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Introducing Environmental Science and Sustainability

Industrial production of chicken requires many inputs, including feed, heating and cooling, and often antibiotics and hormones to accelerate growth. It also generates waste streams that can lead to air and water pollution if not treated or managed.

One of the best ways to understand our complex relationship with the global environment is to use food as a lens. Culture, price, personal tastes, and availability often determine our food choices. However, we rarely think about how a particular meal comes to our plate, and how its production impacts the environment.

Consider a simple chicken sandwich. To make bread, commercial bakeries rely on wheat from farms that require large amounts of inputs (land, irrigation water, fertilizers, and pesticides) and mechanization (usually diesel-fueled trucks and tractors). Using land for agriculture displaces native plants and animals, excess fertilizers and pesticides enter waterways and flow to the ocean, and burning diesel releases pollutants into the atmosphere. Once wheat is harvested, it is sent to a plant that grinds it into flour. This requires additional energy and produces a stream of organic waste material. The wheat is then shipped to a bakery, which adds water, sugar, yeast, corn syrup, vitamins and minerals, preservatives, oil, and other ingredients—each of which has also been processed and transported. The bread is then packed into plastic bags and delivered to stores and restaurants, hundreds or thousands of miles from where the wheat was grown. Each step uses energy, adds packaging, and generates solid and liquid wastes. Packaging, as well as uneaten or damaged bread, is usually thrown into the garbage and sent to a landfill.

Commercially grown chicken produces even more impact on the environment, since chicken feed grain has to be grown, processed, and delivered to a poultry farm (**photo**). Raising, processing, cooking, packaging, and delivering the chicken all require energy and material inputs and result in pollution and waste. In addition, chickens and other animals are often given antibiotics to make them grow faster. This can lead to antibiotic-resistant diseases, and the antibiotics can disrupt natural ecosystems.

There are more sustainable alternatives to the chicken sandwich. Wheat, grain, and chicken can be grown using methods that greatly reduce impacts on the environment. Foods that are grown near where they are consumed require less energy for transportation. Alternative pest management can reduce demand for pesticides and antibiotics. Bulk packaging and composted food waste can reduce or even eliminate the need for landfills. But even when these practices are adopted, growing and processing food requires land, water, energy, and other inputs.

Humans have developed agriculture over several thousand years. In so doing, we have altered ecosystems, cut down forests, shifted waterways, and driven plants and animals to extinction. At the same time, we have helped some plants and animals—including wheat and chicken, but rats and cockroaches as well—to become dominant species. Our agricultural practices have even contributed to climate change, which in turn forces us to adapt our food production practices. Knowing how something as simple as a choice between two sandwiches can have wide-ranging impacts on the environment is a great point from which to begin to understand the relationship between humans and the environment.

In Your Own Backyard...

Where and by whom is food grown near where you live? Look in your cupboards and refrigerator: Where and by whom are most of the foods you eat grown? How might switching to locally grown foods affect your diet and your food budget?

Human Impacts on the Environment

LEARNING OBJECTIVES

- Explain how human activities affect global systems.
- Describe the factors that characterize human development and how they impact environment and sustainability.

Earth is remarkably suited for life. Water, important both in the internal composition of organisms and as an external environmental factor affecting life, covers three-fourths of the planet. Earth's temperature is habitable—neither too hot, as on Mercury and Venus, nor too cold, as on Mars and the outer planets. We receive a moderate amount of sunlight—enough to power photosynthesis, which supports almost all the life-forms that inhabit Earth. Our atmosphere bathes the planet in gases and provides essential oxygen and carbon dioxide that organisms require. On land, soil develops from rock and provides support and minerals for plants. Mountains that arise from geologic processes and then erode over vast spans of time affect weather patterns, provide minerals, and store reservoirs of fresh water as ice and snow that melt and flow to lowlands during the warmer months. Lakes and ponds, rivers and streams, wetlands, and groundwater reservoirs provide terrestrial organisms with fresh water.

Earth's abundant natural resources have provided the backdrop for a parade of living things to evolve. Life has existed on Earth for about 3.8 billion years. Although early Earth was inhospitable by modern standards, it provided the raw materials and energy needed for early life-forms to arise and adapt. Some of these early cells evolved over time into simple multicellular organisms—early plants, animals, and fungi. Today, several million species inhabit the planet. A representative sample of Earth's biological diversity includes intestinal bacteria, paramecia, poisonous mushrooms, leafhoppers, prickly pear cacti, seahorses, dogwoods, angelfish, daisies, mosquitoes, pitch pines, polar bears, spider monkeys, and roadrunners (**Figure 1.1**).

About 100,000 years ago—a mere blip in Earth's 4.5-billion-year history—an evolutionary milestone began with the appearance of modern humans in Africa. Large brains and the ability to communicate made our species successful. Over time, our population grew; we expanded our range throughout the planet and increasingly impacted the environment with our presence and our technologies. These technologies have allowed many people in the world lives with access to well-lit and air-conditioned buildings, effective medical treatment, high-speed transportation, and uninterrupted food supplies. This has been particularly true in North America, Western Europe, and Japan; increasingly, many urban residents in China, India, South America, and parts of Africa have similar access to wealth and material goods.

Figure 1.1 A male greater roadrunner carries a desert spiny lizard it has captured. Life abounds on Earth, and every organism is linked to many others, including humans. Photographed in New Mexico.

Today, the human species is the most significant agent of environmental change on our planet. Our burgeoning population and increasing use of energy, materials, and land transform natural systems to meet our needs and desires. Our activities consume ever-increasing amounts of Earth's abundant but finite resources—rich topsoil, clean water, and breathable air. This alteration of natual systems eradicates many types of ecosystems and thousands upon thousands of unique species that inhabit them. Evidence continues to accumulate that human-induced climate change alters the natural environment in disruptive ways. Human activities are disrupting global **systems**.

system A set of components that interact and function as a whole.

This book introduces the major impacts that humans have on the environment. It considers ways to better manage those impacts, while emphasizing that each possible choice has the potential to cause additional impacts. Most important, it explains the value of minimizing human impact on our planet. Our lives and well-being, as well as those of future generations, depend on our ability to manage Earth's environmental resources effectively.

INCREASING HUMAN NUMBERS

Figure 1.2, a nighttime satellite photograph of North America, including the United States, Mexico, and Canada, depicts the home of about 470 million people. The tiny specks of light represent cities, with the great metropolitan areas, such as New York along the northeastern seacoast, ablaze with light.

The driver of all other environmental problems, the one that links all others, is the many people who live in the area shown in this picture. According to the United Nations, in 1950 only eight cities in the world had populations larger than 5 million, the largest being New York, with 12.3 million. By 2011 Tokyo, Japan had 17.8 million inhabitants, with 37.2 million inhabitants in the greater Tokyo metropolitan area. The combined population of the world's 10 largest urban agglomerations was over 200 million (see Table 9.1).

In 2011, the human population as a whole passed a significant milestone: 7 billion individuals. Not only is this figure incomprehensibly large, but also our population grew this large in a brief span of time. In 1960, the human population was only 3 billion (**Figure 1.3**). By 1975, there were 4 billion people, and by 1999, there were 6 billion. The 7.2 billion people who currently inhabit our planet consume great quantities of food and water, use a great deal of energy and raw materials, and produce much waste.

Despite family planning efforts in many countries, population growth rates do not change quickly. Several billion people will be

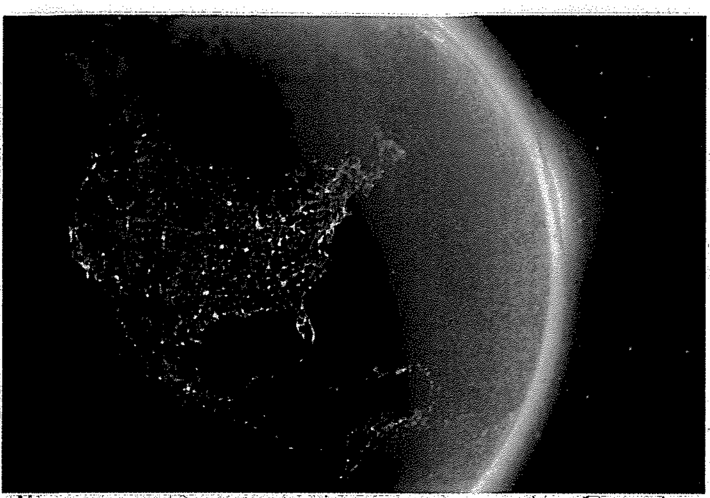

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Figure 1.2 Satellite view of North America at night. This image shows most major cities and metropolitan areas in the United States, Mexico, and Canada.

added to the world in the twenty-first century, so even if we remain concerned about the impacts of a growing population and even if our solutions are effective, the coming decades may be clouded with tragedies. The conditions of life for many people may worsen considerably.

On a global level, nearly one of every two people live in extreme **poverty** (**Figure 1.4**). One measure of poverty is having a per capita income of less than $2 per day, expressed in U.S. dollars adjusted for purchasing power. More than 2.5 billion people—about 40% of the total world population—currently live at this level of poverty. Poverty is associated with low life expectancy, high infant mortality, illiteracy, and inadequate access to health services, safe water, and balanced nutrition. According to the UN Food and Agricultural Organization, at least 1 billion people (many of them children) lack access to the food needed for healthy, productive lives.

overty A condition which people cannot eet their basic needs dequate food, cloth-, shelter, education, or health.

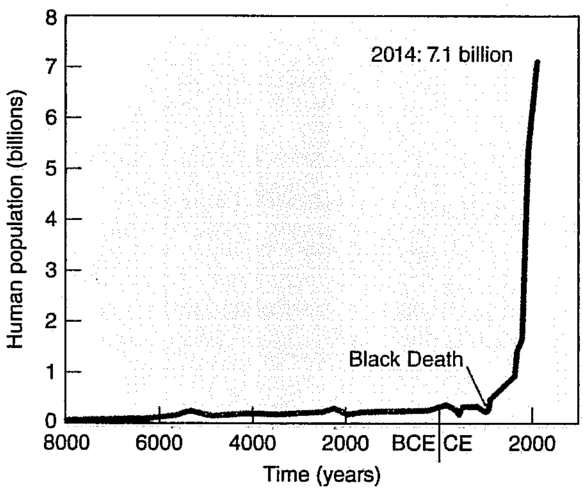
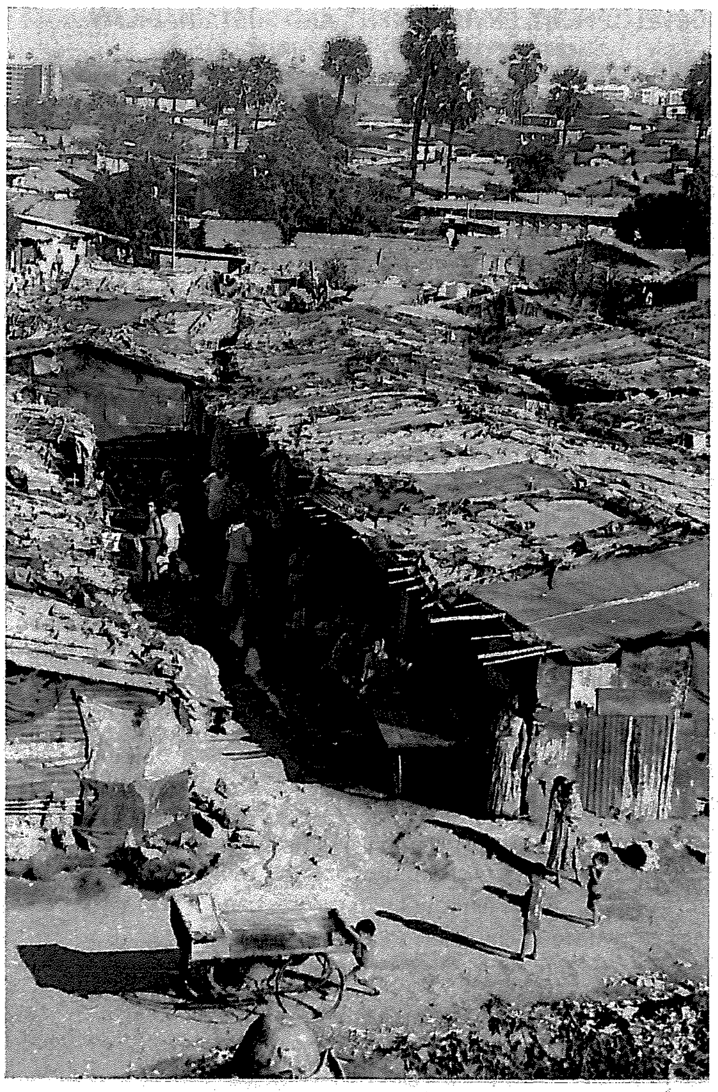


Figure 1.3 Human population growth. It took thousands of years for the human population to reach 1 billion (in 1800) but only 130 years to reach 2 billion (1930). It took only 30 years to reach 3 billion (1960), 15 years to reach 4 billion (1975), 12 years to reach 5 billion (1987), 12 years to reach 6 billion (1999), and 13 years to reach 7 billion (2012). (Population Reference Bureau)



Jerry Cooke/Science Source

Figure 1.4 Slum in Mumbai (Bombay), India. Many of the world's people live in extreme poverty. One trend associated with poverty is the increasing movement of poor people from rural to urban areas. As a result, the number of poor people living in or around the fringes of cities is mushrooming.

Most demographers (people who study human populations) expect the world population to stabilize before the end of the current century. Worldwide, fertility rates have decereased to a current average of about three children per family, and this average is projected to continue to decline in coming decades. Expert projections for world population at the end of the twenty-first century range from about 8.3 billion to 10.9 billion, depending largely on how fast the fertility rate decreases (see Figure 8.3).

No one knows whether Earth can support so many people indefinitely. Among the tasks we must accomplish is feeding a world population considerably larger than the present one without undermining the natural resources that support us. Our ability to achieve this goal will determine the quality of life for our children and grandchildren.

DEVELOPMENT, ENVIRONMENT, AND SUSTAINABILITY

Until recently, demographers differentiated countries as highly developed, moderately developed, and less developed. The United States, Canada, Japan, and most of Europe, which represent 19% of the world's population but more than 50% of global economic activity, are **highly developed countries.** Development in this context is based mainly on total wealth of the country. The world's poorest countries, including Bangladesh, Kenya, and Nicaragua, are considered **less developed countries (LDCs).** Cheap, unskilled labor is abundant in LDCs, but capital for investment is scarce. Most LDC economies are agriculturally based, often for only one or a few crops. As a result, crop failure or a lower world market value for that crop is catastrophic to the economy. Hunger, disease, and illiteracy are common in LDCs.

highly developed :ountries Countries th complex industrial bases, low rates of pulation growth, and ı per capita incomes.

less developed countries (LDCs) Developing countries with a low level of ustrialization, a high fertility rate, a high ıt mortality rate, and w per capita income (relative to highly eveloped countries).

However, recent decades have seen substantial increases in wealth for many urban residents in previously less developed countries, including China, India, Brazil, and Mexico. These countries have substantial *income disparities,* meaning that other urban residents and most of the rural inhabitants of those remain poor, and lack access to cars, electricity, fresh water, and modern medical technology. Consequently, using the total wealth or income of a country may not usefully describe the well-being of people in that country. More appropriate measures can include the percentage of residents who make more than $2 per day, have access to fresh water and electricity, or have access to education.

REVIEW

1. What is one example of a global system?
2. How do the total wealth of a country and income disparity relate to sustainability?

Population, Resources, and the Environment

LEARNING OBJECTIVES

- Differentiate between renewable and nonrenewable resources.
- Explain the impact of population and affluence on consumption.
- Define *ecological footprint.*
- Describe the three most important factors that determine human impact on the environment.

The relationships among population growth, use of natural resources, and environmental degradation are complex. We address the details of resource management and environmental problems in this and later chapters, but for now, let us consider two useful generalizations: (1) The resources essential to an individual's survival are small, but a rapidly increasing population tends to overwhelm and deplete local soils, forests, and other natural resources (**Figure 1.5a**). (2) In highly developed countries, individual resource demands are large, far above what is

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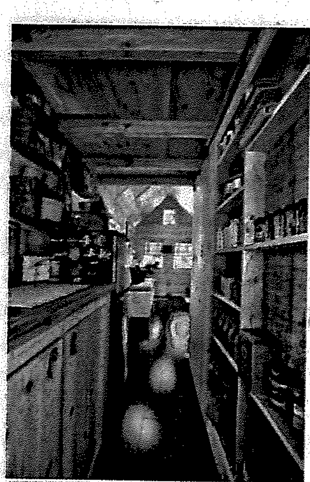
(a) A trend towards larger homes leads to greater consumption in a number of ways: more energy to heat and cool, more distance to travel between homes, and more furnishings inside the home.



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(b) The "tiny house" movement seeks to simplify individual living, and as a consequence reduces consumption. Tiny house occupants have no place to accumulate material goods, and so must be more selective in their purchasing.

Figure 1.5 Consumption of natural resources.

needed for survival. Consumption by people in affluent nations can exhaust resources and degrade the environment on a global scale (**Figure 1.5b**).

TYPES OF RESOURCES

When examining the effects of humans on the environment, it is important to distinguish between two types of natural resources: nonrenewable and renewable (**Figure 1.6**). **Nonrenewable resources**, which include minerals (such as aluminum, copper, and uranium) and fossil fuels (coal, oil, and natural gas), are present in limited supplies and are depleted by use. Natural processes do not replenish nonrenewable resources within a reasonable period on the human time scale. Fossil fuels, for example, take millions of years to form.

In addition to a nation's population, several other factors affect how nonrenewable resources are used, including how efficiently the resource is extracted and processed as well as how much of it

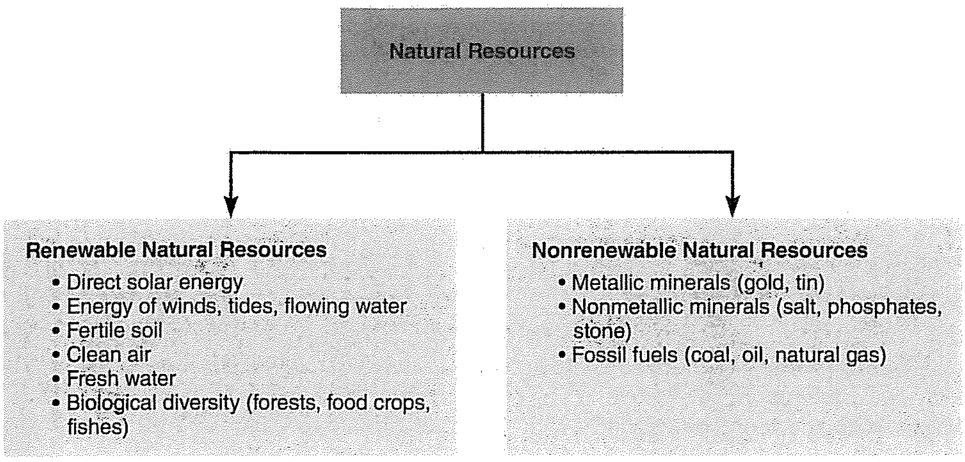


Figure 1.6 Natural resources. Nonrenewable resources are replaced on a geologic time scale, and their supply diminishes with use. Renewable resources can be (but are not always) replaced on a fairly short time scale; as will be explained in later chapters, most renewable resources are derived from the sun's energy.

is required or consumed by different groups. People in the United States, Canada, and other highly developed nations tend to consume most of the world's nonrenewable resources. Nonetheless, Earth has a finite supply of nonrenewable resources that sooner or later will be exhausted. In time, technological advances may provide substitutes for some nonrenewable resources. Slowing the rate of population growth and consumption will buy time to develop such alternatives.

Some examples of **renewable resources** are trees, fishes, fertile agricultural soil, and fresh water. Nature replaces these resources fairly rapidly (on a scale of days to centuries), and they can be used forever as long as they are not overexploited in the short term. In developing countries, forests, fisheries, and agricultural land are particularly important renewable resources because they provide food. Indeed, many people in developing countries are subsistence farmers who harvest just enough food so that they and their families can survive.

Rapid population growth can cause the overexploitation of renewable resources. For example, large numbers of poor people must grow crops on land inappropriate for farming, such as on mountain slopes or in tropical rain forests. Although this practice may provide a short-term solution to the need for food, it does not work in the long term: When these lands are cleared for farming, their agricultural productivity declines rapidly, and severe environmental deterioration occurs. Renewable resources are usually only *potentially* renewable. They must be used in a *sustainable* way—in a manner that gives them time to replace or replenish themselves.

The effects of population growth on natural resources are particularly critical in developing countries. The economic growth of developing countries is often tied to the exploitation of their natural resources, usually for export to highly developed countries. Developing countries are faced with the difficult choice of exploiting natural resources to provide for their expanding populations in the short term (to pay for food or to cover debts) or conserving those resources for future generations.

It is instructive to note that the economic growth and development of the United States, Canada, and other highly developed nations came about through the exploitation and, in some cases, the destruction of resources. Continued economic growth in highly developed countries now relies significantly on the importation of these resources from less developed countries. One of the reasons economic growth in highly developed countries has been possible is the uneven distribution of both renewable and nonrenewable resources around the world. Many very poor countries—Ethiopia, for example—have only limited fossil-fuel resources.

RESOURCE CONSUMPTION

Consumption is the human use of materials and energy. Consumption, which is both an economic and a social act, provides the consumer with a sense of identity as well as status among peers. Advertisers promote consumption as a way to achieve happiness. Western culture encourages spending and consumption well beyond that which is necessary for survival.

In general, people in highly developed countries are extravagant consumers; their use of resources is greatly out of proportion to their numbers. A single child born in a highly developed country may have a greater impact on the environment and on resource depletion than 12 or more children born in a developing country. Many natural resources are used to provide the automobiles, air conditioners, disposable diapers, cell phones, DVD players, computers, clothes, newspapers, athletic shoes, furniture, boats, and other comforts of life in highly developed countries. Yet such consumer goods represent a small fraction of the total materials and energy required to produce and distribute them. According to the Worldwatch Institute, a private research institution in Washington, D.C., Americans collectively consume almost 10 billion tons of materials every year. The disproportionately large consumption of resources by highly developed countries affects natural resources and the environment as much as or more than the population explosion in the developing world.

Unsustainable Consumption Consumption in a country is unsustainable if the level of demand on its resource base damages the environment or depletes resources to such an extent that future generations will have lower qualities of life. In comparing human impact on the environment in developing and highly developed countries, we see that unsustainable consumption can occur in two ways. First, environmental quality and resource depletion can result from too many people, even if those people consume few resources per person. This is the current situation in many developing nations.

