Learning Skills

*Students who can begin early in their lives to think of things as connected, even if they revise their views every year, have begun the life of learning.*

MARK VAN DOREN

Why Is It Important to Study Environmental Science?

Welcome to *environmental science*—an interdisciplinary study of how the earth works, how we interact with the earth, and how we can deal with the environmental problems we face. Because environmental issues affect every part of your life, the concepts, information, and issues discussed in this book and the course you are taking will be useful to you now and throughout your life.

Understandably, we are biased, but we strongly believe that environmental science is the single most important course in your education. What could be more important than learning how the earth works, how we affect its life-support system, and how we can reduce our environmental impact?

We live in an incredibly challenging era. We are becoming increasingly aware that during this century, we need to make a new cultural transition in which we learn how to live more sustainably by sharply reducing our degradation of our life-support system. We hope this book will inspire you to become involved in this change in the way we view and treat the earth, which sustains us, our economies, and all other living things.

You Can Improve Your Study and Learning Skills

Maximizing your ability to learn should be one of your most important lifetime educational goals. It involves continually trying to improve your study and learning skills. Here are some suggestions for doing so:

**Develop a passion for learning.** As the famous physicist and philosopher Albert Einstein put it, “I have no special talent. I am only passionately curious.”

**Get organized.** Becoming more efficient at studying gives you more time for other interests.

**Make daily to-do lists in writing.** Put items in order of importance, focus on the most important tasks, and assign a time to work on these items. Because life is full of uncertainties, you might be lucky to accomplish half of the items on your daily list. Shift your schedule as needed to accomplish the most important items.

**Set up a study routine in a distraction-free environment.** Develop a written daily study schedule and stick to it. Study in a quiet, well-lighted space. Work while sitting at a desk or table—not lying down on a couch or bed. Take breaks every hour or so. During each break, take several deep breaths and move around; this will help you to stay more alert and focused.

**Avoid procrastination.** Avoid putting work off until another time. Do not fall behind on your reading and other assignments. Set aside a particular time for studying each day and make it a part of your daily routine.

**Do not eat dessert first.** Otherwise, you may never get to the main meal (studying). When you have accomplished your study goals, reward yourself with dessert (play or leisure).

**Make hills out of mountains.** It is psychologically difficult to climb a mountain, which is what reading an entire book, reading a chapter in a book, writing a paper, or cramming to study for a test can feel like. Instead, break these large tasks (mountains) down into a series of small tasks (hills). Each day, read a few pages of a book or chapter, write a few paragraphs of a paper, and review what you have studied and learned. As American automobile designer and builder Henry Ford put it, “Nothing is particularly hard if you divide it into small jobs.”

**Look at the big picture first.** Get an overview of an assigned reading in this book by looking at the Key Questions and Concepts box at the beginning of each chapter. It lists both the key questions explored in the chapter sections and their corresponding key concepts, which are the critical lessons to learn in the chapter. Use this list as a chapter roadmap. When you finish a chapter you can also use the list to review.

**Ask and answer questions as you read.** For example, “What is the main point of a particular subsection or paragraph?” Relate your own questions to the key questions and key concepts addressed in each major chapter section. In this way, you can flesh out a chapter outline to help you understand the chapter material. You may even want to do such an outline in writing.

**Focus on key terms.** Use the glossary in your textbook to look up the meaning of terms or words you do not understand. This book shows all key terms in *boldface* type and lesser, but still important, terms in *italicized* type. The review
questions at the end of each chapter also include the chapter's key terms in boldface. Flash cards for testing your mastery of key terms for each chapter are available on the website for this book, or you can make your own by putting a term on one side of an index card or piece of paper and its meaning on the other side.

Interact with what you read. We suggest that you mark key sentences and paragraphs with a highlighter or pen. Consider putting an asterisk in the margin next to material you think is important and double asterisks next to material you think is especially important. Write comments in the margins such as beautiful, confusing, misleading, or wrong. You might fold down the top corners of pages on which you highlighted passages and the top and bottom corners of especially important pages. This way, you can flip through a chapter or book and quickly review the key ideas.

Review to reinforce learning. Before each class session, review the material you learned in the previous session and read the assigned material.

Become a good note taker. Do not try to take down everything your instructor says. Instead, write down main points and key facts using your own shorthand system. Review, fill in, and organize your notes as soon as possible after each class.

Write out answers to questions to focus and reinforce learning. Answer the critical thinking questions found in Thinking About boxes throughout the chapters, in many figure captions, and at the end of each chapter. These questions are designed to inspire you to think critically about key ideas and connect them to other ideas and your own life. Also answer the review questions found at the end of each chapter. The website for each chapter has an additional detailed list of review questions for that chapter. Writing out your answers to the critical thinking and review questions can reinforce your learning. Save your answers for review and test preparation.

Use the buddy system. Study with a friend or become a member of a study group to compare notes, review material, and prepare for tests. Explaining something to someone else is a great way to focus your thoughts and reinforce your learning. Attend any review sessions offered by instructors or teaching assistants.

Learn your instructor's test style. Does your instructor emphasize multiple-choice, fill-in-the-blank, true-or-false, factual, or essay questions? How much of the test will come from the textbook and how much from lecture material? Adapt your learning and studying methods to this style. You may disagree with this style and feel that it does not adequately reflect what you know. But the reality is that your instructor is in charge.

Become a good test taker. Avoid cramming. Eat well and get plenty of sleep before a test. Arrive on time or early. Calm yourself and increase your oxygen intake by taking several deep breaths. (Do this also about every 10–15 minutes while taking the test.) Look over the test and answer the questions you know well first. Then work on the harder ones. Use the process of elimination to narrow down the choices for multiple-choice questions. Paring them down to two choices gives you a 50% chance of guessing the right answer. For essay questions, organize your thoughts before you start writing. If you have no idea what a question means, make an educated guess. You might earn some partial credit and avoid getting a zero. Another strategy for getting some credit is to show your knowledge and reasoning by writing something like this: "If this question means so and so, then my answer is ________.”

Develop an optimistic but realistic outlook. Try to be a “glass is half-full” rather than a “glass is half-empty” person. Pessimism, fear, anxiety, and excessive worrying (especially over things you cannot control) are destructive and lead to inaction. Try to keep your energizing feelings of realistic optimism slightly ahead of any immobilizing feelings of pessimism. Then you will always be moving forward.

Take time to enjoy life. Every day, take time to laugh and enjoy nature, beauty, and friendship.

You Can Improve Your Critical Thinking Skills: Become Good at Detecting Baloney

Critical thinking involves developing the skills to analyze information and ideas, judge their validity, and make decisions. Critical thinking helps you to distinguish between facts and opinions, evaluate evidence and arguments, take and defend informed positions on issues, integrate information and see relationships, and apply your knowledge to dealing with new and different problems, and to your own lifestyle choices. Here are some basic skills for learning how to think more critically.

Question everything and everybody. Be skeptical, as any good scientist is. Do not believe everything you hear and read, including the content of this textbook, without evaluating the information you receive. Seek other sources and opinions.

Identify and evaluate your personal biases and beliefs. Each of us has biases and beliefs taught to us by our parents, teachers, friends, role models, and our own experience. What are your basic beliefs, values, and biases? Where did they come from? What assumptions are they based on? How sure are you that your beliefs, values, and assumptions are right and why? According to the American psychologist and philosopher William James, “A great many people think they are thinking when they are merely rearranging their prejudices.”

Be open-minded and flexible. Be open to considering different points of view. Suspend judgment until you gather more evidence, and be willing to change your mind. Recognize that there may be a number of useful
and acceptable solutions to a problem, and that very few issues are black or white. There are trade-offs involved in dealing with any environmental issue, as you will learn in this book. One way to evaluate divergent views is to try to take the viewpoints of other people. How do they see the world? What are their basic assumptions and beliefs? Are their positions logically consistent with their assumptions and beliefs?

**Be humble about what you know.** Some people are so confident in what they know that they stop thinking and questioning. To paraphrase American writer Mark Twain, “It’s what we know is true, but just ain’t so, that hurts us.”

**Evaluate how the information related to an issue was obtained.** Are the statements you heard or read based on firsthand knowledge and research or on hearsay? Are unnamed sources used? Is the information based on reproducible and widely accepted scientific studies or on preliminary scientific results that may be valid but need further testing? Is the information based on a few isolated stories or experiences or on carefully controlled studies whose results were reviewed by experts in the field involved (peer review)? Is it based on unsubstantiated and dubious scientific information or beliefs?

**Question the evidence and conclusions presented.** What are the conclusions or claims? What evidence is presented to support them? Does the evidence support them? Is there a need to gather more evidence to test the conclusions? Are there other, more reasonable conclusions?

**Try to uncover differences in basic beliefs and assumptions.** On the surface, most arguments or disagreements involve differences in opinions about the validity or meaning of certain facts or conclusions. Scratch a little deeper and you will find that most disagreements are usually based on different (and often hidden) basic assumptions concerning how we look at and interpret the world around us. Uncovering these basic differences can allow the parties involved to understand where each is coming from and to agree to disagree about their basic assumptions, beliefs, or principles.

