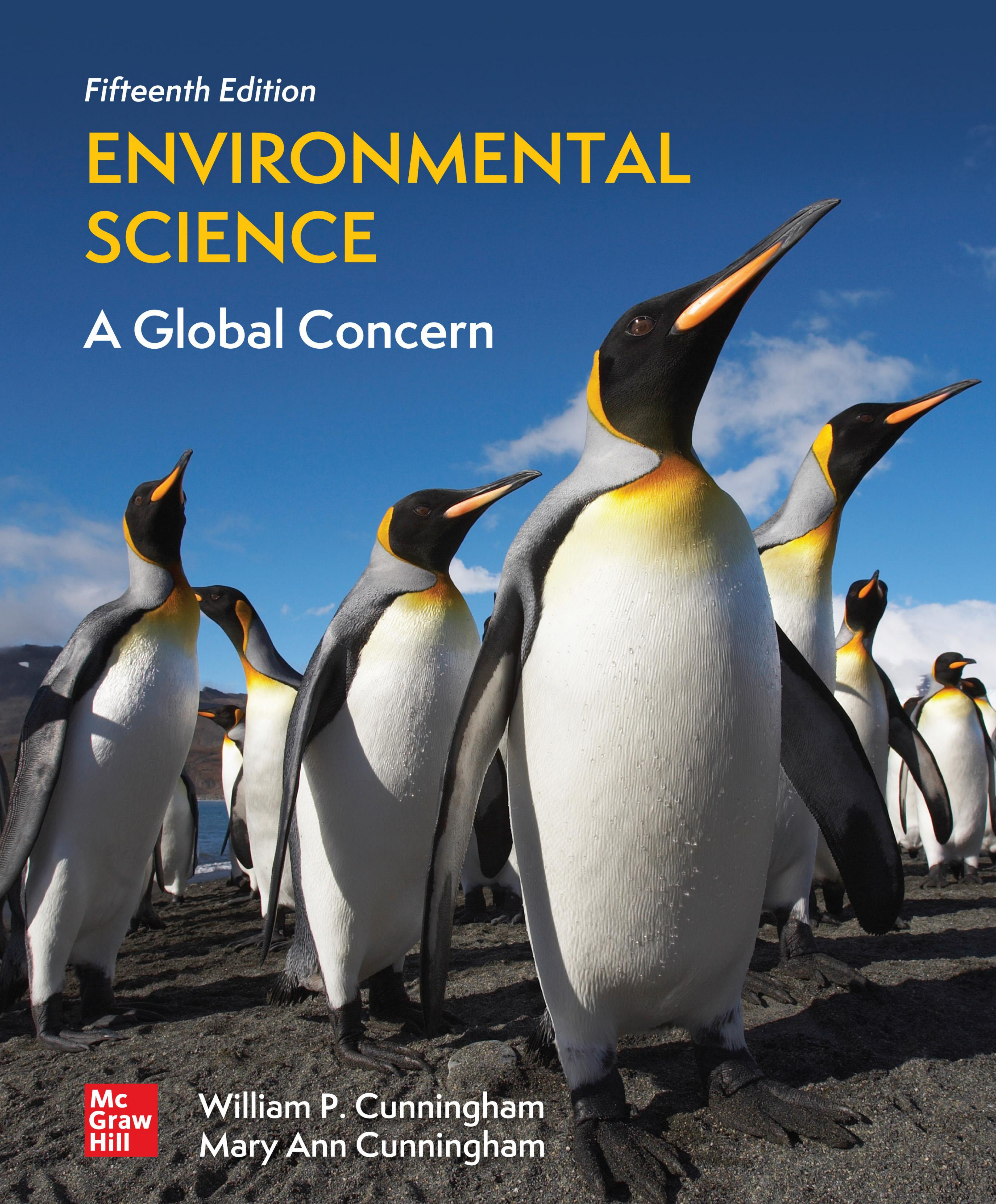
Fifteenth Edition

ENVIRONMENTAL SCIENCE

A Global Concern



McGraw Hill

William P. Cunningham
Mary Ann Cunningham

FIFTEENTH EDITION

Environmental SCIENCE

A Global Concern

William P. Cunningham
University of Minnesota

Mary Ann Cunningham
Vassar College

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ENVIRONMENTAL SCIENCE: A GLOBAL CONCERN, FIFTEENTH EDITION

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William P. Cunningham

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William P. Cunningham is an emeritus professor at the University of Minnesota. In his 38-year career at the university, he taught a variety of biology courses, including Environmental Science, Conservation Biology, Environmental Health, Environmental Ethics, Plant Physiology, and Cell Biology. He is a member of the Academy of Distinguished Teachers, the highest teaching award granted at the University of Minnesota. He was a member of a number of interdisciplinary programs for international students, teachers, and nontraditional students. He also carried out research or taught in Sweden, Norway, Brazil, New Zealand, China, and Indonesia.

Professor Cunningham has participated in a number of governmental and nongovernmental organizations over the past 40 years. He was chair of the Minnesota chapter of the Sierra Club, a member of the Sierra Club national committee on energy policy, vice president of the Friends of the Boundary Waters Canoe Area, chair of the Minnesota governor's task force on energy policy, and a citizen member of the Minnesota Legislative Commission on Energy.

In addition to environmental science textbooks, he edited three editions of the *Environmental Encyclopedia,* published by Thompson-Gale Press. He has also authored or coauthored about 50 scientific articles, mostly in the fields of cell biology and conservation biology, as well as several invited chapters or reports in the areas of energy policy and environmental health. His Ph.D. from the University of Texas was in botany.

Professor Cunningham's hobbies include photography, birding, hiking, gardening, and traveling. He lives in St. Paul, Minnesota, with his wife, Mary. He has three children (one of whom is coauthor of this book) and seven grandchildren.

Both authors have a long-standing interest in the topics in this book. Nearly half the photos in the book were taken on trips to the places they discuss.

Mary Ann Cunningham

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Mary Ann Cunningham is a professor of geography at Vassar College. A biogeographer with interests in landscape ecology, geographic information systems (GIS), and climate impacts on biodiversity and food production, she teaches environmental science, natural resource conservation, land-use planning, and GIS. Field research methods, statistical methods, and data analysis and visualization are regular components of her teaching. Every aspect of this book is woven into, and informed by, her courses and her students' work. As a scientist and an educator, Mary Ann enjoys teaching and conducting research with both science students and non-science liberal arts students. As a geographer, she likes to engage students with the ways their physical surroundings and social context shape their world experience. In addition to teaching at a liberal arts college, she has taught at community colleges and research universities.

Professor Cunningham has been writing in environmental science for nearly two decades, and she has been coauthor of this book since its seventh edition. She is also coauthor of Principles of Environmental Science and an editor of the Environmental Encyclopedia (third edition, Thompson-Gale Press). She has published work on pedagogy in cartography, as well as instructional and testing materials in environmental science, and a GIS lab manual that introduces students to spatial and environmental analysis. She has also been a leader in sustainability programs and climate action planning at Vassar.

In addition to environmental science, Professor Cunningham's primary research activities focus on land-cover change, habitat fragmentation, and distributions of bird populations. This work allows her to conduct field studies in the grasslands of the Great Plains, as well as in the woodlands of the Hudson Valley. In her spare time she loves to travel, hike, and watch birds. Professor Cunningham holds a bachelor's degree from Carleton College, a master's degree from the University of Oregon, and a Ph.D. from the University of Minnesota.

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Brief Contents

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List of Case Studies

About the Cover

King penguins are one of the astonishing and exquisitely adapted species that inhabit our world. They are also among the many species urgently threatened by human activities. Climate change is expected to shift critical feeding areas far from breeding colonies, and rising seas will flood nesting areas; commercial fisheries capture a rising share of the marine food web to support fish farms far away; plastic pollution is growing in the world's marine environments. At the same time, hope for these and other species can be found in global policies and growing cooperation to protect marine reserves, to monitor fisheries, and to curb greenhouse gas emissions. Understanding interconnections in environmental systems is critical to protecting the extraordinary diversity of life around us, and to protecting the ecosystem services on which we also depend. Environmental science helps you explore these interconnections and make sense of this amazing complexity, and the ways survival of these living systems is tied to the well-being of our own communities. Enjoy the journey.

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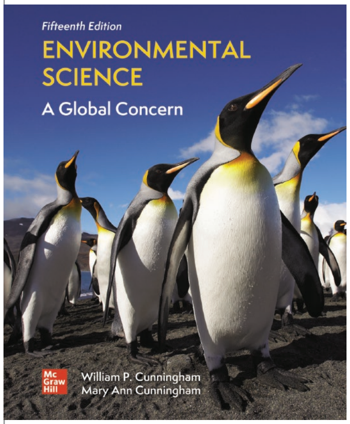
Preface

Environmental Science: A Search for Solutions

Environmental science focuses on understanding challenges that affect our lives, and on finding solutions to those challenges. Your decision to study environmental science is an important step. This field can help you find answers to some of the most important problems facing us today.



Environmental science is an integrative field. It draws on diverse knowledge bases and skills to address issues: For example, preserving healthy ecosystems depends on strategies such as reducing greenhouse gas emissions, developing renewable energy systems, reducing pollution, improving social and environmental justice, improving sustainable farming systems, and reducing resource consumption.

In many ways, environmental science is also an optimistic field. Although you will examine serious environmental challenges in this book, you will also explore many ways you can contribute to finding solutions. Understanding the nature of environmental problems is a first step to fixing them. Learning about new approaches gives you the power to help make a difference, no matter where you come from or what your interests are. For many of us, discovering ways to contribute makes this an exciting and engaging field.

As you will find in the "What Can You Do?" boxes in every chapter, there are countless practical opportunities to protect and sustain natural resources. It doesn't take a huge project to do important work for your local environment. Individuals and small groups have many opportunities to make positive change. As you read this book, look for ways to connect the issues and ideas to your other interests. Whether you are a biologist, a geologist, a chemist, an economist, a political scientist, a writer, or an artist or poet who can capture our imagination, you can find fruitful and interesting ways to connect with the topics in this book.

Sustainable development is a central theme

Several main themes run through this book. As you will read in chapter 1, these include **sustainable development** (including population growth, food production, environmental quality, energy, and resources), **climate change** and its impacts, and fundamentals of how **scientific methods** help us ask and answer questions about the world around us.

These and other themes show both continuing challenges and evidence of progress. **Human population growth** continues, for example, but it is slowing almost everywhere as women's education and economic opportunity allow for small, well-cared-for families. We remain addicted to fossil fuels, but **new energy technologies** now provide reliable alternatives in many countries. Solar, wind, biomass, geothermal energy, and conservation could supply all the energy we need, if we chose to invest in them. **Water quality** and **air pollution** remain dire problems in many areas, but we have shown that we can dramatically improve water quality, air quality, and environmental health, when we put our minds to it.

Governments around the world are acknowledging the costs of environmental degradation and are taking steps to reduce their environmental impacts. From China to Europe to North America and developing countries, policymakers have plans to restore forests, conserve water, reduce air and water pollution, and develop sustainable energy supplies. Public support for environmental protection has been overwhelmingly enthusiastic.

Businesses everywhere increasingly recognize the opportunities in conservation, recycling, producing non-toxic products, and reducing their ecological footprints. New jobs are being created in environmental fields. Public opinion supports environmental protection because voters see the importance of environmental health for the economy, society, and quality of life.

What Sets This Book Apart?

As practicing scientists and educators, we bring to this book decades of experience in the classroom, in the practice of science, and in civic engagement. This experience helps give students a clear sense of what environmental science is and why it matters. Throughout the book, we also provide recent data that underly and inform emerging ideas in the field.

Engaged and active learning

We've given particular attention to learning styles and active learning features in this edition, both in the text and in online **Connect** study materials and supplements. Throughout, the text promotes active, engaged learning practices. In each section heading, **key concepts** identify ideas for students to focus on as they read. **Section reviews** encourage students to check their learning at the end of each main section. These practices of active reading have been shown to improve retention of class topics, as well as higher-order thinking about concepts. **Key terms** at the end of each chapter encourage students to test their understanding. **Critical thinking and discussion questions** and **Data Analysis** exercises push students to explore further the concepts in the text.

A rich collection of online study resources is available on the **Connect** website. **LearnSmart** study resources, practice quizzes, animations, videos, and other resources improve understanding and retention of course material.

The book also engages course material with students' own lives: **What Can You Do?** sections help students identify ways to apply what they are learning to their own lives and communities. **What Do You Think?** readings ask students to critically evaluate their own assessments of a complex problem. We devote a special introduction (**Learning to Learn**) to the ways students can build study habits, take ownership of this course, and practice critical, analytical, and reflective thinking.

Many of these resources are designed as starting points for lectures, discussions in class, essays, lab activities, or projects. Some data analysis exercises involve simple polls of classes, which can be used for graphing and interpretation. Data analysis exercises vary in the kinds of learning and skills involved, and all aim to give students an opportunity to explore data or ideas discussed in the text.

Quantitative reasoning and methods of science

Quantitative reasoning is increasingly recognized as essential in many aspects of education, and this book has greater coverage of this topic, and provides more up-to-date data and graphs, than other books on the market. **Quantitative reasoning** questions in the text push students to evaluate data and graphs they have read about. Attention to statistics, graphing, graph interpretation, and abundant up-to-date data are some of the resources available to help students practice their skills with data interpretation.

Exploring Science readings show how science is done, to demystify the process of answering questions with scientific and quantitative methods. Throughout the text, we emphasize principles and methods of science through discussions of scientific methods, uncertainty and probability, and detailed examination of how scientists observe the world, gather data, and use data to answer relevant questions.

A positive focus on opportunities

Our intent is to empower students to make a difference in their communities by becoming informed, critical thinkers with an awareness of environmental issues and the scientific basis of these issues. Many environmental problems remain severe, but there have been many improvements in recent decades, including cleaner water and cleaner air for most Americans, declining rates of hunger and fertility, and increasing access to education. An entire chapter (chapter 13) focuses on ecological restoration, one of the most important aspects of ecology today. Case studies show examples of real progress, and What Can You Do? sections give students ideas for contributing to solutions. Throughout this text we balance evidence of serious environmental challenges with ideas about what we can do to overcome them.

A balanced presentation for critical thinking

Among the most important practices a student can learn are to think analytically about evidence, to consider uncertainty, and to skeptically evaluate the sources of information. This book offers abundant opportunities to practice the essential skills of critically analyzing evidence, of evaluating contradictory interpretation, and identifying conflicting interests. We ask students to practice critical and reflective thinking in What Do You Think? readings, in end-of-chapter discussion questions, and throughout the text. We present balanced evidence, and we provide the tools for students to discuss and form their own opinions.

An integrated, global perspective

Globalization spotlights the interconnectedness of environmental resources and services, as well as our common interest in how to safeguard them. To remain competitive in a global economy, it is critical that we understand conditions in other countries and cultures. This book provides case studies and topics from regions around the world, with maps and data illustrating global issues. These examples show the integration between environmental conditions at home and abroad.

Google Earth™ placemarks

Our global perspective is supported by placemarks and questions you can explore in Google Earth. This free, online program lets students view detailed satellite images of the earth that aid in understanding the geographical context of topics in the book. Through Connect, students can access placemarks, descriptions, and questions about those places. These stimulate a thoughtful exploration of each site and its surroundings. This interactive geographical exploration is a wonderful tool to give an international perspective on environmental issues.

What's New in This Edition?

This edition has thoroughly updated data, figures, and tables, as well as 16 new opening case studies that reflect new developments in the field, and over a dozen new "Exploring Science" or "What Do You Think?" boxed readings. We have enhanced our focus on climate action and environmental action, something students in our classes find especially valuable. Brief "benchmark data" tables provide reference values or comparisons that reflect key ideas in the chapter. Systematic discussions review topics such as uncertainty, graphing, statistics, experimental design, models, and systems. At the end of each chapter, we conclude with a new section, "Connecting the Dots," that draws together major themes of the chapter.

Specific chapter changes

The Introduction (Learning to learn) explains how each of us can engage with this field. Knowing what you care about is a good way to start connecting your interests to the study of our environment and how it works. We examine the nature of **critical thinking,** and we emphasize that learning to learn helps students not only in studying but in everyday life.

Chapter 1 presents **climate change** as an overarching concern. We introduce **sustainable development** as a topic that runs throughout the book as both a goal and a measure of progress. We discuss new environmental leaders, as well as the idea of **planetary boundaries,** which define limits of environmental services from major sectors of our environment.

Chapter 2 introduces a new case study on camera traps and **citizen science** to monitor migratory wildlife in Tanzania's Serengeti National Park. This example illustrates **study design** as well as ways each of us can contribute to original research. Continuing our discussion of the principles and applications of science, we discuss significance and confidence in data.

Chapter 3 opens with a new case study on the growing hypoxic "dead zone" in the Gulf of Mexico. This case illustrates interconnections in a vast ecological system and shows how chemical elements and energy transfers underlie pollution, wastewater treatment, eutrophication, and other processes. An "Exploring Science" reading reviews the **CRISPR** gene editing system, including ethics of human embryo editing, in this fast-moving field.

Chapter 4 introduces a new contributor to this book. Dr. Kimberly Byrd, a conservation biologist who has revised this crucial chapter. She has written a new case study on the ecological importance of seagrass meadows, including ideas of **ecosystem complexity** and "blue carbon." She has added a discussion of **complex adaptive systems** and system resilience. We hope readers will find her voice refreshing, interesting, and informative.

Chapter 5 has a new case study on **climate-driven shifts** in species ranges and biomes. These ecosystem changes directly affect lives and livelihoods. Recognizing the adaptations that allow species to adapt helps us understand survival factors for both humans and other species. A new section on human **disturbance** to biomes and ecosystems addresses the ways we are transforming the world.

Chapter 6 opens with a new case study on invasive Asian carp in the Mississippi watershed. Millions of dollars in sport fishing, recreation, and ecosystem services are at risk, as well as native species. We discuss growth patterns, life history strategies, and intrinsic and extrinsic factors that regulate growth. A new "Exploring Science" box describes methods for estimating population sizes for species, such as carp, that are difficult to count.