In highly developed countries, unsustainable consumption results when individuals consume substantially more resources than necessary for survival. Both types of unsustainable consumption have the same effect—pollution, environmental degradation, and resource depletion. Many affluent, highly developed countries, including the United States, Canada, Japan, and most of Europe, consume unsustainably: *Highly developed countries represent less than 20% of the world's population, yet they consume significantly more than half of its resources.*

According to the Worldwatch Institute, highly developed countries account for the lion's share of total resources consumed:

- 86% of aluminum used
- 76% of timber harvested
- 68% of energy produced
- 61% of meat eaten
- 42% of the fresh water consumed

These nations also generate 75% of the world's pollution and waste.

ECOLOGICAL FOOTPRINT

Environmental scientists **Mathis Wackernagel** and **William Rees** developed the concept of ecological footprint to help people visualize what they use from the environment. Each person has an **ecological footprint**, an amount of productive land, fresh water, and ocean required on a continuous basis to supply that person with food, wood, energy, water, housing, clothing, transportation, and waste disposal. The *Living Planet Report 2010*, produced by scientists at the Global Footprint Network, World Wildlife Fund, and Zoological Society of London, estimates that since about 1975, the human population has been consuming more of the productive land, water, and other resources than Earth can support (**Figure 1.7**). In 2010, annual consumption was about 50% more than Earth produces. This is an unsustainable consumption rate.

The *Living Planet Report* estimates that Earth has about 11.4 billion hectares (28.2 billion acres) of productive land and water. If we divide this area by the global human population, we see that each person is allotted about 1.6 hectares (4.0 acres). However, the average global ecological footprint is currently about 2.7 hectares (6.7 acres) per person, which means we humans have an *ecological overshoot.* We can see the short-term results around us—forest destruction, degradation of croplands, loss of biological diversity, declining ocean fisheries, local water shortages, and increasing pollution. The long-term outlook, if we do not seriously address our consumption of natural resources, is potentially disastrous. Either per-person consumption will drop, population will decrease, or both.

In the developing nation of India, the per capita ecological footprint is 0.9 hectare (2.2 acres); India is the world's second-largest country in terms of population, so even though its per capita footprint is low, the country's footprint is high: 986.3 million hectares (**Figure 1.8**). In France, the per capita ecological footprint is 4.9 hectares (12.1 acres); although its per capita footprint is high, France's footprint as a country is 298.1 million hectares, which is lower than India's, because its population is much smaller. In the United States, the world's third-largest country, the per capita ecological footprint is 7.9 hectares (19.5 acres); the U.S. footprint as a country is 2,457 million hectares! If all people in the world had the same lifestyle and level of consumption as the average North American, and assuming no changes in technology, we would need about four additional planets the size of Earth.

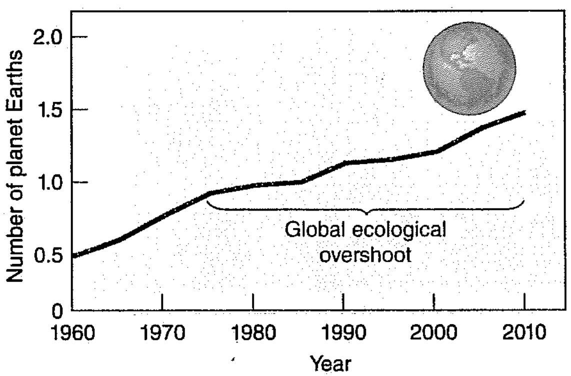
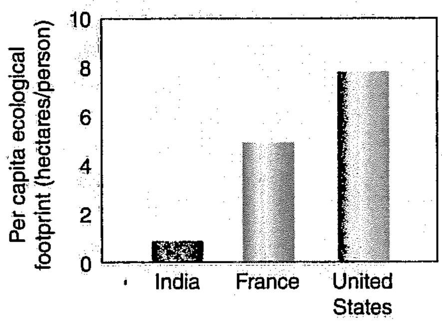
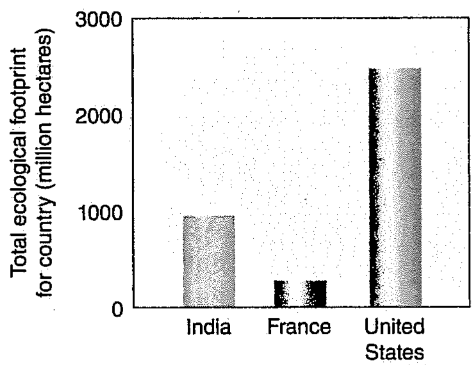


Figure 1.7 Global ecological overshoot. Earth's ecological footprint has been increasing over time. By 2010, humans were using the equivalent of 1.5 Earths, a situation that is not sustainable. (Data from World Wildlife Fund, *Living Planet Report 2010*)



(a) The average ecological footprint of a person living in India, France, or the United States. For example, each Indian requires 0.9 hectare (2.2 acres) of productive land and ocean to meet his or her resource requirements.



(b) The total ecological footprint for the countries of India, France, and the United States. Note that India, although having a low per capita ecological footprint, has a significantly higher ecological footprint as a country because of its large population. If everyone in the world had the same level of consumption as the average American, it would take the resources and area of five Earths.

Figure 1.8 Ecological footprints. (Data from World Wildlife Fund, *Living Planet Report 2012*)

As developing countries increase their economic growth and improve their standard of living, more and more people in those nations purchase consumer goods. More new cars are now sold annually in Asia than in North America and Western Europe combined. These new consumers may not consume at the high level of the average consumer in a highly developed country, but their consumption has increasingly adverse effects on the environment. For example, air pollution caused by automotive traffic in urban centers in developing countries is terrible and getting worse every year. Millions of dollars are lost because of air pollution–related health problems in these cities. One of society's challenges is to provide new consumers in developing countries (as well as ourselves) with less polluting, less consuming forms of transportation.

THE *IPAT* MODEL

Generally, when people turn on the tap to brush their teeth in the morning they do not think about where the water comes from or about the environmental consequences of removing it from a river or the ground. Similarly, most North Americans do not think about where the energy comes from when they flip on a light switch or start a car. We do not realize that all the materials in the products we use every day come from Earth, nor do we grasp that these materials eventually are returned to Earth, much of them in sanitary landfills.

Such human impacts on the environment are difficult to assess. They are estimated using the three factors most important in determining environmental impact (I):

1. The number of people (P)
2. Affluence, which is a measure of the consumption or amount of resources used per person (A)
3. The environmental effects (resources needed and wastes produced) of the technologies used to obtain and consume the resources (T)

These factors are related in this way:

$$I = P \times A \times T$$

el A representation a system; describes e system as it exists and predicts how anges in one part of ystem will affect the rest of the system.

In science, a **model** is a formal statement that describes the behavior of a system. The *IPAT* model, which biologist **Paul Ehrlich** and physicist **John Holdren** first proposed in the 1970s, shows the mathematical relationship between environmental impacts and the forces driving them.

For example, to determine the environmental impact of emissions of the greenhouse gas CO_2 from motor vehicles, multiply the population times the number of cars per person (affluence/consumption per person) times the average car's annual CO_2 emissions per year (technological impact). This model demonstrates that although increasing motor vehicle efficiency and developing cleaner technologies will reduce pollution and environmental degradation, a larger reduction will result if population and per capita consumption are also controlled.

The *IPAT* equation, though useful, must be interpreted with care, in part because we often do not understand all the environmental impacts of a particular technology on complex environmental systems. Motor vehicles are linked not only to global warming from CO_2 emissions but also to local air pollution (tailpipe exhaust), water pollution (improper disposal of motor oil and antifreeze), and solid waste (disposal of nonrecyclable automobile parts in sanitary landfills). There are currently more than 600 million motor vehicles on the planet, and the number is rising rapidly.

The three factors in the *IPAT* equation are always changing in relation to one another. Consumption of a particular resource may increase, but technological advances may decrease the environmental impact of the increased consumption. For example, there are more television and computer screens in the average household than there were 20 years ago (increased affluence) and more households (increased population). However, many of the new units are flat screens, which require less materials to produce and less energy to operate (more efficient technology). Thus, consumer trends and choices may affect environmental impact.

Similarly, the average fuel economy of new cars and light trucks (sport-utility vehicles, vans, and pickup trucks) in the United States declined from 22.1 miles per gallon in 1988 to 20.4 miles per gallon in the early 2000s, in part because of the popularity of sport-utility vehicles (SUVs). In addition to being less fuel efficient than cars, SUVs emit more emissions per vehicle mile. More recently, hybrids have helped to increase the average fuel economy (**Figure 1.9**). Such trends and uncertainties make the *IPAT* equation of limited usefulness for long-term predictions.

The *IPAT* equation is valuable because it helps identify what we do not know or understand about consumption and its environmental impact. The National Research Council of the U.S. National Academy of Sciences[1] has identified research areas we must address, including the following: Which kinds of consumption have the greatest destructive impact on the environment? Which groups in society are responsible for the greatest environmental disruption? How can we alter the activities of these environmentally disruptive groups? It will take years to address such

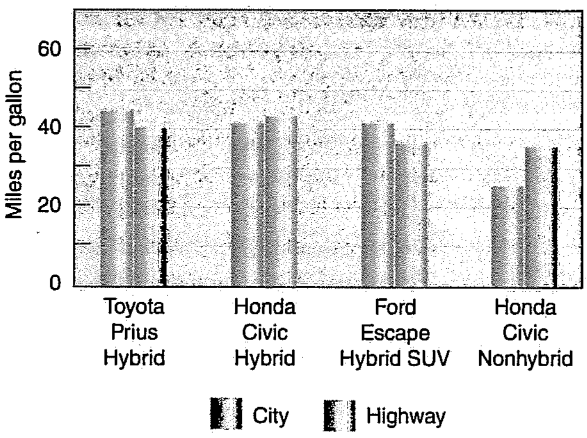


Figure 1.9 Fuel-efficient hybrids. Shown are city and highway miles per gallon for three hybrid models available in 2014. (U.S. Department of Energy)

[1] The National Research Council is a private, nonprofit society of distinguished scholars. It was organized by the National Academy of Sciences to advise the U.S. government on complex issues in science and technology.

questions, but the answers should help decision makers in government and business formulate policies to alter consumption patterns in an environmentally responsible way. Our ultimate goal should be to reduce consumption so that our current practices do not compromise the ability of future generations to use and enjoy the riches of our planet.

REVIEW

1. How do renewable resources differ from nonrenewable resources?
2. How are human population growth and affluence related to natural resource depletion?
3. What is an ecological footprint?
4. What does the *IPAT* model demonstrate?

Sustainability

LEARNING OBJECTIVES

- Define *sustainability*.
- Relate Garrett Hardin's description of the tragedy of the commons in medieval Europe to common-pool resources today.
- Briefly describe sustainable development.

One of the most important concepts in this text is **sustainability.** A sustainable world is one in which humans can have economic development and fair allocation of resources without the environment going into a decline from the stresses imposed by human society on the natural systems (such as fertile soil, water, and air) that maintain life. When the environment is used sustainably, humanity's present needs are met without endangering the welfare of future generations (**Figure 1.10**). Environmental sustainability applies at many levels, including individual, community, regional, national, and global levels.

ustainability The lity to meet current man economic and cial needs without omising the ability of the environment to support future generations.

- Our actions can affect the health and well-being of natural *ecosystems*, including all living things.
- Earth's resources are not present in infinite supply; our access is constrained by ecological limits on how rapidly renewable resources such as fresh water regenerate for future needs.
- The products we consume can impose costs to the environment and to society beyond those captured in the price we pay for those products.
- Sustainability requires a concerted and coordinated effort of people on a global scale.

Many experts in environmental problems think human society is not operating sustainably because of the following human behaviors:

- We extract nonrenewable resources such as fossil fuels as if they were present in unlimited supplies.

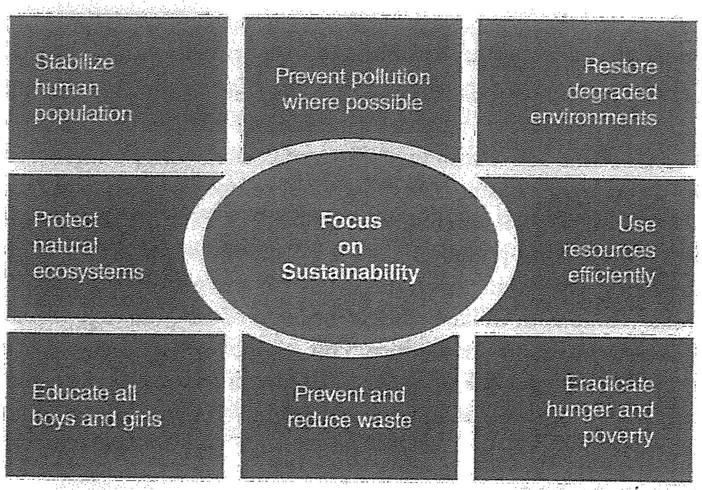
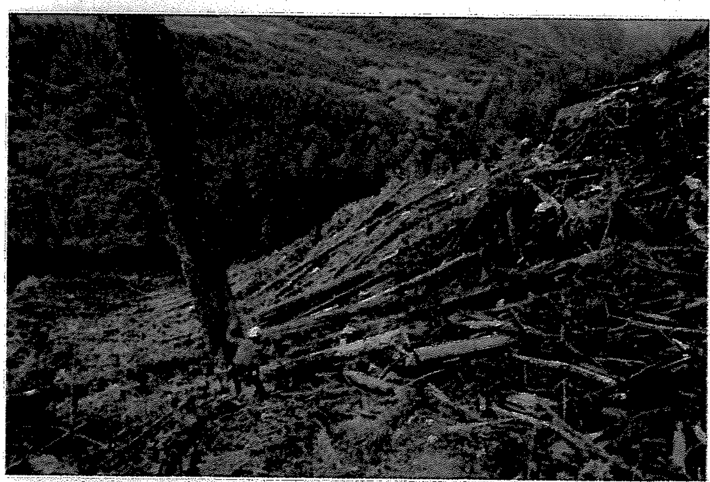


Figure 1.10 Sustainability. Sustainability requires a long-term perspective to protect human welfare and natural resource assets, such as the efforts shown here.

- We consume renewable resources such as fresh water and forests faster than natural systems can replenish them (**Figure 1.11**).
- We pollute the environment with toxins as if the capacity of the environment to absorb them is limitless.
- A small fraction of the human population dominates a large percentage of Earth's resources.
- Our numbers continue to grow despite Earth's finite ability to feed us, sustain us, and absorb our wastes.

If left unchecked, these activities could threaten Earth's life-support systems to such a degree that recovery is impossible. If major resources like agricultural land, fisheries, and fresh water are exhausted to the point that they cannot recover quickly, substantial human suffering would result. Thus managing these resources sustainably means more than protecting the environment: sustainability promotes human well-being.



Topham/The Image Works

Figure 1.11 A logger cuts down the last standing tree on a clear-cut forest slope. Logging destroys the habitat for forest organisms and increases the rate of soil erosion on steep slopes. Photographed in Canada.

At first glance, the issues may seem simple. Why do we not just reduce consumption, improve technology, and limit population growth? The answer is that various interacting ecological, societal, and economic factors complicate the solutions. Our inadequate understanding of how the environment works and how human choices affect the environment is a major reason that problems of sustainability are difficult to resolve. The effects of many interactions between the environment and humans are unknown or difficult to predict, and we generally do not know if we should take corrective actions before our understanding is more complete.

SUSTAINABILITY AND THE TRAGEDY OF THE COMMONS

Garrett Hardin (1915–2003) was a professor of human ecology at the University of California–Santa Barbara who wrote about human environmental dilemmas. In 1968, he published his classic essay, "The Tragedy of the Commons," in the journal *Science.* He contended that our inability to solve many environmental problems is the result of a struggle between short-term individual welfare and long-term environmental sustainability and societal welfare.

Hardin used the commons to illustrate this struggle. In medieval Europe, the inhabitants of a village shared pastureland, called the commons, and each herder could bring animals onto the commons to graze. If the villagers did not cooperatively manage the commons, each might want to bring more animals onto it. If every herder in the village brought as many animals onto the commons as possible, the plants would be killed from overgrazing, and the entire village would suffer. Thus, an unmanaged commons would inevitably be destroyed by the people who depended on it.

Hardin argued that one of the outcomes of the eventual destruction of the commons would be private ownership of land, because when each individual owned a parcel of land, it was in that individual's best interest to protect the land from overgrazing. A second outcome Hardin considered was government ownership and management of such resources, because the government had the authority to impose rules on users of the resource and thereby protect it.

Hardin's essay has stimulated a great deal of research in the decades since it was published. In general, scholars agree that degradation of the self-governing commons—now called **common-pool resources**—typically is not a problem in closely knit communities. Indeed, sociologist **Bill Freudenberg** has pointed out that medieval commons were successfully managed but became degraded after they were privatized. Economist **Elinor Ostrum** demonstrated that common pool resources can be sustainably managed by communities with shared interests, strong local governance, and community-enforced accountability.

common-pool ources Those parts of our environment available to everyone for which no single individual has responsibility—the sphere and climate, water, forests, wild- and ocean fisheries.

As one goes from local to regional to global common-pool resources, the challenges of sustainably managing resources become more complex. In today's world, Hardin's parable has particular relevance at the global level. These modern-day commons are experiencing increasing environmental stress (see, for example, the discussion of climate change in Chapter 20). No individual, jurisdiction, or country owns common-pool resources, and they are susceptible to overuse. Although exploitation may benefit only a few, everyone on Earth must pay for the environmental cost of exploitation.

The world needs effective legal and economic policies to prevent the short-term degradation of common-pool resources and ensure their long-term well-being. We have no quick fixes because solutions to global environmental problems are not as simple or short term as are solutions to some local problems. Most environmental ills are inextricably linked to other persistent problems such as poverty, overpopulation, and social injustice—problems beyond the capacity of a single nation to resolve. The large number of participants who must organize, agree on limits, and enforce rules complicates the creation of global treaties to manage common-pool resources. Cultural and economic differences among participants make finding solutions even more challenging.

Clearly, all people, businesses, and governments must foster a strong sense of **stewardship**—shared responsibility for the sustainable care of our planet. Cooperation and commitment at the international level are essential if we are to alleviate poverty, stabilize the human population, and preserve our environment and its resources for future generations.

stewardship Shared responsibility for the sustainable care of our planet.

GLOBAL PLANS FOR SUSTAINABLE DEVELOPMENT

In 1987, the World Commission on Environment and Development released a groundbreaking report, *Our Common Future* (see Chapter 24). A few years later, in 1992, representatives from most of the world's countries met in Rio de Janeiro, Brazil, for the *UN Conference on Environment and Development.* Countries attending the conference examined environmental problems that are international in scope: pollution and deterioration of the planet's atmosphere and oceans, a decline in the number and kinds of organisms, and destruction of forests.

In addition, the Rio participants adopted *Agenda 21*, an action plan of **sustainable development** in which future economic development, particularly in developing countries, will be reconciled with environmental protection. The goals of sustainable development are achieving improved living conditions for all people while maintaining a healthy environment in which natural resources are not overused and excessive pollution is not generated. Three factors—environmentally sound decisions, economically viable decisions, and socially equitable decisions—are necessary for truly sustainable development. To use sustainability as a guiding principle for environmental management requires that we think about how these three factors interact as parts of a complex and interlinked system (**Figure 1.12**).

sustainable development As defined by the Brundtland report, economic development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs.

A serious application of the principles of environmental sustainability to economic development will require many changes in such fields as population policy, agriculture, industry, economics,

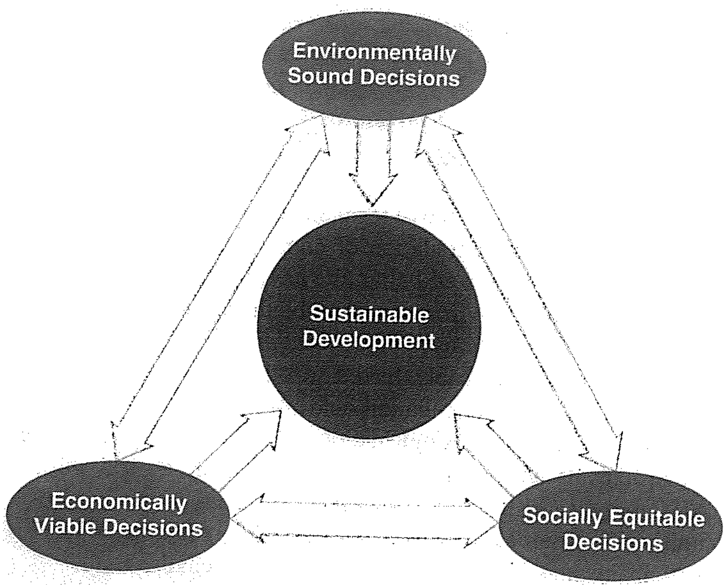


Figure 1.12 Sustainable development, a systems concept. Using sustainable development as an organizing principle for environmental management requires us to recognize that economic development, social justice, and the environment are linked in many and complex ways. We must consider whether economic decisions harm the environment or deplete natural resources, whether resource management decisions are socially equitable, and whether societal decisions impact economic opportunities for current and future generations.

and energy use. In 2000, representatives from 189 countries met at the *UN Millennium Summit* and committed their countries to a global partnership with goals known as the *Millennium Development Goals* (see Chapter 8).

Despite such international summits, we have made only limited progress in improving the quality of life for poor people or in solving the world's most serious environmental problems. Many governments have shifted their attention from serious environmental priorities to other challenges such as terrorism, worsening international tensions, and severe economic problems. Meanwhile, scientific warnings about important environmental problems such as global climate change have increased.

Despite the lack of significant change at the international level, some nations, states, and municipalities have made important environmental progress. Many countries have enacted more stringent air pollution laws, including the phasing out of leaded gasoline. More than 100 countries have created sustainable development commissions. Corporations that promote environmentally responsible business practices have joined to form the World Business Council for Sustainable Development. The World Bank, which makes loans to developing countries, has invested billions of dollars in sustainable development projects around the world.

REVIEW

1. What is sustainability?
2. What is the tragedy of the commons?
3. What are the three foundations of sustainable development?

Environmental Science

LEARNING OBJECTIVES

- Define *environmental science* and briefly describe the role of Earth systems in environmental science.
- Outline the scientific method.

