Science and the Environment

CHAPTER 1

READING WARM-UP

Before you read this chapter, take a few minutes to answer the following questions in your ***EcoLog.***

1. How do you define the term *environment*? Are humans part of the environment?
2. How can science help us understand and solve environmental problems?

More than 2,700 m (9,000 ft) above sea level, a forest ecologist is studying biodiversity in a Costa Rican rain forest. To ascend to the treetops, he shoots an arrow over a branch and hauls himself up with the attached rope.

SECTION 1
Understanding Our Environment

When someone mentions the term *environment*, some people think of a beautiful scene, such as a stream flowing through a wilderness area or a rain-forest canopy alive with blooming flowers and howling monkeys. You might not think of your backyard or neighborhood as part of your environment. In fact, the environment is everything around us. It includes the natural world as well as things produced by humans. But the environment is also more than what you can see—it is a complex web of relationships that connects us with the world we live in.

Objectives

- Define *environmental science,* and compare environmental science with ecology.
- List the five major fields of study that contribute to environmental science.
- Describe the major environmental effects of hunter-gatherers, the agricultural revolution, and the Industrial Revolution.
- Distinguish between renewable and nonrenewable resources.
- Classify environmental problems into three major categories.

Key Terms

environmental science
ecology
agriculture
natural resource
pollution
biodiversity

What Is Environmental Science?

The students from Keene High School in **Figure 1** are searching the Ashuelot River in New Hampshire for dwarf wedge mussels. The mussels, which were once abundant in the river, are now in danger of disappearing completely—and the students want to know why. To find out more, the students test water samples from different parts of the river and conduct experiments. Could the problem be that sewage is contaminating the water? Or could fertilizer from a nearby golf course be causing algae in the river to grow rapidly and use up the oxygen that the mussels need to survive? Another possible explanation might be that a small dam on the river is disrupting the mussels' reproduction.

The students' efforts have been highly praised and widely recognized. Yet they hope for a more meaningful reward—the preservation of an endangered species. The students' work is just one example of a relatively new field—**environmental science,** the study of how humans interact with the environment.

Figure 1 ▶ These students are counting the number of dwarf wedge mussels in part of the Ashuelot River. They hope that the data they collect will help preserve this endangered species.

Connection to History

Rachel Carson Alarmed by the increasing levels of pesticides and other chemicals in the environment, biologist Rachel Carson published *Silent Spring* in 1962. Carson imagined a spring morning that was silent because the birds and frogs were dead after being poisoned by pesticides. Carson's carefully researched book was enthusiastically received by the public and was read by many other scientists as well as policy makers and politicians. However, many people in the chemical industry saw *Silent Spring* as a threat to their pesticide sales and launched a $250,000 campaign to discredit Carson. Carson's research prevailed, although she died in 1964—unaware that the book she had written was instrumental in the birth of the modern environmental movement.

The Goals of Environmental Science One of the major goals of environmental science is to understand and solve environmental problems. To accomplish this goal, environmental scientists study two main types of interactions between humans and their environment. One area of study focuses on how we use natural resources, such as water and plants. The other area of study focuses on how our actions alter our environment. To study these interactions, environmental scientists must gather and analyze information from many different disciplines.

