

The Environment and People

Introduction: A Guide to the Environment

1. Environmental Science: An Overview
2. Human Population Growth

“We stand now where two roads diverge. But . . . they are not equally fair. The road we have long been traveling is deceptively easy, a smooth superhighway on which we progress with great speed, but at its end lies disaster. The other fork of the road—the one less traveled by—offers our last, our only chance to reach a destination that assures the preservation of the earth.”

Rachel Carson (1907–1964), environmentalist and author, *Silent Spring*

Introduction: A Guide to the Environment

This text provides an overview of the natural environment and the way people are increasingly affecting it. Through an understanding of environmental science, you will be in a position to make sound decisions that will affect the future of the entire planet. An important aspect of genuine understanding is the ability to relate seemingly diverse and disparate facts and phenomena to one another within a larger picture. A truism in environmental science is that everything is related to everything else. The environment is a finely tuned, grand, and extremely complex system in which if one component is modified or tampered with there will be ramifications in other, often unexpected, portions of the system. Therefore, it is particularly beneficial to use a **systems approach** in analyzing global environmental issues (discussed in more detail later in this chapter).

FIGURE INTRO.-1 shows how the text is subdivided into the five major sections (each containing a number of chapters). These sections reflect the input–output, or throughput, processes that can be used to describe the global environment, how the environmental system is modified, and solutions to environmental problems (such as the depletion of resources or pollution of nature) brought on by human activities.

- *Section 1: The Environment and People.* The natural environment and the people living on planet Earth form a complex, integrated system, as introduced here. The environmental science overview and discussion on human population growth also describe the explosive growth of the human population, the development of modern technological and industrial society, and some of the ramifications that these have had for the natural environment. Many environmentalists consider human population growth, or more precisely the impact of people on the environment, to be the single most important issue that the world currently faces. Studying Figure Intro.-1, you will see that conceptually

FIGURE INTRO.-1 A system can be technically defined as a “set of components functioning together as a whole.” A systems view allows us to isolate a part of the world and focus on those aspects that interact more closely than others. For example, a cell in the system we call a human body generally interacts much more closely with other cells in the body than with the outside world. By focusing only on the cells that function in digestion, we confine our view further to the digestive system. The key point here is that most systems are hierarchical: They are composed of smaller sets of systems made of smaller interacting parts. Photos: © Photodisc.

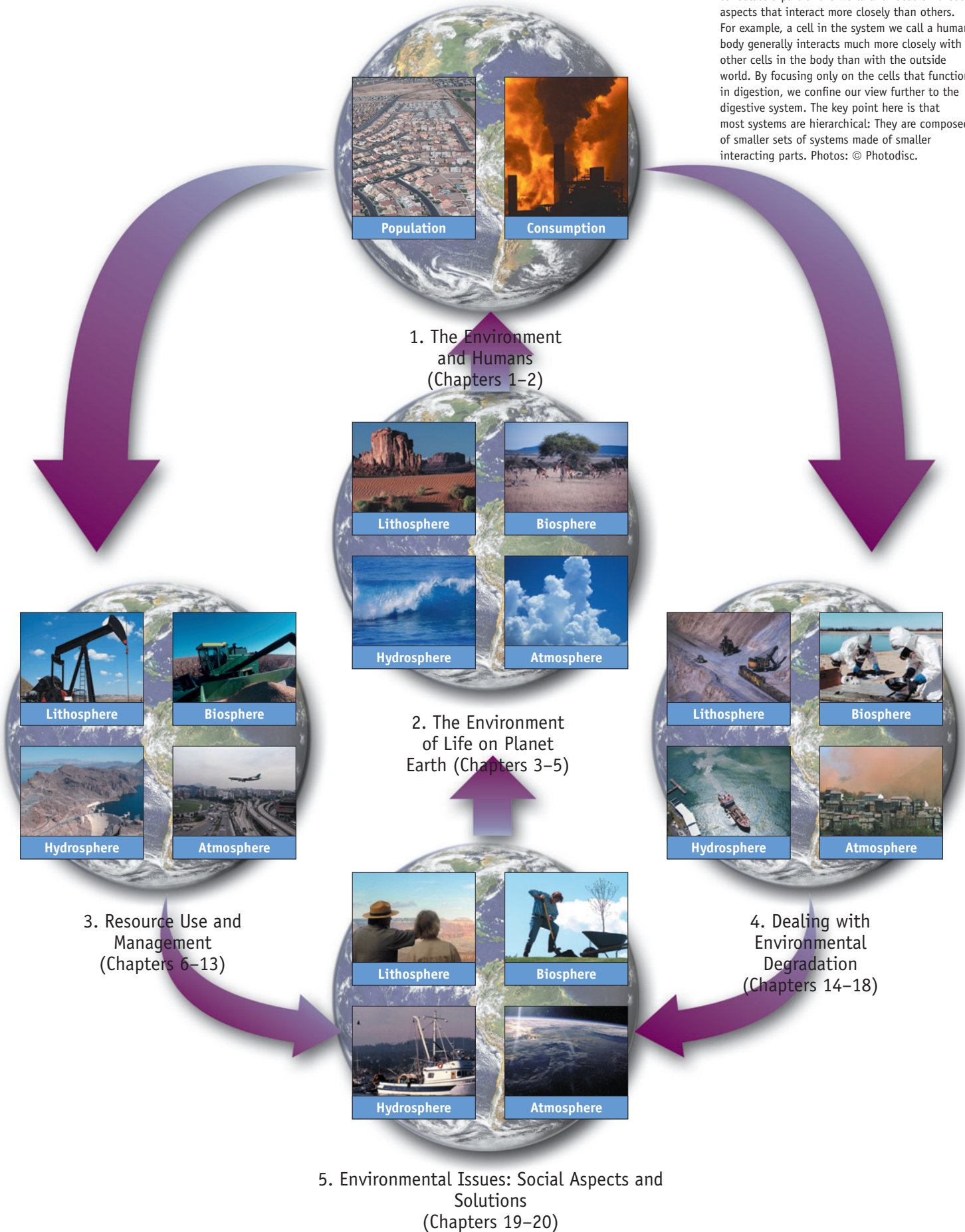




FIGURE INTRO.-2 Even parts of remote Antarctica, shown here, have become dumping grounds for human waste. © William Larose/Greenpeace.

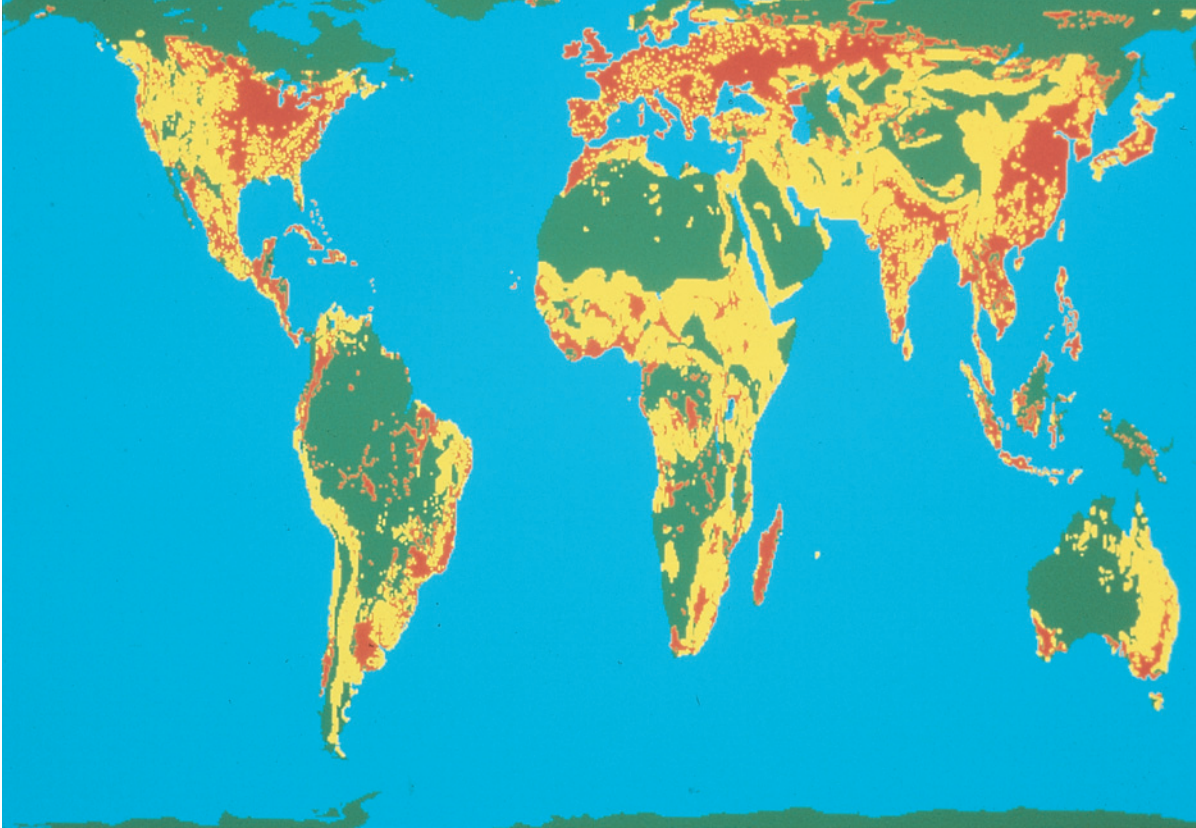
the raw elements of the natural environment pass through human society to produce the global environment in which we currently live. For all practical purposes, there is no pristine wilderness remaining anywhere on Earth (**FIGURE INTRO.-2**).

- *Section 2: The Environment of Life on Planet Earth.* Earth and life form an interconnected system based on energy flow and matter cycles. Study of these natural systems includes the disciplines of biology, chemistry, geology, climatology, and many other natural sciences. Learning the basic principles of these fields permits a better understanding of natural systems and how they can be used, protected, or disturbed. People use, modify, and are dependent on these natural systems.
- *Section 3: Resource Use and Management.* Simply by using resources, we run the risk of overusing and depleting them. Depletion of environmental resources is one of the two basic types of environmental disturbance. It includes depletion of water, minerals (including fossil fuels), soils, wild-

life and wildlife habitat, and many other resources. To avoid depletion problems, we must learn to manage our resources in a more sustainable manner. Issues surrounding depletion and resource scarcity are discussed in Section 3.

- *Section 4: Dealing with Environmental Degradation.* Discharging waste into the environment is the other basic type of environmental disturbance. It includes pollution of air, water, land, and biological communities, but there are ways to use resources productively without the levels of pollution and concomitant environmental damage that have been so widespread in the past. Environmentally friendly options to address problems of pollution are explored in Section 4.
- *Section 5: Social Solutions to Environmental Concerns.* Technological solutions are insufficient unless society is willing to use them. Social solutions are interwoven throughout this text, but these final chapters allow us to focus on specific social institutions and their legal and economic aspects. Ultimately, through a combination of scientific analysis, technological advances, and the continuing development of social institutions, humanity must lessen its detrimental impact on the environment if we are to avoid living on an impoverished planet in a very bleak postindustrial age.

The global environment of the future (represented in Section 5; refer to Figure Intro.-1) will not be the preindustrial environment of the past (represented in Section 2) because we (Section 1) have a tremendous impact on the environment (Sections 1, 3, and 4). Our actions today will have a profound effect on the environment of the future. By our deeds we will determine whether the environment of the future will be more or less hospitable to us and numerous other species.



Much of the world's land area has been disturbed by humans. In this photo, red indicates land that is greatly altered and yellow shows the partially altered land area. Only the green area remains in a relatively natural state, and it is disappearing rapidly. (Source: Lee Hannah, Conservation International.)

Ancient earth and stonework in the Peruvian Andes. See Case Study 13-1 (Photo by Robert Schoch).



1

Environmental Science: An Overview

Chapter Objectives

After reading this chapter, you should be able to explain or describe the following:

- What is meant by environmental science
- How the environment works as a system
- The key traits of the environmental system
- The concepts of consumption and exponential growth
- A brief history of environmental movements
- The concept of a commons
- Throughput
- What is meant by true costs and why people avoid them

The critical importance of environmental science and environmental studies cannot be disputed. Virtually everyone is aware of environmental issues—global warming, the depletion of the ozone layer, the controversy over nuclear power, the global loss of species and biodiversity, the introduction of hormone-altering pollutants into the natural environment, the use of and controversy surrounding genetically engineered crops, or the continuing problem of solid waste disposal. No citizen of the Earth can afford to be ignorant of environmental issues.

Our planet has existed for more than 4 billion years, yet never before has one species dominated the Earth and other species so completely. Humanity now stands at a unique crossroads: because of human technological capabilities and impacts, the next few decades will witness drastic changes in the Earth and its inhabitants. It is our individual responsibility to try to influence the outcome of such changes so that the welfare of both people and the environment is best served.

