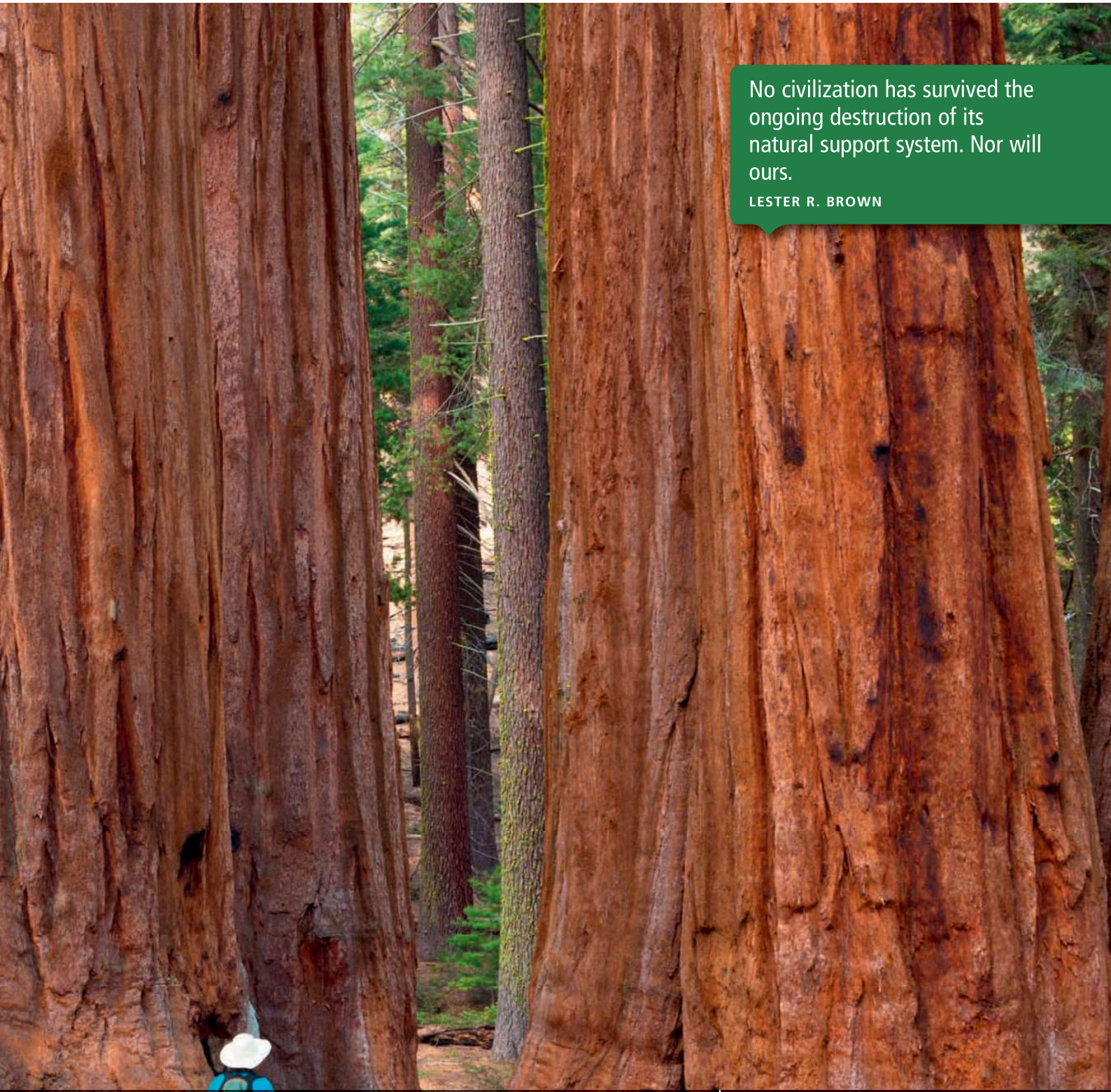
CHAPTER 1

The Environment and Sustainability



No civilization has survived the ongoing destruction of its natural support system. Nor will ours.

LESTER R. BROWN

Key Questions

1.1 What are some key principles of sustainability?

1.2 How are our ecological footprints affecting the earth?

1.3 What causes environmental problems and why do they persist?

1.4 What is an environmentally sustainable society?

Forests such as this one in California's Sequoia National Park help to sustain all life and economies.

Robert Harding World Imagery/Alamy Stock Photo

Core Case Study

Learning from the Earth

Sustainability is the capacity of the earth's natural systems that support life and human social systems to survive or adapt to changing environmental conditions indefinitely. Sustainability is the big idea and the integrating theme of this book.

The earth is a remarkable example of a sustainable system. Life on the earth has existed for around 3.8 billion years. During this time, the planet has experienced several catastrophic environmental changes. They include gigantic meteorite impacts, ice ages lasting millions of years, long warming periods that melted land-based ice and raised sea levels by hundreds of feet, and five mass extinctions—each wiping out 60–95% of the world's species. Despite these dramatic environmental changes, an astonishing variety of life has survived.

How has life survived such challenges? Long before humans arrived, organisms had developed abilities to use sunlight to make their food and to recycle all of the nutrients they needed for survival. Organisms have developed amazing abilities to find food and survive. Spiders create webs strong enough to capture fast-moving flying insects. Bats have a radar system for finding prey and avoiding collisions. These and many other abilities and materials were developed without the use of the high-temperature or high-pressure processes or the harmful chemicals that we employ in manufacturing.

This explains why many scientists call for us to focus on learning from the earth about how to live more sustainably. In recent years, there have been efforts to make people more aware of such earth wisdom. Biologist Janine Benyus (Individuals Matter 1.1, p. 10) is a pioneer in this area. In 1997 she coined the term **biomimicry** to describe the rapidly growing scientific effort to understand, mimic, and catalog the ingenious ways in which nature has sustained life on the earth for 3.8 billion years. She views the earth's life-support system as the world's longest and most successful research and development laboratory.

How do geckos (Figure 1.1, left) cling to and walk on windows, walls, and ceilings? Scientists have learned that these little lizards have many thousands of tiny hairs growing in ridges on the toes of their feet and that each hair is divided into a number of segments that geckos use to grasp the tiniest ridges and cracks on a surface (Figure 1.1, right). They release their iron grip by tipping their foot until the hairs let go.

This discovery led to the development of a sticky, toxin-free "gecko tape" that could replace toxin-containing glues and tapes. It is an excellent example of biomimicry and you will see many more of such examples throughout this book.

Nature can teach us how to live more sustainably on the amazing planet that is our only home. As Benyus puts it, after billions of years of trial-and-error research and development: "Nature knows what works, what is appropriate, and what lasts here on Earth."

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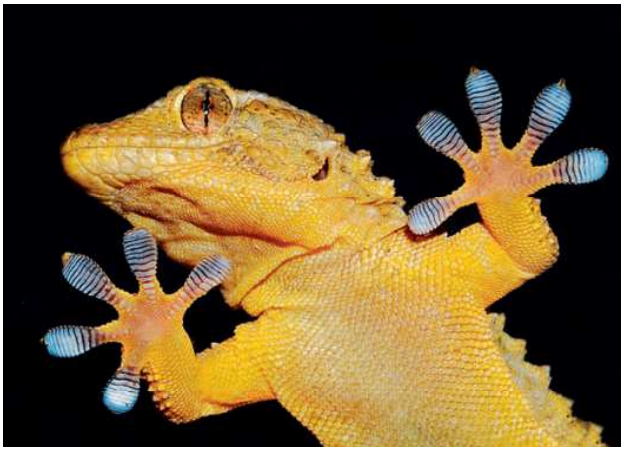

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FIGURE 1.1 The gecko (left) has an amazing ability to cling to surfaces because of projections from many thousands of tiny hairs on its toes (right).

1.1 WHAT ARE SOME KEY PRINCIPLES OF SUSTAINABILITY?

CONCEPT 1.1A Life on the earth has been sustained for billions of years by solar energy, biodiversity, and chemical cycling.

CONCEPT 1.1B Our lives and economies depend on energy from the sun and on natural resources and ecosystem services (*natural capital*) provided by the earth.

CONCEPT 1.1C We could live more sustainably by following six principles of sustainability.

Environmental Science Is a Study of Connections in Nature

The **environment** is everything around you. It includes all the living things (such as plants and animals) and the nonliving things (such as air, water, and sunlight) with which you interact. You are part of nature and live in the environment, as reflected in the title of this textbook. Despite humankind's many scientific and technological advances, our lives depend on sunlight and the earth for clean air and water, food, shelter, energy, fertile soil, a livable climate, and other components of the planet's *life-support system*.

Environmental science is a study of connections nature. It is an interdisciplinary study of **(1)** how the earth (nature) works and has survived and thrived, **(2)** how humans interact with the environment, and **(3)** how we can live more sustainably. It strives to answer several questions: What environmental problems do we face? How serious are they? How do they interact? What are their causes? How has nature solved such problems? How can we solve such problems? To answer such questions, environmental science integrates information and ideas from fields such as biology, chemistry, geology, geography, economics, political science, and ethics.

A key component of environmental science is **ecology**, the branch of biology that focuses on how living organisms interact with the living and nonliving parts of their environment. Each of the earth's organisms, or living things, belongs to a **species**, or a group of organisms having a unique set of characteristics that set it apart from other groups.

A major focus of ecology is the study of ecosystems. An **ecosystem** is a set of organisms within a defined area of land or volume of water that interact with one another and with their environment of nonliving matter and energy. For example, a forest ecosystem consists of plants (especially trees; see chapter-opening photo), animals, and other organisms that decompose organic materials. These organisms interact with one another, with solar energy, and with the chemicals in the forest's air, water, and soil.

Environmental science and ecology should not be confused with **environmentalism** or **environmental activism**, which is a social movement dedicated to protecting the earth's life and its resources. Environmentalism is practiced more in the realms of politics and ethics than in science. However, the findings of environmental scientists can provide evidence to back the claims and activities of environmentalists.

Learning from the Earth: Three Scientific Principles of Sustainability

The latest version of our species has been around for about 200,000 years—less than the blink of an eye, relative to the 3.8 billion years life has existed on the earth (see the Geologic and Biological Time Scale in Supplement 6, p. S46). During our short time on the earth, and especially since 1900, we have expanded into and dominated almost all of the earth's ecosystems.

We have cleared forests and plowed grasslands to grow food on 40% of the earth's land and built cities that are home for more than half of the world's population. We use many of the world's natural resources and add pollution and wastes to the environment. We control 75% of the world's freshwater and most of ocean that covers 71% of the earth's surface. This large and growing human impact threatens the existence of many species and biological centers of life such as tropical rainforests and coral reefs. It also adds pollutants to the earth's air, water, and soil.