**Try to identify and assess any motives on the part of those presenting evidence and drawing conclusions.** What is their expertise in this area? Do they have any unstated assumptions, beliefs, biases, or values? Do they have a personal agenda? Can they benefit financially or politically from acceptance of their evidence and conclusions? Would investigators with different basic assumptions or beliefs take the same data and come to different conclusions?

**Expect and tolerate uncertainty.** Recognize that scientists cannot establish absolute proof or certainty about anything. However, the results of reliable science have a high degree of certainty.

**Do the arguments used involve logical fallacies or debating tricks?** Here are six of many examples of such tricks. First, attack the presenter of an argument rather than the argument itself. Second, appeal to emotion rather than facts and logic. Third, claim that if one piece of evidence or one conclusion is false, then all other related pieces of evidence and conclusions are false. Fourth, say that a conclusion is false because it has not been scientifically proven (scientists never prove anything absolutely). Fifth, inject irrelevant or misleading information to divert attention from important points. Sixth, present only either/or alternatives when there may be a number of options.

**Do not believe everything you read on the Internet.** The Internet is a wonderful and easily accessible source of information, including alternative explanations and opinions on almost any subject or issue—much of it not available in the mainstream media and scholarly articles. Web logs, or blogs, have become a major source of information, and are even more important than standard news media for some people. However, because the Internet is so open, anyone can post anything they want to some blogs and other websites with no editorial control or review by experts. As a result, evaluating information on the Internet is one of the best ways to put into practice the principles of critical thinking discussed here. Use and enjoy the Internet, but think critically and proceed with caution.

**Develop principles or rules for evaluating evidence.** Develop a written list of principles to serve as guidelines for evaluating evidence and claims (such as the list we are presenting here). Continually evaluate and modify this list on the basis of your experience.

**Become a seeker of wisdom, not a vessel of information.** Many people believe that the main goal of education is to learn as much as you can by gathering more and more information. We believe that the primary goal is to learn how to sift through mountains of facts and ideas to find the few *nuggets of wisdom* that are the most useful for understanding the world and for making decisions. This book is full of facts and numbers, but they are useful only to the extent that they lead to an understanding of key ideas, scientific laws, theories, concepts, and connections. The major goals of the study of environmental science are to find out how nature works and sustains itself (*environmental wisdom*) and to use *principles of environmental wisdom* to help make human societies and economies more sustainable, more just, and more beneficial and enjoyable for all. As writer Sandra Carey observed, “Never mistake knowledge for wisdom. One helps you make a living; the other helps you make a life.” Or as American writer Walker Percy suggested, “Some individuals with a high intelligence but lacking wisdom can get all A’s and flunk life.”

To help you practice critical thinking, we have supplied questions throughout this book, found within each chapter in brief boxes labeled *Thinking About*, in the captions of many figures, and at the end of each chapter. There are no right or wrong answers to many of these questions. A good way to improve your critical thinking skills is to try to take the viewpoints of other people. How do they see the world? What are their basic assumptions and beliefs? Are their positions logically consistent with their assumptions and beliefs?
thinking skills is to compare your answers with those of your classmates and to discuss how you arrived at your answers.

**Know Your Own Learning Style**

People have different ways of learning, and it can be helpful to know your own learning style. *Visual learners* learn best by reading and viewing illustrations and diagrams. They can benefit from using flash cards (available on the website for this book) to memorize key terms and ideas. This is a highly visual book with many carefully selected photographs and diagrams designed to illustrate important ideas, concepts, and processes.

*Auditory learners* learn best by listening and discussing. They might benefit from reading aloud while studying and using a tape recorder in lectures for study and review. *Logical learners* learn best by using concepts and logic to uncover and understand a subject rather than relying mostly on memory.

Part of what determines your learning style is how your brain works. According to the *split-brain hypothesis*, the left hemisphere of your brain is good at logic, analysis, and evaluation, and the right half of your brain is good at visualizing, synthesizing, and creating. One of our goals is to provide material that stimulates both sides of your brain.

The study and critical thinking skills encouraged in this book and in most courses largely involve the left brain. However, you can improve these skills by giving your left brain a break and letting your creative side loose. You can do this by brainstorming ideas with classmates with the rule that no left-brain criticism is allowed until the session is over.

When you are trying to solve a problem, try to rest, meditate, take a walk, exercise, or do something to shut down your controlling left-brain activity. This will allow the right side of your brain to work on the problem in a less controlled and more creative manner.

**This Book Presents a Positive and Realistic Environmental Vision of the Future**

There are always trade-offs involved in making and implementing environmental decisions. Our challenge is to give a balanced presentation of different viewpoints, the advantages and disadvantages of various technologies and proposed solutions to environmental problems, and the good and bad news about environmental problems, and to do this without injecting personal bias.

Studying a subject as important as environmental science and ending up with no conclusions, opinions, and beliefs means that both teacher and student have failed. However, any conclusions one does reach must be based on using critical thinking to evaluate different ideas and to understand the trade-offs involved. Our goal is to present a positive vision of our environmental future based on realistic optimism.

**Help Us Improve This Book**

Researching and writing a book that covers and connects ideas in such a wide variety of disciplines is a challenging and exciting task. Almost every day, we learn about some new connection in nature.

In a book this complex, there are bound to be some errors—some typographical mistakes that slip through and some statements that you might question, based on your knowledge and research. We invite you to contact us to point out any bias, to correct any errors you find, and to suggest ways to improve this book. Please e-mail your suggestions to Tyler Miller at mtg@hotmail.com or Scott Spoolman at spoolman@tds.net.

Now start your journey into this fascinating and important study of how the earth works and how we can leave the planet in a condition at least as good as what we found. Have fun.

*Study nature, love nature, stay close to nature. It will never fail you.*

FRANK LLOYD WRIGHT
Environmental Problems, Their Causes, and Sustainability

A Vision of a More Sustainable World in 2060

Emily Briggs and Michael Rodriguez graduated from college in 2014. Michael earned a masters degree in environmental education, became a middle-school teacher, and loved teaching environmental science. Emily, meanwhile, went to law school and later established a thriving practice as an environmental lawyer.

In 2022, Michael and Emily met when they were doing volunteer work for an environmental organization. They later got married, had a child, and taught her about some of the world’s environmental problems (Figure 1-1, left) and about the joys of nature that they had experienced as children (Figure 1-1, right). As a result, their daughter also became heavily involved in working to promote a more sustainable world and eventually passed this on to her child.

When Michael and Emily were growing up, there had been increasing signs of stress on the earth’s life support system—its land, air, water, and wildlife—due to the harmful environmental impacts of more people consuming more resources. But a major transition in environmental awareness began around 2010 when a growing number of people began transforming their lifestyles and economies to be more in tune with the ways in which nature had sustained itself for billions of years before humans walked the earth. Over several decades, this combination of environmental awareness and action paid off.

In January of 2060, Emily and Michael celebrated the birth of their grandchild. He was born into a world that was still rich with a great diversity of plants, animals, and ecosystems. The loss of this biological diversity, which had been a looming threat when Michael and Emily were young adults, had slowed to a trickle. And the atmosphere, oceans, lakes, and rivers were gradually cleansing themselves.

Energy waste had been cut in half. Energy from the sun, wind, flowing water, underground heat, and fuels produced from farm-raised grasses and algae had largely replaced energy from highly polluting oil and coal and from nuclear power with its dangerous, long-lived radioactive wastes. By 2050, significant atmospheric warming and the resulting climate change had occurred as many climate scientists had projected in the 1990s. But the threat of further climate change had begun to decrease, as the use of cleaner energy resources became the norm.

By 2060, farmers producing most of the world’s food had shifted to farming practices that helped to conserve water and renew depleted soils. And the human population had peaked at 8 billion in 2040, instead of at the projected 9.5 billion, and then had begun a slow decline.

In 2060, Emily and Michael felt a great sense of pride, knowing that they and their child and countless others had helped to bring about these improvements so that future generations could live more sustainably on this marvelous planet that is our only home.

Sustainability is the capacity of the earth’s natural systems and human cultural systems to survive, flourish, and adapt to changing environmental conditions into the very long-term future. It is about people caring enough to pass on a better world to all the generations to come. And it is the overarching theme of this textbook. Here, we describe the environmental problems we face, and we explore possible solutions. Our goal is to present to you a realistic and hopeful vision of what could be.
1-1 What are three principles of sustainability?

**CONCEPT 1-1A** Nature has sustained itself for billions of years by relying on solar energy, biodiversity, and nutrient cycling.

**CONCEPT 1-1B** Our lives and economies depend on energy from the sun and on natural resources and natural services (natural capital) provided by the earth.

1-2 How are our ecological footprints affecting the earth?

**CONCEPT 1-2** As our ecological footprints grow, we are depleting and degrading more of the earth’s natural capital.

1-3 Why do we have environmental problems?

**CONCEPT 1-3** Major causes of environmental problems are population growth, wasteful and unsustainable resource use, poverty, and the exclusion of environmental costs of resource use from the market prices of goods and services.

1-4 What is an environmentally sustainable society?

**CONCEPT 1-4** Living sustainably means living off the earth’s natural income without depleting or degrading the natural capital that supplies it.

---

**Alone in space, alone in its life-supporting systems, powered by inconceivable energies, mediating them to us through the most delicate adjustments, wayward, unlikely, unpredictable, but nourishing, enlivening, and enriching in the largest degree—is this not a precious home for all of us? Is it not worth our love?**

BARBARA WARD AND RENÉ DUBOS

---

**1-1 What Are Three Principles of Sustainability?**

**CONCEPT 1-1A** Nature has sustained itself for billions of years by relying on solar energy, biodiversity, and nutrient cycling.