Although this text presents many important facts, it also has three larger goals. One is to help you sort through the huge amount of environmental information available and focus on important “core” issues. Today, especially with the widespread availability of the Internet and the World Wide Web, little bits of information on almost any environmental issue are readily available; nevertheless, even as we become overwhelmed with factoids, the bigger picture, a larger perspective, is often lost. It often

can be difficult to distinguish the truly important from the merely interesting or even the downright trivial. As the old saying indicates, it can be hard to see the forest because all of the trees block the view.

Seeing the big picture will help you to understand differing points of view of individuals or groups who have economic, political, or even personal stakes in the possible solutions. Environmental issues are complex. With every solution comes a different set of potential advantages and disadvantages. The second goal of this text then is to help you understand the problems, evaluate the solutions with all the stakeholders in mind, and make up your own mind.

The third goal of this text is to get you, the reader, seriously thinking about how you can put an understanding of environmental issues to work to effectively help your household, community, or nation make the fundamental changes needed to build a world that can sustain many generations of people with a decent standard of living, while minimizing the human impact on the natural environment. We encourage you to become actively involved in environmental concerns.

What Is Environmental Science?

Environmental science involves all fields of natural science as they bear on the physical and biological environment around us. Aspects of biology, geology, chemistry, physics, meteorology, and many other disciplines must be considered when studying environmental science. A major component of modern environmental science involves addressing current environmental problems brought about directly by human activity. Therefore, in addition to presenting the scientific concepts underlying environmental issues, we also discuss social aspects of environmental problems. Not only technology and scientific understanding, but also laws, ethics, economics, and other aspects of human behavior will play a key role in solving our current environmental dilemmas.

Avoiding “Information Overload”

One of the challenges we face today is how to cope with information overload. Newspapers, radio, television, and the Internet/

World Wide Web bombard us daily with data and statistics. Feeling overwhelmed, most people react by “tuning out.”

Rather than quit trying to assimilate all this information, we might recall Henry David Thoreau’s advice to “simplify! simplify!” Thoreau has become a hero to many environmentalists because he long ago predicted many of the problems that we now face. His advice to simplify was a response to what he saw as a tendency for civilization to become increasingly more complex and removed from the natural world. This, he said, led to anxieties and spiritual impoverishment despite material wealth. On a pragmatic level, it also leads to a weakened and damaged natural environment.

We can heed Thoreau’s advice by mentally stepping back and keeping our priorities set on what we think is important. The systems approach to environmental science greatly heeds the process. In this way, we can focus on the information that we can use, instead of trying to learn it all (which no one can do). Ideally, we can strive to seek what might be called **environmental wisdom**. Wisdom is the ability to sort through all of the facts and information to make reasonable decisions and plan sensible long-term strategies. Wisdom is gained through education and practical experience, so environmental wisdom takes time to develop. Wisdom also means that we take a broad view in solving problems and weigh all kinds of information, social and economic as well as scientific and technical. Environmental science is often called **holistic**, meaning that it seeks connections among all aspects of a problem.

A lack of environmental wisdom is costly in many ways. It is costly to other species, to our quality of life, to future generations, and often to human happiness itself; however, currently the most easily measured costs are economic. A good example is illustrated in **FIGURE 1-1**, which shows that money spent on environmental problems does not always correlate directly to the actual magnitude of the problem. For instance, problems related to land preservation and restoration receive more money than those associated with global change (such as fixing the hole in the ozone layer or addressing clean air issues related to the increased incidence of asthma in children living in urban

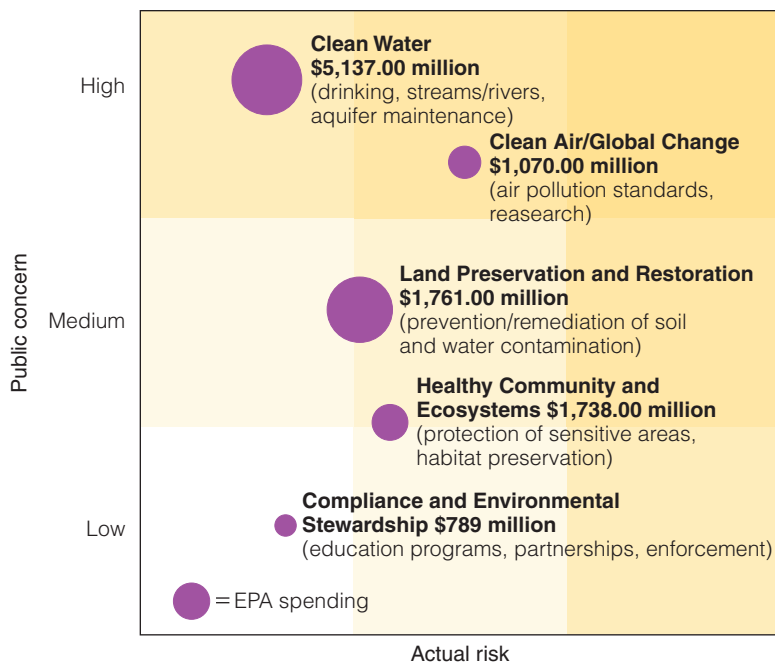


FIGURE 1-1 The actual risk of a hazard compared to the amount of public concern about the risk. There is not always a direct correlation between the actual magnitude of a problem or its associated risks and the amount of money spent to mitigate the problem. As a result, large amounts of money (size of dot) are spent on issues with less direct risks, such as soil remediation projects, while at the same time problems such as air pollution and global climate change with more immediate consequences receive less money. (U.S. Environmental Protection Agency and World Water.org.)

areas). Such spending inefficiencies occur because people often lack adequate information about the true risk of environmental problems.

Building a Sustainable World

Many environmentalists point out that past efforts have tended to focus on short-term emergency actions rather than long-term so-



FIGURE 1-2 Cleaning up toxic waste is an expensive after-the-fact approach. It is much cheaper to design methods that produce less waste. Courtesy of U.S. Army Corps of Engineers.

lutions. Examples of this approach include cleanup of wastes and pollution after they are produced (**FIGURE 1-2**) and trying to save species only when they are nearly extinct. Besides being less effective, such piecemeal, late-acting remedial solutions are almost always the most expensive way to solve environmental problems.

In the last decade, the rising costs and inefficiencies of cleaning up pollution after it is produced have led to a search for better approaches to solving environmental problems. Generally, holistic approaches have been able to solve problems more cheaply and efficiently. By examining society and the environment as an interconnected system, we often can solve many problems at once. The **input** of materials and energy through society is commonly called **throughput**. Environmental resources (or inputs) are referred to as **sources** of throughput. Environmental reservoirs that receive throughput are called **sinks** and are the ultimate repository of societal **output**, which could become input and throughput again, as in recycled materials. As illustrated in **FIGURE 1-3**, environmental problems arise from (1) resource depletion and (2) pollution. Past efforts at pollution control were largely “end-of-pipe” solutions, cleaning up waste after it was produced. Reducing the flow of material through society can also control pollution. Such **input reduction**, which conserves resources and reduces pollution at the same time, is now widely accepted by environmental economists and others as a better solution to most environmental problems. Input reduction illustrates the kind of fundamental change needed to build a society that can be maintained for many years without degrading the environment. The works of chemist Michael Braungart and architect and designer William McDonough illustrate this last point. Together they have put to use nature’s practice that nothing goes to waste and in the end waste equals food. Through their “cradle to cradle” certification process, factories and other businesses worldwide are proving that industrial design that promotes sustainability through reduced negative impact on the environment can occur through

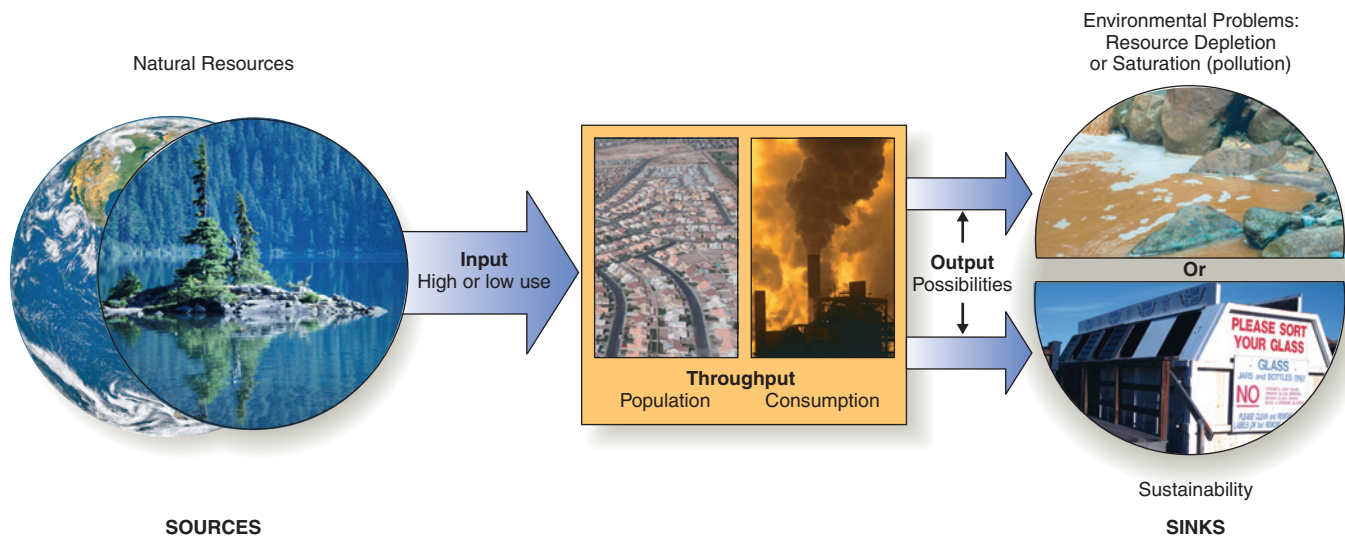


FIGURE 1-3 People use resources from the natural environment and deposit wastes back into the natural environment. Materials and energy that people draw from are known as “sources,” and environmental reservoirs that receive the products of human society are known as “sinks.” Environmental problems can arise from resource depletion and pollution of sinks. Controlling consumption and reducing the flow of material through society can alleviate many environmental problems. Inserts © Photodisc.

creative problem-solving and ingenuity, and these solutions are profitable for the company and society that commit to them.

Figure 1-3 also identifies the two basic causes of most current environmental problems: human population pressures and consumption of material goods. Increases in population and consumption have led to increased resource depletion and pollution. Both need to be addressed if long-term solutions are to be achieved.

1.1 The Environment as a System: An Overview

The entire environment of planet Earth can be divided into four spheres (refer to Figure Intro.-1): the biosphere (living organisms of Earth), atmosphere (the gaseous envelope surrounding the planet), hydrosphere (the liquid water on the surface of Earth), and lithosphere (the stony or rocky matter composing the bulk of the surface of Earth). Matter cycles and energy flows through these spheres (**FIGURE 1-4**). A systems approach provides a convenient overview and manner of understanding how our environment works.

What Is a System?

A **system** can be defined technically as a “set of components functioning together as a whole.” A systems view allows us to isolate a part of

the world and focus on those aspects that interact more closely than others. For example, a cell in the system we call a human body generally interacts much more closely with other cells in the body than with the outside world. By focusing only on the cells that function in digestion, we confine our view further to the digestive system. The key point here is that most systems are *hierarchical*: they are composed of smaller sets of systems made of smaller interacting parts.

Three Key Traits of the Environmental System

We can analyze the global environment in terms of three system traits: openness, integration, and complexity.

Openness refers to whether a system is isolated from other systems. An **open system** is not isolated in that it exchanges matter and/or energy with other systems. A **closed system** is isolated and exchanges nothing.

The law of entropy means that energy cannot be fully recycled; rather, “high-quality” energy is degraded to “lower quality” energy (such as waste heat). Therefore, any system that does not have a renewing supply of energy from outside eventually will cease to exist. Not surprisingly, the Earth is an open system in terms of energy. Figure 1-4 shows how energy flows from the sun and is often radiated back into space. In contrast, the

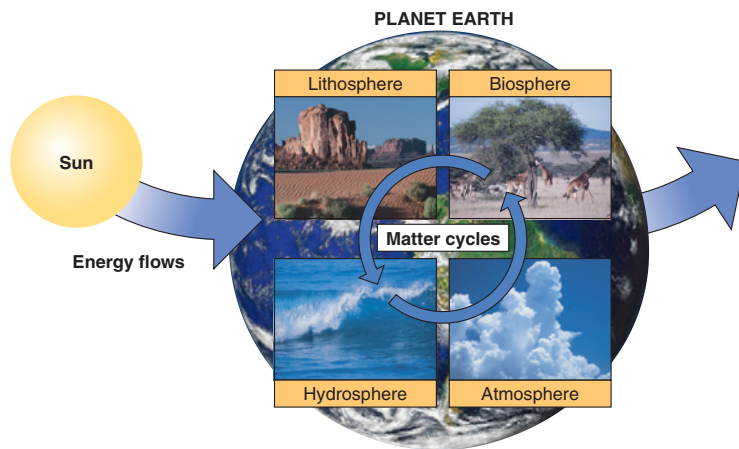


FIGURE 1-4 The Earth is open to energy, which flows into and out of it. However, the Earth is essentially closed to matter, which cycles over and over through the four spheres. Inserts © Photodisc.