Environmental science encompasses the many interconnected issues involving human population, Earth's natural resources, and environmental pollution. Environmental science combines information from many disciplines, such as biology, geography, chemistry, geology, physics, economics, sociology, demography (the study of populations), cultural anthropology, natural resources management, agriculture, engineering, law, politics, and ethics. **Ecology**, the branch of biology that studies the interrelationships between organisms and their environment, is a basic tool of environmental science.

environmental science The interdisciplinary study of humanity's relationship with other organisms and the nonliving physical environment.

Environmental scientists try to establish general principles about how the natural world functions. They use these principles to develop viable solutions to environmental problems—solutions based as much as possible on scientific knowledge. Environmental problems are generally complex, so our understanding of them is often less complete than we would like it to be. Environmental scientists are often asked to reach a consensus before they fully understand the systems that they study. As a result, they often make recommendations based on probabilities rather than precise answers.

Many of the environmental problems discussed in this book are serious, but environmental science is not simply a "doom-and-gloom" listing of problems coupled with predictions of a bleak future. To the contrary, its focus is, and our focus as individuals and as world citizens should be, on identifying, understanding, and finding better ways to manage the stresses that human activities place on environmental resources and systems.

EARTH SYSTEMS AND ENVIRONMENTAL SCIENCE

One of the most exciting aspects of environmental science and many other fields of science is working out how *systems* that consist of many interacting parts function as a whole. As discussed in the chapter introduction, Earth's climate is a system that in turn is composed of smaller, interdependent systems, such as the atmosphere and ocean; these smaller systems are linked and interact with one another in the overall climate system.

The systems approach provides a broad look at overall processes, as opposed to the details of individual parts or steps. A commuter in city traffic may be quite familiar with the production of CO_2 by a car engine, but that knowledge does not automatically translate into an understanding of the global effect of millions of motor vehicles emitting CO_2. Thus, using a systems perspective helps scientists gain valuable insights that are not always obvious from looking at individual components within the system.

Also, problems arise from *not* thinking about systems. For example, if a company decides to burn waste oil to avoid its leaking into groundwater, pollution shifts from groundwater to the air. A systems perspective would require company executives to think about the trade-offs between the two disposal methods and, more importantly, about alternatives that might avoid generating waste oil in the first place.

Environmental scientists often use models to describe the interactions within and among environmental systems. Many of these models are computer simulations that represent the overall effect of competing factors to describe an environmental system in numerical terms. Models help us understand how the present situation developed from the past or how to predict the future course of events, including the long-term impacts of decisions or choices we make today. Models also generate additional questions about environmental issues. (Appendix III contains an introduction to modeling.)

A natural system consisting of a community of organisms and its physical environment is known as an **ecosystem**. In ecosystems, biological processes (such as photosynthesis) interact with physical and chemical processes to modify the composition of gases in the atmosphere, transfer energy from the sun through living organisms, recycle waste products, and respond to environmental changes with resilience. Natural ecosystems are the foundation for our concept of environmental sustainability.

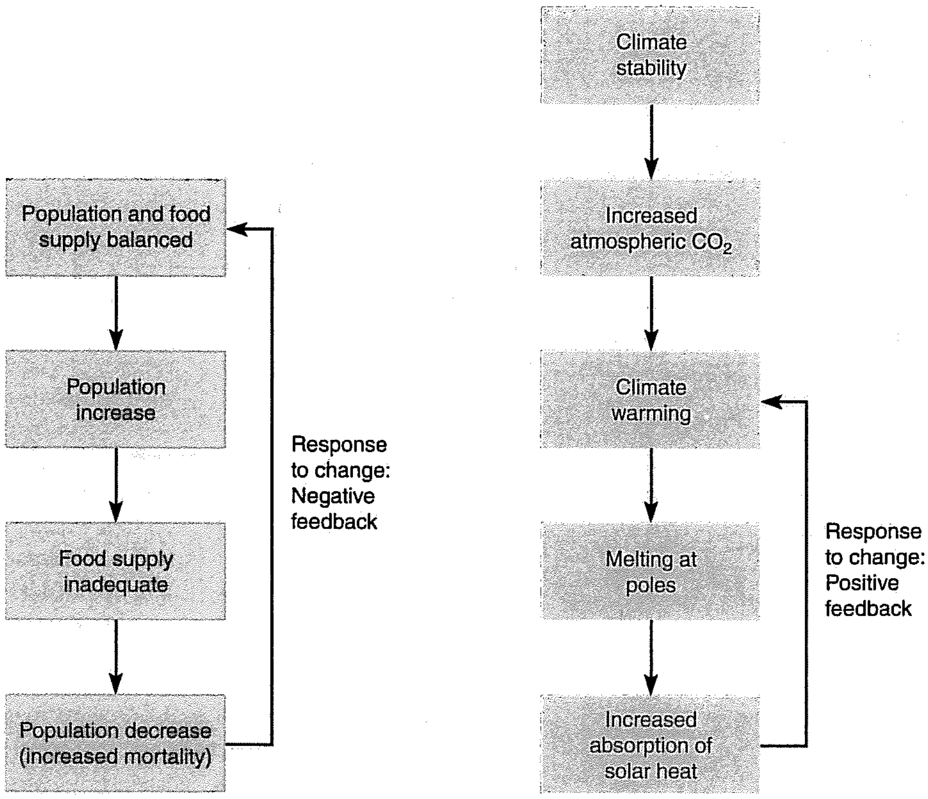
Ecosystems are organized into larger and larger systems that interact with one another (discussed in Chapter 3). At a global level are Earth systems, which include Earth's climate, atmosphere, land, coastal zones, and the ocean. Environmental scientists use a systems approach to try to understand how human activities are altering global environmental parameters such as temperature, CO_2 concentration in the atmosphere, land cover, changes in nitrogen levels in coastal waters, and declining fisheries in the ocean.

Many aspects of Earth systems are in a steady state or, more accurately, a **dynamic equilibrium**, in which the rate of change in one direction is the same as the rate of change in the opposite direction. *Feedback* occurs when a change in one part of a system leads to a change in another part. Feedback can be negative or positive. In a **negative feedback system**, a change in some condition triggers a response that counteracts, or reverses, the changed condition (**Figure 1.13a**). A negative feedback mechanism works to keep an undisturbed system in dynamic equilibrium. For example, consider fish in a pond. As the number of fish increases, available food decreases and fewer fish survive; thus, the fish population declines.

In a **positive feedback system**, a change in some condition triggers a response that intensifies the changing condition (**Figure 1.13b**); a positive feedback mechanism leads to greater change from the original condition. Positive feedback can be very disruptive to an already disturbed system. For example, melting of polar and glacial ice can lead to greater absorption of solar heat by the exposed land area, which in turn leads to more rapid melting. As you will see throughout this text, many negative and positive feedback mechanisms operate in the natural environment.

SCIENCE AS A PROCESS

One key to the successful solution of any environmental problem is a careful evaluation of conditions, causes, and effects. Science—a system for managing and producing information—is the most effective way to do this evaluation. It is important to understand clearly just what science is, as well as what it is not. Many people think of science as a body of knowledge—a collection of facts about the natural world and a search for relationships among these



(a) **Negative feedback.** In this simplified example, the initial balance between a population of fish and its food supply is ultimately restored. Thus, in a negative feedback system, the response to change opposes the change.

(b) **Positive feedback.** In this simplified example of a positive feedback system, the response to change increases, or amplifies, the deviation from the original point.

Figure 1.13 Feedback systems.

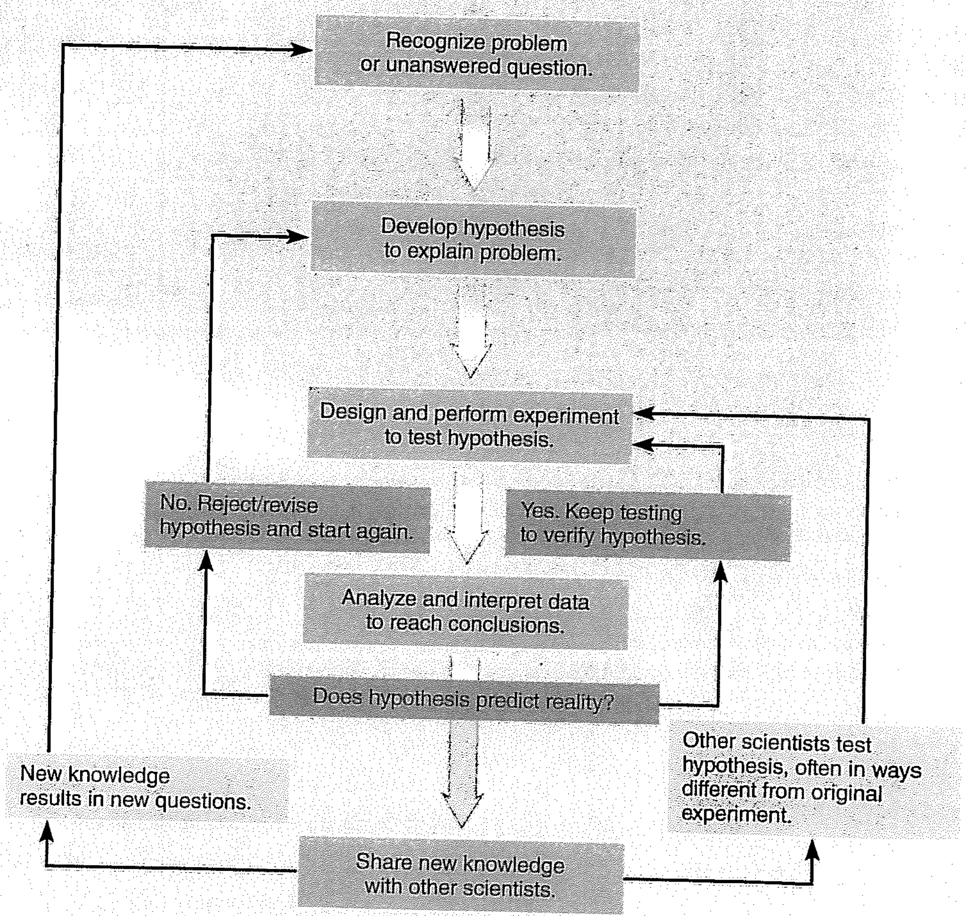
acts. However, science is also a dynamic *process*, a systematic vay to investigate the natural world. Scientists seek to describe he apparent complexity of our world with general scientific laws also called *natural laws*). Scientific laws are then used to make redictions, solve problems, or provide new insights.

Scientists collect objective **data** (singular, *datum*), the infor-nation with which science works. Data are collected by obser-ation and experimentation and then analyzed or interpreted. Conclusions are inferred from the available data and are not based n faith, emotion, or intuition.

Scientists publish their findings in scientific journals, and ther scientists examine and critique their work. Confirming the alidity of new results by *repeatability* is a requirement of sci-nce—observations and experiments must produce consistent esults when other scientists repeat them. Scrutiny by other sci-ntists reveals any inconsistencies in results or interpretation, and ese errors are discussed openly. Thus, science is *self-correcting* ver time.

No absolute certainty or universal agreement exists about nything in science. Science is an ongoing enterprise, and gen-ally accepted ideas must be reevaluated in light of newly dis-overed data. Scientists never claim to know the "final answer" out anything because scientific understanding changes. How-er, this does not prevent us from using current knowledge in vironmental science to make environmental decisions. Science presents the best information, and thus the best opportunity to ake informed decisions.

Uncertainty does not mean that scientific conclusions are valid. Overwhelming evidence links exposure to tobacco smoke d the incidence of lung cancer. We cannot te with absolute certainty which smok- will get lung cancer, but this uncertainty es not mean no correlation exists between oking and lung cancer. On the basis of available evidence, we say each indi-ual who smokes has an increased *risk* of veloping lung cancer, and we can say with at confidence that far more smokers will velop lung cancer than will nonsmokers.



ure 1.14 **Scientific method.** The basic of the scientific method are shown in w. Scientific work rarely proceeds in so ghtforward a manner; examples of additional are shown in orange.

Importantly, science cannot tell what we *should* do when faced with an environmental challenge, only what result we can expect given different choices. Science can provide better guid-ance than can religion or political preference on what will happen if we release pesticides that eventually reach the ocean or green-house gases that can change the climate. But values, politics, reli-gion, and culture must determine whether we find the loss of waterfowl or changes in the climate worth the benefits we get from spraying pesticides or burning fossil fuels.

The Scientific Method The established processes scientists use to answer questions or solve problems are collectively called the **scientific method** (**Figure 1.14**). Although the scientific method has many variations, it basi-cally involves five steps:

scientific method The way a scientist ap-proaches a problem by formulating a hypothesis and then testing it by means of an experiment.

1. **Recognize a question or unexplained occurrence in the natural world.** After a problem is recognized, one investigates relevant scientific literature to determine what is already known about it.
2. **Develop a *hypothesis*, or educated guess, to explain the problem.** A good hypothesis makes a prediction that can be tested and possibly disproved. The same factual evidence is often used to formulate several alternative hypotheses; each must be tested.

3. **Design and perform an experiment to test the hypothesis.** An experiment involves collecting data by making careful observations and measurements. Much of the creativity in science involves designing experiments that sort out the confusion caused by competing hypotheses. The process never "proves" anything; instead, it disproves or falsifies alternative hypotheses until only the most plausible hypothesis is left.
4. **Analyze and interpret the data to reach a conclusion.** Does the evidence match the prediction stated in the hypothesis—that is, do the data support or refute the hypothesis? Should the hypothesis be modified or rejected based on the observed data?
5. **Share new knowledge.** Publishing articles in scientific journals or books and presenting the information at meetings permits others to understand and critique methods and findings, and repeat the experiment or design new experiments that either verify or refute the work.

Although the scientific method is usually described as a linear sequence of events, science is rarely as straightforward or tidy as the scientific method implies. Good science involves creativity and openness to new ideas in recognizing questions, developing hypotheses, and designing experiments. Scientific knowledge progresses by trial and error. Many creative ideas end up as dead ends, and temporary setbacks or reversals of direction often occur as knowledge progresses. Scientific knowledge often expands haphazardly, with the "big picture" emerging slowly from confusing and sometimes contradictory details.

Scientific work is often incorrectly portrayed in the media as "new facts" that have just come to light. At a later time, additional "new facts" that question the validity of the original study are reported. If one were to read the scientific papers on which such media reports are based, one would find that the scientists made tentative conclusions based on their data. Science progresses from uncertainty to less uncertainty, not from certainty to greater certainty. Science leads to a better understanding of nature over time, despite the fact that science never "proves" anything.

Most often, many factors influence the processes scientists want to study. Each factor that influences a process is a **variable**. Ideally, to evaluate alternative hypotheses about a given variable, we run experiments that hold all other variables constant so that they do not confuse or mislead us. To test a hypothesis about a variable, two forms of the experiment are done in parallel. In an **experimental group**, we alter the chosen variable in a known way. In a **control group**, we do not alter that variable. In all other respects the two groups are the same. We then ask, "What is the difference, if any, between the outcomes for the two groups?" Any difference is the result of the influence of that variable because all other variables remained the same. Much of the challenge of environmental science lies in designing control groups and in successfully isolating a single variable from all other variables.

Theories Theories explain scientific laws. A **theory** is an integrated explanation of numerous hypotheses, each supported by a large body of observations and experiments and evaluated by the peer review process. A theory condenses and simplifies many data that previously appeared unrelated. A good theory grows as additional information becomes known. It predicts new data and suggests new relationships among a range of natural phenomena.

A theory simplifies and clarifies our understanding of the natural world because it demonstrates relationships among classes of data. Theories are the solid ground of science, the explanations of which we are most sure. This definition contrasts sharply with the general public's use of the word *theory*, implying lack of knowledge or a guess—as in, "I have a theory about the existence of life on other planets." In this book, the word *theory* is always used in its scientific sense, to refer to a broadly conceived, logically coherent, and well-supported explanation.

Absolute truth is not possible in science, only varying degrees of uncertainty. Science is continually evolving as new evidence comes to light, and its conclusions are always provisional or uncertain. It is always possible that the results of future experiments will contradict a prevailing theory, which will then be replaced by a new or modified theory that better explains the scientific laws of the natural world.

Climate Change: Hypotheses and Theory A dominant theory in environmental science today is that carbon dioxide (CO_2) and other gases released from burning fossil fuels has caused and will continue to cause Earth's climate to change. Clearly, however, the climate is a complex system, with many variables that change over a long period. We cannot run an experiment to test the hypothesis that releasing greenhouse gases over a century causes global temperatures to increase. Understanding climate change requires us to observe what is happening, compare those observations to what existing theory predicts will happen, and adapt our theories based on new observations. The theory of climate change draws on physics, chemistry, oceanography, atmospheric science, astronomy, and other scientific fields.

Many of the components of climate theory can be tested directly (**Figure 1.15**). As one example, scientists have tested the hypothesis that some gases, which we call greenhouse gases, can absorb energy (where energy absorption is a variable). In one such experiment, they filled identical containers with air, varied the concentrations of CO_2 in the containers, and then added heat. They observed temperature increases in the containers with more CO_2. While such experiments do not prove that CO_2 absorbs heat, they demonstrate that it is reasonable to think the hypothesis is correct. Indeed, heat absorption by CO_2 has been understood for over a century.

Climate scientists have combined this experimental evidence about greenhouse gases with our understanding of other parts of the climate, such as natural variability, solar variability, and reflectivity of ice and other surfaces, to establish a theory of climate change. This theory has uncertainties, but it predicts that as greenhouse gas concentrations increase, global atmospheric temperature will increase, sea level will rise, precipitation patterns will change, and glaciers and ice caps will melt (**Figure 1.16**). As we will see in Chapter 20, observations have confirmed this general theory, while allowing us to refine it and make more reliable predictions about the future. Climate theory does not tell us what we should do to avoid climate change, only what we can expect from different possible decisions.

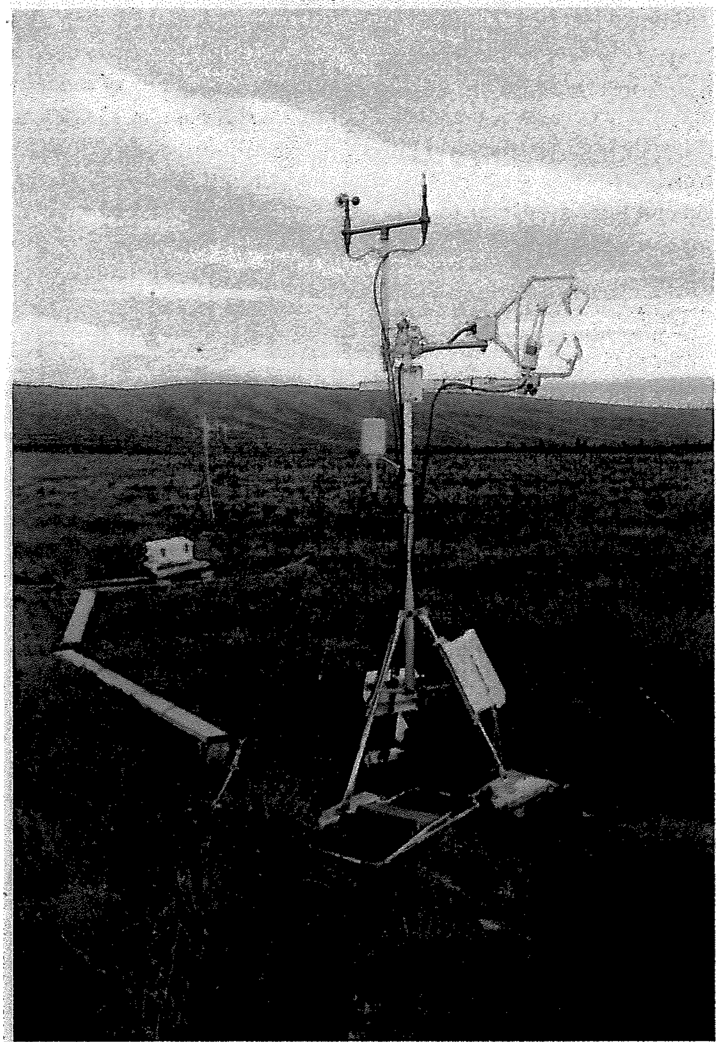
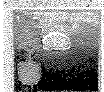


Figure 1.15 Climate change analysis. This equipment is part of a long-term project to explore the release of carbon dioxide (a greenhouse gas) from the melting tundra in Alaska.

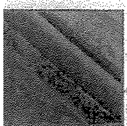


Carbon dioxide is released by warming, and contributes to warming. Is this an example of a positive feedback or a negative feedback?

Figure 1.16 Melting iceberg. Water streams from an iceberg that was once part of the Ilulisat Kangerlua Glacier, Greenland. While icebergs have broken off of glaciers throughout geologic history, evidence shows that the rate at which glaciers are melting has accelerated rapidly over the past hundred years.

REVIEW

1. What is environmental science? Why is a systems perspective so important in environmental science?
2. What are the steps of the scientific method? Does the scientific process usually follow these steps? Why or why not?



Addressing Environmental Problems

LEARNING OBJECTIVES

- List and briefly describe the five stages in addressing environmental problems.
- Briefly describe the history of the Lake Washington pollution problem of the 1950s and how it was resolved.

We have shown the strengths and limitations of science—what science can and cannot do. Before examining the environmental problems in the remaining chapters of this text, let us consider the elements that contribute to addressing those problems. What is the role of science? Given that we can never achieve complete certainty in science, at what point are scientific conclusions considered certain enough to warrant action? Who makes the decisions, and what are the trade-offs?

ADDRESSING ENVIRONMENTAL PROBLEMS

Viewed simply, there are five stages in addressing an environmental problem (**Figure 1.17**):

1. **Scientific assessment.** The first stage in addressing any environmental problem is scientific assessment, the gathering of information. The problem is defined. Data are then collected, and experiments or simulations are performed.
2. **Risk analysis.** Using the results of a scientific investigation, we can analyze the potential effects of doing nothing or of intervening—what is expected to happen if a particular course of action is followed, including any adverse effects the action might generate. In other words, the risks of one or more remediation (correction or cleanup) options are considered.
3. **Public education and involvement.** Public participation and commitment are an essential part of addressing most environmental problems. The public can be a source of both knowledge and values, and many individuals and groups have a stake in the outcome of decisions. People are generally more willing to work together to solve a problem if they have the opportunity to participate from the start.
4. **Political action.** Affected parties select and implement a course of action. Ideally, science provides information on what *can* be done, but in the political process, opinions often differ about how to interpret evidence when selecting a course of action. Often, what people think *should* be done affects their beliefs about science and scientists.
5. **Long-term evaluation.** The results of any action taken should be carefully monitored, both to see if the environmental problem is being addressed and to improve the initial assessment and modeling of the problem.

