CHAPTER 1

Environmental Science, Sustainability, and Critical Thinking

CHAPTER OUTLINE

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Spotlight on Sustainable Development 1-2: The Philadelphia Eagles Go Green!

A problem well stated is a problem half solved.

—Charles Kettering

If you are like most people, you've probably heard a lot of conflicting information about the environment and environmental issues. Teachers, friends, news reporters, writers, and scientists may have warned you of serious problems. Others have offered an opposite view, saying things are not nearly as bad as some people would have you believe or that some of the problems don't exist. What is the truth?

In this book, you will find ample scientific evidence to suggest that the problems are real. In fact, a survey of U.S. environmental trends that I conducted covering 30 years showed that the vast majority (nearly 70%) of environmental indicators are pointing in the wrong direction. They indicate movement away from a healthy environment. Although there are some very encouraging signs of improvement—about 20% of the

CRITICAL THINKING

Exercise

The term *critical thinking* has become the latest buzzword in colleges and universities. This term means different things to different people. Some college textbooks, for example, contain critical thinking questions designed to encourage students to think a little deeper—that is, to assimilate facts and concepts. Other books ask critical thinking questions that call on students to use their ability to reason. This calls on students to weigh evidence.

What do you think the term *critical thinking* might mean? Hint: You might begin by looking up the word *critical* in the dictionary. Ask friends and teachers. After you have completed your inquiry, write a definition, and then check the definition given in this chapter. What rule of critical thinking would you propose based on this exercise?

The author's analysis of this exercise is located at the end of the chapter.

trends showed improving conditions—there is still cause for serious concern and action.

As you read this book, I invite you to explore the issues with an open mind, looking carefully at all aspects of each one. We'll examine the scientific evidence behind the issues and hear what the experts from all sides of the issues have to say. We'll explore traditional solutions and a new brand of responses that could help us find lasting solutions to pressing problems—solutions that are good for people, the environment, *and* the economy. These are part of a new strategy known as *sustainability*. Let's begin with some of the encouraging trends.

KEY CONCEPTS

Although there are some signs of improvement, the vast majority of the environmental trends show signs of movement away from sustainability.

1.1 Encouraging Signs/ Continuing Challenges

All across the world, change is underway. It's not ordinary change, either. It is profound change in the ways societies conduct their everyday affairs—ways that are leading to a new wave of environmental protection with lasting impacts. In Holland, for example, industries have banded together to produce a nationwide Green Plan. Drafted in conjunction with several key government agencies, the Green Plan calls on industries to reduce toxic emissions drastically and pollutants voluntarily (see **Spotlight on Sustainable Development 1-1**). This bold new plan will, if its goals are reached, practically eliminate hazardous wastes and a host of additional pollutants. What is encouraging to many is that the plan does not require regulations and fines, which governments typically use to get companies to improve their environmental performance. Rather, companies are left largely to their own devices to find economical ways to meet national goals. The government is there to lend a hand, providing financial resources and technical assistance if needed. If companies do not meet goals, fines may be imposed. Because of Holland's success, many other nations, including Bhutan, New Zealand, Nepal, Mexico, and Singapore, have launched similar programs.

In the United States, impressive change is also in the works. For example, a number of programs have been established by the **U.S. Environmental Protection Agency (EPA)**, a federal agency charged with writing many environmental regulations and enforcing environmental laws passed by the Congress. One program, EPA's Green Lights program, was designed to reduce electrical consumption by businesses and government agencies. So far, thousands of the nation's largest corporations, including Boeing, and many governmental agencies have signed up to participate in this program (**FIGURE 1-1**).

FIGURE 1-1 EPA Green Lights program. Boeing Corporation, based in Seattle, Washington, joined the EPA Green Lights program (now part of the EPA's Energy Star Program) and saves over $12 million per year by reducing electrical energy consumption. Every eight years, this would buy one Boeing 757 jet.

1-1 The Netherlands' Green Plan Revolutionizes the Way Industries Function

The Netherlands is a tiny country, about one-fourth the size of the state of Illinois (**FIGURE 1**). It is, however, a giant among nations. Why this glowing praise for such a small country?

In 1989, the country adopted a National Environmental Policy Plan (NEPP) commonly called its Green Plan, after widespread public alarm over many environmental trends. An even tougher plan came into existence several years later. Known as the NEPP 2, it gave the Dutch government more power to write and enforce environmental laws and to earmark substantial sums of money to research and redesign industrial processes. Since then, it has been twice upgraded.

The most exciting aspect of the Green Plan is that it allows for a new approach—a set of voluntary agreements with industry and other sectors of society responsible for producing the bulk of the nation's pollution. Why was all of this necessary?

Although the Netherlands has some of the most stringent environmental laws in the world, they weren't working well. Because of this, the government took a bold step: It admitted that there are limitations to regulating complex and interdependent environmental problems on an issue-by-issue basis. In place of this unworkable system of rules and regulations, the government decided to meet with the key players (industries and citizen groups, for example) to reach agreement on establishing bold new targets and timetables for drastically reducing pollution. The government let the companies select ways to reduce pollution; all that it asked of industry was a commitment to meet ambitious government targets and timetables. Industry groups happily signed the agreements, recognizing that the responsibility of meeting the targets was theirs and that failure to meet the goals would result in stiff penalties. The Dutch, therefore, combined the carrot (incentive) and stick (penalty) approaches in hopes of restructuring industry for sustainability.

FIGURE 1 The Netherlands is leading the world in sustainable development.

This approach was widely hailed by many major Dutch industrialists. They liked the agreement because it gave them free rein to find solutions that made the most sense to their businesses. The net effect is a kind of customized implementation that avoids the one-size-fits-all solutions typically employed in industrial nations' environmental control policies. Such approaches have met with considerable resistance in the United States because they often imposed prohibitive and sometimes unnecessary costs on businesses.

