LESSON 1

Our Planet of Life

Guiding Question: What is biodiversity?

Knowledge and Skills

- Differentiate the components of biodiversity.
- Explain two ways in which biodiversity varies across groups or geography.
- Describe the economic benefits of biodiversity.

Reading Strategy and Vocabulary

Reading Strategy Before you read, set up a main idea and details chart for this lesson. Use the blue headings for main ideas. As you read, fill in supporting details from the text.

Vocabulary biodiversity, species diversity, genetic diversity, ecosystem diversity

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7.1 LESSON PLAN PREVIEW

Differentiated Instruction Help struggling students organize information about genetic, species, and ecosystem diversity.

Inquiry Use a globe to help students visualize the latitudinal gradient.

Real World Groups identify ways biodiversity enhances their lives.

7.1 RESOURCES

Outdoors Lab, *Exploring Plant Diversity* • Lesson 7.1 Worksheets • Lesson 7.1 Assessment • Chapter 7 Overview Presentation

SCIENTISTS WORLDWIDE are confirming what most people have suspected for a long time: many once-thriving species are disappearing. This suggests the question, "Does it matter?" There are a number of ways to answer that—from the practical to the ethical. To formulate your own answer, it is important to understand just how much life there is on our planet and what might happen if it is lost forever.

Biodiversity

Species diversity, genetic diversity, and ecosystem diversity are all parts of an area's overall biodiversity.

From tigers to tiger beetles, Earth is full of life. The variety of life across all levels of ecological organization is called **biodiversity.** Overall biodiversity, whether of an isolated population of organisms or the entire biosphere, includes genetic diversity, species diversity, and ecosystem diversity, as seen in **Figure 1.** Of these levels of biodiversity, the most commonly used and easiest to visualize is species diversity.

Genetic diversity Genetic diversity describes the differences in DNA among individuals of a population or species.

Species diversity The number or variety of species in a given area is known as species diversity.

Ecosystem diversity An area's ecosystem diversity refers to its variety of ecosystems, communities, or habitats.

FIGURE 1 Levels of Biodiversity The concept of biodiversity encompasses several levels in the hierarchy of life.

Species Diversity Recall that members of a species share certain characteristics, including similar DNA, and can breed with one another to produce fertile offspring. **Species diversity** is the number or variety of species in a particular region. There is currently a massive project underway, called the *Encyclopedia of Life*, that is attempting to provide an accessible online library of worldwide species diversity.

Speciation generates new species, adding to species diversity, whereas extinction decreases species diversity. Although immigration and emigration may increase or decrease species diversity locally, only speciation and extinction change it globally.

