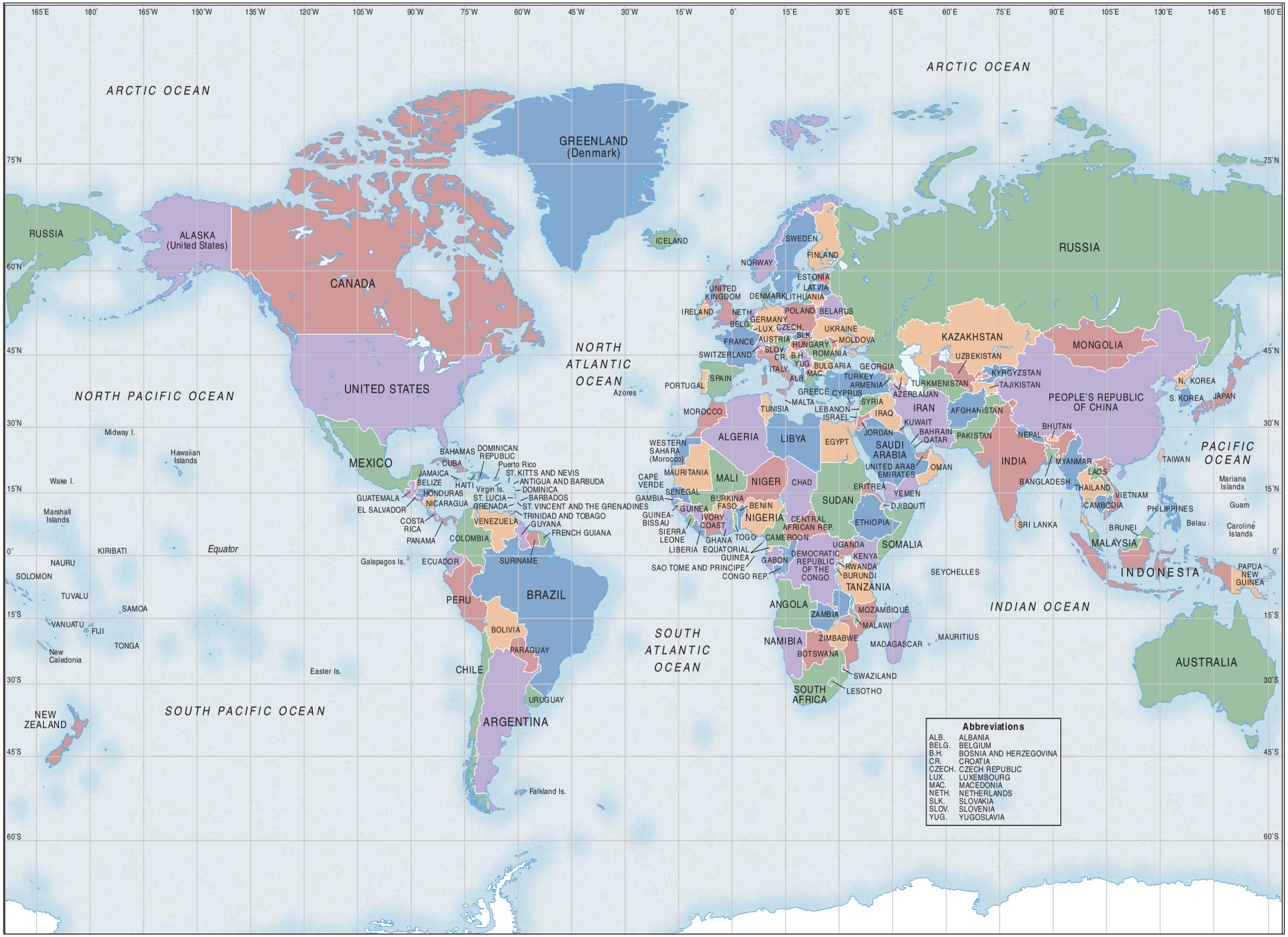

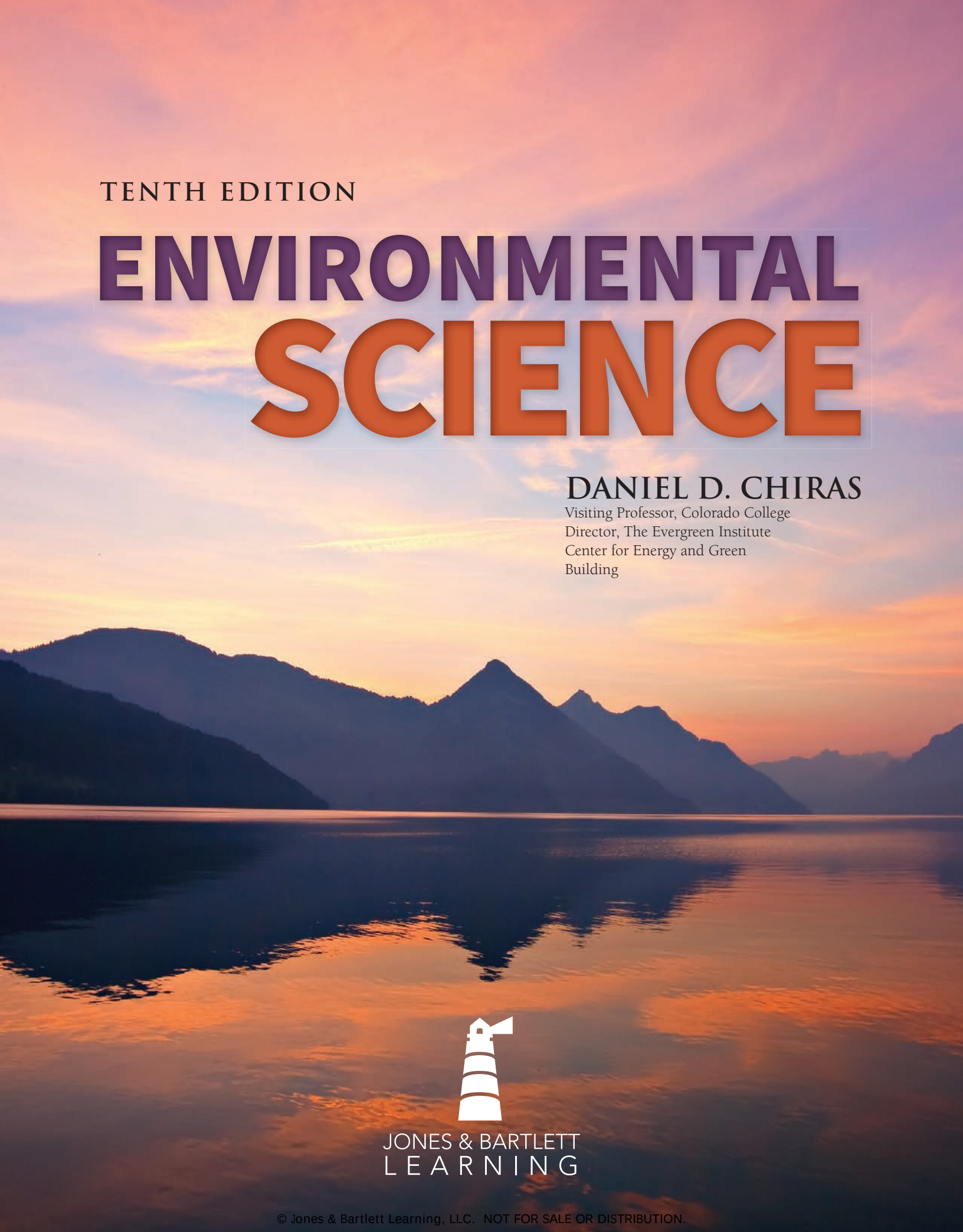

TENTH EDITION

ENVIRONMENTAL SCIENCE

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To my father who started me on the conservation path many years ago.

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PREFACE

Environmental science courses vary widely. Some professors prefer to discuss basic science before they delve into environmental issues such as air pollution, water pollution, global climate change, species, and extinction. Other professors focus closely on the main issues. In between these two approaches are a wide range of options.

This book is meant to serve the diverse approaches of professors. This book presents the basic science needed to understand environmental issues and offers an in-depth look at all of the environmental problems facing the world. This book discusses solutions to environmental issues, including the more traditional ones and a new generation of policies and actions that promise to achieve lasting results. They are sustainable solutions that involve all stakeholders: businesses, governments, and individuals.

During the nearly four decades I have spent working on this book, it has evolved dramatically in response to profound changes in my thinking. Perhaps the most important change has been the shift toward a more comprehensive and more systematic way of viewing environmental problems. One of the useful discoveries I have made over many years is that most environmental problems spring from a common set of root causes. Unlike other environmental science textbooks, this one discusses the common root causes and ways to address them.

Over time, I have also concluded that we've been addressing environmental problems superficially. I've realized that most efforts are stopgap measures—solutions that treat the symptoms while neglecting the underlying root causes. To create lasting solutions we must address their root causes. One root cause is that the systems we depend on—for food, energy, materials, water, waste treatment, and other services—are unsustainable. To solve environmental problems and create an enduring human presence (a sustainable future), we must rethink and restructure basic human systems, such as transportation, energy, waste management, water supply, industry, and housing. This book shows the reader how this can be done—and how such changes can have profound positive effects on the environment.

Another important realization I have made is that to be sustainable, solutions to environmental problems must make sense from social and economic perspectives, not just an environmental one. One-sided solutions don't work. This shift to solutions that make sense from all three perspectives will take enormous creative energy on our part in the years to come.

This edition reflects a pressing need for sustainable solutions—measures that confront the root causes of the environmental crisis and create a society that meets its needs without bankrupting the Earth. This book includes discussions meant to help students understand why human systems need to be revamped and how we go about this challenging task, creating a clean, healthy environment.

In this new edition, I have added new material, updated statistics, and polished the writing. As in the first nine editions, I worked diligently to ensure that this text remains user-friendly. My goal continues to be to present the most important facts and concepts in a clear and exciting fashion. As always, I have strived to present both sides of the issues in the text and in Point/Counterpoint essays that deal with controversial environmental issues. Even though this text presents a strong case for sustainability and systems reform, it is left to you, the reader, to make up your own mind as to the need and desirability of such an approach. My efforts to make this book as unbiased as possible support my objective of letting students make up their own minds about our predicament and ways to extricate ourselves from it. Critical thinking skills presented in the book also help students learn to analyze issues and make up their own minds.