The voluntary approach was also popular because it helped companies become more efficient and more profitable. In addition, the Netherlands has become an exporter of technologies created by the country's industries to meet the goals of the nation's ambitious Green Plan. As other nations see the need for this shift, the Dutch pollution prevention and sustainable technology industry could profit enormously.

The Netherlands' Green Plan relies on four basic principles. First is life cycle management, which makes companies responsible for products throughout their life cycle—from production to consumption to disposal. Under this principle, producers are responsible for disposing of products after their useful life span has expired. This has spawned interest in manufacturing products that are easily recycled.

Another essential component of the strategy is energy efficiency. By using energy more efficiently, companies can save huge sums of money—and gain a competitive edge in the market by producing goods and services more cheaply than international competitors.

Sustainable technologies are also an important component of this plan. The government has launched a major program to develop sustainable technologies and make existing technologies more readily available to people and industries.

Finally, success also hinges on improving public awareness. The government launched a media blitz that echoes the important theme: "A better environment begins with you."

Today, over 250,000 Dutch businesses participate in the Green Plan, focusing on ways to conserve energy, produce more environmentally friendly products, and reduce pollution emissions. Seventy percent of the original goals have already been achieved according to the Resource Renewal Institute, which tracks green plans.

The successes of this ambitious program have been impressive: ozone-depleting substances have been phased out. Industry has reduced its waste disposal by 60%. Recycling has increased to 80%, and sulfur dioxide emissions have been reduced by 70%. In the 1980s, the Rhine river was so polluted the few remaining fish were too toxic to eat. Today, children fish and swim in the river thanks to the Netherlands Green Plan and international agreements that reduce pollutants released into the river. The country has been able to achieve economic growth while reducing its impact on the environment (except for CO_2 emissions).

Not all environmental problems facing this small country were the result of industry. Realizing this, the Dutch government has revised its plan to address the citizens and enlist their aid in reducing consumption. They're even working on land use and transportation issues with a greater emphasis on consumer responsibility. In addition, after 2010 sustainability will become a major criterion for all government purchases, which will stimulate businesses to produce even more green products. All in all, this tiny, progressive country stands as a model for the rest of the world, proving that economic prosperity and environment do not have to be at odds.

Go to http://environment.jbpub.com/9e/ to learn more.

Participating companies are working with the EPA to cut electrical demand through efficiency measures. All efforts are voluntary. The EPA provides technical assistance.

Many businesses have also voluntarily taken on energy efficiency and renewable energy projects to lower their carbon footprint, that is, to reduce the amount of greenhouse gas (carbon dioxide) they emit. Johnson and Johnson, for example, has invested $100 million in energy efficiency and renewable energy projects at their many facilities—and are realizing a substantial return on their investment of around 15%. Wal-Mart has pledged to makes its new stores even more energy efficient than their already energy-efficient stores. They've pledged to cut waste and make their transportation fleet substantially more efficient within 10 years, saving millions of dollars each year while helping reduce greenhouse gas emissions. Google and Microsoft have both recently installed huge solar electric arrays at their facilities on the West Coast. Even the buildings that replace the Twin Towers of the World Trade Center in Manhattan are being built green—using environmentally friendly materials. These energy-efficient buildings and others around them will be powered entirely by renewable energy.

What motivates companies to use energy more efficiently? Many adopted these programs to become better environmental neighbors, but they also did it to save money, sometimes millions of dollars a year in energy bills.

What has brought about all of the changes discussed previously? Quite simply, these and a great many other changes underway have been brought about by a growing recognition that the current paths many nations are following are not sustainable. That is to say, many individuals have realized we can't go on as we have been without serious social, economic, and environmental repercussions. In my analysis of environmental trends spanning a period of 30 years, mentioned earlier, I found that nearly 70% of U.S. indicators, including energy consumption, population growth, waste production, and wildlife habitat, showed decline. About 20% of the trends showed some improvement. The rest of the conditions were neither improving nor deteriorating (**FIGURE 1-2**).

Worldwide, similar trends have caused concern among many political leaders, activists, citizens, scientists, and business leaders. The world population continues to increase. Forests are being cut down. Species are disappearing, and global pollution is increasing. Although global statistics can become overwhelming, consider what will happen in the next 24 hours. During this period, 223,000 people will be added to the world population. In the next 24 hours, a huge amount of tropical rain forest will be leveled to make room for farms, roads, dams, mines, and towns. The daily loss comes to about 525 square kilometers (230 square miles)—that's equivalent to a swath 115 miles long and 2 miles wide. Unfortunately, very few of these trees will ever be replanted—only about 1 for every 10 trees felled. In this same period, 180 square kilometers (70 square miles) of land will turn to desert, in large part because of poor farming practices, overgrazing, and a warming trend that may be caused by pollutants—largely from industrial societies—that trap heat in the Earth's atmosphere. The list goes on.

These and a host of other environmental trends presented throughout this book suggest to many observers that the current course of virtually all nations of the world is unsustainable. This is not to say that we are doomed, however. Stating we're on an unsustainable course is simply another way of asserting that things can't go on as they have been. To avoid problems—potentially serious problems—and to create a better future, experts contend that we will need to change our ways. Thankfully, many of the world's people are realizing this. You should not give up hope. There are many very favorable trends underway and new and promising developments. New technologies are also helping solve problems, as are individual actions (**FIGURE 1-3**). Another encouraging sign is that more and more people have come to realize that there are a number of fundamental driving forces—or root causes—that have created the present conditions. Two of the most important are continuing growth in both economic output and population.

GO GREEN

Use compact fluorescent light bulbs in your dorm room or apartment to save energy and reduce pollution. These bulbs use 75% less energy than a standard light bulb.