Earth, for all practical purposes, is a closed system in terms of matter. If we discount the relatively small amount of matter added from meteorites and other space debris, the Earth contains all of the matter it will ever have. Driven by energy from the sun, this matter cycles over and over among the four spheres, often moving back and forth among the gaseous, liquid, and solid states and participating in the metabolism of living things.

Integration refers to the strength of the interactions among the parts of the system. For instance, the human body is a highly integrated system whose cells are interdependent and in close communication. The loss of certain cells, such as those composing the heart or brain, can result in death of all of the other cells in the system (the whole organism) because the cells are so interdependent. At the other extreme are systems with very weak integration, such as the cells in a colony of single-celled organisms (such as the green algae *Volvox*). Removal of many cells (to a point) will have little effect on the remaining cells because they are less dependent on each other.

The degree of integration of the global environmental system is a matter of debate. At one extreme are scientists who argue that the global system is a superorganism: many complex pathways intimately interconnect the lithosphere, hydrosphere, atmosphere, and biosphere. According to this **Gaia hypothesis**, the Earth is similar to an organism, and its component parts are so integrated that they are like cells in a living body. However, many

scientists believe the global environment is less integrated than the Gaia hypothesis argues. This does not mean that the environment is “unconnected” or even as weakly connected as a colony of cells. As we describe in future chapters, many kinds of matter cycles and energy flows interconnect the spheres and cycle within the spheres as well. The true level of integration in the global system probably is somewhat less than a “superorganism” but considerably more than a loose collection of independent parts.

Complexity is often defined as how many kinds of parts a system has. This definition conforms to our intuition: a tiny insect seems more complex to us than a large rock because it has many more types of “parts.” The insect has more complex molecules, as well as more different types of molecules, and these are used to construct cells and organs. This example also illustrates that complexity is often hierarchical, with smaller components being used to construct larger ones.

As you would expect, the environment is enormously complex. The four spheres, with their matter cycles and energy flows, have trillions and trillions of different components operating at many spatial and temporal scales. Organisms, soils, rainwater, air, and many other components interact in complicated ways. The individual spheres themselves are equally complex. Even with advanced computers, no one has been able to predict accurately and precisely the weather, or even climate, very far into the future because the atmosphere is so complex. Indeed, the many interactions make unpredictability a basic characteristic of complex systems. This inability to predict how the environment will respond to changing conditions (which is why it is so dangerous to tamper) is perhaps the major reason for so much controversy about and inaction with regard to environmental problems.

Major Obstacles: Delayed and Unpredictable Impacts. Social responses to environmental problems are greatly hindered by two of the key traits of the environmental system: its moderate integration and high complexity. Any system that is integrated, such as the environment, can transmit disturbances from one part of the system to another. Integration

results from connectedness so that resource depletion or pollution of one part of the environment can have cascading, or domino, effects into other parts. For example, burning sulfur-rich coal affects the atmosphere as air pollution, but it also affects the hydrosphere when it falls as acid rain to acidify lakes. The biosphere is also affected because aquatic organisms in the lake can die from the more acidic lake water. The burning coal can even affect the lithosphere when the acid rain dissolves limestone and other alkaline rocks to form caves and sinkholes. This example shows how just one activity, burning coal, can affect all four spheres of the environment. Such wide-ranging cascading effects are anything but rare, as we see in later chapters. This connectedness of the environment means that virtually any action has a number of consequences, many of which are unforeseen and unintended. Such cascades are so important that the biologist Garrett Hardin has formulated the **first law of ecology**: “We can never do merely one thing.” This is often called the “law of unintended consequences.”

That the environment is only moderately integrated (“loosely connected”) greatly hinders our ability to observe, predict, and ultimately correct the unintended consequences of our actions. The indirect connections and interactions in the environment create delays, or long lag times, before cascading effects become visible (FIGURE 1-5). Returning to the acid rain example, it may take many years of coal burning before the trees on mountaintops or fish populations in lakes are affected. In other cases, the impacts can be delayed for centuries, millennia, or even longer. Environmental impacts on a global scale usually take an especially long time to occur. Many decades and probably centuries will pass before the full effects of added atmospheric carbon dioxide on global temperature are observable. This lag time is one of the main reasons for the debate over global warming. To make matters more complicated, corrective measures may themselves have unanticipated consequences.

As we have seen, the complexity of the environment leads to unpredictability, which hinders social responses to environmental

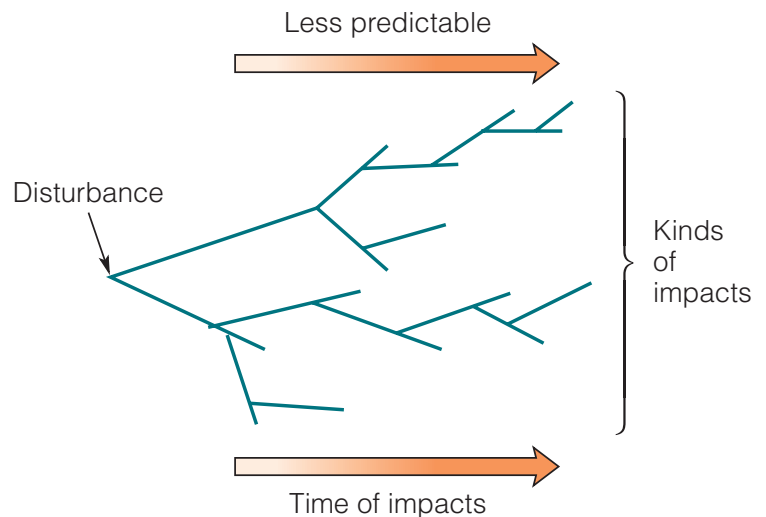


FIGURE 1-5 “We can never do merely one thing.” Whenever we do something, we cause a cascade of impacts. These impacts become less predictable with time.

problems. As Figure 1-5 illustrates, the unintended cascades we cause not only take a long time, but also occur as unexpected, complicated chains of events. Take the example of global warming and disease. Strong evidence has shown for many years that many tropical diseases are spreading because of global warming. In 1993, an article was published in *The Lancet* concluding that a 1991 cholera outbreak in South America was related to localized warming of Pacific Ocean waters caused by global climate changes. The article argued that the warming had caused the rapid growth of plankton that harbors the cholera bacterium, leading to thousands of deaths (FIGURE 1-6). Since then, many other studies have linked global warming with the



FIGURE 1-6 In a hospital in Ecuador, a mother holds her cholera-stricken son. The cholera outbreak occurred in Ecuador in June 1991. © Ricardo Mazalan/AP Photos.

CASE STUDY

1-1

Systems and Chaos Theories: Ways to Study Complexity



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Studying complex systems can be difficult because they have many parts that often interact in different ways. Over the last few decades, researchers have developed several methods of studying complexity. For example, systems theory and chaos theory try to produce general “laws” of complexity. Such laws would not only make complex systems more understandable, but they also would allow us to predict more accurately how these systems will behave. Think of how important such predictions could be for a complex system such as the stock market or for weather and climate forecasting!

None of these theories has been entirely successful in providing a complete understanding of complexity or producing accurate predictions of how any particular complex system will behave. Nevertheless, these theories have provided a better idea of how complex systems will generally behave under a given set of conditions. Consequently, we have a general understanding of how a lake ecosystem will respond to excess nutrients even though we cannot specify every event.

Systems theory (or general systems theory) was one of the first widely used attempts to find “laws” of complex systems. It traditionally has focused on how systems are regulated and become unregulated. Systems theory treats a complex system as a “black box” with inputs and outputs. Such a system is kept at equilibrium by negative feedback processes, defined as processes that counteract perturbations. An example is a thermostat that turns a furnace on to produce heat when a house is cold and turns on air conditioning when it is hot. In contrast, positive feedback processes amplify perturbations. For example, a cooling global climate can cause more snow to remain on the ground, which leads to more global cooling because the snow reflects sunlight back into space. This in turn causes yet more snow, and so on (a snowball effect).

Systems theory often has been criticized as too general or vague because by treating a system as a “black box,” the theory omits many of the details of how the system operates. More recent efforts to study complex systems have focused on more mathematical, rigorous descriptions of them. One

theory that has received much attention is chaos theory. A chaotic system is one in which the workings are sensitive to even the slightest change: this slight perturbation can become greatly amplified through positive feedback. The classic example is the weather, as E. Lorenz, who helped establish chaos theory in the early 1960s, first described. Lorenz created a set of equations that precisely described atmospheric conditions and showed how even tiny changes in one of the parameters could cause a massive alteration of the weather in a few days. This is often called the “butterfly effect,” with the idea that the flapping of a butterfly’s wings in South America could eventually affect the weather in North America (**FIGURE CS-1**). By creating tiny changes in atmospheric turbulence, which in turn creates cascading effects on larger airflows, the butterfly’s wing flapping could have a major impact. (Of course, the chances that it actually will produce such a major impact are extremely low.)

Chaos theory’s most important finding so far is that even simple systems, such as several atoms, often have chaotic properties. How can we make predictions when a minute unseen change, as in the butterfly effect, can have cascading effects? Many theorists think it will always be impossible to predict accurately precise future behaviors in complex systems, which have even more potential for chaos than do simple systems. Nevertheless, by applying chaos theory, patterns of regularity can be discerned and studied.



CS 1-1 FIGURE 1 Can a butterfly in the rain forest affect the weather in North America? © Photodisc.

spread of diseases. In a 2007 article in the *Online Journal of Issues in Nursing*, Brenda Afzal indicated that not only is insect-borne illness a challenge, but warming trends leading to migration of insects into new habitats and other factors such as daily air quality caused by intensified pollution also are becoming increasingly urgent issues for global health as Earth's climate continues to change. The World Health Organization and the National Institutes of Health indicate that these trends are not found only in developing nations: West Nile virus, which made its comeback in the United States in 1994, is now found in 44 states, and more alarming is the fact that the mosquitoes that carry dengue fever are found in counties within the United States where 173.5 million Americans live.

Along with safe food, water scarcity, and the impact of extreme weather on communication and transportation systems, U.S. intelligence officials list the spread of disease as one of their top four climate-change-related security concerns.

In addition to having many interactions, complex systems are unpredictable because some of the interactions exhibit positive feedback. **Positive feedback** occurs when part of a system responds to change in a way that magnifies the initial change. For example, evidence indicates that a slight increase in average global temperature can cause a further increase by melting some of the glaciers and snow that reflect sunlight back into space. Instead of reflecting light, more of the Earth's surface becomes available to absorb heat. Another example is poverty in developing countries that results from overpopulation; the poverty leads to high reproductive rates and thus still more overpopulation. In nontechnical terms, positive feedback is often referred to as a "snowball effect" or "vicious circle."

Society in the Environmental System

FIGURE 1-7 illustrates how modern society is embedded within the environment, being dependent on it for the materials and energy needed to maintain civilization. It also shows how industrialized society accelerates the cycling of

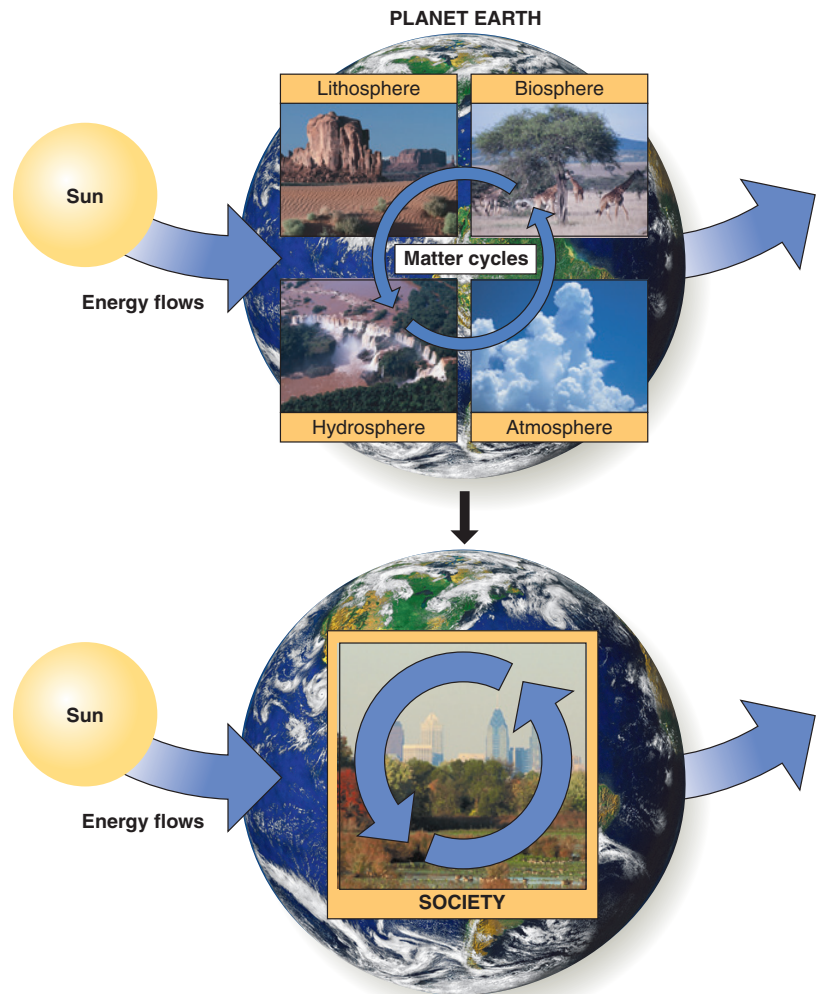


FIGURE 1-7 Society accelerates the cycling of matter through the four spheres, which depletes resources (matter inputs to society) and causes pollution (matter outputs by society). This acceleration is increasing because of increasing population (P) and consumption (C). Slowing population growth and reducing personal consumption will reduce this acceleration. Inserts © Photodisc.

matter and the flow of energy through itself and the four spheres.