Themes

All textbooks have a central theme or, in some cases, a set of themes that shape the presentation. This book is molded by six central ideas: focus on key principles, sustainability, addressing root causes, systems reform, critical thinking, and action.

FOCUS ON KEY PRINCIPLES Environmental science is a vast field, requiring many years to master. Most students, however, can become proficient in the subject much more quickly when they are taught key concepts. Vital principles are highlighted in special Key Concept boxes at the end of each section. They encapsulate the material covered in each section and provide an excellent tool for studying.

SUSTAINABILITY The main theme of this book is that the long-term well-being of this planet and its inhabitants is in jeopardy and that to create an enduring human presence we must make a massive course change. We must transition to a sustainable society. A sustainable society seeks balance between human and ecological needs. Its economic systems serve people and the planet. Creating a sustainable society may be our only realistic hope for surviving on a finite planet, but it will not evolve without foresight, planning, and action.

ADDRESSING ROOT CAUSES AND SYSTEMS REFORM Creating a sustainable future requires serious efforts to understand and confront the root causes of the environmental crisis. This book outlines those causes and shows ways to address them. Part of this struggle will involve efforts to revamp human systems—make sustainable systems to provide energy, transportation, and waste management, for example.

CRITICAL THINKING This text also stresses critical thinking skills—learning to think critically about issues, a task that is essential to create a sustainable society.

ACTION Finally, this text emphasizes an often overlooked point, that building a sustainable future requires actions by all of us. Air pollution is not just caused by inadequate laws or corporate wrongdoings, it is a result of our own often wasteful lifestyles. Because we are all part of the problem, we must all be part of the solution. Individual action is as essential as responsible corporate and government policies and practices. This book offers even more advice than previous editions on ways we can all go green.

Expanded Basic Science

In recent editions, I have expanded the coverage of basic science, especially information to help students understand global climate and energy. You'll find detailed discussion, for instance, of weather, ocean currents, aquatic ecology, the laws of thermodynamics, and other important facts that help you better understand the world we live in.

Global Focus and Expanded Coverage of International Issues and Solutions

Environmental problems affect us locally, in our own homes and towns and cities. They affect larger regions, too, often covering many states or crossing international borders. And, of course, they often span the globe. As in previous editions, I present a wealth of information on local, regional, and global problems and solutions. Special efforts were made to include examples from Canada as well as countries in Europe, Africa, and Asia.

Organization

This book is divided into six parts.

PART I introduces students to four of the principal themes of this book: sustainability, addressing root causes, restructuring human systems, and critical thinking. It lays an important foundation for the study of environmental science.

PART II introduces the student to basic principles of ecology necessary for understanding environmental issues. These chapters elaborate on six operating principles of sustainability—ideas that will help us revamp modern society one system at a time.