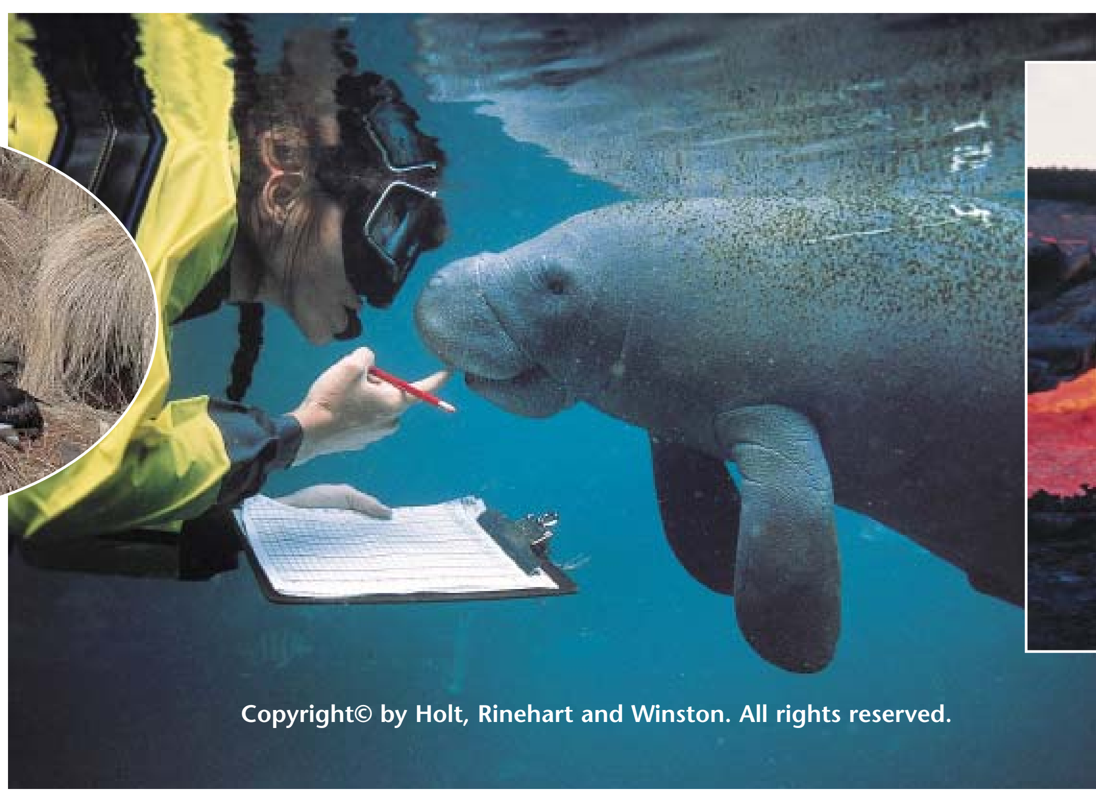
Many Fields of Study Environmental science is an interdisciplinary science, which means that it involves many fields of study. One important foundation of environmental science is ecology. **Ecology** is the study of how living things interact with each other and with their nonliving environment. For example, an ecologist might study the relationship between bees and the plants bees pollinate. However, an environmental scientist might investigate how the nesting behavior of bees is influenced by human activities such as the planting of suburban landscaping.

Many sciences other than ecology also contribute to environmental science. For example, chemistry helps us understand the nature of pollutants. Geology helps us model how pollutants travel underground. Botany and zoology can provide information needed to preserve species. Paleontology, the study of fossils, can help us understand how Earth's climate has changed in the past. Using such information about the past can help us predict how future climate changes could affect life on Earth. At any given time, an environmental scientist may use information provided by other sciences. **Figure 2** shows a few examples of disciplines that contribute to environmental science.

Figure 2 ▶ Many Fields of Study

▶ This marine biologist (right) is studying a marine mammal called a *manatee.*

▶ This ornithologist (above) is studying the nesting behavior of seabirds called *albatrosses.*



But studying the environment also involves studying human populations, so environmental scientists may use information from the social sciences, which include economics, law, politics, and geography. Social sciences can help us answer questions such as, How do cultural attitudes affect the ways that people use the U.S. park system? or How does human migration from rural to urban areas affect the local environment? **Table 1** lists some of the major fields of study that contribute to the study of environmental science.

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Table 1

Major Fields of Study That Contribute to Environmental Science	
Biology is the study of living organisms.	**Zoology** is the study of animals. **Botany** is the study of plants. **Microbiology** is the study of microorganisms. **Ecology** is the study of how organisms interact with their environment and each other.
Earth science is the study of the Earth's nonliving systems and the planet as a whole.	**Geology** is the study of the Earth's surface, interior processes, and history. **Paleontology** is the study of fossils and ancient life. **Climatology** is the study of the Earth's atmosphere and climate. **Hydrology** is the study of Earth's water resources.
Physics is the study of matter and energy.	**Engineering** is the science by which matter and energy are made useful to humans in structures, machines, and products.
Chemistry is the study of chemicals and their interactions.	**Biochemistry** is the study of the chemistry of living things. **Geochemistry,** a branch of geology, is the study of the chemistry of materials such as rocks, soil, and water.
Social sciences are the study of human populations.	**Geography** is the study of the relationship between human populations and Earth's features. **Anthropology** is the study of the interactions of the biological, cultural, geographical, and historical aspects of humankind. **Sociology** is the study of human population dynamics and statistics.

▶ This geologist is studying a volcano in Hawaii.

▶ This biologist is examining a plant that was grown in a lab from just a few cells.