**CONCEPT 1-1B** Our lives and economies depend on energy from the sun and on natural resources and natural services (natural capital) provided by the earth.

Environmental Science Is a Study of Connections in Nature

The environment is everything around us, or as the famous physicist Albert Einstein put it, “The environment is everything that isn’t me.” It includes the living and the nonliving things (air, water, and energy) with which we interact in a complex web of relationships that connect us to one another and to the world we live in.

Despite our many scientific and technological advances, we are utterly dependent on the environment for clean air and water, food, shelter, energy, and everything else we need to stay alive and healthy. As a result, we are part of, and not apart from, the rest of nature.

This textbook is an introduction to environmental science, an interdisciplinary study of how humans interact with the living and nonliving parts of their environment. It integrates information and ideas from the natural sciences such as biology, chemistry, and geology; the social sciences such as geography, economics, and political science; and the humanities such as philosophy and ethics. The three goals of environmental science are to learn how nature works, to understand how we interact with the environment, and to find ways to deal with environmental problems and to live more sustainably.

A key component of environmental science is ecology, the biological science that studies how organisms, or living things, interact with one another and
with their environment. Every organism is a member of a certain species, a group of organisms that have a unique set of characteristics that distinguish them from all other organisms and, for organisms that reproduce sexually, can mate and produce fertile offspring. For example, all humans are members of a species that biologists have named Homo sapiens sapiens. (See Supplement 5, p. S18).

A major focus of ecology is the study of ecosystems. An ecosystem is a set of organisms within a defined area or volume that interact with one another and with and their environment of nonliving matter and energy. For example, a forest ecosystem consists of plants (especially trees), animals, and tiny microorganisms that decompose organic materials and recycle their chemicals, all interacting with one another and with solar energy and the chemicals in the ecosystem's air, water, and soil.

We should not confuse environmental science and ecology with environmentalism, a social movement dedicated to protecting the earth’s life-support systems for all forms of life. Environmentalism is practiced more in the political and ethical arenas than in the realm of science.

Nature’s Survival Strategies Follow Three Principles of Sustainability

Nature has been dealing with significant changes in environmental conditions that affect the planet for at least 3.5 billion years. This is why many environmental experts say that when we face an environmental change that becomes a problem for us or other species, we should learn how nature has dealt with such changes and then mimic nature’s solutions.

In our study of environmental science, the most important question we can ask is, how did the incredible variety of life on the earth sustain itself for at least 3.5 billion years in the face of catastrophic changes in environmental conditions? Such changes had various causes, including gigantic meteorites impacting the earth, ice ages lasting for hundreds of millions of years, and long warming periods during which melting ice raised sea levels by hundreds of feet.

Considering the billions of years that life has existed on the earth, our species has been around for less than the blink of an eye (Figure 1-2). We named ourselves Homo sapiens sapiens (Latin for “wise man”). With our large and complex brains and language ability, we are a very smart species, but it remains to be seen whether we are as wise as we claim to be. Within only a few hundred years, we have taken over most of the earth to support our basic needs and rapidly growing wants. But in the process, we have degraded much of the earth. Many argue that a species in the process of degrading its own life-support system could not be considered wise.

To learn how to live more sustainably and thus more wisely, we need to find out how life on the earth has sustained itself. Our research leads us to believe that in the face of drastic environmental changes, there are three overarching themes relating to the long-term sustainability of life on this planet: solar energy, biodiversity, and chemical cycling (Concept 1-1A), as summarized in Figure 1-3 (p. 8). In other words, rely on the sun, promote multiple options for life, and reduce waste. These
powerful and simple ideas make up three principles of sustainability that we use throughout this book to guide us in living more sustainably.

- **Reliance on solar energy:** The sun warms the planet and supports photosynthesis—a complex chemical process used by plants to provide the nutrients, or chemicals that most organisms need in order to stay alive and reproduce. Without the sun, there would be no plants, no animals, and no food. The sun also powers indirect forms of solar energy such as wind and flowing water, which we can use to produce electricity.

- **Biodiversity** (short for biological diversity): This refers to the astounding variety of organisms, the natural systems in which they exist and interact (such as deserts, grasslands, forests, and oceans), and the natural services that these organisms and living systems provide free of charge (such as renewal of topsoil, pest control, and air and water purification). Biodiversity also provides countless ways for life to adapt to changing environmental conditions. Without it, most life would have been wiped out long ago.

- **Chemical cycling:** Also referred to as nutrient cycling, this circulation of chemicals from the environment (mostly from soil and water) through organisms and back to the environment is necessary for life. Natural processes keep this cycle going, and the earth receives no new supplies of these chemicals. Thus, for life to sustain itself, these nutrients must be cycled in this way, indefinitely. Without chemical cycling, there would be no air, no water, no soil, no food, and no life.
Sustainability Has Certain Key Components

*Sustainability,* the central integrating theme of this book, has several critical components that we use as subthemes. One such component is **natural capital**—the natural resources and natural services that keep us and other forms of life alive and support our human economies (Figure 1-4).

**Natural resources** are materials and energy in nature that are essential or useful to humans. They are often classified as **renewable resources** (such as air, water, soil, plants, and wind) or **nonrenewable resources** (such as copper, oil, and coal). **Natural services** are processes in nature, such as purification of air and water and renewal of topsoil, which support life and human economies.

In economic terms, **capital** refers to money and other forms of wealth that can support a person, a population, or an economy. It can provide a sustainable income if we use it properly—that is, if we do not spend it too quickly. If we protect capital by careful investment and spending, it can last indefinitely. Similarly, natural capital can support the earth’s diversity of species as long as we use its natural resources and services in a sustainable fashion.

![Natural Capital Diagram](image)

**Figure 1-4** These key **natural resources** (blue) and **natural services** (orange) support and sustain the earth’s life and human economies (*Concept 1-1A*).
One vital natural service is nutrient cycling (Figure 1-5), an important component of which is topsoil, the upper layer of any soil in which plants can grow. It provides the nutrients that support plants, animals, and microorganisms living on land. Without nutrient cycling in topsoil, life as we know it could not exist. Hence, it is the basis for one of the three principles of sustainability.

Natural capital is supported by energy from the sun—another of the principles of sustainability (Figure 1-3). Without solar energy, natural capital and the life it supports would collapse. Thus, our lives and economies depend on energy from the sun, and on natural resources and natural services (natural capital) provided by the earth (Concept 1-1B).

A second component of sustainability—and another subtheme of this text—is to recognize that many human activities can degrade natural capital by using normally renewable resources faster than nature can restore them, and by overloading natural systems with pollution and wastes. For example, in some parts of the world, we are clearing mature forests much faster than they can grow back (Figure 1-6), eroding topsoil faster than nature can renew it, and withdrawing groundwater that was stored for thousands of years faster than nature can replenish it. We are also loading some rivers, lakes, and oceans with chemical and animal wastes faster than these bodies of water can cleanse themselves.

This leads us to a third component of sustainability: solutions. While environmental scientists search for solutions to problems such as the unsustainable use of forests and other forms of natural capital, their work is limited to finding the scientific solutions. The political solutions are left to political processes. For example, a scientific solution to the problem of depletion of forests might be to stop burning and cutting down biologically diverse, mature forests and to allow nature to replenish them. A scientific solution to the problem of pollution of rivers might be to prevent the dumping of chemicals and wastes into streams and allow them to recover naturally. But to implement such solutions, governments would probably have to enact and enforce environmental laws and regulations.

Figure 1-5 Nutrient cycling: This important natural service recycles chemicals needed by organisms from the environment (mostly from soil and water) through those organisms and back to the environment.

Figure 1-6 Natural capital degradation: This was once a large area of diverse tropical rain forest in Brazil, but it has now been cleared to grow soybeans. According to ecologist Harold Mooney of Stanford University, conservative estimates suggest that between 1992 and 2008, an area of tropical rain forest larger than the U.S. state of California was destroyed in order to graze cattle and plant crops for food and biofuels.
The search for solutions often involves conflicts. For example, when a scientist argues for protecting a natural forest to help preserve its important diversity of plants and animals, the timber company that had planned to harvest the trees in that forest might protest. Dealing with such conflicts often involves making trade-offs, or compromises—another component of sustainability. For example, the timber company might be persuaded to plant a tree farm, a piece of land systematically planted with a rapidly growing tree species in an area that had already been cleared or degraded, instead of clearing the trees in a diverse natural forest. In return, the company might receive the land at little or no cost and could harvest the trees for income in a fairly short time.

A shift toward environmental sustainability should be based on scientific concepts and results that are widely accepted by experts in a particular field, as discussed in more detail in Chapter 2. But in making such a shift, what each of us does every day is important. In other words, individuals matter. This is another subtheme of this book. Some people are good at thinking of new scientific ideas and innovative solutions. Others are good at putting political pressure on government and business leaders to implement those solutions. In any case, a society’s shift toward sustainability ultimately depends on the actions of individuals, beginning with the daily choices we all make. Thus, sustainability begins at personal and local levels.