PART III begins the discussion of environmental issues, dealing with one of the most pressing of all; the population crisis. This part examines the impact of rapid population growth—one of the root causes of modern environmental problems—and explores culturally acceptable ways of slowing it down.

PART IV deals with a variety of resource issues, such as wildlife extinction and energy, and outlines strategies for solving them sustainably. In this material, I attempt to show how we can overhaul some of the vital human systems such as energy and waste management.

PART V discusses pollution and legal, technical, and personal solutions for it, including both traditional and sustainable strategies.

PART VI the capstone of the book, attempts to place the population, resource, and pollution crises in a social context. It reexamines ethics and explores economics and government in more detail.

New to This Edition

The *Tenth Edition* has been thoroughly updated with new discoveries, new concepts, and the most recent statistics on resources, population, and pollution. I have added information on changes in environmental laws and regulations. I have also included important new information on peak oil and natural gas, renewable energy options, global climate change, environmentally friendly transportation, environmentally friendly building, ecosystem protection, tropicial rainforests, species extinction, and more.

The Student Experience

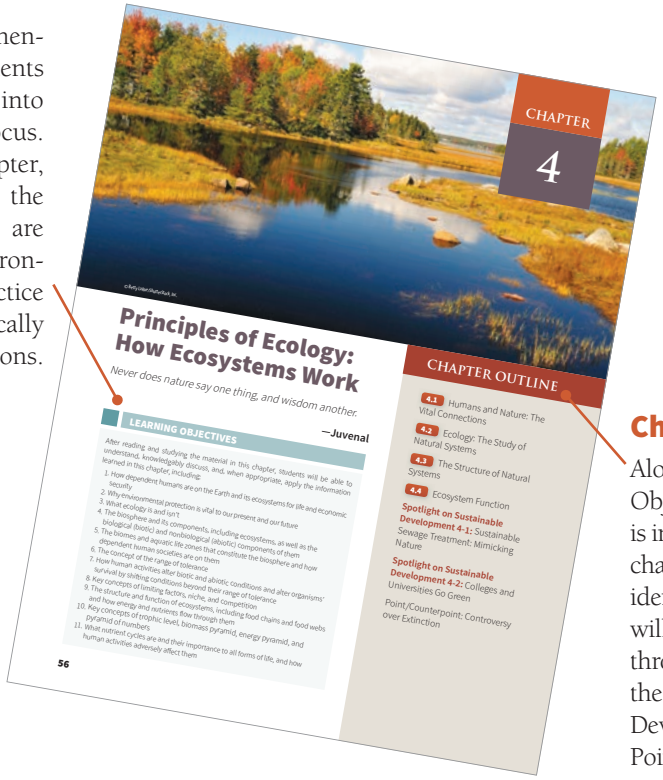
Over the years, this book has undergone some dramatic changes to help make the study of environmental science more interesting, meaningful, and memorable. Below is a list of features students should find helpful:

Study Skills

Immediately following the preface is a brief section on study skills. The study skills section includes numerous simple but effective tips that help students improve their memory, note-taking skills, reading abilities, test-taking abilities, and much more. Study skills can help all students, even A students, become more efficient learners. Skills learned here will carry over to virtually every other course students take and will be helpful throughout life.

Learning Objectives

Every chapter opens with a comprehensive list of Learning Objectives. Students should review this list before diving into the chapter to help guide their focus. As they progress through the chapter, they should periodically flip back to the Learning Objectives to ensure they are fully grasping that chapter's key environmental science concepts. This practice will encourage students to think critically about environmental issues and solutions.



Chapter Outlines

Along with the Learning Objectives, a Chapter Outline is included at the start of every chapter. This list succinctly identifies the sections students will encounter as they progress through a chapter, including the Spotlight on Sustainable Development boxes and the Point/Counterpoint topic. It provides students with a "big picture" understanding of the overarching environmental principles for each chapter.

Critical Thinking

As I mentioned earlier, critical thinking is one of the central themes of this book. It enables students to analyze complex issues and make rational decisions.

A number of important critical thinking rules are discussed in Chapter 1. Each chapter also begins with a brief critical thinking exercise, which asks students to critically analyze an issue, a research finding, or an assertion.

Students are also asked to exercise critical thinking skills after Point/Counterpoints, and many of the discussion questions at the end of each chapter call on students to put their knowledge and their critical thinking skills to use.

Key Concepts

Key concepts are highlighted in boxes at the end of each section. These brief encapsulations are designed to help students understand the concepts that form the foundation of environmental science. They serve as a great tool for reviewing chapters as well as studying for tests. Read them before you read each chapter, after completing a chapter, and while you're studying for tests. They're the glue that holds this book together.

Green Living Tips

In this edition, I've added even more green living tips, labeled *Go Green*. These simple, inexpensive, and practical tips will help you become a part of the solution and help all of us build a sustainable future.

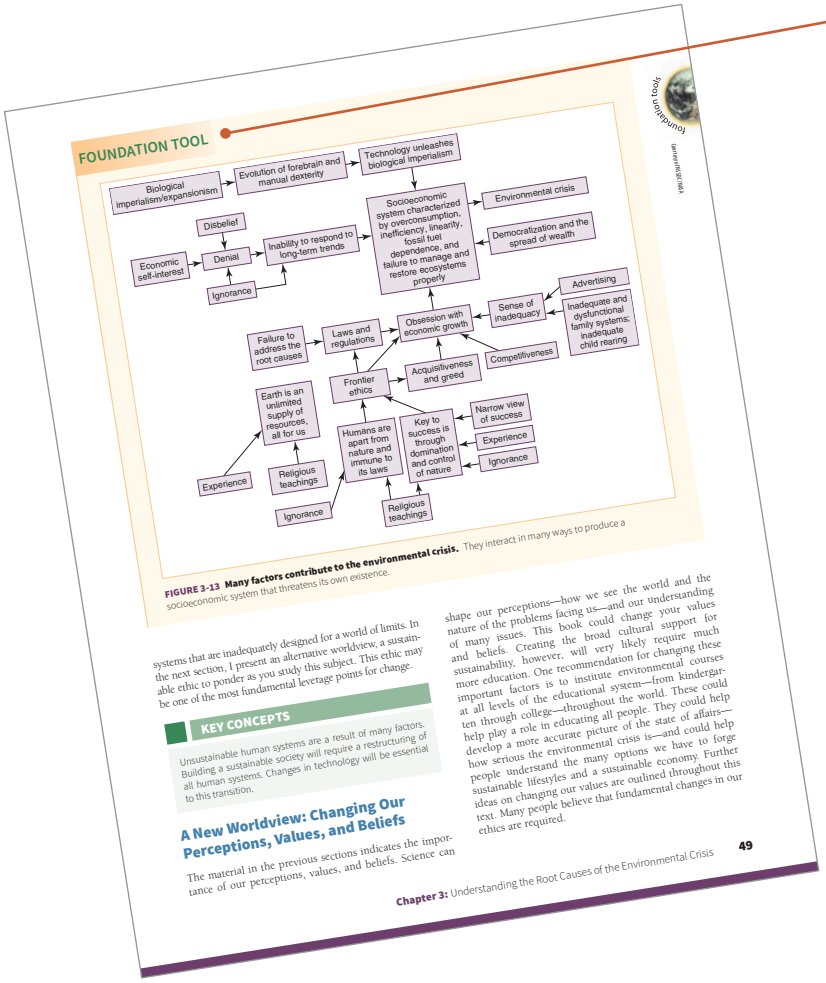


FIGURE 3-13 Many factors contribute to the environmental crisis. They interact in many ways to produce a socioeconomic system that threatens its own existence.