Ecofact

The Fall of Troy Environmental problems are nothing new. Nearly 3,000 years ago, the Greek poet Homer wrote about the ancient seaport of Troy, which was located beneath a wooded hillside. The Trojans cut down all the trees on the surrounding hills. Without trees to hold the soil in place, rain washed the soil into the harbor. So much silt accumulated in the harbor that large ships could not enter and Troy's economy collapsed. Today, the ruins of Troy are several miles from the sea.

Scientists as Citizens, Citizens as Scientists

Governments, businesses, and cities recognize that studying our environment is vital to maintaining a healthy and productive society. Thus, environmental scientists are often asked to share their research with the world. **Figure 3** shows scientists at a press conference that was held after a meeting on climate change.

Often, the observations of nonscientists are the first step toward addressing an environmental problem. For example, when deformed frogs started appearing in lakes in Minnesota, middle school students noticed the problem first. Likewise, the students at Dublin Scioto High School in Ohio, shown in **Figure 3**, study box turtle habitats every year. The students want to find out how these endangered turtles live and what factors affect the turtles' nesting and hibernation sites. The students track the turtles, measure the atmospheric conditions, analyze soil samples, and map the movements of the small reptiles. Why do these efforts matter? They matter because the box turtle habitat is threatened. At the end of the year, students present their findings to city planners in hopes that the most sensitive turtle habitats will be protected.

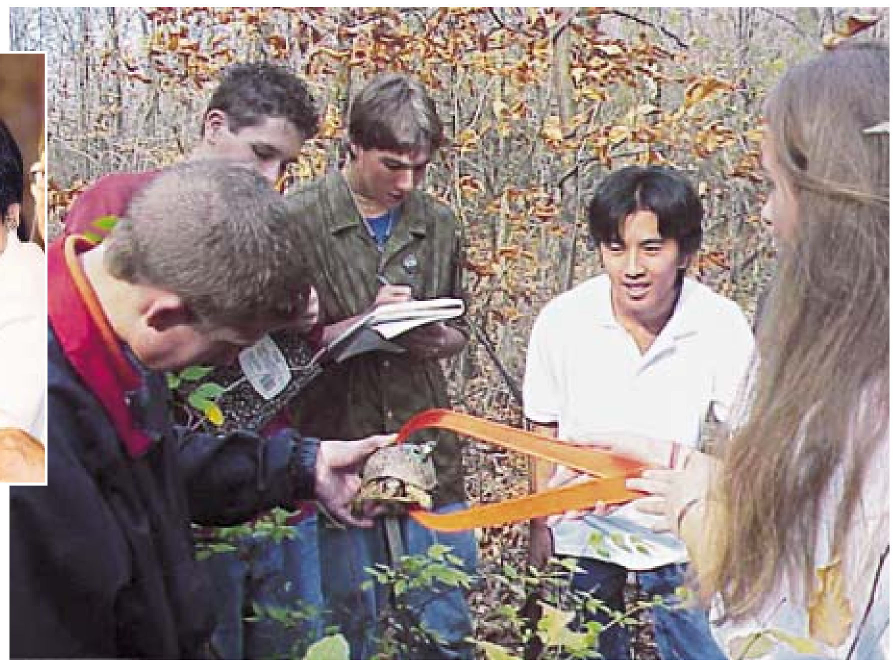

Figure 3 ▶ Environmental Science and Public Life Scientists hold a press conference on climate change (above). Students (right) are studying the movements of box turtles.

SECTION 1 Mid-Section Review

1. **Describe** the two main types of interactions that environmental scientists study. Give an example of each.
2. **Describe** the major fields of study that contribute to environmental science.
3. **Explain** why environmental science is an interdisciplinary science.

CRITICAL THINKING

4. **Making Comparisons** What is the difference between environmental science and ecology?
5. **Making Inferences** Read the Ecofact. Propose a solution to prevent the environmental problems of the seaport of Troy described in the Ecofact. READING SKILLS

Our Environment Through Time

You may think that environmental change is a modern issue, but wherever humans have hunted, grown food, or settled, they have changed the environment. For example, the land where New York City now stands was once an area where Native Americans hunted game and gathered food, as shown in **Figure 4.** The environmental change that occurred on Manhattan Island over the last 300 years was immense, yet that period of time was just a "blink" in human history.

Figure 4 ▶ Three hundred years ago Manhattan was a much different place. This painting shows an area where Native Americans hunted and fished.