Fundamentally, all environmental problems involve either depletion of sources (consumption) or pollution of sinks (production of waste). Therefore, these two processes can help us measure the net environmental impact of society. Depletion occurs when the accelerated cycling and flow remove matter and energy faster than natural processes are renewing them. Conversely, pollution occurs when the accelerated cycling and flow are discharged into the environment, overwhelming the local natural purification processes (**FIGURE 1-8**).



FIGURE 1-8 Pollution occurs when natural purification processes are overwhelmed, such as by large amounts of nutrients or poisons. Shown here is acid rain damage. Courtesy of NOAA Restoration Center and Damage Assessment and Restoration Program.

Problems of environmental depletion and pollution both exhibit the delayed and unpredictable impacts we have discussed. Much of the remainder of this text is concerned with these issues (Figure Intro.-1).

1.2 What Is Environmental Impact?

Environmental impact refers to the alteration of the natural environment by human activity. We have already identified two basic types of environmental impact: resource depletion and pollution (Figure 1-3). In other words, there is either too much input (resources)

and/or too much output (pollution). Input reduction seeks to slow both depletion and pollution, whereas output reduction slows only pollution.

Population and consumption are two main forces accelerating resource depletion and pollution. The following equation is a simple way to remember this:

$$\text{Impact} = \text{Population} \times \text{Consumption}$$

$$\text{or } I = P \times C$$

It is easy to see why the number of people affects impact (FIGURE 1-9). Consumption historically has tended to increase the effect of each person. For example, a baby born in the United States has many times the impact of a baby born in a developing country because over a lifetime the U.S. resident consumes many more resources, close to 20 times more, such as fossil fuels, and produces much more pollution. Although the United States accounts for only about 5% of the world's population, researchers have pointed out that the United States consumes nearly a quarter of all the energy used worldwide.

Current research indicates that population growth rates remain high but have begun to decrease slightly for most industrialized countries, while continuing to rise extremely rapidly in many developing nations. Today (2011), 95% of all population growth occurs in areas most challenged by poverty, civil unrest, malnutrition, and the lack of resources needed to disrupt the cycle. Despite differences in growth rate, consumption of nonrenewable

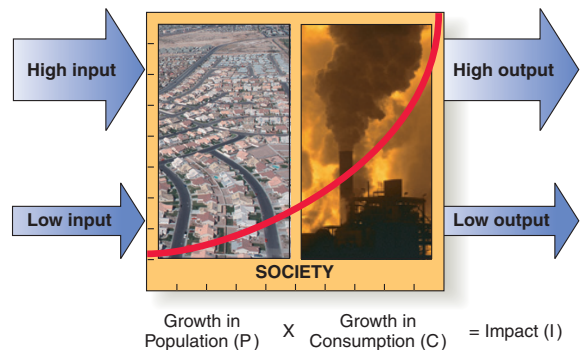


FIGURE 1-9 Personal consumption (C) has increased the throughput per person. This is multiplied by the number of people (population or P) to obtain the total resource depletion and pollution produced by society. Inserts © Photodisc.

resources continues to increase at alarming rates. This worldwide trend has led to a rapid increase in environmental impact. This section briefly examines both of these factors.

Exponential Growth

Multiplicative processes cause **exponential growth** of any kind. It occurs in population growth because biological reproduction is inherently multiplicative: most organisms have the ability to produce more offspring than are necessary to simply replace the parental generation. If conditions allow, the population of each successive generation will be larger than the previous generation. Consider, for example, a pond where the algae cover starts from a single algal cell and doubles in size each day. For a long time, you would see nothing happening. However, after larger areas were covered, the algae would spread quickly: one day, the pond would be only half covered; the next day, it would be completely covered.

Exponential Growth of the Human Population

The current world population (2011) stands at approximately 7 billion people. For millions of years, relatively few people were on Earth at any given time. The total human population on Earth remained quite low until the development of agriculture. Even then, population growth did not become explosive until the 1900s, when it was aided by the global spread of industry and modern medicine. Currently, each year the world population experiences a net gain of approximately 77 million people, the equivalent of nearly one-third of the population of the United States. Since 1960, the world population has more than doubled. At the current world population growth rate (estimated to be approximately 1.2%), the world population will double again in less than 60 years. In the last 50 years, there has been more population growth than in the entire history of human existence. Even if population growth rates stabilize around the year 2050, as many scientists predict they might, world population would still be about 9 billion people, an increase of approximately 30% over the 2011 population. The stabilization of population growth rates is speculative,

based on several factors, including increasing access to education and birth control for women in developing nations, increasing financial assistance and programs promoting more sustainable ways of life, and natural causes such as diseases assisting in the stabilization of the population. Because population growth is most dramatic in the most politically unstable regions of the world, there is disagreement about the accuracy of stability models. One fact remains, Earth's resources are being consumed at rates never before seen with consequences that are hard to predict.

How long will human population growth continue before it encounters environmental limitations? The answer depends on how many people the Earth can support, a question that is much debated, in part because the answer depends on how high a standard of living one assumes. However, many estimates predict that the Earth can adequately and sustainably support between 6 and 8 billion people at a reasonable standard of living. If this is true, population growth clearly must decline very soon if **overshoot** is to be avoided. Almost all of the United Nations, the World Bank, and other organizations' population projections indicate that world population probably will not stabilize until it reaches 9 billion, sometime in the middle to late 21st century.

Exponential Growth of Consumption

The second basic factor in our impact equation, $I = P \times C$, is consumption. Here, we use the term **consumption** in the economic sense to refer to the purchase and use of material goods, energy, and services in our daily lives. Consumption includes all of the things we do and buy to meet our wants and needs. Consumption has increased the overall environmental impact by increasing the impact per person:

$$\begin{aligned} \text{Overall impact} &= \text{population} \times \text{consumption} \\ &= \text{number of individuals} \\ &\quad \times (\text{impact/individual}) \end{aligned}$$

This impact per person occurs through an increase in both resource depletion and pollution. Because natural resources are used to

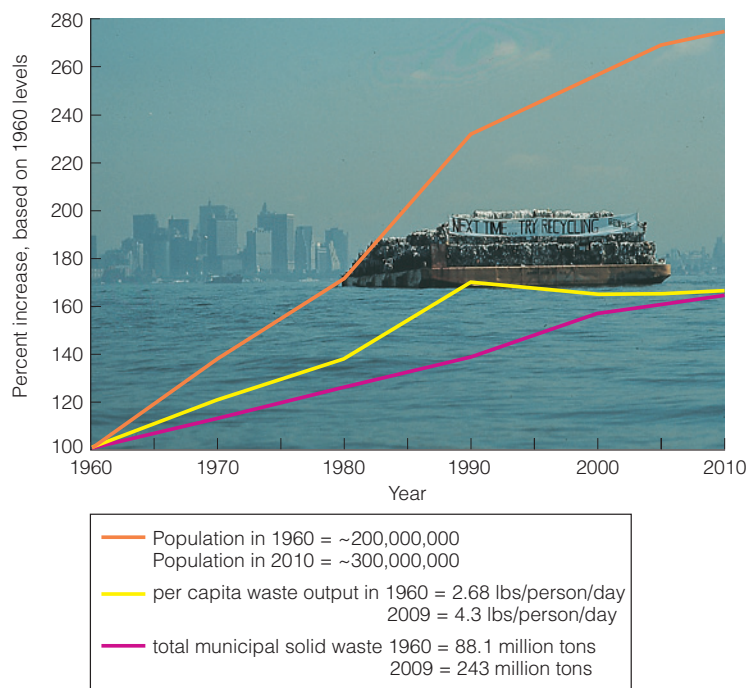


FIGURE 1-10 Trends in U.S. total solid waste production, output per person, and population. The background photo shows Greenpeace protesters on a New York garbage barge. (Sources: The chart is based on data from the U.S. Environmental Protection Agency and the U.S. Bureau of the Census.)

make the increasing amount of things we buy, consumption has tended to increase per capita resource use and pollution. **FIGURE 1-10** illustrates that solid-waste output has grown dramatically in the United States in the last few decades.

However, personal consumption in wealthy nations could be reduced easily with no reduction in quality of life. For example, many new sustainable or “green” technologies are being developed that can greatly reduce individual impact. More efficient technologies, such as fuel-efficient cars, use fewer resources and produce less pollution when an individual uses them. Alternative technologies can eliminate many impacts altogether. For example, replacing coal-burning machines with solar-powered machines conserves nonrenewable fossil fuels and eliminates many air pollutants that burning coal releases. Other current trends include encouraging pharmaceutical plants to recycle solvents instead of incinerating them and fast food restaurants to use completely compostable dining ware made from potato starch and the increased use of home energy audits to reduce waste and energy consumption.

Exponential Growth of Environmental Impact

The exponential increases of population and traditional industrial technology (which correlate with increasing consumption) have caused an exponential increase in environmental impact. The increase in total solid waste shown in Figure 1-10 is typical of the pattern seen in many other kinds of pollution. A society that produces such waste is likely to be consuming many resources that ultimately generate the waste. For example, global consumption of fossil fuel has risen exponentially because of the growing world population and the spread of technologies that use fossil fuels (increasing per capita use of fuels). As consumptive technology and population grow, more materials and energy move through society. This accelerates the depletion of environmental resources. In addition, the materials and energy that move through society must have somewhere to go when society is finished with them. Solid waste, air and water pollution, and other outputs ultimately end up in the environment.

In summary, there are two basic kinds of environmental impacts: depletion and pollution. Both have increased because growing consumption of resources increases pollution as throughput is accelerated. The main causes of increased throughput have been the growth of (1) population and (2) consumption.

1.3 A Brief History of Environmental Impact

Considering that our human species (*Homo sapiens*) has inhabited Earth for 100,000 or more years, the current massive global environmental impact of people is a very recent development. Indeed, our relationship with the environment has changed dramatically as we and our technology have evolved.