Chapter 7 uses a new case study on the rapid aging of China's population to discuss **population momentum** and factors that influence **birth rates**. China now has the largest number of senior citizens in the world, and has one of the largest percentages of old people of any country. This phenomenon is becoming global, as world population growth has fallen from about 2.1 percent in 1960 to 0.1 percent today. Half us now live in countries where the birth rate just replaces the death rate. We have long called for this shift, but its implications for societies are not entirely clear.

Chapter 8 has an updated case study on perflourocarbons, including an $850 million settlement in 2018 between the state of Minnesota and the 3M corporation for uncontrolled dumping of these persistent chemicals. Developments in **contagious diseases** among humans and wildlife have necessitated major chapter updates. A new section reviews growing transfer of **antibiotic resistance** from livestock that threaten human health. Building on the opening case study, we highlight four widely distributed persistent organic pollutants that threaten the health of millions of people. The "What Do You Think?" box on acceptable risk has also been revised.

Chapter 9 opens with a new case study on low-cost **food security** initiatives in Burkina Faso, one of the world's poorest countries. Farmers there are fighting land degradation and hunger using simple, traditional water conservation and farming techniques to improve food production. We also consider dietery diversity. We have new discussions of climate impacts on food production and on *Diet for a Small Planet*, and eating low on the food chain.

Chapter 10 has an updated opening case study on farming in Brazil's Cerrado. This case became even more urgent with the 2019 election of Jair Bolsonaro, who aims to expand soy production and reduce protections for Amazonian rainforest. Destruction of the world's largest tropical forest has dire implications for our climate and for survival of indigenous people. A new section discusses **carbon farming,** which could be part of the solution to controlling climate change. We also have updated the "What do you Think?" box on the environmental benefits of shade-grown coffee and cocoa.

Chapter 11 leads with a new case study on how the reintroduction of wolves, a top predator, has enhanced **biodiversity** in Yellowstone National Park, with cascading effects through both the food chain and the physical environment. We have emphasized the "climate" component of HIPPO factors in threats to species survival. We have enhanced discussion of the "sixth extinction" and added a boxed reading on the startling crisis of **disappearing insects**. Studies show losses of 80 percent of the flying insect fauna in some areas, with probably profound impacts on biodiversity more broadly.

Chapter 12 has a new case study on ecosystems in transition. Longer fire seasons and more extreme outbreaks of bark beetles threaten to alter western forests, as climate warming has produced the largest, most intense, and most damaging forest fires in U.S. history. Continuing our survey of landscapes in transition, we have added a new "Exploring Science" box on the effects of palm oil plantations on endangered orangutan populations on Borneo. A new "What Do You Think?" box examines new threats to U.S. national monuments from mining and other extractive industries.

Chapter 13 introduces **restoration ecology** with a new case study on the science and practice of restoring coral reefs. At least one-third of all coral reefs have been damaged beyond recovery by pollution, overharvesting, ocean acidification, and climate change. Some experts warn there may be no coral reefs anywhere in the world by the end of this century. But restoration ecologists are exploring innovative strategies for protecting and restoring these amazing systems. A new box on the "monarch highway" project describes both the threats to these charismatic insects and efforts to restore their populations.

Chapter 14 begins an **environmental geology** discussion with a new case study on the proposed Pebble Mine in headwater salmon streams of Alaska's Bristol Bay. This controversial project pits the fate of pristine wilderness and the world's largest sockeye salmon run against the estimated profits and likely environmental damage from a mammoth copper-nickel mine. On one side are about 850 high-paying mining jobs over the expected 20-year life of the mine compared to 12,000 permanent jobs for native people and Alaskan citizens in the salmon fishing industry. This struggle reflects issues in many controversies about earth resources.

Chapter 15 demonstrates leadership in **climate action** with a new case study on groundbreaking climate policy in California. Challenges are daunting, but solutions are diverse, creative, and exciting. We have enhanced the discussion of jet streams and **polar vortex** effects on local weather, as well as the latest IPCC report as well as current information about major greenhouse gases as well as the latest news about polar ice melting and warming seas. A new box illustrates the effects of **black carbon** emissions on climate systems. We also examine options for **carbon capture** and other efforts to combat climate change.

Chapter 16 provides updated data on air pollution as well as updated discussion of the Montreal Protocol on ozone-destroying substances—including the **Kigali Amendment,** which accelerates the phase out of refrigerants that are also critical greenhouse gases. This step alone could prevent 0.5 degrees of global warming by 2100. We increase emphasis of the dangers of air pollution particulates smaller than 2.5 um, and we discuss the problems of air pollution in developing countries.

Chapter 17 updates the opening case study, "When Will Lake Mead Go Dry?" and the demands for Colorado River water that exceed the river's flow. We provide recent data on looming **water shortages,** especially in regions dependent on glacial rivers, as in South Asia. Water is likely to be the most contentious natural resource in the future, but smarter **water conservation** policies, including pricing, irrigation and farming practices, and low-flow household appliances could reduce these risks. We also discuss China's expanding dam-building projects, especially on the Mekong River.

Chapter 18 continues the water resource discussion with the example of the Ganges River, on which nearly a billion people in South Asia depend. We know how to prevent **water pollution,** and we know how to capture and remove pollutants. But finding ways to implement policies and pay for treatment is difficult even in wealthy countries. These challenges are even steeper in developing regions as they struggle to improve health and quality of life.

Chapter 19 presents a new case study on the demise of one of the U.S. coal companies. We emphasize that while fossil fuels still provide most energy, the future of energy is not the past. We update data on production and consumption and discuss the shifting landscape of conventional energy, including growth in China. A new "Exploring Science" box discusses the growing importance of indigenous resistance to new pipelines across their land. We also highlight new debates about nuclear power, which is both expensive and low carbon.

Chapter 20 explores the fast-changing landscape of **renewable energy** with an updated case study on Germany's *Energiewende*, or **energy transition** from fossil fuels to renewable energy. This chapter is heavily revised to reflect new developments in technology and energy production. Explanations of new systems include a discussion of *efficiency* and *power capacity*, as well as battery storage. We examine analysis showing how sustainable energy systems could meet all our needs, often saving money as well as reducing pollution.

Chapter 21 includes an updated case study on the phenomenal amounts of **plastic pollution** in the world's oceans. A new section reviews the options for waste disposal and updates both the amounts and types of materials in our waste stream. We examine China's decision to reject U.S. recycling and what this means for waste management.

Chapter 22 opens with a new case study showing how cities are leading efforts to become environmentally, socially, and economically sustainable. We update data on **urban growth,** especially in African states, where some cities may have 100 million residents by the end of this century. How will these cities manage pollution, traffic, energy, food, and water supplies? We also examine the plight of sinking coastal cities amid rising seas. A final section discusses ways cities can be livable and sustainable.

Chapter 23 has an updated case study about British Columbia's **carbon tax** and notes that when Washington State tried to pass a similar tax, the fossil fuel industry spent $30 million to block the plan. Will other states be able to overcome this spending power? A new "Exploring Science" box notes that estimates of the value of global **ecosystem services** have increased from $33 trillion a few decades ago to $173 trillion today. Another boxed essay compares rapid job growth in sustainable energy compared to the fossil fuel industry. With interest growing in a Green New Deal, we have added a new "What Do You Think?" box to review this proposal.

Chapter 24 opens with a new case study about the recovery of North American green sea turtles with the help of the Endangered Species Act. In 1978 fewer than 300 sea turtles nested in Florida. By 2017, more than 39,000 turtles came ashore to nest, a major success in species protection. We review the provisions and successes of this and other major environmental policies. A new section discusses problems of **regulatory capture** in government agencies, as well as debates about how much regulation we want.

Chapter 25 presents a new case study on the history of Earth Day. It is critical that students understand how we got to where we are, and how public involvement with environmental issues has emerged. A new box discusses fossil fuel divestment debates at U.S. colleges and universities. We end the chapter with a review of sustainability as an overarching goal for environmental science.

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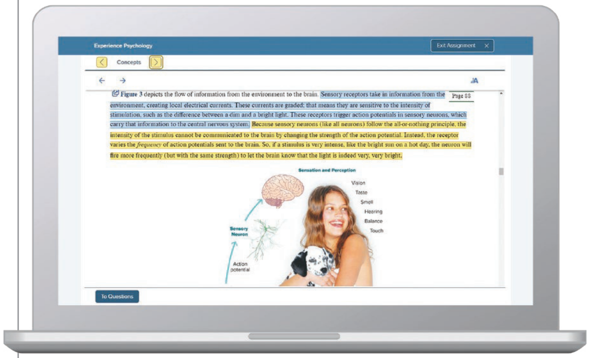

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Key Elements

A global perspective is vital to learning about environmental science.

Case Studies

All chapters open with a real-world case study to help students appreciate and understand how environmental science impacts lives and how scientists study complex issues.

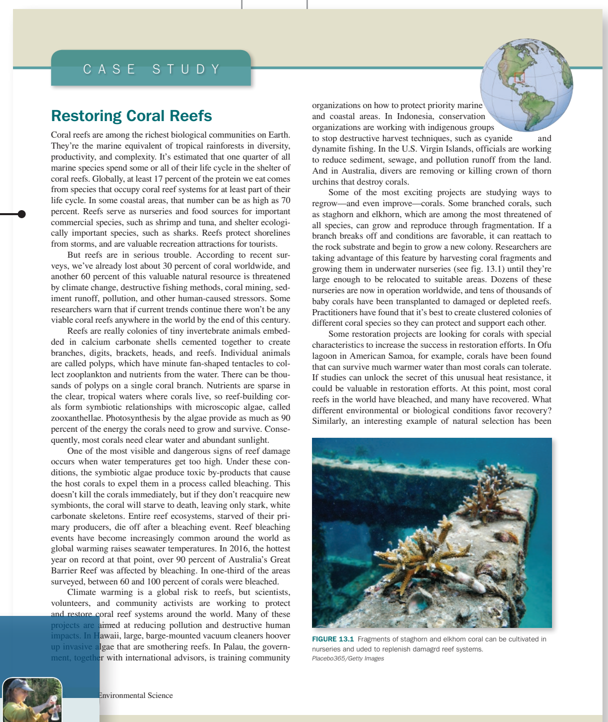


FIGURE 13.1 Fragments of staghorn and elkhorn coral can be cultivated in nurseries and used to replenish damaged reef systems.

Google Earth

Google Earth interactive satellite imagery gives students a geographical context for global places and topics discussed in the text. Google Earth icons indicate a corresponding exercise in Connect. In these exercises, students will find links to locations mentioned in the text, as well as corresponding assessments that will help them understand environmental topics.

Exploring Science

Current environmental issues exemplify the principles of scientific observation and data-gathering techniques to promote scientific literacy.

FIGURE 1 Lactobacillus bacteria are part of the normal flora of human intestine and are often used as probiotic supplements.

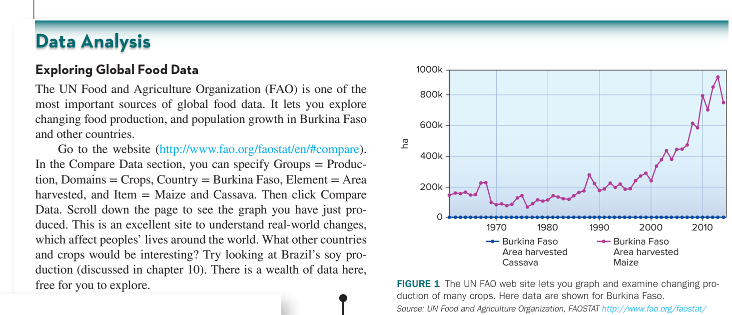


FIGURE 1 The UN FAO web site lets you graph and examine changing production of many crops. Here data are shown for Burkina Faso.

Data Analysis

At the end of every chapter, these exercises give students further opportunities to apply critical-thinking skills and analyze data. These are assigned through Connect in an interactive online environment. Students are asked to analyze data in the form of documents, videos, and animations.

What Do You Think?

Students are presented with challenging environmental studies that offer an opportunity to consider contradictory data, special interest topics, and conflicting interpretations within a real scenario.

White-tailed deer (odocoileus virginianus) can become emaciated and sick when they exceed their environment's carrying capacity.

Learning Outcomes

Found at the beginning of each chapter, and organized by major headings, these outcomes give students an overview of the key concepts they will need to understand.

Learning Outcomes

After studying this chapter, you should be able to:

9.1 Describe patterns of world hunger and nutritional requirements.
9.2 Identify key food sources, including protein-rich foods.
9.3 Explain new crops and genetic engineering.
9.4 Discuss how policy can affect food resources.

Section Reviews

Section reviews are a series of content-specific questions that appear at the end of each section in the chapter. These questions encourage students to periodically review what they have read and offers an opportunity to check their understanding of key concepts.

Section Review

1. How many people in the world are chronically undernourished? What does chronically undernourished mean?
2. List at least five African countries with high rates of hunger (fig. 9.3; use a world map to help identify countries).
3. What are some of the health risks of overeating? What percentage of adults are overweight in the United States?

Connecting the Dots

This section summarizes the chapter by highlighting key ideas and relating them to one another.

Connecting the Dots

The potential location of biological communities is largely determined by temperature and moisture availability. Consequently, ecologists anticipate that changes in climate patterns will produce changes in biome distributions. For people accustomed to familiar ecosystems, such as the maple-rich northern hardwood forests of New England, these changes are likely to disrupt livelihoods and even cultural references.

Understanding the global distribution of biomes, and knowing the differences in what lives where and why, are essential to ... nce. Plants and animals ... hem to live in particular ... alpine tundra, or chapar- ... you understand limiting ... man occupation and use ... ent on the biomes found in particular locations. Humans tend to prefer mild climates and the highly productive biological communities found in temperate zones. These biomes also suffer the highest rates of degradation and overuse.

While many of us pay most attention to terrestrial systems, oceans cover over 70 percent of the earth's surface. Marine biomes, such as coral reefs or mangroves, can be as biologically diverse and productive as any terrestrial biome. Freshwater ecosystems, too, are critically important, even though their extent is small overall. People have always depended on rich, complex ecosystems. In recent times, the rapid growth of human populations, coupled with more powerful ways to harvest resources, has led to extensive destruction of these environments. Awareness of emerging threats like climate change may help inspire more action to protect these living systems.

Critical Thinking and Discussion Questions

1. Do people around you worry about hunger? Do you think they should? Why or why not? What factors influence the degree to which people worry about hunger in the world?
2. Global issues such as hunger and food production often seem far too large to think about solving, but it may be that many strategies can help us address chronic hunger. Consider your own skills and interests. Think of at least one skill that could be applied (if you had the time and resources) to helping reduce hunger in your community or elsewhere.
3. Suppose you are a farmer who wants to start a confined animal feeding operation. What conditions make this a good strategy for you, and what factors would you consider in weighing its costs and benefits? What would you say to neighbors who wish to impose restrictions on how you run the operation?
4. Debate the claim that famines are caused more by human actions (or inactions) than by environmental forces. What kinds of evidence would be needed to resolve this debate?
5. Outline arguments you would make to your family and friends for why they should eat a mostly vegetarian diet, along the lines of *Diet for A Small Planet*. What reasons would be most compelling? What are some reasons why it is, or is not, fair to influence someone else's food practices?
6. Given what you know about GMO crops, identify some of the costs and benefits associated with them. Which of the costs and benefits do you find most important? Why?
7. Corn is by far the dominant crop in the United States. In what ways is this a good thing for Americans? How is it a problem? Who are the main beneficiaries of this system?

Critical Thinking and Discussion Questions

Brief scenarios of everyday occurrences or ideas challenge students to apply what they have learned to their lives.

What Can You Do?

This feature gives students realistic steps for applying their knowledge to make a positive difference in our environment.

What Can You Do?

Controlling Pests

Based on the principles of integrated pest management, the U.S. EPA releases helpful guides to pest control. Among their recommendations:

1. *Identify pests, and decide how much pest control is necessary.* Does your lawn really need to be totally weed-free? Could you tolerate some blemished fruits and vegetables? Could you replace sensitive plants with ones less sensitive to pests?
2. *Eliminate pest sources.* Remove from your house or yard any food, water, and habitat that encourages pest growth. Eliminate hiding places or other habitats. Rotate crops in your garden.
3. *Develop a weed-resistant yard.* Pay attention to your soil's pH, nutrients, texture, and organic content. Grow grass or cover varieties suited to your climate. Set realistic goals for weed control.
4. *Use biological controls.* Encourage beneficial insect predators such as birds, bats that eat insects, ladybugs, spiders, centipedes, dragonflies, wasps, and ants.
5. *Use simple manual methods.* Cultivate your garden and handpick weeds and pests from your garden. Set traps to control rats, mice, and some insects. Mulch to reduce weed growth.
6. *Use chemical pesticides carefully.* If you decide that the best solution is chemical, choose the right pesticide product, read safety warnings and handling instructions, buy the amount you need, store the product safely, and dispose of any excess properly.

Source: *Citizen's Guide to Pest Control and Pesticide Safety*: EPA 730-K-95-001

Quantitative Reasoning

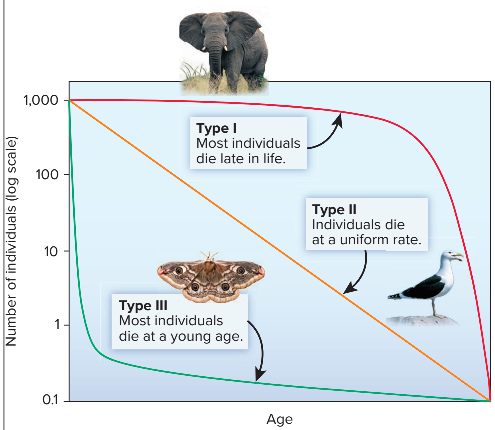
Compare the estimates of known and threatened species in table 11.1. Are some groups overrepresented? Are we simply more interested in some organisms, or are we really a greater threat to some species?