Hunter-Gatherers For most of human history, people were *hunter-gatherers,* or people who obtain food by collecting plants and by hunting wild animals or scavenging their remains. Early hunter-gatherer groups were small, and they migrated from place to place as different types of food became available at different times of the year. Even today there are hunter-gatherer societies in the Amazon rain forests of South America and in New Guinea, as shown in **Figure 5.**

Hunter-gatherers affect their environment in many ways. For example, some Native American tribes hunted bison, which live in grasslands. The tribes set fires to burn the prairies and prevent the growth of trees. In this way, the tribes kept the prairies as open grassland where they could hunt bison. In addition, hunter-gatherer groups probably helped spread plants to areas where the plants did not originally grow.

In North America, a combination of rapid climate changes and overhunting by hunter-gatherers may have led to the disappearance of some large mammal species. These species include giant sloths, giant bison, mastodons, cave bears, and saber-toothed cats. Huge piles of bones have been found in places where ancient hunter-gatherers drove thousands of animals into pits and killed them.

Figure 5 ▶ This modern hunter-gatherer group lives in New Guinea, a tropical island off the north coast of Australia.

Figure 6 ▶ This grass is thought to be a relative of the modern corn plant. Native Americans may have selectively bred a grass like this to produce corn.

The Agricultural Revolution Eventually many hunter-gatherer groups began to collect the seeds of the plants they gathered and to domesticate some of the animals in their environment. **Agriculture** is the practice of growing, breeding, and caring for plants and animals that are used for food, clothing, housing, transportation, and other purposes. The practice of agriculture started in many different parts of the world over 10,000 years ago. This change had such a dramatic impact on human societies and their environment that it is often called the *agricultural revolution*.

The agricultural revolution allowed human populations to grow at an unprecedented rate. An area of land can support up to 500 times as many people by farming as it can by hunting and gathering. As populations grew, they began to concentrate in smaller areas. These changes placed increased pressure on local environments.

The agricultural revolution also changed the food we eat. The plants we grow and eat today are descended from wild plants. During harvest season, farmers collected seeds from plants that exhibited the qualities they desired. The seeds of plants with large kernels or sweet and nutritious flesh were planted and harvested again. Over the course of many generations, the domesticated plants became very different from their wild ancestors. For example, the grass shown in **Figure 6** may be related to the grass that corn was bred from.

As grasslands, forests, and wetlands were replaced with farmland, habitat was destroyed. Slash-and-burn agriculture, shown in **Figure 7**, is one of the earliest ways that land was converted to farmland. Replacing forest with farmland on a large scale can cause soil loss, floods, and water shortages. In addition, much of this converted land was farmed poorly and is no longer fertile. The destruction of farmland had far-reaching environmental effects. For example, the early civilizations of the Tigris-Euphrates River basin collapsed, in part, because the overworked soil became waterlogged and contaminated by salts.

FIELD ACTIVITY

Germinating Corn Many people do not realize how easy it is to grow corn plants from unpopped popcorn kernels. This ancient grass will sprout in a matter of days if it is watered frequently. Place a few popcorn kernels on a wet paper towel, and place the paper towel in a clear plastic cup so that the kernels are visible from the outside. Leave the cup on a windowsill for several days and water it frequently. As your plant grows, see if you can observe any grasslike features. Record your observations in your ***EcoLog.***

Figure 7 ▶ For thousands of years humans have burned forests to create fields for agriculture. In this photo, a rain forest in Thailand is being cleared for farming.