Some Resources Are Renewable and Some Are Not

From a human standpoint, a resource is anything that we can obtain from the environment to meet our needs and wants. Some resources such as solar energy, fertile topsoil, and edible wild plants are directly available for use. Other resources such as petroleum, iron, underground water, and cultivated crops become useful to us only with some effort and technological ingenuity. For example, petroleum was just a mysterious, oily fluid until we learned how to find and extract it and convert it into gasoline, heating oil, and other products.

Resources vary in terms of how quickly we can use them up and how well nature can replenish them after we use them. Solar energy is called a perpetual resource because its supply is continuous and is expected to last at least 6 billion years, while the sun completes its life cycle. A resource that takes anywhere from several days to several hundred years to be replenished through natural processes is a renewable resource, as long as we do not use it up faster than nature can renew it. Examples include forests, grasslands, fish populations, freshwater, fresh air, and fertile topsoil. The highest rate at which we can use a renewable resource indefinitely without reducing its available supply is called its sustainable yield.

Nonrenewable resources are resources that exist in a fixed quantity, or stock, in the earth’s crust. On a time scale of millions to billions of years, geologic processes can renew such resources. But on the much shorter human time scale of hundreds to thousands of years, we can deplete these resources much faster than nature can form them. Such exhaustible stocks include energy resources (such as coal and oil), metallic mineral resources (such as copper and aluminum), and nonmetallic mineral resources (such as salt and sand).

As we deplete such resources, human ingenuity can often find substitutes. For example, during this century, a mix of renewable energy resources such as wind, the sun, flowing water, and the heat in the earth’s interior could reduce our dependence on nonrenewable fuel resources such as oil and coal. Also, various types of plastics (some made from plants) and composite materials can replace certain metals. But sometimes there is no acceptable or affordable substitute.

We can recycle or reuse some nonrenewable resources, such as copper and aluminum, to extend their supplies. Reuse involves using a resource over and over in the same form. For example, we can collect, wash, and refill glass bottles many times (Figure 1-7). Recycling involves collecting waste materials (Figure 1-8, p. 12) and processing them into new materials. For example, we can crush and melt discarded aluminum to make new aluminum cans or other aluminum products. But we cannot recycle energy resources such as oil and coal. Once burned, their concentrated energy is no longer available to us. Reuse and recycling are two

---

*We use the opening Core Case Study as a theme to connect and integrate much of the material in each chapter. The arrow logo indicates these connections.

---

Figure 1-7 Reuse: This child and his family in Katmandu, Nepal, collect beer bottles and sell them for cash to a brewery that will reuse them.
ways to live more sustainably (Core Case Study) by following one of nature’s three principles of sustainability (Figure 1-3).

Recycling nonrenewable metallic resources uses much less energy, water, and other resources and produces much less pollution and environmental degradation than exploiting virgin metallic resources. Reusing such resources (Figure 1-7) requires even less energy, water, and other resources and produces less pollution and environmental degradation than recycling does.

Countries Differ in Levels of Unsustainability

Very few people consciously want to degrade their environment. In the past, most have done so probably without realizing it. But as the human population grows, more and more people seek to satisfy their needs and wants by using more resources. Governmental and societal leaders are charged with making this possible by maintaining and expanding their national economies, which can lead to growing environmental problems.

Economic growth is an increase in a nation’s output of goods and services. It is usually measured by the percentage of change in a country’s gross domestic product (GDP), the annual market value of all goods and services produced by all businesses, foreign and domestic, operating within a country. Changes in a country’s economic growth per person are measured by per capita GDP, the GDP divided by the total population at midyear.

While economic growth provides people with more goods and services, economic development is an effort to use economic growth to improve living standards. The United Nations (UN) classifies the world’s countries as economically more developed or less developed, based primarily on their average income per person. The more-developed countries are those with high average income and they include the United States, Canada, Japan, Australia, New Zealand, and most European countries. According to UN and World Bank data, the more-developed countries, with only 19% of the world’s population, use about 88% of all resources and produce about 75% of the world’s pollution and waste.

All other nations, in which 81% of the world’s people live, are classified as less-developed countries, most of them in Africa, Asia, and Latin America. Some are middle-income, moderately-developed countries such as China, India, Brazil, Turkey, Thailand, and Mexico. Others are low-income, least-developed countries such as the Congo, Haiti, Nigeria, and Nicaragua. (See Figure 2, p. S32, in Supplement 8 for a map of high-, upper-middle-, lower-middle-, and low-income countries.)

1-2 How Are Our Ecological Footprints Affecting the Earth?

As our ecological footprints grow, we are depleting and degrading more of the earth’s natural capital.

We Are Living Unsustainably

The bad news is that according to a massive and growing body of scientific evidence, we are living unsustainably by wasting, depleting, and degrading the earth’s natural capital at an accelerating rate. The entire process is known as environmental degradation, summarized in Figure 1-9. We also refer to this as natural capital degradation.

We are a civilization in serious trouble. In many parts of the world, potentially renewable forests are...
shrinking, deserts are expanding, soils are eroding, and agricultural lands are deteriorating. In addition, the lower atmosphere is warming, glaciers are melting, sea levels are rising, and floods, droughts, severe weather, and forest fires are increasing in some areas. In many areas, potentially renewable rivers are running dry, harvests of many species of edible fish are dropping sharply, and coral reefs are disappearing. Species are becoming extinct at least 100 times faster than they were in pre-human times, and this rate is expected to increase.

In 2005, the UN released its *Millennium Ecosystem Assessment*. According to this 4-year study by 1,360 experts from 95 countries, human activities have degraded about 60% of the earth’s natural services (Figure 1-4), mostly in the past 50 years. In its summary statement, the report warned that “human activity is putting such a strain on the natural functions of Earth that the ability of the planet’s ecosystems to sustain future generations can no longer be taken for granted.”

The good news, also included in the UN report, is that we have the knowledge and tools to conserve rather than degrade or destroy the planet’s natural capital, and there are a number of common-sense strategies for doing so.

**Pollution Comes from a Number of Sources**

One of the earliest problems environmental scientists have addressed, and one that is basic to many other environmental issues, is pollution—any presence within the environment of a chemical or other agent such as noise or heat at a level that is harmful to the health, survival, or activities of humans or other organisms. Polluting substances, or pollutants, can enter the environment naturally, such as from volcanic eruptions, or through human activities, such as the burning of coal or gasoline, and the dumping of chemicals into rivers and oceans.

The pollutants we produce come from two types of sources. **Point sources** are single, identifiable sources. Examples are the smokestack of a coal-burning power or industrial plant (Figure 1-10, p. 14), the drainpipe of a factory, and the exhaust pipe of an automobile. **Non-point sources** are dispersed and often difficult to identify. Examples are pesticides blown from the land into the air and the runoff of fertilizers, pesticides, and trash.

**RESEARCH FRONTIER**

Gaining better and more comprehensive information about the state of the earth’s natural capital and the health of its life-support systems; see www.cengage.com/login.

---

*Environmental science is a developing field with many exciting research frontiers that are identified throughout this book.

**HOW WOULD YOU VOTE?**

Do you believe that the society you live in is on an unsustainable path? Cast your vote online at www.cengage.com/login.
Pollutants can have three types of unwanted effects. First, they can disrupt or degrade life-support systems for humans and other species. Second, they can damage wildlife, human health, and property. Third, they can create nuisances such as noise and unpleasant smells, tastes, and sights.

We have tried to deal with pollution in two very different ways. One method is pollution cleanup, or output pollution control, which involves cleaning up or diluting pollutants after we have produced them. The other method is pollution prevention, or input pollution control, which reduces or eliminates the production of pollutants.

Environmental scientists have identified three problems with relying primarily on pollution cleanup. First, it is only a temporary bandage as long as population and consumption levels grow without corresponding improvements in pollution control technology. For example, adding catalytic converters to car exhaust systems has reduced some forms of air pollution. At the same time, increases in the number of cars and the total distance each car travels have reduced the effectiveness of this cleanup approach.

Second, cleanup often removes a pollutant from one part of the environment only to cause pollution in another. For example, we can collect garbage, but the garbage is then burned (possibly causing air pollution and leaving toxic ash that must be put somewhere), dumped on the land (possibly causing water pollution through runoff or seepage into groundwater), or buried (possibly causing soil and groundwater pollution).

Third, once pollutants become dispersed into the environment at harmful levels, it usually costs too much to reduce them to acceptable levels.

We need both pollution prevention (front-of-the-pipe) and pollution cleanup (end-of-the-pipe) solutions. But environmental scientists and some economists urge us to put more emphasis on prevention because it works better and in the long run is cheaper than cleanup.

The Tragedy of the Commons: Overexploiting Commonly Shared Renewable Resources

There are three types of property or resource rights. One is private property, where individuals or companies own the rights to land, minerals, or other resources. A second is common property, where the rights to certain resources are held by large groups of individuals. For example, roughly one-third of the land in the United States is owned jointly by all U.S. citizens and held and managed for them by the government.

A third category consists of open-access renewable resources, owned by no one and available for use by anyone at little or no charge. Examples of such shared renewable resources include the atmosphere, underground water supplies, and the open ocean and its marine life.
Many common-property and open-access renewable resources have been degraded. In 1968, biologist Garrett Hardin (1915–2003) called such degradation the *tragedy of the commons*. It occurs because each user of a shared common resource or open-access resource reasons, “If I do not use this resource, someone else will. The little bit that I use or pollute is not enough to matter, and anyway, it’s a renewable resource.”

