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Sixteenth Edition

ENVIRONMENTAL SCIENCE

A Global Concern

William P. Cunningham | Mary Ann Cunningham
Catherine M. O'Reilly | Katherine E. Winsett

SIXTEENTH EDITION

Environmental SCIENCE

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About the Authors

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Mary Ann Cunningham

Mary Ann Cunningham is a professor of geography and environmental studies 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, and GIS. Climate change and climate solutions are central aspects of her teaching and research, and her courses focus on field methods, statistics, and data visualization. Every aspect of this book is woven into, and informed by, her courses and her students' work. As a scientist and educator, she has done research with students on a wide variety of environmental topics. As a geographer, she likes to engage students with the ways their physical surroundings and social context shape their world experience.

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. 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.

Courtesy William Perry

Catherine M. O'Reilly

Catherine O'Reilly is a professor in the Department of Geography, Geology and the Environment at Illinois State University. She has taught courses in natural disasters, environmental geology, and ecology. She is inspired to create opportunities for students to experience science by doing it, through working in the field, the laboratory, or looking at data to explore environmental concepts. Both her courses and her research highlight how human activities interact with earth processes.

Her research focuses on impacts of human activities on lakes and rivers, focusing on the effects of climate change and land-use patterns such as agriculture and urbanization. She was a member of the 2007 IPCC, which shared the Nobel Peace Prize with Al Gore.

Katherine E. Winsett

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Katherine Winsett is an assistant professor of biology at Wake Technical Community College in Raleigh, NC. She has taught courses in general biology, environmental science, and anatomy and physiology for non-science and science majors. She has worked in different institutional settings including regional university, large research university, and community college and in different classroom settings including large and extremely large (400+) classes in face-to-face, blended, and online formats.

Katherine contributes to projects that develop interactive materials for biology and environmental sciences and support higher order thinking about concepts in these subjects. She has presented and published on effective teaching, student engagement, and the biodiversity of myxomycetes, which was the basis for her interest in teaching environmental sciences to undergraduate students.

The thread that ties together Katherine's diverse teaching experience is a focus on developing active learning experiences that require students to think about ideas in different ways, providing opportunities for students to analyze data that describe our impact on the planet, and facilitating students' understanding of the scientific foundations for environmental and biological processes.

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Brief Contents

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About the Cover

A filter-feeding whale shark foraging among plastic debris reminds us that human influences reach to the remotest parts of the globe. Environmental science provides a deeper understanding of these concerns, from plastic pollution and climate change to declining biodiversity. Environmental science helps us perceive the processes involved in these changes and the ways complex environmental systems, from waste production to ecosystem diversity, interact. These insights are necessary for envisioning strategies to address environmental issues.

The good news is that many strategies exist. We have emerging policies to protect marine reserves, to monitor fisheries, and to curb greenhouse gas emissions. Awareness of ocean plastic pollution and threats to ocean ecosystems is leading to global efforts to reduce pollution and protect biodiversity. Understanding interconnected environmental systems is critical to maintaining the ecosystem services on which we depend, and to protecting the extraordinary diversity of life that surrounds us.

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.

Finding your place in environmental science

Although the challenges are daunting, this book points out countless ways that you can use your interests and ideas to engage with environmental science. In the Learning to Learn chapter, we focus on finding your strengths in studying; in chapter 1, we consider the diverse array of approaches that contribute to understanding environmental challenges. Our Restoration Ecology chapter (13) highlights some of the many strategies to restore environmental quality.

For major issues such as climate change (chapter 15) or air and water pollution (chapters 17 and 19), we examine diverse strategies, from personal to global, to combat environmental degradation. Our chapters on conventional and renewable energy (chapters 19 and 20)—perhaps the main key to both climate solutions and pollution—are the most up-to-date in the field. The policy chapter (24) includes a focus on campus engagement.

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. 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.

As teachers, we have worked with students in large universities, community colleges, and liberal arts colleges. All the material in the chapters has been developed in connection with courses the authors have taught, and this experience shapes the material. We give special attention to questions students have and to student motivation to find their role in environmental science.

Because we have observed that students vary in their academic backgrounds, we also provide an introductory "Learning to Learn" chapter. This chapter focuses on aspects of critical thinking and ways to be purposeful in learning and goals.

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.

What's New in This Edition?

This edition has updated discussions of major topics as well as current data, figures, and tables. We have given special attention to visual accessibility and inclusive presentation throughout. The previous

edition had over 28 new opening case studies and "Exploring Science" or "What Do You Think?" readings, and the current builds on these new readings with recent developments and recent data. We have further enhanced our focus on climate action and environmental engagement, topics that are especially important for students in our classes. We have updated "benchmark data" tables, which provide reference values reflecting key ideas in chapters. These tables provide good content for discussion, as well as ideas for review.