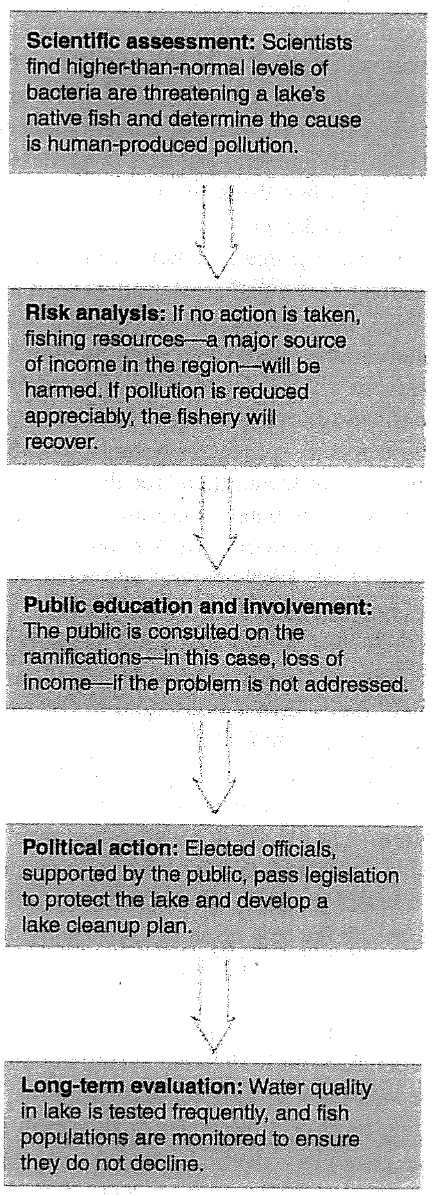


Figure 1.17 Addressing environmental problems. These five steps provide a framework for addressing environmental problems, such as the hypothetical example given. Solving environmental problems rarely proceeds in such a straightforward manner.

These five stages represent an ideal approach to systematically addressing environmental problems. In real life, addressing environmental problems is rarely so neat and tidy, particularly when the problem is of regional or global scale, or when those bearing the costs are not those who stand to benefit from a new policy. Quite often, the public becomes aware of a problem, which triggers discussion regarding remediation before the problem has been clearly identified. Also, we often do not know what scientific information is needed until stage 2, 3, or even 4, which means that to make informed decisions, we often need to ask scientists to develop additional research.

To demonstrate the five steps as they operate in an ideal situation, let us consider a relatively simple environmental problem recognized and addressed in the 1950s—pollution in Lake Washington. This problem, unlike many environmental issues we face today, was relatively easy to diagnose and solve.

CASE IN POINT

LAKE WASHINGTON

Lake Washington is a large, deep freshwater lake on the eastern boundary of Seattle (**Figure 1.18**). During the first part of the twentieth century, the Seattle metropolitan area expanded eastward toward the lake from the shores of Puget Sound, putting Lake Washington under increasingly intense environmental pressures. Between 1941 and 1954, 10 suburban sewage treatment plants began operating around the lake. Each plant treated the raw sewage to break down the organic material within it and released the effluent (treated sewage) into the lake. By the mid-1950s, a great deal of treated sewage had been poured into the lake.

Scientists at the University of Washington were the first to note the effects of this discharge on the lake. Their studies indicated that large masses of cyanobacteria (photosynthetic bacteria) were growing in the lake. Cyanobacteria require a plentiful supply

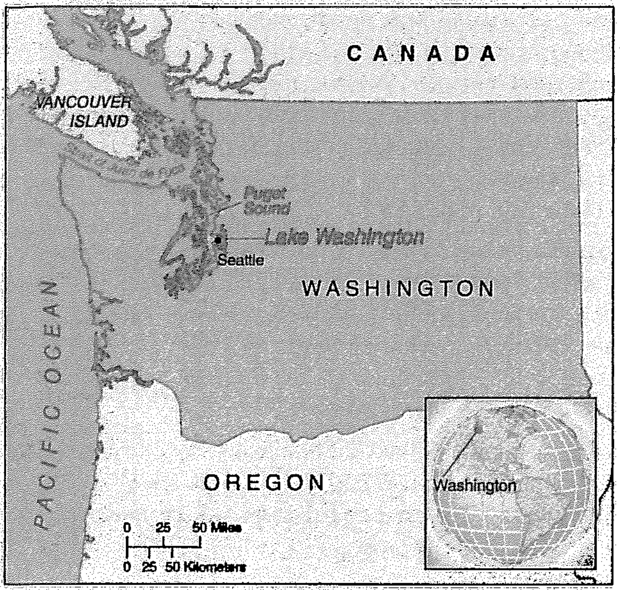


Figure 1.18 Lake Washington. This large freshwater lake forms the eastern boundary of Seattle, Washington.

of nutrients such as nitrogen and phosphorus, and deepwater lakes such as Lake Washington do not usually have many dissolved nutrients. The increase in filamentous cyanobacteria indicated that the quality of water in Lake Washington was diminishing.

In 1955, the Washington Pollution Control Commission, citing the scientists' work, concluded that the treated sewage effluent was raising the levels of dissolved nutrients to the point of serious pollution. The sewage treatment was not eliminating many chemicals, particularly phosphorus, a major component of detergents. Mats of cyanobacteria formed a smelly green scum over the surface of the water. The bacteria that decompose cyanobacteria when they die multiplied explosively, consuming vast quantities of oxygen, until the lake's deeper waters could no longer support oxygen-requiring organisms such as fishes and small invertebrates.

Scientific assessment of an environmental problem verifies that a problem exists and builds a sound set of observations on which to base a solution. Scientists predicted that the lake's decline could be reversed: If the pollution was stopped, the lake would slowly recover. They outlined three steps necessary to save the lake:

1. Comprehensive regional planning by the many suburbs surrounding the lake
2. Complete elimination of sewage discharge into the lake
3. Research to identify the key nutrients causing the cyanobacteria to grow

It is one thing to suggest that treated sewage no longer be added to Lake Washington and quite another to devise an acceptable remediation option. Further treatment of sewage could remove some nutrients, but it might not be practical to remove all of them. The alternative was to dump the sewage somewhere else—but where? In this case, officials decided to discharge the treated sewage into Puget Sound. In their plan, a ring of sewers built around the lake would collect the treated sewage and treat it further before discharging it into Puget Sound.

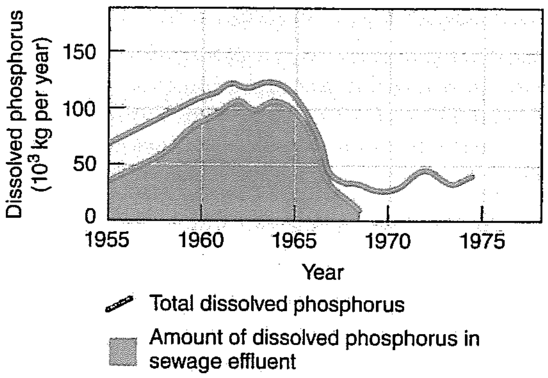
The plan to further treat the sewage was formulated to minimize the environmental impact on Puget Sound. It was assumed that the treated effluent would have less of an impact on the greater quantity of water in Puget Sound. Also, phosphate does not control cyanobacterial growth in Puget Sound as it does in Lake Washington. The growth of photosynthetic bacteria and algae in Puget Sound is largely limited by tides, which mix the water and transport the tiny organisms into deeper water, where they cannot get enough light to grow rapidly.

Despite the Washington Pollution Control Commission's conclusions, local sanitation authorities were not convinced that urgent action was necessary. Public action required further education, and scientists played a key role. They wrote articles for the general public that explained what nutrient enrichment is and what problems it causes. The general public's awareness increased as local newspapers published these articles.

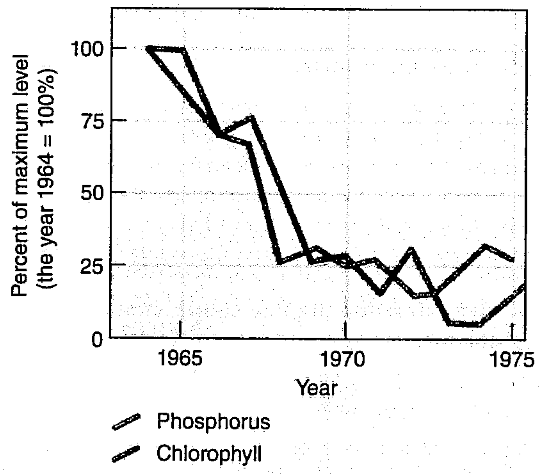
Cleaning up the lake presented serious political problems because there was no regional mechanism in place to permit the many local suburbs to act together on matters such as sewage disposal. In late 1957, the state legislature passed a bill permitting a public referendum in the Seattle area regarding the formation of a regional government with six functions: water supply, sewage disposal, garbage disposal, transportation, parks, and planning. The referendum was defeated, apparently because suburban voters felt the plan was an attempt to tax them for the city's expenses. An advisory committee immediately submitted a revised bill limited to sewage disposal to the voters. Over the summer there was widespread discussion of the lake's future, and when the votes were counted, the revised bill passed by a wide margin.

At the time it was passed, the Lake Washington plan was the most ambitious and most expensive pollution-control project in the United States. Every household in the area had to pay additional taxes for construction of a massive trunk sewer to ring the lake, collect the effluent, treat it, and discharge it into Puget Sound. Meanwhile, the lake had deteriorated further. Visibility had declined from 4 m (12 ft) in 1950 to less than 1 m (3 ft) in 1962 because the water was clouded with cyanobacteria. In 1963, the first of the waste treatment plants around the lake began to divert its effluent into the new trunk sewer. One by one, the others diverted theirs, until the last effluent was diverted in 1968. The lake's condition began to improve (**Figure 1.19**).

Water transparency returned to normal within a few years. Cyanobacteria persisted until 1970 but eventually disappeared. By 1975, the lake was back to normal, and today the lake remains clear. Continuing to protect the water quality even as population around the lake grows has required a systems perspective. Rather than just clean up wastewater, more recent efforts have included strategies that reduce the generation of wastes, such as water recycling and efforts to reduce oil and other industrial wastes.



(a) Dissolved phosphorus in Lake Washington from 1955 to 1974. Note that the level of dissolved phosphorus declined in the lake as the phosphorus contributed by sewage effluent (shaded area) declined.



(b) Cyanobacterial growth from 1964 to 1975, during Lake Washington's recovery, as measured indirectly by the amount of chlorophyll, the pigment involved in photosynthesis. Note that as the level of phosphorus dropped in the lake, the number of cyanobacteria (that is, the chlorophyll content) declined.

Figure 1.19 Nutrients in Lake Washington compared with cyano bacterial growth. (From W.T. Edmondson) *The Uses of Ecology: Lake Washington and Beyond.* University of Washington Press (1991).

ENVIRONEWS

Green Roofs

A roof that is completely or partially covered with vegetation and soil is known as a *green roof.* Also called *eco-roofs*, green roofs can provide several environmental benefits. For one thing, the plants and soil are effective insulators, reducing heating costs in winter and cooling costs in summer. The rooftop mini-ecosystem filters pollutants out of rainwater and reduces the amount of stormwater draining into sewers. In urban areas, green roofs provide wildlife habitat, even on the tops of tall buildings. A city with multiple green roofs provides "stepping stones" of habitat that enable migrating birds and insects to pass unharmed through the city. Green roofs can also serve as local food resources (see Chapter 18 opener); some restaurants have begun including rooftop gardens for herbs, vegetables, and even beekeeping. Green roofs can also provide an outdoor refuge for people living or working in the building as they allow urban systems to more closely resemble the natural systems they have replaced.

The largest individual green roof in the United States is on the Ford Motor Company factory in Dearborn, Michigan. Planted with nine varieties of hardy plants that require little or no maintenance, the Ford green roof absorbs excess rainwater. This water is naturally cleaned as it passes through a series of wetlands before entering the Rouge River, allowing Ford to avoid costly water treatment.

REVIEW

1. What are the steps used to solve an environmental problem?
2. What was the Lake Washington pollution problem of the 1950s? How was it addressed?

REVIEW OF LEARNING OBJECTIVES WITH SELECTED KEY TERMS

- **Explain how human activities affect global systems.**

Earth consists of many physical and biological **systems**. Its abundant resources have allowed many forms of life to thrive and evolve. Humans, through our growing population and technology, have exploited these resources to the point that we are putting the environment at risk.

- **Describe the factors that characterize human development and how they impact environment and sustainability.**

Human development is typically characterized by factors associated with wealth, such as access to energy resources and medical technology. Historically, **highly developed countries** have represented less than 20% of the global population but account for more than 50% of resource use. **Less developed countries (LDCs)** are developing countries with high **poverty** rates, low levels of industrialization, high fertility rates, high infant mortality rates, and very low per capita incomes (relative to highly developed countries). Increasingly, many of the world's countries, such as China and India, have mixed development, with some urban residents owning considerable wealth but other urban and most rural residents living in poverty.

- **Differentiate between renewable and nonrenewable resources.**

Renewable resources are those that nature replaces fairly rapidly (on a scale of days to centuries), and can be used forever as long as they are not overexploited in the short term. **Nonrenewable resources** are present in limited supplies and are depleted by use.

- **Explain the impact of population and affluence on consumption.**

As population increases, people can exceed the capacity of a region to support basic needs for food, shelter, and clean water. When **consumption** by individuals substantially exceeds these basic needs, the resources in a region will be exceeded even more quickly. In either case, consumption that exhausts both **nonrenewable** and **renewable resources** is unsustainable.

- **Define *ecological footprint*.**

An individual's **ecological footprint** is the amount of productive land, fresh water, and ocean required on a continuous basis to supply that person with food, energy, water, housing, material goods, transportation, and waste disposal.

- **Describe the three most important factors that determine human impact on the environment.**

One **model** of environmental impact *(I)* has three factors: the number of people *(P)*; the affluence per person *(A)*, which is a measure of the consumption or amount of resources used per person; and the environmental effect of the technologies used to obtain and consume those resources *(T)*. This model uses an equation to represent the relationship between environmental impacts and the forces that drive them:

$$I = P \times A \times T$$

- **Define *sustainability*.**

Sustainability is the ability to meet current human natural resource needs without compromising the ability of future generations to meet their needs; in other words, it is the ability of humans to manage natural resources indefinitely without the environment going into a decline from the stresses imposed by human society on the natural systems that maintain life.

- **Relate Garrett Hardin's description of the tragedy of the commons in medieval Europe to common-pool resources today.**

Garrett Hardin contended that our inability to solve many environmental problems is the result of a struggle between short-term individual welfare and long-term environmental sustainability and societal welfare. In today's world, Hardin's parable has particular relevance at the global level. **Common-pool resources** are those parts of our environment that are available to everyone but for which no single individual has responsibility—shared resources such as the atmosphere, fresh water, forests, wildlife, and ocean fisheries.

- **Briefly describe *sustainable development*.**

Sustainable development is economic development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. Three factors—environmentally sound decisions, economically viable decisions, and socially equitable decisions—interact to promote sustainable development.

- **Define *environmental science* and briefly describe the role of Earth systems in environmental science.**

Environmental science is the interdisciplinary study of humanity's relationship with other organisms and the nonliving physical environment. Environmental scientists study *systems*; each system is a set of components that interact and function as a whole. A natural system consisting of a community of organisms and its physical environment is an **ecosystem**. Ecosystems are organized into larger and larger systems that interact with one another. At a global level are Earth systems, which include Earth's climate, atmosphere, land, coastal zones, and the ocean.

- **Outline the scientific method.**

The **scientific method** is the way a scientist approaches a problem by formulating a hypothesis and then testing it by means of an experiment. There are many variations of the scientific method, which basically involves these steps: State the problem or unanswered question; develop a **hypothesis**; design and perform an experiment to test the hypothesis; analyze and interpret the **data**; and share the conclusion with others.

- **List and briefly describe the five stages in addressing environmental problems.**

1. Scientific assessment involves gathering information about a potential environmental problem.
2. Risk analysis evaluates the potential effects of intervention.
3. Public education and involvement occur when the results of scientific assessment and risk analysis are placed in the public arena.
4. Political action is the implementation of a particular course of action by elected or appointed officials.
5. Long-term evaluation monitors the effects of the action taken.

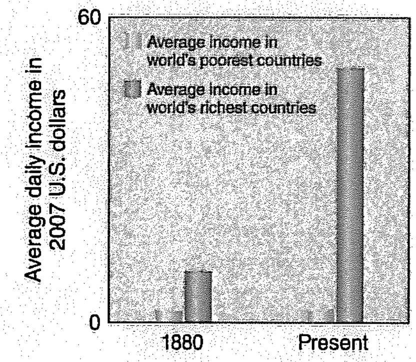
- **Briefly describe the history of the Lake Washington pollution problem of the 1950s and how it was resolved.**

Lake Washington exemplifies a successful approach to addressing a relatively simple environmental problem. The pouring of treated sewage into Lake Washington had raised its level of nutrients to the point where the lake supported excessive growth of cyanobacteria. Disposal of the sewage in another way solved the lake's pollution problem.

Critical Thinking and Review Questions

1. Explain why a single child born in the United States can have a greater effect on the environment than 12 or more children born in a developing country.
2. Do you think it is possible for the world to sustain its present population of 7.2 billion indefinitely? Why or why not?
3. Is consumption driven more by population than affluence in highly developed countries? Less developed countries? Explain the difference.
4. In this chapter, we said the current global ecological footprint is 2.7 hectares (6.7 acres) per person. Do you think it will be higher, lower, or the same in 15 years? Explain your answer.
5. How are the concepts of ecological footprint and the *IPAT* model similar? Which concept do you think is easier for people to grasp?
6. Explain the following proverb as it relates to the concept of environmental sustainability: We have not inherited the world from our ancestors; we have borrowed it from our children.

7. Name an additional example of a common-pool resource other than those mentioned in this chapter.
8. Explain why economic well-being, environment, and ethics all contribute to sustainable development.
9. Give an example of an Earth system.
10. Thomas Henry Huxley once wrote, "The great tragedy of science—the slaying of a beautiful hypothesis by an ugly fact." Explain what he meant, based on what you have learned about the nature of science.
11. In the chapter, the term *model* is defined as a formal statement that describes a situation and that can be used to predict the future course of events. On the basis of this definition, is a model the same thing as a hypothesis? Explain your answer.
12. Some people want scientists to give them precise, definitive answers to environmental problems. Explain why this is not possible, and explain its implications for making decisions about climate change.
13. Explain why it might be difficult to make a decision about whether to allow farmers to spray pesticides even if we all agree about the negative health effects of the pesticide.
14. Place the following stages in addressing environmental problems in order and briefly explain each: long-term evaluation, public education and involvement, risk analysis, scientific assessment, political action.
15. What does the term *system* mean in environmental science?
16. In what ways do decisions about energy use and climate change that we make today limit the possibilities available to the next generation? Explain your answer.
17. Examine the graph, which shows an estimate of the discrepancy between the wealth of the world's poorest countries and that of the richest countries.



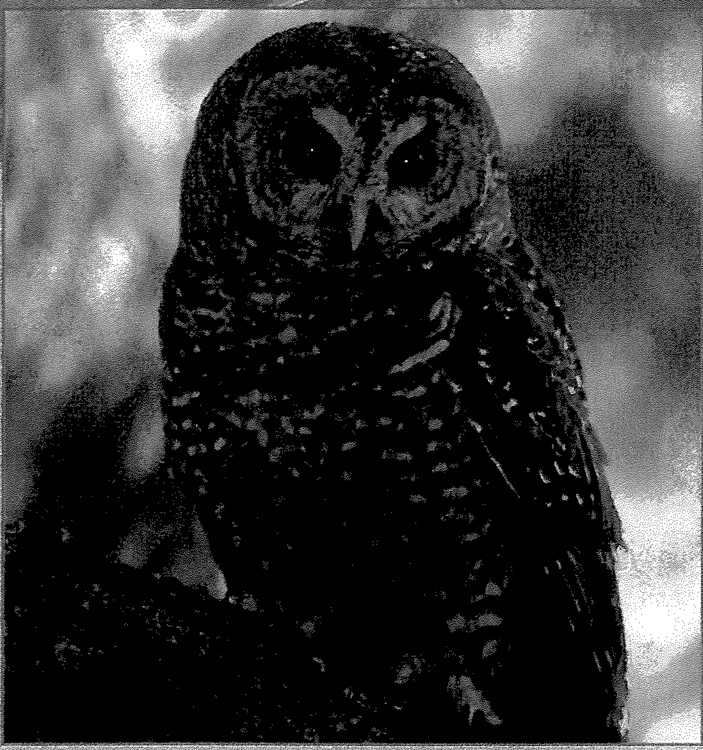
a. How has the distribution of wealth changed from the 1880s to the present? What explains this difference?
b. Based on the trend evident in this graph, predict what the graph might look like in 100 years.
c. Some economists think that our current path of economic growth is unsustainable. Are the data consistent with this idea? Explain your answer.

Food for Thought

For one week, keep track of the food you eat. Where does your food come from? How is it packaged? Did you produce any of it yourself, or do you know the individuals who did? Would you be able to eat only foods grown within 100 kilometers of your house? 500 kilometers? Explain the benefits and challenges of trying to do so.

2

Environmental Laws, Economics, and Ethics



Northern spotted owl. This rare species (*Strix occidentalis caurina*) is found predominantly in old-growth forests in the Pacific Northwest, from northern California to southern British Columbia. Protecting the owl's habitat benefits many other species that reside in the same environment.

uring the late 1980s, an environmental controversy began in western Oregon, Washington, and northern California that continues today. At stake were thousands of jobs and the future of large tracts of *old-growth coniferous forest*, along with the existence of organisms that depend on the forest. The northern spotted owl came to symbolize the confrontation because of its dependence on mature forests for habitat (**see photo**).

Old-growth forests have never been logged. Because most of the forests in the United States were logged at one time or another, less than 10% of old-growth forests remain, and this fraction is decreasing. Most old-growth forests in the United States are found in the Pacific Northwest and Alaska.

Old-growth forests provide biological habitats for many species, including the northern spotted owl and 40 other endangered or threatened species. Provisions of the *Endangered Species Act* require the government to protect the habitat of endangered species; under this law, a 1991 court order suspended logging in about 1.2 million hectares (3 million acres) of forest where the owl lives. The timber industry opposed the moratorium, stating that thousands of jobs would be lost if the area were set aside.

