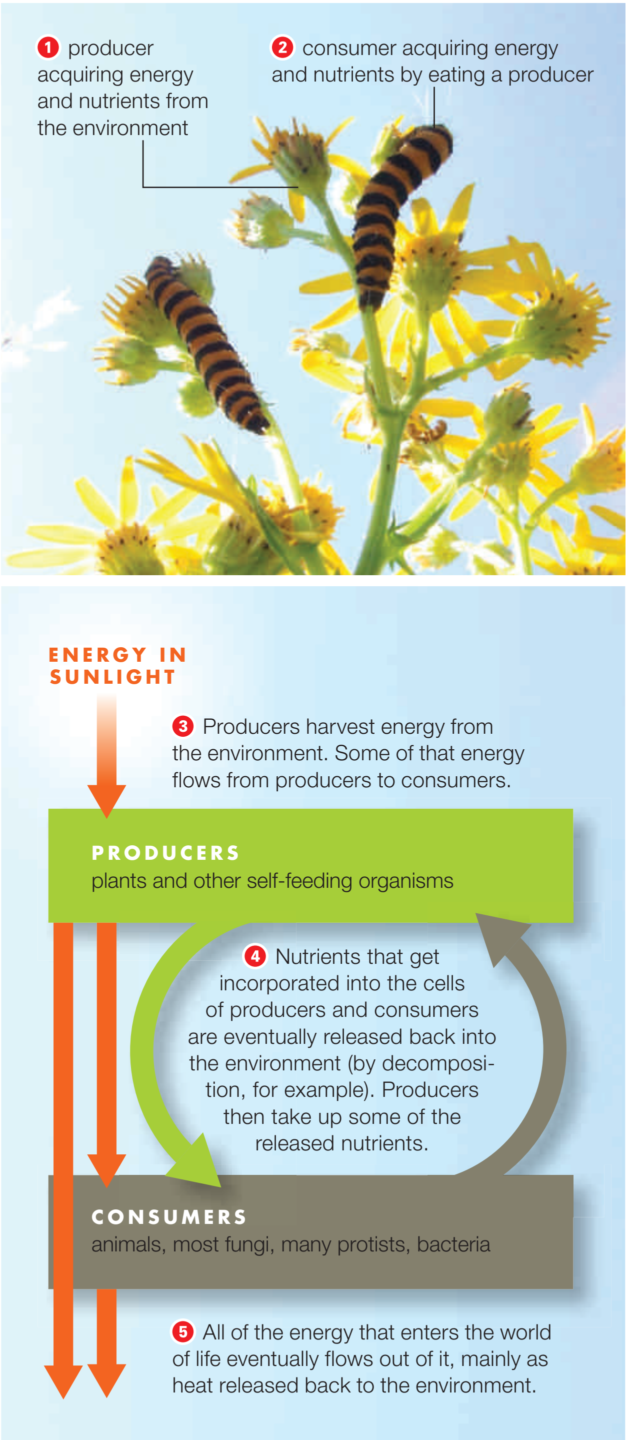

FIGURE 1.3 ▶**Animated** The one-way flow of energy and cycling of materials in the world of life.

Even though we cannot precisely define "life," we can intuitively understand what it means because all living things share a set of key features. All require ongoing inputs of energy and raw materials; all sense and respond to change; and all pass DNA to offspring.

Organisms Require Energy and Nutrients

Not all living things eat, but all require energy and nutrients on an ongoing basis. Both are essential to maintain the functioning of individual organisms and the organization of life. A **nutrient** is a substance that an organism needs for growth and survival but cannot make for itself.