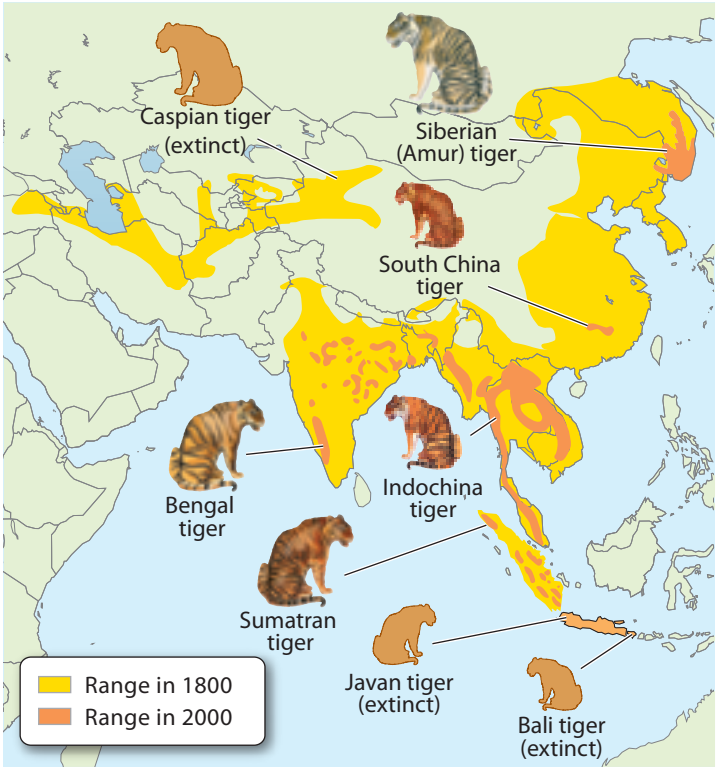
ANSWERS

Reading Checkpoint A population of organisms that has different inherited characteristics from members of the same species in a different area

Figure 2 Caspian tiger, Javan tiger, and Bali tiger

▶ ***Classifying Species*** *Taxonomists,* the scientists who classify species, use an organism's physical appearance and genetic makeup to determine its species. Species are then placed within a hierarchy of categories, called *taxonomic groups,* that reflect evolutionary relationships. Closely related species are grouped together into *genera* (singular, *genus*). In traditional classification, there are five taxonomic groups above the level of genus: family, order, class, phylum, and kingdom. As our knowledge of evolutionary relationships increases, however, there have been some changes to the system. For example, many scientists now use a taxonomic group even larger than the kingdom, called the domain, to classify phyla.

Every species is given a two-part scientific name denoting its genus and species. The tiger, *Panthera tigris,* differs from the world's other species of large cats, such as the jaguar (*Panthera onca*), the leopard (*Panthera pardus*), and the African lion (*Panthera leo*). These four species are closely related in evolutionary terms, as indicated by the genus name they share, *Panthera.* They are more distantly related to cats in other genera such as the cheetah (*Acinonyx jubatus*) and the bobcat (*Felis rufus*), although all cats are classified together in the family Felidae.



Data from the Tiger Information Center.

Connect to the Central Case

FIGURE 2 Subspecies Deforestation, hunting, and other pressures have caused tigers to disappear from most of the geographic range they historically occupied. This map contrasts the ranges of the eight tiger subspecies in the years 1800 (yellow) and 2000 (orange).
Interpret Maps Which tiger subspecies are extinct?

▶ ***Classification Below the Species Level*** Below the species level organisms may be classified into subspecies. A *subspecies* is a population of organisms that has genetically based characteristics, such as size or color, that differ from members of the same species in a different area. Subspecies are formed by the same processes that drive speciation. However, divergences stop short of producing separate species. Scientists denote subspecies with a third part of the scientific name. The Siberian tiger, *Panthera tigris altaica,* is one of five subspecies of tiger still surviving, as shown in **Figure 2.** Tiger subspecies differ in color, coat thickness, stripe patterns, and size, but could interbreed if they lived together.