Three scientific natural factors play key roles in the long-term sustainability of the planet's life, as summarized below and in Figure 1.2 (**Concept 1.1A**). Understanding these three **scientific principles of sustainability**, or major *lessons from nature*, can help us move toward a more sustainable future.

- **Dependence on solar energy**: The sun's energy warms the planet and provides energy that plants use to produce **nutrients**, the chemicals that plants and animals need to survive.
- **Biodiversity**: The variety of genes, species, ecosystems, and ecosystem processes are referred to as **biodiversity** (short for *biological diversity*). Interactions among species provide vital ecosystem services and keep any population from growing too large. Biodiversity also provides ways for species to adapt to changing environmental conditions and replace species wiped out by catastrophic environmental changes with new species.
- **Chemical cycling**: The circulation of chemicals or nutrients needed to sustain life from the environment (mostly from soil and water) through various organisms and back to the environment is called **chemical cycling**, or **nutrient cycling**. The earth receives a continuous supply of energy from the sun but it receives no new supplies of life-supporting chemicals. Through billions of years of interactions with their living and nonliving environment, organisms have developed ways to continually recycle the

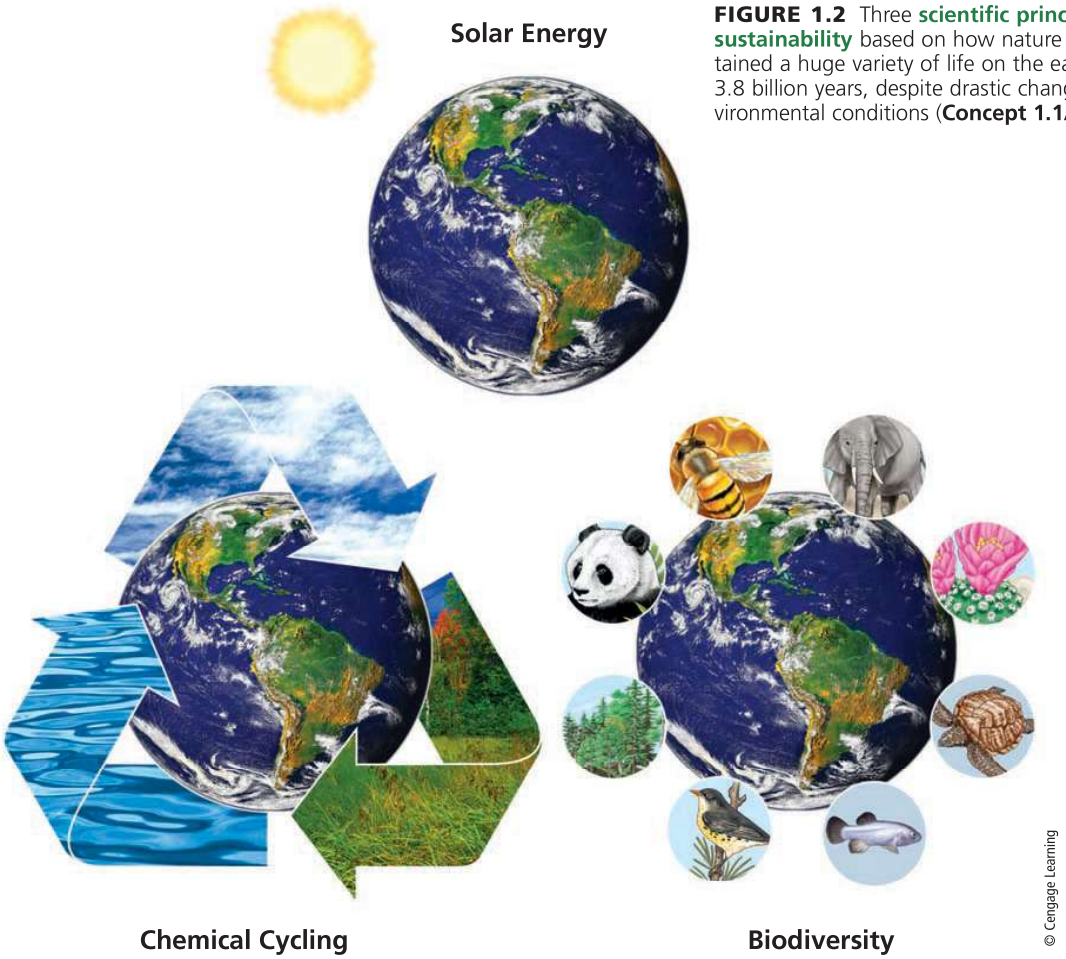


FIGURE 1.2 Three **scientific principles of sustainability** based on how nature has sustained a huge variety of life on the earth for 3.8 billion years, despite drastic changes in environmental conditions (**Concept 1.1A**).

chemicals they need to survive. This means that the wastes and decayed bodies of organisms become nutrients or raw materials for other organisms. In nature, **waste = useful resources**.

Key Components of Sustainability

Sustainability, the integrating theme of this book, has several key components that we use as subthemes. One is **natural capital**—the natural resources and ecosystem services that keep humans and other species alive and that support human economies (Figure 1.3).

Natural resources are materials and energy provided by nature that are essential or useful to humans. They fall into three categories: *inexhaustible resources*, *renewable resources*, and *nonrenewable (exhaustible) resources* (Figure 1.4). Solar energy is an **inexhaustible resource** because it is expected to last for at least 5 billion years until the death of the star we call the sun. A renewable resource is any resource that can be replenished by natural processes within hours to centuries, as long as people do not use the resource faster than natural processes can replace it. Examples include forests, grasslands, fertile topsoil, fishes, clean air, and freshwater. The highest rate at which people can use a renewable resource indefinitely without reducing its available supply is called its **sustainable yield**.

Nonrenewable or **exhaustible resources** exist in a fixed amount, or *stock*, in the earth's crust. They take millions to billions of years to form through geological processes. On the much shorter human time scale, we can use these resources faster than nature can replace them. Examples of nonrenewable resources include fossil fuel energy resources (such as oil, coal, and natural gas), metallic mineral resources (such as copper and aluminum), and nonmetallic mineral resources (such as salt and sand). As we deplete such resources, sometimes we can find substitutes.

Ecosystem services are natural services provided by healthy ecosystems that support life and human economies at no monetary cost to us (Figure 1.3). For example, forests help purify air and water, reduce soil erosion, regulate climate, and recycle nutrients. Thus, our lives and economies are sustained by energy from the sun and by natural resources and ecosystem services (natural capital) provided by the earth (**Concept 1.1B**).

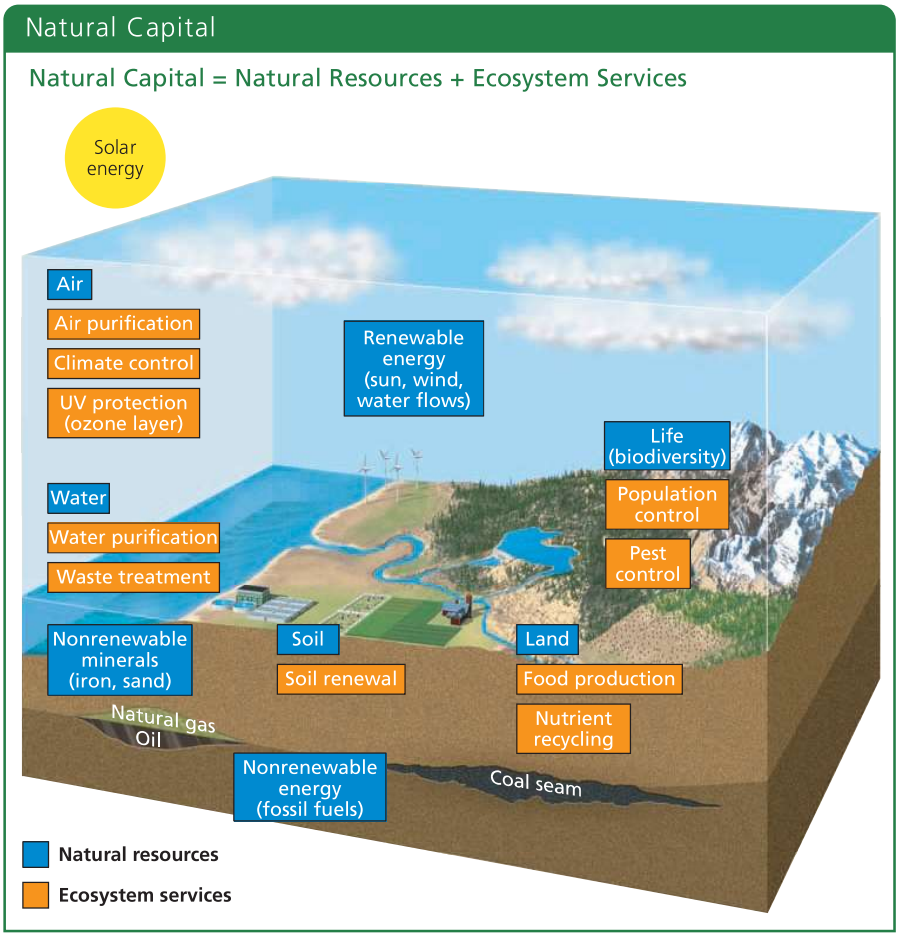


FIGURE 1.3 Natural capital consists of natural resources (blue) and ecosystem services (orange) that support and sustain the earth's life and human economies (**Concept 1.1B**).

Inexhaustible
Solar energy
Wind energy
Geothermal energy

Renewable
Trees
Topsoil
Freshwater

Nonrenewable (Exhaustible)
Fossil fuels (oil, natural gas, coal)
Iron and copper

FIGURE 1.4 We depend on a combination of inexhaustible, renewable, and exhaustible (nonrenewable) natural resources.

John Lee/Aurora Photos

FIGURE 1.5 Small remaining area of once diverse Amazon rain forest surrounded by vast soybean fields in the Brazilian state of Mato Grosso.

A vital ecosystem service is **nutrient cycling**, which is a **scientific principle of sustainability**. For example, without nutrient cycling in topsoil there would be no land plants, no pollinators (another ecosystem service), and no humans or other land animals. This would also disrupt the ecosystem services that purify air and water.

A second component of sustainability—and another subtheme of this text—is that human activities can *degrade natural capital*. We do this by using renewable resources faster than nature can restore them and by overloading the earth's normally renewable air, water, and soil with pollution and wastes. For example, people in many parts of the world are replacing forests with crop plantations (Figure 1.5) that require large inputs of energy, water, fertilizer, and pesticides. We also add pollutants to the air and dump chemicals and wastes into rivers, lakes, and oceans faster than they can be cleansed through natural processes. Many of the plastics and other synthetic materials people use poison wildlife and disrupt nutrient cycles because they cannot be broken down and used as nutrients by other organisms.

This leads us to a third component of sustainability: creating *solutions* to the environmental problems we face. For example, a solution to the loss of forests (see chapter-opening photo) is to stop burning or cutting down mature forests. This cannot be done unless citizens become educated about the ecosystem services forests provide and governments pass laws to protect forests.