Conceptually, we can distinguish five basic developmental stages in the relationship between people and their environment (**FIGURE 1-11**). The economic activity people engage in using the technologies available to them at the time largely determines these stages. In turn, this activity affects how people have an impact on the environment. At any one time on Earth, different human populations may

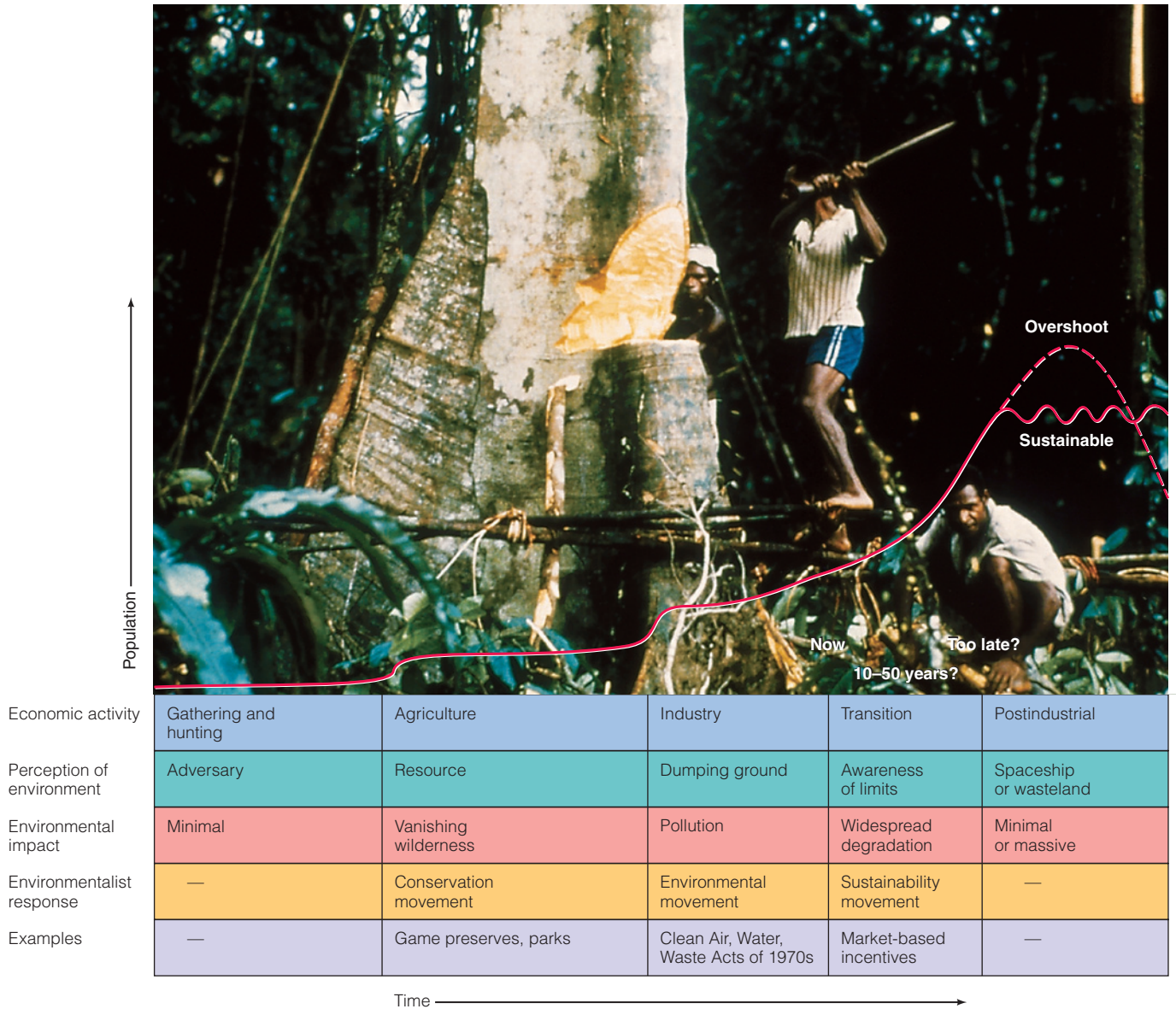


FIGURE 1-11 Population and personal consumption have increased the human impact on the environment in an exponential fashion. Environmentalists have responded with the conservation movement, the environmental movement, and the sustainability movement. Many people believe that we are in a transition stage and that people have no more than 50 years to prevent “overshoot” and attain sustainability. (Photo) UN Photo Library.

be in different stages simultaneously, yet the general global trend has been to progress through these stages.

1. *Gathering and hunting.* Early humans were largely at the mercy of their environment, so they might have viewed it in adversarial terms. Weather, predators, food shortages, and disease were constant threats. However, during this stage, humans also had a familiarity with the environment that in general has been lost.

2. *Agriculture and conservationism.* The shift from hunting and gathering to cultivating food is one of the most profound milestones in human evolution. It allowed a great increase in population size and permitted people to settle in large towns and cities; however, agriculture also had a major impact on the environment. People

began to view land as a resource to be exploited as needed. As land was cleared and cultivated, the wilderness vanished.

3. *Industry and environmentalism.* As nations industrialize, population grows faster, and the environment is increasingly perceived as both a source of raw materials and a place to dispose of the concentrated waste by-products of industry. The result is a rapid increase in air and water pollution, as well as problems with solid and hazardous waste disposal. Toward the end of this stage, pollution becomes so widespread that antipollution social movements emerge. In the United States, these social movements began in the early 1960s and peaked in the 1970s. When people talk about classic “environmentalism,” this antipollution movement may be what they mean.
4. *Transition and sustainability.* Today we live in a time of rapid change and technological advancement. The decisions we as a global community make over the next few decades almost certainly will determine the long-term fate of the environment for many future generations. For this reason, we can refer to the current stage of many developed countries as a “transition” stage. Although some forms of pollution have been reduced, many other environmental problems have increased. For example, in the United States, species of wildlife are imperiled as habitat is destroyed unnecessarily. Recently released reports indicate that the catastrophic events surrounding the April 2010 Deepwater Horizon rig explosion and oil well blowout in the Gulf of Mexico that killed 11 people were preventable and caused primarily by lack of communication, poor management, and profit-driven greed. Such reports underscore the urgency for sustainable industry practices grounded in policies, decisions, and practices that hold stewardship for the environment in higher regard. The actions we undertake in the first part of the 21st century will affect subsequent generations’ sustainability in ways seen at no other time

in history. Among other challenges we face are groundwater contamination, including endocrine-altering by-products from pharmaceutical waste that interrupt normal adolescent development and the presence of many thousands of hazardous and radioactive waste sites that likely will not be cleaned up for centuries. Despite efforts in recycling and precycling (the reduction of packaging material by manufacturers), the amount of solid waste produced per person remains high. Globally, the Environmental Protection Agency has cited global warming, ozone depletion, and increasing species extinction as the greatest environmental threats to future generations. As developing nations grow, it is important for them to look beyond the often-inadequate example of developed nations’ use of the environment. Current models for sustainable development include technological advances that are sustainable by design. Both the rapidly increasing populations in developing countries and the increasing demands for goods and services by the populations of developed countries cause these problems. No single group or nation carries all of the blame. In their book *New World, New Mind* (1989), Robert Ornstein and Paul Ehrlich argue that people generally had a short-term, “putting out fires” approach to problems; another term might be a “band-aid” approach. Only recently, with the sustainability movement, has there been widespread interest in addressing the systematic causes that underlie these problems. **Sustainability** means meeting the needs of today without reducing the quality of life for future generations. This includes not reducing the quality of the future environment. Sustainability can be achieved in many ways, such as through the use of sustainable (“green”) technologies that use renewable resources (for instance, solar power) and recycling or upcycling (converting waste materials or useless products into usable materials or better products) of

material components. These technologies allow a **sustainable economy** that produces wealth and provides jobs for many human generations without degrading the environment. An example of the practical application of sustainable design is looking at materials as natural components of an ecosystem. Nature recycles and does not waste. Waste in nature ends up as the basic components of food, achieved by natural decomposition of biological by-products. Industry that commits to material reuse, renewable energy use, water stewardship, and social responsibility can qualify for the “Cradle to Cradle” recognition, which means that the manufacturer commits to safe materials that can be reused or composted and accepts the responsibility of business-as-stewards in the use of environmental materials. Not only does this model make sense for future generations, but it also is profitable for business owners.

5. *Postindustrial stage—sustainability or overshoot?* The next (future) stage of society has been called the “postindustrial” stage. Just what form postindustrial society will take is open to speculation and debate, but two possible alternatives have been proposed. One is a sustainable future, where the human population stabilizes and technology becomes less environmentally harmful. The second alternative is overshoot, where population climbs so high and technology is so harmful that the environment is degraded to the point that relatively few people can be supported, at least with a decent standard of living. Which alternative comes into being could depend on the collective actions of humanity during this first half of the 21st century.

1.4 The Environment as a Commons

In 1968, the biologist Garrett Hardin wrote the famous essay “The Tragedy of the Commons.” He argued that property that many people hold in common will be destroyed or at least overused until it deteriorates. He gave the

example of a pasture where each herdsman in the village can keep his cattle. The herdsman who overgrazes the most will also benefit the most. Each cow that a herdsman adds will benefit the owner, but the community as a whole will bear the cost of overgrazing. Because the benefit of adding another cow goes to the individual and the cost of overgrazing goes to the community, the “rational” choice of each individual is to add cows. Thus, the commons rewards behaviors that lead to deterioration, such as overgrazing, and punishes individuals who show restraint. Those who add fewer cows will simply obtain fewer benefits while the commons itself deteriorates because of the individuals who continue to add cows. This problem with common property was known long before Hardin’s eloquent essay. For instance, the ancient Greek philosopher Aristotle noted, “What is common to the greatest number has the least care bestowed upon it.”

Hardin’s pasture exemplifies the problems that arise when any part of our natural environment is treated as common property. However, privatization can lead to private exploitation of resources as well, and the key is well-managed property, whether private or public. Public space is important but must be taken care of. Unless there is some kind of regulation, overexploitation will likely occur via both input and output impacts.

1. Commonly held resources, such as the pasture, will become depleted through excessive consumption.
2. Commonly held environmental sinks will be overwhelmed by pollution.

Many local, regional, and global environmental problems illustrate this view of the commons as a source or a sink:

Problem	
Atmosphere as global common sink	Global warming, ozone loss
Atmosphere as regional common sink	Acid rain
Atmosphere as local common sink	Urban smog
Ocean as global common sink	Ocean pollution
Ocean as global common resource	Many fish species overfished
Rain forest as common resources	Global warming promoted by deforestation, biodiversity reduced by deforestation

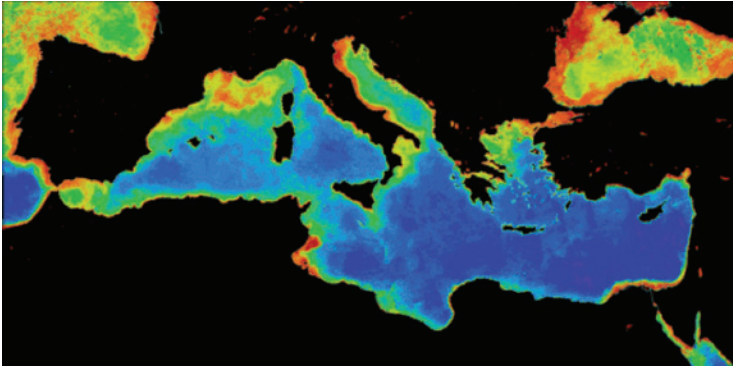


FIGURE 1-12 A computer-enhanced image of pollution in the Mediterranean Sea. Red, yellow, and orange areas are concentrations of plankton growth promoted by discharge of raw sewage. (Blue indicates clear water.) Many coastal cities lack sewage treatment. Courtesy of Gene Carl Feldman/NASA Goddard Space Flight Center.

Many nations share some of these commons. The international nature of many environmental problems adds greatly to the complexity of solving them because international agreements are required. Consider the Mediterranean Sea. A confined shallow ocean basin surrounded by many nations, this sea is one of the most over fished and polluted large bodies of water on Earth (**FIGURE 1-12**).

1.5 Saving the Commons

If we are to save the environmental commons, the throughput of matter and energy through all societies must be reduced. This will slow both depletion and pollution. Increasing population (P) and consumption (C) have driven increased impact (I), so their growth must be reduced.

We are in the transition stage (as previously discussed). Environmental problems have become so widespread that they demand large-scale regional and global solutions involving many aspects of society. Furthermore, countries such as China and India are in the process of rapid industrialization that consumes a tremendous amount of Earth's resources. It is important that these economies learn to work in a sustainable manner instead of using their resources in a wasteful and inefficient manner, as do the United States and other countries. Likewise, the United States must improve. Beginning in the early 1980s, a sustainability movement

emerged to try to deal with these problems. Unlike the conservation and antipollution movements of the past, which emphasized specific problems rather than a global approach, the sustainability movement seeks long-term coexistence with the environment. As mentioned, sustainability means meeting the needs of today without reducing the quality of life for future generations.

The sustainability movement uses three approaches not attempted by previous environmental movements. First, it focuses explicitly on trying to reduce society's use of all resources; therefore, emphasis is on input reduction, as opposed to end-of-pipe solutions. *Waste is viewed as a symptom, not a cause, of the environmental crisis.*

Second, the sustainability movement is more holistic. It realizes the necessity of addressing the social, and especially economic, causes of environmental degradation. This has led to an increasing appreciation of the role of poverty and other economic factors that encourage people to deplete resources and pollute. Market-based solutions are becoming more popular, and less emphasis is placed on the legal solutions used in the past. For example, many experts now agree that it is often more effective and cheaper for society to tax coal, gasoline, and other polluting substances than to pass laws specifying how much pollution may be emitted. For instance, higher gasoline prices encourage people to drive less or buy fuel-efficient cars.