Reading Checkpoint *What is a subspecies?*

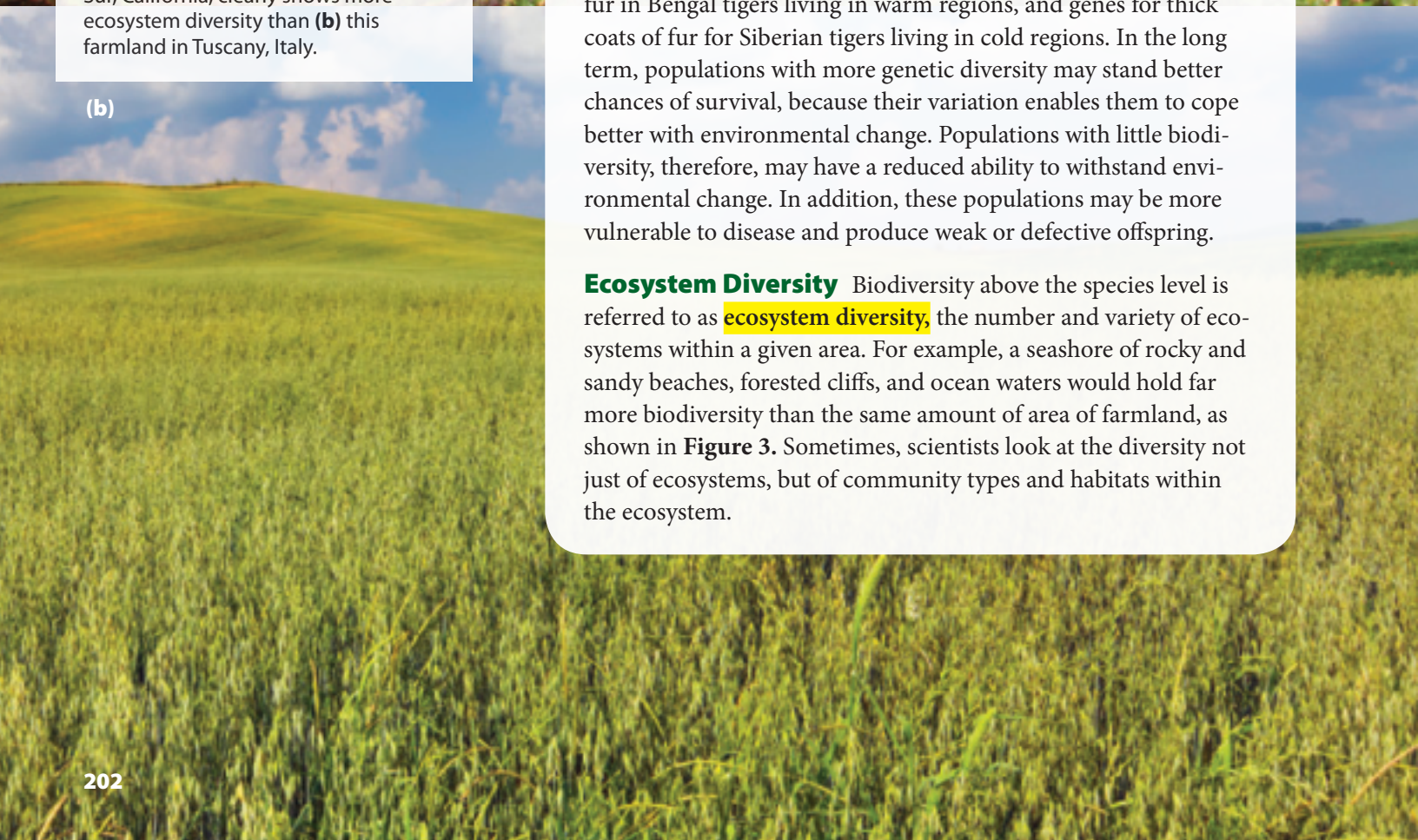


FIGURE 3 Ecosystem Diversity Ecosystem diversity is not uniform. **(a)** This area of coastline in Big Sur, California, clearly shows more ecosystem diversity than **(b)** this farmland in Tuscany, Italy.

Genetic Diversity Scientists designate subspecies when they recognize major, genetically based differences among individuals of the same species but different populations. However, within each species, all individuals vary genetically to some degree. **Genetic diversity** describes the differences in DNA among individuals within species and populations.

Genetic diversity provides the raw material for adaptation to local conditions. For example, different genes for coat thickness in tigers allowed natural selection to favor genes for thin coats of fur in Bengal tigers living in warm regions, and genes for thick coats of fur for Siberian tigers living in cold regions. In the long term, populations with more genetic diversity may stand better chances of survival, because their variation enables them to cope better with environmental change. Populations with little biodiversity, therefore, may have a reduced ability to withstand environmental change. In addition, these populations may be more vulnerable to disease and produce weak or defective offspring.