Quantitative Reasoning

Quantitative reasoning questions in the text push students to evaluate data and graphs they have read about. Attention to statistics, graphing, graph interpretation, and abundant up-to-date data are some of the resources available to help students

Relevant Photos and Instructional Art Support Learning

High-quality photos and realistic illustrations display detailed diagrams, graphs, and real-life situations.



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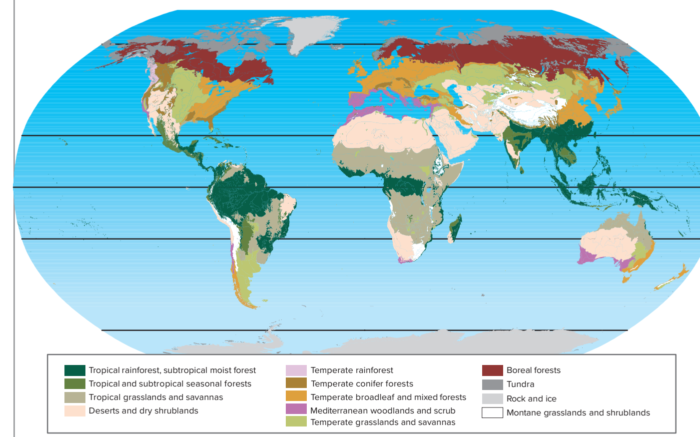
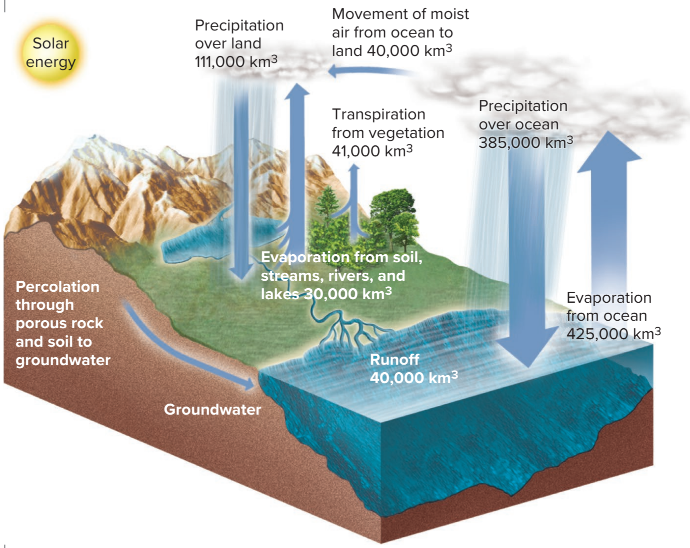
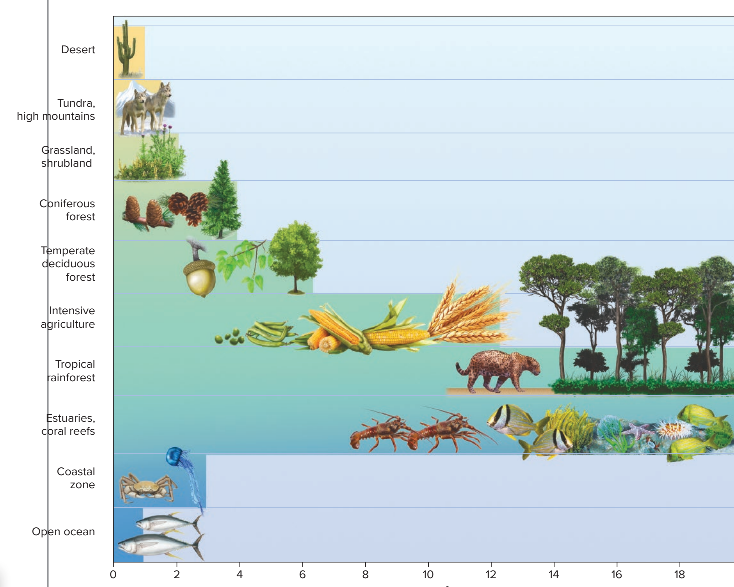


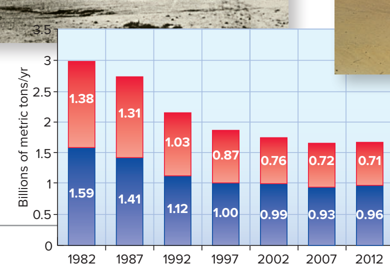




(a)

(b)

Source: a -b. USDA Natural Resources Conservation Service



(c)

Introduction

Learning to Learn

▲ Learning to learn is a lifelong skill.
William P. Cunningham

Learning Outcomes

After studying this introduction, you should be able to:

L.1 Form a plan to organize your efforts and become a more effective and efficient student.

L.2 Apply critical and reflective thinking in environmental science.

L.3 Identify logical errors, persuasive tricks, and biases used in popular media.

L.4 Describe issues that motivate you and consider ways they connect to environmental science.

"What kind of world do you want to live in? Demand that your teachers teach you what you need to know to build it."

– Peter Kropotkin

CASE STUDY

How can I do well in environmental science?

Case studies in environmental science examine a particular place or theme that draws together many of the themes in a chapter. For this chapter on learning to learn, a good case study to start with is you. You come to this course with particular backgrounds and ideas. You have expertise and skills. As you start reading this book, consider these two questions: How do you want to draw on your abilities and background and connect them to themes in this book? And how do you want to develop your knowledge and skills to answer questions that are important to you?

Responses to these question will differ for everyone. But the questions are relevant for everyone because environmental science is a field that involves a diversity of topics, with connections to basic ecology, natural resources, and policy questions that influence those systems. Topics in this course primarily involve our natural environment, but we also examine our human environment, including the built world of technology and cities, as well as human social or cultural institutions. All of these interrelated aspects of our life affect us, and, in turn, are affected by what we do.

FIGURE L.1 Knowing what you care about and why is a good start to connecting your interests to the study of our environment and how it works.
Hero Images/Image Source

Another way this chapter relates to you is that it gives suggestions for how you can organize your learning process as you study. This means being aware and intentional about your study habits. Take time as you read this chapter to consider what you do well as you study, and what you need to do better to be effective with study time. This is another skill set that will serve you well in other contexts.

Part of doing well in this course is to develop your habits of critical thinking, that is, assessing how and why we think about things as we do. Critical thinking is one of the most useful skills you can learn in any of your classes, and so it is a focus of this chapter. Many central topics in environmental science are highly contested: What kinds of energy are most important? Where should they come from? What is a resource? How should we manage and conserve water resources? Who should pay the cost of controlling air pollution? Answering these questions requires analysis of evidence. But evidence can depend on when and by whom it was gathered and evaluated. For every opinion there is an equal and opposite opinion. How can you make sense out of this welter of ever-changing information?

As you consider these sometimes contradictory views, pay attention to developing your capacity to think independently, systematically, and skillfully to form your own opinions (fig. L.1). These qualities and abilities can help you in many aspects of life. Throughout this book you will find "What Do You Think?" boxes that invite you to practice your critical and reflective thinking skills.

Thinking about how we think is a practice that applies in ordinary conversation, as well as in media you encounter, and even in textbooks. Finding these patterns in arguments can be fun; it's also important. Paying attention to these sorts of argument strategies is also a good practice in any class you take. These are a few of the logical errors you can watch for:

- *Red herring:* Introducing extraneous information to divert attention from the important point.
- *Ad hominem attacks:* Criticizing the opponent rather than the logic of the argument.
- *Hasty generalization:* Drawing conclusions about all members of a group based on evidence that pertains only to a selected sample.
- *False cause:* Drawing a link between premises and conclusions that depends on some imagined causal connection that does not, in fact, exist.
- *Appeal to ignorance:* Because some facts are in doubt, a conclusion is impossible.
- *Appeal to authority:* It's true because someone says so.
- *Equivocation:* Using words with double meanings to mislead the listener.
- *Slippery slope:* A claim that some event or action will cause some subsequent action.
- *False dichotomy:* Giving either/or alternatives as if they are the only choices.

These skills are important to doing well in this class, and they are part of becoming a responsible and productive environmental citizen. Each of us needs a basis for learning and evaluating scientific principles, as well as some insights into the social, political, and economic systems that impact our global environment. We hope this book and the class you're taking will give you the information you need to reach those goals. As the noted Senegalese conservationist and educator Baba Dioum once said, "In the end, we will conserve only what we love, we will love only what we understand, and we will understand only what we are taught." The more you can connect ideas in this course to topics you care about, the better you can make use of them—and the more likely you will be to do well in the class.

L.1 How Can I Get an A in This Class?

- *Making a frank and honest assessment of your strengths and weaknesses will help you do well in this class.*
- *Reading in a purposeful, deliberate manner is an important part of productive learning.*

What do you need to know to succeed in a class on environmental science? This chapter provides an overview of some skills to keep in mind as you begin. As Henry Ford once said, “If you think you can do a thing, or think you can’t do a thing, you’re right.”

One of the first things that will help you do well in this class—and enjoy it—is to understand that science is useful and accessible, if you just take your time with it. To do well in this class, start by identifying the ways that science connects with your interests and passions. Most environmental scientists are motivated by a love for something: a fishery biologist might love fishing; a plant pathologist might love gardening; an environmental chemist might be motivated by wanting to improve children’s health in the city in which she lives. All these people use the tools of science to help them understand something they get excited about. Finding that angle can help you do better in this class, and it can help you be a better and happier member of your community (fig. L.2).

Another key to success is understanding what “science” is. Basically, science is about trying to figure out how things work. This means examining a question carefully and methodically. It means questioning your own assumptions, as well as the statements you hear from others. Understanding some basic ideas in science can be very empowering: Learning to look for evidence and to question your assumptions is a life skill, and building comfort with thinking about numbers can help you budget your groceries, prioritize your schedule, or plan your vacation. Ideas in this book can help you understand the food you eat, the weather you encounter, the policies you hear about in the news—from energy policy to urban development to economics.

FIGURE L.2 Finding the connections between your studies and the community, places, and ideas you care about can make this class more rewarding and fun.
Source: Gwen Bausmith, U.S. EPA

What are good study habits?

What are your current study skills and habits? Making a frank and honest assessment of your strengths and weaknesses will help you set goals and make plans for achieving them during this class. A good way to start is to examine your study habits. Rate yourself on each of the following study skills and habits on a scale of 1 (excellent) to 5 (needs improvement). If you rate yourself below 3 on any item, think about an action plan to improve that competence or behavior.

- How well do you manage your time (do you tend to run late, or do you complete assignments on time)?
- Do you have a regular study environment where you can focus?
- How effective are you at reading and note-taking (do you remember what you’ve read; do you take notes regularly)?
- Do you attend class regularly, listen for instructions, and participate actively in class discussions? Do you bring questions to class about the material?
- Do you generally read assigned chapters in the textbook before attending class, or do you wait until the night before the exam?
- How do you handle test anxiety (do you usually feel prepared for exams and quizzes or are you terrified of them? Do you have techniques to reduce anxiety or turn it into positive energy)?
- Do you actively evaluate how you are doing in a course based on feedback from your instructor and then make corrections to improve your effectiveness?
- Do you seek out advice and assistance outside of class from your instructors or teaching assistants?

Procrastination is something almost everyone does, but a few small steps can help you build better habits. If you routinely leave your studying until the last minute, then consider making a study schedule, and keep a written record of how much time you spend studying. Schedule time for sleep, meals, exercise, and recreation so that you will be rested and efficient when you do study. Divide your work into reasonable sized segments that you can accomplish on a daily basis. Carry a calendar to keep track of assignments. And find a regular study space in which you can be effective and productive.

How you behave in class and interact with your instructor also can have a big impact on how much you learn and what grade you get. Make an effort to get to know your instructor. Sit near the front of the room where you can see and be seen. Learn to ask questions: This can keep you awake and engaged in class. Practice the skills of good note-taking (table L.1). Attend every class and arrive on time. Don’t fold up your papers and prepare to leave until after the class period is over. Arriving late and leaving early says to your instructor that you don’t care much about either the class or your grade.

Practice active, purposeful learning. It isn’t enough to passively absorb knowledge provided by your instructor and this textbook. You need to actively engage the material in order to really understand it. The more you invest yourself in the material, the easier it will be to comprehend and remember. It is very helpful to have a study buddy with whom you can compare notes and try out ideas (fig. L.3).

Table L.1 Learning Skills—Taking Notes

1. Identify the important points in a lecture and organize your notes in an outline form to show main topics and secondary or supporting points. This will help you follow the sense of the lecture.
2. Write down all you can. If you miss something, having part of the notes will help your instructor identify what you've missed.
3. Leave a wide margin in your notes in which you can generate questions to which your notes are the answers. If you can't write a question about the material, you probably don't understand it.
4. Study for your test under test conditions by answering your own questions without looking at your notes. Cover your notes with a sheet of paper on which you write your answers, then slide it to the side to check your accuracy.
5. Go all the way through your notes once in this test mode, then go back to review those questions you missed.
6. Compare your notes and the questions you generated with those of a study buddy. Did you get the same main points from the lecture? Can you answer the questions someone else has written?
7. Review your notes again just before test time, paying special attention to major topics and questions you missed during study time.

Source: Dr. Melvin Northrup, Grand Valley State University.

It's well known that the best way to learn something is to teach it to someone else. Take turns with your study buddy explaining the material you're studying. You may think you've mastered a topic by quickly skimming the text, but you're likely to find that you have to struggle to give a clear description in your own words. Anticipating possible exam questions and taking turns quizzing each other can be a very good way to prepare for tests.

FIGURE L.3 Cooperative learning, in which you take turns explaining ideas and approaches with a friend, can be one of the best ways to comprehend material.
Prostock-studio/Shutterstock

How can you use this textbook effectively?

An important part of productive learning is to read assigned material in a purposeful, deliberate manner. Ask yourself questions as you read. What is the main point being made here? How does the evidence presented support the assertions being made? What personal experience have you had or what prior knowledge can you bring to bear on this question? Can you suggest alternative explanations for the phenomena being discussed? A study technique developed by Frances Robinson and called the **SQ3R** method can improve your reading comprehension. It's also helpful to have a study group (fig. L.4). After class and before exams, you can compare notes, identify priorities, and sort out points that are unclear. Try these steps as you read the first few chapters of this book, and see if they improve your recall of the material:

1. *Survey* the entire chapter or section you are about to read, so you can see how it fits together. What are the major headings and subdivisions?
2. *Question* what the main points are likely to be in each of the sections. Which parts look most important or interesting? Where should you invest the most time and effort?
3. *Read* the material, taking brief notes as you go. Read in small segments and stop frequently for reflection and to make notes.
4. *Recite*: Stop periodically to recite to yourself what you have just read. Check your comprehension at the end of each major section. Ask yourself: Did I understand what I just read? What are the main points being made here? Summarize the information in your own words to be sure that you really understand and are not just depending on rote memory.
5. *Review:* Once you have completed a section, review the main points to make sure you remember them clearly. Did you miss any important points? Do you understand things differently

FIGURE L.4 Talking through ideas with your peers is an excellent way to test your knowledge. If you can explain it, then you probably understand the material.
Tara Moore/Getty Images

the second time through? This is a chance to think critically about the material. Do you agree with the conclusions suggested by the authors?

Will this be on the test?

You should develop different study strategies depending on whether you are expected to remember and choose between a multitude of facts and details, or whether you will be asked to write a paragraph summarizing some broad topic. Organize the ideas you're reading and hearing in lecture. This course will probably include a great deal of information, so try to organize for yourself what ideas are most important. What's the big picture? As you read and review, ask yourself what might be some possible test questions in each section. Memorize some benchmark figures: Just a few will help a lot. Pay special attention to ideas, relationships, facts, and figures about which your instructor seemed especially interested. Usually those points are emphasized in class because your teacher thinks they are most important to remember. There is a good chance you'll see those topics again on a test.

Pay special attention to tables, graphs, and diagrams. They were chosen because they illustrate important points, and they are often easy to put on a test. Also pay attention to units. You probably won't be expected to remember all the specific numbers in this book, but you probably should know orders of magnitude. The world population is about 7.3 *billion* people (not thousands, millions, or trillions). It often helps to remember facts and figures if you can relate them to some other familiar example. The United States, for instance, has about 330 million residents. The populations of the European Union is slightly larger; India and China are each more than four times as large. Those general relationships are usually easier to remember and compare than detailed figures.

Section Review

1. What is your strongest learning style?
2. What are the five techniques of the SQ3R method for studying?

L.2 THINKING ABOUT THINKING

- Critical thinking is a valuable tool in learning and in life.
- Certain attitudes, skills, and approaches are essential for well-reasoned analysis.

Perhaps the most valuable skill you can learn in any of your classes is the ability to think clearly, creatively, and purposefully. Developing the ability to learn new skills, examine new facts, evaluate new theories, and formulate your own interpretations is essential to keep up in a changing world. In other words, you need to learn how to learn on your own.

Thinking about thinking means pausing to examine you are forming ideas, or how you interpret what you hear and read. A number of approaches can help us evaluate information and make decisions. **Analytical thinking** asks, "How can I break this problem down into its constituent parts?" **Creative thinking** asks, "How might I approach this problem in new and inventive ways?" **Logical thinking** asks, "How can orderly, deductive reasoning help me think clearly?" **Critical thinking** asks, "What am I trying to accomplish here and how will I know when I've succeeded?" **Reflective thinking** asks, "What does it all mean?" As figure L.5 suggests, critical thinking is central in the constellation of thinking skills. Thinking critically can help us discover hidden ideas and means, develop strategies for evaluating reasons and conclusions in arguments, recognize the differences between facts and values, and avoid jumping to conclusions.

How do you tell the news from the noise?

With the explosion of cable channels, blogs, social networks, and e-mail access, most of us are interconnected constantly to a degree unique in history. There are well over 150 million blogs on the Web, and new ones are added every day. Most of us, even in low-income countries and regions, are linked in social networks. Every day several billion e-mails, tweets, text messages, online videos, and social media postings connect us to one another. As you participate in these networks, you probably already think about the sources of information you are exposed to on a daily basis.