The situation was more complex than simply jobs versus the environment, however. From 1977 to 1987, logging in Oregon's national forests increased by over 15%, while automation in the timber industry eliminated an estimated 12,000 jobs. By the 1980s, the rate at which industry was removing trees would have eliminated most remaining old-growth forests by about 2000.

The 1994 **Northwest Forest Plan** provided federal aid to retrain some timber workers for other careers. Hundreds of former loggers were employed to restore watersheds and salmon habitats in the forests they once logged. The plan, along with previous congressional and administrative actions, reserved about 75% of federal timberlands to safeguard watersheds and protect the northern spotted owl and several hundred other species. Logging was resumed on federal forests in Washington, Oregon, and northern California, but at only about one-fifth of the 1980s level.

Timber-cutting interests were not happy with the plan, and they tried unsuccessfully to revoke or revise the laws. Environmental groups were also unhappy; in 1999 they sued the U.S. Forest Service and the Bureau of Land Management, the two agencies overseeing logging of old-growth forests on federal land, maintaining that these agencies had not adequately carried out the provisions of the plan. The judge agreed that the plan required agencies to survey local endangered and threatened species before approving logging plans. The Forest Service conducted these surveys until 2004, when it discontinued the practice, arguing that they were an inconsequential bureaucratic hurdle.

In mid-2008, responding to lawsuits from the timber industry, the Fish and Wildlife Service released a new management plan that would reduce the protected habitat area by 23%. Critics immediately countered that the decision ignored input from agency scientists. In mid-2009, the Northwest Forest Plan was reinstated as the governing policy.

A weakened species becomes vulnerable to other threats as well. In 2013, the Fish and Wildlife Service approved a plan to remove barred owls from northern spotted owl habitats. The barred owl, native to eastern forests, has become established in areas previously dominated by northern spotted owls.

This chapter examines the environmental history of the United States and the roles of government, economics, and ethics in environmental management.

In Your Own Backyard...

Look into a contested environmental issue in your community. Are they described as environment versus economics? Do you think that's a fair depiction?

A Brief Environmental History of the United States

LEARNING OBJECTIVES

- Briefly outline the environmental history of the United States.
- Describe the environmental contributions of the following people: George Perkins Marsh, Theodore Roosevelt, Gifford Pinchot, John Muir, Aldo Leopold, Wallace Stegner, Rachel Carson, and Paul Ehrlich.
- Distinguish between utilitarian conservationists and biocentric preservationists.

From the establishment of the first permanent English colony at Jamestown, Virginia, in 1607, the first two centuries of U.S. history were a time of widespread environmental exploitation. Land, timber, wildlife, rich soil, clean water, and other resources were cheap and seemingly inexhaustible. Early European settlers did not dream that the bountiful natural resources of North America would one day become scarce. During the 1700s and early 1800s, most Americans had a **frontier attitude**, a desire to conquer and exploit nature as quickly as possible. Concerns about the depletion and degradation of resources occasionally surfaced, but efforts to conserve were seldom made because the vastness of the continent made it seem that we would always have enough resources.

PROTECTING FORESTS

The great forests of the Northeast were leveled within a few generations, and shortly after the Civil War in the 1860s, loggers began deforesting the Midwest at an accelerated rate. Within 40 years, they deforested an area the size of Europe, stripping Minnesota, Michigan, and Wisconsin of virgin forest (**Figure 2.1**). By 1897, the sawmills of Michigan had processed 160 billion board feet of white pine, leaving less than 6 billion board feet standing in the whole state.

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Figure 2.1 Logging operations in 1884. This huge logjam occurred on the St. Croix River near Taylors Falls, Minnesota.

During the nineteenth century, many U.S. naturalists began to voice concerns about conserving natural resources. **John James Audubon** (1785–1851) painted lifelike portraits of birds and other animals in their natural surroundings. His paintings, based on detailed field observations, aroused widespread public interest in the wildlife of North America. **Henry David Thoreau** (1817–1862), a prominent U.S. writer, lived for two years on the shore of Walden Pond near Concord, Massachusetts. There he observed nature and contemplated how people could economize and simplify their lives to live in harmony with the natural world. **George Perkins Marsh** (1801–1882) was a farmer, linguist, and diplomat at various times during his life. Today he is most remembered for his book *Man and Nature*, which recognized the interrelatedness of human and environmental systems and provided one of the first discussions of humans as agents of global environmental change. Marsh was widely traveled, and *Man and Nature* was based in part on his observations of environmental damage in areas as geographically separate as the Middle East and his native Vermont.

In 1875, a group of public-minded citizens formed the *American Forestry Association*, with the intent of influencing public opinion against the wholesale destruction of America's forests. Sixteen years later, in 1891, the **General Revision Act** gave the president the authority to establish forest reserves on federally owned land. **Benjamin Harrison** (1833–1901), **Grover Cleveland** (1837–1908), and **Theodore Roosevelt** (1858–1919) used this law to remove 17.4 million hectares (43 million acres) of forest, primarily in the West, from logging.

In 1907 angry northwestern congressmen pushed through a bill rescinding the president's powers to establish forest reserves. Theodore Roosevelt, an important contributor to the conservation movement, responded by designating 21 new national forests that totaled 6.5 million hectares (16 million acres). He then signed into law the bill that prevented him and future presidents from establishing additional forest reserves.

Roosevelt appointed **Gifford Pinchot** (1865–1946) as the first head of the U.S. Forest Service. Both Roosevelt and Pinchot were **utilitarian conservationists** who viewed forests in terms of their usefulness for people—such as in providing jobs. Pinchot supported expanding the nation's forest reserves and managing forests scientifically, such as by harvesting trees only at the rate at which they regrow. Today, national forests are managed for multiple uses, from biological habitats to recreation to timber harvest to cattle grazing.

utilitarian conservationist A person who values natural resources because of their usefulness for practical purposes but uses them sensibly and carefully.

ESTABLISHING AND PROTECTING NATIONAL PARKS AND MONUMENTS

Congress established the world's first national park in 1872 after a party of Montana explorers reported on the natural beauty of the canyon and falls of the Yellowstone River; Yellowstone National Park now includes parts of Idaho, Montana, and Wyoming. In 1890, the *Yosemite National Park Bill* established the Yosemite

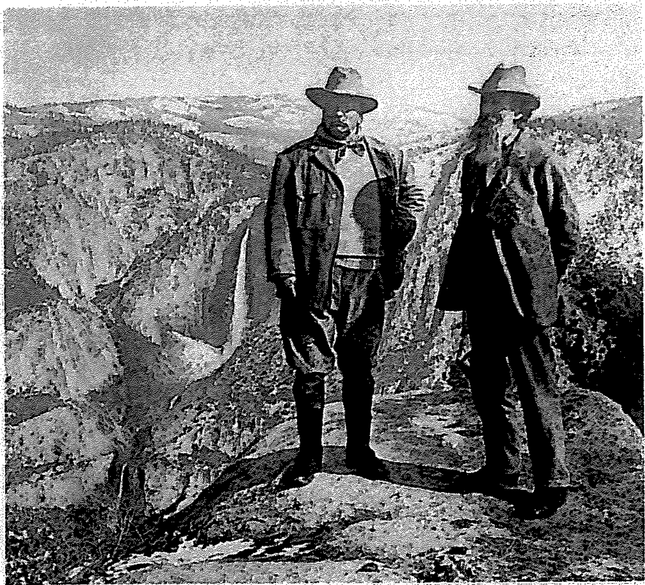

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Figure 2.2 President Theodore Roosevelt (left) and John Muir. This photo was taken on Glacier Point above Yosemite Valley, California.

and Sequoia National Parks in California, largely in response to the efforts of a single man, naturalist and writer **John Muir** (1838–1914) (**Figure 2.2**). Muir, a **biocentric preservationist**, founded the *Sierra Club*, a national conservation organization that is still active on a range of environmental issues.

ntric preserva-ist A person who eves in protecting because all forms fe deserve respect nd consideration.

In 1906, Congress passed the **Antiquities Act**, which authorized the president to set aside certain sites that had scientific, historical, or prehistoric importance, such as the Badlands in South Dakota, as national monuments. By 1916, the U.S. Army was managing 13 national parks and 20 national monuments. (Today the *National Park Service* manages the 58 national parks and 73 national monuments.)

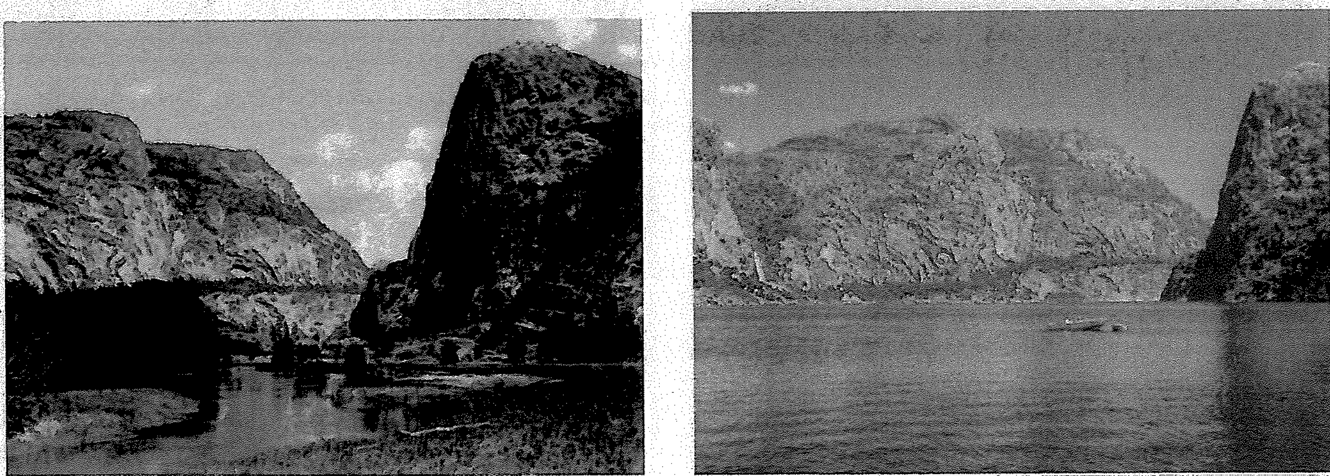
Some environmental battles involving the protection of national parks were lost. John Muir's Sierra Club fought such a battle with the city of San Francisco over its efforts to dam a river and form a reservoir in the Hetch Hetchy Valley (**Figure 2.3**), which lay within Yosemite National Park and was as beautiful as Yosemite Valley. In 1913, Congress voted to approve the dam.

The controversy generated a strong sentiment favoring better protection for national parks, and in 1916 Congress created the National Park Service to manage the national parks and monuments for the enjoyment of the public "without impairment." It was this clause that gave a different outcome to another battle, fought in the 1950s between conservationists and dam builders over the construction of a dam within Dinosaur National Monument. No one could deny that to drown the canyon with 400 feet of water would "impair" it. This victory for conservation established the "use without impairment" clause as the firm backbone of legal protection afforded to U.S. national parks and monuments. Today, discussion is under way to restore Hetch Hetchy, which the state of California estimates would cost as much as $10 billion.

CONSERVATION IN THE MID-TWENTIETH CENTURY

During the Great Depression, the federal government financed many conservation projects to provide jobs for the unemployed. During his administration, **Franklin Roosevelt** (1882–1945) established the Civilian Conservation Corps, which employed more than 175,000 men to plant trees, make paths and roads in national parks and forests, build dams to control flooding, and perform other activities to protect natural resources.

During the droughts of the 1930s, windstorms carried away much of the topsoil in parts of the Great Plains, forcing many farmers to abandon their farms and search for work elsewhere (see Chapter 14). The *American Dust Bowl* alerted the United States to the need for soil conservation, and in 1935, President Roosevelt formed the *Soil Conservation Service*.



AP Photo/Bancroft Library via Environmental Defense

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Figure 2.3 Hetch Hetchy Valley in Yosemite. A view in Hetch Hetchy Valley (left) before and (right) after Congress approved a dam to supply water to San Francisco. (National Archives, WallaceKleck/Terraphotographics/BPS)

Aldo Leopold (1886–1948) was a wildlife biologist and environmental visionary who was influential in the conservation movement of the mid- to late-twentieth century. His textbook *Game Management*, published in 1933, supported the passage of a 1937 act in which new taxes on sporting weapons and ammunition funded wildlife management and research. Leopold also wrote philosophically about humanity's relationship with nature and about the need to conserve wilderness areas. In *A Sand County Almanac*, published in 1949, Leopold argued persuasively for a land ethic and the sacrifices such an ethic requires.

Aldo Leopold had a profound influence on many American thinkers and writers, including **Wallace Stegner** (1909–1993), who penned his famous "Wilderness Essay" in 1962. Stegner's essay, written to a commission conducting a national inventory of wilderness lands, helped create support for passage of the Wilderness Act of 1964. Stegner wrote:

> *Something will have gone out of us as a people if we ever let the remaining wilderness be destroyed; if we permit the last virgin forests to be turned into comic books and plastic cigarette cases; if we drive the few remaining members of the wild species into zoos or to extinction; if we pollute the last clean air and dirty the last clean streams and push our paved roads through the last of the silence, so that never again will Americans be free in their own country from the noise, the exhausts, the stinks of human and automotive waste. We simply need that wild country available to us, even if we never do more than drive to its edge and look in. For it can be a means of reassuring ourselves of our sanity as creatures, a part of the geography of hope.*

During the 1960s, public concern about pollution and resource quality began to increase, in large part because of marine biologist **Rachel Carson** (1907–1964). Carson wrote about interrelationships among living organisms, including humans, and the natural environment (**Figure 2.4**). Her most famous work, *Silent Spring*, was published in 1962. In this work, Carson wrote against the indiscriminate use of pesticides.

Silent Spring heightened public awareness and concern about the dangers of uncontrolled use of DDT and other pesticides, including poisoning of wildlife and contamination of food supplies. Ultimately, this heightened public awareness led to restrictions on the use of certain pesticides. At about this time, the media began to increase its coverage of environmental incidents, such as hundreds of deaths in New York City from air pollution (1963), closed beaches and fish kills in Lake Erie from water pollution (1965), and detergent foam in a creek in Pennsylvania (1966).

In 1968, when the population of Earth was "only" 3.5 billion people (compared to 7.0 billion in 2011), ecologist **Paul Ehrlich** published *The Population Bomb*. In it, he described the unavoidable environmental damage necessary for Earth to support such a huge population, including soil loss, groundwater depletion, and extinctions. Ehrlich's book triggered public debate on the issue of overpopulation and how to address it effectively. As will be discussed later in this chapter, Ehrlich's *environmental worldview* influenced his theory that the world could comfortably hold only around 1 billion people.

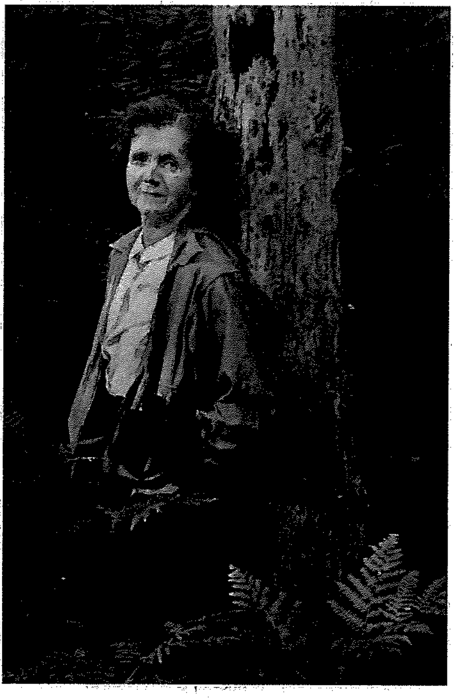


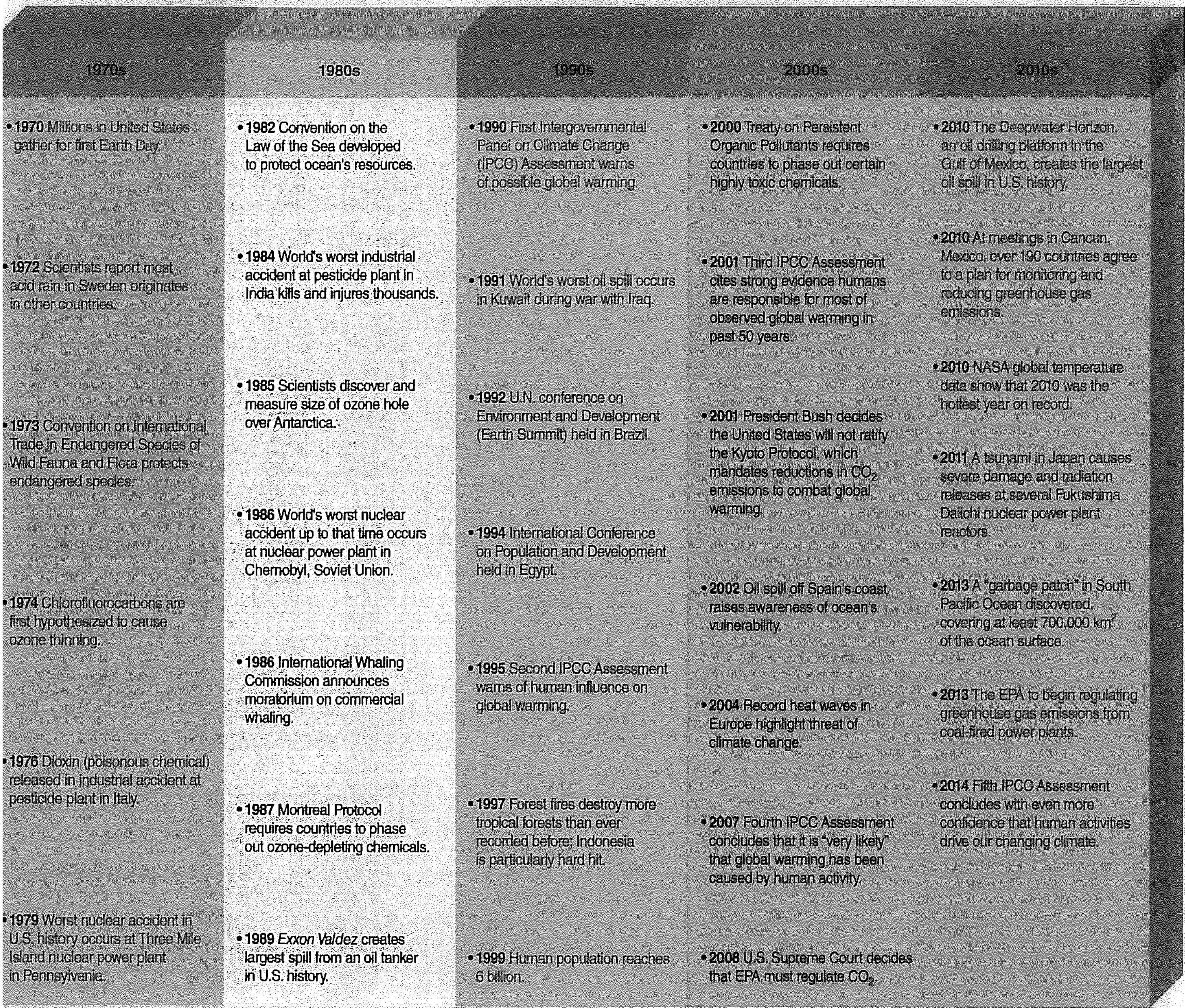
Figure 2.4 Rachel Carson. Carson's book *Silent Spring* heralded the beginning of the environmental movement. Photographed in Maine in 1962.

THE ENVIRONMENTAL MOVEMENT OF THE LATE TWENTIETH CENTURY

Until 1970, the voices of **environmentalists** were heard in the United States primarily through societies such as the *Sierra Club* and the *National Wildlife Federation*. There was no generally perceived environmental movement until the spring of 1970, when **Gaylord Nelson**, former senator from Wisconsin, urged Harvard graduate student **Denis Hayes** to organize the first nationally celebrated Earth Day. This event awakened U.S. environmental consciousness to population growth, overuse of resources, and pollution and degradation of the environment. On Earth Day 1970, an estimated 20 million people in the United States demonstrated their support for environmental quality by planting trees, cleaning roadsides and riverbanks, and marching in parades. (**Figure 2.5** presents a list of selected environmental events since Earth Day 1970.)

In the years that followed the first Earth Day, environmental awareness and the belief that individual actions could repair the damage humans were doing to Earth became a pervasive, popular movement. Musicians popularized environmental concerns, and many of the world's religions embraced environmental themes such as protecting endangered species.

By Earth Day 1990, the movement had spread around the world, signaling the rapid growth in environmental consciousness; an estimated 200 million people in 141 nations demonstrated to increase public awareness of the importance of individual efforts. Earth Day continues to be a popular event around the world, and many years include an organizing theme, such as "Think Globally, Act Locally" (1990) and "The Face of Climate Change" (2013, **Figure 2.6**).



igure 2.5 Selected environmental events, 1970 to the present.

EVIEW

. Which occurred first in the U.S. environmental movement: concerns about forest conservation or concerns about pollution?

. Describe how an individual can influence U.S. environmental history or policy.

. Explain how the attitudes of utilitarian conservationists toward environmental policy differ from those of biocentric preservationists.

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igure 2.6 Earth Day 2013. Maria Martinez Head Start students, along ith faculty and staff, plant a tree as part of Earth Day events in 2014.

U.S. Environmental Legislation

LEARNING OBJECTIVES

- Explain why the National Environmental Policy Act is the cornerstone of U.S. environmental law.
- Explain how environmental impact statements provide powerful protection of the environment.

By the late 1960s, much of the U.S. public had become increasingly disenchanted with governmental secrecy, and many did not trust industry to work in the public interest. This broad social transformation, which included opposition to the Vietnam War and resistance to racist policies, was reflected in environmental attitudes as well. Galvanized by well-publicized ecological disasters, such as the 1969 oil spill off the coast of Santa Barbara, California, and by overwhelming public support for the Earth Day movement, in 1970 the **Environmental Protection Agency (EPA)** was formed, and the **National Environmental Policy Act (NEPA)** was signed into law. A key provision of NEPA required the federal government to consider the environmental impact of any proposed federal action, such as financing highway or dam construction. NEPA provides the basis for developing detailed **environmental impact statements (EISs)** to accompany every federal recommendation or legislative proposal. These EISs are supposed to help federal officials make informed decisions. Each EIS must include the following:

environmental mpact statement (EIS) A document that summarizes tential and expected /erse impacts on the ronment associated vith a project as well is alternatives to the)posed project; typilly mandated by law ublic and/or private projects.