Third, the sustainability movement has encouraged the growth of thousands of local community action groups, as opposed to the national groups that dominated the conservationism and environmentalism periods. Many of the national and international environmental organizations arose well before 1980. For instance, the Sierra Club was founded in 1892, the National Audubon Society in 1905, the National Wildlife Federation in 1936, and the World Wildlife Fund in 1961. Since the exposure of the toxic dump at Love Canal, New York (1978), and the Three Mile Island nuclear accident in Pennsylvania (1979), residents of communities have become increasingly active in addressing local environmental problems. Vocal debates over incinerators, landfills, land

development, mountain top removal, water contamination, and many other environmental issues now often dominate the local news (FIGURE 1-13). Such local participation is often called **grassroots activism**. Recently, grassroots groups with common interests have begun to network by establishing regional and national newsletters and computer nets. By the mid-1990s, many of the national organizations had begun to experience a decline in membership. Although some people suggest that this decline means environmental interest is waning in the United States, others argue that it simply reflects the transfer of environmental allegiance from national to grassroots organizations.

All three characteristics of the sustainability movement historically arose from the desire to find better ways to solve widespread environmental problems. Grassroots activism is often the best way to deal with local issues. The rise of input reduction and economic approaches reflects the need to reduce social costs. Although litigation and lobbying are still used, the sustainability movement also uses direct action and lifestyle changes. In keeping with its more holistic approach, many members of the sustainability movement are also **ecocentric** (“environment centered”) instead of **anthropocentric** (“human centered”). In other words, they seek to preserve nature for reasons beyond simply improving the quality of human life. Nature is viewed as having a high “intrinsic” value that is not related to human needs. Nature is worth protecting for its own sake. As the sustainability movement spreads, addressing the needs of the 21st century, it will continue to develop many new strategies and approaches to further the goal of sustaining the environment for the generations that follow.

Reducing Consumption: Defusing the Bomb of the North

Rapid population growth is often described as a “time bomb” that will greatly degrade the environment in coming years. Although population growth is especially rapid in the Southern Hemisphere, the industrialized nations of the Northern Hemisphere are also contributing to environmental degradation through their habit of excessive and wasteful



FIGURE 1-13 Citizen protest is an effective and growing way to promote local environmental sustainability. © UPI Photo/Roger L. Wollenberg/Landov.

resource consumption developed during a time of abundant resources. Consumption may be viewed as the environmental “time bomb” of the North. The solution is to reduce consumption or C in the impact equation $I = P \times C$.

There are three basic ways to reduce consumption. None of these ways needs to involve painful self-sacrifice or a lowered quality of life. In contrast, reducing consumption can improve the quality of life in many ways by improving human health and the environment.

- *Reduce material needs.* Psychological studies have statistically documented what many religions have long taught: increasing a person’s material wealth will rarely produce an increase in happiness or contentment. The “treadmill of wealth” says that the more we accumulate, the more we want. When Americans are surveyed, most respond that they have far too much “stuff.”
- *Use less technology to meet our needs.* Long before Thoreau, many people observed that some machines might have detrimental effects on people. Riding bicycles to work (instead of driving cars), buying products with fewer artificial chemicals and less superfluous packaging, and using fewer unnecessary convenience appliances are but a few ways that people have reduced their reliance on technology.

- *Use sustainable technology to meet our needs.* Another way to reduce technology's impact is to use technologies that are much more "environmentally friendly" than the fossil fuel-based, industrial technologies of the past. **Sustainable technology** permits people to meet their needs with minimum impact on the environment. It produces a sustainable economy that provides jobs for many generations without degrading the environment.

There are many kinds of sustainable technologies, ranging from direct solar and wind power to recycling. Although advances in pollution cleanup technologies are often heralded, true sustainability results from input reduction: slowing resource depletion also slows pollution. The three basic ways that sustainable technologies achieve input reduction, or conservation, are (1) efficiency improvements, (2) reuse and recycle, and (3) substitution.

Efficiency improvements reduce the flow of throughput by decreasing the per capita resource use. The United States, more than almost any other country, uses technologies developed during times of abundant resources. As a result, it generates much waste, providing enormous opportunities to save many resources by relatively simple changes in existing technologies. The amount of waste is so great that, in many cases, the large amount of resources saved will more than compensate for the cost of investment to make the change.

Let us use the example of energy, which drives all economies. It is estimated that changes in U.S. technology, ranging from high-mileage cars to superefficient heating and cooling systems to new lighting technologies, could reduce overall energy consumption by as much as 80%. For example, the incandescent light bulb converts 95% of the electricity it uses to waste heat instead of light. Compact fluorescent bulbs (CFLs) generate 70% less heat and use between 50% and 80% less energy to produce light. According to the Environmental Protection Agency, if every household in the United States replaced incandescent lights with compact fluorescent lights, the society would benefit by a reduction of greenhouse gas equivalent to removing 800,000 cars from

the road. Recent discussion about the use of compact fluorescent bulbs often mentions that the bulbs contain mercury. Although it is true that the bulbs contain a small amount of mercury (5 grams; a little less than the weight of a modern quarter), The Union of Concerned Scientists points out that the bulbs can be recycled and that the energy savings must take into account that "the average coal-fired power plant emits only 3.2 milligrams of mercury for each CFL running six hours per day for five years, but emits nearly 15 milligrams of mercury for an incandescent bulb running the same amount of time" (www.ucsusa.org/publications/greentips/let-there-be-fluorescent.html December 13, 2011). Even more efficient are light-emitting diode (LED) lights that are becoming more readily available as costs decrease, making them more attractive to consumers. LEDs can last as long as 50,000 hours, more than eight times as long as CFLs, and also contain no mercury, making this evolution of technology a promising answer to home energy efficiency challenges.

In addition to reducing environmental damage, efficiency improvements have two immediate economic advantages. First, as noted, the improvement usually pays for itself. The cost of a technological change that increases efficiency is usually recovered within a few years and sometimes almost immediately. For instance, a study by a major beverage company found that each reduction of one thousandth of an inch (0.001) reduces aluminum costs by \$1 million. (Of course, there is a limit to how thin aluminum cans can be and remain structurally sound.) In addition, increased efficiency tends to produce many more jobs than do wasteful technologies. The traditional energy industries, such as oil, coal, and nuclear power, are much less labor intensive than the energy-conservation industry that designs and maintains many kinds of energy-conservation equipment.

Many other resources in the United States could be used much more efficiently. Here are just a couple of examples:

1. *Wood.* The United States converts only about 50% of raw timber (compared with 70% in Japan) directly into furniture and other refined timber products.

2. *Water.* The United States uses more than twice as much water per person as most other nations on Earth. The average U.S. farmer typically could cut water use by more than half by adopting water-conservation measures, such as micro-irrigation that pipes water directly to crops instead of using evaporation-prone irrigation ditches. In the home, installing a low-flow toilet can save a family of four more than 1,350 gallons of water per month.

Reuse and recycling are the second best ways to accomplish input reduction. **Reuse** refers to using the same resource over and over in the same form. An example would be soda bottles that are returned, sanitized, and refilled. **Recycling** refers to using the same resource over and over but in modified form. For instance, the soda bottles could be melted to produce new soda bottles. Wastewater, paper, plastics, and many other resources can be recycled. In general, reuse is less costly than recycling because the resource is not modified. Both measures are often less costly than extracting “virgin” resources, such as aluminum ore or cutting trees for paper, because they usually consume less energy and fewer natural resources than does making products from virgin materials. For example, recycling aluminum cans saves as much as 95% of the energy cost of cans made from newly mined aluminum. Recycling and reuse are less costly in both economic and environmental terms than is using natural raw materials.

Substitution of one resource for another can benefit the environment in a number of ways. A renewable resource can be substituted for a nonrenewable one, or a less-polluting resource can substitute for a highly polluting resource. Often the newly substituted resource provides both benefits. Substituting renewable, cleaner alternative fuels, such as solar and wind energy, for fossil fuels is an example. Another example is making products from paper instead of plastics, which are generally made from fossil fuels and last longer in the environment (although there are now biodegradable plastics, and plastics produced from plants have been developed recently). Like conservation, reuse, and recycling,

substitution often yields economic benefits. Studies routinely show that substitution of solar and wind power technologies for the fossil fuel energy now consumed in the United States would produce three to five times as many jobs as now exist in fossil fuel industries.

Some people are surprised to learn that many sustainable technologies were invented centuries ago. Wind power and water power are examples. The solar cell was invented in the 1950s. These technologies have failed to become widespread largely for social and economic reasons, not technical ones. When nonrenewable resources are cheap, they will be wasted because people have no incentive to increase efficiency, recycle/reuse, and substitute renewable resources. The current interest in solar energy has reached record highs, with industry journals indicating a 26% increase in jobs in the solar industry throughout 2011. This is particularly impressive when considering the current average unemployment rate (2011) is as great as 10% in some states. Combining other renewable energy industry data results in trends predicting approximately 2.5 million people by 2025 will have jobs related to renewable energy. Cost of installation is becoming more attractive to consumers, as are incentive plans and infrastructure improvements. For instance, more than 42 states and the District of Columbia now have net metering rules that allow an individual owner of a solar energy system to sell excess electricity back to the grid. In other nations such as Germany and Japan where governmental and private incentive plans are in place, growth in renewable energy soared in recent years.

1.6 Promoting Sustainability by Paying the True Costs of Nature’s Benefits

The economic forces that promote population growth and overconsumption have arisen because the goods and services that the environment provides, such as water purification, erosion control, and carbon sequestration, have been undervalued in the past. These and other benefits collectively

are known as **ecosystem services**. Essentially, the true costs of using the environment as both a source and a sink have not been incorporated into global economic activity. This trend, according to the Millennium Ecosystem Assessment (a 2005 United Nations-sponsored report designed to assess the state of the world's ecosystems), has led to a degradation of more than 60% of the ecosystem services that were evaluated degraded over the last 50 years. **FIGURE 1-14A** shows the situation when resources are cheap and sinks are free and treated as “commons.” There is much throughput, which leads to high rates of resource depletion and pollution. It also contributes greatly to the rapid population growth of developing nations. Poverty is strongly correlated with high population growth rates, and people in resource-rich tropical developing nations are often underpaid for their resources (as compared with prices in many developed nations).

Market prices that do not reflect all the true costs of a product or service are called

market failure (or “externality”) by economists. Most ecosystem services are either undervalued or considered free in our current economic system. Many environmental problems ultimately can be traced to market failures. A few examples are listed:

1. The cost of gasoline does not include the cost of smog and other urban air pollutants, contamination of groundwater by leaking underground oil tanks, oil spills, and many other well-known impacts of gasoline use.
2. Electricity from nuclear energy does not include the cost of disposing of nuclear waste; electricity produced by coal burning omits the cost of most air pollution.
3. Water used by many U.S. farmers does not reflect the fact that in many regions the groundwater is being depleted much faster than it is being replenished by rainfall.

Many economists suggest society can correct market failures by imposing **green fees** that adjust the costs of products and services to include environmental costs (**FIGURE 1-14B**). Fees that increase the price of a resource are particularly effective because they promote conservation of the resource and also reduce pollution by reducing throughput. For example, a “gas tax” or “carbon tax” covering all fossil fuels would encourage reduced and more efficient use of these fuels. Charging for garbage by the bag motivates people to reduce the waste they produce.

Another emerging solution to address market failures is known collectively as payments for ecosystem services (PES), which involve offering incentives to landowners in exchange for managing their land to provide an ecological service, such as carbon sequestration and storage, water quality, endangered species habitat, and wetlands. PES programs are contracts between the consumers of ecosystem services and the suppliers of these services. The beneficiaries of the ecosystem services are willing to pay a price that is lower than their welfare gain because of these services, whereas the providers of the service are willing to accept a payment that is greater than the cost of providing the

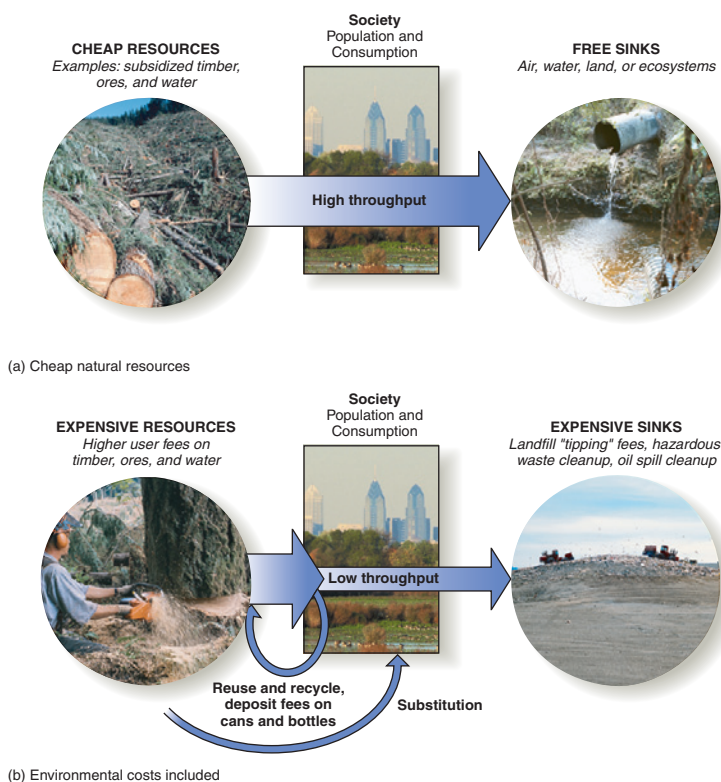


FIGURE 1-14 (a) Excluding environmental costs by allowing cheap resources and free sinks promotes high throughput (and thus much depletion and pollution). (b) Including environmental costs by imposing user fees and deposit fees promotes an increase in efficiency, recycling, and all other forms of input reduction. Inserts © Photodisc.

service. Some examples of these programs include:

- **The Conservation Reserve Program:** A U.S. federal government program in which landowners are paid to retire portions of land that are considered “environmentally sensitive.” Landowners agree to plant cover crops to help improve water quality, control soil erosion, and enhance habitat for wildlife.
- **Quito, Ecuador,** established a water fund in the early 2000s to restore upstream forests and better protect national parks to reduce sedimentation of the city’s water supply. The fund’s principal was raised by the city’s water utility (via a water user levy), a local brewer, a bottler, and a hydroelectric company. The principal was invested in stocks and other financial instruments and allowed to grow before interest earnings were used to finance forest restoration projects. An independent governing body selects the conservation projects. By late 2010, more than 2 million trees had been planted and more than 5,000 acres of land have been restored.