Conflicts can arise when environmental protection has a negative economic effect on groups of people or certain industries. Dealing with such conflicts often involves both sides making compromises or *trade-offs*. For example, a timber company might be persuaded to plant and harvest trees in an area that it had already cleared or degraded instead of clearing an undisturbed forest area. In return, the government may subsidize (pay part of the cost) of planting the new trees.

Each of us can play an important role in learning how to live more sustainably. Thus, *individuals matter*—another sustainability subtheme of this book.

Three Additional Principles of Sustainability

Economics, politics, and ethics can provide us with three additional **principles of sustainability** (Figure 1.6):

- **Full-cost pricing** (from economics): Some economists urge us to find ways to include the harmful environmental and health costs of producing and using goods and services in their market prices. This practice, called *full-cost pricing*, would give consumers information about the harmful environmental impacts of products.
- **Win-win solutions** (from political science): Political scientists often look for *win-win solutions* to environmental problems based on cooperation and compromise that will benefit the largest number of people as well as the environment.
- **Responsibility to future generations** (from ethics): Ethics is a branch of philosophy devoted to studying ideas about what is right or wrong. According to environmental ethicists, we should leave the planet's life-support systems in a condition that is as good as or better than it is now as our responsibility to future generations.

These six **principles of sustainability** (see inside back cover of book) can serve as guidelines to help us move toward a future that is more sustainable ecologically, economically, and socially. This includes using biomimicry as a major tool for learning how to live more sustainably (**Core Case Study** and Individuals Matter 1.1).

Countries Differ in Their Resource Use and Environmental Impact

The United Nations (UN) classifies the world's countries as economically more developed or less developed, based primarily on their average income per person. **More-developed countries**—industrialized nations with high average incomes per person—include the United States, Japan, Canada, Australia, and Germany and most other European countries. These countries, with 17% of the world's population, use about 70% of the earth's natural resources. The United States, with only 4.3% of the world's population, uses about 30% of the world's resources.

All other nations are classified as **less-developed countries**, most of them in Africa, Asia, and Latin America. Some are *middle-income, moderately developed countries*

FIGURE 1.6 Three **principles of sustainability** based on economics, political science, and ethics can help us make a transition to a more environmentally and economically sustainable future.

Left: Minerva Studio/Shutterstock.com. Center: mikeledray/Shutterstock.com. Right: iStockphoto.com/ Kali Nine LLC

INDIVIDUALS MATTER 1.1

ecowatch.com

Janine Benyus: Using Nature to Inspire Sustainable Design and Living

Janine Benyus has had a lifelong interest in learning how nature works and how to live more sustainably. She realized that 99% of the species that have lived on the earth became extinct because they could not adapt to changing environmental conditions. She views the surviving species as examples of *natural genius* that we can learn from.

Benyus says that when we need to solve a problem or design a product, we should ask: Has nature done this and how did it do it? We should also think about what nature does not do as a clue to what we should not do, she argues. For example, nature does not produce waste materials or chemicals that cannot be broken down and recycled.

Benyus has set up the nonprofit Biomimicry Institute that has developed a curriculum for K–12 and university students and has a 2-year program to train biomimicry professionals. She has also established a network called Biomimicry 3.8, named for the 3.8 billion years during which organisms have developed their genius for surviving. It is a network of scientists, engineers, architects, and designers who share examples of successful biomimicry through an online database called AskNature.org.

such as China, India, Brazil, Thailand, and Mexico. Others are *low-income, least-developed countries* such as Nigeria, Bangladesh, Congo, and Haiti. (For a map showing high-, upper-middle-, lower-middle-, and low-income countries see Supplement 4, Figure 4, p. S19). The less-developed countries, with 83% of the world's population, use about 30% of the world's natural resources.

1.2 HOW ARE OUR ECOLOGICAL FOOTPRINTS AFFECTING THE EARTH?

CONCEPT 1.2A Humans dominate the earth with the power to sustain, add to, or degrade the natural capital that supports all life and human economies.

CONCEPT 1.2B As our ecological footprints grow, we deplete and degrade more of the earth's natural capital that sustains us.

Good News: Many People Have a Better Quality of Life

As the world's dominant animal, we have an awesome power to degrade or sustain our life-support system. We decide whether forests are preserved or cut down and engineer the flows of rivers. Our activities affect the temperature of the atmosphere and the temperature and acidity of the ocean. We can also contribute to the extinction of species. At the same time, our creativity, economic growth, scientific research, grassroots political pressure by citizens, and regulatory laws have improved the quality of life for many of the earth's people, especially in the United States and in most other more-developed countries.

We have developed an astounding array of useful materials and products. We have learned how to use wood, fossil fuels, the sun, wind, flowing water, the nuclei of certain atoms, and the earth's heat (geothermal energy) to supply us with enormous amounts of energy. We have created artificial environments in the form of buildings and cities. We have invented computers to extend our brains, robots to do much of our work, and electronic networks to enable instantaneous global communication.

Globally, life spans are increasing, infant mortality is decreasing, education is on the rise, some diseases are being conquered, and the population growth rate has slowed. Although one out of seven people live in extreme poverty, we have witnessed the greatest reduction in poverty in human history. The food supply is generally more abundant and safer, air and water are getting cleaner in many parts of the world, and exposure to toxic chemicals is more avoidable. We have protected some endangered species and ecosystems and restored some grasslands and wetlands, and forests are growing back in some areas that we cleared.

Scientific research and technological advances financed by affluence helped achieve these improvements in life and environmental quality. Education also spurred many citizens to insist that businesses and governments work toward improving environmental quality. We are a globally connected species with growing access to information that could help us to shift to a more sustainable path.

We Are Living Unsustainably

According to a large body of scientific evidence, we are living unsustainably. We waste, deplete, and degrade much of the earth's life-sustaining natural capital—a process known as **environmental degradation**, or **natural capital degradation** (Figure 1.7).

According to research by the Wildlife Conservation Society and the Columbia University Center for International Earth Science Information Network, human activities directly affect about 83% of the earth's land surface (excluding Antarctica) (Figure 1.8). This land is used for urban development, growing crops, energy production, pasture for livestock, mining, timber cutting, and other purposes.

In parts of the world, we are destroying forests and grasslands, withdrawing water from some rivers and underground aquifers faster than nature replenishes them, and harvesting many fish species faster than they can be renewed. We also litter the land and oceans with wastes faster than they can be recycled by the earth's natural chemical cycles. In addition, we add pollutants to the air (including some that are altering the earth's climate), soil, aquifers, rivers, lakes, and oceans.

In many parts of the world, renewable forests are shrinking (Figure 1.5), deserts are expanding, and topsoil is eroding. The lower atmosphere is warming, floating ice and many glaciers are melting at unexpected rates, sea levels are rising, and ocean acidity is increasing. There are more intense floods, droughts, severe weather, and forest fires in many areas. In a number of regions, rivers are running dry, harvests of many species of fish are dropping sharply, and 20% of the world's species-rich coral reefs are gone and others are threatened. Species are becoming extinct at least 100 times faster than in pre-human times. And extinction rates are projected to increase at least another 100-fold during this century, creating a mass extinction caused by human activities.

In 2005 the UN released its *Millennium Ecosystem Assessment*, a 4-year study by 1,360 experts from 95 countries. According to this study, human activities have overused about 60% of the ecosystem services provided by nature (see orange boxes in Figure 1.3), mostly since 1950. According to these researchers, "human activity is putting such a strain on the natural functions of Earth that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted." They also concluded that there are scientific, economic, and political solutions to these problems that could be implemented within a few decades.

There is much talk about saving the earth, but the earth does not need saving. It has been around for 4.6 billion years, has sustained life for 3.8 billion years, and has

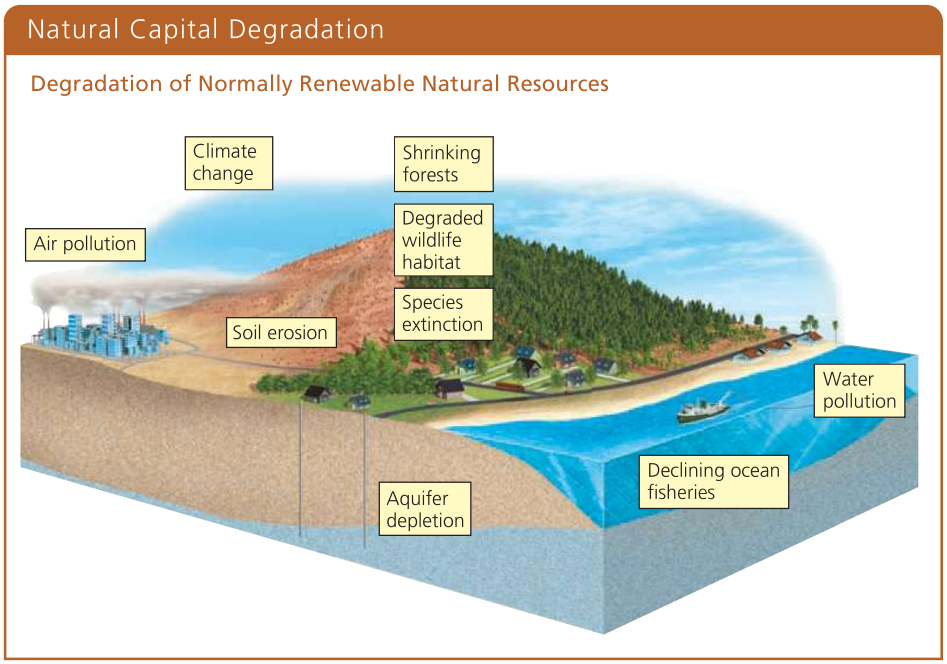


FIGURE 1.7 Natural capital degradation: Degradation of normally renewable natural resources and natural services (Figure 1.3), mostly from population growth and increased resource use per person.