Ecosystem Diversity Biodiversity above the species level is referred to as **ecosystem diversity,** the number and variety of ecosystems within a given area. For example, a seashore of rocky and sandy beaches, forested cliffs, and ocean waters would hold far more biodiversity than the same amount of area of farmland, as shown in **Figure 3.** Sometimes, scientists look at the diversity not just of ecosystems, but of community types and habitats within the ecosystem.

Biodiversity Distribution

Biodiversity varies among taxonomic groups and geographic regions.

Coming up with precise ways to express a region's biodiversity is difficult. Scientists often express biodiversity in terms of its most easily measured component, species diversity. But counting species is a lot harder than it sounds, and scientists still can only estimate the total species richness of our planet.

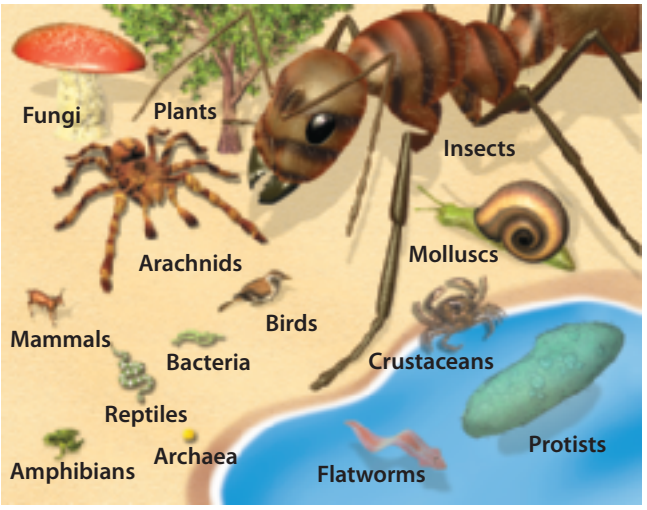
Measuring Biodiversity Species are not evenly distributed among taxonomic groups. Although most insects are small, in terms of number of known and described species, they dwarf all other forms of life, as shown in **Figure 4.** Among known insects, about 40 percent are beetles. A scientist from the Smithsonian Institution named Terry Erwin fogged rainforest trees in Central America with clouds of insecticide and then collected organisms as they died and fell from the treetops. His results, published in 1982, include finding 1200 species of beetle living on 19 trees of the same species. Of those, he concluded that 163 of the beetle species lived *only* on that particular species of tree.

So far, scientists have identified and described 1.7 million to 2 million species of plants, animals, fungi, and microorganisms. However, using a variety of methods, including tree fogging, scientists estimate the total number of species that actually exists is far greater. Most estimates are in the range of 3 million to 100 million, with best-educated guesses spanning from 5 million to 30 million. Why do these estimates vary so much? First, some areas of Earth, such as the deepest ocean, remain relatively unexplored. Second, many species, such as bacteria and many fungi, are tiny and easily overlooked. Third, many organisms are extremely difficult to identify and tell apart from other species. This is frequently the case with microbes, fungi, and small insects, but also sometimes with organisms as large as birds, trees, and whales.

Patterns of Biodiversity In addition to being unevenly distributed across organism groups, living things are also unevenly distributed across our planet. For example, there is a general increase in species richness toward the equator. This pattern of variation with latitude, called the *latitudinal gradient,* is one of the most obvious and striking patterns in ecology.

At smaller scales, diversity patterns vary with habitat type. Generally, habitats that are structurally diverse have more ecological niches and support greater species richness. For instance, forests usually support greater diversity than grasslands. For any given geographic area, species diversity tends to increase with diversity of habitats because each habitat supports a somewhat different community of organisms.

Reading Checkpoint *Why don't scientists know exactly how many species there are on Earth?*



Data from Groombridge, B., and M.D. Jenkins, 2002. *Global biodiversity: Earth's living resources in the 21st century.* UNEP-World Conservation Monitoring Centre. Cambridge, U.K.: Hoechst Foundation.