When the number of users is small, this logic works. Eventually, however, the cumulative effect of many people trying to exploit a shared resource can degrade it and eventually exhaust or ruin it. Then no one can benefit from it. Such degradation threatens our ability to ensure the long-term economic and environmental sustainability of open-access resources such as the atmosphere or fish species in the ocean.

There are two major ways to deal with this difficult problem. One is to use a shared renewable resource at a rate well below its estimated sustainable yield by using less of the resource, regulating access to the resource, or doing both. For example, governments can establish laws and regulations limiting the annual harvests of various types of ocean fish that we are harvesting at unsustainable levels, and regulating the amount of pollutants we add to the atmosphere or the oceans.

The other way is to convert open-access renewable resources to private ownership. The reasoning is that if you own something, you are more likely to protect your investment. That may be so, but this approach is not practical for global open-access resources such as the atmosphere and the ocean, which cannot be divided up and sold as private property.

**Ecological Footprints: A Model of Unsustainable Use of Resources**

Many people in less-developed countries struggle to survive. Their individual use of resources and the resulting environmental impact is low and is devoted mostly to meeting their basic needs (Figure 1-12, top). However, altogether, people in some extremely poor countries clear virtually all available trees to get enough wood to use for heating and cooking. In such cases, short-term survival is a more urgent priority than long-term sustainability. By contrast, many individuals in more-developed nations enjoy *affluence*, or wealth, consuming large amounts of resources far beyond their basic needs (Figure 1-12, bottom).

---

**Figure 1-12 Patterns of natural resource consumption:** The top photo shows a family of five subsistence farmers with all their possessions. They live in the village of Shingkhey, Bhutan, in the Himalaya Mountains, which are sandwiched between China and India in South Asia. The bottom photo shows a typical U.S. family of four living in Pearland, Texas, with their possessions.
Supplying people with renewable resources results in wastes and pollution, and can have an enormous environmental impact. We can think of it as an ecological footprint—the amount of biologically productive land and water needed to provide the people in a particular country or area with an indefinite supply of renewable resources and to absorb and recycle the wastes and pollution produced by such resource use. (The developers of this tool chose to focus on renewable resources, although the use of nonrenewable resources also contributes to environmental impacts.) The per capita ecological footprint is the average ecological footprint of an individual in a given country or area.

If a country’s (or the world’s) total ecological footprint is larger than its biological capacity to replenish its renewable resources and to absorb the resulting wastes and pollution, it is said to have an ecological deficit. In other words, it is living unsustainably by depleting its natural capital instead of living off the income provided by such capital. In 2008, the World Wildlife Fund (WWF) and the Global Footprint Network estimated that humanity’s global ecological footprint exceeded the earth’s biological capacity to support humans and other forms of life indefinitely by at least 30% (Figure 1-13, bottom left). That figure was about 88% in high-income countries such as the United States.

In other words, humanity is living unsustainably. According to the WWF, we need roughly the equivalent of at least 1.3 earths to provide an endless supply of renewable resources at their current average rate of use per person and to dispose of the resulting pollution and wastes indefinitely. If the number of people and the average rate of use of renewable resources per person continue growing as projected, by around 2035, we will need the equivalent of two planet earths (Figure 1-13, bottom, right) to supply such resources indefinitely (Concept 1-2). (In Supplement 8, see Figure 7, pp. S38–S39, for a map of the human ecological footprint for the world, and Figure 8, p. S40, for a map of countries that are either ecological debtors or ecological creditors. For more on this subject, see the Guest Essay by Michael Cain at CengageNOW™.)

The per capita ecological footprint is an estimate of how much of the earth’s renewable resources an individual consumes. Next to the oil-rich United Arab Emirates, the United States has the world’s second largest per capita ecological footprint. In 2003 (the latest data available), the U.S. per capita ecological footprint was about 4.5 times the average global footprint per person, 6 times larger than China’s per capita footprint, and 12 times the average per capita footprint of the world’s low-income countries.

Figure 1-13 Natural capital use and degradation: These graphs show the total and per capita ecological footprints of selected countries (top). In 2008, humanity’s total, or global, ecological footprint was at least 30% higher than the earth’s biological capacity (bottom) and is projected to be twice the planet’s biological capacity by around 2035.

Question: If we are living beyond the earth’s renewable biological capacity, why do you think the human population and per capita resource consumption are still growing rapidly? (Data from Worldwide Fund for Nature, Global Footprint Network, Living Planet Report 2008. See www.footprintnetwork.org/en/index.php/GFN/page/world_footprint/)
Some ecological footprint analysts have attempted to put these measurements in terms of actual land area. Others say that such estimates are debatable, but for rough comparison purposes, they agree that the estimates work well. According to one study, the world’s per capita ecological footprint equals about 5 football fields of land. Other values are 18 football fields per person in the United States, 8 in Germany, and 4 in China.

According to William Rees and Mathis Wackernagel, the developers of the ecological footprint concept, with current technology, it would take the land area of about five more planet Earths for the rest of the world to reach current U.S. levels of renewable resource consumption. Put another way, if everyone consumed as much as the average American does today, the earth could indefinitely support only about 1.3 billion people—not today’s 6.9 billion. At current levels of resource consumption, the land area of the United States could indefinitely sustain about 186 million people. The actual U.S. population in 2010 was 310 million—67% higher than the nation’s estimated biological capacity.

**THINKING ABOUT**

**Your Ecological Footprint**

Estimate your own ecological footprint by visiting the website www.myfootprint.org. Is it larger or smaller than you thought it would be, according to this estimate? Why do you think this is so?

---

**IPAT Is Another Environmental Impact Model**

In the early 1970s, scientists Paul Ehrlich and John Holdren developed a simple model showing how population size ($P$), affluence, or resource consumption per person ($A$), and the beneficial and harmful environmental effects of technologies ($T$) help to determine the environmental impact ($I$) of human activities. We can summarized this model by the simple equation

$$I = P \times A \times T.$$
In most less-developed countries, the key factors in total environmental impact (Figure 1-14, top) are population size and the degradation of renewable resources as a large number of poor people struggle to stay alive. In such countries, where per capita resource use is low, about 1.4 billion poor people struggle to survive on the equivalent of $1.25 a day and about half of the world’s people must live on the equivalent of less than $2.25 a day.

In more-developed countries, high rates of per capita resource use and the resulting high per capita levels of pollution and resource depletion and degradation usually are the key factors determining overall environmental impact (Figure 1-14, bottom). In other words, overconsumption by about 1 billion people is putting tremendous pressure on our life-support systems. To some analysts this factor is more important than the population growth factor.

As the human population continues to grow by more than 80 million people a year, we deplete more topsoil by increasing food production, we drill more and deeper water wells, and we use more energy and spend more money to transport fossil fuels, water, minerals, and food farther. This combination of population growth and increasing resource use per person is depleting nonrenewable mineral and energy resources and degrading renewable resources.

These processes will accelerate as countries with large populations such as China (see the Case Study that follows) and India become more developed and as their per capita resource use grows toward the per capita levels of more-developed countries such as the United States.

**CASE STUDY**

**China’s New Affluent Consumers**

More than a billion super-affluent consumers in more-developed countries are putting immense pressure on the earth’s potentially renewable natural capital and its nonrenewable resources. And more than a billion new consumers are attaining middle-class, affluent lifestyles in 20 rapidly developing middle-income countries, including China, India, Brazil, South Korea, and Mexico. In China and India, the number of middle-class consumers is about 150 million—roughly equal to half of the U.S. population—and the number is growing rapidly. In 2006, the World Bank projected that by 2030 the number of middle-class consumers living in today’s less-developed nations will reach 1.2 billion—about four times the current U.S. population.

China has the world’s largest population and second-largest economy. It is the world’s leading consumer of wheat, rice, meat, coal, fertilizer, steel, and cement, and it is the second-largest consumer of oil after the United States. China leads the world in consumption of goods such as televisions, cell phones, and refrigerators. It has built the world’s largest building, the fastest train, and the biggest dam. It has produced more wind turbines than any other country and will soon become the world’s largest producer of solar cells. In 2009, the number of Internet users in China was greater than the entire U.S. population and this number is growing rapidly. By 2015, China is projected to be the world’s largest producer and consumer of cars, most of them more fuel-efficient than cars produced in the United States and Europe.

On the other hand, after 20 years of industrialization, China now contains two-thirds of the world’s most polluted cities. Some of its major rivers are choked with waste and pollution and some areas of its coastline are basically devoid of fishes and other ocean life. A massive cloud of air pollution, largely generated in China, affects other Asian countries, the Pacific Ocean, and the West Coast of North America.

Suppose that China’s economy continues to grow at a rapid rate and its population size reaches 1.5 billion by around 2025, as projected by some experts. Environmental policy expert Lester R. Brown estimates that if such projections are accurate, China will need two-thirds of the world’s current grain harvest, twice the world’s current paper consumption, and more than all the oil currently produced in the world. According to Brown:

*The western economic model—the fossil fuel-based, automobile-centered, throwaway economy—is not going to work for China. Nor will it work for India, which by 2033 is projected to have a population even larger than China’s, or for the other 3 billion people in developing countries who are also dreaming the “American dream.”*

For more details on China’s growing ecological footprint, see the Guest Essay by Norman Myers for this chapter at CengageNOW.