systems that are inadequately designed for a world of limits. In the next section, I present an alternative worldview, a sustainable ethic to ponder as you study this subject. This ethic may be one of the most fundamental leverage points for change.

KEY CONCEPTS

Unsustainable human systems are a result of many factors. Building a sustainable society will require a restructuring of all human systems. Changes in technology will be essential to this transition.

A New Worldview: Changing Our Perceptions, Values, and Beliefs

The material in the previous sections indicates the importance of our perceptions, values, and beliefs. Science can shape our perceptions—how we see the world and the nature of the problems facing us—and our understanding of many issues. This book could change your values and beliefs. Creating the broad cultural support for sustainability, however, will very likely require much more education. One recommendation for changing these important factors is to institute environmental courses at all levels of the educational system—from kindergarten through college—throughout the world. These could help play a role in educating all people. They could help develop a more accurate picture of the state of affairs—how serious the environmental crisis is—and could help people understand the many options we have to forge sustainable lifestyles and a sustainable economy. Further ideas on changing our values are outlined throughout this text. Many people believe that fundamental changes in our ethics are required.

Foundation Tools

This book offers several Foundation Tools, conceptual models that help students understand how the world works and how solutions can be applied. These models are designed to encourage systems thinking and help students organize facts into a solid conceptual framework. Below is a brief description of each model.

POPULATION, RESOURCES, AND POLLUTION This model shows how populations of organisms, like ourselves, affect their environment and how their actions, in turn, affect the populations themselves.

IMPACT ANALYSIS This model shows the impacts that humans have on various components of the environment. It helps to clarify a confusing topic.

RISK ANALYSIS This model presents an overview of a process called *risk assessment*. This process helps us assess risks in a meaningful way.

ROOT CAUSES This model shows the many factors that contribute to the crisis of unsustainability and helps students identify key leverage points for change.

HUMAN SYSTEMS This model shows the complex systems that support our lives and how they are functionally related to one another.

SUSTAINABLE PRINCIPLE APPLICATION This model demonstrates how the ecological principles of sustainability can be applied to complex human systems.

Examining Both Sides of the Issue

In keeping with my long-standing belief that students must examine all sides of an issue, I have continued to present information from opposing viewpoints. You will find this approach exercised in the text itself, where I examine contradictory positions, and in the Point/Counterpoints.

POINT/COUNTERPOINTS AND VIEWPOINTS

Complex environmental issues often result in hotly contested debates. These editorials can stimulate individual thinking as well as classroom discussion on complex problems. They are also a perfect avenue for developing one's critical thinking skills.

SPOTLIGHT on Sustainable Development

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

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

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

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

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

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

Spotlights on Sustainable Development

To give students further insight into sustainable solutions, I've included numerous case studies throughout the text called Spotlights on Sustainable Development. They show what cities, towns, businesses, and even professional sports teams are doing to create a sustainable future. They provide guidance and hope.

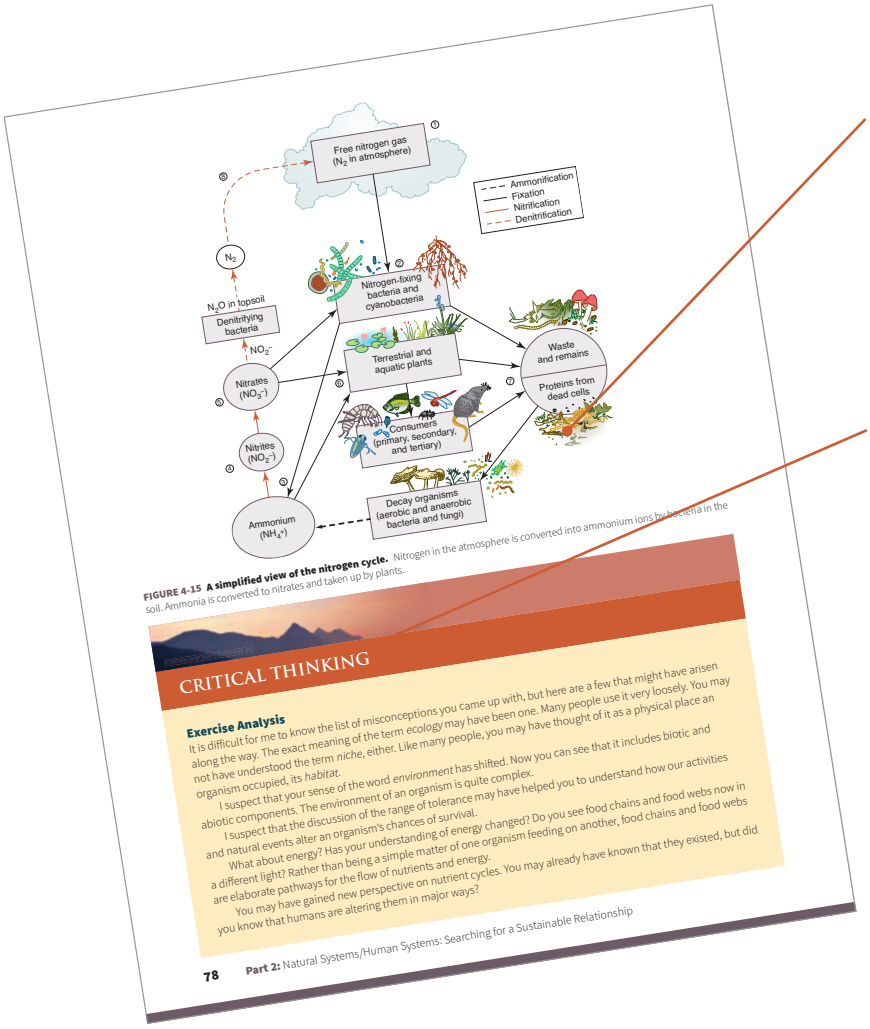


FIGURE 4-15 **A simplified view of the nitrogen cycle.** Nitrogen in the atmosphere is converted into ammonium ions by bacteria in the soil. Ammonia is converted to nitrates and taken up by plants.