Encouragingly, many nations have responded swiftly to the population challenge. They have developed educa-

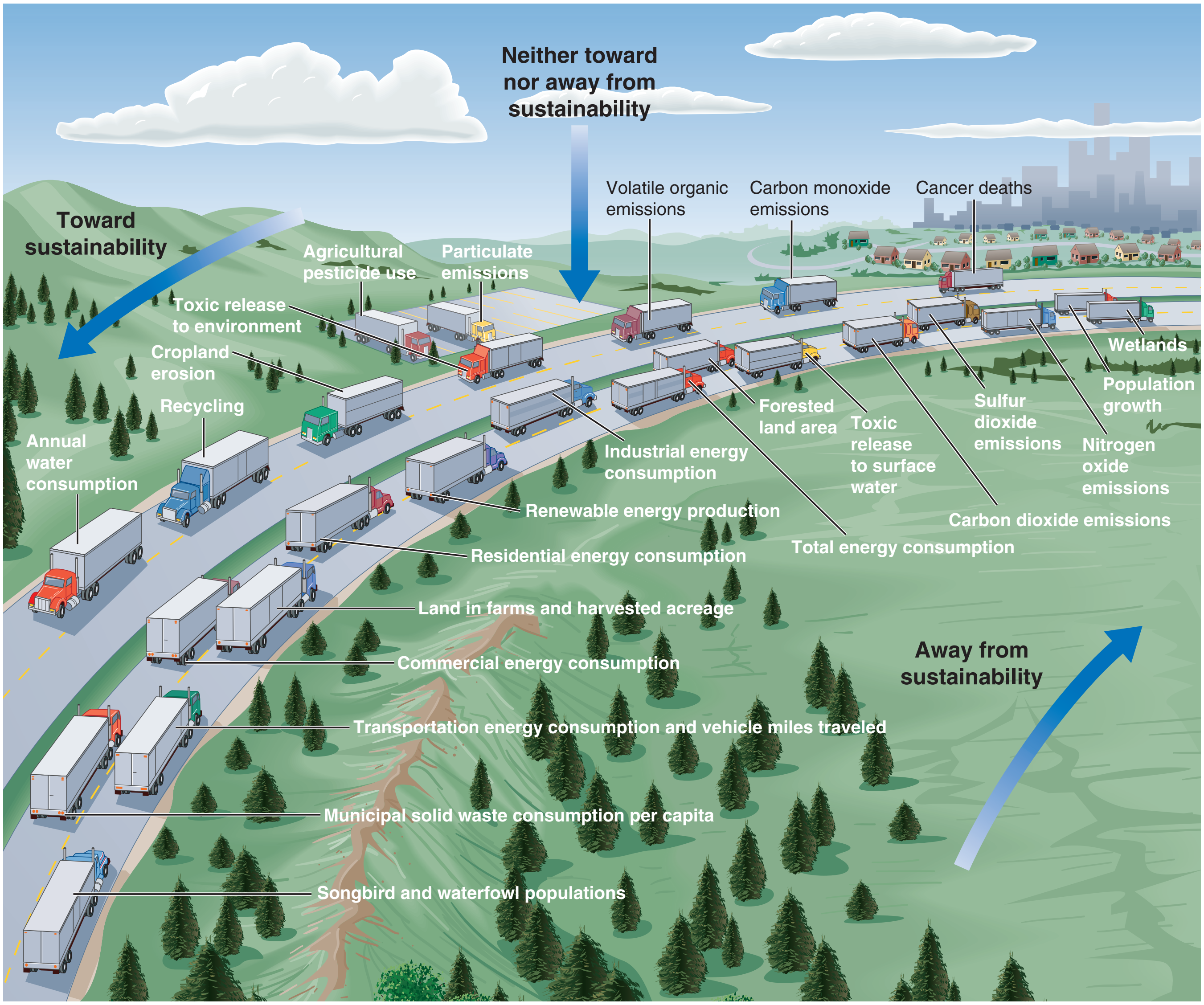

FIGURE 1-2 Environmental trends. Summary of 25 environmental trends studied by the author.

FIGURE 1-3 Solar electricity. Photovoltaic (PV) modules produce electricity from sunlight. On these homes in Brazil, PVs provide electricity for two indoor compact fluorescent lights.

tional programs and other voluntary measures that are helping to slow the growth of their populations.

Many countries have begun to take steps to create economies that are better for the environment. Important agreements have been reached to curb global pollution, protect forests, and protect wild species and in recent years, some nations have taken steps to combat global climate change. Although there's a lot more to do, the world seems to be moving in the right direction.

KEY CONCEPTS

There are many positive changes in perception and policy that have led to real progress in solving local, regional, and global environmental problems. However, the problems still outweigh the solutions.

1-2 The Philadelphia Eagles Go Green!

"The Philadelphia Eagles may not have a winning record on the field," writes NBC's Laura Marquez, "but they are setting the record in the NFL as the greenest team in football." How can a football team become a leader in green?

Like individuals, businesses, and governments, the Philadelphia Eagles football team has adopted a number of policies and practices to help ease their impact on the environment. For example, they now print their programs and tickets on recycled paper. They also require the use of plastic made from corn, a renewable resource, for the beer cups sold on the premises. Plates used in the executive suites are made from plant products.

Even the lights in their stadium are green—powered by renewable energy. Overall, one-third of the energy the team consumes derives from renewable resources, mostly wind power. The team even subsidizes renewable energy purchases by employees.

The team minimizes the use of potentially toxic chemicals and fertilizes their playing field with organic fertilizer. They also recycle much of the mountain of waste left behind after each home game.

The team is also helping to educate its fans on the importance of little things they can do to reduce their impact on the environment. They do this by sharing facts about their individual contributions to the problems and the solutions.