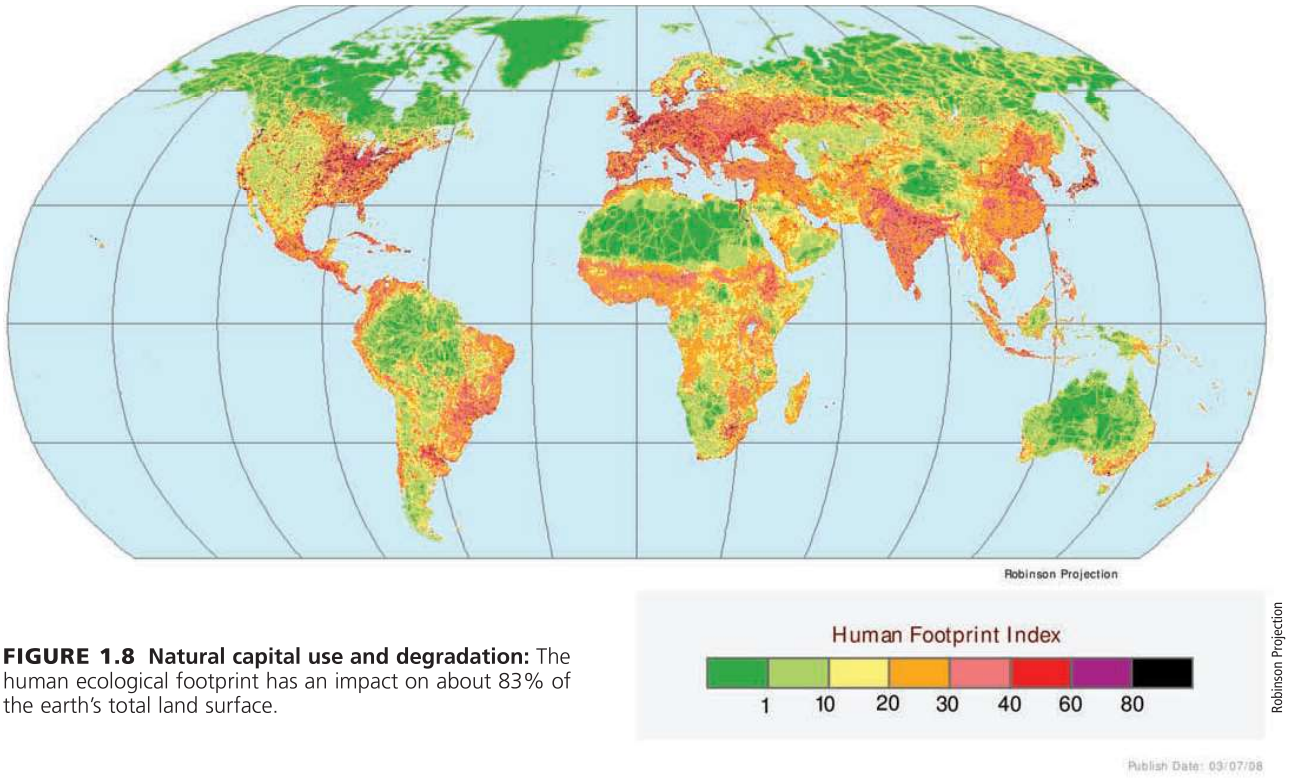


FIGURE 1.8 Natural capital use and degradation: The human ecological footprint has an impact on about 83% of the earth's total land surface.

survived massive changes in environmental conditions (**Core Case Study**). Our activities are degrading the earth's life-support system but over millions of years, it will persist. What needs saving is our own civilization and perhaps the existence of our species if we continue to degrade the earth's life-support system that sustains our economies and us.

Degrading Commonly Shared Renewable Resources: The Tragedy of the Commons

Some renewable resources are not owned by anyone and can be used by almost anyone. Examples are the atmosphere, the open ocean and its fishes, and the earth's life-support system. Other examples of less open, but often *shared resources*, are grasslands, forests, streams, and aquifers. Many of these renewable resources have been environmentally degraded. In 1968, biologist Garrett Hardin (1915–2003) called such degradation the *tragedy of the commons*.

Degradation of such shared or open-access renewable resources occurs because each user reasons, "The little bit that I use or pollute is not enough to matter, and anyway, it's a renewable resource." When the level of use is small, this logic works. Eventually, however, the cumulative effect of large numbers of people trying to exploit a widely available or shared renewable resource can degrade it and eventually exhaust or ruin it. Then no one benefits and everyone loses. That is the tragedy.

One way to deal with this difficult problem is to use a shared or open-access renewable resource at a rate well below its estimated sustainable yield. This is done by mutually agreeing to use less of the resource, regulating access to the resource, or doing both.

Another way is to convert shared renewable resources to private ownership. The reasoning is that if you own something, you are more likely to protect your investment. However, history shows that this does not necessarily happen. In addition, this approach is not possible for open-access resources such as the atmosphere, the open ocean, and our global life-support system, which cannot be divided up and sold as private property.

Our Growing Ecological Footprints

Using renewable resources benefits us but can result in natural capital degradation (Figure 1.7), pollution, and wastes. This harmful environmental impact is called an **ecological footprint**—the amount of biologically productive land and water (biocapacity) needed to supply a population in an area with renewable resources and to

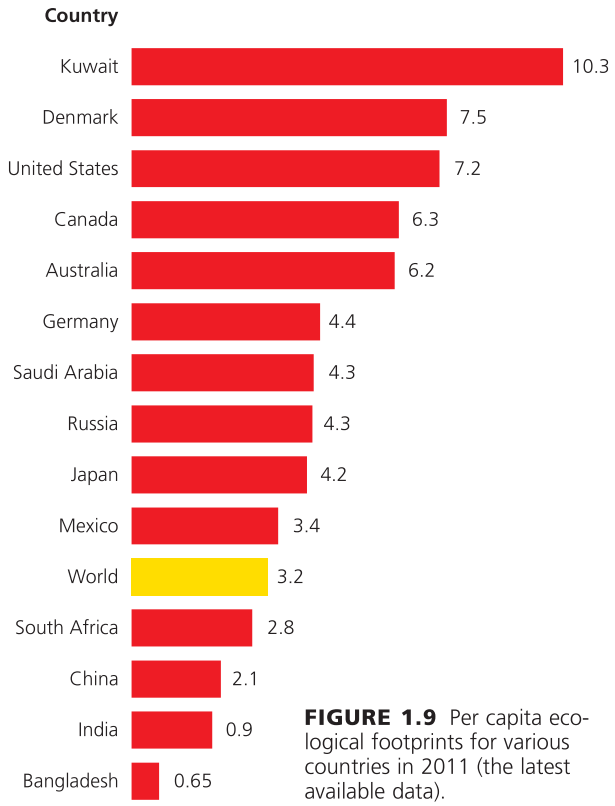


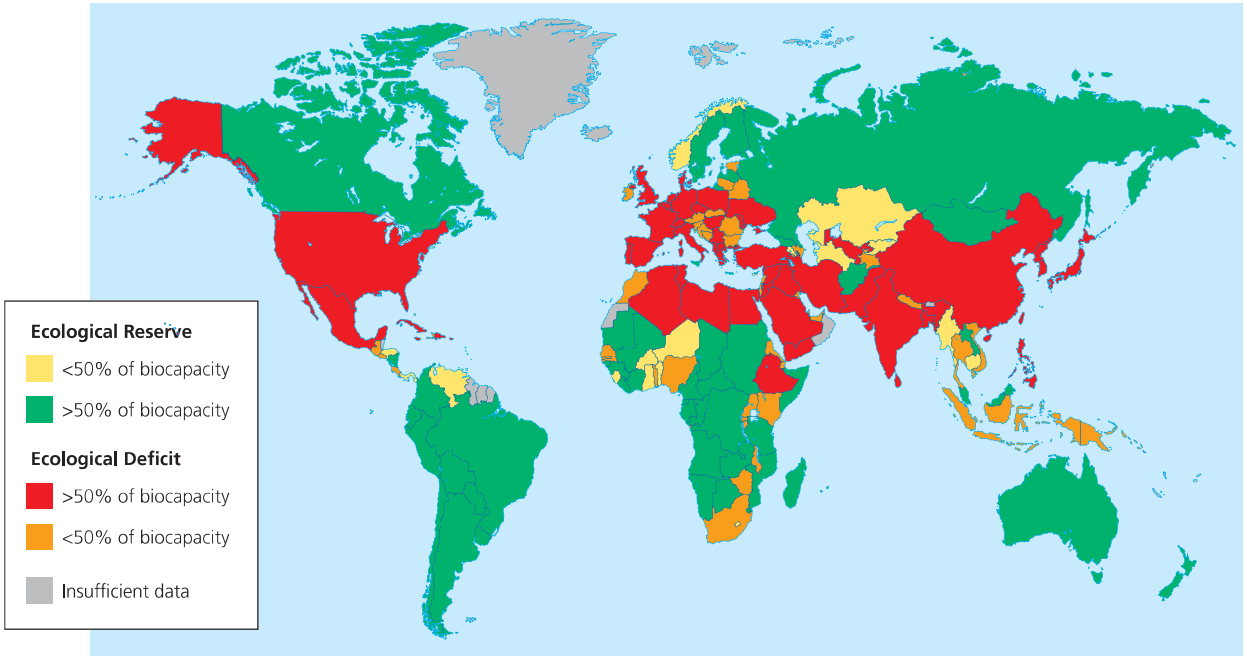
FIGURE 1.9 Per capita ecological footprints for various countries in 2011 (the latest available data).

Compiled by the authors using data from Global Footprint Network and WWF: Living Planet Report 2014.

absorb and recycle the wastes and pollution such resource use produces. Ecologist William Rees and environmental scientist Mathis Wackernagel developed this concept in the 1990s.

This measure of sustainability relates to the earth's **biocapacity**—the ability of its productive ecosystems to regenerate the renewable resources used by a population, city, region, country, or the world, and to absorb the resulting wastes and pollution indefinitely. The largest component of our ecological footprint is the air pollution, climate change, and ocean acidification caused by the burning of fossil fuels—oil, coal, and natural gas—to provide 90% of the commercial energy used in the world and in the United States. The **per capita ecological footprint** is the average ecological footprint of an individual in a given country or area (Figure 1.9).

Scientists estimate how much land and water we need to support an area's people, economy, and average lifestyle and then compare it with how much land and water is available to do this. If the total ecological footprint is larger than its biocapacity, the area is said to have an *ecological deficit*. In other words, its people are living unsustainably by depleting natural capital instead of living off the renewable resources and ecosystem services provided by such capital. Figure 1.10 is a map of ecological debtor and creditor countries (see also the Ecological Footprint Analysis exercise on p. 27).



Compiled by the authors using data from Global Footprint Network and WWF: Living Planet Report 2014.

FIGURE 1.10 *Ecological debtors and creditors*. The ecological footprints of some countries exceed their biocapacity, while other countries have ecological reserves. ***Critical thinking:*** Why do you think that the United States is an ecological debtor country?

The World Wide Fund for Nature (WWF) and the Global Footprint Network (headed by Wackernagel) estimate that we would need 1.5 planet Earths to sustain the world's 2012 rate of resource use far into the future. In other words, the world's total ecological footprint in 2012 was 50% higher than the planet's estimated long-term biocapacity. This overdraft of the earth's natural resources and ecosystem services is being passed on to future generations.

1.5 Number of earths needed to sustain the world's 2012 rate of renewable resource use indefinitely

Architect William McDonough and scientist Michael Braungart recognize the need to reduce our harmful environmental impacts but call for us to also create and expand our beneficial environmental impacts. For example, we can replant forests on degraded land, restore degraded wetlands and grasslands, and protect species from becoming extinct.