One of the issues that has emerged with this proliferation of media is partisan journalism—reports that serve one viewpoint, rather than trying to weigh diverse evidence and perspectives. Partisan journalism has become much more prevalent since the deregulation of public media in 1988. From the birth of the broadcasting industry, the airwaves were regulated as a public trust. Broadcasters, as a condition of their licenses, were required to operate in the "public interest" by covering important policy issues and providing equal time to both sides of contested issues. In 1988, however, the

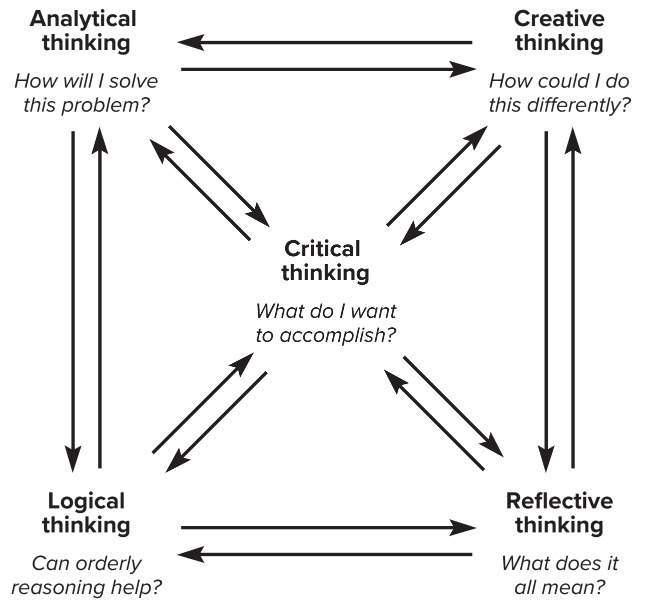


FIGURE L.5 Different approaches to thinking are used to solve different kinds of problems or to study alternate aspects of a single issue.

Federal Communications Commission ruled that the proliferation of mass media gives the public adequate access to diverse sources of information. Media outlets are no longer obliged to provide fair and balanced coverage of issues. Presenting a single perspective or even a deceptive version of events is no longer regarded as a betrayal of public trust.

An important aspect of partisan reporting is attack journalism. Commentators often ridicule and demean their opponents rather than weighing ideas or reporting objective facts and sources, because shouting matches are entertaining and sell advertising. Most newspapers have laid off almost all their investigative reporters and most television stations have abandoned the traditional written and edited news story. According to the Center for Journalistic Excellence, more than two-thirds of all TV news segments now consist of on-site "stand-up" reports or live interviews in which a single viewpoint is presented as news without any background or perspective.

Part of the reason for the growth of sensationalist media is that real news—topics that affect your community and your environment—often don't make exciting visuals. So they don't make it into TV coverage. Instead, crime, accidents, disasters, lifestyle stories, sports, and weather make up more than 90 percent of the coverage on a typical television news program. An entire day of cable TV news would show, on average, only 1 minute each about the environment and health care, 2 minutes each on science and education, and 4 minutes on art and culture. More than 70 percent of the segments are less than 1 minute long, which allows them to convey lots of emotion but little substance. People who get their news primarily from TV are significantly more fearful and pessimistic than those who get news from print media. And it becomes hard to separate rumor from truth. Evidence and corroboration take a backseat to dogma and passion.

How can you detect bias in blogs, social media, or news reporting? Ask the questions below as you look at media. Also ask these questions as you examine your own work, to avoid falling into these traps.

1. Are speakers discussing facts and rational ideas, or are they resorting to innuendo, name-calling, character assassination, and *ad hominem* (personal) attacks? When people start calling each other Nazi or communist (or both), civil discourse has probably come to an end.
2. What special interests might be involved? Who stands to gain presenting a particular viewpoint? Who is paying for the message?
3. What sources are used as evidence in this communication? How credible are they?
4. Are facts or statistics cited in the presentation? Are they credible? Are citations provided so you can check the sources?
5. If the presentation claims to be fair and balanced, are both sides represented by credible spokespersons, or is one simply a foil set up to make the other side look good?
6. Are the arguments presented based on evidence, or are they purely emotional appeals?

Applying critical thinking

In logic, an argument is made up of one or more introductory statements (called **premises**), and a **conclusion** that supposedly follows logically from the premises. Often in ordinary conversation, different kinds of statements are mixed together, so it is difficult to distinguish between them or to decipher hidden or implied meanings.

We all use critical or reflective thinking at times. Suppose a television commercial tells you that a new breakfast cereal is tasty and good for you. You may be suspicious and ask yourself a few questions. What do they mean by good? Good for whom or what? Does "tasty" simply mean more sugar and salt? Might the sources of this information have other motives in mind besides your health and happiness? Although you may not have been aware of it, you already have been using some of the techniques of critical analysis. Working to expand these skills helps you recognize the ways information and analysis can be distorted, misleading, prejudiced, superficial, unfair, or otherwise defective. Here are some steps in critical thinking:

Identify and evaluate premises and conclusions in an argument. What is the basis for the claims made here? What evidence is presented to support these claims and what conclusions are drawn from this evidence? If the premises and evidence are correct, does it follow that the conclusions are necessarily true?

Acknowledge and clarify uncertainties, vagueness, equivocation, and contradictions. Do the terms used have more than one meaning? If so, are all participants in the argument using the same meanings? Are ambiguity or equivocation deliberate? Can all the claims be true simultaneously?

Distinguish between facts and values. Are claims made that can be tested? (If so, these are statements of fact and should be able to be verified by gathering evidence.) Are claims made about the worth or lack of worth of something? (If so, these are value statements or opinions and probably cannot be verified objectively.) For example, claims of what we *ought* to do to be moral or righteous or to respect nature are generally value statements.

Recognize and assess assumptions. Given the backgrounds and views of the protagonists in this argument, what underlying reasons might there be for the premises, evidence, or conclusions presented? Does anyone have an "axe to grind" or a personal agenda in this issue? What do they think you know, need, want, or believe? Is there a subtext based on race, gender, ethnicity, economics, or some belief system that distorts this discussion? (fig. L.6).

Distinguish the reliability or unreliability of a source. What makes the experts qualified in this issue? What special knowledge or information do they have? What evidence do they present? How can we determine whether the information offered is accurate, true, or even plausible?

Recognize and understand conceptual frameworks. What are the basic beliefs, attitudes, and values that this person, group, or society holds? What dominating philosophy or ethics control their outlook and actions? How do these beliefs and values affect the way people view themselves and the world around them? If there are conflicting or contradictory beliefs and values, how can these differences be resolved?

FIGURE L.6 Often the conditions that lead to environmental problems like hazardous waste, and the explanations that surround them, are based on unspoken assumptions. Identifying underlying assumptions is a key step to finding solutions.
Source: Eric Vanceonse, U.S. EPA

As you read this book, you will have many opportunities to practice critical thinking. Every chapter includes facts, figures, opinions, and theories. Are all of them true? Probably not. They were the best information available when this text was written, but scientific knowledge is always growing. Data change constantly as does our interpretation of them. Environmental conditions change, evidence improves, and different perspectives and explanations evolve over time.

As you read this book or any book, try to distinguish between statements of fact and opinion. Ask yourself if the premises support the conclusions drawn from them. Although we have tried to present the best available scientific data and to represent the main consensus among environmental scientists, it is always important for you, as a reader, to think for yourself and utilize your critical and reflective thinking skills to find the truth.

Section Review

1. Describe seven attitudes needed for critical thinking.
2. List six steps in critical thinking.

Connecting the Dots

In each chapter, we try to help connect issues in the topic back to the case study. Sometimes the connections will be obvious, sometimes less so. You can try to make those connections for yourself, too, as you read and study.

There are many ways to do well in a course like this. Finding the ways topics are meaningful and useful for you will help make the work worthwhile. Doing well also involves paying attention to things like good study habits, setting realistic goals for yourself, taking the initiative to look for interesting topics, finding an appropriate study space, and working with a study partner. We all have our own learning styles. You may understand and remember things best if you see them in writing, hear them spoken by someone else, reason them out for yourself, or learn by doing. By determining your preferred style, you can study in the way that is most comfortable and effective for you.

1 Understanding Our Environment

▲ Many of the most important challenges in environmental quality and sustainable development occur in informal settlements like Kibera, in Nairobi, Kenya.
Tatsiana Hendzel/Shutterstock

Learning Outcomes

After studying this chapter, you should be able to:

1.1 Explain what environmental science is, and how it draws on different kinds of knowledge.

1.2 Identify some early thinkers on environment and resources, and contrast some of their ideas.

1.3 Describe sustainable development and its goals.

1.4 Explain core concepts in sustainable development.

1.5 Identify ways in which ethics and faith might promote sustainability and conservation.

"Working together, we have proven that sustainable development is possible; that reforestation of degraded land is possible; and that exemplary governance is possible when ordinary citizens are informed, sensitized, mobilized and involved in direct action for their environment."

– Wangari Maathai (1940–2011)

Winner of 2004 Nobel Peace Prize

CASE STUDY

Sustainable Development Goals for Kibera

The idea of sustainable development is that we can improve well-being for poor populations, including reducing severe poverty, while maintaining or improving the environment on which we depend. These goals might seem contradictory, but increasing evidence shows that they can go together. In fact, as our resource consumption and population grow, it is increasingly necessary that they go together. Starting in 2016, the United Nations launched a new program to promote 17 Sustainable Development Goals, including access to education, health care, a safe natural environment, clean water, and other priorities, as well as conserving biodiversity and slowing climate change (fig. 1.1). Are all these goals possible?

FIGURE 1.1 Sustainable development goals include access to education and electricity to study by at night.
Mark Boulton/Alamy Stock Photo

Perhaps the greatest test case of this question is in fast-growing urban settlements of the developing world. One of the largest of these is a slum known as Kibera in Nairobi, Kenya. Every week, some 2,500 people arrive in Nairobi, drawn by hopes for better jobs and education. The city cannot build housing fast enough for this influx. Nor can it provide sanitary sewage, safe water systems, electric power, or other services. New arrivals build informal neighborhoods on the margins, using whatever materials are available to construct simple shelters of mud, brick, and tin roofing. Kibera is the largest of about 200 such settlements in Nairobi. These are home to over 2.5 million people, around 60 percent of the city's population (although reliable numbers are hard to come by).

Kibera grew on lowlands along the Nairobi River, in an area prone to flooding that periodically inundates houses and muddy informal streets. Because there is no system for managing sewage or garbage, both end up in the river, often entering homes with flood waters. Much of the time, a fetid odor of decomposing waste fills the air, and plastic shopping bags and other debris fill the corners of roadways and buildings. Occupying degraded outskirts of large cities, neighborhoods like Kibera suffer from the pollution produced by wealthy neighborhoods, and also create their own pollution and health hazards.

The city government has a complicated relationship with Kibera. The settlement provides much-needed housing, and residents contribute labor and consumer markets for growing businesses. But substandard housing is an embarrassment for city governments. Impoverished and unemployed populations turn to crime, even while they are the main victims of criminal activity. The city regularly tries to remove this and other slums, replacing them with modern housing, but the new flats are usually too expensive, and insufficient in supply, for the displaced residents.

Similar settlements exist in many of the world's fast-growing urban areas—Rio de Janeiro, Manila, Lagos, Cairo, Mumbai, Delhi, and many others—because global processes drive the growth of these vast slums. Rural population growth reduces access to farmland; forest destruction and soil degradation make traditional lifestyles difficult to maintain. Large landholders expand, displacing rural communities. Climate change threatens crop production. Declining water resources make farming difficult, and farmers are driven to the city.

In striving to enter the middle class, residents of Kibera also increase their environmental impacts. As they succeed, they consume more material goods, more energy, more cars and fuel, and electronics. All of these expand the environmental footprint of residents. On the other hand, the per capita energy and resource consumption of most Kibera residents is vanishingly small compared to consumption of their wealthy neighbors, who may have multiple cars and large houses, many appliances, and rich diets.

The global challenge of sustainable development is to find ways to improve the lives and the environment of people everywhere, including those in Kibera and other informal settlements. Slum residents have energy and ideas and are eager to improve the lives of their children, like people everywhere.

Environmental science is a discipline that seeks to understand both the natural systems we depend on and the ways we exploit or steward those resources. Sustainable development is central to environmental science, as we seek to protect resources and also support human well-being. As you read this book, you'll consider many issues of environmental systems, stewardship, and resource use. Ideally, a better understanding of these issues can help us find ways to address them, both locally and globally.

1.1 What Is Environmental Science?

- *This subject draws on many disciplines, skills, and interests.*
- *We face persistent challenges, as well as progress, in themes such as population growth, climate change, pollution, and biodiversity losses.*
- *Ecological footprints are a way to estimate our impacts.*

Humans have always inhabited two worlds. One is the natural world of plants, animals, soils, air, and water that preceded us by billions of years and of which we are a part. The other is the world of social institutions and artifacts that we create for ourselves using science, technology, and political organization. Both worlds are essential to our lives, but their intersections often cause enduring tensions: More than ever before, we have power to extract and consume resources, produce waste, and modify our world in ways that threaten both our continued existence and that of many organisms with which we share the planet. We also have better access than ever before to new ideas, efficient technologies, and opportunities to cooperate in finding sustainable strategies. To ensure a sustainable future for ourselves and future generations, we need to understand more about how our world works, what we are doing to it, and what we can do to protect and improve it.

Environment (from the French *environner:* to encircle or surround) can be defined as (1) the circumstances or conditions that surround an organism or group of organisms, or (2) the complex of social or cultural conditions that affect an individual or community. Because humans inhabit the natural world, as well as the "built" or technological, social, and cultural world, all constitute important parts of our environment (fig. 1.2).

Environmental science is the systematic study of our environment and the ways in which we both depend on it and influence it. Environmental science is interdisciplinary, integrating natural sciences, social sciences, and humanities in a broad, holistic study of the world around us. Much of environmental science focuses on understanding and resolving problems in our natural environment, such as pollution or lost biodiversity. But solutions have to do with how we consume resources and dispose of waste. This is why environmental science also includes discussion of policy, population, economics, and urbanization.

For an increasing number of environmental issues, the difficulty is not to identify remedies. Remedies are now well understood. The problem is to make them socially, economically, and politically acceptable. Foresters know how to plant trees, but not how to establish conditions under which we can agree to let forests grow to maturity. Engineers know how to control pollution, but not how to persuade factories to install the necessary equipment. We even know how to address climate change and sustainable development, although we have not agreed to do so. These are complex problems, then, that require input from multiple perspectives.

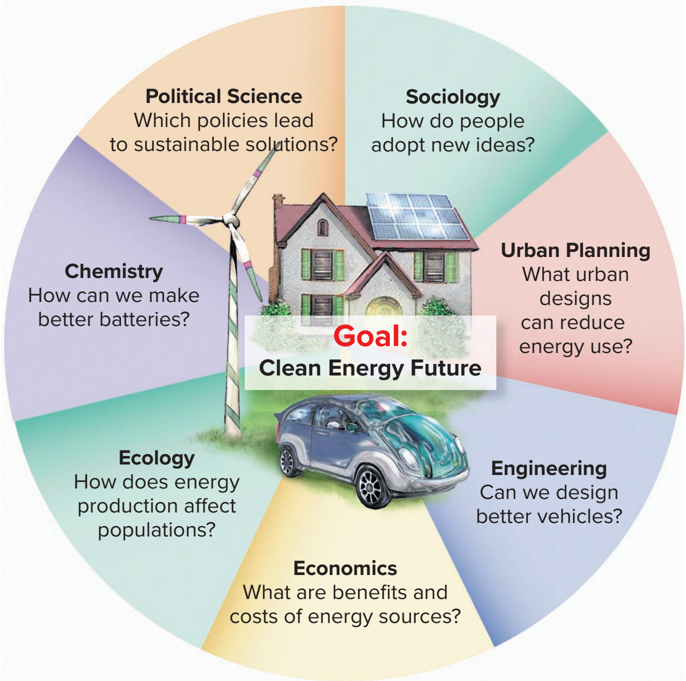


FIGURE 1.2 Many kinds of knowledge contribute to solutions in environmental science. For a goal such as achieving clean and sustainable energy, strategies involve input from many disciplines.

As you study environmental science, you should aim to do the following:

- understand how natural systems function;
- understand ecological concepts that explain biological diversity;
- understand current environmental challenges, such as pollution and climate change; and
- use critical thinking to envision solutions to these challenges.

Environmental science is about understanding where we live

In this course, you will examine processes in our physical environment, including factors affecting biological diversity, biological productivity, sources of earth resources and energy, and circulation of climate and of water resources. You will also consider the ways resource use, policy, and practices influence those environmental systems. But as you read, also remember that the systems we discuss are amazing and beautiful. Imagine you are an astronaut

Benchmark Data

Among the ideas and values in this chapter, the following are a few worth remembering.

7.7 billion	Global human population, 2019
2.1	Replacement fertility rate (children/woman)
0.3 tons	CO_2 per person in least developed countries
11 tons	In most developed countries (table 1.1)
1.7	Number of planet Earths to satisfy our global footprint

FIGURE 1.3 Perhaps the most amazing feature of our planet is its rich diversity of life.
Fuse/Getty Images

returning to Earth after a trip to the moon or Mars. What a relief it would be to come back to this beautiful, bountiful planet after experiencing the hostile, desolate environment of outer space. We live in a remarkably prolific and hospitable world. Compared to the conditions on other planets in our solar system, temperatures on the earth are mild and relatively constant. Plentiful supplies of clean air, fresh water, and fertile soil are regenerated endlessly and spontaneously by geological and biological cycles (discussed in chapters 3 and 4).

Perhaps the most amazing feature of our planet is the rich diversity of life that exists here. Millions of beautiful and intriguing species populate the earth and help sustain a habitable environment (fig. 1.3). This vast multitude of life creates complex, interrelated communities where towering trees and huge animals live together with, and depend upon, tiny life-forms such as viruses, bacteria, and fungi. Together, all these organisms make up delightfully diverse, self-sustaining communities, including dense, moist forests, vast sunny savannas, and richly colorful coral reefs. From time to time, we should pause to remember that, in spite of the challenges and complications of life on earth, we are incredibly lucky to be here. We should ask ourselves: What is our proper place in nature? What *ought* we do and what *can* we do to protect the irreplaceable habitat that produced and supports us?