Detailed Illustrations

The text features numerous detailed illustrations to demonstrate clearly important environmental processes and cycles, such as the carbon cycle and the nitrogen cycle, pictured here. The illustrations serve as powerful study tools for students in preparation for lectures and exams.

CRITICAL THINKING

Exercise Analysis

It is difficult for me to know the list of misconceptions you came up with, but here are a few that might have arisen along the way. The exact meaning of the term ecology may have been one. Many people use it very loosely. You may not have understood the term *niche*, either. Like many people, you may have thought of it as a physical place an organism occupied, its habitat.

I suspect that your sense of the word environment has shifted. Now you can see that it includes biotic and abiotic components. The environment of an organism is quite complex.

I suspect that the discussion of the range of tolerance may have helped you to understand how our activities and natural events alter an organism's chances of survival.

What about energy? Has your understanding of energy changed? Do you see food chains and food webs now in a different light? Rather than being a simple matter of one organism feeding on another, food chains and food webs are elaborate pathways for the flow of nutrients and energy.

You may have gained new perspective on nutrient cycles. You may already have known that they existed, but did you know that humans are altering them in major ways?

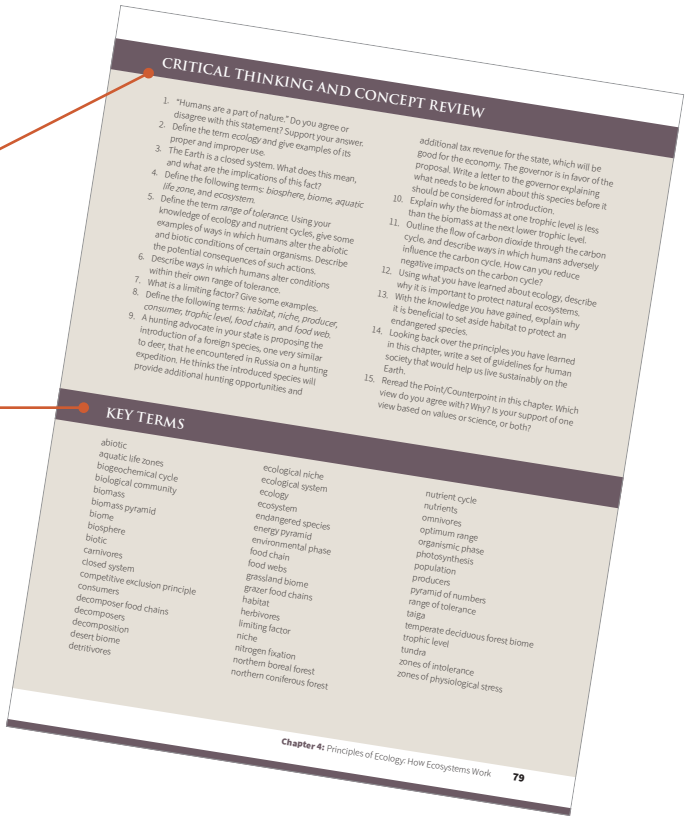
Critical Thinking Analysis

Each chapter begins with a brief critical thinking exercise, which asks students to critically analyze an issue, a research finding, or an assertion. The author responds to the exercise at the end of each chapter and walks the reader through the steps to thinking critically about the environmental issue under discussion, with reference back to the chapter material.

78 **Part 2:** Natural Systems/Human Systems: Searching for a Sustainable Relationship

Critical Thinking and Concept Review Questions

Every chapter concludes with Critical Thinking and Concept Review Questions. These questions challenge students to apply the information from the chapter, ensuring they thoroughly grasp the important environmental science concepts. Many of the questions encourage students to think critically about a specific environmental issue and push them to think deeply about both sides of the matter.


CRITICAL THINKING AND CONCEPT REVIEW

1. "Humans are a part of nature." Do you agree or disagree with this statement? Support your answer.
2. Define the term *ecology* and give examples of its proper and improper use.
3. The Earth is a closed system. What does this mean, and what are the implications of this fact?
4. Define the following terms: *biosphere, biome, aquatic life zone,* and *ecosystem.*
5. Define the term *range of tolerance.* Using your knowledge of ecology and nutrient cycles, give some examples of ways in which humans alter the abiotic and biotic conditions of certain organisms. Describe the potential consequences of such actions.
6. Describe ways in which humans alter conditions within their own range of tolerance.
7. What is a limiting factor? Give some examples.
8. Define the following terms: *habitat, niche, producer, consumer, trophic level, food chain,* and *food web.*
9. A hunting advocate in your state is proposing the introduction of a foreign species, one very similar to deer, that he encountered in Russia on a hunting expedition. He thinks the introduced species will provide additional hunting opportunities and additional tax revenue for the state, which will be good for the economy. The governor is in favor of the proposal. Write a letter to the governor explaining what needs to be known about this species before it should be considered for introduction.
10. Explain why the biomass at one trophic level is less than the biomass at the next lower trophic level.
11. Outline the flow of carbon dioxide through the carbon cycle, and describe ways in which humans adversely influence the carbon cycle. How can you reduce negative impacts on the carbon cycle?
12. Using what you have learned about ecology, describe why it is important to protect natural ecosystems.
13. With the knowledge you have gained, explain why it is beneficial to set aside habitat to protect an endangered species.
14. Looking back over the principles you have learned in this chapter, write a set of guidelines for human society that would help us live sustainably on the Earth.
15. Reread the Point/Counterpoint in this chapter. Which view do you agree with? Why? Is your support of one view based on values or science, or both?

KEY TERMS

abiotic
aquatic life zones
biogeochemical cycle
biological community
biomass
biomass pyramid
biome
biosphere
biotic
carnivores
closed system
competitive exclusion principle
consumers
decomposer food chains
decomposers
decomposition
desert biome
detritivores
ecological niche
ecological system
ecology
ecosystem
endangered species
energy pyramid
environmental phase
food chain
food webs
grassland biome
grazer food chains
habitat
herbivores
limiting factor
niche
nitrogen fixation
northern boreal forest
northern coniferous forest
nutrient cycle
nutrients
omnivores
optimum range
organismic phase
photosynthesis
population
producers
pyramid of numbers
range of tolerance
taiga
temperate deciduous forest biome
trophic level
tundra
zones of intolerance
zones of physiological stress

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Key Terms

A list of Key Terms is included at the end of every chapter. Furthermore, the key terms in the chapter appear in bold to draw the reader's attention. Students should refer to the Key Terms as part of their study to assess their understanding of chapter material.