FIGURE 4 Where Insects Are King This illustration shows organisms scaled in size to the number of species known in several major groups, giving a visual sense of the difference in their species diversity. However, scientists think that many species have not been described or even discovered. So, some groups (such as bacteria, archaea, insects, flatworms, protists, fungi, and others) most likely contain far more species than we now know about.

ANSWERS

Reading Checkpoint It is hard to determine exactly how many species are on Earth because some areas of Earth are relatively unexplored, some species are easy to overlook, and some species are difficult to distinguish from one another.

Your world • your turn •

What Do You Think?

Companies search the world for organisms that can provide new drugs, foods, medicines, or other valuable products. If a company discovers a compound that could be turned into a billion-dollar drug, who should benefit? Do you think the company should have to share any profits with the country in which it found the drug? Or, should the company get to keep all of the money because it made the discovery and performed the research?

ANSWERS

What Do You Think? Answers will vary. Responses should indicate an understanding of the economic value of biodiverse ecosystems.

Benefits of Biodiversity

Biodiverse ecosystems provide economically valuable services and products.

Contrary to popular opinion, some things in life can indeed be free. Intact ecosystems provide valuable processes, known as *ecosystem services,* for all of us free of charge. The United Nations Environment Programme (UNEP) identifies ecosystem services provided by biodiversity, including purification of air and water, control of pests and diseases, and decomposition of wastes. Biodiversity also provides food, fuel, and fiber. One 1997 study published in the journal *Nature* estimated that Earth's ecosystems, such as the wetland in **Figure 5,** provide at least $33 trillion worth of ecosystem services a year.

Biodiversity and Ecosystem Function Functioning ecosystems are clearly important, but what does biodiversity have to do with it? Ecologists are finding that high levels of biodiversity tend to increase the stability of communities and ecosystems. An ecosystem is considered stable if it is both resistant and resilient. *Resistant* ecosystems can resist environmental change without losing function. *Resilient* ecosystems are affected by change but can bounce back and regain function. Most of the research on ecosystem stability has dealt with species diversity, but new work is finding that high genetic diversity can also have a stabilizing effect on ecosystems. Thus, a loss of biodiversity at any level could decrease a natural system's ability to function and provide services to our society.

What about the extinction of individual species? Ecological research suggests that this depends on which species are removed. Ecosystems are complex, and it is difficult to predict which particular species may be important. Removing a species that can be replaced by others—one grazing herbivore for another grazing herbivore, for example—may make little difference. Recall, however, that removal of a keystone species results in significant changes in an ecological system.