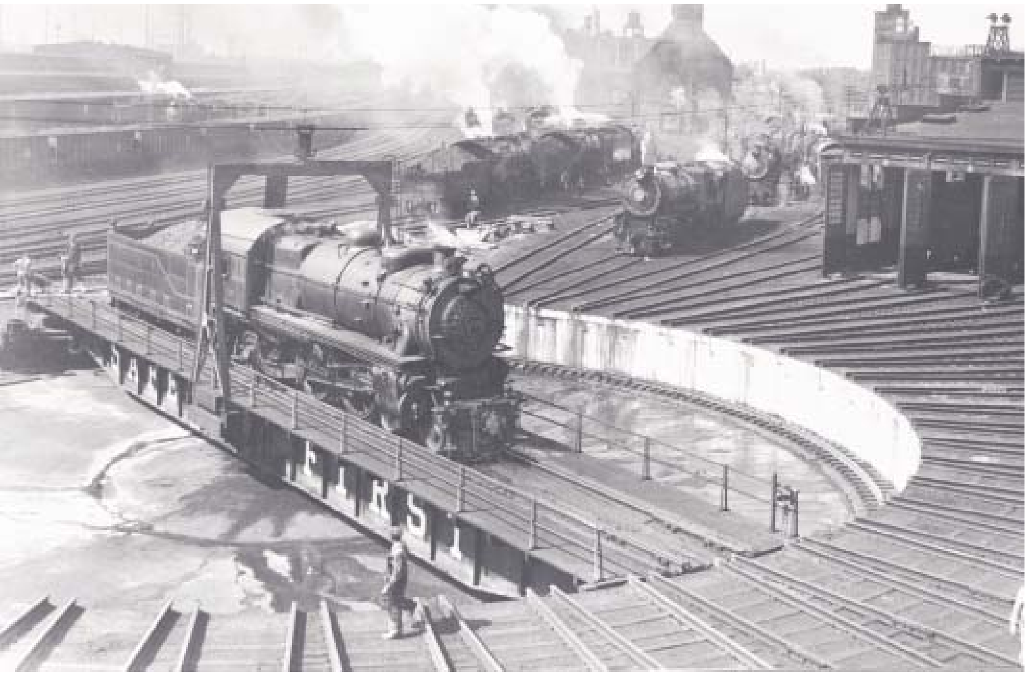

Figure 8 ▶ During much of the Industrial Revolution, few limits were placed on the air pollution caused by burning fossil fuels. Locomotives such as these are powered by burning coal.

Figure 9 ▶ Modern communication technology, such as radios, TVs, and computers characterize the later stages of the Industrial Revolution.

The Industrial Revolution For almost 10,000 years the tools of human societies were powered mainly by humans or animals. However, this pattern changed dramatically in the middle of the 1700s with the Industrial Revolution. The Industrial Revolution involved a shift from energy sources such as animal muscle and running water, to fossil fuels, such as coal and oil. The increased use of fossil fuels and machines, such as the steam engines shown in **Figure 8,** changed society and greatly increased the efficiency of agriculture, industry, and transportation.

During the Industrial Revolution, the large-scale production of goods in factories became less expensive than the local production of handmade goods. On the farm, machinery further reduced the amount of land and human labor needed to produce food. As fewer people grew their own food, populations in urban areas steadily grew. Fossil fuels and motorized vehicles also allowed food and other goods to be transported cheaply across great distances.

Improving Quality of Life The Industrial Revolution introduced many positive changes. Inventions such as the light bulb greatly improved our quality of life. Agricultural productivity increased, and sanitation, nutrition, and medical care vastly improved. Yet with all of these advances, the Industrial Revolution introduced many new environmental problems. As the human population grew, many environmental problems such as pollution and habitat loss became more common.

In the 1900s, modern societies increasingly began to use artificial substances in place of raw animal and plant products. Plastics, artificial pesticides and fertilizers, and many other materials are the result of this change. While many of these products have made life easier, we are now beginning to understand some of the environmental problems they present. Much of environmental science is concerned with the problems associated with the Industrial Revolution.

Figure 10 ▶ This photograph was taken from the moon's surface in 1968 by the crew of *Apollo 8*. Photographs such as this helped people realize the uniqueness of the planet we share.

Spaceship Earth

Earth has been compared to a ship traveling through space that cannot dispose of waste or take on new supplies as it travels. Earth is essentially a *closed system*—the only thing that enters Earth's atmosphere in large amounts is energy from the sun, and the only thing that leaves in large amounts is heat. A closed system of this sort has some potential problems. Some resources are limited, and as the population grows, the resources will be used more rapidly. In a closed system, there is also the chance that we will produce wastes more quickly than we can dispose of them.

Although the Earth can be thought of as a complete system, environmental problems can occur on different scales: local, regional, or global. For example, your community may be discussing where to build a new landfill, or local property owners may be arguing with environmentalists about the importance of a rare bird or insect. The drinking water in your region may be affected by a polluted river hundreds of miles away. Other environmental problems are global. For example, ozone-depleting chemicals released in Brazil may destroy the ozone layer that everyone on Earth depends on.