Organisms spend a lot of time acquiring energy and nutrients (**FIGURE 1.3**). However, the source of energy and the type of nutrients acquired differ among organisms. These differences allow us to classify all living things into two categories: producers and consumers. **Producers** make their own food using energy and simple raw materials they obtain from nonbiological sources ❶. Plants are producers that use the energy of sunlight to make sugars from water and carbon dioxide (a gas in air), a process called **photosynthesis**. By contrast, **consumers** cannot make their own food. They obtain energy and nutrients by feeding on other organisms ❷. Animals are consumers. So are decomposers, which feed on the wastes or remains of other organisms. The leftovers from consumers' meals end up in the environment, where they serve as nutrients for producers. Said another way, nutrients cycle between producers and consumers.

Unlike nutrients, energy is not cycled. It flows through the world of life in one direction: from the environment ❸, through organisms ❹, and back to

---

consumer Organism that gets energy and nutrients by feeding on tissues, wastes, or remains of other organisms.
development Multistep process by which the first cell of a new multicelled organism gives rise to an adult.
DNA Deoxyribonucleic acid; carries hereditary information that guides development and other activities.
growth In multicelled species, an increase in the number, size, and volume of cells.
homeostasis Process in which an organism keeps its internal conditions within tolerable ranges by sensing and responding to change.
inheritance Transmission of DNA to offspring.
nutrient Substance that an organism needs for growth and survival but cannot make for itself.
photosynthesis Process by which producers use light energy to make sugars from carbon dioxide and water.
producer Organism that makes its own food using energy and nonbiological raw materials from the environment.
reproduction Processes by which parents produce offspring.

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FIGURE 1.4 Organisms sense and respond to stimulation. This baby orangutan is laughing in response to being tickled. Apes and humans make different sounds when being tickled, but the airflow patterns are so similar that we can say apes really do laugh.

the environment ❺. 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 (we return to this topic in Chapter 5).

Organisms Sense and Respond to Change

An organism cannot survive for very long in a changing environment unless it adapts to the changes. Thus, every living thing has the ability to sense and respond to change both inside and outside of itself (**FIGURE 1.4**). For example, after you eat, the sugars from your meal enter your bloodstream. The added sugars set in motion a series of events that causes cells throughout the body to take up sugar faster, so the sugar level in your blood quickly falls. This response keeps your blood sugar level within a certain range, which in turn helps keep your cells alive and your body functioning.

The fluid portion of your blood is a component of your internal environment, which is all of the body fluids outside of cells. That internal environment must be kept within certain ranges of temperature and other conditions, or the cells that make up your body will die. By sensing and adjusting to change, you and all other organisms keep conditions in the internal environment within a range that favors survival. **Homeostasis** is the name for this process, and it is one of the defining features of life.

Organisms Use DNA

With little variation, the same types of molecules perform the same basic functions in every organism. For example, information in an organism's **DNA** (deoxyribonucleic acid) guides ongoing functions that sustain the individual through its lifetime. Such functions include **development**: the process by which the first cell of a new individual gives rise to a multicelled adult; **growth**: increases in cell number, size, and volume; and **reproduction**: processes by which individuals produce offspring.

Individuals of every natural population are alike in certain aspects of their body form and behavior because their DNA is very similar: Orangutans look like orangutans and not like caterpillars because they inherited orangutan DNA, which differs from caterpillar DNA in the information it carries. **Inheritance** refers to the transmission of DNA to offspring. All organisms inherit their DNA from one or two parents.

DNA is the basis of similarities in form and function among organisms. However, the details of DNA molecules differ, and herein lies the source of life's diversity. Small variations in the details of DNA's structure give rise to differences among individuals, and also among types of organisms. As you will see in later chapters, these differences are the raw material of evolutionary processes.

TAKE-HOME MESSAGE 1.3

How are all living things alike?

✔ A one-way flow of energy and a cycling of nutrients sustain life's organization.

✔ Organisms sense and respond to conditions inside and outside themselves. They make adjustments that keep conditions in their internal environment within a range that favors cell survival, a process called homeostasis.

✔ All organisms use information in the DNA they inherited from their parent or parents to develop, grow, and reproduce. DNA is the basis of similarities and differences in form and function among organisms.

CREDIT: (4) © Dr. Marina Davila Ross, University of Portsmouth.