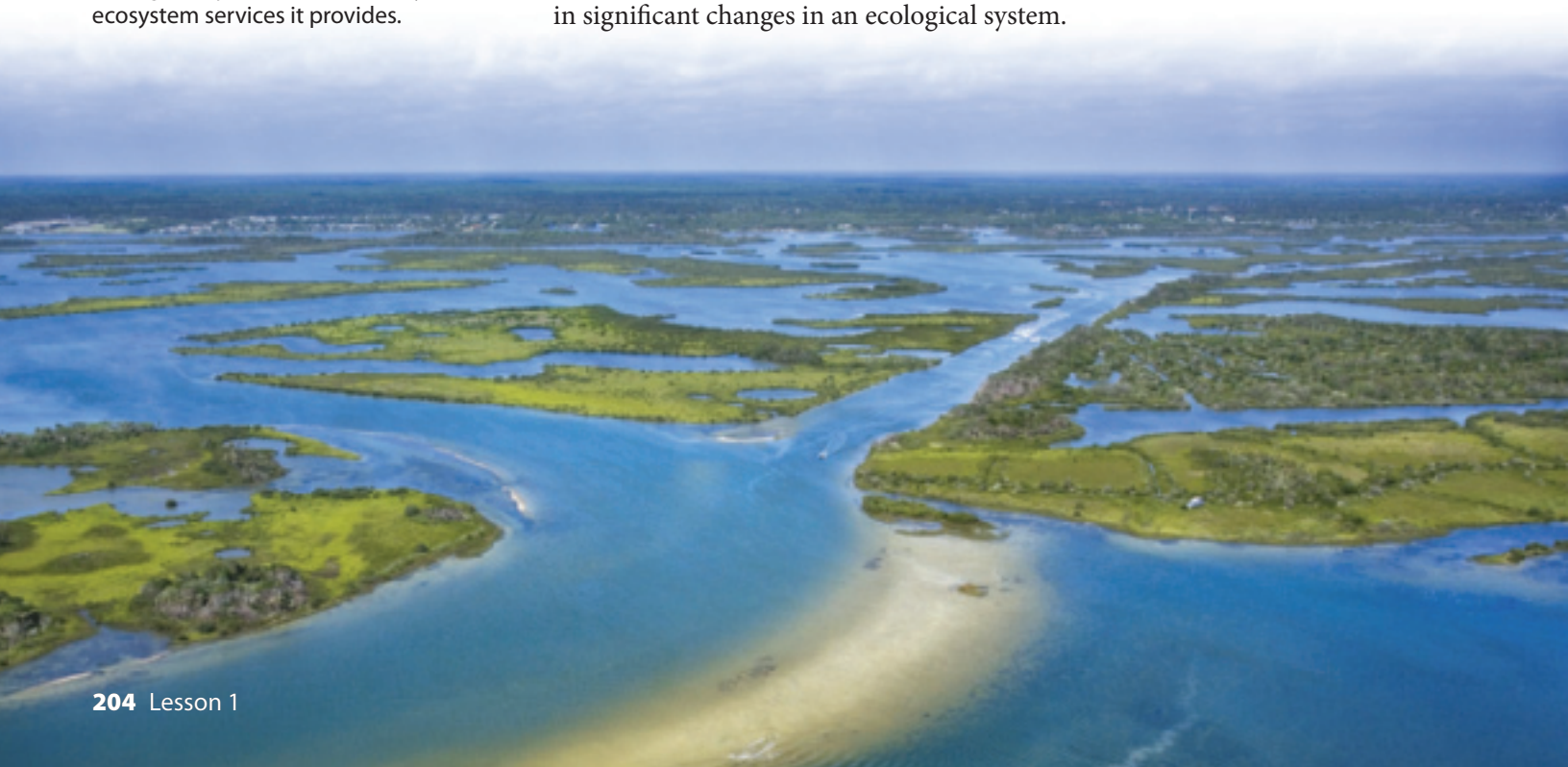


FIGURE 5 Ecosystem Goods and Services This wetland in Georgia naturally purifies the water that flows through it—just one of the many ecosystem services it provides.

FIGURE 6 Biodiversity's Benefits Nature provides us with a variety of resources—some we have only begun to use. **(a)** The fruit of the babassu palm produces large quantities of oil that can be used for everything from cooking to fuel. **(b)** Medicines derived from the rosy periwinkle are used to treat two forms of life-threatening cancer.

Top predators, such as tigers, are often considered keystone species because a single individual may prey on many other carnivores, each of which may prey on many herbivores. In turn, each herbivore may consume many plants. Thus the removal of a top predator produces effects that multiply as they cascade down the food web, ultimately changing how the ecosystem functions. Similarly, removal of a species at the base of a food web can set huge changes in motion. In Antarctica, almost all life is indirectly dependent upon microscopic, photosynthetic algae that grow beneath the ice—without them, the whole food web collapses.