**Natural Systems Have Tipping Points**

One problem that we face in dealing with environmental degradation is the time delay between the unsustainable use of renewable resources and the resulting harmful environmental effects. Time delays can allow an environmental problem to build slowly until it reaches a threshold level, or ecological tipping point, which causes an often irreversible shift in the behavior of a natural system (Figure 1-15).

Reaching a tipping point is somewhat like stretching a rubber band. We can get away with stretching it to several times its original length. But at some point, we reach an irreversible tipping point where the rubber band breaks.

Three potential tipping points that we now face are the collapse of certain populations of fish due to overfishing; premature extinction of many species resulting from humans overhunting them or reducing their
species, *Homo sapiens sapiens*, has walked the earth for about 200,000 years—less than an eye-blink in the earth’s 3.5 billion years of life (Figure 1-2). Until about 12,000 years ago, we were mostly *hunter–gatherers* who obtained food by hunting wild animals or scavenging their remains, and gathering wild plants. Early hunter–gathers lived in small groups and moved as needed to find enough food for survival.

Since then, three major cultural changes have occurred (Figure 1-16). First was the *agricultural revolution*, which began 10,000–12,000 years ago when humans learned how to grow and breed plants and animals for food, clothing, and other purposes. Second was the *industrial–medical revolution*, beginning about 275 years ago when people invented machines for the large-scale production of goods in factories. This involved learning how to get energy from fossil fuels (such as coal and oil) and how to grow large quantities of food in an efficient manner. It also included medical advances that have allowed a growing number of people to live longer and healthier lives. Finally, the *information–globalization revolution* began about 50 years ago, when we developed new technologies for gaining rapid access to much more information and resources on a global scale.

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

Cultural Changes Have Increased Our Ecological Footprints

*Culture* is the whole of a society’s knowledge, beliefs, technology, and practices, and human cultural changes have had profound effects on the earth.

Evidence of organisms from the past and studies of ancient cultures suggest that the current form of our habitats; and long-term climate change caused in part by the burning of oil and coal, which emits gases into the atmosphere that cause it to warm more rapidly than it would without such emissions. We examine each of these problems in later chapters.

Figure 1-15 In this example of a tipping point, you can control the ball as you push it up to the tipping point. Beyond that point, you lose control. Ecological tipping points can threaten all or parts of the earth’s life-support system.

Figure 1-16 Technological innovations have led to greater human control over the rest of nature and to an expanding human population.
Many environmental scientists and other analysts now call for a fourth major cultural change in the form of a sustainability revolution during this century. This cultural transformation would involve learning how to reduce our ecological footprints and to live more sustainably (Core Case Study). One way to do this is to copy nature by using the three principles of sustainability (Figure 1-3) to guide our lifestyles and economies.

1-3 Why Do We Have Environmental Problems?

Experts Have Identified Four Basic Causes of Environmental Problems

According to a number of environmental and social scientists, the major causes of pollution, environmental degradation, and other environmental problems are population growth, wasteful and unsustainable resource use, poverty, and failure to include the harmful environmental costs of goods and services in their market prices (Figure 1-17) (Concept 1-3).

We discuss in detail all of these causes in later chapters. But let us begin with a brief overview of them.

The Human Population Is Growing Exponentially at a Rapid Rate

Exponential growth occurs when a quantity such as the human population increases at a fixed percentage per unit of time, such as 2% per year. Exponential growth starts off slowly. But eventually, it causes the quantity to double again and again. After only a few doublings, it grows to enormous numbers because each doubling is twice the total of all earlier growth.

Here is an example of the immense power of exponential growth. Fold a piece of paper in half to double its thickness. If you could continue doubling the thickness of the paper 50 times, it would be thick enough to reach almost to the sun—149 million kilometers (93 million miles) away! Hard to believe, isn’t it?

Because of exponential growth in the human population (Figure 1-18), in 2010 there were about 6.9 billion people on the planet. Collectively, these people consume vast amounts of food, water, raw materials, and energy, producing huge amounts of pollution and wastes in the process. Each year, we add more than 80 million people to the earth’s population. Unless death rates rise sharply, there will probably be 9.5 billion of us by 2050. This projected addition of 2.6 billion more people within your lifetime is equivalent to about 8 times the current U.S. population and twice that of China, the world’s most populous nation.

The exponential rate of global population growth has declined some since 1963. Even so, in 2010, we added about 83 million more people to the earth—an average of a about 227,000 people per day. This is roughly equivalent to adding a new U.S. city of Los Angeles, California, every 2 weeks, a new France every 9 months, and a new United States—the world’s third most populous country—about every 4 years.

No one knows how many people the earth can support indefinitely, and at what level of resource con-

Figure 1-17 Environmental and social scientists have identified four basic causes of the environmental problems we face (Concept 1-3). Question: For each of these causes, what are two environmental problems that result?
resources per year to support one American, or 8.3 billion truckloads per year to support the entire U.S. population. Stretched end-to-end, each year these trucks would reach beyond the sun! In its 2006 _Living Planet Report_, the World Wildlife Fund (WWF) estimated that the United States is responsible for almost half of the global ecological footprint (Figure 1-13).

Some analysts say that many affluent consumers in the United States and other more-developed countries are afflicted with _affluenza_—an eventually unsustainable addiction to buying more and more stuff. They argue that this type of addiction fuels our currently unsustainable use of resources, even though numerous studies show that beyond a certain level, more consumption does not increase happiness. Another downside to wealth is that it allows the affluent to obtain the resources they need from almost anywhere in the world without seeing the harmful environmental impacts of their high-consumption, high-waste lifestyles.

On the other hand, affluence can allow for better education, which can lead people to become more concerned about environmental quality. It also provides money for developing technologies to reduce pollution, environmental degradation, and resource waste. As a result, in the United States and most other affluent countries, the air is clearer, drinking water is purer, and most rivers and lakes are cleaner than they were in the 1970s. In addition, the food supply is more abundant and safer, the incidence of life-threatening infectious disease has been greatly reduced, life spans are longer, and some endangered species are being rescued from extinction that may be hastened by human activities.

These improvements in environmental quality were achieved because of greatly increased scientific research and technological advances financed by affluence. And
education spurred many citizens to insist that businesses and governments work toward improving environmental quality (Core Case Study).

**Poverty Has Harmful Environmental and Health Effects**

**Poverty** occurs when people are unable to fulfill their basic needs for adequate food, water, shelter, health, and education. According to a 2008 study by the World Bank, 1.4 billion people—one of every five people on the planet and almost five times the number of people in the United States—live in extreme poverty (Figure 1-19) and struggle to live on the equivalent of less than $1.25 a day. (All dollar figures used in this book are in U.S. dollars.) Could you do this?

Poverty causes a number of harmful environmental and health effects (Figure 1-20). The daily lives of the world’s poorest people are focused on getting enough food, water, and fuel for cooking and heating to survive. Desperate for short-term survival, some of these individuals degrade potentially renewable forests, soils, grasslands, fisheries, and wildlife at an ever-increasing rate. They do not have the luxury of worrying about long-term environmental quality or sustainability. Even though the poor in less-developed countries have no choice but to use very few resources per person, their large population size leads to a high overall environmental impact (Figure 1-14, top).

**CONNECTIONS**

**Poverty and Population Growth**

To many poor people, having more children is a matter of survival. Their children help them gather fuel (mostly wood and animal dung), haul drinking water, and tend crops and livestock. The children also help to care for their parents in their old age (their 40s or 50s in the poorest countries) because they do not have social security, health care, and retirement funds. This is largely why populations in some less-developed countries continue to grow at high rates.

While poverty can increase some types of environmental degradation, the converse is also true. Pollution and environmental degradation have a severe impact on the poor and can increase their poverty. Consequently, many of the world’s poor people die prematurely from several preventable health problems. One such problem is malnutrition caused by a lack of protein and other nutrients needed for good health (Figure 1-21). The resulting weakened condition can increase an individual’s chances of death from normally nonfatal ailments such as diarrhea and measles.

A second health problem is limited access to adequate sanitation facilities and clean drinking water. More than 2.6 billion people—more than 8 times the population of the United States—have no decent bathroom facilities. They are forced to use backyards, alleys, ditches, and streams. As a result, a large portion of these
THINKING ABOUT
The Poor, the Affluent, and Rapidly Increasing Population Growth
Some see the rapid population growth of the poor in less-developed countries as the primary cause of our environmental problems. Others say that the much higher resource use per person in more-developed countries is a more important factor. Which factor do you think is more important? Why?

Prices Do Not Include the Value of Natural Capital

Another basic cause of environmental problems has to do with how goods and services are priced in the marketplace.

Companies using resources to provide goods for consumers generally are not required to pay for the harmful environmental costs of supplying such goods. For example, fishing companies pay the costs of catching fish but do not pay for the depletion of fish stocks. Timber companies pay the cost of clear-cutting forests but do not pay for the resulting environmental degradation and loss of wildlife habitat. The primary goal of these companies is to maximize profits for their owners or stockholders, which is how capitalism works. Indeed, it would be economic suicide for them to add these costs to their prices unless government regulations created a level economic playing field by using taxes or regulations to require all businesses to pay for the environmental costs of producing their products.