1.4 How Living Things Differ

✔ There is great variation in the details of appearance and other observable characteristics of living things.

Living things differ tremendously in their observable characteristics. Various classification schemes help us organize what we understand about the scope of this variation, which we call Earth's **biodiversity**.

For example, organisms can be grouped on the basis of whether they have a nucleus, which is a sac with two membranes that encloses and protects a cell's DNA. **Bacteria** (singular, bacterium) and **archaea** (singular, archaeon) are organisms whose DNA is *not* contained within a nucleus. All bacteria and archaea are single-celled, which means each organism consists of one cell (**FIGURE 1.5A,B**). Collectively, these organisms are the most diverse representatives of life. Different kinds are producers or consumers in nearly all regions of Earth. Some inhabit such extreme environments as frozen desert rocks, boiling sulfurous lakes, and nuclear reactor waste. The first cells on Earth may have faced similarly hostile environments.

Traditionally, organisms without a nucleus have been called **prokaryotes**, but this designation is now used only informally. This is because, despite the similar appearance of bacteria and archaea, the two types of cells are less related to one another than we once thought. 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 (**FIGURE 1.5C**). Eukaryotic cells are typically larger and more complex than bacteria or archaea.

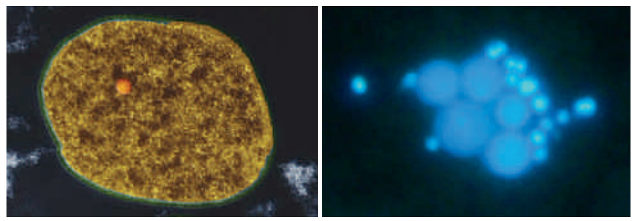
Structurally, **protists** are the simplest eukaryotes, but as a group they vary dramatically, from single-celled consumers to giant, multicelled producers.

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

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

Animals are multicelled consumers that ingest tissues or juices of other organisms. 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.

A Bacteria are the most numerous organisms on Earth. Clockwise from upper left, a bacterium with a row of iron crystals that acts like a tiny compass; a common resident of cat and dog stomachs; spiral cyanobacteria; types 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 ▸**Animated** A few representatives of life's diversity.

animal Multicelled consumer that develops through a series of stages and moves about during part or all of its life.
archaea Group of single-celled organisms that lack a nucleus but are more closely related to eukaryotes than to bacteria.
bacteria The most diverse and well-known group of single-celled organisms that lack a nucleus.
biodiversity Scope of variation among living organisms.
eukaryote Organism whose cells characteristically have a nucleus.
fungus Single-celled or multicelled eukaryotic consumer that breaks down material outside itself, then absorbs nutrients released from the breakdown.
plant A multicelled, typically photosynthetic producer.
prokaryote Single-celled organism without a nucleus.
protist Member of a diverse group of simple eukaryotes.

TAKE-HOME MESSAGE 1.4

How do organisms differ from one another?

✔ Organisms differ in their details; they show tremendous variation in observable characteristics.

✔ We divide Earth's biodiversity into broad groups based on traits such as having a nucleus or being multicellular.

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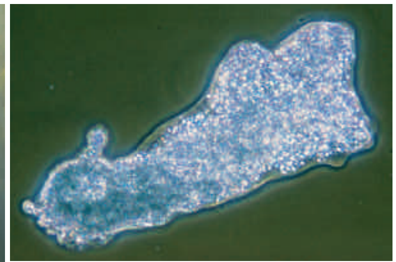

Protists are a group of extremely diverse eukaryotes that range from giant multicelled seaweeds to microscopic single cells.

Plants are multicelled eukaryotes, most of which are photosynthetic. Nearly all have roots, stems, and leaves.

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

Animals are multicelled eukaryotes that ingest tissues or juices of other organisms. All actively move about during at least part of their life.

C Eukaryotes are single-celled or multicelled organisms whose DNA is contained within a nucleus.

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