Although the Eagles are leading the charge, they're not alone. The St. Louis Rams are also taking steps to become a greener team. Their efforts have spurred interest in greening high school and college teams, not just in football, but in other sports as well.

1.2 What Is Environmental Science?

This book focuses on the environmental problems that we face—issues in three principal areas: pollution, natural resources, and population. However, it also focuses on solutions, that is, what individuals, businesses, and governments can do about our many environmental problems. The topics covered in this book fall within the domain of a relatively new science, known as *environmental science*. What is environmental science?

Environmental science is, in broadest terms, a branch of science that seeks to understand the many ways that we affect our environment and the many ways that we can address these issues. Environmental science draws on the research and expertise of specialists from numerous traditional sciences, including biology, ecology, chemistry, geology, engineering, and physics. The study of environmental issues and solutions also draws heavily on the humanities: economics, political science, anthropology, history, law, sociology, and even psychology. Thus, environmental science is a multidisciplinary field of endeavor.

To many observers, myself included, a full understanding of issues and solutions requires this broad, multidisciplinary approach. We won't solve the complex environmental issues that we face today through science and technology. We must understand and address the human element.

This book takes a multidisciplinary approach. It discusses the science behind the issues, technologies that will help us address problems, but also draws on a wide range of other disciplines to help you develop a deeper understanding of issues and solutions.

Environmental science, like engineering, is an applied science. Environmental scientists seek knowledge to expand our body of knowledge, but also to enable us to develop solutions to our problems. Those solutions may involve new technologies, but they may also involve new ways of thinking, new behaviors, and new laws and regulations. Today, numerous environmental scientists realize that many solutions proposed since the 1960s were stop-gap measures—that is, they solved the problems but only temporarily. This realization has led many to rethink previous ideas and propose more lasting, preventive measures—solutions that are good for people, the economy, and the environment. We call these sustainable solutions. In this book, I present traditional, stop-gap–type solutions and the newer set of sustainable solutions. As you shall see, these solutions are part of a new movement called **sustainable development**. You'll see the connection in the next chapter. Basically, though, sustainable solutions will help us create a more sustainable course of development.

KEY CONCEPTS

Environmental science is a multidisciplinary endeavor that seeks to understand and solve a wide range of environmental problems. More recently environmentalists and environmental scientists have taken steps to implement solutions that eliminate problems, thus promoting sustainable development.

1.3 Science and Scientific Method: Keys to Understanding Environmental Issues and Creating Lasting Solutions

The term *science* comes from the Latin word *scientia*, which means "to know or to discern." Technically, the term **science** refers to a body of knowledge derived from observation, measurement, study, and experimentation—and to the process of accumulating such knowledge.

Throughout this book you will learn both fundamental principles of science and many of the scientific concepts and facts behind environmental issues. Some of the most important scientific principles come from the science of **ecology**, the study of ecosystems (Chapters 4–6). An **ecosystem** is a system composed of living things (animals, plants, microorganisms) and the interrelated physical and chemical environment. Before we can delve into the realm of science, however, it is helpful to understand how scientific information is acquired.

KEY CONCEPTS

Science is a body of knowledge and a method of acquiring further knowledge about the world around us.

Scientific Method: The Basis of Good Science

Scientific study of the world around us generally occurs in an orderly fashion. As a rule, scientific discovery begins with observations and measurements of the subject under study (FIGURE 1-4). From such observations, scientists often formulate tentative explanations, or **hypotheses**. Consider an example: Scientists hypothesize that rattlesnakes shake their rattles to warn large animals to stay away. It is not an aggressive act, but a protective measure that reduces the chances of a snake's being stepped on and killed. This hypothesis is based on observations of wild rattlesnakes. Hypotheses (generalizations) such as this one that are based on observation and measurement are derived by inductive reasoning. **Inductive reasoning** occurs any time a person uses facts and observations to arrive at general rules or hypotheses. This is very common in scientific study. Charles Darwin based his theory of natural selection on observations. He was engaged in inductive reasoning.

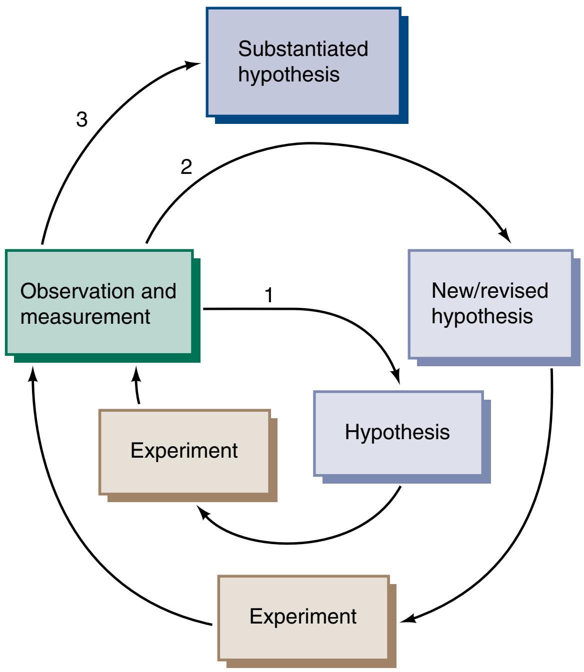

FIGURE 1-4 **The scientific method.** This drawing shows a simplified view of the scientific method, beginning with observation and measurement. In some cases, the original hypothesis may have to be revised many times.