According to research in ecology and environmental science, everything in nature is connected. Thus, what we do to the earth, we do to ourselves. This is why living more sustainably requires expanding our beneficial environmental impact. Throughout this book, we discuss ways to use existing and emerging technologies and economic tools to reduce our harmful ecological footprints and to increase our beneficial environmental impacts by working with rather than against the earth.

IPAT Is Another Environmental Impact Model

In the early 1970s, scientists Paul Ehrlich and John Holdren developed a simple environmental impact model. This IPAT model shows that the environmental *impact* (**I**) of human activities is the product of three factors: *population size* (**P**), *affluence* (**A**) or resource consumption per person, and the beneficial and harmful environmental effects of *technologies* (**T**). The following equation summarizes this IPAT model:

$$\text{Impact } (\mathbf{I}) = \text{Population } (\mathbf{P}) \times \text{Affluence } (\mathbf{A}) \times \text{Technology } (\mathbf{T})$$

While the ecological footprint model emphasizes the use of renewable resources, the IPAT model includes the environmental impact of using both renewable and nonrenewable resources.

The T factor can be harmful or beneficial. Some forms of technology such as polluting factories, gas-guzzling motor vehicles, and coal-burning power plants increase our harmful environmental impact by raising the T factor. Other technologies reduce our harmful environmental impact by decreasing the T factor. Examples are pollution control and prevention technologies, fuel-efficient cars, and wind turbines and solar cells that generate electricity with a low environmental impact.

In a less-developed country such as India, population size is a more important factor than resource use per person in determining the country's environmental impact. In a highly developed country such as the United States with a much smaller population, resource use per person and the ability to develop environmentally beneficial technologies play key roles in the country's environmental impact.

China's Growing Number of Affluent Consumers

Globally, about 1.4 billion affluent consumers put immense pressure on the earth's renewable and nonrenewable natural capital. Most of these middle-class consumers live in more-developed countries. China's estimated 109 million middle-class consumers make up 8% of its population, but this number of consumers may double by 2020.

China has the world's largest population and second-largest economy. It is the world's leading consumer of wheat, rice, meat, coal, fertilizer, steel, cement, and oil. China also leads the world in the production of goods such as televisions, cell phones, refrigerators, and drones for consumers. It is the world's largest producer of wind turbines and solar cells and will soon become the world's largest producer of fuel-efficient cars. China also plans to become the world's largest manufacturer of robots to replace workers as the world's population is aging.

After 30 years of industrialization, China has two-thirds of the world's most polluted cities. Some of its major rivers are choked with waste and pollution and some areas of its coastline are devoid of fishes and other ocean life. A massive cloud of air pollution, largely generated in China, affects China and other Asian countries, areas of the Pacific Ocean, and even parts of the West Coast of North America.

Suppose that China's economy continues to grow at a rapid rate and its population size reaches 1.42 billion by 2030, as projected by UN population experts. Environmental policy expert Lester R. Brown estimates that if such projections are accurate, China will need two-thirds of the world's current grain harvest, twice the amount of paper now consumed in the world, and more than all the oil currently produced in the world. According to Brown:

> *The western economic model—the fossil fuel–based, automobile-centered, throwaway economy—is not going to work for China . . . or for the other 3 billion people in developing countries who are also dreaming the "American dream."*

Cultural Changes Can Increase or Shrink Our Ecological Footprints

Until about 10,000 to 12,000 years ago, we were mostly *hunter–gatherers* who obtained food by hunting wild animals or scavenging their remains, and gathering wild plants. Our hunter–gatherer ancestors lived in small groups, consumed few resources, had few possessions, and moved as needed to find enough food to survive.

Since then, three major cultural changes have occurred. *First* was the *agricultural revolution*, which began around 10,000 years ago when humans learned how to grow and breed plants and animals for food, clothing, and other purposes and began living in villages instead of frequently moving to find food. They had a more reliable source of food, lived longer, and produced more children who survived to adulthood.

Second was the *industrial–medical revolution*, beginning about 300 years ago when people invented machines for the large-scale production of goods in factories. Many people move from rural villages to cities to work in the factories. This shift involved learning how to get energy from fossil fuels (such as coal and oil) and how to grow large quantities of food in an efficient manner. It also included medical advances that allowed a growing number of people to have longer and healthier lives. *Third*, about 50 years ago the *information–globalization revolution* began when we developed new technologies for gaining rapid access to all kinds of information and resources on a global scale.

Each of these three cultural changes gave us more energy and new technologies with which to alter and control more of the planet's resources to meet our basic needs and increasing wants. They also allowed expansion of the human population, mostly because of larger food supplies and longer life spans. In addition, these cultural changes resulted in greater resource use, pollution, and environmental degradation and allowed us to dominate the planet and expand our ecological footprints (Figures 1.8 and 1.9).

On the other hand, some technological leaps have enabled us to shrink our ecological footprints by reducing our use of energy and matter resources and our production of wastes and pollution. For example, the use of the energy-efficient LED light bulbs and energy-efficient cars and buildings is on the rise.

Many environmental scientists and other analysts see such developments as evidence of an emerging fourth major cultural change: a **sustainability revolution**, in which we could learn to live more sustainably during this century. This involves avoiding degradation and depletion of the natural capital that supports all life and our economies and restoring natural capital that we have degraded (Figure 1.3). Making this shift involves learning how nature has sustained life for over 3.8 billion years and using these lessons from nature to shrink our ecological footprints and grow our beneficial environmental impacts. GOOD NEWS

1.3 WHAT CAUSES ENVIRONMENTAL PROBLEMS AND WHY DO THEY PERSIST?

CONCEPT 1.3A Basic causes of environmental problems are population growth, wasteful and unsustainable resource use, poverty, avoidance of full-cost pricing, increasing isolation from nature, and different environmental worldviews.

CONCEPT 1.3B Our environmental worldviews play a key role in determining whether we live unsustainably or more sustainably.

Basic Causes of Environmental Problems

To deal with the environmental problems we face we must understand their causes. According to a significant number of environmental and social scientists, the major causes of today's environmental problems are:

- population growth
- wasteful and unsustainable resource use
- poverty
- omission of the harmful environmental and health costs of goods and services in market prices
- increasing isolation from nature
- competing environmental worldviews.

We discuss each of these causes in detail in later chapters of this book. Let us begin with a brief overview from them.

The Human Population Is Growing at a Rapid Rate

Exponential growth occurs when a quantity increases at a fixed percentage per unit of time, such as 0.5% or 2% per year. Exponential growth starts slowly but after a few doublings it grows to enormous numbers because each doubling is twice the total of all earlier growth. When we plot the data for an exponentially growing quantity, we get a curve that looks like the letter J.

For an example of the awesome power of exponential growth, consider a simple form of bacterial reproduction in which one bacterium splits into two every 20 minutes. Starting with one bacterium, after 20 minutes, there would be two; after an hour, there would be eight; ten hours later, there would be more than 1,000; and after just 36 hours (assuming that nothing interfered with their reproduction), there would be enough bacteria to form a layer 0.3 meters (1 foot) deep over the entire earth's surface.

The human population has grown exponentially (Figure 1.11) to the current population of 7.3 billion people. In 2015, the rate of growth was 1.20%. Although this rate

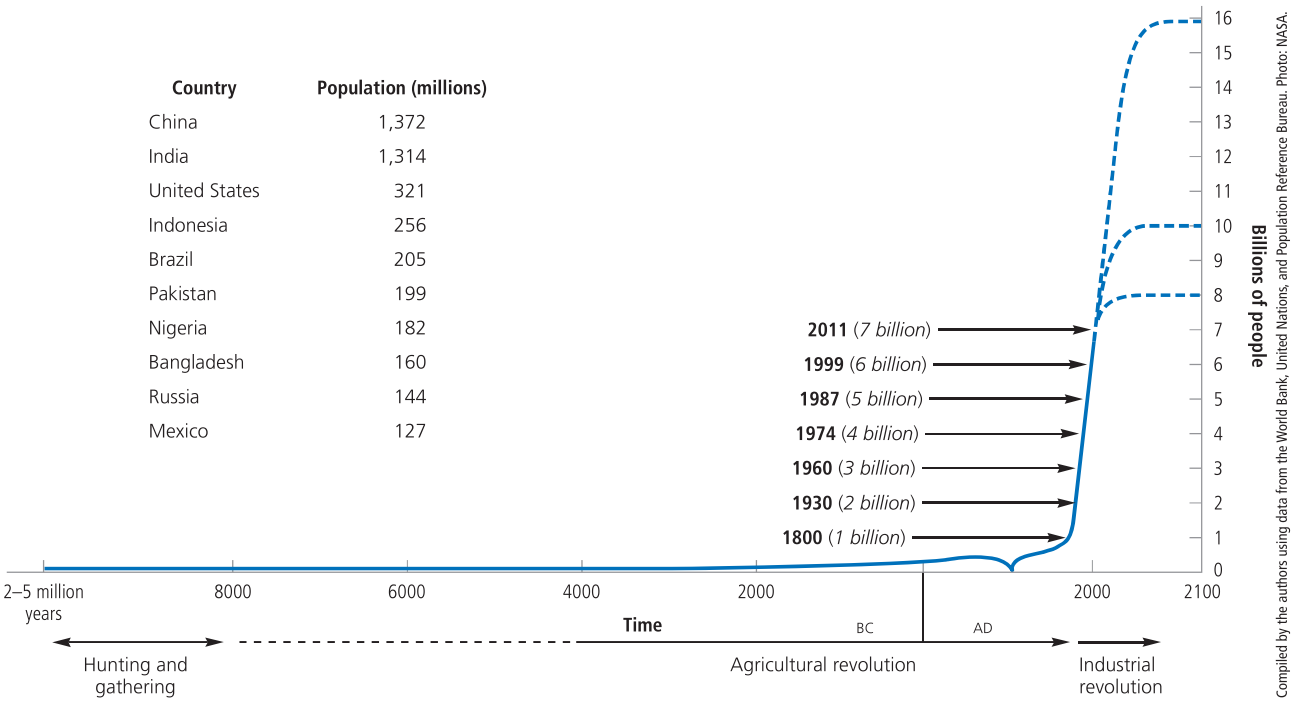


FIGURE 1.11 *Exponential growth:* The J-shaped curve represents past exponential world population growth, with projections to 2100 showing possible population stabilization as the J-shaped curve of growth changes to an S-shaped curve. The top 10 countries (left) represent nearly 60% of the world's total population in 2015. ***Data analysis:*** By what percentage did the world's population increase between 1960 and 2015? (This figure is not to scale.)

of growth seems small, it added 88.9 million people to the world's 7.34 billion people. By 2050, the population could reach 9.8 billion—an addition of 2.5 billion people.

CONSIDER THIS . . .