To really understand our environment, we also need to get outdoors and experience nature, in our backyard, a local park, or somewhere new. As author Ed Abbey said, “It is not enough to fight for the land; it is even more important to enjoy it. While you can. While it is still there. So get out there and mess around with your friends, ramble out yonder and explore the forests, encounter the grizz, climb the mountains. Run the rivers, breathe deep of that yet sweet and lucid air, sit quietly for a while and contemplate the precious stillness, that lovely, mysterious and awesome space. Enjoy yourselves, keep your brain in your head and your head firmly attached to your body, the body active and alive.”

Major themes in environmental science

Environmental science covers several major themes. One of these is sustainable development, a question that runs through many chapters of this book. How do we foster healthy, rewarding livelihoods under conditions of population growth, shifting food systems, precarious water resources and water quality, air pollution, and growing demands for energy? Why is it important to protect resources and biodiversity, and how can they be protected, as human needs expand?

A second major theme that runs through most chapters is climate change and climate action. Climate change is the single most urgent issue of our time. It will affect human health, economies, poverty, and conflict, as well as dramatically changing environmental systems, including water resources, weather, food production, and biodiversity, on which we depend. Over the past 200 years, atmospheric CO_2 concentrations have increased about 35 percent. Climatologists warn that if current trends continue, by 2100 mean global temperatures will probably increase by 2° to 6°C (3.6° to 12.8°F) compared to temperatures in 1900 (fig. 1.5*a*). This warming explains the increasing severity and frequency of droughts, storms, and wildfires observed in recent years.

Fortunately, we know many ways to reduce climate change, from protecting forests to developing renewable energy and transforming food and farming systems. Global agreement on the importance of acting is nearly universal. At the 2015 Paris Climate Conference, and at multiple conferences since then, the world’s nations have gradually strengthened efforts to take action. We are not acting fast enough, but we know many of the strategies that we need to pursue. As you read this book, one of your tasks is to understand solutions to this and other major challenges. You should also try to understand some of the many co-benefits to climate action and other environmental progress, including reductions in poverty, pollution, and illness.

In most topics we discuss, there are major challenges and also key areas of progress. It is important to recognize that both dire threats and exciting opportunities exist simultaneously. We tend to forget that in many cases, conditions were much worse in the past—air and water pollution in most U.S. cities, for example, were far more unhealthy in past decades, and global population growth has slowed dramatically from previous decades. Recognizing where conditions have improved over time also reminds us that the hard work of generations before us has been fruitful.

Here are a few examples of major topics in environmental science, with both challenges and encouraging progress.

Population and resource consumption

One of the most widely debated challenges is population growth. With some 7.7 billion humans on earth, we’re adding about 80 million more every year. Family sizes have declined almost everywhere, from about five children per family 60 years ago to about two today, but still demographers project a population between 8 and 10 billion by 2050 (fig. 1.4*a*). The impacts of that many people on our natural resources and ecological systems is a serious concern. All high–birth rate countries are low-income, often

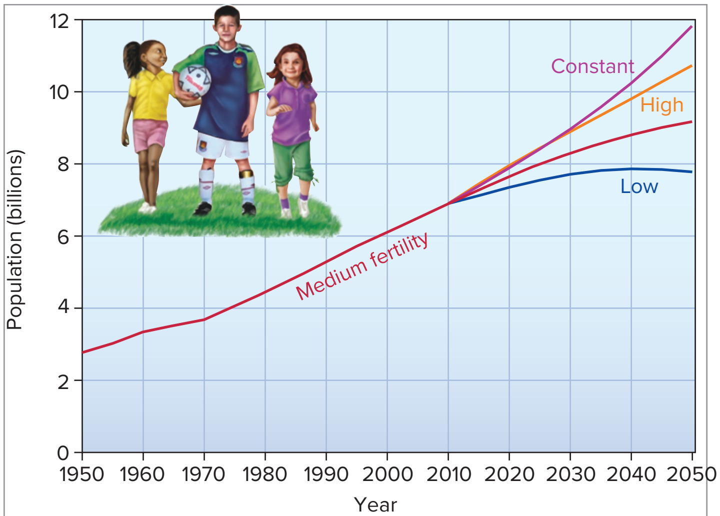


FIGURE 1.4 Bad news and good news: Globally, populations continue to rise, but our rate of growth has plummeted. Nearly half of countries are below the replacement rate of about two children per woman.

war-affected areas. Of the 40 countries with the highest birth rates, all are in Africa except Afghanistan.

On the other hand, population growth has stabilized in nearly all industrialized countries and even in most poor countries where social security and democracy have been established. Over the last 20 years, the average number of children born per woman worldwide has decreased from 6.1 to 2.5 (fig. 1.4*b*). The UN Population Division predicts that by 2050 all developed countries and 75 percent of the developing world will experience a below-replacement fertility rate of 2.1 children per woman. This prediction suggests that the world population could stabilize sooner and lower than previously estimated.

Rising resource consumption per person is also an urgent concern. Poor populations consume very little energy, food, and other resources, compared to wealthy populations, which consume energy and goods from around the globe. As wealth rises around the world, people emerging from poverty desire the same high levels of consumption. Thus, both population and consumption rates are persistent questions in environmental science.

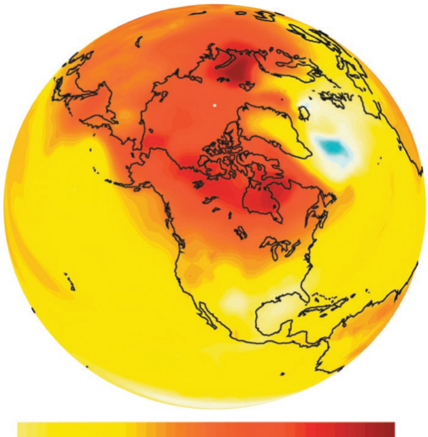
Hunger

In spite of population growth that added nearly a billion people to the world during the 1990s, the number facing food insecurity and chronic hunger during this period declined by about 40 million. Global food production has more than kept pace with human population growth, but hunger persists in many areas (fig. 1.5*b*). In a world of food surpluses, the United Nations estimates that some 800 million people are chronically undernourished, often because of drought, floods, displacement from land, or war. On the other hand, the *percentage* of people suffering from chronic hunger has declined, even in developing regions. Soil scientists report that about two-thirds of all agricultural lands show signs of degradation. Biotechnology and intensive farming techniques, responsible for much of our recent production gains, are too expensive for poor farmers, and they contaminate waterways and deplete soils. Small-scale farms still produce 80 percent of food consumed worldwide, according to the United Nations Development Programme. Can we ensure the sustainability of these farms without further environmental degradation?

Biodiversity loss and conservation efforts

Biologists report that habitat destruction, overexploitation, pollution, and the introduction of exotic organisms are eliminating species at a rate comparable to the great extinction that marked the end of the age of dinosaurs. The UN Environment Programme reports that, over the past century, more than 800 species have disappeared and at least 10,000 species are now considered threatened (fig. 1.5*c*). This includes about half of all primates and freshwater fish, together with around 10 percent of all plant species. Top predators, including nearly all the big cats in the world, are particularly rare and endangered. At least half of the forests existing before the introduction of agriculture have been cleared, and much of the diverse "old growth" on which many species depend for habitat is rapidly being cut and replaced by ecologically impoverished forest plantations.

Despite ongoing losses, we are also finding ways to conserve resources and use them more sustainably. Restoration ecology (chapter 13) has contributed to species monitoring and recovery. Improved monitoring of fisheries and networks of marine protected areas promote species conservation, as well as human development (fig. 1.5*d*). Brazil, which has the largest area of tropical rainforests in the world, reduced forest destruction by nearly two-thirds during just half a decade of conservation-minded policy. (Politics are fickle, though, and subsequent administrations have reversed this progress.) In addition to protecting endangered species, forest conservation is necessary to stabilize our global climate. Nature preserves and protected areas have increased sharply, from about 7 million km^2 in 1990 to nearly 25 million km^2 in



(a) Climate change

(b) Hunger

(c) Biodiversity

(d) Resource management

FIGURE 1.5 Major environmental themes: (a) Climate change is projected to raise temperatures, especially in northern winter months. (b) Chronic hunger remains a persistent problem, especially in regions of political conflict. (c) Poaching and habitat loss threaten many species, including rhinos, but (d) sustainable resource use can safeguard vital resources, such as local fisheries.

a: Source: NOAA Geophysical Fluid Dynamics Laboratory; b: Jonas Gratzer/LightRocket/Getty Images; c: Tom Finkle; d: William P. Cunningham

2018, or around 12 percent of global land area. Marine preserves add another 33 million km^2 of designated reserves. Many of these areas are weakly protected, however, and rapidly expanding agriculture, forestry, mining, and urbanization make improved protection more critical than ever (see chapter 12).

Energy

How we obtain and use energy will determine our environmental future. Fossil fuels (oil, coal, and natural gas) presently provide around 80 percent of the energy used in industrialized countries. These resources have transformed our society and economies, giving us unprecedented access to new opportunities and goods. But our dependence on these resources has grown unsustainably high. Acquiring and using these fuels causes air and water pollution, mining damage, shipping accidents, and political conflict. Fossil fuels are also nonrenewable resources, with finite supplies, at least on a human time scale. Cleaner energy resources, including solar power, wind, geothermal, and biomass, are renewable (naturally replenished). These, together with conservation, could give us cleaner, less destructive options if we invest appropriately. Cities and regions everywhere are investing in renewable energy sources in order to protect energy security, employment, and the climate (fig. 1.6*a*).

Rapidly developing countries have the capacity to make real progress. China leads the world in solar energy, wind turbines, and biogas generation (from agricultural waste), and developing countries are increasingly investing in renewable energy sources. Progress in photovoltaic production has helped prices for solar panels in the United States drop by from $20 per watt in the 1980s to less than 50 cents today. The price of solar and wind is now competitive with fossil fuels. The European Union has pledged to get 20 percent of its energy from renewable sources by 2020. Improved permitting, financing, and installation strategies have been almost as important as improved technology. The United Kingdom aims to cut carbon dioxide emissions by 60 percent through energy conservation and a switch to renewables. Denmark and Sweden aim to eliminate most fossil fuel uses by 2050.

Pollution and environmental health

In developing areas, especially China and India, air quality has worsened dramatically in recent years. Over southern Asia, for example, satellite images recently revealed that a 3-km (2-mile)-thick toxic haze of ash, acids, aerosols, dust, and photochemical products regularly covers the entire Indian subcontinent for much of the year. At least 3 million people die each year from diseases triggered by air pollution. The United Nations estimates that, worldwide, more than 2 billion metric tons of air pollutants (not including carbon dioxide or windblown soil) are emitted each year, and many of these pollutants travel worldwide. Mercury, pesticides, perfluorocarbons, and other long-lasting pollutants accumulate in arctic ecosystems and native people after being transported by air currents from industrial regions thousands of kilometers to the south. And on some days, 75 percent of the smog and particulate pollution recorded in California can be traced to Asia.

The good news is that we know how to control air pollution. Metals, dust, even greenhouse gases can be captured before they leave the smoke stack. Most cities in Europe and North America are cleaner and healthier now than they were a half century ago. Clean technology benefits the economy and saves lives. The question is how to ensure that pollution controls are used where they are needed.

Water resources

Water may well be the most critical resource in the twenty-first century. Climate change is reducing irrigation supplies in many farming regions. Over 600 million people (9 percent of us) lack safe drinking water, and 2.4 billion (32 percent) don't have safe sanitation (fig. 1.6*b*). These figures are considerably better than 25 years ago, but polluted water and inadequate sanitation are estimated to contribute to illness in more than a billion people annually, and to the death of over 5 million children per year. About 40 percent of the world population lives in countries where water demands now exceed supplies, and the UN projects that by 2025 as many as three-fourths of us could live under similar conditions. Water shortages and drought are frequently blamed for displacement of "climate refugees," who lack water for farming or basic subsistence.

Health and quality of life have improved in many regions, however, as safer water supplies have lowered incidence of waterborne illnesses. These and other infectious diseases have declined, while life expectancy has nearly doubled, on average (fig. 1.6*c*). Since 1990, more than 800 million people have gained access to improved water supplies and modern sanitation.

Information and education

Education, especially for girls, is now recognized to be the most powerful strategy for slowing population growth and reducing child mortality. In this and many other cases, increasing access to education and information are transforming lives around the

(a) Renewable energy **(b) Water resources** **(c) Health care** **(d) Education**

FIGURE 1.6 Renewable energy (a) is a central theme. Water quality (b) continues to cause illness around the world, but there has been substantial progress in (c) health care, and (d) education.
a: Source: Dennis Schroeder/NREL/U.S. Dept. of Energy; b: Roger A. Clark/Science Source; c: Dimas Ardian/Getty Images News/Getty Images; d: Anjo Kan/Shutterstock

world. Rates of illiteracy are falling in many areas, including very poor regions (fig. 1.6*d*). Because so many environmental issues can be fixed by new ideas, technologies, and strategies, expanding access to knowledge is essential to progress. The increased speed at which information now moves around the world offers unprecedented opportunities for sharing ideas. Developing countries may be able to avoid the mistakes made by industrialized countries and grow with new, efficient, and environmentally sustainable technologies.

Quantitative Reasoning

In the Ecological Footprint discussion, examine figure 1.7. Which factor shown has the largest effect? The second largest? Which has the smallest? Can you explain the idea of a "global hectare"? Finally, which factor has increased the most since 1963?

Think of a parent or grandparent who was an adult in 1963. In what ways was his or her energy use different from yours? Why?

What Do You Think?

Calculating Your Ecological Footprint

Can the earth sustain our current lifestyles? Will there be adequate natural resources for future generations? These questions are among the most important in environmental science today. We depend on our environment for food, water, energy, oxygen, waste disposal, and other life-support systems. For resource use to be sustainable, we cannot consume them faster than nature can replenish them. Degradation of ecological systems ultimately threatens everyone's well-being. Although we may be able to overspend nature's budget temporarily, future generations will have to pay the debts we leave behind.

To calculate your debts, you need a good accounting system. Organizations such as Redefining Progress provide tools to calculate an **ecological footprint,** a measure used to quantify the demands placed on nature by individuals or by nations. Online footprint calculators, such as the WWF Footprint Calculator, or the Redefining Progress calculator, let you assess your own footprint by answering a simple questionnaire about consumption patterns, such as electricity use, shopping, and driving habits.

Footprints are often calculated in terms of global hectares ("gha") of productive capacity, or the global area that would be needed to support one person. Part of the power of this metaphor is that we can visualize a specific area of land—one hectare is an area 100 m × 100 m—and we can use the numbers to compare overall consumption patterns among countries. The term "global hectares" also reminds us that we are always consuming resources from around the world.

According to Redefining Progress, the average world citizen has an ecological footprint equivalent to 2.7 gha, while the biologically productive land available is only 1.8 gha per person. How can this be? We're using nonrenewable resources (such as fossil fuels) to support a lifestyle beyond the productive capacity of our environment. It's like living by borrowing on your credit cards. You can do it for a while, but eventually you have to pay off the deficit. The imbalance is far more pronounced in wealthier countries. The average resident of the United States, for example, lives at a consumption level that requires 7.2 gha of biologically productive land. If everyone in the world were to adopt a North American lifestyle, we'd need about four more planets to support us all.

Like any model, an ecological footprint gives a usefully simplified description of a system. Also like any model, it is built on a number of simplifying assumptions: (1) Various measures of resource consumption and waste flows can be converted into the biologically productive area required to maintain them; (2) different kinds of resource use and dissimilar types of productive land can be standardized into roughly equivalent areas; (3) because these areas stand for mutually exclusive uses, they can be added up to a total—a total representing humanity's demand—that can be compared to the total world area of productive land.

Technological change sometimes can reduce our footprint: For example, world food production has increased about fourfold since 1950, mainly through advances in irrigation, fertilizer use, and higher-yielding crop varieties, rather than through increased croplands. How to sustain this level of production is another question, but this progress shows that land area isn't always an absolute limit. Similarly, switching to renewable energy sources such as wind and solar power can greatly reduce our ecological footprint. Note that in figure 1.7, carbon emissions (from energy consumption) make up the largest share of the calculated footprint globally. In Germany, which has invested heavily in wind, solar, small-scale hydropower, and public transportation, the ecological footprint is only 4.6 gha per person.

What are the most important steps your community could take to reduce its footprint? Are there things you could do to reduce your personal footprint? Is technological progress most important, or are there policy measures that could be just as important in helping developing areas grow without increasing their ecological footprint?

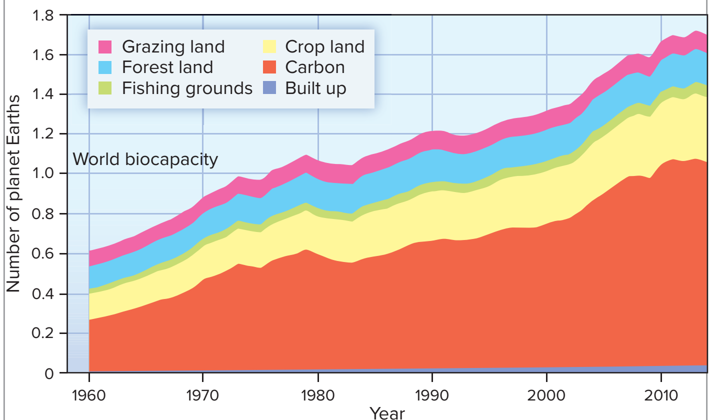


FIGURE 1.7 Humanity's ecological footprint has nearly tripled since 1961, when we began to collect global environmental data.
Source: WWF, Global Footprint Network, 2018.

Section Review

1. Why is population an important question in environmental science? In what ways is population less of a problem than in earlier years?
2. In what ways is pollution still a problem? Has it improved? Why?
3. What is an "ecological footprint"?