1. The nature of the proposal and why it is needed
2. The environmental impacts of the proposal, including short-term and long-term effects and any adverse environmental effects if the proposal is implemented (**Figure 2.7**)
3. Alternatives to lessen the adverse effects of the proposal; providing ways to mitigate the impact of the project

A required step in the EIS process is the solicitation of public comments, which generally provide a broader perspective on the proposal and its likely effects. NEPA established the **Council on Environmental Quality** to monitor the required EISs and report directly to the president. This council had no enforcement powers, and NEPA was originally considered innocuous, generally more a statement of good intentions than a regulatory policy.

During the next few years, environmental activists took people, corporations, and the federal government to court to challenge their EISs and use them to block proposed development. The courts decreed that EISs must be substantial documents that thoroughly analyze the environmental consequences of anticipated projects on soil, water, and organisms. The courts also said that the public must have access to EISs. These rulings put sharp teeth into the law—particularly the provision for public scrutiny, which placed intense pressure on federal agencies to respect EIS findings.

NEPA revolutionized environmental protection in the United States. In addition to overseeing federal highway construction, flood and erosion control, military projects, and many other public works, federal agencies oversee nearly one-third of the land in the United States. Federally owned holdings include extensive fossil-fuel and mineral reserves as well as millions of hectares of public grazing land and public forests, all subject to NEPA. Many states and local governments now require EISs for public (and sometimes private) projects, as do many foreign countries.

NEPA has evolved considerably through four decades of litigation and eight presidential administrations, but the fundamental effect of publicly available information remains. Although almost everyone agrees that NEPA has helped federal agencies reduce adverse environmental impacts of their activities and projects, it has its critics. Environmentalists complain that EISs are sometimes incomplete, include only alternatives that make a predetermined alternative look attractive, or are ignored when decisions are made. Other critics think the EISs delay important projects ("paralysis by analysis") because EISs are too involved, take too long to prepare, and are often the targets of lawsuits.

ENVIRONMENTAL POLICY SINCE 1970

Although legislation to manage many environmental problems existed before 1970, the regulatory system that exists today was largely put into place during the 1970s. Congress has passed many environmental laws that address a wide range of issues, such as endangered species, clean water, clean air, energy conservation, hazardous wastes, and pesticides (**Table 2.1**). These laws have greatly increased federal regulation of pollution, creating a tough interlocking mesh of laws to improve environmental quality.

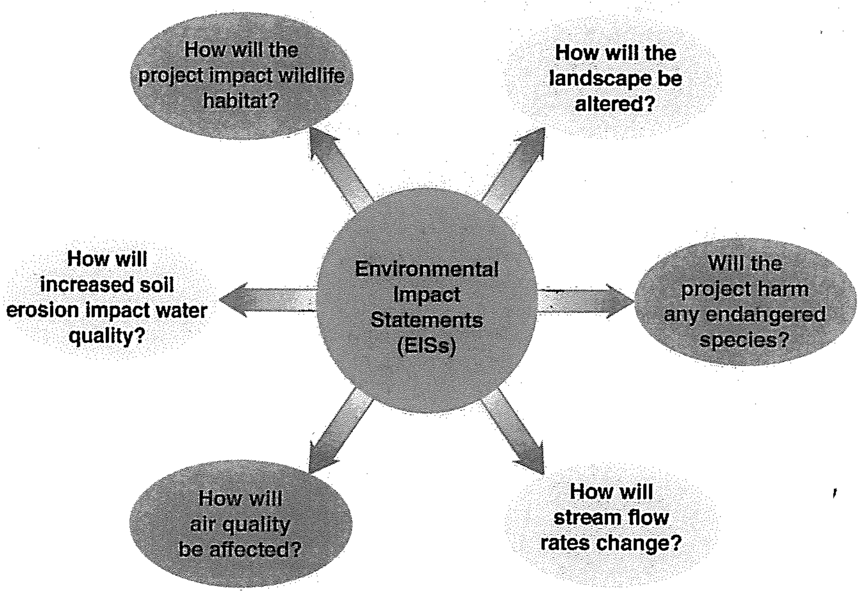


Figure 2.7 Environmental impact statements. These detailed statements help federal agencies and the public consider the environmental impacts of proposed activities. When anticipated impacts are likely to be high, decision makers will feel pressure to seek alternative actions.

Many environmental laws contain provisions that allow private citizens to take violators, whether they are private industries or government-owned facilities, to court for noncompliance. These citizen suits have contributed significantly in the enforcement of environmental legislation.

In the early 1980s, President Reagan attempted to reverse the pro-environmental trend by appointing a pro-business EPA administrator, **Ann Gorsuch**, and leaving many top-level positions in the agency unfilled. Congressional and public backlash led to even more restrictive environmental laws. Gorsuch was replaced with **William Ruckleshaus**, who had been the first EPA administrator and was widely respected for having established the agency's credibility and authority. Ruckleshaus advocated a rational, organized approach to environmental regulation that would avoid the "pendulum" effect of stringent and then relaxed environmental regulation.

Table 2.1 Some Important Federal Environmental Legislation

General
Freedom of Information Act of 1966
National Environmental Policy Act of 1969
National Environmental Education Act of 1990

Conservation of Energy and Renewable Energy Resources
Energy Policy and Conservation Act of 1975
Northwest Power Act of 1980
National Appliance Energy Conservation Act of 1987
Energy Policy Act of 1992
American Recovery and Reinvestment Act of 2008

Conservation of Wildlife
Fish and Wildlife Act of 1956
Anadromous Fish Conservation Act of 1965
Fur-Seal Act of 1966
National Wildlife Refuge System Act of 1966
Species Conservation Act of 1966
Marine Mammal Protection Act of 1972
Marine Protection, Research, and Sanctuaries Act of 1972
Endangered Species Act of 1973
Federal Noxious Weed Act of 1974
Magnuson Fishery Conservation and Management Act of 1976
Whale Conservation and Protection Study Act of 1976
Fish and Wildlife Improvement Act of 1978
Fish and Wildlife Conservation Act of 1980
Fur Seal Act Amendments of 1983
Wild Bird Conservation Act of 1992
National Invasive Species Act of 1996

Conservation of Land
General Revision Act of 1891
Taylor Grazing Act of 1934
Soil Conservation Act of 1935
Multiple Use Sustained Yield Act of 1960 (re: national forests)
Wilderness Act of 1964
Land and Water Conservation Fund Act of 1965
Wild and Scenic Rivers Act of 1968
National Trails System Act of 1968
Coastal Zone Management Act of 1972
National Reserves Management Act of 1974
Forest and Rangeland Renewable Resources Act of 1974
Federal Land Policy and Management Act of 1976
National Forest Management Act of 1976
Soil and Water Resources Conservation Act of 1977
Surface Mining Control and Reclamation Act of 1977
Public Rangelands Improvement Act of 1978
Antarctic Conservation Act of 1978
Endangered American Wilderness Act of 1978
Alaska National Interest Lands Act of 1980
Coastal Barrier Resources Act of 1982
Emergency Wetlands Resources Act of 1986
North American Wetlands Conservation Act of 1989
California Desert Protection Act of 1994
Food, Conservation, and Energy Act of 2008 (the latest version of the "farm bill," which has been amended and renamed every 5 years or so since the 1930s)

Air Quality and Noise Control
Noise Control Act of 1965
Clean Air Act of 1970
Quiet Communities Act of 1978
Asbestos Hazard and Emergency Response Act of 1986
Clean Air Act Amendments of 1990

Water Quality and Management
Refuse Act of 1899
Water Resources Research Act of 1964
Water Resources Planning Act of 1965
Clean Water Act of 1972
Ocean Dumping Act of 1972
Safe Drinking Water Act of 1974
National Ocean Pollution Planning Act of 1978
Water Resources Development Act of 1986
Great Lakes Toxic Substance Control Agreement of 1986
Water Quality Act of 1987 (amendment of Clean Water Act)
Ocean Dumping Ban Act of 1988
Oceans Act of 2000

Control of Pesticides
Food, Drug, and Cosmetics Act of 1938
Federal Insecticide, Fungicide, and Rodenticide Act of 1947
Food Quality Protection Act of 1996

Management of Solid and Hazardous Wastes
Solid Waste Disposal Act of 1965
Resource Recovery Act of 1970
Hazardous Materials Transportation Act of 1975
Toxic Substances Control Act of 1976
Resource Conservation and Recovery Act of 1976
Low-Level Radioactive Policy Act of 1980
Comprehensive Environmental Response, Compensation, and Liability ("Superfund") Act of 1980
Nuclear Waste Policy Act of 1982
Hazardous and Solid Waste Amendments of 1984
Superfund Amendments and Reauthorization Act of 1986
Medical Waste Tracking Act of 1988
Marine Plastic Pollution Control Act of 1987
Oil Pollution Act of 1990
Pollution Prevention Act of 1990
State or Regional Solid Waste Plans (RCRA Subtitle D) of 1991

Since 1980, the rate of new major environmental legislation has slowed, but environmental policy continues to evolve through administrative actions and the judicial process. In 1994, President Clinton issued an executive order requiring that environmental justice be considered in all regulatory actions. Environmental policy through the Clinton and George W. Bush administrations was characterized by expanded use of cost–benefit analysis in environmental regulation.

The George W. Bush administration placed higher priority on extracting environmental resources than reducing human impacts on the environment. No major environmental laws were passed between 2000 and 2008, and a number of major land-use regulations—such as preserving habitat for the spotted owl—were relaxed. In addition, in some cases states were barred from passing regulations more stringent than those required by the federal government, most notably the attempt by California and 13 other states to impose automobile efficiency standards on cars and light trucks. One of the first acts of the Obama administration was to reverse this prohibition.

In one significant legal case during the George W. Bush administration, Massachusetts sued the EPA to require that greenhouse gases be regulated under the **Clean Air Act (CAA)**. The EPA made two arguments: (1) that the CAA did not authorize climate change regulations and (2) that the CAA was not an appropriate way to manage climate change since it is a global problem, not amenable to local or even national solutions. The Supreme Court disagreed, concluding that greenhouses gases are pollutants emitted into the air and capable of endangering public health or welfare. It further noted that the EPA claim that it *should not* regulate greenhouse gases was inconsistent with the CAA, since the EPA had acknowledged that greenhouse gases contribute to climate change.

The EPA is usually given the job of translating environmental laws into specific regulations. Before the regulations become official, several rounds of public comments allow affected parties to present their views; the EPA is required to respond to all of these comments. Next, the Office of Management and Budget reviews the new regulations. Some regulations proposed by the EPA must be justified by **cost–benefit analysis**, while others (including those under the Clean Air Act) are barred from considering economic impacts. Implementation and enforcement of environmental regulations often fall to state governments, which must send the EPA detailed plans showing how they intend to achieve regulatory goals and standards. Currently, the EPA oversees thousands of pages of environmental regulations that affect individuals, corporations, local communities, and states.

Environmental laws have not always worked as intended. The Clean Air Act of 1977 required coal-burning power plants to outfit their smokestacks with expensive *scrubbers* to remove sulfur dioxide from their emissions but made an exception for tall smokestacks (**Figure 2.8**). This loophole led to the proliferation of tall stacks that have since produced *acid rain* throughout the Northeast. The Clean Air Act Amendments of 1990, described in Chapter 19, go a long way toward closing this loophole. In addition, many environmental regulations are not enforced properly. According to **Oliver Houck** of the Tulane Law School, environmental laws such as the Clean Water Act have compliance rates of about 50%.

Despite imperfections, U.S. environmental legislation has had overall positive effects. Since 1970:

1. Twenty-three national parks have been established, and the National Wilderness Preservation System now totals more than 43 million hectares (107 million acres).
2. Millions of hectares of land vulnerable to erosion have been withdrawn from farming, reducing soil erosion in the United States by more than 60%.
3. Many previously endangered species are better off now than they were in 1970, and the American alligator, California gray whale, bald eagle, and brown pelican have recovered enough to be removed from the endangered species list. (Dozens of other species, however, such as the manatee, ivory-billed woodpecker, polar bear, and Kemp's sea turtle, have suffered further declines or extinction since 1970.)
4. Energy efficiency and conservation technology have improved markedly for buildings, vehicles, and consumer products.

Although we still have a long way to go, pollution-control efforts have been particularly successful. According to the EPA's most recent *Report on the Environment (2008)*:

1. Both emissions and ambient concentrations of six important air pollutants have dropped by at least 25% since 1970, much more in the case of lead. (Carbon dioxide emissions have continued to rise.)
2. Since 1990, levels of wet sulfate, a major component of acid rain, have dropped by about 33%.

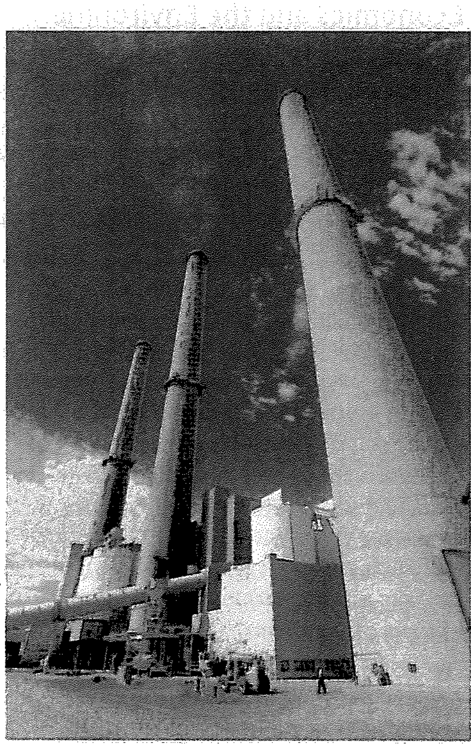


Figure 2.8 Tall smokestacks. Such smokestacks, which emit sulfur dioxide from coal-burning power plants, were exempt from the requirement of pollution-control devices under the Clean Air Act of 1977.

3. In 2008, 92% of the U.S. population got its drinking water from community water systems with no violations of EPA standards, up from around 75% in 1993.
4. In 2014, 45% of municipal solid waste was combusted for energy recovery or recovered for composting or recycling, up from 6% in the 1960s. While total municipal solid waste has been increasing, the amount sent to landfills has remained roughly constant since 1980.
5. In 2007, the EPA considered human exposures to contamination to be under control at 93% of listed hazardous waste sites, up from 37% of the sites listed in 2000.

However, not all environmental trends are positive. In some major urban areas, such as Houston and Las Vegas, air quality has begun to deteriorate since about 2000. While technology has reduced environmental impacts of industries and products, population increases have outpaced technological improvements (recall the *IPAT* model from Chapter 1). In addition, despite broad and increasing concern about climate change, no effective U.S. or international policies have been established. Future environmental improvement will require more sophisticated strategies, involving technological and behavior changes.

REVIEW

1. Which law is the cornerstone of U.S. environmental law? Why?
2. In what ways has the U.S. environment improved as the result of regulations?

Economics and the Environment

LEARNING OBJECTIVES

- Explain why economists prefer efficient solutions to environmental problems.
- Describe command and control regulation, incentive-based regulation, and cost-effectiveness analysis.
- Give two reasons why the national income accounts are incomplete estimates of national economic performance.

Economics is the study of how people use their limited resources to try to satisfy unlimited wants. Economists combine theoretical assumptions about individual and institutional behavior with analytical tools that include developing hypotheses, testing models, and analyzing observations and data. They try to understand the consequences of the ways in which people, businesses, and governments allocate their resources.

Economists who work on environmental problems must take a systems perspective. For example, Nobel Prize–winning economist **Amartya Sen** addresses overlapping issues of environment, poverty, nationalism, gender, and governmental structure (**Figure 2.9**). This approach recognizes the complex interactions among the environment, society, health, and well-being.

Economics, especially as applied to public policy, relies on several precepts. First, economics is utilitarian. This means that all goods and services—including those provided by the environment—have value to people and that those values can be converted into some common currency. Thus, in a market economy such as that of the United States, goods and services have dollar values, which are determined by the amount of money someone is willing to pay for them.

This leads to a second precept, the **rational actor model**. Economists assume two things about all individuals. First, individuals have preferences among different goods and services, which economists refer to as **utility**. Second, individuals can and do spend their limited resources (money and time) in a way that provides them the most utility.

rational actor model In economics, the assumption that all individuals spend their limited resources in a fashion that maximizes their individual utilities.

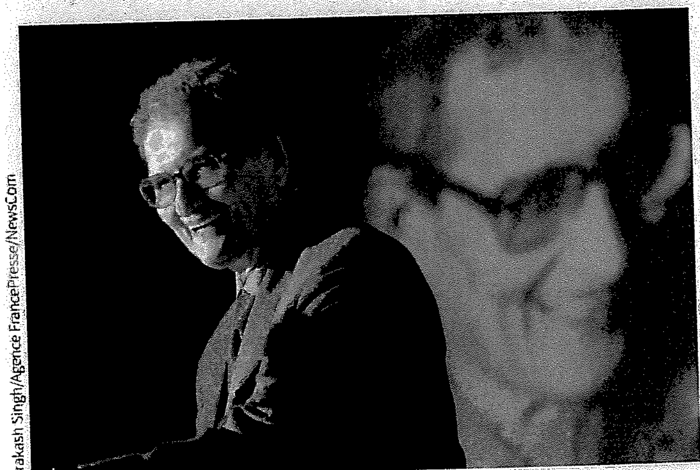
utility An economic term referring to the benefit that an individual gets from some good or service. Rational actors try to maximize utility.

Third, in an ideal economy, resources will be allocated efficiently. *Efficiency* is a term economists use to describe multiple individuals getting the greatest amount of goods or services from a limited set of resources. For example, if business plan A will build 9 cars with a given amount of material and number of workers, while business plan B will build 10 equivalent cars with the same resources, business plan B is more efficient and will succeed. To economists, environmental problems arise when market failures occur in one of several ways, principal among which are externalities and inefficiency.

Externalities occur when the producer of a good or service does not have to pay the full costs of production. An example is a blacksmith shop next door to a drip-dry laundry. If soot from the blacksmith shop lands on the laundry, then the laundry owner will have to rewash the laundry and try to pass on the additional cost to its customers. Here, the blacksmith shop is causing a negative externality on the laundry and its customers, who in effect pay part of the cost of the blacksmith operation.

externality In economics, the effects (usually negative) of a firm that does not have to pay all the costs associated with its production.

A simple solution—advocated by some economists—is to clearly define rights and ownership. If the blacksmith does not have the right to release soot, then the laundry owner can demand



Prakash Singh/Agence FrancePresse/NewsCom

Figure 2.9 Nobel laureate Amartya Sen. Economist Amartya Sen's work includes critiques of traditional assumptions about economic valuation of the environment and recognizes the complex, systemic nature of the environment, society, health, and well-being.

compensation for the added cost of business. The blacksmith then has several options—for example, to close the shop, find a way to control the soot, or pay the laundry owner for the extra cost of business. The efficient solution is the one that costs the least money for everyone. If closing the shop costs $10,000 per year, using soot-control equipment costs $200 per year, and paying to rewash laundry costs $500 per year, the blacksmith should choose to control soot. This same solution will occur even if the blacksmith *does* have the right to release soot, since the laundry owner should be willing to pay the blacksmith $200 to use soot-control equipment rather than spending $500 to rewash laundry.

Unfortunately, most environmental externalities are not as clearly defined as the laundry/blacksmith example. Usually, there are many polluters and many affected individuals. A small town may have 5,000 automobiles, each of which generates a different amount of pollution that affects each of 10,000 residents. Damage associated with the releases may depend on time of day as well as where in the town pollution is generated. Even if we could assess those damages, it would be impossible for each driver to compensate each person impacted by the car's emissions. The problem becomes even more extreme for climate change, where billions of individuals generate and are affected by greenhouse gases.

Several economic solutions exist for cases of multiple polluters, all of which rely on the idea that we can identify an efficient or **optimal amount of pollution**. At this optimum, the cost to society of having less pollution is offset by the benefits to society of the activity creating the pollution. To find this optimum requires that we identify the **marginal cost of pollution**, which refers to the cost of a small additional amount of pollution. Determining the marginal cost of pollution involves assessing pollution damage to health, property, agriculture, and aesthetics. Pollution can also reduce **ecosystem services (see Table 5.1)**, which are benefits to humans—including clean water and fresh air—provided by natural systems. Determining the marginal cost of pollution is generally not an easy process.

Similarly, the **marginal cost of abatement** is the cost associated with reducing (abating) a small additional amount of pollution. Untreated wastewater from a pulp mill contains a variety of chemicals and suspended wood fibers. The cost of filtering the fibers is relatively low, requiring mechanical screening. The cost of removing inorganic chemicals, however, may be quite high (see Chapter 21). The societal benefit of filtering is relatively high compared to the benefit of removing a small amount of a chemical. If we insist that only perfectly pure water comes out of the pulp mill, the cost of paper will be extremely high.

Figure 2.10 demonstrates how the marginal cost of pollution and the marginal cost of abatement lead to an optimal amount of pollution. The green line represents the marginal cost of abatement, and the red line the marginal cost of pollution. When the amount of pollution being generated is high, abatement costs are relatively low. Similarly, when pollution concentration is low, abatement costs are high; in this case, the benefit of additional control is low. Pollution is at an optimal level when marginal costs of pollution and abatement are equal (the point at which the red and green lines intersect). When that is the case, the economic system is efficient, meaning that society would be worse off with either more *or less* pollution. If a pulp mill operating at that optimal level

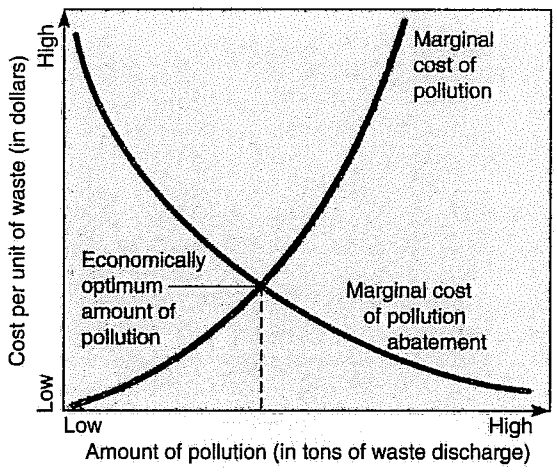


Figure 2.10 Economic optimality and pollution. This figure represents the economically optimal level of pollution in an efficient market. The upward-sloping curve (red line) represents the cost of damage associated with pollution at various levels. As pollution rises, the social cost (in terms of human health and a damaged environment) increases sharply. The downward-sloping curve (green line) represents the cost of reducing pollution to a lower, less damaging level. The intersection of these two curves is the economically optimal point, where a shift in either direction (more or less pollution) will lead to lower total societal benefits.

were to spend an additional $1 on control equipment, the value to society of the reduction in pollution would be less than $1.