Inductive reasoning is the opposite of **deductive reasoning**, in which one arrives at a specific conclusion drawn from general principles. Deductive reasoning is common in mathematics, philosophy, politics, and ethics. General principles are used to examine and evaluate decisions. Consider an example: Scientists have found that brightly colored frogs of the tropics are generally poisonous, a fact established by scientific research (inductive reasoning). Brightly colored snakes are also often poisonous. Studies suggest that this is a kind of warning coloration. Wary predators know to avoid such colorful meals. If you were to encounter a brightly colored snake or frog, you might assume that it is poisonous (FIGURE 1-5). You would have used deductive reasoning to do this. You would have used a general principle to derive a conclusion about a specific organism.

KEY CONCEPTS

Scientific knowledge is often gained through a deliberate process of observation and measurement, which leads scientists to formulate hypotheses that can then be tested through experiments. This is a form of inductive reasoning.

Experimentation: Testing Hypotheses

After a hypothesis is made, the scientist must determine if it is valid. This is usually done by experimentation. Properly performed, experiments provide information that either supports or refutes the hypothesis under question. As shown in

FIGURE 1-5 **Predator beware.** Many brightly colored reptiles and amphibians are poisonous, like this poison dart frog from the tropical rain forest. Predators learn to avoid them.

Figure 1-4, if a hypothesis is refuted, a modified or new one is generally substituted. The new hypothesis must then be tested.

Scientific method, then, consists of observations and measurements that result in hypotheses. These are tested through experimentation and refined as needed. Surprisingly, most people use scientific method nearly every day of their lives. Suppose, for example, that every time you went to a friend's house you became ill. To determine what made you sick, you'd probably start by making a mental list of all of the activities you engaged in at your friend's house during your visits. After making the list and weeding out activities that seem irrelevant, you might conclude that your problems began when you petted your friend's cat. That's your hypothesis.

To test this hypothesis, you could perform an experiment. For instance, you might ask your friend to keep the cat outdoors when you were there. If you come home feeling sick again, you might alter your hypothesis. Maybe it's the new carpet in her apartment. Of course, scientific study is much more involved than this example, but the process is much the same.

Many scientific experiments are carried out on animals, plants, and other living organisms. Studies such as these are often designed to test the effects of a chemical substance—for example, the effect of a pollutant on an animal's lungs. In experiments of this nature, it is necessary to establish two distinct groups of organisms, an experimental group and a control group. The **experimental group** is the one that you treat or "experiment on." In a study of the effects of air pollution on laboratory mice, for example, the experimental group would be exposed to certain amounts of air pollution. The **control group** is treated identically, except that it is not exposed to the pollution. By setting up experiments in this manner, scientists can test the effect of one and only one variable, which is known as the **independent variable**. Any observed differences in the two groups should result from the treatment.

In experiments outside the laboratory, it is not always easy to isolate one variable. Scientists studying areas in which acidic air pollutants are being deposited in rain, for example, have found many biological effects. However, other pollutants such as ozone may be responsible for some of the effects. Sorting out the specific pollutants involved can be quite complicated.

KEY CONCEPTS

Experiments enable scientists to test hypotheses and gain new knowledge, but experiments must be carried out very carefully. Good experiments often require control and experimental groups.

Studies on Human Health Studying the effects of pollution on humans is much more difficult than analyzing the effects of chemicals on laboratory animals described previously. Why? First, ethics generally prohibits experimentation on humans such as those performed on laboratory rats or mice. Second, unlike laboratory mice, which are genetically identical, humans represent a genetically diverse group of organisms. Setting up control and experimental groups containing large numbers of genetically similar humans who have been exposed to the same conditions throughout life is impossible. Consequently, scientists often rely on **epidemiological** (EP-eh-DEEM-ee-ah-LO-jeh-cul) studies to study the effects of chemical pollutants on people.

Literally translated, **epidemiology** (EP-eh-DEEM-ee-OL-oh-gee) is the study of epidemics caused by infectious disease organisms. Today, however, epidemiology refers to a branch of science that also studies the health effects of environmental pollutants, food additives, radiation, and a variety of other agents. Epidemiological studies generally rely on statistical analysis of data on populations that have been exposed to various potentially harmful substances. Consider an example: Suppose a scientist wanted to know the cause of a kind of cancer in humans. If she were an epidemiologist, she would generally begin by searching through death certificates from hospitals to identify patients who had succumbed to the cancer in question. She would then interview their next of kin to learn about the deceased's personal habits, lifestyle, and possible exposures. She would then put all of the information into a computer and sort through it to see if she could find any commonalities. For example, a large percentage of the people might have been employed in a chemical factory. The job is not finished yet, though. Before any conclusions could be drawn, the researcher would assemble a control group as identical to the first group as possible. The control group would consist of people of the same age and sex, except that these people would have died from causes other than the cancer under study. By analyzing their life histories and comparing the results with those from the cancer group, she might be able to pinpoint the cause of the cancer in the experimental group.

Epidemiological studies may also involve comparisons of living subjects. For example, a scientist might compare the health records of workers exposed to a certain pollutant in a factory to workers at the same company who are not exposed to the pollutant (for example, office workers). This may turn up differences that could be attributed to workplace exposure.

Science requires a lot of experimentation to validate hypotheses. No one study can be taken as the final word. However, by repeating experiments and achieving the same results each time, scientists can gain confidence in their hypotheses. (Such repetition may seem like overkill to some people, but it is essential to the scientific process.)

KEY CONCEPTS

Studies of the effects of chemicals on humans are often performed by comparing carefully selected groups of individuals exposed at work or at home to individuals of the same sex and age who were not exposed. These are known as epidemiological studies.

Scientific Theories and Paradigms

Scientific knowledge grows little by little. As facts accumulate from observation and experimentation, researchers gain an understanding of how things work. They often formulate

theories, explanations that account for many different facts, observations, and hypotheses. Theories are scientifically acceptable principles, broad generalizations regarding natural, physical, and chemical phenomena. Unlike hypotheses, theories generally cannot be tested by single experiments because they encompass many different pieces of information. Atomic theory, for instance, explains the structure of the atom and fits numerous observations.

