For my sister, Dorothy B. Rosenthal
who has been a source of inspiration, support, ideas,
and books to read, and is one of my harshest and best critics.

    Dan Botkin

and

For Valery Rivera
who contributed so much to this book and
is a fountain of inspiration in our work and lives.

    Ed Keller
Daniel B. Botkin is President of The Center for the Study of Environment, and Professor Emeritus of Ecology, Evolution, and Marine Biology, University of California, Santa Barbara, where he has been on the faculty since 1978, serving as Chairman of the Environmental Studies Program from 1978 to 1985. For more than four decades, Professor Botkin has been active in the application of ecological science to environmental management. He is the winner of the Mitchell International Prize for Sustainable Development and the Fernow Prize for International Forestry, and he has been elected to the California Environmental Hall of Fame.

Trained in physics and biology, Professor Botkin is a leader in the application of advanced technology to the study of the environment. The originator of widely used forest gap models, he has conducted research on endangered species, characteristics of natural wilderness areas, the biosphere, and global environmental problems including possible ecological effects of global warming. During his career, Professor Botkin has advised the World Bank about tropical forests, biological diversity, and sustainability; the Rockefeller Foundation about global environmental issues; the government of Taiwan about approaches to solving environmental problems; the state of California on the environmental effects of water diversion on Mono Lake. He served as the primary advisor to the National Geographic Society for its centennial edition map on “The Endangered Earth.” He directed a study for the states of Oregon and California concerning salmon and their forested habitats.

He has published many articles and books about environmental issues. His latest books are Beyond the Stoney Mountains: Nature in the American West from Lewis and Clark to Today (Oxford University Press), Strange Encounters: Adventures of a Renegade Naturalist (Penguin/Tarcher), The Blue Planet (Wiley), Our Natural History: The Lessons of Lewis and Clark (Oxford University Press), Discordant Harmonies: A New Ecology for the 21st Century (Oxford University Press), and Forest Dynamics: An Ecological Model (Oxford University Press).

Professor Botkin was on the faculty of the Yale School of Forestry and Environmental Studies (1968–1974) and was a member of the staff of the Ecosystems Center at the Marine Biological Laboratory, Woods Hole, MA (1975–1977). He received a B.A. from the University of Rochester, an M.A. from the University of Wisconsin, and a Ph.D. from Rutgers University.

Edward A. Keller was chair of the Environmental Studies and Hydrologic Sciences Programs from 1993 to 1997 and is Professor of Earth Science at the University of California, Santa Barbara, where he teaches earth surface processes, environmental geology, environmental science, river processes, and engineering geology. Prior to joining the faculty at Santa Barbara, he taught geomorphology, environmental studies, and earth science at the University of North Carolina, Charlotte. He was the 1982–1983 Hartley Visiting Professor at the University of Southampton, a Visiting Fellow in 2000 at Emmanuel College of Cambridge University, England, and recipient of the Easterbrook Distinguished Scientist award from the Geological Society of America in 2004.

Professor Keller has focused his research efforts into three areas: studies of Quaternary stratigraphy and tectonics as they relate to earthquakes, active folding, and mountain building processes; hydrologic process and wildfire in the chaparral environment of Southern California; and physical habitat requirements for the endangered Southern California steelhead trout. He is the recipient of various Water Resources Research Center grants to study fluvial processes and U.S. Geological Survey and Southern California Earthquake Center grants to study earthquake hazards.

Professor Keller has published numerous papers and is the author of the textbooks Environmental Geology, Introduction to Environmental Geology and (with Nicholas Pinter) Active Tectonics (Prentice-Hall). He holds bachelor’s degrees in both geology and mathematics from California State University, Fresno; an M.S. in geology from the University of California; and a Ph.D. in geology from Purdue University.
What Is Environmental Science?
Environmental science is a group of sciences that attempt to explain how life on the Earth is sustained, what leads to environmental problems, and how these problems can be solved.

Why Is This Study Important?
• We depend on our environment. People can live only in an environment with certain kinds of characteristics and within certain ranges of availability of resources. Because modern science and technology give us the power to affect the environment, we have to understand how the environment works, so that we can live within its constraints.
• People have always been fascinated with nature, which is, in its broadest view, our environment. As long as people have written, they have asked three questions about ourselves and nature:
  - What is nature like when it is undisturbed by people?
  - What are the effects of people on nature?
  - What are the effects of nature on people?

Environmental science is our modern way of seeking answers to these questions.
• We enjoy our environment. To keep it enjoyable, we must understand it from a scientific viewpoint.
• Our environment improves the quality of our lives. A healthy environment can help us live longer and more fulfilling lives.
• It’s just fascinating.