Specific chapter updates

Chapter 1 presents **climate change** and **sustainable development** as two themes that run through the book. We have updated the discussion of ecological footprints to consider their ambiguous messages about corporate versus individual responsibility for climate action. Our discussion of environmental ideas, which has always given attention to diverse viewpoints, has added discussion of contributions from youth and people of color.

Chapter 2 retains a focus on scientific processes, including a case study on **citizen science** in wildlife monitoring and a discussion of statistical evidence. This example illustrates **study design,** as well as questions of significance in data. We have updated the discussion of **critical thinking** in science to reflect public debates around trust of science, as well as ways students can decide whom to trust, in public policy questions.

Chapter 3 opens with a 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, and eutrophication. A new periodic table in the appendices, annotated to emphasize environmental science topics, supports this chapter. An "Exploring Science" reading reviews the CRISPR gene editing system, including ethics of human embryo editing.

Chapter 4 uses a case study on "blue carbon" to introduce concepts of ecosystem function and biodiversity. These key ideas are foundational for later topics.

Chapter 5 opens with a 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.

Chapter 6 uses a case study on invasive carp in the Mississippi watershed to illustrate population dynamics. 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 has updated population data, including a focus on China's aging population, to discuss **population momentum** and factors that influence **birth rates.** China now has the largest number of senior citizens in the world, and it raises questions of global concern. We also discuss the changing dynamics of population growth, as birth rates decline almost everywhere. Ecologists have long called for this shift, but now economists are fighting back in policy arenas.

Chapter 8 new discussion of climate change-related **heat stress,** an issue of growing concern, as well as public health considerations in a time of **COVID-19.** We have fully updated data on health and mortality risks, as well as new discussion of disability life-years (DALYs), an increasingly important measure as global populations live with chronic health conditions. We provide an updated discussion of the connection of **emergent diseases,** such as COVID-19 to wildlife contact; this includes critical risks to wildlife, such as amphibians and bats. Discussions of toxicity levels and impacts are updated, and a new section focuses on risk tolerance, as well as EPA assessments of environmental health risk factors.

Chapter 9 opens with a 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 dietary diversity. We focus on climate impacts on food production and on *Diet for a Small Planet,* and eating low on the food chain. Updated discussions focus on food insecurity, nutrition, and hunger, with a new table showing global rates of food insecurity.

Chapter 10 has an updated opening case study on farming in Brazil's Cerrado, where expanding soy production and reduced protections for Amazonian rainforest have global climate and biodiversity impacts. A new section discusses **carbon farming,** which could contribute to slowing climate change. We also have updated the "What do you Think?" box on the environmental benefits of shade-grown coffee and cocoa. A new "What do you Think?" box examines community building through urban gardening.

Chapter 11 leads with an updated 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.** We have updated data on species vulnerability and added a discussion of the "**30 by 30**" targets introduced to promote habitat conservation worldwide. A new section on rebuilding biodiversity includes attention to the importance of local action for backyard biodiversity. A new Data Analysis exercises use the Seek app to explore local diversity.

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. We have updated discussions of old-growth forests, wood consumption, Indigenous fire management, and local park conservation. Continuing our survey of landscapes in transition, we have updated the "Exploring Science" box on the effects of palm oil plantations on endangered orangutan populations in Borneo. An updated "What Do You Think?" box examines political debates on mining in U.S. national monuments.

Chapter 13 introduces **restoration ecology** with a case study on the science and practice of restoring coral reefs. Globally, coral reefs have been damaged by pollution, overharvesting, ocean acidification, and climate change. A box on the "monarch highway" project

describes both the threats to these charismatic insects and efforts to restore their populations. Updated discussions address stream restoration and the challenges of restoring ecosystem functions.

Chapter 14 begins an **environmental geology** discussion with a 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. Updated content discusses earthquakes resulting from oil and gas extraction.

Chapter 15 demonstrates leadership in **climate action** with a case study on groundbreaking climate policies in California. Challenges are daunting, but solutions are diverse, creative, and exciting. We also examine options for **carbon capture** and other efforts to combat climate change. A new section examines the necessity of **climate adaptation,** which countries are only slowly beginning to acknowledge.

Chapter 16 provides updated data on air pollution, especially in developing regions, as well as updated discussion of mercury pollution, greenhouse gases, and regulation of greenhouse gases as pollutants. Among these are halogen gases, which are addressed in the Kigali amendment to the Montreal Protocol on ozone-destroying substances. This step alone could prevent 0.5 degrees of global warming by 2100.

Chapter 17 updates the opening case study on demands for Colorado River water, which 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 examines **water pollution** with an opening focus on the Ganges River, which supports nearly a billion people in South Asia. We know how to prevent water pollution, but finding ways to implement policies and pay for treatment is difficult, in both wealthy and developing countries. Updated data and discussions address acidic mine drainage, water shortages, and water treatment.