Science is not static, however. It constantly grows and evolves. Thus, scientists sometimes find that new interpretations emerge, replacing entrenched ideas. This sometimes forces scientists to alter or abandon well-established theories. Consequently, scientists must be open-minded about theories; they must be willing to replace their most cherished theories with new ones, as more information accumulates.

Perhaps the best known example of a changing theory is the **Copernican revolution** (coe-PURR-nick-in) in astronomy. The Greek astronomer Ptolemy (TOLL-eh-me) hypothesized in A.D. 140 that the Earth was at the center of the solar system. This is called the *geocentric view*. The moon, the stars, and the sun, he argued, all revolve around the Earth. In 1580, however, Nicolaus Copernicus (coe-PURR-nick-us) showed that the many observations of astronomers of the time were better explained by assuming that the sun was the center of the solar system. Copernicus was not the first to suggest this *heliocentric* view. Early Greek astronomers had proposed the idea, but it gained little attention until his time.

GO GREEN

Make a list of your environmental values—what you think is right or wrong, environmentally. For example: It is wrong to waste water. Then make a list of things you can do to put your values into action.

Over time, scientists have created philosophical and theoretical frameworks within which theories, laws, and generalizations are formulated. These frameworks that underlie all scientific disciplines are called *paradigms*, a term popularized by the philosopher and science historian Thomas Kuhn. A **paradigm** is a basic model of reality in science. For example, evolution is a paradigm of the biological sciences. Atomic theory is the dominant paradigm of modern chemistry.

Paradigms govern the way scientists think, form theories, and interpret the results of experiments. They also govern the way nonscientists think. Once a paradigm is accepted, it is rarely questioned. New observations are generally interpreted according to the paradigm; those that are inconsistent with it are often ignored or disputed. In some cases, though, observations that fail to fit the paradigm may amass to a point at which they can no longer be ignored, causing scientists to rethink their most cherished beliefs and, sometimes, discard them. This is called a **paradigm shift**.

The term *paradigm* is commonly used today in a more general way, referring simply to the way we see the world. Many observers, for instance, speak about the **dominant social paradigm** of modern society when they refer to the set of beliefs that govern our lives. As you will see in Chapter 3, our attitudes and behaviors often flow from our beliefs. Unsustainable systems, for instance, are largely a result of our beliefs.

FIGURE 1-6 Science is Fun for the Mind! Robert Bakker, one of America's most creative scientists is a man of great energy, enthusiasm, and creativity.

Paradigms also shape our language, thought, and perceptions. Slogans and common sayings reflect our paradigms and are repeated and reinforced day after day. Perhaps the most obvious expression of the dominant social paradigm is the growth-is-essential philosophy. You hear it in the business world every day when businesspeople proclaim, "A company must grow or die." Politicians echo a similar sentiment. Systems analyst Donella Meadows wrote in her book *The Global Citizen*, "Your paradigm is so intrinsic to your mental process that you are hardly aware of its existence, until you try to communicate with someone with a different paradigm." Perhaps the most difficult problem is that people often get attached to their paradigms and fiercely resist any effort to change them. Because of the importance of our paradigms, success in building a sustainable future may require concerted efforts to overcome this resistance.

Although this description of science and scientific method shows that they require analytical skills and reasoning, they are also creative and fascinating endeavors. Scientific research may sound dull and boring to many people, but the truth is that, in many cases, it is extremely exciting. Far from being the left-brained, analytical types depicted in many movies and books, scientists are often highly creative and—believe it or not—intuitive people (**FIGURE 1-6**). They see hidden connections in the chaos of experimental data and make leaps of logic that, upon testing, often turn out to be true.

KEY CONCEPTS

As scientific knowledge accumulates, scientists are able to formulate theories that explain their observations. Overarching theories or paradigms emerge and profoundly shape scientific thought and our perceptions of reality.

Science and Values

Science is all about facts and figures that explain our world. Scientists endeavor to remain objective, letting the data determine their hypotheses and theories. Ultimately, scientists hope to find objective truths—assertions about the world around us that can be backed up by data they've acquired through careful experimentation and observation. Because of this, most scientists argue that science is amoral—outside the sphere in which moral judgments are made; that is, it is not about right and wrong.

Scientists bring human qualities to their work, including their own values and preconceived notions that can taint their observations. Thus, scientists are not always as objective as one might hope. Today, scientists can be found to argue both sides of controversial issues. They may look at the same data and come away with markedly different conclusions because their biases often get in the way of objective analysis. Numerous Point/Counterpoints in this book illustrate this situation.

Just as human values affect scientific interpretation of data, science can also affect public values. A good understanding of ecological science, for instance, can help reshape human values concerning nature and our part in the natural world.

Societal values can be based on accurate scientific knowledge. This book will help expand your knowledge of natural and human systems, helping you see things more clearly. This may help you to rethink your values.

One value-shaping role of science rests in its ability to help us see hidden connections—for example, the role of forests in maintaining atmospheric carbon dioxide levels and global climate. This book shows the many ways that natural systems support human life. Knowing how important the planet is to our future cannot help but change our attitudes and, possibly, our actions.

KEY CONCEPTS

Scientists seek to be objective in their work so that science is fact based and value free. However, biases based on values can influence scientific analysis at times. Scientific knowledge can also affect human values.

1.4 Critical Thinking Skills

One of the skills a good scientist (and many a great thinker) has is called *critical thinking*. **Critical thinking** is the capacity to distinguish between beliefs (what we think is true) and knowledge (facts that are backed by accurate observation and valid experimentation). Critical thinking helps us separate judgment from facts. It is the most ordered kind of thinking of which people are capable. Critical thinking involves subjecting facts and conclusions to careful analysis, looking for weaknesses in logic and other errors of reasoning. Critical thinking skills are essential in analyzing a wide range of environmental problems, issues, and information.