What Is the “Science” in Environmental Science?
Many sciences are important to environmental science. These include biology (especially ecology, that part of biology that deals with the relationships among living things and their environment), geology, hydrology, climatology, meteorology, oceanography, and soil science.

How Is Environmental Science Different from other Sciences?
• It involves many sciences.
• It includes sciences, but also involves related nonscientific fields that have to do with how we value the environment, from environmental philosophy to environmental economics.
• It deals with many topics that have great emotional effects on people, and therefore are subject to political debate and to strong feelings that often ignore scientific information.

What Is Your Role as a Student and as a Citizen?
Your role is to understand how to think through environmental issues so that you can arrive at your own decisions.

What Are the Professions That Grow Out of Environmental Science?
Many professions have grown out of the modern concern with environment, or have been extended and augmented by modern environmental sciences. These include park, wildlife, and wilderness management; urban planning and design; landscape planning and design; conservation and sustainable use of our natural resources.

Goals of This Book
*Environmental Science: Earth as a Living Planet* provides an up-to-date introduction to the study of the environment. Information is presented in an interdisciplinary perspective necessary to deal successfully with environmental problems. The goal is to teach you, the student, how to think through environmental issues.

Critical Thinking
We must do more than simply identify and discuss environmental problems and solutions. To be effective, we must know what science is and is not. Then, we need to develop critical thinking skills. Critical thinking is so important that we have made it the focus of its own chapter, Chapter 2. With this in mind, we have also developed *Environmental Science* to present the material in a factual and unbiased format. Our goal is to help you think through the issues, not tell you what to think. To this purpose, at the end of each chapter, we present “Critical Thinking Issues.” Critical thinking is further emphasized throughout the text in analytical discussions of topics, evaluation of perspectives, and integration of important themes, which are described in detail later.

Interdisciplinary Approach
The approach of *Environmental Science* is interdisciplinary in nature. Environmental science integrates many disciplines, including the natural sciences, in addition to fields such as anthropology, economics, history, sociology, and philosophy of the environment. Not only do we need the best ideas and information to deal successfully with our environmental problems, but we also must be aware of the cultural and historical contexts in which we make decisions about the environment. Thus, the field of environmental science also integrates the natural sciences with environmental law, environmental impact, and environmental planning.
Themes
Our book is based on the philosophy that six threads of inquiry are of particular importance to environmental science. These key themes, called threads of inquiry, are woven throughout the book.

These six key themes are discussed in more detail in Chapter 1. They are also revisited at the end of each chapter and are emphasized in the Closer Look boxes, each of which is highlighted by an icon suggesting the major underlying theme of the discussion. In many cases, more than one theme is relevant.

Human Population
Underlying nearly all environmental problems is the rapidly increasing human population. Ultimately, we cannot expect to solve environmental problems unless the total number of people on Earth is an amount the environment can sustain. We believe that education is important to solving the population problem. As people become more educated, and as the rate of literacy increases, population growth tends to decrease.

Sustainability
Sustainability is a term that has gained popularity recently. Speaking generally, it means that a resource is used in such a way that it continues to be available. However, the term is used vaguely, and it is something experts are struggling to clarify. Some would define it as ensuring that future generations have equal opportunities to access the resources that our planet offers. Others would argue that sustainability refers to types of developments that are economically viable, do not harm the environment, and are socially just. We all agree that we must learn how to sustain our environmental resources so that they continue to provide benefits for people and other living things on our planet.

A Global Perspective
Until recently it was common to believe that human activity caused only local, or at most regional, environmental change. We now know that human activities can affect the environment globally. An emerging science known as Earth System Science seeks a basic understanding of how our planet’s environment works as a global system. This understanding can then be applied to help solve global environmental problems. The emergence of Earth System Science has opened up a new area of inquiry for faculty and students.

The Urban World
An ever-growing number of people are living in urban areas. Unfortunately, our urban centers have long been neglected, and the quality of the urban environment has suffered. It is here that we experience the worst of air pollution, waste disposal problems, and other stresses on the environment. In the past we have centered our studies of the environment more on wilderness than the urban environment. In the future we must place greater focus on towns and cities as livable environments.

People and Nature
People seem to be always interested—amazed, fascinated, pleased, curious—in our environment. Why is it suitable for us? How can we keep it that way? We know that people and our civilizations are having major effects on the environment, from local ones (the street where you live) to the entire planet (we have created a hole in the Earth’s ozone layer) which can affect us and many forms of life.

Science and Values
Finding solutions to environmental problems involves more than simply gathering facts and understanding the scientific issues of a particular problem. It also has much to do with our systems of values and issues of social justice. To solve our environmental problems, we must understand what our values are and which potential solutions are socially just. Then we can apply scientific knowledge about specific problems and find acceptable solutions.