Chapter 19 uses a new case study to focus on the importance of oil and gas in geopolitical conflict, with a focus on the Russian invasion of Ukraine. We emphasize that while fossil fuels still provide most energy, the future of energy is not the past. We have updated data on production and consumption and discuss the shifting landscape of conventional energy, including growth in China. An "Exploring Science" box discusses the growing importance of indigenous resistance to fossil fuel development.

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. Updated data reflect new developments in solar, wind, and other energy options. A new section on battery storage, including a discussion of global lithium resources, highlights this critical part of sustainable energy systems. 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 the challenge of recycling and waste management, which long depended on China accepting the world's waste materials. A new table outlines the evolution of policies for managing hazardous waste.

Chapter 22 opens with a case study on the leadership of cities in efforts for environmental, social, and economic sustainability. Updated data describe changes in **urban growth,** especially in African states. 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,** a strategy vigorously opposed by fossil fuel interests in U.S. states. An "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. Updated sections explore the power of green economies to increase jobs and the ideals of a green new deal.

Chapter 24 focuses on environmental policy, with a case study on the Endangered Species Act and its success in restoring green sea turtles in Florida. 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. A new section focuses on **international agreements** on environmental policy, including major treaties and strategies for enforcing agreements.

Chapter 25 opens with a 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. We have updated data on the fossil fuel divestment movement, on environmental literacy, and on options for environmental action.

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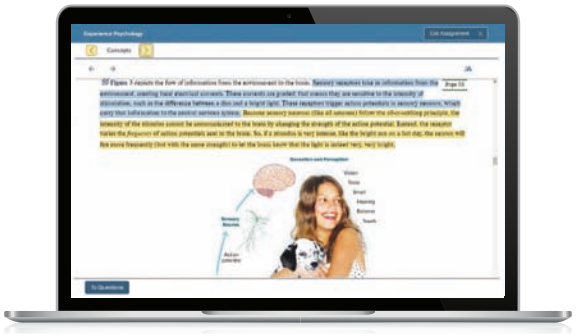

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"I really liked this app—it made it easy to study when you don't have your textbook in front of you."

- Jordan Cunningham, Eastern Washington University

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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 vary, 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.

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.

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

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 making observations 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. Q*uestion* 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 fig. 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

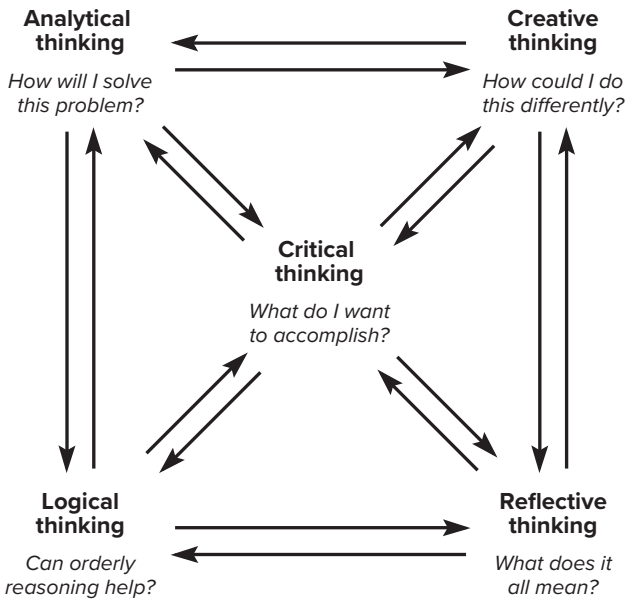

FIGURE L.5 Different approaches to thinking are used to solve different kinds of problems or to study alternate aspects of a single issue.

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

▲ Ensuring a safe environment and hopeful future for people everywhere, including these children in Kibera, is the goal of sustainable development.
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

Is it possible to improve well-being for low-income 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. To encourage the search for sustainable solutions, the United Nations has identified a set of 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?

Perhaps the greatest test case of this question is in fast-growing urban settlements of the developing world. One of the largest of these settlements is the district of 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.

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

Kibera occupies the 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 waste, both sewage and garbage end up in the river, often entering homes with flood waters. Much of the time, an 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 informal settlements, 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. Numerous factors drive people into these cities. Climate change and soil degradation undermine rural livelihoods, driving farmers off the land. Competition for declining water resources further threatens food production. Forest destruction makes traditional lifestyles difficult to maintain. Large landholders expand, displacing rural communities. In wealthier countries, state support often stabilize rural incomes, but in developing regions, people may have few options.

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 improve both the lives and the environment of people in low-income areas. Sustainable development also tries to draw on the ideas and energy of people like those in Kibera, who want to a safe and healthy life for their children, just 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 work 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.