Biodiversity and Agriculture Biodiversity, especially genetic diversity, benefits agriculture. Wild strains can be cross-bred with their crop plant relatives, passing on traits such as pest resistance in the process. During the 1970s, for example, a researcher discovered a maize species in Mexico known as *Zea diploperennis*. This maize is highly resistant to disease, and it is a perennial, meaning it will grow back year after year without being replanted. Plant breeders can cross-breed *Zea diploperennis* with other maize species to create a variety of disease-resistant, perennial hybrids. In addition, scientists continue to discover new plants that have potential for widespread use. The babassu palm *(Orbignya phalerata)* in **Figure 6a,** for example, yields more vegetable oil than either coconut or palm nuts. The oil, similar to coconut oil, can be used for cooking, fuel, and many industrial processes.

Biodiversity and Medicine Every species that goes extinct represents a lost opportunity to find a cure for a disease. The rosy periwinkle *(Catharanthus roseus)* in **Figure 6b,** for example, produces compounds that treat Hodgkin's lymphoma and a particularly deadly form of leukemia. Had this native plant of Madagascar become extinct before its discovery by medical researchers, these deadly diseases would have claimed far more victims. Many other common medicines come from plants, such as the cancer drugs colchicine and paclitaxel, the heart medicine digitoxin, and the antimalarial drug quinine. In fact, of the 150 most often prescribed drugs in the United States, 118 originate from nature, not from labs.

Reading Checkpoint *How can the extinction of a single species affect how an ecosystem functions?*

BIG QUESTION

Why is it important to protect biodiversity?

Perspective Have students write a short paragraph explaining the importance of preserving biodiversity from the point of view of one of the following: a medical researcher, a farmer, a professional chef, an ecotourist, or an organism (other than a human) in an ecosystem. Have several students share their completed paragraphs with the class. Wrap up the activity with a brief discussion emphasizing the many reasons why it is important to protect biodiversity.

ANSWERS

Reading Checkpoint Extinction of even a single keystone species will cause significant change to the ecosystem. Extinction of a species that is easily replaced by others may have little impact.

FIGURE 7 Ecotourism Ecotourism can bring millions of dollars into a nation's economy. Here, a tourist is photographing cheetahs on the Masai Mara Game Reserve in Kenya.

Biodiversity, Tourism, and Recreation

Besides providing for our food and health, biodiversity can be a direct source of income. *Ecotourism* describes environmentally responsible travel to protected natural areas for the purpose of appreciating nature, promoting conservation, and providing economic benefits to local peoples. Ecotourism is different from tourism because it emphasizes conservation, education, sustainability, and community participation.

Ecotourism has become a vital source of income for nations such as Costa Rica, with its rain forests; Australia, with its Great Barrier Reef; Belize, with its reefs, caves, and rain forests; and Kenya and Tanzania, with their savanna wildlife. The United States, too, benefits from ecotourism. American national parks, for example, draw millions of visitors each year from around the world.

Money from ecotourism provides a good reason for nations, states, and local communities to preserve natural areas and species. However, critics have warned that too many visitors to natural areas can disturb and harm wildlife. As ecotourism continues to increase, so will debate over its costs and benefits for local communities and for biodiversity.

ANSWERS

Lesson 1 Assessment For answers to the Lesson 1 Assessment, see page A–10 at the back of the book.

LESSON 1 Assessment

1. **Contrast** Explain the differences among genetic diversity, species diversity, and ecosystem diversity.
2. **Apply Concepts** Do the location and general biodiversity of tropical rain forests and boreal forests agree with what you would predict according to the latitudinal gradient pattern? Explain your answer. (*Hint:* You may want to refer to the biome map in the previous chapter.)
3. **Form an Opinion** You are trying to convince a friend about the importance of protecting biodiversity. Which one of the economic benefits discussed (ecosystem function, agricultural, medical, recreational) makes the strongest argument? Why?
4. Explore the **BIG**QUESTION Scientists are worried about the future of some species that have experienced extreme decreases in both population size and genetic diversity, including cheetahs, bison, and elephant seals. Using the concept of genetic diversity, explain why these animals may be in trouble even if their population sizes have increased in recent years.