Organization
Our text is divided into four parts. Part I Introductory Chapters provides a broad overview of the key themes in Environmental Science, introduces the scientific method and the fundamentals of a scientific approach to the environment: Earth as a system; basic biochemical cycles; population dynamics, focusing on the human population; and environmental economics. Part II Ecology Chapters explains the scientific basis of ecosystems, biological diversity, ecological restoration and environmental health. Part III Resource Management is about management of our environmental resources: agriculture and environment; forests, parks, wilderness; wildlife and fisheries; as well as chapters on energy: basic principles of energy, fossil fuels and environment, alternative energy, and nuclear energy. Part IV: Where People Have A Heavy Hand discusses water pollution; climate change and air pollution; urban environments, and integrated waste management. The section ends with a capstone chapter, integrating and summarizing the main messages of the book.

Special Features
In writing Environmental Science we have designed a text that incorporates a number of special features that we believe will help teachers to teach and students to learn. These include the following:
• **A Case Study** introduces each chapter. The purpose is to interest students in the chapter’s subject and to raise important questions on the subject matter. For example, in Chapter 11, Agriculture, Aquaculture, and Environment, the opening case study tells about a farmer feeding his pigs trail mix, banana chips, yogurt-covered raisins, dried papaya, and cashews, because growing corn for biofuels is raising the costs of animal feed so much.

• **Learning Objectives** are introduced at the beginning of each chapter to help students focus on what is important in the chapter and what they should achieve after reading and studying the chapter.

• **A Closer Look** is the name of special learning modules that present more detailed information concerning a particular concept or issue. For example, **A Closer Look 13.2** discusses the reasons for conserving endangered species.

• Many of these special features contain figures and data to enrich the reader's understanding, and relate back to the book themes.

• Near the end of each chapter, a **Critical Thinking Issue** is presented to encourage critical thinking about the environment and to help students understand how the issue may be studied and evaluated. For example, Chapter 22 presents a critical thinking issue about **How Can Urban Sprawl Be Controlled?**

• Following the Summary, a special section, **Reexamining Themes and Issues**, reinforces the six major themes of the textbook.

• **Study Questions** for each chapter provide a study aid, emphasizing critical thinking.

• **Further Readings** are provided with each chapter so that students may expand their knowledge by reading additional sources of information (both print and electronic) on the environment.

• **References** cited in the text are provided at the end of the book as notes for each chapter. These are numbered according to their citation in the text. We believe it's important that introductory textbooks carefully cite sources of information used in the writing. These are provided to help students recognize those scholars whose work we depend on, and so that students may draw upon these references as needed for additional reading and research.

**Changes in the Eighth Edition**

Environmental science is a rapidly developing set of fields. The scientific understanding of environment changes rapidly. Even the kinds of science, and the kinds of connections between science and our ways of life change. Also, the environment itself is changing rapidly: Populations grow; species become threatened or released from near-extinction; our actions change. To remain contemporary, a textbook in environmental science requires frequent updating and with this edition we have examined the entire text and worked to streamline and update every chapter.

Other changes and special features in the eighth edition include:

• A new capstone chapter, Chapter 24, which features a case study on the Gulf oil spill, and revisits the critical themes of the text.

• An updated Chapter on Global Warming, presenting balanced coverage of this important Environmental Science topic.

**Combined Chapters**

• The former chapters Air Pollution and Indoor Air Pollution have been folded into Chapter 21 to streamline the coverage of Air Pollution and Ozone Depletion.

• Former chapters on Agricultural Production and Environmental Effects of Agriculture have been combined into one.

• Biodiversity and Biogeography have been combined into one chapter.

• Biological Productivity and Energy Flow has been combined with Ecological Restoration.

• Minerals and the Environment and Waste Management have been integrated into one chapter, Materials Management.

**New and updated Case Studies, Closer Look Boxes, and Critical Thinking Issues**

Updated videos and resources are available to engage students in the key issues and topics of environmental science and provides resources for instructors, including PowerPoints, test bank, prelecture and post-lecture online quizzes, Lecture Launcher PowerPoints with clicker questions, and a variety of news video clips and animations.

**Augmentation of Web Site References**

Valid information is becoming increasingly available over the Web, and easy access to these data is of great value. Government data that used to take weeks of library search are available almost instantly over the Web. For this reason, we have greatly augmented the number of Web site references and have gathered them all on the book’s companion Web site.

**Updated Case Studies**

Each chapter begins with a case study that helps the student learn about the chapter’s topic through a specific example. A major improvement in the eighth edition is the replacement of some older case studies with new ones that discuss current issues and are more closely integrated into the chapter.