CONNECTIONS Exponential Growth and Doubling Time: The Rule of 70

The doubling time of the human population or of any exponentially growing quantity can be calculated by using the rule of 70: doubling time (years) = 70/annual growth rate (%). The world's population is growing at about 1.20% per year. At this rate how long will it take to double its size?

No one knows how many people the earth can support indefinitely. However, our large and expanding ecological footprints and the resulting widespread natural capital degradation are disturbing warning signs.

Some analysts call for us to reduce environmental degradation by slowing population growth and level it off at around 8 billion by 2050 instead of 9.8 billion. We examine the possible ways to do this in Chapter 6. Other analysts call for us to shift from environmentally harmful to environmentally beneficial forms of economic growth, which we discuss in Chapter 23.

Affluence and Unsustainable Resource Use

The lifestyles of the world's expanding population of consumers are built on growing affluence, or resource consumption per person, as more people earn higher incomes. As total resource consumption and average resource consumption per person increase, so does environmental degradation, wastes, and pollution from the increase in environmental footprints.

The effects can be dramatic. The WWF and the Global Footprint Network estimate that the United States, with only 4.3% of the world's population, is responsible for about 23% of the global ecological footprint. The average American consumes about 30 times the amount of resources that the average Indian consumes and 100 times the amount consumed by the average person in the world's poorest countries. The WWF has projected that we would need five planet Earths if everyone used renewable resources at the same rate as the average American did in 2012.

On the other hand, affluence can allow for widespread and better education that can lead people to become more concerned about environmental quality. Affluence also makes more money available for developing technologies to reduce pollution, environmental degradation, and resource

Dr. Morley Reed/Shutterstock.com

FIGURE 1.12 Poor settlers in Peru have cleared and burned this small plot in a tropical rain forest in the Amazon and planted it with seedlings to grow food for their survival.

5 Number of earths needed to sustain the world's population at U.S. consumption rates in 2012

waste along with ways to increase our beneficial environmental impacts.

Poverty Has Harmful Environmental and Health Effects

Poverty is a condition in which people lack enough money to fulfill their basic needs for food, water, shelter, health care, and education. *Bad News*: According to the World Bank, about one of every three people, or 2.6 billion people, struggled to live on less than $2.25 a day in 2014. In addition, 1 billion people living in *extreme poverty* struggled to live on the equivalent of less than $1.25 a day—less than what many people spend for a bottle of water or a cup of coffee. Could you do this? *Good news*: The percentage of the world's population living on less than $1.25 a day decreased from 52% in 1981 to 14% in 2014.

Poverty causes a number of harmful environmental and health effects. The daily lives of the world's poorest people center on getting enough food, water, and cooking and heating fuel to survive. Typically, these individuals are too desperate for short-term survival to worry about long-term environmental quality or sustainability. Thus, collectively, they may be forced to degrade forests (Figure 1.12), topsoil, and grasslands, and deplete fisheries and wildlife populations to stay alive.

Poverty does not always lead to environmental degradation. Some of the poor increase their beneficial environmental impact by planting and nurturing trees and conserving the soil that they depend on as a part of their long-term survival strategy.

CONSIDER THIS . . .

CONNECTIONS Poverty and Population Growth

To many poor people, having more children is a matter of survival. Their children help them gather firewood, haul water, and tend crops and livestock. The children also help take care of their aging parents, most of whom do not have social security, health care, and retirement funds. This daily struggle for survival is largely why populations in some of the poorest countries continue to grow at high rates.

Rowan Gillson/Design Pics/Superstock

FIGURE 1.13 One of every three children younger than age 5 in less-developed countries, such as this starving child in Bangladesh, suffers from severe malnutrition caused by a lack of calories and protein.

Environmental degradation can have severe health effects on the poor. One problem is life-threatening *malnutrition*, a lack of protein and other nutrients needed for good health (Figure 1.13). Another effect is illness caused by limited access to adequate sanitation facilities and clean drinking water. As a result, about one of every nine of the world's people get water for drinking, washing, and cooking from sources polluted by human and animal feces.

In 2010 the World Health Organization estimated that these factors—mostly related to poverty—cause premature death for about 7 million children under age 5 each year. Some hopeful news is that this number of annual deaths is down from about 10 million in 1990. Even so, every day an average of at least 19,000 young children die prematurely from these causes. This is equivalent to *95 fully loaded 200-passenger airliners crashing every day with no survivors*. The news media rarely cover this ongoing human tragedy.

CONSIDER THIS . . .

THINKING ABOUT The Poor, the Affluent, and Environmental Harm

Some see the rapid population growth in less-developed countries as the primary cause of our environmental problems. Others say that the high rate of resource use per person in more-developed countries is a more important factor. Which factor do you think is more important? Why?

Prices of Goods and Services Rarely Include Their Harmful Environmental and Health Costs

Another basic cause of environmental problems has to do with how the marketplace prices goods and services. Companies providing goods for consumers generally are not required to pay for most of the harmful environmental and health costs of supplying such goods. For example, timber companies pay the cost of clear-cutting forests but do not pay for the resulting environmental degradation and loss of wildlife habitat.

The primary goal of a company is to maximize profits for its owners or stockholders, so it is not inclined to add these costs to its prices voluntarily. Because the prices of goods and services do not include most of their harmful environmental and health costs, consumers have no effective way to know the harm caused by what they buy. This lack of information is a major reason for why we are degrading key components of our life-support system (Figure 1.7).

For example, producing and using gasoline results in air pollution and other problems that damage the environment and people's health. Scientists and economists have estimated that the price of gasoline to U.S. consumers would rise by $3.18 per liter ($12 per gallon) if the estimated short- and long-term harmful environmental and health costs were included in its pump price. Thus, when gas costs $2 per gallon, U.S. consumers are really paying about $14 per gallon, as discussed in more detail in Chapter 23. Consumers pay these hidden costs, but not at the gas pump.

CONSIDER THIS . . .

THINKING ABOUT Real Gasoline Prices

Suppose the price of gasoline included its harmful environmental and health effects and was therefore $14 a gallon. How would this affect your decision on what type of car to buy or whether to go without a car and instead make greater use of walking, bicycling, and mass transit?

Another problem arises when governments (taxpayers) give companies *subsidies* such as tax breaks and payments to assist them with using resources to run their businesses. This helps to create jobs and stimulate economies, but some subsidies encourage the depletion and degradation of natural capital.

Steve Winter/National Geographic Creative

FIGURE 1.14 These ecotourists atop Asian elephants in India's Kaziranga National Park are learning about threatened barasingha deer and other species.

According to environmental economists, we could live more sustainably and increase our beneficial environmental impact by including the harmful environmental and health costs of the goods and services into market prices and placing a monetary value on the natural capital that supports all economies. This would not be an easy economic or political task, but it can be done—and the alternative is to continue degrading natural capital. Such full-cost pricing is the basis for one of the six **principles of sustainability**.

Economists propose two ways to implement full-cost pricing over the next two decades. One is to shift from environmentally harmful government subsidies to environmentally beneficial subsidies that sustain or enhance natural capital. The other is to increase taxes on pollution and wastes that we want less of and reduce taxes on income and wealth that we want more of. We discuss such *subsidy shifts* and *tax shifts* in Chapter 23.

People Are Increasingly Isolated from Nature

Today, more than half of the world's people and three out of four people in more-developed countries live in urban areas. This shift from rural to urban living is continuing at a rapid pace. Urban environments and the increasing use of cell phones, computers, and other electronic devices are isolating people, especially children, from the natural world. Some argue that this has led to a phenomenon known as *nature-deficit disorder*.

Children and adults can gain many benefits from outdoor activities. Research indicates that experiencing nature (see Figure 1.14 and the chapter-opening photo) can lead to better health, reduced stress, improved mental abilities, and increased imagination and creativity. It also can provide a sense of wonder and connection to the earth's life-support system that keeps us alive and supports our economies.

People Have Different Views about Environmental Problems and Their Solutions

One of the reasons why environmental problems persist is that people differ over the nature and seriousness of the world's environmental problems, as well as how to solve them. These disagreements arise mostly because of differing environmental worldviews. Your **environmental worldview** is your set of assumptions and values concerning how the natural world works and how you think you should interact with the environment.

Environmental ethics, the study of varying beliefs about what is right and wrong with how we treat the environment, provides useful tools for examining worldviews. For example, here are some important *ethical questions* relating to the environment:

- Why should we care about the environment?
- Are we the most important species on the planet or are we just another one of the earth's millions of life forms?
- Do we have an obligation to see that our activities do not cause the extinction of other species? If so, should we try to protect all species or only some? How do we decide which to protect?
- Do we have an ethical obligation to pass the natural world on to future generations in a condition that is as good as or better than what we inherited?
- Should every person be entitled to equal protection from environmental hazards regardless of race, gender, age, national origin, income, social class, or any other factor? (This is the central ethical and political issue for what is known as the *environmental justice* movement; see Chapter 24 for more on this topic.)
- Should we seek to live more sustainably, and if so, how?

CONSIDER THIS . . .

THINKING ABOUT Our Responsibilities

How would you answer each of the questions above? Compare your answers with those of your classmates. Record your answers and, at the end of this course, return to these questions to see if your answers have changed.

People with different environmental worldviews can take the same data, be logically consistent with it, and arrive at quite different answers to such questions. This happens because they start with different assumptions and moral, ethical, or religious beliefs. Environmental worldviews are discussed in detail in Chapter 25, but here is a brief introduction.

There are three major categories of environmental worldviews: human-centered, life-centered, and earth-centered.

A **human-centered environmental worldview** sees the natural world as a support system for human life. Two variations in this worldview are the *planetary management worldview* and the *stewardship worldview*. According to both of these variations, humans are separate from and in charge of nature; we should manage the earth for our benefit; and if we degrade or deplete a natural resource or ecosystem service, we can use our technological ingenuity to find a substitute. The stewardship worldview also calls for us to be caring and responsible managers, or *stewards*, of the earth for current and future human generations. It also calls for us to encourage environmentally beneficial forms of economic growth and development and discourage environmentally harmful forms.

According to the **life-centered environmental worldview**, all species have value in fulfilling their particular role within the biosphere, regardless of their potential or actual use to humans. Most people with a life-centered worldview believe we have an ethical responsibility to avoid hastening the extinction of species through our activities.

According to the **earth-centered environmental worldview**, we are part of, and dependent on, nature, and the earth's natural capital exists for all species, not just for humans. According to this view, our economic success and the long-term survival of our cultures, our species, and many other species depend on learning how life on the earth has sustained itself for billions of years (Figure 1.2) and integrating such lessons from nature (**Core Case Study** and Science Focus 1.1) into the ways we think and act.

CASE STUDY

The Rise of Environmental Conservation and Protection in the United States

When European colonists arrived in what is now the United States in the early 1600s, they viewed North America as a land with inexhaustible resources and a wilderness to be conquered and managed for human use. As the colonists spread across the continent, they cleared forests to build settlements, plowed up grasslands to plant crops, and mined gold, lead, and other minerals.