Additional Online Study Tools

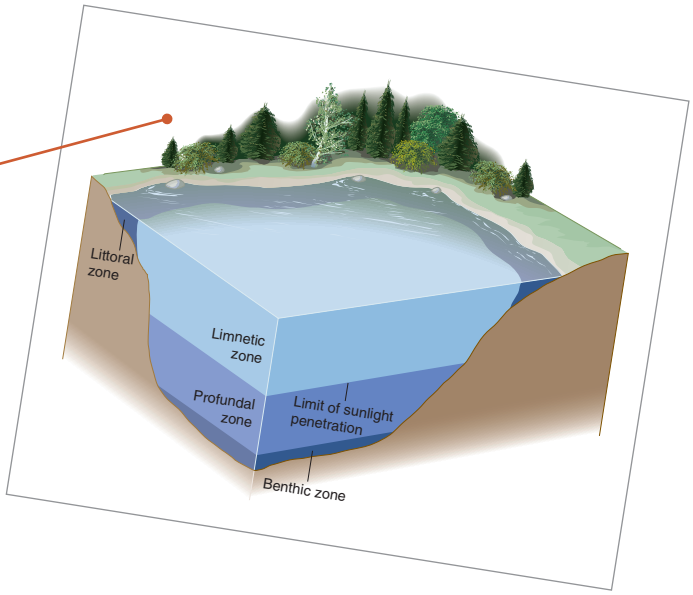
Additional resources such as practice activities, links to relevant websites, flashcards, and an interactive glossary are available online to help students study.

Focus on Sustainability and Systems Reform

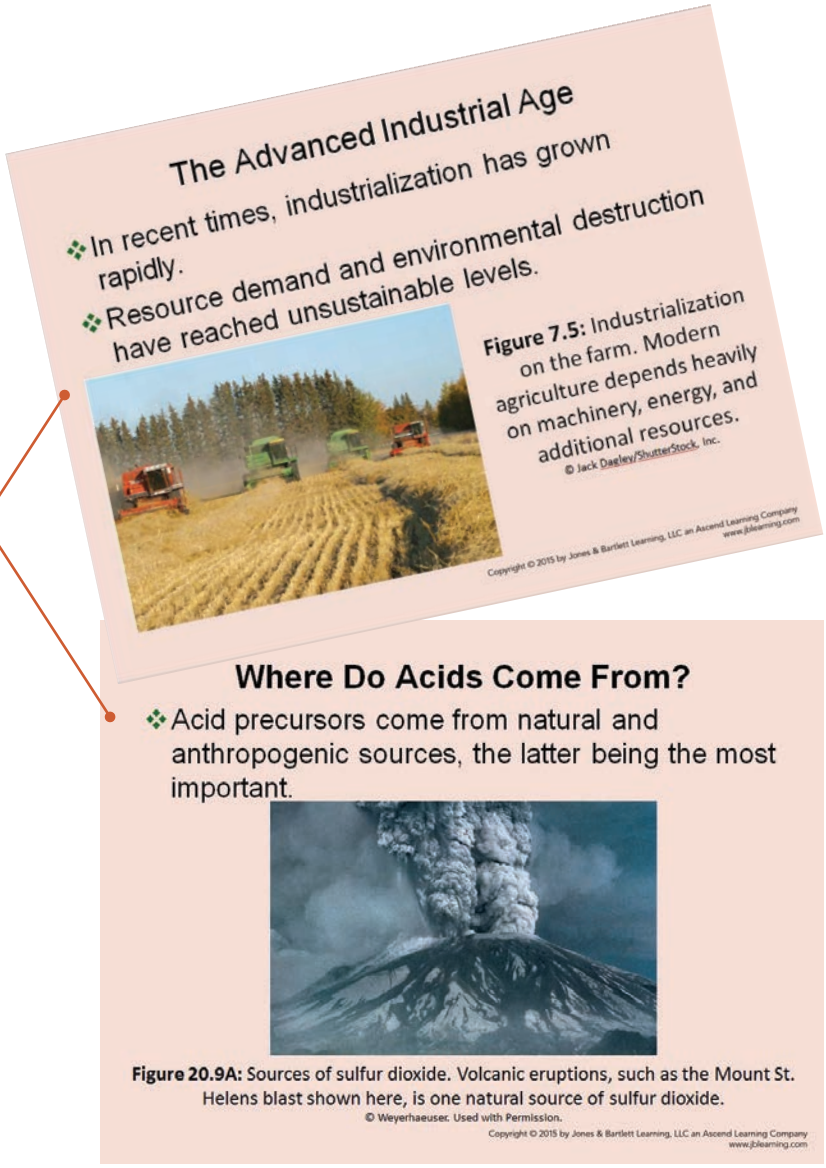
While the main focus of the book is environment, not development, I attempt to show how development must be revamped to become sustainable. I describe basic human systems and why they are unsustainable. Moreover, I outline a variety of ways that we can make them environmentally, socially, and economically sustainable.

Teaching Tools

The **IMAGE BANK** provides the illustrations, photographs, and tables (to which Jones & Bartlett Learning holds the copyright or has permission to reprint digitally). These images are not for sale or distribution but may be used to enhance your existing slides, tests, and quizzes, or other classroom material.



The **LECTURE OUTLINES** in PowerPoint format provide lecture notes and images for each chapter of *Environmental Science, Tenth Edition*. Instructors with Microsoft PowerPoint software can customize the outlines, art, and order of presentation.



The **INSTRUCTOR'S MANUAL** is provided as a text file. The Instructor's Manual has been updated and expanded for this edition. It contains chapter outlines, objectives, and key terms as well as suggestions for presenting each chapter. We have also included sample syllabi to demonstrate a few of the many approaches that can be taken to an environmental science course.

A **TESTBANK** is available with hundreds of questions in a variety of formats.

WEB LINKS are available to direct instructors and students to outside sources where they can learn more about topics discussed in the book and environmental issues specific to their own areas.

Acknowledgments

Although I have spent thousands of hours researching and writing it, this book is really the product of thousands of researchers and scholars in anthropology, biology, chemistry, demography, natural resources, political science, economics, ecology, and dozens of other disciplines. Their findings and their thoughts form the foundation on which this book rests. To them, a world of thanks!