1.2 Where Do Our Ideas About Our Environment Come From?

- *Utilitarian conservation seeks to protect useful resources.*
- *Wilderness preservation aims to preserve wilderness for aesthetic, intellectual, or philosophical value.*
- *Modern environmental movements have formed to fight pollution, injustice, and poverty.*

Debates about human misuse of nature have a long history. Plato complained in the fourth century B.C.E. that Greece once had been blessed with fertile soil and clothed with abundant forests of fine trees. After the trees were cut to build houses and ships, however, heavy rains washed the soil into the sea, leaving only a rocky "skeleton of a body wasted by disease." Springs and rivers dried up and farming became all but impossible (fig. 1.8). Many classical authors regarded Earth as a living being, vulnerable to aging, illness, and even mortality following the devastation of forest clearing, soil degradation, and other activities.

Some of the earliest *scientific* studies of environmental degradation were carried out in the eighteenth century by French and British colonial administrators. These administrators, some of whom were trained scientists, observed rapid soil loss and drying wells that resulted from intensive colonial production of sugar and other commodities. These early conservationists observed and understood the connection between deforestation, soil erosion, and local climate change, so they recognized that environmental stewardship was an economic necessity. The pioneering British plant physiologist Stephen Hales, for instance, suggested that conserving green plants preserved rainfall. His ideas were put into practice in 1764 on the Caribbean island of Tobago, where about 20 percent of the land was designated as "reserved in wood for rains."

FIGURE 1.8 Nearly 2,500 years ago, Plato lamented land degradation that denuded the hills of Greece. Have we learned from history's lessons?
Ken Walsh/Alamy Stock Photo

Similarly, Pierre Poivre, an early French governor of Mauritius, an island in the Indian Ocean, was appalled at the environmental and social devastation caused by destruction of wildlife (such as the flightless dodo) and the felling of ebony forests on the island by early European settlers. In 1769, Poivre declared that one-quarter of the island was to be preserved in forests, particularly on steep mountain slopes and along waterways. Mauritius remains a model for balancing nature and human needs. Its forest reserves shelter a larger percentage of its original flora and fauna than most other human-occupied islands.

Current ideas have followed industrialization

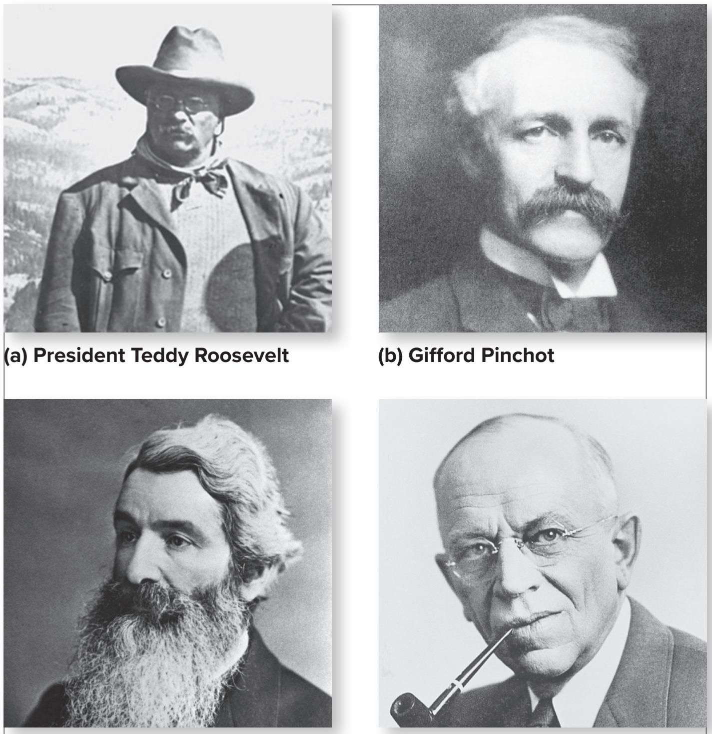
Many of our current ideas about our environment and its resources were articulated by writers and thinkers in the past 150 years. Although many earlier societies had negative impacts on their environments, recent technological innovations have greatly accelerated our impacts. As a consequence of these changes, different approaches have developed for understanding and protecting our environment.

We can divide conservation history and environmental activism into at least four distinct stages: (1) pragmatic resource conservation, (2) moral and aesthetic nature preservation, (3) a growing concern about health and ecological damage caused by pollution, and (4) global environmental citizenship. Each era focused on different problems and each suggested a distinctive set of solutions. These stages are not necessarily mutually exclusive, however. Ideas from all these stages persist today, shaping our ideas and priorities about environmental resources and conservation. But it is useful to associate these ideas with particular stages in history that inspired their widespread adoption.

Stage 1. Resource waste inspired pragmatic, utilitarian conservation

Many historians consider the publication of *Man and Nature* in 1864 by geographer George Perkins Marsh as the wellspring of environmental protection in North America. Marsh, who also was a lawyer, politician, and diplomat, traveled widely around the Mediterranean as part of his diplomatic duties in Turkey and Italy. He read widely in the classics (including Plato) and personally observed the damage caused by the excessive grazing by goats and sheep and by the deforestation of steep hillsides. Alarmed by the wanton destruction and profligate waste of resources still occurring on the American frontier in his lifetime, he warned of its ecological consequences. Largely as a result of his book, national forest reserves were established in the United States in 1873 to protect dwindling timber supplies and endangered watersheds.

Among those influenced by Marsh's warnings were President Theodore Roosevelt (fig. 1.9*a*) and his chief conservation advisor,



(a) President Teddy Roosevelt (b) Gifford Pinchot (c) John Muir (d) Aldo Leopold

FIGURE 1.9 Some early pioneers of the American conservation movement. President Teddy Roosevelt (a) and his main advisor Gifford Pinchot (b) emphasized pragmatic resource conservation, while John Muir (c) and Aldo Leopold (d) focused on ethical and aesthetic relationships.

a: Source: Library of Congress Prints & Photographs Division [LC-USZ62-77199]; b: Source: Library of Congress Prints & Photographs Division [LC-USZ62-103915]; c: Bettmann/Getty Images; d: AP Images

Gifford Pinchot (fig. 1.9*b*). In 1905, Roosevelt, who was the leader of the populist, progressive movement, moved the Forest Service out of the corruption-filled Interior Department into the Department of Agriculture. Pinchot, who was the first native-born professional forester in North America, became the founding head of this new agency. He put resource management on an honest, rational, and scientific basis for the first time in our history. Together with naturalists and activists such as John Muir, William Brewster, and George Bird Grinnell, Roosevelt and Pinchot established the framework of our national forest, park, and wildlife refuge systems, passed game protection laws, and tried to stop some of the most flagrant abuses of the public domain.

The basis of Roosevelt's and Pinchot's policies was pragmatic **utilitarian conservation.** They argued that the forests should be saved "not because they are beautiful or because they shelter wild creatures of the wilderness, but only to provide homes and jobs for people." Resources should be used "for the greatest good, for the greatest number for the longest time." "There has been a fundamental misconception," Pinchot said, "that conservation means nothing but husbanding of resources for future generations. Nothing could be further from the truth. The first principle of conservation is development and use of the natural resources now existing on this continent for the benefit of the people who live here now. There may be just as much waste in neglecting the development and use of certain natural resources as there is in their destruction." This pragmatic approach still can be seen today in the multiple use policies of the Forest Service.

Stage 2. Ethical and aesthetic concerns inspired the preservation movement

John Muir (fig. 1.9*c*) was a geologist, author, and first president of the Sierra Club. He strenuously opposed Pinchot's utilitarian approach. Muir argued that nature deserves to exist for its own sake, regardless of its usefulness to us. Aesthetic and spiritual values formed the core of his philosophy of nature protection. This outlook has been called **biocentric preservation** because it emphasizes the fundamental right of other organisms to exist and to pursue their own interests. Muir wrote: "The world, we are told, was made for man. A presumption that is totally unsupported by the facts. . . . Nature's object in making animals and plants might possibly be first of all the happiness of each one of them. . . . Why ought man to value himself as more than an infinitely small unit of the one great unit of creation?"

Muir, who was an early explorer and interpreter of the Sierra Nevada Mountains in California, fought long and hard for the establishment of Yosemite and Kings Canyon National Parks. The National Park Service, established in 1916, was first headed by Muir's disciple Stephen Mather and has always been oriented toward preservation of nature in its purest state. It has often been at odds with Pinchot's utilitarian Forest Service.

In 1935, pioneering wildlife ecologist Aldo Leopold (fig. 1.9*d*) bought a small, worn-out farm in central Wisconsin. A dilapidated chicken shack, the only remaining building, was remodeled into a rustic cabin (fig. 1.10). Working together with his children, Leopold planted thousands of trees in a practical experiment in restoring the health and beauty of the land. Leopold argued for stewardship of the land. He wrote of "the land ethic," by which we should care for the land because it's the right thing to do—as well as the smart thing. "Conservation," he wrote, "is the positive exercise of skill and insight, not merely a negative exercise of abstinence or caution." The shack became a writing refuge and became the main focus of *A Sand County Almanac,* a much beloved collection of essays about our relation with nature. In it, Leopold wrote, "We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect."

Quantitative Reasoning

Most successful pollution control and conservation efforts have succeeded only when it became possible to gather reliable data, such as the number of illnesses and economic losses resulting from air pollution. Discuss with other students: Are you more convinced of a problem when you see data? Why or why not? Do you, or those around you, feel that environmental data is easy to understand when you see it?

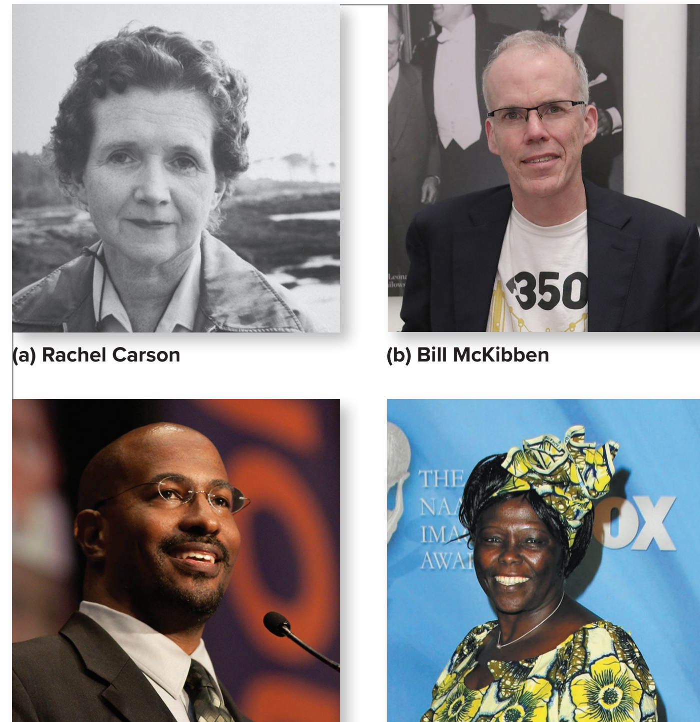
FIGURE 1.10 Aldo Leopold's Wisconsin shack, the main location for his *Sand County Almanac,* in which he wrote, "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise." How might you apply this to your life?
William P. Cunningham

Stage 3. Rising pollution levels led to the modern environmental movement

The undesirable effects of pollution probably have been recognized at least as long as those of forest destruction. In 1273, King Edward I of England threatened to hang anyone burning coal in London, because of the acrid smoke it produced. In 1661, the English diarist John Evelyn complained about the noxious air pollution caused by coal fires and factories and suggested that sweet-smelling trees be planted to purify city air. Increasingly dangerous smog attacks in Britain led in 1880 to the formation of a national Fog and Smoke Committee to combat this problem.

The tremendous industrial expansion during and after the Second World War added a new set of concerns to the environmental agenda. *Silent Spring,* written by Rachel Carson (fig. 1.11*a*) and published in 1962, awakened the public to the threats of pollution and toxic chemicals to humans as well as other species. The movement she engendered has been called **modern environmentalism,** with concerns that include both environmental resources and pollution. Like many environmentalists, Carson was concerned with the ways pollution simultaneously endangered human health and the survival of other species.

As environmental concerns have expanded to climate action, one of the new leaders has been Bill McKibben (fig. 1.11*b*), an author, educator, and environmentalist who has written extensively about climate change and has led campaigns to demand political action on this existential threat. As scholar in residence at Middlebury College, he worked with a group of undergraduate students to create 350.org, an organization that has sponsored thousands of demonstrations around the world to raise public awareness about climate change. The group, which sparked actions for fossil fuel divestment in many campuses and communities, has been widely praised for its creative use of social media and public organization. McKibben and 350.org led the opposition to the Keystone XL pipeline project, which was designed to transport crude oil from Alberta's tar sands to export terminals in Texas. Many pipeline protests since then have helped push for alternatives to oil and gas.



(a) Rachel Carson **(b) Bill McKibben** **(c) Van Jones** **(d) Wangari Maathai**

FIGURE 1.11 Among many distinguished environmental leaders in modern times, (a) Rachel Carson, (b) Bill McKibben, (c) Van Jones, and (d) Wangari Maathai stand out for their dedication, innovation, and bravery.
a: Alfred Eisenstaedt/The LIFE Picture Collection/Getty Images; b: Cindy Ord/Getty Images; c: Ryan Rodrick Beiler/Shutterstock; d: s_bukley/Shutterstock

Stage 4. Environmental quality is tied to social progress

Some have claimed that the roots of the environmental movement are elitist—promoting the interests of a wealthy minority who can afford to vacation in wilderness. In fact, most environmental leaders have seen social justice and environmental equity as closely linked. Gifford Pinchot, Teddy Roosevelt, and John Muir all strove to keep land and resources accessible to everyone, at a time when public lands, forests, and waterways were increasingly controlled by industrial interests, especially railroad, mining, and logging companies. The idea of national parks, one of our principal strategies for nature conservation, is to provide public access to natural beauty and outdoor recreation. Aldo Leopold, a founder of the Wilderness Society, promoted ideas of land stewardship among farmers, fishers, and hunters. Robert Marshall, also a founder of the Wilderness Society, campaigned all his life for social and economic justice for low-income groups. Many environmental leaders grew up in working-class families, so their sympathy with social causes is not surprising.

Issues of social justice are increasingly central to discussions of sustainablility and environmental policy. Anthony Kapel "Van" Jones (fig. 1.11*c*) is one who has spoken powerfully for social and environmental progress, helping to bring visibility to the power that people of color can have in environmental action. As both a social justice and environmental activist, Jones has fought poverty and racial injustice by creating hundreds of thousands of "green-collar" jobs installing solar systems and upgrading the energy efficiency of millions of American homes. He served as President Barack Obama's Special Advisor for Green Jobs and has worked to build a "green economy for everyone." He has also brought artists, athletes, and local leaders into national dialogues and engagement around social and environmental issues.

Some of today's leading environmental thinkers come from developing nations, where poverty and environmental degradation plague hundreds of millions of people. Dr. Wangari Maathai of Kenya (1940–2011) was a notable example. In 1977, Dr. Maathai (see fig. 1.11*d*) founded the Green Belt Movement in her native Kenya as a way of both organizing poor rural women and restoring their environment. Beginning at a small, local scale, this organization has grown to more than 600 grassroots networks across Kenya. They have planted more than 30 million trees, while mobilizing communities for self-determination, justice, equity, poverty reduction, and environmental conservation. Dr. Maathai was elected to the Kenyan Parliament and served as assistant minister for environment and natural resources. Her leadership helped bring democracy and good government to her country. In 2004, she received the Nobel Peace Prize for her work, the first time a Nobel has been awarded for environmental action. In her acceptance speech, she said, "Working together, we have proven that sustainable development is possible; that reforestation of degraded land is possible; and that exemplary governance is possible when ordinary citizens are informed, sensitized, mobilized and involved in direct action for their environment."

Photographs of the earth from space (fig. 1.12) provide a powerful icon for the fourth wave of ecological concern, which might be called **global environmentalism.** These photos remind us how small, fragile, beautiful, and rare our home planet is. We all share a common environment at this global scale. As our attention shifts from questions of preserving particular landscapes or preventing pollution of a specific watershed or airshed, we begin to worry about the life-support systems of the whole planet.

A growing number of Chinese activists are part of this global environmental movement. In 2006, Yu Xiaogang was awarded the Goldman Prize, the world's top honor for environmental protection. Yu was recognized for his work on Yunan's Lashi Lake, where he brought together residents, government officials, and entrepreneurs to protect wetlands, restore fisheries, and improve water quality. He also worked on sustainable development programs, such as women's schools and microcredit loans. His leadership was instrumental in stopping plans for 13 dams on the Nu River (known as the Salween in Thailand and Burma). Another Goldman Prize winner is Dai Qing, who was jailed for her book that revealed the social and environmental costs of the Three Gorges Dam on the Yangtze River.

FIGURE 1.12 The life-sustaining ecosystems on which we all depend are unique in the universe, as far as we know.
StockTrek/age fotostock

Section Review

1. Differentiate "conservation" and "preservation." Identify one person associated with each.
2. What was Rachel Carson's *Silent Spring* about? Why?
3. In what ways is environmental quality tied to social progress?

1.3 Sustainable Development

- *Poverty affects quality of life in many ways.*
- *Poverty has declined dramatically in recent years, but so has environmental quality.*
- *Sustainable development aims to reduce poverty without damaging environmental resources.*

Policymakers are becoming aware that eliminating poverty and protecting our common environment are inextricably interlinked, because the world's poorest people are both victims and agents of environmental degradation. The poorest people are often forced to meet short-term survival needs at the cost of long-term sustainability. Desperate for croplands to feed their families, and for fuel, many clear forests or cultivate steep hillsides, where soil is rapidly eroded. Others migrate to the crowded shantytowns that surround most major cities in the developing world.

As we have noted, one of the core concepts of modern environmental thought is **sustainable development,** often defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." In other words, we should be able to improve conditions for the world's poorest populations without devastating the environment. This definition was given in a 1987 report of the World Commission on Environment and Development, Our Common Future. This report is often called the Brundtland Report, after the chair of the commission, Norwegian prime minister Gro Harlem Brundtland.