As a result, the prices of goods and services do not include their harmful environmental costs (Figure 1-22, p. 24). So consumers have no effective way to evaluate the harmful effects, on their own health and on the earth’s life-support systems, of producing and using these goods and services.

Another problem arises when governments (taxpayers) give companies subsidies such as tax breaks and payments to assist them with using resources to run their businesses. This helps to create jobs and stimulate economies. But it can also degrade natural capital because, again, the companies do not include the value of the natural capital in the market prices of their goods and services. Indeed, environmentally harmful subsidies encourage the depletion and degradation of natural capital. (See the Guest Essay for this chapter about these subsidies by Norman Myers at CengageNOW.)

We can live more sustainably (Core Case Study) by including in their market prices the harmful environmental costs of the goods and services we use. Two ways to do this over the next two decades are to shift from earth-degrading government subsidies to earth-sustaining subsidies, and to tax pollution and waste heavily while reducing taxes on income and wealth. We discuss such subsidy shifts and tax shifts in Chapter 23.
Another challenge we face is that people differ over the seriousness of the world’s environmental problems and what we should do to help solve them. This can delay our dealing with these problems, which can make them harder to solve.

Differing opinions about environmental problems arise mostly out of differing environmental worldviews. Your environmental worldview is your set of assumptions and values reflecting how you think the world works and what you think your role in the world should be. Consciously or unconsciously, we base most of our actions on our worldviews. Environmental ethics, which are beliefs about what is right and wrong with how we treat the environment, are an important element in our worldviews. Here are some important ethical questions relating to the environment:

- Why should we care about the environment?
- Are we the most important beings on the planet or are we just one of the earth’s millions of different life-forms?
- Do we have an obligation to see that our activities do not cause the extinction of other species? Should we try to protect all species or only some? How do we decide which ones to protect?
- Do we have an ethical obligation to pass on to future generations the extraordinary natural world in a condition that is at least as good as what we inherited?
- Should every person be entitled to equal protection from environmental hazards regardless of race, gender, age, national origin, income, social class, or any other factor? This is the central ethical and political issue for what is known as the environmental justice movement. (See the Guest Essay by Robert D. Bullard at CengageNOW.)
- How do we promote sustainability?

**THINKING ABOUT Our Responsibilities**

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

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

The planetary management worldview holds that we are separate from and in charge of nature, that nature exists mainly to meet our needs and increasing wants, and that we can use our ingenuity and technology to manage the earth’s life-support systems, mostly for our benefit, indefinitely.

The stewardship worldview holds that we can and should manage the earth for our benefit, but that we have an ethical responsibility to be caring and responsible managers, or stewards, of the earth. It says...
What Is an Environmentally Sustainable Society?

Environmentally Sustainable Societies Protect Natural Capital and Live Off Its Income

According to most environmental scientists, our ultimate goal should be to achieve an environmentally sustainable society—one that meets the current and future basic resource needs of its people in a just and equitable manner without compromising the ability of future generations to meet their basic needs (Core Case Study).

Imagine you win $1 million in a lottery. Suppose you invest this money (your capital) and earn 10% interest per year. If you live on just the interest, or the income made by your capital, you will have a sustainable annual income of $100,000 that you can spend each year indefinitely without depleting your capital. However, if you spend $200,000 per year, while still allowing interest to accumulate, your capital of $1 million will be gone early in the seventh year. Even if you spend only $110,000 per year and allow the interest to accumulate, you will be bankrupt early in the eighteenth year.

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

The same lesson applies to our use of the earth’s natural capital—the global trust fund that nature has provided for us, our children and grandchildren (Figure 1-1), and the earth’s other species. Living sustainably means living on natural income, the renewable resources such as plants, animals, and soil provided by the earth’s natural capital. It also means not depleting or degrading the earth’s natural capital, which supplies this income, and providing the human population with adequate and equitable access to this natural capital and natural income for the foreseeable future (Concept 1-4).

There is considerable and growing evidence that we are living unsustainably. A glaring example of this is our growing total and per capita ecological footprints (Figure 1-13).

We Can Work Together to Solve Environmental Problems

Making the shift to more sustainable societies and economies includes building what sociologists call social capital. This involves getting people with different views and values to talk and listen to one another, to find common ground based on understanding and trust, and to work together to solve environmental and other problems facing our societies.

Solutions to environmental problems are not black and white, but rather are all shades of gray, because proponents of all sides of these issues have some legitimate and useful insights. In addition, any proposed solution has short- and long-term advantages and disadvantages that we must evaluate. This means that citizens need to work together to find trade-off solutions to environmental problems—an important theme of this book. They can also try to agree on shared visions of the future and work together to develop strategies for implementing such visions beginning at the local level, as the citizens of Chattanooga, Tennessee (USA), have done.

CASE STUDY

The Environmental Transformation of Chattanooga, Tennessee

Local officials, business leaders, and citizens have worked together to transform Chattanooga, Tennessee, from a highly polluted city to one of the most sustainable and livable cities in the United States (Figure 1-23, p. 26).

During the 1960s, U.S. government officials rated Chattanooga as one of the dirtiest cities in the United States. Its air was so polluted by smoke from its industries that people sometimes had to turn on their vehicle headlights in the middle of the day. The Tennessee River, flowing through the city’s industrial center, bubbled with toxic waste. People and industries fled the downtown area and left a wasteland of abandoned and polluting factories, boarded-up buildings, high unemployment, and crime.

we should encourage environmentally beneficial forms of economic growth and development and discourage environmentally harmful forms.

The environmental wisdom worldview holds that we are part of, and dependent on, nature and that nature exists for all species, not just for us. According to this view, our success depends on learning how life on earth sustains itself (Figure 1-3 and back cover of this book) and integrating such environmental wisdom into the ways we think and act.
In 1984, the city decided to get serious about improving its environmental quality. Civic leaders started a Vision 2000 process with a 20-week series of community meetings in which more than 1,700 citizens from all walks of life gathered to build a consensus about what the city could be at the turn of the century. Citizens identified the city’s main problems, set goals, and brainstormed thousands of ideas for solutions.

By 1995, Chattanooga had met most of its original goals. The city had encouraged zero-emission industries to locate there and replaced its diesel buses with a fleet of quiet, zero-emission electric buses, made by a new local firm.

The city also launched an innovative recycling program after environmentally concerned citizens blocked construction of a new garbage incinerator that would have emitted harmful air pollutants. These efforts paid off. Since 1989, the levels of the seven major air pollutants in Chattanooga have been lower than the levels required by federal standards.

Another project involved renovating much of the city’s low-income housing and building new low-income rental units. Chattanooga also built the nation’s largest freshwater aquarium, which became the centerpiece for downtown renewal. The city developed a riverfront park along both banks of the Tennessee River, where it runs through town. The park draws more than 1 million visitors per year. As property values and living conditions have improved, people and businesses have moved back downtown.

In 1993, the community began the process again in Revision 2000. Goals included transforming an abandoned and blighted area in South Chattanooga into a mixed community of residences, retail stores, and zero-emission industries where employees can live near their workplaces. Most of these goals have been implemented.

Chattanooga’s environmental success story, based on people working together to produce a more livable and sustainable city, is a shining example of what other cities could do by building their social capital.

**Individuals Matter**

Chattanooga’s story shows that a key to finding solutions to environmental problems and making a transition to more sustainable societies is to recognize that most social change results from individual actions and individuals acting together to bring about change through bottom-up grassroots action. In other words, *individuals matter*—another important theme of this book.

Here are two pieces of good news: *First,* research by social scientists suggests that it takes only 5–10% of the population of a community, a country, or the world to bring about major social change. *Second,* such research also shows that significant social change can occur in a much shorter time than most people think.

Anthropologist Margaret Mead summarized our potential for social change: “Never doubt that a small group of thoughtful, committed citizens can change the world. Indeed, it is the only thing that ever has.”

Scientific evidence indicates that we have perhaps 50 years and no more than 100 years to make a new cul-
A natural shift from unsustainable living to more sustainable living, if we start now. Many analysts argue that because these changes could take at least 50 years to implement fully, we now face a critical fork in the road where we must either choose a path toward sustainability or continue on our current unsustainable course. One of the goals of this book is to provide a realistic vision of a more environmentally sustainable future. Instead of immobilizing you with fear, gloom, and doom, we hope to energize you by inspiring realistic hope as you play your role in deciding which path to follow.

Based on the three **principles of sustainability** (Figure 1-3), we can derive three strategies for reducing our ecological footprints, helping to sustain the earth’s natural capital, and making a transition to more sustainable lifestyles and economies (**Core Case Study**). Those strategies are summarized in the **three big ideas** of this chapter:

- **Rely more on renewable energy from the sun,** including indirect forms of solar energy such as wind (Figure 1-24) and flowing water, to meet most of our heating and electricity needs.

- **Protect biodiversity** by preventing the degradation of the earth’s species, ecosystems, and natural processes, and by restoring areas we have degraded (Figure 1-25).

- **Help to sustain the earth’s natural chemical cycles** by reducing the production of wastes and pollution, not overloading natural systems with harmful chemicals, and not removing natural chemicals faster than nature’s cycles can replace them.