It is unusual to find unregulated economic systems at the point of economic optimality. In unregulated markets, those who pollute often must pay only a fraction of the total costs of pollution. Thus, the marginal cost of pollution faced by the polluter (private cost) is substantially lower than the marginal cost of pollution faced by society as a whole. This is represented by **Figure 2.11**, which contains two marginal cost of pollution curves. The marginal cost curve on the left (red line) is the societal marginal cost of pollution, which includes that faced by the polluter. To the right of this is the private marginal cost of pollution curve (blue line), which is the fraction of the overall marginal cost paid by the polluter. Without some sort of regulation, the amount of pollution generated will be determined by the point at which the private marginal cost of pollution is equal to the marginal cost of abatement (intersection of green and blue lines). Substantially more pollution may be generated at this intersection than is optimal from a societal perspective.

STRATEGIES FOR POLLUTION CONTROL

Economists favor market-based solutions to environmental externality problems. Historically, many environmental regulations have been **command and control** solutions. This means the EPA or other government agency requires that a particular piece of equipment be installed to limit emissions to water, air, or soil. Industries regulated in this fashion often object that they are thereby discouraged from developing lower-cost alternatives that would achieve the same level of pollution control for less money.

Command and control regulations may result in pollution levels that are lower or higher than the economically optimum level; for this reason, they are not popular with economists.

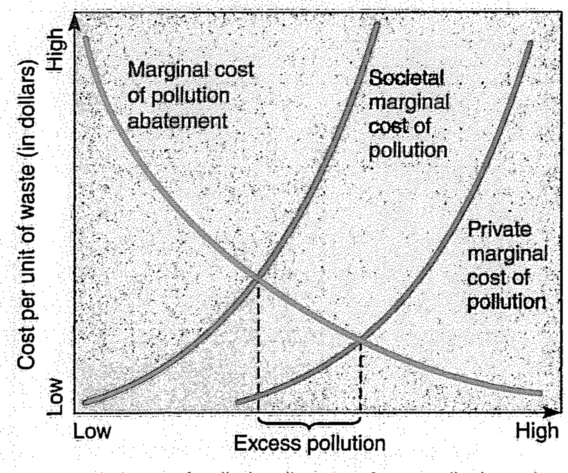


Figure 2.11 Inefficiency arising from different marginal costs. This figure represents the marginal costs of pollution faced by society (red line), the private marginal cost of pollution faced by the polluter (blue line), and the marginal cost of abatement (green line). The polluter will generate pollution at the point where the private marginal cost of pollution intersects with the marginal cost of abatement. At this point, substantially more pollution is generated than is optimal from a societal perspective.

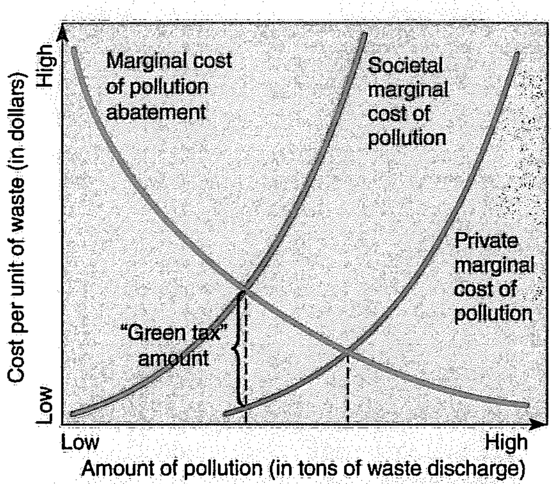


Figure 2.12 The corrective effect of "green taxes." This figure represents the marginal costs of pollution faced by society (red line), the private marginal cost of pollution faced by the polluter (blue line), and the marginal cost of abatement (green line). A tax is assessed on the polluter equal to the difference between the private marginal cost of pollution and the social marginal cost of pollution. As a result, the entire private marginal cost curve is shifted upward. If the tax is designed well, the cost faced by the polluter will be identical to the marginal societal cost of pollution.

Consequently, most economists, whether they have progressive or conservative views, prefer **incentive-based regulations** over command and control ones. Two major incentive-based approaches that have met with mixed policy success are environmental taxes and *tradable permits*. *Cost-effectiveness analysis* is a cost–benefit-based approach for prioritizing diverse environmental regulations.

A popular incentive-based approach for regulating pollution, particularly in Europe, involves imposing an **emission charge** on polluters. In effect, this charge is a tax on pollution. Economists propose such "green taxes" to correct what they perceive as distortions in the market caused by not including the external cost of driving an automobile or cutting down trees or polluting streams. The purpose of this tax is to force polluters to pay the full cost of pollution. If the tax is set at the correct level, the private marginal cost of pollution will be equivalent to the societal cost of pollution. This is depicted in **Figure 2.12**.

Many European countries have restructured their taxes to take into account environmentally destructive products and activities. Germany increased taxes on gasoline, heating oil, and natural gas while simultaneously lowering its income tax. One result was an increase in carpooling. There were concerns, however, about whether Germany's energy-intensive industries could remain competitive with industries in countries without similar energy taxes. The Netherlands introduced a tax on natural gas, electricity, fuel oil, and heating oil that includes incentives for energy efficiency; income taxes were decreased to offset the tax burden on individuals. Electricity and fuel use has declined as a result. Finland has implemented a carbon dioxide tax. Sweden introduced taxes on carbon and sulfur while simultaneously reducing income taxes. These charges increase the cost of polluting or of overusing natural resources. They also are usually *revenue-neutral* since they are offset by rebates or reductions in other taxes.

If taxes are set at the correct level, users will react to the increase in cost resulting from emission charges by decreasing pollution or decreasing consumption. However, it can be very difficult to identify the economically optimal level of taxation, and taxes on pollution are almost always set too low to have the desired effect on the behavior of people or companies. It is difficult to enact such taxes, especially in the United States, because people object to paying a tax on something they perceive as "free," and they tend to doubt that such taxes will be revenue-neutral.

While environmental taxes are designed to identify and replicate the societal cost of pollution, **tradable permits** rely on identifying the optimal level of pollution. Government sets a cap on pollution and then issues a fixed number of tradable permits (sometimes called **marketable waste-discharge permits**), allowing holders to emit a specified amount of a given pollutant, such as sulfur dioxide. A permit owner can decide whether to generate the pollution or sell the permit, ideally choosing the option that earns the most money. Once the market for permits has been established, industries that can easily reduce emissions will do so and then sell their extra permits to industries that cannot.

Tradable permits can also be designed to reduce emissions over time. The Clean Air Act Amendments of 1990 included a plan to cut acid rain–causing sulfur dioxide emissions by issuing tradable permits for coal-burning electricity utilities. The amount of allowable pollution decreases with each trade. This approach has been effective. Sulfur dioxide emissions are being reduced ahead of schedule at about 50% of the original projected cost.

Cost-effectiveness analysis is an increasingly common regulatory tool. Rather than setting an optimum level of pollution, cost-effectiveness analysis asks, "If we establish this regulation, how much will it cost to achieve some outcome?" Here, the outcome is lives saved or years of life saved. Thus, a regulatory action that costs $5,000 per saved life would be preferable to one that costs $10,000 per saved life. This approach could be used to compare a wide range of interventions, from banning pesticides to requiring catalytic converters on cars.

CRITIQUES OF ENVIRONMENTAL ECONOMICS

Two classes of critiques are leveled at economic approaches to environmental regulation. First, it is difficult to assess the true costs of environmental damage by pollution and pollution abatement. The impacts of pollution on people and nature are extremely uncertain. We often do not know how effective pesticides are at eliminating pests, or whether a pesticide harms humans. If we do not understand the economic benefits of ecosystem services, they may be undervalued. Trying to place a value on quality of life or on damage to natural beauty can be highly controversial (**Figure 2.13**). As you will see in the next few chapters, the web of relationships within the environment is intricate, and environmental systems may be more vulnerable to pollution damage than is initially obvious. When the optimal level of pollution is highly uncertain, too many or too few permits may be issued, and green taxes may be set too high or too low.

Second, we do not all agree that economics is an appropriate decision tool. Economics may not take the risks of unanticipated environmental catastrophes into account and may not consider dynamic changes over time. Utilitarian economics does not account for fairness, so even if society were better off overall, some individuals might lose out. Many people distrust economic approaches to environmental regulation, since they are so strongly associated with industry groups. Economists assign prices based on what people can or do pay for things. This means that the knowledge that a pristine stream or songbird exists will not have much impact in an economic assessment. Additionally, economics dictates that if it is inefficient to save a species, we should not do so. This idea clashes with many religious and ethical beliefs.

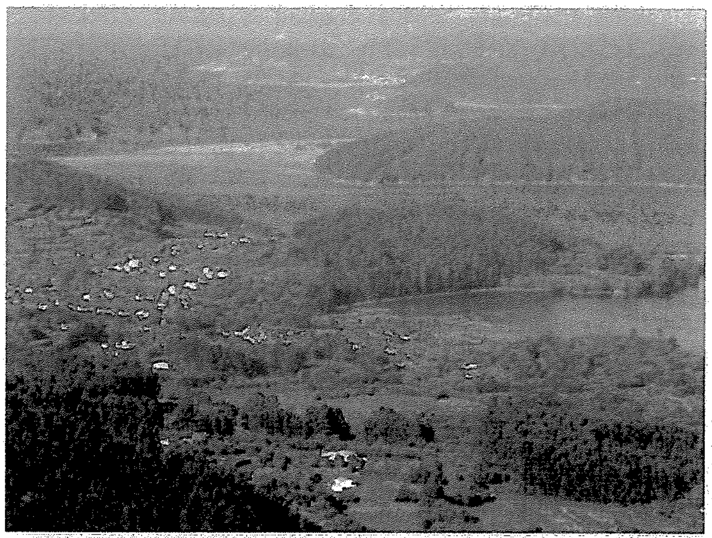


Figure 2.13 Agriculture, timber, and scenic beauty at Coruña, Spain. The value of the environment derives from many factors that constitute a complex, interrelated system. These factors include aesthetics, recreation, agriculture, real estate, and ecosystem services. It can be difficult or impossible to accurately assess the monetary value of all possible options for an area such as this one.

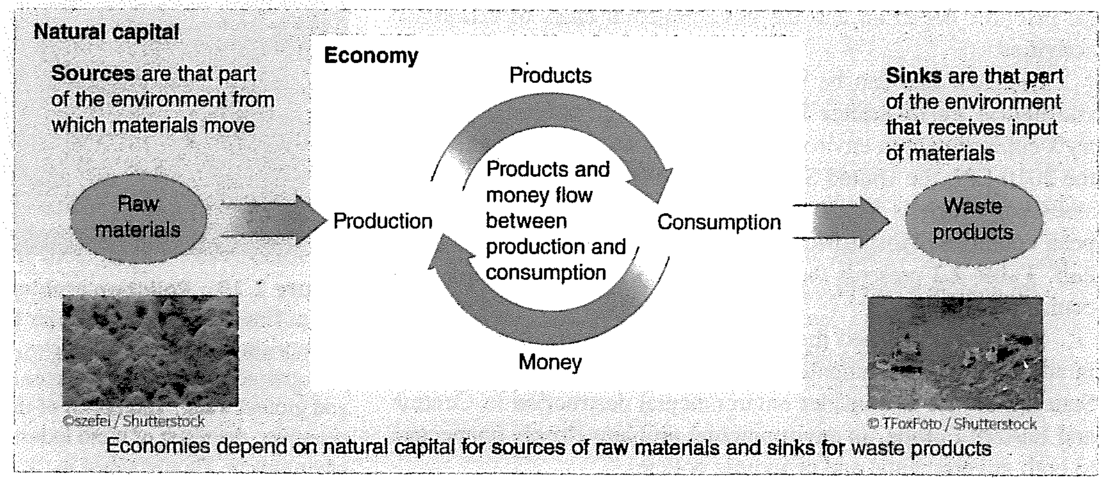
NATURAL RESOURCES, THE ENVIRONMENT, AND NATIONAL INCOME ACCOUNTS

Because much of our economic well-being flows from natural, rather than human-made, assets, we should include the use and misuse of natural resources and the environment in national income accounts. **National income accounts** represent the total income of a nation for a given year. Two measures used in national income accounting are *gross domestic product (GDP)* and *net domestic product (NDP)*. Both GDP and NDP provide estimates of national economic performance used to make important policy decisions.

Unfortunately, current national income accounting practices are misleading and incomplete because they do not incorporate environmental factors. At least two important conceptual problems affect the way national income accounts currently handle the economic use of natural resources and the environment. These problems involve costs and benefits of pollution control and depletion of **natural capital**, which refers to Earth's resources and processes that sustain living organisms (**Figure 2.14**).

Natural Resource Depletion If a firm produces some product (output) but in the process wears out a portion of its plant and

Figure 2.14 Natural capital and the environment. Goods and services (products) and money (to pay for the products) flow between businesses (production) and consumers (consumption). Economies depend on natural capital to provide sources for raw materials and sinks for waste products.



equipment, the firm's output is counted as part of GDP, but the depreciation of capital is subtracted in the calculation of NDP. Thus, NDP is a measure of the net production of the economy after a deduction for used-up capital. In contrast, when an oil company drains oil from an underground field, the value of the oil produced is counted as part of the nation's GDP, but no offsetting deduction to NDP is made to account for the nonrenewable resources used up.

The Cost and Benefits of Pollution Control at the National Level Imagine that a company has the following choices: It can produce \$100 million worth of output and, in the process, pollute the local river by dumping its wastes. Alternatively, by properly disposing of its wastes, it can avoid polluting but will only get \$90 million of output. Under current national income accounting rules, if the firm chooses to pollute, its contribution to GDP is larger (\$100 million rather than \$90 million). National income accounts attach no explicit value to a clean river. In an ideal accounting system, the economic cost of environmental degradation (loss of natural capital) would be subtracted in the calculation of a firm's contribution to GDP, and activities that improve the environment—because they provide real economic benefits—would be added to GDP.

Discussing the national income accounting implications of resource depletion and pollution may seem to trivialize these important problems. However, because GDP and related statistics are used regularly in policy analyses, abstract questions of measurement may turn out to have significant effects. Economic development experts have expressed concern that some poor countries, in attempting to raise their GDPs as quickly as possible, overexploit their natural capital and impair the environment. If "hidden" resource and environmental costs were explicitly incorporated into official measures of economic growth, policies that harm the environment might be modified.

Similarly, in industrialized countries, political debates about the environment have sometimes emphasized the impact on GDP of proposed pollution-control measures rather than the impact on overall economic welfare. Better accounting for environmental quality might refocus these debates on the more relevant question of whether, for any given environmental proposal, the benefits (economic and noneconomic) exceed the cost. One option is to replace GDP and NDP with a more comprehensive measure of national income accounting that includes estimates of both natural resource depletion and the environmental costs of economic activities.

One tool that can be used alongside the GDP is the **Environmental Performance Index (EPI)**, which assesses a country's commitment to environmental and resource management. In the 2010 EPI, the United States ranked 61st out of 163 countries assessed, which is below the rankings of most Western European countries. Most African countries are ranked in the bottom half. **Table 2.2** presents the 2010 EPI rankings of some selected countries.

We have examined the roles of government and economics in addressing environmental concerns, particularly in the United States. Now let us consider environmental destruction in Central and Eastern Europe, an environmental problem closely connected to both governmental and economic policies.

Table 2.2 Environmental Performance Index Scores and Rankings for Select Countries

Country	*2010 EPI Score*	*2010 EPI Ranking**
New Zealand	73.4	15
Sweden	86.0	4
Finland	74.7	12
United Kingdom	74.2	14
Canada	66.4	46
Japan	72.5	20
Iceland	93.5	1
Costa Rica	86.4	3
United States	63.5	61
Mexico	67.3	43
China	49.0	121
Sierra Leone	32.1	163
India	48.3	123
Niger	37.6	158

Canada ranks highest among North American countries. The lowest-ranked countries are in sub-Saharan Africa.
*Out of 163 countries
Source: www.yale.edu/epi

CASE IN POINT

ENVIRONMENTAL PROBLEMS IN CENTRAL AND EASTERN EUROPE

The fall of the Soviet Union and communist governments in Central and Eastern Europe during the late 1980s revealed a grim legacy of environmental destruction (**Figure 2.15**). Over the previous decades, the value of natural capital had been ignored. Water was so poisoned from raw sewage and chemicals that it could not be used for industrial purposes, let alone for drinking. Unidentified

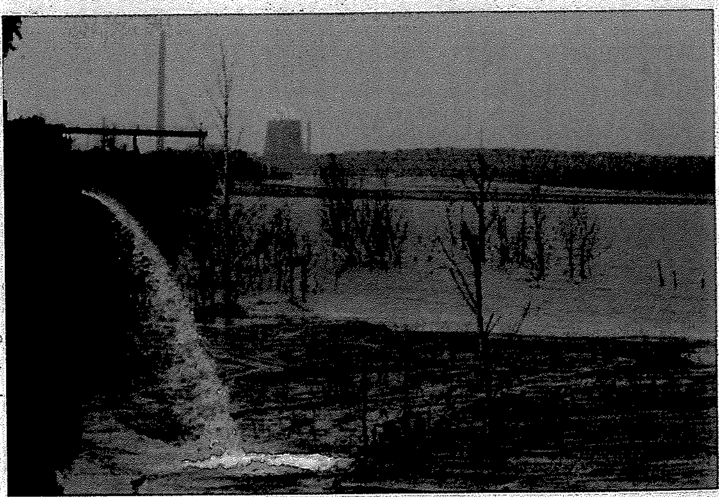


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Figure 2.15 Pollution problems in former communist countries. This section of a river near Espenhain in Saxony is covered in a scummy layer of chemical wastes. Note the coal-fired power plant in the background, one of many sources that contaminated soils, surface water, and ground water. Thousands of these sites exist in former communist countries, the result of rapid industrialization without regard for the environment. Photographed in the late 1990s.

chemicals leaked out of dumpsites into the surrounding soil and water, while fruits and vegetables were grown nearby in chemical-laced soil. Power plants emitted soot and sulfur dioxide into the air, producing a persistent chemical haze. Buildings and statues eroded, and entire forests died because of air pollution and acid rain. Crop yields fell despite intensive use of chemical pesticides and fertilizers. One of the most polluted areas in the world was the "Black Triangle," which consisted of the bordering regions of the former East Germany, northern Czech Republic, and southwest Poland.

Many Central and Eastern Europeans suffered from asthma, emphysema, chronic bronchitis, and other respiratory diseases as a result of breathing the filthy, acrid air. By the time most Polish children were 10 years old, they suffered from chronic respiratory diseases or heart problems. The levels of cancer, miscarriages, and birth defects were extremely high. Life expectancies are still lower in Eastern Europe than in other industrialized nations; in 2011, the average Eastern European lived to age 71, which was 10 years less than the average Western European.

The economic assumption behind communism was one of high production and economic self-sufficiency, regardless of damages to the environment and natural resources, and so pollution in communist-controlled Europe went largely unchecked. Meeting industrial production quotas always took precedence over environmental concerns, even though production was not carried out for profit. It was acceptable to pollute because clean air, water, and soil were granted no economic value. The governments supported heavy industry—power plants, chemicals, metallurgy, and large machinery—at the expense of the more environmentally benign service industries. As a result, Central and Eastern Europe were overindustrialized with old plants that lacked pollution-abatement equipment.

Communism did little to encourage resource conservation, which can curb pollution. Neither industries nor individuals had incentives to conserve energy because energy subsidies and lack of competition allowed power plants to provide energy at prices far below its actual cost.

More recently, while switching from communism to democracies with market economies, Central and Eastern European governments have faced the overwhelming responsibility of improving the environment. Although no political system in transition will make the environment its first priority, several countries have formulated environmental policies based on the experiences of the United States and Western Europe over the past several decades. However, experts predict it will take decades to clean up the pollution legacy of communism. How much will it cost? The figures are staggering. For example, according to one United Nations estimate, improving the environment in what was formerly East Germany will cost up to $300 billion. This represents the loss of natural capital during the 1960s, 1970s, and 1980s. Eastern Europeans today are paying the costs of their parents' environmental neglect.

The environment of countries in the former Soviet bloc is slowly improving. Some, such as Hungary, Poland, and the Czech Republic, have been relatively successful in moving toward market economies. They generate enough money to invest in environmental cleanup. Latvia, Lithuania, and Slovakia ranked above the United States in the 2010 EPI Assessment. In other countries, such as Romania and Bulgaria, the transition to a market economy has not been as smooth. Economic recovery has been slow in these countries, and severe budgetary problems have forced the environment to take a backseat to political and economic reform. ■

ENVIRONEWS ON CAMPUS

Greening Higher Education

No longer restricting their environmental education to the classroom, students at many colleges and universities are identifying environmental problems on their campuses, then mapping out and implementing solutions. The tremendous success of many of these efforts has required understanding the campus as a system and demands the cooperation of faculty, administrators, staff, and students. Real-life environmental situations become educational opportunities. Notable examples include the following:

- The 2010 Game Day Challenge, in which 77 colleges and universities diverted over 2,500 tons of waste from landfills during home football game days.
- The Rebel Recycling program at the University of Nevada–Las Vegas, which accepts materials from off campus and collects reusable materials during dorm moveouts. The program was based on the senior thesis of an environmental studies major who continues to run it.
- Participation by hundreds of campuses in the American College and University Presidents' Climate Commitment.
- The reduction of hazardous wastes in chemistry labs across the United States, a result of a student/faculty effort to develop "microscale" experiments at Bowdoin College in Maine.

Overall, student efforts nationally include recycling programs on 80% of campuses and have resulted in a total annual savings of nearly $17 million from 23 campus conservation projects, ranging from transportation initiatives to energy and water conservation, reuse and recycling, and composting. Organizations such as the Campus Ecology program associated with the National Wildlife Federation, the Sierra Student Coalition, the Campus Climate Challenge, and the American Association of Sustainability in Higher Education reflect an increasing level of environmental stewardship found at the nation's institutions of higher learning.

See www.aashe.org

REVIEW

1. What do economists mean by "efficient" regulation?
2. When might command and control regulations be more or less effective than economics-based policies?
3. What does the EPI measure that the GNP does not?