Although the United States is the world’s largest resource consumer and polluter (by most measures), it unfortunately lags far behind most of the industrialized world in the use of green fees and other economic incentives to conserve resources and reduce pollution. The general trend has been the continuation of cheap resources and free sinks. In fact, in many cases, the United States actively discourages conservation and encourages pollution by subsidies that reward harmful activities (as opposed to green taxes that discourage them).

FIGURE 1-15 shows an example of great importance, the historically relatively cheap cost of oil (affecting retail prices of gasoline at the pump) in the United States between the early 1980s and the beginning of the 21st century. The cheap costs led to a reversal of the previous trend toward more fuel-efficient cars. However, with the terrorist attacks of September 11, 2001, and the subsequent wars in Afghanistan and Iraq, along with natural disasters such as Hurricane Katrina, the 2010 BP oil spill in the Gulf of Mexico, and the unrest in Libya and the Middle East more generally, the price of oil surged. Many observers think that a “greener” economy is inevitable, not only because of the increasing cost of oil, but also because of consumer demand

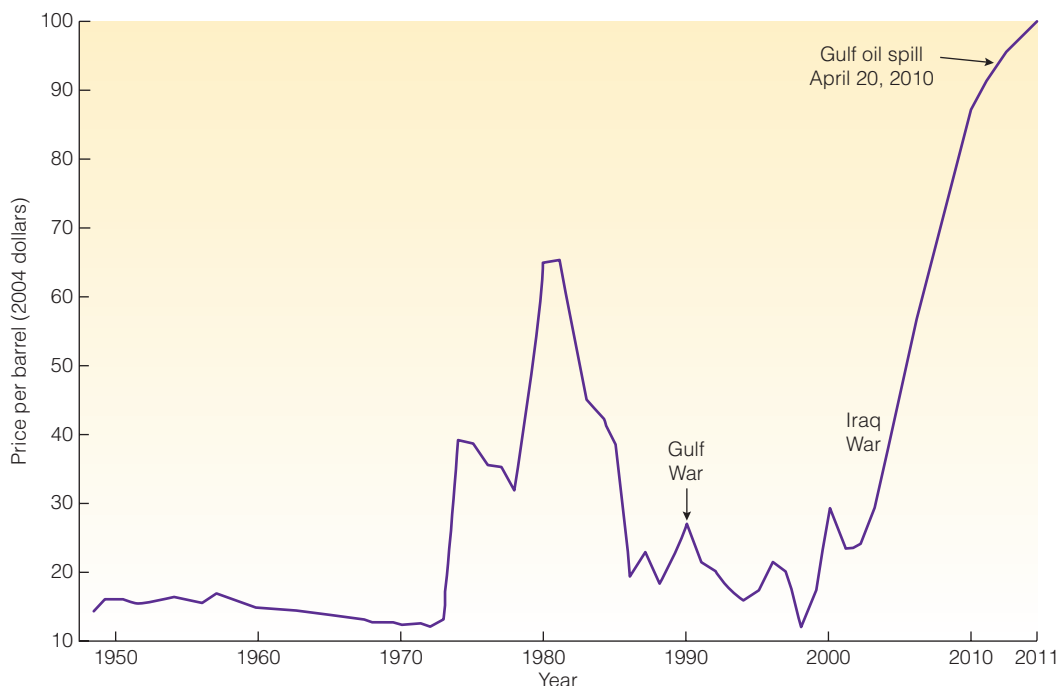


FIGURE 1-15 Price of oil per barrel. (Source: U.S. Department of Energy.)

for environmental quality and the economic benefits of sustainable technologies, such as increased efficiency, reduced resource imports, and more jobs. There are signs that U.S. business is responding to “green” pressures. More companies are advertising that their products are made from reused or recycled materials or are “environmentally friendly.” The rapid increase in gasoline costs in 2005 led to a dramatic decline in sales of large vehicles, such as sport utility vehicles (SUVs), so that automobile makers became much more interested in producing smaller and more fuel-efficient vehicles, such as those with hybrid engines. This trend has been accompanied by increased discussion of green fees and the removal of government subsidies on timber, grazing lands, ore deposits, and oil companies.

Reducing Population: Defusing the Bomb of the South

More than 90% of world population growth occurs in developing nations. Most developing nations are in the Southern Hemisphere; thus the cause of throughput is especially important there. To defuse this so-called **population bomb**, we must address its central causes, which often are economic. **FIGURE 1-16** illustrates how population growth is often driven by poverty. Poor people tend to have more offspring for a variety of reasons, including lack of education about and easy access to birth control, lack of economic opportunities for women, and the need for children to perform chores and care for the aged. The result is a

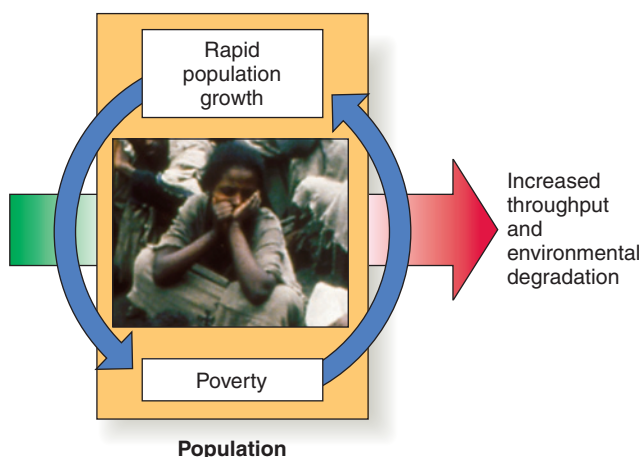


FIGURE 1-16 Poverty and population growth feed on each other, and both produce environmental degradation. Inserts © Photodisc.

“vicious circle” in which population growth leads to poverty because increasing numbers of people reduce the standard of living. Impoverished people tend not to focus on environmental concerns but must turn their attention to simply surviving from one day to the next.

Can this “poverty–population–environment cycle” of human misery and environmental destruction be broken? Many people still subscribe to the **fallacy of enlightenment**, or the idea that education will solve the problem. Education is very important, but often it is not enough; realistic solutions that remove the root causes of the problem must be found. Attempting to protect the environment by legal means, such as creating game reserves, is often not effective either because desperate people will break laws. Decades of experience show that the economic causes of this cycle must be addressed. Eliminating poverty will not only reduce many causes of population growth, but it also will reduce environmental degradation.

Reducing Population Growth by Paying True Costs

The gap in wealth between the developed and developing nations has widened at an increasing rate. Between 1961 and 1999, the gross economic product per capita increased \$15,000 for industrial countries. Africa’s gross economic product per capita increased by approximately \$600.

This gap continues to grow because developing countries now pay a huge amount of interest on money that was lent to them many years ago; they now owe more than \$2 trillion. As a result of interest on this debt, the net flow of money has been from South to North since 1982. Rich countries now receive more money from poor countries (variously estimated at more than \$50 billion per year) than they transfer to them. This is sometimes called the **debt bomb**.

Some economists argue that foreign aid to poor countries should not be viewed as charity. They note that these poor but resource-rich nations would not need charity if they were paid the true value for their resources. They maintain that if people in the developed Northern Hemisphere wish to save rain forests, they should pay for the environmental goods and

services the forests produce. Although it is often difficult to estimate the true environmental costs and values in most cases, nearly all estimates indicate that developing nations are greatly underpaid for their resources. As payments for ecosystem service markets develop (discussed in the section on promoting sustainability by paying the true costs of nature's benefits), the true costs of environmental goods and services will be better valued in the economic system. Programs such as the United Nations Collaborative Program on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD) are structured to help alleviate the debt bomb issue.

Appropriate payment for ecosystem services could help eliminate poverty, probably much more effectively than foreign aid donations. These payments would break the vicious poverty–population growth cycle and reduce population growth. A key necessity is that this increased wealth be used to buy sustainable technologies that focus on efficiency, recycling/reuse, and renewable resources.

1.7 The Role of the Individual

The environmentalist Wendell Berry said that the roots of all environmental problems ultimately lie in the values of the individuals who comprise society. As the writer Paul Hawken put it, “The environment is not being degraded by corporate presidents; it is being degraded by popular demand.” By this, he means that companies produce only things that people buy, and they cause depletion and pollution only as long as society permits such behavior to be profitable.

Values on the Here and Now: Why We Avoid True Costs

Why do individuals have values that lead to environmental degradation by “popular demand?” Many writers have argued that most large-scale problems arise because individuals are not good at dealing with problems beyond their own immediate situation. We tend to focus on the “here and now.”

Discounting the future results from focusing on the “now”: Environmental costs of our actions on future generations are not fully paid,

mostly because they are not fully valued in the current economic system. For instance, cheap gasoline and minerals lead to rapid depletion of these nonrenewable resources, making them unavailable to future generations. These resources are cheap because their current cost does not include the future effects of their use, such as global warming or other pollution hazards. **Discounting by distance** results from focusing on the “here”: environmental costs of our actions on people living in another area are not fully paid. For instance, cheap ivory, imported animals, and tropical timber lead to rapid depletion of those tropical resources, thereby degrading the environment for the people who live there. These resources are so cheap because their cost does not incorporate their full value to their local environment.

A Solution: Values Beyond the Self and Recognizing the True Value of Ecosystem Services

It can be argued that the single greatest obstacle to building a sustainable society is this tendency of the human mind to focus on the here and now. It limits our ability to make the systemic social changes needed to solve regional and global problems. This is why David Ehrenfeld, in *The Arrogance of Humanism* (1981), warns that history shows that people have never successfully managed anything for very long. How can we expect to solve global environmental problems with such limitations?

FIGURE 1-17 illustrates how people can extend their sphere of concern, beginning with close relatives and progressing through other social groupings to include all people. Ultimately, all living things can be included, as in the philosophy of “**deep ecology**.” If we are to place a higher value on the environment of the future and in other parts of the world, such extended spheres of concern are needed. If many people adopt this view, society will be more willing to pay green taxes, vote for politicians who favor sustainable lifestyles, and in general, promote solutions that require looking beyond the here and now.

Most sociologists believe that the trend has been in the opposite direction until now. The growth of modern civilization has promoted individualism that has progressively shrunk

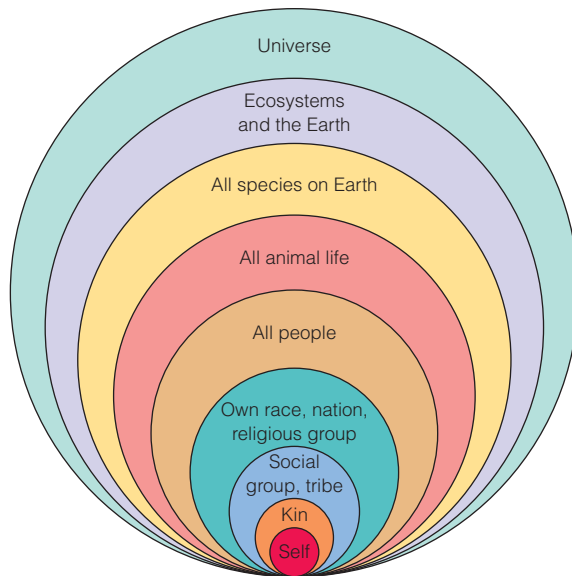


FIGURE 1-17 An ethical sequence in which the individual concerns extend outward beyond the self to progressively more inclusive levels. (Source: Adapted from R. Noss, 1992.)

the sphere of concern. Large cities have fostered a loss of community and the fragmentation of social groups, including even families. Can this trend be reversed? No one knows, but some encouraging signs have appeared. For example, the grassroots activism of the current sustainability movement is based on community concerns. There are also many examples of exceptional unselfishness in individuals.