CASE STUDY

Lake Washington: An Environmental Success Story

Seattle is located on a narrow strip of land between two large bodies of water. To the west is the Puget Sound, which is part of the Pacific Ocean, and to the east is Lake Washington, which is a deep freshwater lake. During the 1940s and early 1950s, cities on the east side of Lake Washington built 11 sewer systems that emptied into the lake. Unlike raw sewage, this sewage was treated and was not a threat to human health. So, people were surprised by research in 1955 showing that the treated sewage was threatening their lake. Scientists working in Dr. W. T. Edmondson's lab at the University of Washington found a bacterium, *Oscillatoria rubescens,* that had never been seen in the lake before.

Dr. Edmondson knew that in several lakes in Europe, pollution from sewage had been followed by the appearance of *O. rubescens*. A short time after, the lakes deteriorated severely and became cloudy, smelly, and unable to support fish. The scientists studying Lake Washington realized that they were seeing the beginning of this process.

About this same time, Seattle set up the Metropolitan Problems Advisory Committee, chaired by James Ellis. Dr. Edmondson wrote Ellis a letter that explained what could be expected in the future if action was not taken. The best solution to the problem seemed to be to pump the sewage around the lake and empty it deep into Puget Sound. Although this solution may seem like it would save one body of water by polluting another one, it was actually a good choice. Diluting the sewage in Puget Sound is less of an environmental problem than allowing it to build up in an enclosed lake.

Cities around the lake had to work together to connect their sewage plants to large lines that would carry the treated sewage to Puget Sound. Because there was no legal way for cities to connect plants

Population Growth: A Local Pressure One reason many environmental problems are so pressing today is that the agricultural revolution and the Industrial Revolution allowed the human population to grow much faster than it had ever grown before. The development of modern medicine and sanitation also helped increase the human population. As shown in **Figure 11,** the human population almost quadrupled during the 20th century. Producing enough food for such a large population has environmental consequences. In the past 50 years, nations have used vast amounts of resources to meet the world's need for food. Many of the environmental problems that affect us today such as habitat destruction and pesticide pollution are the result of feeding the world in the 20th century.

There are many different predictions of population growth for the future. But most scientists think that the human population will almost double in the 21st century before it begins to stabilize. We can expect that the pressure on the environment will continue to increase as the human population and its need for food and resources grows.

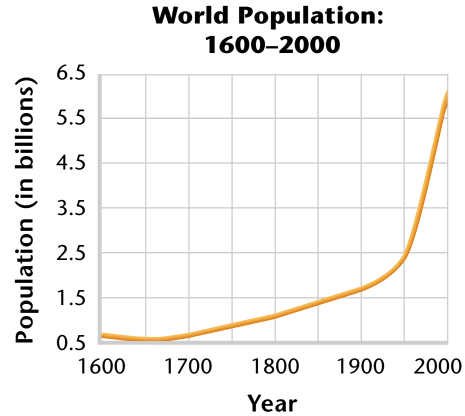

Figure 11 ▶ The human population is now more than 10 times larger than the population of 400 years ago.

▶ Lake Washington is now clean enough for everyone to enjoy.

at the time, Ellis successfully worked for the passage of a bill in the state legislature that set up committees to handle projects of this kind. Newspaper articles and letters to the editor addressed the issue. Public forums and discussion groups were also held.

The first sewage plant was connected in 1963. Today, the lake is clearer than it has been since scientists began their studies of the lake in the 1930s. The story of Lake Washington is an example of how environmental science and public action work together to solve environmental problems. Science was essential to understanding a healthy lake ecosystem, to documenting changes that were beginning to cause problems, and to making predictions about what would happen if changes were made or if nothing was done. Engineers offered practical solutions to the problem of moving the sewage. Legislators and civic leaders addressed the legal problems. Volunteers, local media, and local activists provided public education and pressed to get the problem solved quickly. The clear, blue waters of Lake Washington stand as a monument to citizens' desires to live in a clean, healthy environment and to their ability to work together to make it happen.

CRITICAL THINKING

1. Analyzing Processes Explain how each person and group played a crucial role in the cleanup of Lake Washington.

2. Analyzing Relationships How was the scientists' work similar to the work of the Keene High School students you read about in this section?

QuickLAB

Classifying Resources

Procedure

1. Create a table similar to Table 2.
2. Choose five objects in your classroom, such as a **pencil**, a **notebook**, or a **chair**.
3. Observe your objects closely, and list the resources that comprise them. For example, a pencil is made of wood, graphite, paint, aluminum, rubber, and pumice.
4. Classify the resources you have observed as nonrenewable or renewable.