In 1864, George Perkins Marsh, a scientist and member of Congress from Vermont, questioned the idea that America's resources were inexhaustible. He used scientific studies and case studies to show how the rise and fall of past civilizations were linked to the use and misuse of their soils, water supplies, and other resources. He was one of the founders of the U.S. conservation movement.

Early in the 20th century, this movement split into two factions with differing views over how to use U.S. public lands owned jointly by all American citizens. The *preservationist view*, led by naturalist John Muir (Figure 1.15),

SCIENCEFOCUS 1.1

Some Biomimicry Principles

According to Janine Benyus (Individuals Matter 1.1): "The study of biomimicry reveals that life creates conditions conducive to life." She calls for us to evaluate each of the goods and services we produce and use by asking: Is it something nature would do? Does it help sustain life? Will it last?

Benyus recognizes three levels of biomimicry. The first involves mimicking the characteristics of species such as bumps on a whale's fins or the wing and feather designs of birds that are believed to have enhanced the long-term survival of such species. The second and deeper level involves mimicking the processes that species use to make shells, feathers, and other parts that benefit their long-term survival without using or producing toxins and without using the high-temperature or high-pressure processes we use in manufacturing. The third and deepest level involves mimicking the long-term survival strategies and beneficial environmental effects of natural ecosystems such as forests and coral reefs. Benyus is working with others to use this third level of biomimicry to design more sustainable cities.

Since 1997 scientists, engineers, and others working in the field of biomimicry have identified several principles that have sustained life on the earth for billions of years. They have found that life:

- Runs on sunlight, not fossil fuels
- Does not waste energy
- Uses only what it needs
- Adapts to changing environmental conditions
- Depends on biodiversity for population control and adaptation
- Creates no waste because the matter outputs of one organism are resources for other organisms
- Does not pollute its own environment
- Does not produce chemicals that cannot be recycled by the earth's chemical cycles.

By learning from nature and using such principles, innovative scientists, engineers, and business people are leading a *biomimicry revolution* by creating life-friendly goods and services and profitable businesses that could enrich and sustain life far into the future.

CRITICAL THINKING

Which, if any, of the proposed principles of biomimicry do you follow in your life? How might your lifestyle change if you followed all of these principles? Would you resist or embrace doing this?

wanted wilderness areas on some public lands to be left untouched so they could be preserved indefinitely, an idea that was not enacted into law until 1964. He was largely responsible for establishing Yosemite National Park in 1890. In 1892 he founded the Sierra Club, which to this day is a political force working on behalf of the environment.

The *conservationist view* was promoted by Teddy Roosevelt (Figure 1.16) and Gifford Pinchot. Roosevelt was president of the United States and Pinchot was the first chief of the U.S. Forest Service. They believed all public lands should be managed wisely and scientifically, primarily to provide resources for people. Roosevelt's term of office, 1901–1909, has been called the country's *Golden Age of Conservation*. He established 36 national wildlife reserves and more than tripled the size of the national forest reserves.

Aldo Leopold (Figure 1.17)—wildlife manager, professor, writer, and conservationist—was trained in the conservation view but shifted toward the preservation view. In 1935 he helped found the U.S. Wilderness Society. Through his writings, especially his 1949 book *A Sand*

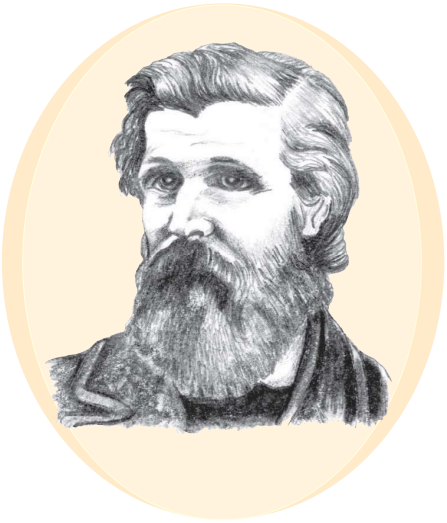


FIGURE 1.15 As leader of the preservationist movement, John Muir (1838–1914) called for setting aside some of the country's public lands as protected wilderness, an idea that was not enacted into law until 1964.

© Cengage Learning

FIGURE 1.16 Effective protection of forests and wildlife on federal lands did not begin until Theodore (Teddy) Roosevelt (1858–1919) became president.

U.S. Fish and Wildlife Service

FIGURE 1.18 Rachel Carson (1907–1964) alerted us to the harmful effects of the widespread use of pesticides. Many environmental historians mark Carson's wake-up call as the beginning of the modern environmental movement in the United States.

Robert McCabe/Courtesy of the University of Wisconsin-Madison Archives

FIGURE 1.17 Aldo Leopold (1887–1948) became a leading conservationist and his book, *A Sand County Almanac*, is considered an environmental classic that helped to inspire the modern conservation and environmental movements.

County Almanac, he laid the groundwork for the field of environmental ethics. He argued that the role of the human species should be to protect nature, not conquer it.

Later in the 20th century, the concept of resource conservation was broadened to include preservation of the *quality* of the planet's air, water, soil, and wildlife. A prominent pioneer in that effort was biologist Rachel Carson (Figure 1.18). In 1962 she published *Silent Spring*, which documented the pollution of air, water, and wildlife from the widespread use of pesticides such as DDT. This influential book heightened public awareness of pollution problems and led to the regulation of several dangerous pesticides.

Between 1940 and 1970, the United States underwent rapid economic growth and industrialization. This increased air and water pollution and produced large quantities of solid and hazardous wastes. Air pollution was so bad in many cities that drivers had to use their car headlights during the daytime. Thousands died each year from the harmful effects of air pollution. A stretch of the Cuyahoga River running through Cleveland, Ohio, was so polluted with oil and other flammable pollutants that it caught fire several times. There was a devastating oil spill off the California coast in 1969. Well-known wildlife species such as the American bald eagle, the grizzly bear, the whooping crane, and the peregrine falcon became endangered.

Growing publicity over these problems led the American public to demand government action. When the first Earth Day was held on April 20, 1970, some 20 million people in more than 2,000 U.S. communities and college and university campuses attended rallies to demand improvements in environmental quality. The first Earth Day and the resulting bottom-up political pressure it created led the U.S. government to establish the Environmental

Protection Agency (EPA) in 1970 and to enact most of the U.S. environmental laws now in place during the 1970s, known as the *decade of the environment*. During this period, the United States led the world in environmental awareness, wildlife conservation, and environmental protection.

Since 1970, many grassroots environmental organizations have sprung up to help deal with environmental threats. Interest in environmental issues has grown on many college and university campuses, resulting in the expansion of environmental science and environmental studies courses and programs. In addition, awareness of critical, complex, and largely invisible environmental issues has increased. They include losses in biodiversity, aquifer depletion, ocean warming and acidification, and atmospheric warming and climate change.

In the 1980s, there was a political backlash against environmental laws and regulations led by some corporate leaders and members of Congress. They contended that environmental laws were hindering economic growth and tried to weaken or eliminate many environmental laws passed during the 1970s and do away with the EPA. The 1990s saw increasingly sophisticated "disinformation" campaigns, funded by powerful business interests, that were meant to confuse or mislead the public on important environmental issues—efforts that continue today.

Since the 1980s, environmental leaders and their supporters have had to spend much of their time and resources fighting efforts to keep key environmental laws from being weakened or repealed. Some analysts call for the United States to regain and strengthen its global role in improving environmental quality and in making the shift to more environmentally sustainable societies and economies.

1.4 WHAT IS AN ENVIRONMENTALLY SUSTAINABLE SOCIETY?

CONCEPT 1.4 Living sustainably means living on the earth's natural income without depleting or degrading the natural capital that supplies it.

Protecting Natural Capital and Living on Its Income

An **environmentally sustainable society** protects natural capital and lives on its income. Such a society would meet the current and future basic resource needs of its people. This would be done in a just and equitable manner without compromising the ability of future generations to meet their basic resource needs. This is in keeping with the ethical **principle of sustainability**.

Imagine that you win $1 million in a lottery. Suppose you invest this money (your capital) and earn 10% interest per year. If you live on just the interest income made by your capital, you will have a sustainable annual income of $100,000. You can spend $100,000 each year indefinitely and not deplete your capital. However, if you consistently spend more than your income, you will deplete your capital. Even if you spend just $10,000 more per year while still allowing the interest to accumulate, your money will be gone within 18 years.

The lesson here is an old one: *Protect your capital and live on the income it provides*. Deplete or waste your capital and you will move from a sustainable to an unsustainable lifestyle.

The same lesson applies to our use of the earth's natural capital (Figure 1.3). This natural capital is a global trust fund of natural resources and ecosystem services available to people now and in the future and to the earth's other species. *Living sustainably* means living on **natural income**, which is the renewable resources such as plants, animals, soil, clean air, and clean water, provided by the earth's natural capital. By preserving and replenishing the earth's natural capital that supplies this income, we can reduce our ecological footprints and expanding our beneficial environmental impact (**Concept 1.4**). For example, the earth's elephants are in trouble and some people are working to help protect them (Individuals Matter 1.2).

We Can Live More Sustainably

Living more sustainability means learning to live within limits imposed on all life by the earth and the unbreakable scientific laws that govern our use of matter and energy (discussed in the next chapter). Doing this requires:

- Learning from nature (**Core Case Study** and Science Focus 1.1)
- Protecting natural capital
- Not wasting resources (there is no waste in nature)
- Recycling and reusing nonrenewable resources
- Using renewable resources no faster than nature can replenish them
- Incorporating the harmful health and environmental impacts of producing and using goods and services in their market prices
- Preventing future ecological damage and repairing past damage
- Cooperating with one another to find win-win solutions to the environmental problems we face
- Accepting the ethical responsibility to pass the earth that sustains us on to future generations in a condition as good as or better than what we inherited.

INDIVIDUALS MATTER 1.2

Tuy Sereivathana: Elephant Protector

Courtesy Tom Dusenbery

Since 1970, Cambodia's rain forest cover has dropped from over 70% of the country's land area to 3%, primarily because of population growth, rapid development, illegal logging, and warfare. This severe forest loss forced elephants to search for food and water on farmlands. This set up a conflict between elephants and poor farmers, who killed the elephants to protect their food supply.

Since 1995, Tuy Sereivathana, with a master's degree in forestry, has been on a mission to accomplish two goals. One is to more than double the population of Cambodia's endangered Asian elephants by 2030. The other is to show poor farmers that protecting elephants and other forms of wildlife can help them escape poverty.

Sereivathana has helped farmers set up nighttime lookouts for elephants. He has taught them to scare elephants away by using foghorns and fireworks and to use solar-powered electric fences to mildly shock them. He has also encouraged farmers to stop growing watermelons and bananas, which elephants love, and to grow eggplant and chili peppers that elephants shun.