The Brundtland Report led to the pivotal 1992 Earth Summit, a United Nations meeting held in Rio de Janeiro, Brazil. The Rio meeting was a pivotal event because it brought together many diverse groups. Environmentalists and politicians from wealthy countries, indigenous people and workers struggling for rights and land, and government representatives from developing countries all came together and became more aware of their common needs. The Rio meeting is largely credited with spreading the idea of sustainable development.

The World Bank estimates that 700 million people (nearly 10 percent of us) live below an international poverty line of (U.S.) $1.90 per day. This is less than a third as many severely impoverished people as there were in 1990, so it represents tremendous progress. Still, the human suffering engendered by this poverty is tragic. The very poor often lack access to an adequate diet, decent housing, basic sanitation, clean water, education, medical care, and other essentials for a humane existence (fig. 1.13). Seventy percent of those people are women and children.

Poverty affects many **quality-of-life indicators** (table 1.1). Infant mortality in the least-developed countries is about 25 times as high as in the most-developed countries. Modern sanitation, essential for controlling disease, is available to only 23 percent of residents in poorer countries. Meanwhile, carbon dioxide emissions (a measure of both energy use and contributions to global warming) are over 30 times greater in rich countries.

FIGURE 1.13 People living in extreme poverty generally lack adequate food, housing, medical care, clean water, and safety.
William P. Cunningham

Table 1.1 Quality-of-Life Indicators

	Least-Developed Countries	Most-Developed Countries
GDP/Person[1]	$2,122	$41,395
Life Expectancy	63 years	81 years
Adult Literacy	58%	99%
Child Labor[2]	21.7	~0
Female Secondary Education	17%	95%
Total Fertility[3]	4.1	1.8
Infant Mortality[4]	55	5
Percent Urban	29.8%	81.9%
Electricity Access	34.2%	99.9%
CO_2/Capita[5]	0.3 tons	11 tons

[1]Annual gross domestic product per person, U.S. dollar equivalent
[2]Percent ages 5–14
[3]Average births/woman
[4]Per 1,000 live births
[5]Metric tons/yr/person
Source: UNDP Human Development Index, 2018.

Global regions of extreme poverty and wealth are distinctly separate (fig. 1.14). The Human Development Index (HDI) is an index that aggregates factors such as health, education, and poverty, some of which appear in table 1.1. Having an index like this allows us to compare countries, and to see where need is greatest.

Affluence is a goal and a liability

About one-sixth of the world's population live in the richest countries, where the average per capita income is above (U.S.) $41,000 per year. Most of these countries are in North America or Western Europe, but Japan, Singapore, and Australia also fall into this group. Another one-sixth live in the least-developed countries, with per capita income averaging less than $2,500. The remaining two-thirds of the world's population live in middle- or low-income countries, where incomes average over $10,000, and where most people live above the extreme poverty line, by global standards.

Those of us in the richer nations enjoy unprecedented affluence and comfort. To do so, we consume an inordinate share of the world's resources and produce unsustainable amounts of pollution—although much of that pollution occurs far from where we live, in industrial cities and degraded mining regions and farmlands of distant countries. The United States, for example, with about 4.6 percent of the world's population, consumes about 20 percent of all oil, and produces about 15 percent of all carbon dioxide and half of all toxic wastes in the world (fig. 1.15).

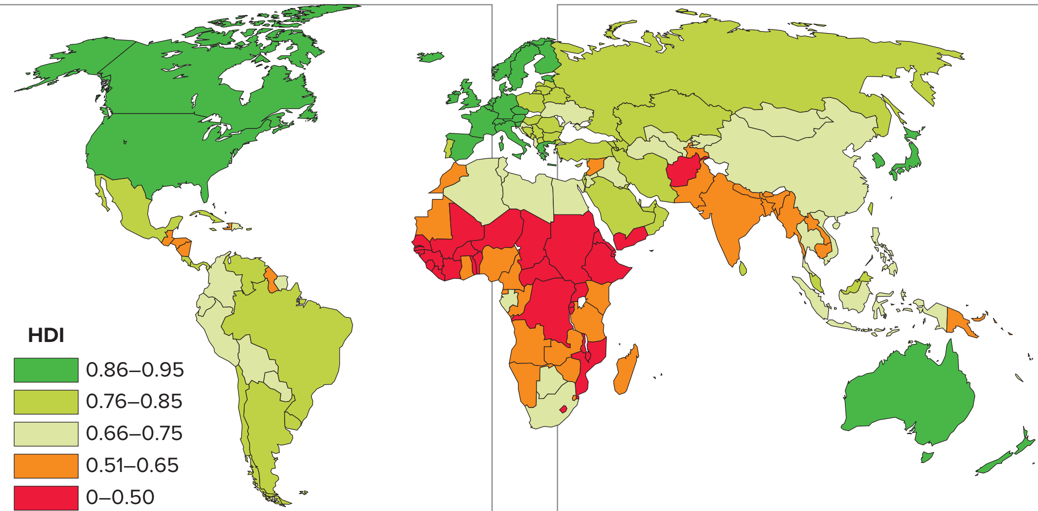


FIGURE 1.14 Human Development Index. Values near 1 represent strong health, education, and quality of life indicators.
Source: UNEP 2016.

FIGURE 1.15 "And may we continue to be worthy of consuming a disproportionate share of this planet's resources."
©Lee Lorenz, The New Yorker Collection. ©The Cartoon Bank. Used with permission. All rights reserved

FIGURE 1.16 A rapidly growing economy has brought increasing affluence to China that has improved standards of living for many Chinese people, but it also brings environmental and social problems associated with Western lifestyles.
06photo/Shutterstock

Low-income countries hope to emulate this prosperity. Take the example of China, the world's most dramatic case of development. In the early 1960s, some 300 million Chinese suffered from chronic hunger, and perhaps 50 million starved to death in the worst famine in world history. Since then, China has experienced amazing economic growth and modernization. The national GDP has been increasing at about 5–10 percent per year. Hundreds of millions of people have been lifted out of extreme poverty. Chronic hunger has become uncommon. Average life expectancy has increased from 42 to 76 years, and infant mortality dropped from 150 per 1,000 live births in 1960 to 11 today. Annual per capita GDP has grown from less than (U.S.) $200 per year to more than $12,000 (fig. 1.16).

As a consequence of this growth, pollution has become more severe each year, as demand has exploded for resources, consumer goods, cars, and other luxuries. Most Chinese still consume far less than Americans or Europeans, though. In terms of ecological footprints (What Do You Think?, p. 15), it takes about 9.7 global hectares (gha, or hectares worth of resources) to support the

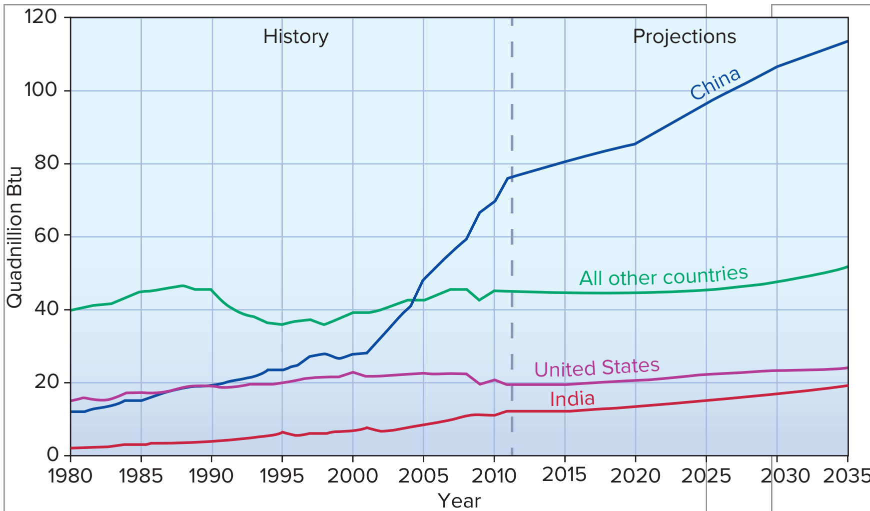


FIGURE 1.17 Coal consumption, most of it used for electricity generation, has fueled much of China's recent growth. Because coal is our primary source of air pollutants and greenhouse gases, projected increases would be disastrous.
Source: US Energy Information Agency 2013.

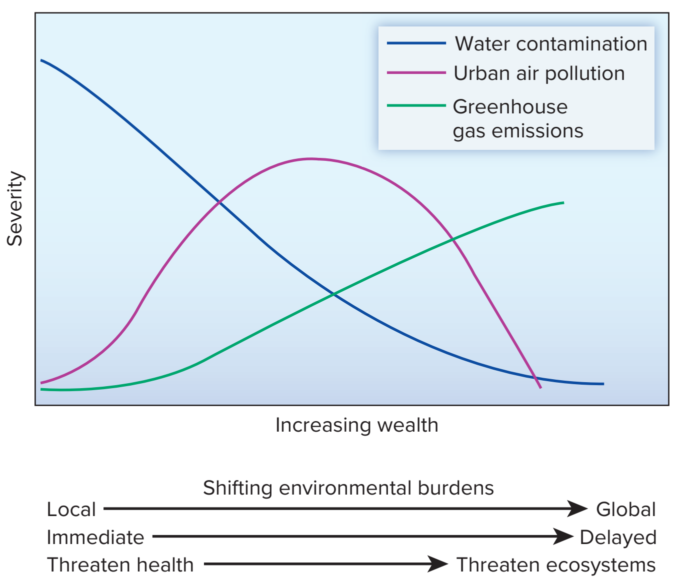


FIGURE 1.18 Environmental indicators show different patterns as incomes rise. Water contamination decreases as people can afford wastewater treatment and drinking water filtration. Local air pollution, on the other hand, often increases as more fuel is burned; eventually, development reaches a point at which people can afford clean air technology. Delayed, distant problems, such as greenhouse gas emissions that lead to global climate change, tend to rise steadily with income because people make decisions based on immediate needs and wants rather than long-term consequences. Thus, we tend to shift environmental burdens from local and immediate to distant and delayed if we can afford to do so.
Source: World Energy Assessment, UNDP.

average American each year. By contrast, the average person in China consumes about 2.1 gha per year. Providing the 1.3 billion Chinese with American standards of consumption would require about 10 billion gha, or almost another entire earth's worth of resources. China's use of coal-powered electricity, one of the most important sources of greenhouse gases and air pollution, has doubled in less than a decade (fig. 1.17).

Historically, some problems such as waste generation and carbon dioxide emissions have tended to increase with economic growth (fig. 1.18). Other problems, such as urban air pollution, tend to rise and then decline. A common explanation for the decline is that increasing wealth leads to better regulation and pollution controls. Some environmental costs can fall steadily with increasing development, as in the case of household sanitation: Communities can pay more to clean and protect water resources as they become wealthier (fig. 1.18). Some of these rules are changing, too. Economic growth has been tied to coal and oil burning ever since the Industrial Revolution. But in recent years, economic growth in many areas has proceeded despite regionally falling greenhouse gas emissions (see chapter 15).

Quantitative Reasoning

Examine figure 1.17. Describe in your own words how increasing wealth might affect water contamination, air pollution, and greenhouse gas emissions. Why might greenhouse gas emissions rise? Describe and explain the air pollution curve.

Is sustainable development possible?

Most poor nations, and most poor families, desperately want to become wealthier, to have more material goods, more food, and more cars, lights, computers, and other amenities. Can everyone have their share without destroying our shared environment? This depends on how development happens, how resources are shared, and whether developing regions find new paths to prosperity, different from the resource-intensive paths of the twentieth century.

Two basic principles of sustainable development, put forth by Herman Daly in the 1970s, are that we cannot consume natural resources faster than they are produced, and we cannot produce waste faster than nature can recycle it, if we intend to be here for the long term. Note, however, that the measures in the Human Development Index (table 1.1) are not resource-intensive factors. Providing basic access to health care and education, or providing clean drinking water and controlling pollution, improves people's lives with few natural resources. At the same time, they greatly advance human resources—our capacity to work and dream. Increasing wealth for the already-wealthy is more costly.

Sustainable development can mean many things. Many forms of sustainable farming, for example, produce food while protecting wildlife habitat, soil, and water resources. Often, sustainable development simply means distributing investment to small producers, who circulate money in their local communities. Fair trade organizations, for example, help people in developing countries to grow or make high-value products—often using traditional techniques and designs—that can be sold on world markets for good prices (fig. 1.19).

It is important to recognize that many innovations for climate action, along with sustainable development, are coming from the developing world. Already by 2015, Kenya produced more than half its electric power from geothermal, wind, and solar energy sources. The World Bank calculates that Sub-Saharan Africa could produce 170 gigawatts of low-carbon energy. This sustainable development potential exists across much of the world. In the Americas, Uruguay achieved 95 percent renewable electricity due to a decade of policy commitment. Costa Rica, with abundant geothermal energy, is approaching 100 percent renewable energy. Nicaragua is aiming for 90 percent renewable energy by 2020.

FIGURE 1.19 A Mayan woman from Guatemala weaves on a backstrap loom. A member of a women's weaving cooperative, she sells her work to nonprofit organizations in the United States at much higher prices than she would get at the local market.
Barry Barker/McGraw-Hill Education

Growth can also occur without increased resource consumption. Markets in arts, entertainment, education, services, and leisure time can improve our lives with little environmental cost. These are growth industries whose primary resource is human ingenuity. This is an idea recognized by economists at least since John Stuart Mill in 1857: "It is scarcely necessary to remark that [resource limitation] implies no stationary state of human improvement. There would be just as much scope as ever for all kinds of mental culture and moral and social progress; as much room for improving the art of living and much more likelihood of its being improved when minds cease to be engrossed by the art of getting on."

The UN has identified 17 Sustainable Development Goals

Beginning in 2016, the United Nations initiated a program to promote 17 **Sustainable Development Goals** (SDGs). The goals are ambitious and global, and they include eliminating the most severe poverty and hunger, promoting health, education, and gender equality, providing safe water and clean energy, and preserving biodiversity (see fig. 1.20). This global effort, developed by representatives of the member states of the UN, seeks to coordinate data gathering and reporting, so that countries can monitor their progress, to share resources, and to promote sustainable investment in developing areas.

For each of the 17 goals, organizers identified targets, some quantifiable, some more general. For example, Goal 1, "End poverty," includes targets to eradicate extreme poverty everywhere, and to ensure that all people have rights to basic services, ownership and inheritance of property, and other economic needs. Goal 7, "Ensure access to affordable, sustainable energy," includes targets of doubling energy efficiency and enhancing international investment in clean energy. Goal 12, "Ensure sustainable consumption and production," calls for cutting per capita food waste in half, as well as phasing out fossil fuel subsidies that encourage wasteful consumption. The UN aims to meet these targets by 2030, in a span of 15 years.

The SDGs also include a number of targets for economic and social equity, and for better governance. To most economists and policymakers, it seems obvious that economic growth is the only way to bring about a long-range transformation to more advanced and productive societies and to provide resources to improve the lot of all people. As former U.S. president John F. Kennedy said, "A rising tide lifts all boats." But the Brundtland report (previous section) emphasized that equity is also essential: Political stability, democracy, and fair access to resources and opportunity are needed to ensure that the poor will get a fair share of the benefits of greater wealth in a society. According to a study released in 2006 by researchers at Yale and Columbia Universities, environmental sustainability tends to occur where there are open political systems and good government.

FIGURE 1.20 The United Nations Sustainable Development Goals are intended to improve well-being of the world's poorest people while also protecting biodiversity, natural resources, and climate. These goals follow the largely successful Millennium Development Goals.
Source: UN Development Programme.

The Millennium Development Goals were largely successful

These ambitious goals might appear unrealistic, but they build on the remarkable (though not complete) successes of the **Millennium Development Goals.** These eight goals were a 15-year effort, from 2000 to 2015, to improve literacy, health, access to safe water, child survival, and other goals. Targets included ending poverty and hunger, universal education, gender equity, child health, maternal health, combating HIV/AIDS, environmental sustainability, and global cooperation in development efforts. While only modest progress was achieved on some goals, UN Secretary General Ban Ki-Moon called that effort the most successful anti-poverty movement in history. Extreme poverty dropped from nearly half the population of developing countries to just 14 percent in only 15 years. The proportion of undernourished people dropped by almost half, from 23 percent to 13 percent. Primary school enrollment rates climbed from 83 percent to 91 percent in developing countries. Girls gained access to education, employment, and political representation in national parliaments.

At the same time, UN reports stressed that many goals were not met. Some 2.6 billion people gained access to safe drinking water, but over 40 percent of the world's population still lacks access to piped drinking water at home. The proportion of urban populations living in slums fell from 39 percent to 30 percent, but that still represents a large population with inadequate and unsafe housing.

The value of having clearly stated goals, especially with quantifiable targets, is that they help people agree on what to work for. With so many simultaneous problems in developing areas, it can be hard for leaders to know where to focus first. Agreed-upon targets, especially when they are shared and monitored by many countries, can strongly motivate action. International agreement on goals can also help motivate financial and planning assistance, both often badly needed in developing areas.

Development depends on how wealthy countries allocate spending

Economist Jeffery Sachs, director of the UN Millennium Development Project, says we could end extreme poverty worldwide by 2025 if the richer countries would donate just 0.7 percent of their national income for development aid in the poorest nations. These funds could be used for universal childhood vaccination against common infectious diseases, access to primary schools for everyone, family planning and maternal health services, safe drinking water and sanitation for all, food supplements for the hungry, and microcredit loans to promote self-employment.

The United States, the world's largest total donor, sets aside only 0.16 percent of its gross domestic product for development aid. That amounts to about 18 cents per citizen per day for both private and government aid to foreign nations. As former Canadian prime minister Jean Chrétien said, "Aid to developing countries isn't charity; it's an investment. It will make us safer, and when standards of living increase in those countries, they'll become customers who will buy tons of stuff from us."