Analysis

1. What percentage of the resources you observed are renewable? What percentage of the resources are nonrenewable?
2. Hypothesize the origin of three of the resources you observed. If time permits, research the origin of the resources you chose to find out if you were correct.

What Are Our Main Environmental Problems?

You may feel as though the world has an unlimited variety of environmental problems. But we can generally group environmental problems into three categories: resource depletion, pollution, or loss of biodiversity.

Resource Depletion Any natural material that is used by humans is called a **natural resource.** Natural resources can be classified as renewable and nonrenewable as shown in **Table 2.** A *renewable resource* is a resource that can be replaced relatively quickly by natural processes. Fresh water, air, soil, trees, and crops are all resources that can be renewed. Energy from the sun is also a renewable resource. A *nonrenewable resource* is a resource that forms at a much slower rate than the rate that it is consumed. The most common nonrenewable resources are minerals and fossil fuels. Once the supply of a nonrenewable resource is used up, it may take millions of years to replenish it.

Resources are said to be *depleted* when a large fraction of the resource has been used up. **Figure 12** shows a mine where copper, a nonrenewable resource, is removed from the Earth's crust. Some renewable resources can also be depleted. For example, if trees are harvested faster than they can grow naturally in an area, deforestation will result.

Pollution One effect of the Industrial Revolution is that societies began to produce wastes faster than the wastes could be disposed of. These wastes accumulate in the environment and cause pollution. **Pollution** is an undesired change in air, water, or soil that adversely affects the health, survival, or activities of humans or

Table 2 ▼

Renewable and Nonrenewable Resources

Renewable	Nonrenewable
energy from the sun water wood soil air	metals such as iron, aluminum, and copper nonmetallic materials such as salt, sand, and clay fossil fuels

Figure 12 ▶ More than 12 million tons of copper have been mined from the Bingham mine in Utah. Once all of the copper that can be profitably extracted is used up, the copper in this mine will be depleted.

other organisms. Much of the pollution that troubles us today is produced by human activities. Air pollution in Mexico City, as shown in **Figure 13,** is dangerously high, mostly because of car exhaust.

There are two main types of pollutants. *Biodegradable pollutants* are pollutants that can be broken down by natural processes. They include materials such as human sewage or a stack of newspapers. Degradable pollutants are a problem only when they accumulate faster than they can be broken down. Pollutants that cannot be broken down by natural processes, such as mercury, lead, and some types of plastic, are called *nondegradable pollutants*. Because nondegradable pollutants do not break down easily, they can build up to dangerous levels in the environment.

Figure 13 ▶ The problem of air pollution in Mexico City is compounded because the city is located in a valley that traps air pollutants.

Loss of Biodiversity The term biodiversity refers to the number and variety of species that live in an area. Earth has been home to hundreds of millions of species. Yet only a fraction of those species are alive today—the others are extinct. Extinction is a natural process, and several large-scale extinctions, or *mass extinctions,* have occurred throughout Earth's history. For example, at the end of the Permian period, 250 million years ago, as much as 95 percent of all species became extinct. So why should we be concerned about the modern extinction of an individual species such as the Tasmanian tiger shown in **Figure 14**?

The organisms that share the world with us can be considered natural resources. We depend on other organisms for food, for the oxygen we breathe, and for many other things. A species that is extinct is gone forever, so a species can be considered a nonrenewable resource. We have only limited information about how modern extinction rates compare with those of other periods in Earth's history. But many scientists think that if current rates of extinction continue, it may cause problems for human populations in the future. Many people also argue that all species have potential economic, ecological, scientific, aesthetic, and recreational value, so it is important to preserve them.

Figure 14 ▶ The Tasmanian tiger may be the only mammal to become extinct in the past 200 years on the island of Tasmania. During the same period of time, on nearby Australia, as much as 50 percent of all mammals became extinct.

SECTION 1 Review

1. **Explain** how hunter-gatherers affected the environment in which they lived.
2. **Describe** the major environmental effects of the agricultural revolution and the Industrial Revolution.
3. **Explain** how environmental problems can be local, regional, or global. Give one example of each.
4. **Identify** an example of a natural source of pollution.

CRITICAL THINKING

5. **Analyzing Relationships** How did the Industrial Revolution affect human population growth?
6. **Making Inferences** Fossil fuels are said to be nonrenewable resources, yet they are produced by the Earth over millions of years. By what time frame are they considered nonrenewable? Write a paragraph that explains your answer. WRITING SKILLS