Since 2005, mostly because of Sereivathana's efforts, no elephants have been killed in Cambodia over conflicts with humans. In 2010 Sereivathana was one of the six recipients of the Goldman Environmental Prize (often dubbed the "Nobel Prize for the environment"). In 2011 he was named a National Geographic Explorer.

Environmental problems are so complex and widespread that it may seem hopeless, but that is not true. There is plenty of reason to hope and to act. For instance, consider these two pieces of good news from the social sciences. *First,* research suggests that it takes only 5–10% of the population of a community, a country, or the world to bring about major social and environmental change. *Second,* this research also shows that such change can occur much faster than most people believe.

Anthropologist Margaret Mead summarized the potential for social change: "Never doubt that a small group of thoughtful, committed citizens can change the world. Indeed, it is the only thing that ever has." Engaged citizens in communities and schools around the world are proving Mead right.

One of our goals in writing this book has been to provide a realistic vision of how we can live more sustainably. We base this vision not on immobilizing fear, gloom, and doom, but on education about how the earth sustains life and on energizing and realistic hope.

BIG IDEAS

- We can ensure a more sustainable future by relying more on energy from the sun and other renewable energy sources, protecting biodiversity through the preservation of natural capital, and avoiding the disruption of the earth's vital chemical cycles.
- A major goal for achieving a more sustainable future is full-cost pricing—the inclusion of harmful environmental and health costs in the market prices of goods and services.
- We will benefit ourselves and future generations if we commit ourselves to finding win-win solutions to environmental problems and to leaving the planet's life-support system in a condition as good as or better than what we now enjoy.

Tying It All Together

Learning from the Earth and Sustainability

We opened this chapter with a **Core Case Study** about learning from nature by understanding how the earth—our only truly sustainable system—has sustained an incredible diversity of life for 3.8 billion years despite drastic and long-lasting changes in the planet's environmental conditions. Part of the answer involves learning how to apply the six **principles of sustainability** (Figures 1.2 and 1.6 and inside back cover of this book) to the design and management of our economic and social systems, and to our individual lifestyles.

We can use such strategies to slow the rapidly expanding losses of biodiversity, to sharply reduce our production of wastes and pollution, to switch to more sustainable sources of energy, and to promote more sustainable forms of agriculture and other uses of land and water. We can also use these principles to sharply reduce poverty and slow human population growth.

Pecold/Shutterstock.com

You and your fellow students have the good fortune to be members of the 21st century's *transition generation* that will play a major role in deciding whether humanity creates a more sustainable future or continues on an unsustainable path toward further environmental degradation and disruption. It is an incredibly exciting and challenging time to be alive as we struggle to develop a more sustainable relationship with the earth that keeps us alive and supports our economies.

Chapter Review

Core Case Study

1. What is **sustainability**? What is **biomimicry**? Explain why learning from the earth is a key to learning how to live more sustainably.

Section 1.1

2. What are the three key concepts for this section? Define **environment**. Distinguish among **environmental science**, **ecology**, and **environmentalism**. What is an **ecosystem**? What are three **scientific principles of sustainability** derived from how the natural world works? Define **solar energy**, **biodiversity**, and **chemical cycling** (or **nutrient cycling**) and explain why they are important to life on the earth.
3. Define **natural capital**. Define **natural resources** and **ecosystem services**, and give two examples of each. Give three examples of how we are degrading natural capital. Explain how finding solutions to environmental problems involves making trade-offs. Explain why individuals matter in dealing with the environmental problems we face. What are three economic, political, and ethical **principles of sustainability**? What is **full-cost pricing** and why is it important? Describe the role of Janine Benyus in promoting the important and growing field of biomimicry.
4. What is a **resource**? Distinguish between an **inexhaustible resource** and a **renewable resource** and give an example of each. What is the **sustainable yield** of a renewable resource? Define and give an example of a **nonrenewable** or **exhaustible resource**. Distinguish between **more-developed countries** and **less-developed countries** and give one example each of a high-income, middle-income, and low-income country.

Section 1.2

5. What is the key concept for this section? How have humans improved the quality of life for many people? How are humans living unsustainably? Define and give three examples of **environmental degradation** (or **natural capital degradation**). About what percentage of the earth's natural or ecosystem services have been degraded by human activities? What is the tragedy of the commons? What are two ways to deal with this effect?
6. What is an **ecological footprint**? What is a **per capita ecological footprint**? Define **biocapacity**. Use the ecological footprint concept to explain how we are living unsustainably. What is the IPAT model for estimating our environmental impact? Explain how three major cultural changes taking place over

the last 10,000 years have increased our overall environmental impact. What would a **sustainability revolution** involve?

Section 1.3

7. What are the two key concepts for this section? Identify six basic causes of the environmental problems that we face. What is **exponential growth**? What is the rule of 70? What is the current size of the human population? About how many people are added each year? How big is the world's population projected to be in 2050? How do Americans, Indians, and the average people in the poorest countries compare in terms of average resource consumption per person? Summarize the potentially harmful and beneficial environmental effects of affluence.
8. What is **poverty** and what are three of its harmful environmental and health effects? About what percentage of the world's people struggle to live on the equivalent of $1.25 a day? About what percentage have to live on $2.25 a day? How are poverty and population growth connected? List three major health problems faced by many of the poor.
9. Explain how excluding the harmful environmental and health costs of production from the prices of goods and services affects the environmental problems we face. What is the connection between government subsidies, resource use, and environmental degradation? What are two ways to include the harmful environmental and health costs of the goods and services in their market prices? Explain how a lack of knowledge about nature and the importance of natural capital, along with our increasing isolation from nature, can intensify the environmental problems we face. What is an **environmental worldview**? What is **environmental ethics**? What are five important ethical questions relating to the environment? Distinguish among the **human-centered**, **life-centered**, and **earth-centered environmental worldviews**. What are three levels of biomimicry? List eight key biomimicry principles.

Section 1.4

10. What is the key concept for this section? What is an **environmentally sustainable society**? What is **natural income** and how is it related to sustainability? Describe Tuy Sereivathana's efforts to prevent elephants from becoming extinct in Cambodia and to reduce the country's poverty. List nine principles for living more sustainably. What are two pieces of good news about making the transition to a more sustainable society? What are this chapter's three big ideas?

Note: Key terms are in bold type. Knowing the meanings of these terms will help you in the course you are taking.

Critical Thinking

1. Why is biomimicry so important? Find an example of something in nature that you think could be mimicked for some beneficial purpose. Explain that purpose and how biomimicry could apply.
2. What do you think are the three most environmentally unsustainable components of your lifestyle? List two ways in which you could apply each of the six **principles of sustainability** (Figures 1.2 and 1.6) to making your lifestyle more environmentally sustainable.
3. For each of the following actions, state one or more of the three **scientific principles of sustainability** that are involved: **(a)** recycling aluminum cans; **(b)** using a rake instead of a leaf blower; **(c)** walking or bicycling to class instead of driving; **(d)** taking your own reusable bags to a store to carry your purchases home; and **(e)** volunteering to help restore a prairie or other degraded ecosystem.
4. Explain why you agree or disagree with the following propositions:
   a. Stabilizing population is not desirable because, without more consumers, economic growth would stop.
   b. The world will never run out of resources because we can use technology to find substitutes and to help us reduce resource waste.
   c. We can shrink our ecological footprints while creating beneficial environmental impacts.
5. Should nations with large ecological footprints reduce their footprints to decrease their harmful environmental impact and leave more resources for nations with smaller footprints and for future generations? Explain.
6. When you read that at least 19,000 children age 5 and younger die each day (13 per minute) from preventable malnutrition and infectious disease, what is your response? How would you address this problem?
7. Explain why you agree or disagree with each of the following statements: **(a)** humans are superior to other forms of life; **(b)** humans are in charge of the earth; **(c)** the value of other forms of life depends only on whether they are useful to humans; **(d)** all forms of life have a right to exist; **(e)** all economic growth is good; **(f)** nature has an almost unlimited storehouse of resources for human use; **(g)** technol-

ogy can solve our environmental problems; **(h)** I don't have any obligation to future generations; and **(i)** I don't have any obligation to other forms of life.

8. What are the basic beliefs of your environmental worldview? Record your answer. At the end of this course, return to your answer to see if your environmental worldview has changed. Are the beliefs included in your environmental worldview consistent with the answers you gave to Question 7 above? Are your actions that affect the environment consistent with your environmental worldview? Explain.

Doing Environmental Science

Estimate your own ecological footprint by using one of the many estimator tools available on the Internet. Is your ecological footprint larger or smaller than you thought it would be, according to this estimate? Why do you think this is so? List three ways in which you could reduce your ecological footprint. Try one of them for a week, and write a report on this change. List three ways you could increase your beneficial environmental impact.

Global Environment Watch Exercise

Go to your MindTap course to access the GREENR database. Use the world maps in Figure 1, p. S14, in Supplement 4 and Figure 1.10 to choose one more-developed country and one less-developed country to compare their ecological footprints. Use the "World Map" link at the top of the page to access information about the countries you have chosen to research. Once on the country page, view the "Quick Facts" panel at the right. Click on the ecological footprint number to view a graph of both the ecological footprint and biocapacity of each country. Using those graphs, determine whether these countries are living sustainably or not. What would be some reasons for these trends?

Ecological Footprint Analysis

If the *ecological footprint per person* of a country or the world is larger than its *biocapacity per person* to replenish its renewable resources and absorb the resulting waste products and pollution, the country or the world is said to have an *ecological deficit*. If the reverse is true, the country or the world has an *ecological credit* or *reserve*. Use the data in the accompanying table to calculate the ecological deficit or credit for the countries listed. (As an example, this value has been calculated and filled in for World.)

1. Which three countries have the largest ecological deficits? For each of these countries, why do you think it has a deficit?
2. Rank the countries with ecological credits in order from highest to lowest credit. For each country, why do you think it has an ecological credit?
3. Rank all of the countries in order from the largest to the smallest per capita ecological footprint.

Place	Per Capita Ecological Footprint (hectares per person)	Per Capita Biocapacity (hectares per person)	Ecological Credit (+) or Deficit (−) (hectares per person)
World	2.6	1.8	−0.8
United States	6.8	3.8	
Canada	7.0	13.0	
Mexico	2.4	1.3	
Brazil	2.5	9.0	
South Africa	2.5	1.2	
United Arab Emirates	8.0	0.7	
Israel	4.6	0.3	
Germany	4.3	1.9	
Russian Federation	4.4	6.6	
India	0.9	0.4	
China	0.5	0.8	
Australia	7.5	15.0	
Bangladesh	0.65	0.35	
Denmark	4.0	4.0	
Japan	3.7	0.7	
United Kingdom	4.0	1.1	

Compiled by the authors using data from World Wide Fund for Nature: *Living Planet Report 2014*.