The United Nations Development Programme has estimated that it would take about (U.S.) $135 billion per year to abolish extreme poverty and the worst infectious diseases over the next 20 years. That's a lot of money, but it's not much more than the $120 billion in subsidies and tax breaks the U.S. government gives

FIGURE 1.21 Every year, military spending equals the total income of half the world's people. The cost of a single large aircraft carrier equals 10 years of human development aid given by all the world's industrialized countries.
Source: Kyle Gahlau/DVIDS.

to oil companies each year. And it's far less than the $1 trillion of global military spending each year (fig. 1.21).

Many experts propose that if we were to shift one-tenth of that spending to development aid, we would be much safer than we are spending it on the military. The Worldwatch Institute warns that "poverty, disease and environmental decline are the true axis of evil." Terrorist attacks—and the responses they provoke—are symptoms of the underlying sources of global instability, including the dangerous interplay among poverty, hunger, disease, environmental degradation, and rising competition for resources. Unless the world takes action to promote sustainability and equity, Worldwatch suggests, we are unlikely to resolve persistent problems of wars, terrorism, and natural disasters. As writer H. L. Mencken once said, "If you want peace, work for justice."

Section Review

1. List any three quality of life indicators (table 1.1). How do they differ between wealthy and poor countries?
2. Why is affluence a liability? Give an example.
3. Explain the idea of sustainable development.

1.4 Core Concepts in Sustainable Development

- *"Ecosystem services" is a term for goods, services, and products we rely on; often these are invisible.*
- *Shared resources and ecosystem services can be described as "common property," or as a "commons." Managing common property is a key challenge.*
- *Indigenous peoples often protect biodiversity.*

Some general organizing ideas help us make sense of the problem of sustainable development and of how to think about prosperity in a world of limits. The ideas raised in this section will help you think about issues such as water resource management, ways to preserve water quality, how to encourage greenhouse gas reductions, questions of biodiversity, air quality, and many other natural resource considerations. These issues will also come up in later chapters on economics and policy.

How do we describe resource use?

The natural world supplies the water, food, metals, energy, and other resources we use. Because we use so many kinds of resources, one widely used measure for evaluating resource consumption is the ecological footprint (see What Do You Think?, p. 15, and the Data Analysis section, at the end of this chapter). Our ecological footprint is an index, a number representing a complex array of factors.

Another widely used concept for describing resource use is **throughput,** the amount of material or resources that flow through a system. A household that consumes abundant consumer goods, foods, and energy brings in a great deal of natural resource–based materials; that household also disposes of a great deal of materials. Conversely, a household that consumes very little also tends to produce little waste.

Ecosystem services refers to services or resources provided by environmental systems (fig. 1.22). Provisioning of resources, such as the fuels we burn, may be the most obvious service we require. Supporting services are less obvious until you start listing them: These include water purification, production of food and atmospheric oxygen by plants, or decomposition of waste by fungi and bacteria. Regulating services include maintenance of temperatures suitable for life by the earth's atmosphere, or carbon capture by green plants, which maintains a stable atmospheric composition. Cultural services include a diverse range of recreational, aesthetic, and other nonmaterial benefits. Usually we rely on these resources without thinking about them. They support all our economic activities in some way, but we don't put a price on them because nature doesn't force us to pay for them.

How can we protect these services over the long term? One of the answers to this basic question was given in an essay entitled **"Tragedy of the Commons,"** published in 1968 in the journal *Science* by ecologist Garret Hardin. In this classic framing of the problem, Hardin argued that population growth leads inevitably to overuse and then destruction of common resources—such as shared pastures, unregulated fisheries, fresh water, land, and clean air. Hardin's essay has influenced our ideas about resource management for decades.

Examples of destroyed commons abound. The North Atlantic cod fishery, once one of the world's greatest fish populations, was functionally destroyed by a free-for-all of unregulated fishing by fleets of many nations. The species is not extinct, but it may never recover to its historic abundance. Air pollution is another familiar example: Industries emit pollution from unregulated incinerators and burners, spilling soot, sulfur dioxide, and carbon dioxide into

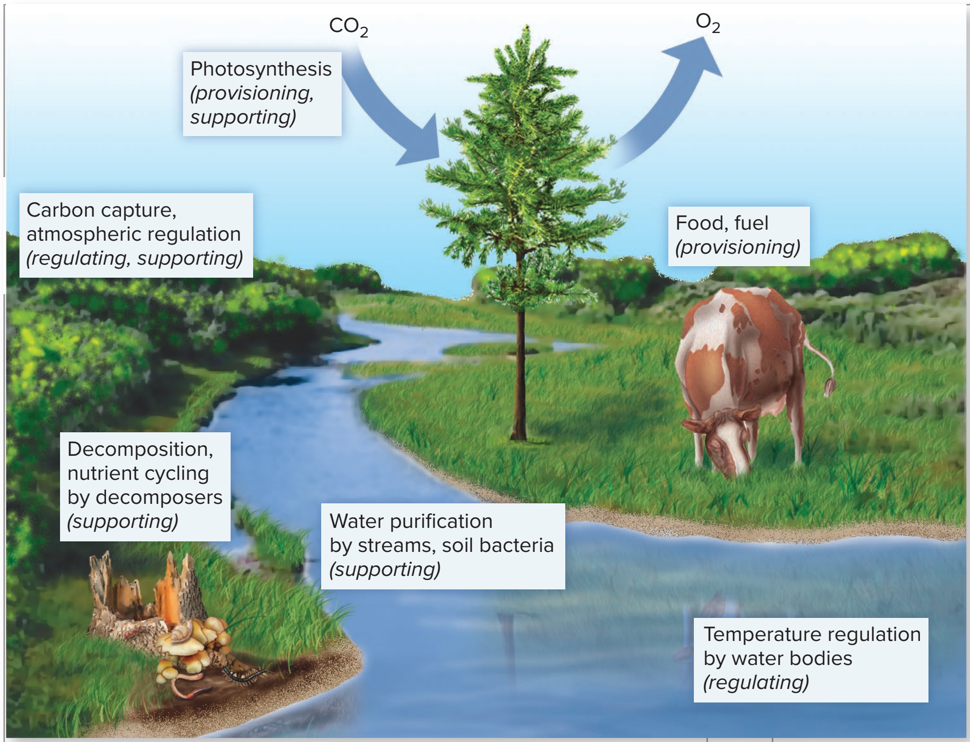


FIGURE 1.22 Ecosystem services we depend on are countless and often invisible.

the air, which is then contaminated for all users. Hardin proposed that there are only two ways to avoid this destruction: (a) a system of private property, in which owners protect resources because of self-interest, or (b) coercive regulation by the state.

An alternative perspective to Hardin's framework is strategies for **managing the commons;** that is, for collectively safe-guarding commonly used resources. The importance of common property management was publicized by Elinor Ostrom, who won the 2009 Nobel Prize in Economic Sciences. Ostrom and her colleagues demonstrated that ordinary people have often created rules and institutions for the sustainable management of shared resources. They examined cases of successful long-term management of sustainably managed fisheries, common forests, common grazing lands, and other resources in communities around the world. They emphasized that not all common properties are well managed, but a great many are.

What conditions can help communities manage their commons over the long term? Many strategies exist, but Ostrom and her colleagues found that some conditions occur frequently in successful cases. Among these are (1) effective and inexpensive monitoring of resource use; (2) an ability to exclude outsiders, who don't understand rules of use; and (3) frequent face-to-face communications and strong social networks among users, which reduce distrust and promote communication about the state of the resource.

What type of institution is best for managing a global commons, such as climate or biodiversity? Garret Hardin, with many others, has argued that local solutions to climate change are irrelevant as long as countries and international institutions fail to make policy changes. Ostrom and her colleagues argued that these large institutions are often incapable of taking strong or quick action for resource conservation. So it is also important to invest in smaller, local, even individual policy changes, whose effects and ideas may spread contagiously or inform broader improvements in resource management. Both positions are probably correct: Often mixtures of different types of institutions, large and small, may be needed, to contribute simultaneously to solutions at different scales.

Planetary boundaries define broad limits

Another way to think about environmental services is planetary boundaries, or thresholds of abrupt or irreversible environmental change. Studies by Johan Rockström and colleagues at the Stockholm Resilience Centre have identified nine major systems with these critical thresholds: climate change, biodiversity, land system change, freshwater use, biogeochemical flows (nitrogen and phosphorus), ocean acidification, atmospheric aerosols, stratospheric ozone loss, and "novel entities," including chemical pollution and other factors (fig. 1.23). Calculations are that we have already passed the planetary boundaries for some of these systems, and that we

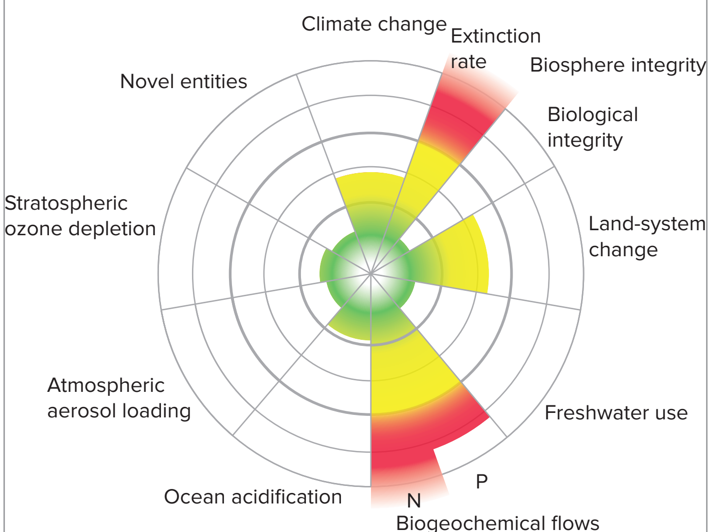


FIGURE 1.23 Calculated planetary boundaries, or thresholds beyond which irreversible change is likely. Green shading represents safe ranges; yellow represents a zone of increasing risk; red wedges represent factors exceeding boundaries.

are approaching limits for others. These overshoots are expected to cause rapid declines in ecosystem function and ecosystem services in many areas.

Ecosystem services are tightly coupled. Destruction of tropical forests in Southeast Asia, for example, can influence heat and drought in North America. Drought and fires in North America enhance climate warming and sea ice loss in the Arctic. A planetary perspective helps us see interconnections in global systems and their effects on human well-being. What it means to pass these boundaries remains uncertain.

Indigenous peoples often protect biodiversity

Development challenges are especially severe for indigenous peoples in both rich and poor countries. Typically descendants of the original inhabitants of an area taken over by more powerful outsiders, indigenous peoples are distinct from their country's dominant language, culture, religion, and racial communities. Consequently, these groups often generally are the least powerful, most neglected groups in an area. Of the world's nearly 6,000 recognized cultures, 5,000 are indigenous; and these account for only about 10 percent of the total world population. In many countries, traditional caste systems, discriminatory laws, economics, or prejudices repress indigenous people. At least half of the world's 6,000 distinct languages are dying because they are no longer taught to children. When the last elders who still speak the language die, so will the culture that was its origin. Lost with those cultures will be a rich repertoire of knowledge about nature and a keen understanding of a particular environment and way of life (fig. 1.24).

FIGURE 1.24 Do indigenous people have unique knowledge about nature and inalienable rights to traditional territories?
Barry Barker/McGraw-Hill Education

Nonetheless, the 500 million indigenous people who remain in traditional homelands still possess valuable ecological wisdom and are the guardians of little-disturbed habitats that are refuges for rare and endangered species and undamaged ecosystems. As we seek strategies for sustainable development and biodiversity conservation, this knowledge may be an essential resource.

Recognizing native land rights and promoting political pluralism can be among the best ways to safeguard ecological processes and endangered species. A few countries, such as Papua New Guinea, Fiji, Ecuador, Canada, and Australia, acknowledge indigenous title to extensive land areas. As the Kuna Indians of Panama say, "Where there are forests, there are native people, and where there are native people, there are forests."

Section Review

1. Think of five ecosystem services on which you rely.
2. What is the "tragedy of the commons"? What are two ways to avoid it?
3. List any two of the factors that can help communities manage a commons.
4. Why do indigenous people often have an interest in protecting biodiversity?

1.5 Environmental Ethics, Faith, and Justice

- *Moral extensionism means extending value beyond ourselves.*
- *Many faiths encourage stewardship because they see divine value in our environment.*
- *Environmental justice involves human rights and environmental justice.*

The ways we interpret environmental issues, or our decisions about what we should or should not do with natural resources, depend partly on our basic worldviews. Perhaps you have a basic ethical assumption that you should be kind to your neighbors, or that you should try to contribute in positive ways to your community. Do you have similar responsibilities to take care of your environment? To conserve energy? To prevent the extinction of rare species? Why? Or why not?

Your position on these questions is partly a matter of **ethics,** or your sense of what is right and wrong. Some of these ideas you learn early in life; some might change over time. Ethical views in society also change over time. In ancient Greece, many philosophers who were concerned with ethics and morality owned slaves. A slave owner could mistreat or even kill a slave with little or no consequences. Today, few societies condone slavery. Most societies now believe it is unethical to treat other humans as property. On the other hand, most societies now consider land, water, forests, and other natural resources as private property. It is the owner's right to conserve or degrade those private resources as they like. Other people (or other organisms) have no legal right to restrict how private property is used or abused. Normally, if you have ancient trees on your property, it is your right to cut and sell them, regardless of your neighbors' opinions. Is this ethical? That depends on your perspective.

Often, our core beliefs are so deeply held that we have difficulty even identifying them. But they can influence how you act, how you spend money, or how you vote. Try to identify some of your core beliefs. What is a basic thing you simply should or should not do? Where does your understanding come from about those actions?

We can extend moral value to people and things

One of the reasons we don't accept slavery now, as the ancient Greeks did, is that most societies believe that all humans have basic rights. The Greeks granted **moral value** (value or worth, based on moral principles) only to adult male citizens within their own community. Women, slaves, and children had few rights and were essentially treated as property. Over time, we have gradually extended our sense of moral value to a wider and wider circle, an idea known as **moral extensionism;** that is, extending moral value to a larger circle of people, organisms, or objects (fig. 1.25). In most countries, women and minorities have basic civil rights, children cannot be treated as property, and even domestic pets have some legal protections against cruel treatment. For many people, moral value also extends to domestic livestock (cattle, hogs, poultry), which makes eating meat a fundamentally wrong thing to do. For others, this moral extension ends with pets, or with humans. Some people extend moral value to include forests, biodiversity, inanimate objects, or the earth as a whole.

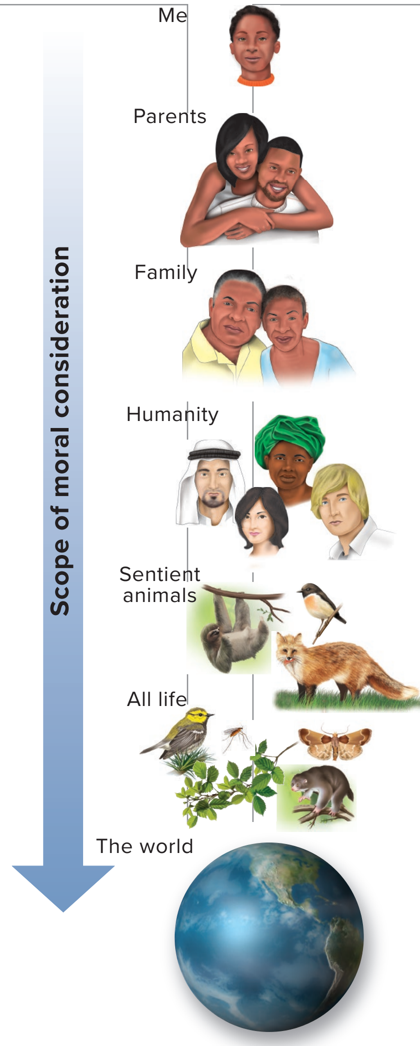


FIGURE 1.25 Moral extensionism describes an increasing consideration of moral value in other living things—or even nonliving things.

How we treat other people, animals, or things can also depend on whether we believe they have **inherent value** (an intrinsic right to exist) or **instrumental value** (usefulness to someone). If I hurt you, I owe you an apology. If I borrow your car and crash it into a tree, I don't owe the car an apology, I owe *you* an apology—or reimbursement.

Does this apply to other species? Domestic animals clearly have an instrumental value because they are useful to (or give comfort to) their owners. But some philosophers would say they also have inherent values and interests. By living, breathing, struggling to stay alive, the animal carries on its own life independent of its usefulness to someone else.

Some argue that even nonliving things also have inherent worth. Rocks, rivers, mountains, landscapes, and certainly the earth itself, have value. These things were in existence before we came along, and we couldn't re-create them if they are altered or destroyed. This philosophical debate became a legal dispute in a historic 1969 court case, when the Sierra Club sued the Disney Corporation on behalf of the trees, rocks, and wildlife of Mineral King Valley in the Sierra Nevada Mountains (fig. 1.26), where Disney wanted to build a ski resort. The Sierra Club argued that it represented the interests of beings that could not speak for themselves in court.

A legal brief entitled *Should Trees Have Standing?,* written for this case by Christopher D. Stone, proposed that organisms as well as ecological systems and processes should have standing (or rights) in court. After all, corporations—such as Disney—are treated as persons and given legal rights even though their "personhood" is only a figment of our imagination. Why shouldn't nature have similar standing? The case went all the way to the Supreme Court but was overturned on a technicality. In the meantime, Disney lost interest in the project and the ski resort was never built. What do you think? Where would you draw the line, regarding what deserves moral standing? Are there ethical limits on what we can do to nature?

Many faiths promote conservation and justice

Ethical and moral values are often rooted in religious traditions, which try to guide us in what is right and wrong to do. With growing public awareness of environmental problems, religious organizations have begun to take stands on environmental concerns. They recognize that some of our most pressing environmental problems don't need technological or scientific solutions; they're not so much a question of what we're able to do, but what we're willing to do. Are we willing to take the steps necessary to stop global climate change? Do our values and ethics require us to do so? In what ways might religious views influence our attitudes toward nature?

Environmental scientists have long been concerned about religious perspectives. In 1967, historian Lynn White Jr. published a widely influential paper, "The Historic Roots of Our Ecological Crisis." He argued that Christian societies have often exploited natural resources carelessly because the Bible says that God