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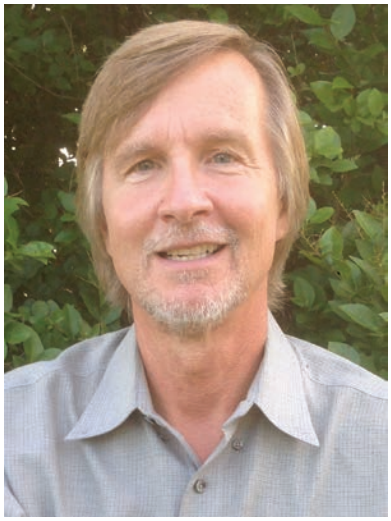
Courtesy of Dan Chiras

Dan Chiras received a Ph.D. in reproductive physiology from the University of Kansas Medical School. In 1976, he accepted a teaching and research position at the University of Colorado, Denver, where he taught a variety of courses, including general biology, cell biology, histology, reproductive biology, and endocrinology. Over the years, Dr. Chiras pursued his interest in environmental issues and developed a number of courses on the environment, including a graduate course on global environmental issues and the environmental and health effects of pollution. He has also taught undergraduate science modules on air pollution, nuclear power, noise pollution, impacts of coal development, and strategies for sustainability.

While at the university, Dr. Chiras worked on several EPA projects, including a study of the health impacts of chlorinated organics from wastewater treatment and the impacts of coal mining in the West. He also prepared an assessment of the impacts of shale oil development in Colorado for the U.S. Department of Energy.

In 1981, Dr. Chiras resigned his full-time position at the university to pursue a writing career. Since that time, he has published nearly 350 articles in journals, magazines, encyclopedias, and other publications, including *Environment, American Biology Teacher, The Amicus Journal, Solar Today, Natural Home, Mother Earth News, Sustainable Futures, Colorado Outdoors, Home Power*, and *Environmental Carcino-genesis and Ecotoxicology Reviews*.

Dr. Chiras wrote the environment section for World Book Encyclopedia's Science Year from 1993 to 2010. He wrote an extensive article titled "The Population Explosion" in Science Year 1998. Dr. Chiras has written articles on ecology, the environment, environmental issues, air pollution, and population articles for *Encyclopedia Americana*.

Dr. Chiras has published 30 books on ecological design, environmental science, sustainable systems design, green building, and residential renewable energy. Included in this list are a college-level textbook titled *Natural Resource Conservation* (with John P. Reganold) and a high-school textbook titled *Environmental Science: Framework for Decision Making*. Dr. Chi-ras has also published two college-level biology textbooks: *Human Biology* and *Biology: The Web of Life*.

Dr. Chiras has written several books for a more general audience, *Beyond the Fray: Reshaping America's Environmental Response*, which offers advice on building a truly effective response to the environmental crisis, and *Lessons from Nature: Learning to Live Sustainably on the Earth*, which outlines ways to build a sustainable future. He has also assembled an anthology titled *Voices for the Earth: Vital Ideas from Amer-ica's Best Environmental Book*s. This book includes 14 essays summarizing the key ideas of books nominated by a national committee as America's best environmental books.

Dr. Chiras's more recent books include *Power from the Wind, Power from the Sun, Wind Energy Basics, Solar Electricity Basics, Green Home Improvement, Green Transportation Basics, Solar Home Heating Basics, The Natural House: A Complete Guide to Healthy, Energy-Efficient, Environmental Homes; The Solar House; The New Ecological Home; Superbia!; 31 Ways to Create Sustainable Neighborhoods; The Homeowner's Guide to Renewable Energy; The Natural Plasters Book;* and *EcoKids: Raising Children Who Care for the Earth*.

Dr. Chiras is a visiting professor in the environmental science program at Colorado College, where he has taught courses on renewable energy, green building, and climate change. Dr. Chiras has also served as a visiting professor at the University of Washington in Seattle, where he taught the introductory environmental science course.

Besides teaching and writing, Dr. Chiras has played an active role in the environmental movement. He has served on the Board of Directors of the Colorado Environmental Coalition for five years and was president of this coalition of 40 environmental groups for two years. In 1988, he co-founded Friends of Curbside Recycling, which was instrumental in convincing the city of Denver to begin a curbside recycling program. In 1989, he cofounded Speakers for a Sustainable Future, which offered slide programs

on recycling, water conservation, and sustainability. In 1993, Dr. Chiras cofounded another nonprofit organization, the Sustainable Futures Society. He served on the board of directors of the Advanced Technology Environmental Education Library, which produced a website that serves as a repository for environmental information.

Dr. Chiras has spoken to a wide range of audiences, including the National Association of County Agricultural Agents; the American Society of Interior Designers; the American Home Economics Association; Architects, Designers, Planners for Social Responsibility; the Colorado Renewable Energy Society; the American Solar Energy Society; and many others.

In 2009, Dr. Chiras formed The Evergreen Institute: Center for Renewable Energy and Green Building in east-central Missouri (www.evergreeninstitute.org), where he teaches classes on solar electricity, wind energy, passive solar heating and cooling, green building, natural building, and more. He is currently turning the 60-acre farm and educational center into a net-zero energy facility by implementing efficiency measures and installing solar electric, solar hot water, passive solar, and wind energy systems that generate all the energy the facility consumes.

In addition to his active scientific pursuits, Dr. Chiras is an organic gardener and bicyclist. He raises homing pigeons and all natural grass-fed cattle, Belted Galloways.

STUDY SKILLS

College can be an extremely demanding time. For many students, term papers, tests, reading assignments, and classes require a new and higher level of commitment to their education. At times, the workload can become overwhelming.

Fortunately, there are many ways to lighten the load and make time spent in college more profitable. This section offers some helpful tips on ways to enhance your study skills. It teachers you how to improve your memory, how to become a better note taker, and how to get the most out of what you read. It also helps you prepare better for tests and become a better test taker.

Mastering these study skills will require some work, mostly to break old, inefficient habits. In the long run, though, the additional time you spend now learning to become a better learner will pay huge dividends. Over the long haul, improved study skills will save you lots of time and help you improve your knowledge of facts and concepts. That will, no doubt, lead to better grades and very likely a more fruitful life.

General Study Skills

- Study in a quiet, well-lighted space. Avoid noisy, distracting environments.
- Turn off televisions, radios, and cell phones.
- Work at a desk or table. Don't lie on a couch or bed.
- Establish a specific time each day to study, and stick to your schedule.
- Study when you are most alert. Many students find that they retain more if they study in the evening a few hours before bedtime.
- Take frequent breaks—one every hour or so. Exercise or move around during your study breaks to help you stay alert.
- Reward yourself after a study session with a mental pat on the back or a snack.
- Study each subject every day to avoid cramming for tests. Some courses may require more hours than others, so adjust your schedule accordingly.
- Look up new terms or words whose meaning is unclear to you in the glossaries in your textbooks or in a dictionary.