So how does one think critically? Clearly, there is no single formula. However, most critical thinkers would agree that several steps contribute to this process. These steps or principles of critical thinking, summarized in **Table 1-1**, will help you analyze arguments, research findings, issues, and statements you read.

Table 1-1

Summary of Critical Thinking Rules

Gather all information.
- Dig deeper.
- Learn all you can before you decide.
- Don't mistake ignorance for perspective.

Understand all terms.
- Define all terms you use.
- Be sure you understand terms and concepts others use.

Question how information/facts were derived.
- Were they derived from scientific studies?
- Were the studies well conceived and carried out?
- Were there an adequate number of subjects?
- Was there a control group and an experimental group?
- Has the study been repeated successfully?
- Is the information anecdotal?

Question the source of the information.
- Is the source invested in the outcome of the issue?
- Is the source biased?
- Do underlying assumptions affect the viewpoint of the source?

Question the conclusions.
- Do the facts support the conclusion?
- Correlation does not necessarily mean causation.

Expect and tolerate uncertainty.
- Hard-and-fast answers aren't always possible.
- Learn to be comfortable with not knowing.

Examine the big picture.
- Study the whole system.
- Look for hidden causes and effects.
- Avoid simplistic thinking.
- Avoid dualistic thinking.

KEY CONCEPTS

Critical thinking is an acquired skill that helps us analyze issues and discern the validity of experimental results and assertions.

Gather All Information

The first requirement of critical thinking is to gather all of the information you can before you make a decision. In order to understand most issues, it is often necessary to seek out additional information. When you do, you often find a slightly different picture of reality. This is especially true in environmental debates, in which advocates tend to simplify issues or to present information that supports their case while ignoring contradictory findings. Although you'll rarely have all the information you need to make a decision, you can always get more. So get in the habit of learning all you can before you make a decision. Don't mistake ignorance for perspective.

When gathering facts, be sure to seek out statistics. Watch out for anecdotes—or stories—that may sound convincing but don't accurately represent the truth. Humans prefer stories to statistics and often reach erroneous conclusions as a result.

KEY CONCEPTS

Critical thinking requires one to know as much information about an issue as possible before rendering an opinion or making a decision.

Understand All Terms

The second rule of critical thinking is that when analyzing any issue, solving any problem, or judging the accuracy of someone's statements, you must understand all terms. In some instances, you will find that the people presenting a case have inaccurate or incomplete understanding. A good example is the term *sustainability*, which is currently being used by people who have a poor understanding of the term. They even use the word to construct oxymorons, such as *sustainable economic growth*. In a finite system, as you will soon see, growth cannot be sustained.

KEY CONCEPTS

To think critically about an issue, one must understand the terms and concepts related to it.

Question the Methods

The third principle of critical thinking is to question the methods by which information has been acquired. Were the facts derived from experimentation? Was the experiment performed correctly? Did the experimenters use an adequate number of subjects? Did the experiment have a control group? Were the control and experimental groups treated identically except for the experimental variable?

KEY CONCEPTS

Critical thinking requires that we know how information has been acquired and that we question the methods by which it was derived.

Question the Source

A fourth requirement of critical thinking is to question the source of the facts. Ask yourself who is giving the information. When business owners say that pollution from their factories isn't causing any harm, beware. Environmentalists are not immune to bias and are also fair game for your critical thinking skills.

Be on the lookout for bias and underlying assumptions, even in this text. Some of the most well-entrenched assumptions and myths are listed in **Table 1-2**. Study them and be aware of them. Also, look at the Individual Actions Count! table. It will help you examine your own values and assumptions for bias.

Table 1-2

Sixteen Myths and Assumptions of Modern Society

1. People do not shape their future; it happens to them.
2. Individual actions don't count.
3. People care only about themselves and money; they can't be counted on to take action on the part of a good cause unless they'll gain.
4. Conservation is sacrifice.
5. For every problem there is only one solution; find it, correct the problem, and all will be well.
6. For every cause, there is one effect.
7. Technology can solve all problems.
8. Environmental protection is bad for the economy.
9. People are apart from nature.
10. The key to success is through the control of nature.
11. The natural world is here to serve our needs.
12. All growth is unqualifiably good.
13. Favorable economics justifies all actions; if it's economical it's all right.
14. The systems in place today were always here and will always remain.
15. Results can be measured by the amount of money spent on a problem.
16. Slowing the rate of environmental destruction and pollution solves the problems.

Source: Adapted from Donella Meadows (1991). *The Global Citizen*. Washington, DC: Island Press; and Daniel D. Chiras (1990). *Beyond the Fray: Reshaping America's Environmental Response*. Boulder, CO: Johnson Books.

KEY CONCEPTS

Critical thinking requires one to search for hidden biases and assumptions that may influence one's understanding of an issue or interpretation of data.

Question the Conclusions

The fifth requirement of critical thinking is to question the conclusions derived from facts. Do the facts support the conclusions? Are other interpretations possible? One of the earliest studies on lung cancer, for instance, showed a correlation between lung cancer and sugar consumption. The researchers who performed the study found that people with the highest rate of lung cancer ate the most sugar. However, upon reexamination it turned out that cigarette smokers consumed more sugar than nonsmokers. The real cause of cancer was cigarette smoking.

This example illustrates a key scientific principle worth remembering: Correlation doesn't necessarily mean causation. A correlation is an apparent connection between two variables. For example, just because people living near a chemical plant have a high rate of leukemia (cancer of the blood) doesn't mean that the factory is causing it.

KEY CONCEPTS

Critical thinking requires us to question the conclusions drawn from facts to see if other interpretations might be possible.