Environmental Justice

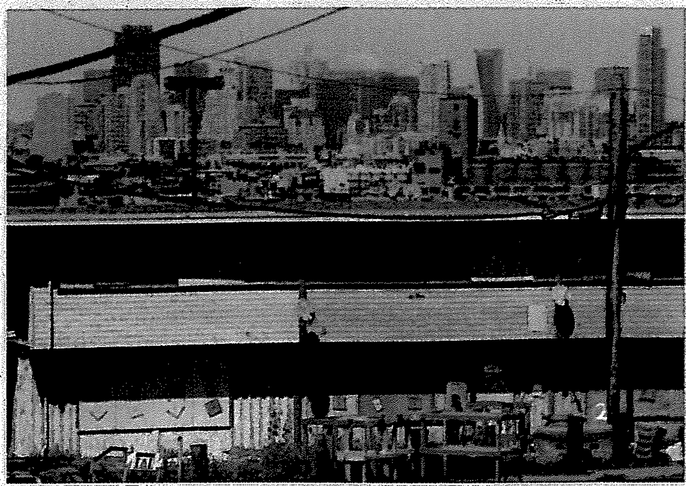
LEARNING OBJECTIVE

- Define *environmental justice* and explain why climate change is an environmental justice issue.

Over the past several decades, there has been increasing recognition that low-income and minority communities in both rural and urban areas face more environmental threats such as pollution and hazardous waste facilities and have fewer environmental amenities such as parks, trees, and clean air. At the same time, members of those communities have less of a voice in planning, including decisions about siting industrial facilities, sanitary landfills, and major transportation routes. Beginning in the late 1970s, environmental sociologist **Robert Bullard** at Clark Atlanta University identified patterns of injustice in Houston. For example, Bullard found that six of Houston's eight incinerators were located on less expensive land in predominantly black neighborhoods.

In addition, residents of low-income communities frequently have less access to other factors that influence health, including quality healthcare, fresh foods, and educational opportunities. The high incidence of asthma in many minority communities is an example of a health condition that may be caused or exacerbated by exposure to environmental pollutants. Few studies have examined how environmental pollutants interact with other socioeconomic factors to cause health problems. Those studies that have been done often fail to conclusively tie exposure to environmental pollutants to the health problems of poor and minority communities.

A 1997 health study of residents in San Francisco's Bayview–Hunters Point area found that hospitalizations for chronic illnesses were almost four times higher than the state average. Bayview–Hunters Point is heavily polluted. It has 700 hazardous waste facilities, 325 underground oil storage tanks, and two Superfund sites. Currently, little scientific evidence shows to what extent a polluted environment is responsible for the disproportionate health problems of poor and minority communities. Progress is being made: The EcoCenter at Heron's Head Park Partnership won a 2010 Achievements in Environmental Justice Award from the EPA for developing an environmental justice education center for the Bayview–Hunters Point neighborhoods (**Figure 2.16**).



©Michael Macor/San FranciscoChronicle / Corbis

Figure 2.16 Bay View - Hunters Point. This housing project was among the last parts of the old neighborhood to be replaced.

ENVIRONMENTAL JUSTICE AND ETHICAL ISSUES

Environmental decisions such as where to locate a hazardous waste landfill have important ethical dimensions. The most basic ethical dilemma centers on the rights of the poor and disenfranchised versus the rights of the rich and powerful. Whose rights should have priority in these decisions? The challenge of **environmental justice** is to find and adopt equitable solutions that respect all groups of people, including those not yet born. Viewed ethically, environmental justice is a fundamental human right. Although we may never completely eliminate environmental injustices of the past, we have a moral imperative to prevent them today so that the negative effects of pollution do not disproportionately affect any segment of society.

environmental stice The right of citizen, regardless age, race, gender, class, or other fac- adequate protec- om environmental hazards.

In response to these concerns, a growing environmental justice movement has emerged at the grassroots level as a strong motivator for change. Advocates of the environmental justice movement call for special efforts to clean up hazardous sites in low-income neighborhoods, from inner-city streets to rural communities. Many environmental justice groups base their demands on the inherent "rightness" of their position. Other groups want science to give their demands legitimacy. Many advocates cite the need for more research on human diseases that environmental pollutants may influence.

MANDATING ENVIRONMENTAL JUSTICE AT THE FEDERAL LEVEL

In 1994, President Clinton signed an executive order requiring all federal agencies to develop strategies and policies to ensure that their programs do not discriminate against poor and minority communities when decisions are made about where future hazardous facilities are located. The first response to President Clinton's initiative came in 1997 when the Nuclear Regulatory Commission (NRC) rejected a request to build a uranium processing plant near two minority neighborhoods in northern Louisiana. The commission decided that racial considerations were a factor in site selection because the applicant had ruled out all potential sites near predominantly white neighborhoods. This NRC decision sent a message that the U.S. government will protect the rights of vulnerable members of society.

ENVIRONMENTAL JUSTICE AT THE INTERNATIONAL LEVEL

Environmental justice applies to countries as well as to individuals (**Figure 2.17**). Although it is possible to reduce and dispose of

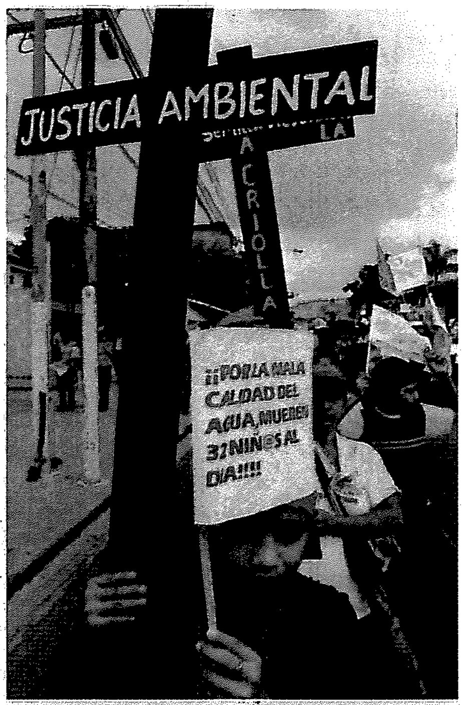


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Figure 2.17 International environmental justice. Protestors march for "justicia ambiental," or environmental justice. Photographed in San Salvador.

waste in an environmentally sound manner, industrialized countries have sometimes chosen to send their waste to other countries. (As industrialized nations develop more stringent environmental standards, disposing of hazardous waste at home becomes much more expensive than sending it to a developing nation, where property values and labor costs are lower.) Some waste is exported for legitimate recycling, but other waste is exported strictly for disposal.

The export of solid and hazardous wastes by the United States, Canada, Japan, and the European Union was highly controversial in the 1980s. Developing nations in Africa, Central and South America, and the Pacific Rim of Asia, as well as Eastern and Central European countries, often imported hazardous wastes in return for hard currency. In 1989, the UN Environment Programme developed a treaty, the **Basel Convention**, to restrict the international transport of hazardous waste. Originally, the treaty allowed countries to export hazardous waste only with the prior informed consent of the importing country as well as of any countries that the waste passed through in transit. In 1995, the Basel Convention was amended to ban the export of *any* hazardous waste from industrialized to developing countries.

At the 1996 meeting of the Association for the Advancement of Sustainability in Higher Education, scholar **Bill McKibben** described climate change not only as an environmental justice issue but also as "the greatest social justice issue of all times." He argues that more than any other issue in history, climate change has the most inequitable distribution of benefits (the use of fossil fuels by a small but very wealthy percentage of the world's population) and risks (the adverse effects of climate change on a large but very poor percentage of the world's population).

REVIEW

1. Is environmental justice a local issue, an international issue, or both? Explain.

Environmental Ethics, Values, and Worldviews

LEARNING OBJECTIVES

- Define *environmental ethics.*
- Define *environmental worldview* and discuss distinguishing aspects of the Western and deep ecology worldviews.

We now shift our attention to the worldviews of different individuals and societies and how those worldviews affect our ability to understand and solve sustainability problems. **Ethics** is the branch of philosophy that is derived through the logical application of human values. These **values** are the principles that an individual or society considers important or worthwhile. Values are not static entities but change as societal, cultural, political, and economic priorities change. Ethics helps us determine which forms of conduct are morally acceptable or unacceptable, right or wrong. Ethics plays a role in whatever types of human activities involve intelligent judgment and voluntary action. When values conflict, ethics helps us choose which value is better, or worthier, than other values.

ENVIRONMENTAL ETHICS

Environmental ethics examines moral values to determine how humans should relate to the natural environment. Environmental ethicists consider such questions as the role we should play in determining the fate of Earth's resources, including other species. Another question is whether we should develop an environmental ethic that is acceptable in the short term for us as individuals but also in the long term for our species and the planet. These are difficult intellectual issues that involve political, economic, societal, and individual trade-offs.

environmental ethics A field of applied ethics that considers the moral basis of environmental responsibility and the appropriate extent of this responsibility.

Environmental ethics considers not only the rights of people living today, both individually and collectively, but also the rights of future generations (**Figure 2.18**). This aspect of environmental ethics is critical because the impacts of today's activities and technologies are changing the environment. In some cases, these impacts may be felt for hundreds or even thousands of years. Addressing issues of environmental ethics puts us in a better position to use science, government policies, and economics to achieve long-term environmental sustainability.

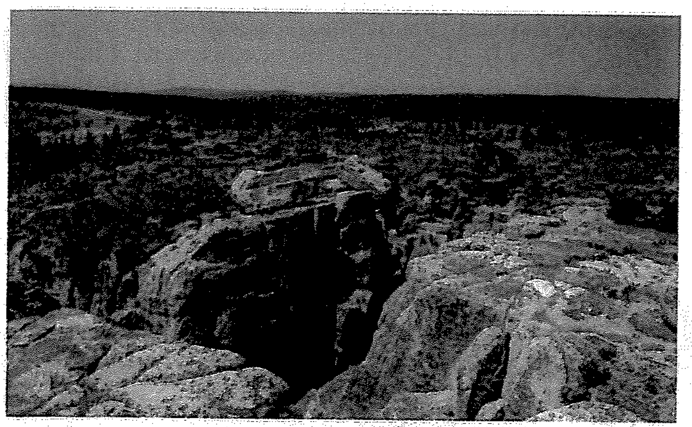

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Figure 2.18 Dolly Sods National Wilderness. The United States has chosen to protect many areas, such as the Dolly Sods National Wilderness in West Virginia, so that they will be available for enjoyment and use by future generations.

ENVIRONMENTAL WORLDVIEWS

Each of us has a particular **worldview**—a commonly shared perspective based on a collection of our basic values that helps us make sense of the world, understand our place and purpose in it, and determine right and wrong behaviors. These worldviews lead to behaviors and lifestyles that may or may not be compatible with environmental sustainability. Some worldviews share certain fundamental beliefs, whereas others are mutually exclusive. A worldview that is considered ethical in one society may be considered irresponsible or even sacrilegious in another. The following are two extreme, opposing **environmental worldviews**: the Western worldview and the deep ecology worldview. These two worldviews, admittedly broad generalizations, are near opposite ends of a spectrum of worldviews relevant to problems of global sustainability, and each approaches environmental responsibility in a radically different way.

environmental orldview A worldview that helps us ıke sense of how the ironment works, our ›lace in the environment, and right and rong environmental behaviors.

The **Western worldview**, also known as the *expansionist worldview*, is *anthropocentric* (human-centered) and utilitarian. This perspective mirrors the beliefs of the eighteenth-century *frontier attitude*, a desire to conquer and exploit nature as quickly as possible. The Western worldview also advocates the inherent rights of individuals, accumulation of wealth, and unlimited consumption of goods and services to provide material comforts. According to the Western worldview, humans have a primary obligation to humans and are therefore responsible for managing natural resources to benefit human society. Thus, any concerns about the environment are derived from human interests.

Western world-ew An understand-g of our place in the rld based on human eriority over nature, : unrestricted use of tural resources, and increased economic owth to manage an xpanding industrial e to benefit society.

ENVIRONEWS

Religion and the Environment

A new degree of commitment to environmental issues has grown steadily in many religious faiths and organizations. Many of the world's major religions have collaborated in conferences on religious perspectives and the natural environment. Here are several examples:

- In 2000, more than 1,000 religious leaders met at the Millennium World Peace Summit of Religious and Spiritual Leaders. Protecting the environment was a major topic of discussion.
- In 2001, the U.N. Environment Programme and the Islamic Republic of Iran sponsored an International Seminar on Religion, Culture, and Environment. They considered ways to counter environmental degradation.
- In 2006, the Evangelical Climate Initiative, which includes traditionally conservative evangelicals in the United States, identified global warming as an important religious issue requiring responsible stewardship and attention to future generations.
- The 2010 Baha'i Social and Economic Development Conference focused on the role of religion in dealing with global environmental challenges.
- In 2014, Roman Catholic Pope Francis I identified climate change as a "moral issue."
- On April 3, 2014, evangelical Christians around the United States gathered for a "Day of Prayer and Action" on climate change.

The **deep ecology worldview** is a diverse set of viewpoints that dates from the 1970s and is based on the work of the late **Arne Naess**, a Norwegian philosopher, and others. The principles of deep ecology, as expressed by Arne Naess in *Ecology, Community, and Lifestyle*, include the following:

deep ecology worldview An understanding of our place in the world based on harmony with nature, a spiritual respect for life, and the belief that humans and all other species have an equal worth.

1. All life has intrinsic value. The value of nonhuman life-forms is independent of the usefulness they may have for narrow human purposes.
2. The richness and diversity of life-forms contribute to the flourishing of human and nonhuman life on Earth.
3. Humans have no right to reduce this richness and diversity except to satisfy vital needs.
4. Present human interference with the nonhuman world is excessive, and the situation is rapidly worsening.
5. The flourishing of human life and cultures is compatible with a substantial decrease in the human population. The flourishing of nonhuman life requires such a decrease.
6. Significant improvement of life conditions requires changes in economic, technological, and ideological structures.
7. The ideological change is mainly that of appreciating the quality of life rather than adhering to a high standard of living.
8. Those who subscribe to the foregoing points have an obligation to participate in the attempt to implement the necessary changes.

Compared to the Western worldview, the deep ecology worldview represents a radical shift in how humans relate themselves to the environment. The deep ecology worldview stresses that all forms of life have the right to exist and that humans are not different or separate from other organisms. Humans have an obligation to themselves and to the environment. The deep ecology worldview advocates sharply curbing human population growth. It does not favor returning to a society free of today's technological advances but instead proposes a significant rethinking of our use of current technologies and alternatives. It asks individuals and societies to share an inner spirituality connected to the natural world.

Most people today do not fully embrace either the Western worldview or the deep ecology worldview. The Western worldview emphasizes the importance of humans as the overriding concern in the grand scheme of things. In contrast, the deep ecology worldview is **biocentric** (life-centered) and views humans as one species among others. The planet's natural resources could not support its more than 7 billion humans if each consumed the high level of goods and services sanctioned by the Western worldview. On the other hand, if all humans adhered completely to the tenets of deep ecology, it would entail giving up many of the material comforts and benefits of modern technology.

The world as envisioned by the deep ecology worldview could support only a fraction of the existing human population (recall the discussion of ecological footprints in Chapter 1). These worldviews, although not practical for widespread adoption, are useful to keep in mind as you examine various environmental issues in later chapters. In the meantime, think about your own worldview and discuss it with others. Listen carefully to their worldviews, which will probably be different from your own. Thinking leads to actions, and actions lead to consequences. What are the short-term and long-term consequences of your particular worldview? We must develop and incorporate a long-lasting, environmentally sensitive worldview into our culture if the environment is to be sustainable for us, for other living organisms, and for future generations.

REVIEW

1. What is environmental ethics?
2. What are worldviews? How do Western and deep ecology worldviews differ?

REVIEW OF LEARNING OBJECTIVES WITH SELECTED KEY TERMS

• Briefly outline the environmental history of the United States.

The first two centuries of U.S. history were a time of widespread environmental exploitation. During the 1700s and early 1800s, Americans saw nature primarily as resources to be used. During the nineteenth century, naturalists became concerned about conserving natural resources. The earliest conservation legislation revolved around protecting land—forests, parks, and monuments. By the late twentieth century, environmental awareness had become pervasive, and a suite of environmental laws were in place.

• Describe the environmental contributions of the following people: George Perkins Marsh, Theodore Roosevelt, Gifford Pinchot, John Muir, Aldo Leopold, Wallace Stegner, Rachel Carson, and Paul Ehrlich.

George Perkins Marsh wrote about humans as agents of global environmental change. **Theodore Roosevelt** appointed **Gifford Pinchot** as the first head of the U.S. Forest Service. Pinchot supported expanding the nation's forest reserves and managing forests scientifically. The Yosemite and Sequoia National Parks were established, largely in response to the efforts of naturalist **John Muir**. In *A Sand County Almanac*, **Aldo Leopold** wrote about humanity's relationship with nature. **Wallace Stegner** helped create support for passage of the Wilderness Act of 1964. **Rachel Carson** published *Silent Spring*, alerting the public to the dangers of uncontrolled pesticide use. **Paul Ehrlich** wrote *The Population Bomb*, which raised the public's awareness of the dangers of overpopulation.

• Distinguish between utilitarian conservationists and biocentric preservationists.

A **utilitarian conservationist** is a person who values natural resources because of their usefulness for practical purposes but uses them sensibly and carefully. A **biocentric preservationist** is a person who believes in protecting nature because all forms of life deserve respect and consideration.

• Explain why the National Environmental Policy Act is the cornerstone of U.S. environmental law.

The **National Environmental Policy Act (NEPA)**, passed in 1970, stated that the federal government must consider the environmental impact of a proposed federal action, such as financing a highway or constructing a dam. NEPA established the **Council on Environmental Quality** to monitor required **environmental impact statements (EISs)** and report directly to the president.

• Explain how environmental impact statements provide powerful protection of the environment.

By requiring EISs that are open to public scrutiny, NEPA initiated serious environmental protection in the United States. NEPA allows citizen suits, in which private citizens take violators, whether they are private industries or government-owned facilities, to court for noncompliance.

• Explain why economists prefer efficient solutions to environmental problems.

Economists assume that individuals behave as **rational actors** who seek to maximize **utility**. Groups of individuals behaving according to these assumptions result in economic **efficiency**, the greatest possible total societal benefit. Solutions that are inefficient will spend more on abatement than the pollution costs or will spend less on abatement than pollution reductions are worth.

• Describe command and control regulation, incentive-based regulation, and cost-effectiveness analysis.

Governments often use **command and control regulations**, which are pollution-control laws that require specific technologies. **Incentive-based regulations** are pollution-control laws that work by establishing emission targets and providing industries with incentives to reduce emissions. **Cost-effectiveness analysis** is an economic tool used to estimate costs associated with achieving some goal, such as saving a life.

• Give two reasons why the national income accounts are incomplete estimates of national economic performance.

National income accounts are a measure of the total income of a nation's goods and services for a given year. An **externality** is a harmful environmental or social cost that is borne by people not directly involved in buying or selling a product. Currently, national income accounting does not include estimates of externalities such as depletion of **natural capital** and the environmental cost of economic activities.

• Define *environmental justice* and explain why climate change is an environmental justice issue.

Environmental justice is the right of every citizen, regardless of age, race, gender, social class, or other factor, to adequate protection from environmental hazards. The primary benefit associated with climate change is energy from fossil fuels, which are available to the world's wealthier people, while the risks of climate change are spread across a much larger group of much poorer people.

• Define *environmental ethics*.

Environmental ethics is a field of applied **ethics** that considers the moral basis of environmental responsibility and the appropriate extent of this responsibility. Environmental ethicists consider how humans should relate to the natural environment.

• Define *environmental worldview* and discuss distinguishing aspects of the Western and deep ecology worldviews.

An **environmental worldview** is a worldview that helps us make sense of how the environment works, our place in the environment, and right and wrong environmental behaviors. The **Western worldview** is an understanding of our place in the world based on human superiority and dominance over nature, the unrestricted use of natural resources, and increased economic growth to manage an expanding industrial base. The **deep ecology worldview** is an understanding of our place in the world based on harmony with nature, a spiritual respect for life, and the belief that humans and all other species have an equal worth.

Critical Thinking and Review Questions

1. Briefly describe each of these aspects of U.S. environmental history: protection of forests, establishment and protection of national parks and monuments, conservation in the mid-20th century, and the environmental movement of the late twentieth century.
2. Describe the environmental contributions of two of the following: George Perkins Marsh, Theodore Roosevelt, Gifford Pinchot, John Muir, Aldo Leopold, Wallace Stegner, Rachel Carson, or Paul Ehrlich.
3. If you were a member of Congress, what legislation would you introduce to deal with each of these problems?
   a. Toxic materials from a major sanitary landfill are polluting some rural drinking-water wells.
   b. Acid rain from a coal-burning power plant in a nearby state is harming the trees in your state. Loggers and foresters are upset.
   c. Oceanfront property is at risk from sea-level rise caused by global warming.
4. Explain why the National Environmental Policy Act is considered the cornerstone of U.S. environmental law. Research some examples of when it has been effective and when it has not.
5. Based on what you have learned in this chapter, do you think the economy is part of the environment, or is the environment part of the economy? Explain your answer.
6. Following the 2010 oil platform collapse and associated oil spill in the Gulf of Mexico, Congress began considering new laws regulating deep-ocean oil drilling. Do you think command and control or incentive-based regulations would be more effective? Explain.
7. Can economic approaches to environmental management adequately account for the complex interactive systems that make up the environment? Why or why not?
8. The Environmental Performance Index has detractors among both environmentalists and industry groups. Based on what you have learned in this chapter, suggest reasons for each group to object to it.
9. Can economic solutions be used to address environmental justice concerns? Explain your answer.
10. Do you agree or disagree with the idea that climate change is an environmental justice issue? Explain your position.
11. Describe how environmental destruction in formerly communist countries relates to natural capital.
12. Determine whether each of these statements reflects the Western worldview, the deep ecology worldview, or both:
    a. Species exist for humans to use.
    b. All organisms, humans included, are interconnected and interdependent.
    c. Humans and nature exist in unity.
    d. Humans are a superior species capable of dominating other organisms.
    e. Humans should protect the environment.
    f. Nature should be used, not preserved.
    g. Economic growth will help Earth manage an expanding human population.

h. Humans have the right to modify the environment to benefit society.

i. All forms of life are intrinsically valuable and have the right to exist.

13. What is this cartoon trying to say? When do you think this cartoon was published?

© Steve Greenberg

Food for Thought

Several generations ago, many people in cities raised edible plants and animals at their homes. Now, however, local zoning laws prohibit livestock and even vegetable gardens in many urban areas. Research zoning laws about growing food in your area, or a nearby town if you live in a rural area. What foods are people allowed to raise at home? What, if any, are the environmental concerns about raising plants and animals for personal consumption in urban areas?