Improving Your Memory

You can improve your memory by following the PMC method. The PMC method involves three simple learning steps: (1) paying attention, (2) making information memorable, (3) correlating new information with facts you already know.

STEP 1. Paying attention means taking an active role in your education—taking your mind out of neutral. Eliminate distractions when you study. Review what you already know, and formulate questions about what you are going to learn before a lecture or before you read a chapter in the text. Reviewing and questioning help prime the mind.

STEP 2. Making information memorable means finding ways to help you retain information in your memory. Repetition, mnemonics, and rhymes are three helpful tools.

- Repetition can help you remember things. The more you hear or read something, the more likely you are to remember it, especially if you're paying attention. Jot down important ideas and facts while you read or study to help involve all of the senses.
- Mnemonics are useful learning tools to help remember lists of things. I use the mnemonic CAR-RRP to remember the biological principles of sustainability: conservation, adaptability, recycling, renewable resources, restoration, and population control.
- Rhymes and sayings can also be helpful when trying to remember lists of facts.
- If you're having trouble remembering key terms, look up their roots in the dictionary. This often helps you remember their meaning.
- You can also draw pictures and diagrams of processes to help remember them.

STEP 3. Correlating new information with the facts and concepts you already know helps tie facts together, making sense out of the bits and pieces you are learning.

- Instead of filling your mind with disjointed facts and figures, try to see how they relate with what you already know. When studying new concepts, spend some time trying information together to get a view of the big picture.

- After studying your notes or reading your textbook, go back and review the main points. Ask yourself how this new information affects your view of life or critical issues and how you may be able to use it.

Becoming a Better Note Taker

- Spend 5 to 10 minutes before each lecture reviewing the material you learned in the previous lecture. This is extremely important!
- Know the topic of each lecture before you enter the class and spend a few minutes reflecting on facts you already know about the subject about to be discussed.
- If possible, read the text before each lecture. If not, at least look over the main headings in the chapter, read the topic sentence of each paragraph, and study the figures. If your chapter has a summary, read it too.
- Develop a shorthand system of your own to facilitate note taking. Symbols such as = (equals), > (greater than), < (less than), w/ (with), and w/o (without) can save lots of time so you don't miss the main points or key facts.
- Develop special abbreviations to cut down on writing time. E might stand for energy, AP might be used for air pollution, and AR could be used to signify acid rain.
- Omit vowels, abbreviate words, and use special symbols to decrease writing time (for example: omt vwls & abbrvte wrds to ↓ wrtng tme). This will take some practice.
- Don't take down every word your professor says, but be sure your notes contain the main points, supporting information, and important terms.
- Watch for signals from your professor indicating important material that might show up on the next test (for example, "This is an extremely important point…").
- If possible, sit near the front of the class to avoid distractions.
- Review your notes soon after the lecture is over while they're still fresh in your mind. Be sure to leave room in your notes written during class so you can add material you missed. If you have time, copy your notes after each lecture.
- Compare your notes with those of your classmates to be sure you understood everything and did not miss any important information.
- Attend all lectures.
- Use a tape recorder if you have trouble catching important points.
- If your professor talks too quickly, politely ask him or her to slow down.
- If you are unclear about a point, ask during class. Chances are other students are confused as well. If you are too shy, go up after the lecture and ask, or visit your professor during his or her office hours.

How to Get the Most Out of What You Read

- Before you read a chapter or other assigned readings, preview the material by reading the main headings or chapter outline to see how the material is organized.
- Pause over each heading and ask a question about it.
- Next, read the first sentence of each paragraph. When you have finished, turn back to the beginning of the chapter and read it thoroughly.
- Take notes in the margin or on a separate sheet of paper.
- Underline or highlight key points.
- Don't skip terms that are confusing to you. Look them up in the glossary or in a dictionary. Make sure you understand each term before you move on.
- Use the study aids in your textbook, including summaries and end-of-chapter questions. Don't just look over the questions and say, "Yeah, I know that." Write out the answer to each question as if you were turning it in for a grade, and save your answers for later study. Look up answers to questions that confuse you. This book has questions that test your understanding of facts and concepts. Critical thinking questions are also included to sharpen your skills.

Preparing for Tests

- Don't fall behind on your reading assignments.
- Review lecture notes as often as possible.
- If you have the time, you may want to outline your notes and assigned readings.
- Space your study to avoid cramming. One week before your exam, go over all of your notes. Study for two nights, then take a day off that subject. Study again for a couple of days. Take another day off from that subject. Then make one final push before the exam, being sure to study not only the facts and concepts but also how the facts are related. Unlike cramming, which puts a lot of information into your brain for a short time, spacing will help you retain information for the test and for the rest of your life.
- Be certain you can define all terms and give examples of how they are used.
- You may find it useful to write flash cards to review terms and concepts.
- After you have studied your notes and learned the material, look at the big picture—the importance of the knowledge and how the various parts fit together.
- You may want to form a study group to discuss what you are learning and to test one another.
- Attend review sessions offered by your instructor or by your teaching assistant, and study before the session and go to the session with questions.
- See your professor or class teaching assistant with questions as they arise.

- Take advantage of free or low-cost tutoring offered by your school, or, if necessary, hire a private tutor to help you through difficult material. Get help quickly, though. Don't wait until you are hopelessly lost. Remember that learning is a two-way street. A tutor won't help unless you are putting in the time.
- If you are stuck on a concept, it may be that you have missed an important point in earlier material. Look back over your notes or ask your tutor or professor what facts might be missing and causing you to be confused.
- Write and take your own tests. Include all types of questions.
- Study tests from previous years, if they are available legally.
- Determine how much of a test will come from lecture notes and how much will come from the textbook.
- Purchase a study guide, if one is available, and use it to review material and test our knowledge.
- Check out your instructor's website or the online resources that accompany this text. Offered are valuable study aids, such as review questions and practice quizzes.

Taking Tests

- Eat well and get plenty of exercise and sleep before tests.
- Remain calm during the test by deep breathing.
- Arrive at the exam on time or early.
- If you have questions about the wording of a question, ask your professor.
- Skip questions you can't answer right away, and come back to them at the end of the session if you have time.
- Read each question carefully and be sure you understand its full meaning before answering it.
- For essay questions and definitions, organize your thoughts first on the back of the test before you start writing. A sample outline may help you get your thoughts straight and allow you to write a coherent answer.

Now take a few moments to go back over the list. Check off those things you already do. Then, mark the new ideas you want to incorporate into your study habits. Make a separate list, if necessary, and post it by your desk or on the wall and keep track of your progress.