**Figure 1-24** Capturing wind power is one of the world’s most rapidly growing and least environmentally harmful ways to produce electricity.

**Figure 1-25** This young child—like the grandchild of Emily and Michael in our fictional scenario of a possible future (**Core Case Study**)—is promoting sustainability by preparing to plant a tree. A global program to plant and tend billions of trees each year will help to restore degraded lands, promote biodiversity, and reduce the threat of climate change from atmospheric warming.
A Vision of a More Sustainable Earth

We face an array of serious environmental problems. This book is about solutions to these problems. A key to most solutions is to apply the three principles of sustainability (Figure 1-3 and the three big ideas listed above) to the design of our economic and social systems, and to our individual lifestyles. We can use such strategies to try to slow the rapidly increasing losses of biodiversity, switch to more sustainable sources of energy, spread more sustainable forms of agriculture and other uses of land and water, sharply reduce poverty, slow human population growth, and create a better world for ourselves and future generations.

If we make the right choices during this century, as Emily and Michael and people like them did in the Core Case Study that opens this chapter, we can create an extraordinary and more sustainable future for ourselves and for most other forms of life on our planetary home. If we get it wrong, we face irreversible ecological disruption that could set humanity back for centuries and wipe out as many as half of the world’s species as well as much of the human population.

You have the good fortune to be a member of the 21st century’s transition generation that will decide which path humanity takes. This means confronting the urgent challenges presented by the major environmental problems discussed in this book. However, those challenges will also present you with opportunities for a promising and exciting future based on working with and for the earth that sustains us. As environmental author and entrepreneur Paul Hawken reminds us, “Working for the earth is not a way to get rich, it is a way to be rich.”

What’s the use of a house if you don’t have a decent planet to put it on?
HENRY DAVID THOREAU

1. Review the Key Questions and Concepts for this chapter on p. 6. What is sustainability and why should we care about it? What are three principles that nature has used to sustain itself for at least 3.5 billion years, and how can we use these principles to live more sustainably?

2. Define environment. Distinguish among environmental science, ecology, and environmentalism. Distinguish between an organism and a species. What is an ecosystem? Define natural capital, natural resources, and natural services. Define nutrient cycling and explain why it is important. Describe how we can degrade natural capital and how finding solutions to environmental problems involves making trade-offs. Explain why individuals matter in dealing with the environmental problems we face.

3. What is a resource? Distinguish between a perpetual resource and a renewable resource and give an example of each. What is sustainable yield? Define and give two examples of a nonrenewable resource. Distinguish between recycling and reuse and give an example of each. What is economic growth? Distinguish between gross domestic product (GDP) and per capita GDP. What is economic development? Distinguish between more-developed countries and less-developed countries.

4. Define and give three examples of environmental degradation (natural capital degradation). Define pollution. Distinguish between point sources and nonpoint sources of pollution. Distinguish between pollution cleanup (output pollution control) and pollution prevention (input pollution control) and give an example of each. Describe three drawbacks to solutions that rely mostly on pollution cleanup. What is the tragedy of the commons?

5. What is an ecological footprint? What is a per capita ecological footprint? Compare the total and per capita ecological footprints of the United States and China. Use the ecological footprint concept to explain how we are living unsustainably. What is the IPAT model for estimating our environmental impact? Explain how we can use this model to estimate the impacts of the human populations in less-developed and more-developed countries. Describe the environmental impacts of China’s new affluent consumers. What is an ecological tipping point?

6. Define culture. Describe three major cultural changes that have occurred since humans were hunter–gatherers. What would a sustainability revolution involve?

7. Identify four basic causes of the environmental problems that we face. What is exponential growth? Describe the past, current, and projected exponential growth of the world’s human population. What is affluence? How do Americans, Indians, and the average people in the poorest countries compare in terms of consumption? What are two types of environmental damage resulting from growing affluence? How can affluence help us to solve environmental problems? What is poverty and what are three of its harmful environmental and health effects? Describe the connection between poverty and population growth.
8. Explain how excluding from the prices of goods and services the harmful environmental costs of producing them affects the environmental problems we face. What is the connection between government subsidies, resource use, and environmental degradation? What is an environmental worldview? What are environmental ethics? Distinguish among the planetary management, stewardship, and environmental wisdom worldviews.


10. How long do some scientists estimate that we have to make a shift to more environmentally sustainable economies and lifestyles? Based on the three principles of sustainability, what are the three best ways to make such a transition as summarized in this chapter’s three big ideas? Explain how we can use these three principles to get us closer to the vision of a sustainable earth described in the Core Case Study that opens this chapter.

Note: Key terms are in **bold** type.

---

## CRITICAL THINKING

1. Do you think you are living unsustainably? Explain. If so, what are the three most environmentally unsustainable components of your lifestyle? List two ways in which you could apply each of the three principles of sustainability (Figure 1-3) to making your lifestyle more environmentally sustainable.

2. Do you believe a vision such as the one described in the Core Case Study that opens this chapter is possible? Why or why not? What, if anything, do you believe will be different from that vision? Explain. If your vision of what it will be like in 2060 is sharply different from that in the Core Case Study, write a description of your vision. Compare your answers to this question with those of your classmates.

3. For each of the following actions, state one or more of the three principles of sustainability (Figure 1-3) that are involved: (a) recycling aluminum cans; (b) using a rake instead of leaf blower; (c) walking or bicycling to class instead of driving; (d) taking your own reusable bags to the grocery store to carry your purchases home; (e) volunteering to help restore a prairie; and (f) lobbying elected officials to require that 20% of your country’s electricity be produced with renewable wind power by 2020.

4. Explain why you agree or disagree with the following propositions:
   a. Stabilizing population is not desirable because, without more consumers, economic growth would stop.
   b. The world will never run out of resources because we can use technology to find substitutes and to help us reduce resource waste.

5. What do you think when you read that (a) the average American consumes 30 times more resources than the average citizen of India; and (b) human activities are projected to make the earth’s climate warmer? Are you skeptical, indignant, sad, helpless, guilty, concerned, or outraged? Which of these feelings can help to perpetuate such problems, and which can help to solve them?

6. When you read that at least 16,400 children age five and younger die each day (13 per minute) from preventable malnutrition and infectious disease, how does it make you feel? Can you think of something that you and others could do to address this problem? What might that be?

7. Explain why you agree or disagree with each of the following statements: (a) humans are superior to other forms of life; (b) humans are in charge of the earth; (c) the value of other forms of life depends only on whether they are useful to humans; (d) based on past extinctions and the history of life on the earth over the last 3.5 billion years, all forms of life eventually become extinct so we should not worry about whether our activities cause their premature extinction; (e) all forms of life have an inherent right to exist; (f) all economic growth is good; (g) nature has an almost unlimited storehouse of resources for human use; (h) technology can solve our environmental problems; (i) I do not believe I have any obligation to other forms of life; (j) I do not believe I have any obligation to future generations; and (k) I do not believe I have any obligation to other forms of life.

8. What are the basic beliefs within your environmental worldview (pp. 24-25)? Record your answer. Then at the end of this course return to your answer to see if your environmental worldview has changed.

9. Are the beliefs included in your environmental worldview (Question 8) consistent with your answers to question 7? Are your actions that affect the environment consistent with your environmental worldview? Explain.

10. List two questions that you would like to have answered as a result of reading this chapter.
**ECOLOGICAL FOOTPRINT ANALYSIS**

If the ecological footprint per person of a country or of the world (Figure 1-13) is larger than its biological capacity per person to replenish its renewable resources and absorb the resulting waste products and pollution, the country or the world is said to have an ecological deficit. If the reverse is true, the country or the world has an ecological credit or reserve. Use the data below to calculate the ecological deficit or credit for the countries listed and for the world. (For a map of ecological creditors and debtors, see Figure 8, p. S40, in Supplement 8.)

<table>
<thead>
<tr>
<th>Place</th>
<th>Per Capita Ecological Footprint (hectares per person)</th>
<th>Per Capita Biological Capacity (hectares per person)</th>
<th>Ecological Credit (+) or Debit (−) (hectares per person)</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>2.2</td>
<td>1.8</td>
<td>− 0.4</td>
</tr>
<tr>
<td>United States</td>
<td>9.8</td>
<td>4.7</td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>1.6</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>India</td>
<td>0.8</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Russia</td>
<td>4.4</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>4.4</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>2.1</td>
<td>9.9</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>4.5</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td>United Kingdom</td>
<td>5.6</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>Mexico</td>
<td>2.6</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td>Canada</td>
<td>7.6</td>
<td>14.5</td>
<td></td>
</tr>
</tbody>
</table>

Source: Data from WWF Living Planet Report 2006.

1. Which two countries have the largest ecological deficits? Why do you think they have such large deficits?
2. Which two countries have an ecological credit? Why do you think each of these countries has an ecological credit?
3. Rank the countries in order from the largest to the smallest per capita ecological footprint.

**LEARNING ONLINE**

**STUDENT COMPANION SITE** Visit this book’s website at www.cengagebrain.com/shop/ISBN/0538735341 and choose Chapter 1 for many study aids and ideas for further reading and research. These include flashcards, practice quizzing, Weblinks, information on Green Careers, and InfoTrac® College Edition articles.

For students with access to premium online resources, log on to www.cengage.com/login.