Tolerate Uncertainty

The sixth rule of critical thinking is to tolerate uncertainty. Although this may seem contradictory at first, it really isn't. As noted earlier, science is a dynamic process. Scientific knowledge is constantly being refined. What we know, however, is dwarfed by our ignorance. Although knowledge of poisons and hazardous materials is immense, in actuality very little is known about the toxic effects of chemicals on humans. How do they interact? Are impacts affected by diet?

Some current debates on environmental issues involve a fair amount of uncertainty. Hard-and-fast answers just aren't available yet. Sometimes we have to make decisions with limited data.

KEY CONCEPTS

Our knowledge of the world around us is evolving, and, thus, it is necessary to accept uncertainty as an inevitable fact of life and make decisions with the best information possible.

Examine the Big Picture

The seventh rule of critical thinking is always to examine the big picture. Don't get trapped in simplistic thinking. Dualistic thinking is one of the most common forms of simplistic thinking. Dualistic thinking is reasoning that is black-and-white, right-or-wrong oriented. Dualistic thinking sees two options for every issue and nothing in between.

This book presents several conceptual models that will help you understand the big picture. These learning tools organize a great deal of information into a simple format.

To understand the big picture, we must often look at whole systems, both human and natural. For example, it is important to understand how value systems influence the systems (infrastructure) that serve our needs, such as our economic system. The economy, for example, is largely based on a belief that the Earth is an unlimited supply of resources, all for human use. Economic expansion is perceived as a positive thing even though continued economic expansion is at the root of many potentially catastrophic environmental trends.

As an additional example, agricultural systems in many countries are a reflection of the view that the key to success is through domination and control of nature. We level grasslands, plant acre after acre of the same crop, and then control the insects that arise to take advantage of this bonanza with an arsenal of potentially harmful pesticides (**FIGURE 1-7**).

Human systems obviously have profound effects on natural systems. One of the goals of this book is to help you become a better systems thinker. This is one of the most valuable skills architects of a sustainable future must possess.

KEY CONCEPTS

To become a critical thinker it is necessary to examine the big picture—relationships and entire systems.

To be ignorant of one's ignorance is the malady of the ignorant.

—Bronson Alcott

CRITICAL THINKING

Exercise Analysis

Critical thinking requires students to think carefully and objectively and to assimilate facts and concepts. At the heart of critical thinking, however, is something much more important. Your dictionary probably offered several definitions of the word critical. For example, it may have defined it as "finding fault," which is clearly not appropriate in this instance. The dictionary may have also defined critical as "being characterized by careful analysis."

Careful analysis requires that we examine issues very thoughtfully, that we study the facts that back up our opinions. It also means that we look for loopholes in people's logic. Critical thinking helps us separate beliefs that may have little factual basis from facts.

One of the rules of critical thinking illustrated by this exercise is that to be a critical thinker you must understand terms you encounter. Be sure a speaker explains the terms he or she is using. Don't be timid about asking for an explanation. Also, be sure you understand new words you're reading. Don't launch into an argument until you really understand what the other person is saying. One thing you might try when you're talking with someone is a process called active listening—repeating what you think someone is trying to say. This technique is very simple and is one way you can be sure you truly understand another person's point before you propose your own ideas.

FIGURE 1-7 The control of nature. A belief that humans are superior to other living things and that domination and control of natural systems are the key to success profoundly influences how we design human systems such as agriculture. Sustainability calls for systems to be ecologically intelligent.

CRITICAL THINKING AND CONCEPT REVIEW

1. Companies throughout the world are recognizing that good environmental practices are good for business. Make a list of reasons why this may be true.
2. In what ways can science help us solve problems sustainably? What are the limitations of science in problem solving?
3. Describe the scientific method. What are the steps, and why is each one necessary?
4. Describe the components of a good scientific experiment.
5. A graduate student interested in studying the effects of air pollutants on lichens (a fungus that grows on rocks) designed an experiment as follows: He proposed to bring rocks with lichens into the laboratory, where he would expose them to urban air pollution. (His university was located downtown in a major metropolitan area.) He then proposed to circulate outside air into the laboratory and measure the effects. What is wrong with this experimental design? How would you design a better experiment?
6. What is the difference between a theory and a hypothesis?
7. Numerous studies on the natural toxin known as aflatoxin, which is found in peanuts, show that it is mutagenic and carcinogenic; that is, it causes mutations in the genetic material and cancer in some organisms. Drawing on these studies, scientists have labeled aflatoxin as a potentially dangerous substance. What kind of reasoning is this, inductive or deductive?
8. "From the facts of the case," said Sherlock Holmes, famous investigator of fictional repute, "I can deduce that the butler did it." Is Holmes using the word *deduce* correctly in this context?
9. In what ways do our values affect science? How can science affect our values?
10. Make a list of the critical thinking skills outlined in this chapter. Describe and give an example of each one. Over the next week, make a list of all the times you use these rules.
11. Study the list of myths and assumptions in Table 1-2. Which ones do you agree with? Which ones do you disagree with?

KEY TERMS

control group
Copernican revolution
critical thinking
deductive reasoning
dominant social paradigm
ecology
ecosystem
epidemiological
epidemiology
experimental group
hypotheses
independent variable
inductive reasoning
paradigm
paradigm shift
sustainable development
theories
U.S. Environmental Protection Agency (EPA)

REFERENCES AND FURTHER READING

To save on paper and allow for updates, additional reading recommendations and the list of sources for the information discussed in this chapter are available at http://environment.jbpub.com/9e/.

Connect to this book's website:
http://environment.jbpub.com/9e/
The site features eLearning, an online review area that provides quizzes, chapter outlines, and other tools to help you study for your class. You can also follow useful links for in-depth information, research the differing views in the Point/Counterpoints, or keep up on the latest environmental news.