Payments for ecosystem service markets, whereby the true cost of an environmental service or benefit is incorporated into the costs of decision-making, can help people realize more directly the value of environmental services. Other initiatives, such as fair trade labeling, organic food, and green products, are also making it easier for people to become more environmentally literate and make choices that result in less environmental harm.

1.8 Toward a Sustainable World

Although no one knows if sustainability will be attained, there is certainly no shortage of debate and speculation. Historically, two schools of thought have existed on the urgency of overpopulation and resource limitation, and they tend to be polarized. At one extreme are **cornucopians**, who argue that human ingenuity has always overcome environmental limitations. They suggest, for example, that inventions

such as genetic engineering could make agriculture more productive so that the planet will be able to support many more people at a high standard of living. At the other extreme are **cassandras** (also known as neomalthusians), who argue that people have always altered the environment and managed things poorly; they insist that exponential growth of populations and consumptive technology will finally degrade the environment so much that it will lead to overshoot (see Figure 1-11). Cornucopian and cassandran views have been common, in various forms, throughout history.

As is often the case, extreme views can be counterproductive. Too much optimism, such as a cornucopian view, can lull people into inactivity because they think that the future will take care of itself. Too much pessimism, such as a cassandran view, can cause despair, which leads to inaction because people think that the future is bleak no matter what they do. Thus, many writers suggest a more moderate view that acknowledges that urgent environmental problems exist. These problems need to be addressed within the next few years, or at least decades, or they may lead to large-scale environmental degradation and overshoot. This moderate view relies on the **precautionary principle**, which says that in the face of uncertainty the best course of action is to assume that a potential problem is real and should be addressed. In other words, we are “better safe than sorry.” The worst that can happen with this approach is that society will become more efficient, less wasteful, and less polluting, even if environmental problems prove to be not as bad as some people argue. On the other hand, the results can be disastrous if the precautionary principle is not used and problems are indeed as urgent as some people believe.

Assuming that a person wishes to rely on the precautionary principle, which specific environmental problems should be of most concern? A good starting place is the following priority list based on material published by the U.S. Environmental Protection Agency and other sources (**TABLE 1-1**):

Highest Priority: Species extinction, ecological disruption and habitat destruction, stratospheric ozone depletion, and global climate change.

What Are Your Values? Would You Decline \$600,000 to Save a Rain Forest?

CASE STUDY 1-2

Although many of us say that we are “pro environment,” we never really know how strong our values are until we are asked to make personal sacrifices for them. For example, in this chapter we have asserted that the environment of future generations is often discounted or devalued. Most of us would like to change that situation, but just how much are we willing to sacrifice?

Consider the case of Miguel Sanchez, a subsistence farmer in Costa Rica. He was offered \$600,000 for a piece of land that he and his family have tended for many years. This land consists of a spectacular old-growth rain forest and a beautiful black sand beach in an area where land is rapidly being developed. A hotel developer offered the money. Sanchez declined, knowing that this was more money than he, his children, and all of his grandchildren would ever accumulate. Sanchez explained his decision: “I have no desire to live anywhere else. Money can be evil. People will ask me for money.”

Miguel knows that cleared forest means less rain, less water in the rivers, less escape from the

blazing tropical sun; however, he is reluctant to talk about his decision. Hundreds of other farmers and fishermen in his area feel the same way and are fighting development. (*Source:* Adapted from A. Carothers, “Letters from Costa Rica,” *E Magazine*, September 1993.)

Questions

1. How does Miguel’s sacrifice compare with sacrifices that you have made to promote long-term environmental health? What would you do if you were in Miguel’s position?
2. Comment on this statement from writer Andre Carothers: America has “a skewed moral universe, where people regularly swoon over each other’s negligible acts of charity.” The writer’s point is that we make a big deal about recycling cans, buying organic foods, and giving tiny donations to environmental funds. Is this a fair criticism or unjustified cynicism?

Middle Priority: Problems associated with pesticides and herbicides, lake and river pollution, acid rain, and airborne toxics.

Lowest Priority: Oil spills, groundwater pollution and depletion, airborne radiation, waste dumping, thermal pollution to water bodies, and acid runoff.

The highest priority problems are global and are very long term in their scope. Lower priority problems tend to be geographically more localized and can (in theory) be solved within shorter time spans.

Visualizing a Sustainable World

Recall that sustainability means meeting the needs of today without degrading the environment for future generations. Table 1-1 summarizes many of the changes that are necessary to create a sustainable society. Most of

these changes are discussed later in the text, but for now, some major points can be noted. First, many aspects of our society are affected: scientific paradigms, role of the human, and values toward nature, land, and people. Second, many of our social institutions are affected: religion, education, political systems, and economic systems. Third, technology and agriculture are affected. Fourth, many of these changes ultimately are based on increasing the importance of our communities, from encouraging community values among individuals to creating decentralized, community-based economies and political systems.

The need for such pervasive changes is reflected in academic disciplines such as the social sciences and humanities, which traditionally have studied society as an entity distinct from the natural environment or at most only moderately influenced by the natural



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TABLE 1-1 Transition From the Industrial to the Ecological Age*		
	Industrial Age	Sustainability or Ecological Age
Scientific paradigms	Mechanistic Earth as inert matter Determinism Atomism	Organismic Gaia: Earth as a superorganism Indeterminacy, probability Holism/systems theory
Role of the human	Conquest of nature Individual versus world Resource management	Living as part of nature Extended sense of self Ecological stewardship
Values in relationship to nature	Nature as resource Exploit or conserve Anthropocentric/humanist Nature has instrumental value	Preserve biodiversity Protect ecosystem integrity Biocentric/ecocentric Nature has intrinsic value
Relation to land	Land use; farming, herding Competing for territory Owning "real estate"	Land ethic: think like mountain Dwelling in place Reinhabiting the bioregion
Human/social values	Sexism, patriarchy Racism, ethnocentrism Hierarchies of class and caste	Ecofeminism, partnership Respect and value differences Social ecology, egalitarianism
Theology and religion	Nature as background Nature as demonic/frightening Transcendent divinity Monotheism and atheism	Animism: everything lives Nature as sacred Immanent divinity Pantheism and panentheism
Education and research	Specialized disciplines	Multidisciplinary, integrative
Political systems	Nation-state sovereignty Centralized national authority Cultural homogeneity National security focus Militarism	Multinational federations Decentralized bioregions Pluralistic societies Humans and environment focus Commitment to nonviolence
Economic systems	Multinational corporations Competition Limitless progress "Economic development" No accounting of nature	Community-based economies Cooperation Limits to growth Steady state, sustainability Economics based on ecology
Technology	Addiction to fossil fuels Profit-driven technologies Waste overload Exploitation/consumerism	Reliance on renewables Appropriate technologies Recycling, reusing Protect and restore ecosystems
Agriculture	Monoculture farming Agribusiness, factory farms Chemical fertilizers and pesticides Vulnerable high-yield hybrids	Polyculture and permaculture Community and family farms Biological pest control Preservation of genetic diversity
<p>*Some of these may be considered speculative attempts to understand the personal and humanistic aspects of sustainable living. <i>Source:</i> Adapted from R. Metzner, "The Emerging Ecological World View," in M. Tucker and J. Grim, eds. <i>World Views and Ecology</i>. Cranbury, NJ: Associated University Presses, 1993, pp. 170–171. Reprinted with the permission from Associated University Presses.</p>		

world. For example, economics once (and still largely does) focused almost exclusively on the flow of goods through society, ignoring the costs of depletion and pollution that the flows impose on the environment. Similarly, other disciplines such as ecology studied the environment as a largely separate entity. The new field of environmental economics is a more holistic discipline that includes both society and the environment. It incorporates externalities into the overall profit or loss of the product. It studies not just the flow of goods within society but also the effects on the environment and makes

an effort to value the true costs of ecosystem services.

Other socially oriented disciplines are also rapidly developing an interest in studies that incorporate the environment. Findings from such fields are included throughout this text and are emphasized in the section on social solutions to environmental concerns).

Supporting Services

Supporting services are those that are necessary for the production of all other ecosystem services. They differ from provisioning, regulating,

and cultural services in that their impacts on people are often indirect or occur over a long time, whereas changes in the other categories have relatively direct and short-term impacts on people. (Some services, such as erosion regulation, can be categorized as both a supporting and a regulating service, depending on the time scale and immediacy of their impact on people).

- *Soil formation.* Because many provisioning services depend on soil fertility, the rate of soil formation influences human well-being in many ways.
- *Photosynthesis.* Photosynthesis produces oxygen necessary for most living organisms.

- *Primary production.* The assimilation or accumulation of energy and nutrients by organisms.
- *Nutrient cycling.* Approximately 20 nutrients essential for life, including nitrogen and phosphorus, cycle through ecosystems and are maintained at different concentrations in different parts of ecosystems.
- *Water cycling.* Water cycles through ecosystems and is essential for living organisms.

Source: <http://www.greenfacts.org/en/ecosystems/toolboxes/box2-1-services.htm>

■ study guide

SUMMARY

- Environmental science uses a holistic approach to realize the interconnected aspects of environmental problems and apply solutions.
- Human–environmental interactions evolve through five basic stages: gathering and hunting, agriculture and conservationism, industry and environmentalism, transition and sustainability, and the postindustrial stage.
- We are in the transition phase, which has produced the sustainability movement.
- The sustainability movement
 - focuses on reducing societal consumption of resources.
 - seeks to solve holistically the structural social causes of environmental problems such as poverty.
 - relies on grassroots activism.
- The postindustrial stage will likely witness either sustainability or catastrophic overshoot of human civilization.
- Environmental impact, the alteration of the natural environment by human activity, involves either resource depletion or pollution.
- Impact is promoted by population and consumption: $I = P \times C$.
- The world's population continues to increase by about 77 million people a year.
- Traditionally, resource-intensive industrial technology and consumption have increased exponentially.
- Impact is often measured as throughput—the movement of materials and energy through society.

KEY TERMS

anthropocentric
cassandras
closed system
complexity
consumption
cornucopians
debt bomb
deep ecology
discounting by distance
discounting the future
ecocentric

ecosystem services
efficiency improvements
environmental science
environmental wisdom
exponential growth
fallacy of enlightenment
first law of ecology
Gaia hypothesis
grassroots activism
green fees
holistic

input
input reduction
integration
market failure
open system
openness
output
overshoot
population bomb
positive feedback
precautionary principle

recycling
reuse
sinks
sources

substitution
sustainability
sustainable economy
sustainable technology

system
systems approach
throughput

STUDY QUESTIONS

1. What are the major goals of this text?
2. Define environmental science. What relevance does it have to people?
3. Name several costs of a lack of environmental wisdom.
4. What is often the most expensive way to solve environmental problems?
5. What is the throughput model and the systems approach as applied to environmental science?
6. Why is input reduction a good solution to many environmental problems?
7. Name the two basic causes of environmental problems.
8. What are the key traits of the environmental system?
9. State and explain the “first law of ecology.”
10. What is environmental impact? Identify two basic types of environmental impact and explain their causes.
11. Why was the cultivation of food such an important development in human technological evolution?
12. What are the five basic developmental stages in the relationship between people and the environment? Briefly describe each.
13. Define sustainable technology and a sustainable economy. Define “ecosystem services” and name a few examples and which category they fall under according to the Millennium Ecosystem Assessment. Read over Case Study 1-2 and think about the ecosystem services that landowners provide to you and your family.
14. Explain the concept of “The Tragedy of the Commons” and how it applies to environmental issues.
15. What are some basic ways that have been suggested to reduce consumption? Does a reduction in consumption need to entail a decreased quality of life?
16. What is a green fee? What does “market failure” refer to?
17. What is “discounting the future?”
18. What is the “precautionary principle,” and how can it be applied to environmental issues?

WHAT'S THE EVIDENCE?

1. The authors contend that many people suffer from information overload and thus “tune out.” Do you really believe that this is true? Isn't it better to have more information rather than less? Cite examples that either support or contradict the authors' assertion relative to information overload and a lack of environmental wisdom on the part of some people.
2. The authors suggest in the context of the history of environmental impact that the United States and other developed nations are in a transition stage and that the decisions we make during the next few decades (in your lifetime) will determine the long-term fate of the environment. Do you believe this assertion? Is it simply alarmist rhetoric on the part of the authors? Cite specific and general examples to support your position.

ILLUSTRATION AND TABLE REVIEW

1. Study Figure 1-10. Which of the three statistics shown (total solid waste, per capita solid waste output, population) has increased most quickly during the last few decades? Why? How are these factors related to one another?
2. Using Figure 1-15, determine the approximate price per barrel of oil in 1980.
3. Using Figure 1-15, determine the approximate price per barrel of oil in 2000. How does this compare with the price 20 years earlier?

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