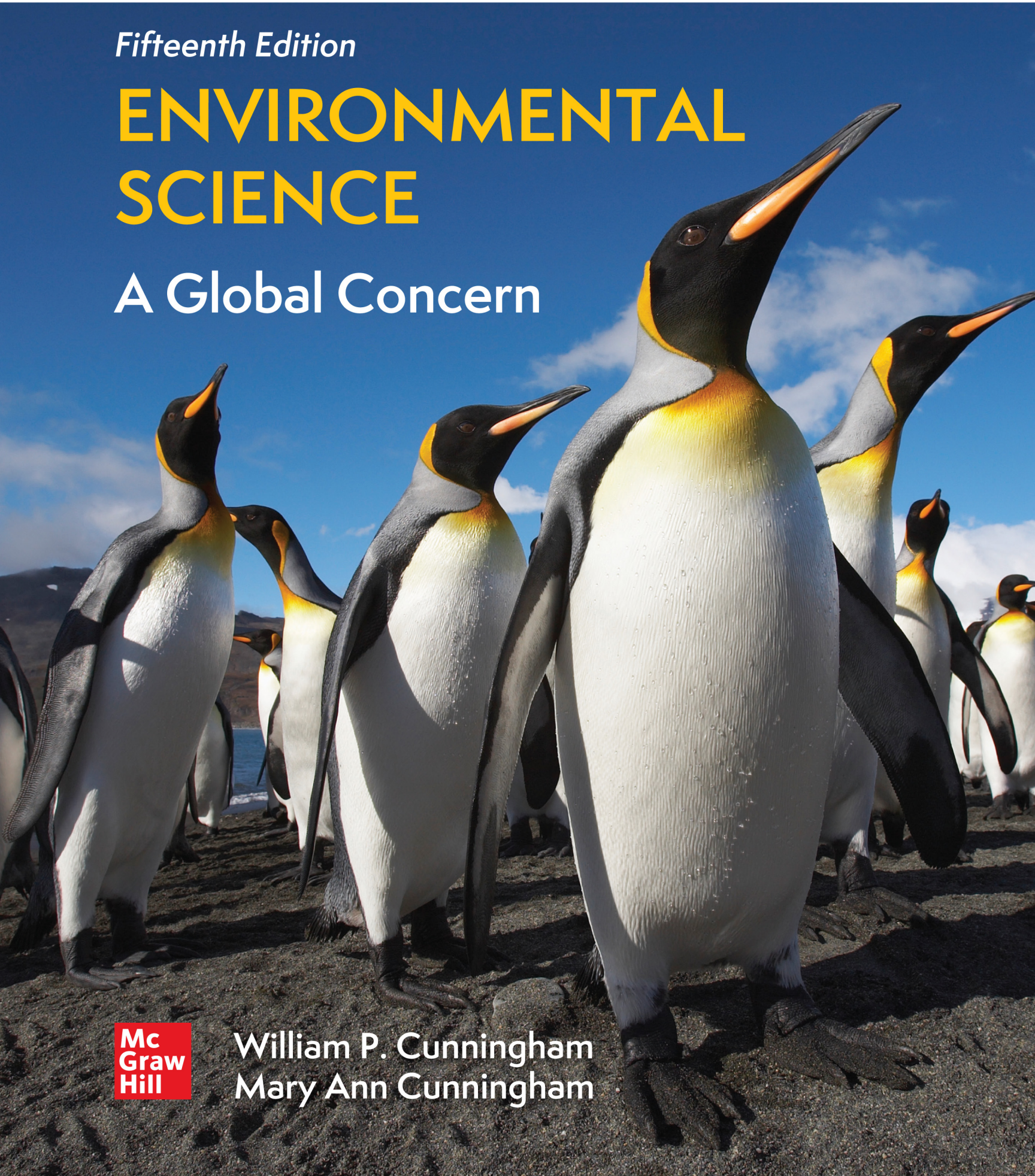
This International Student Edition is for use outside of the U.S.

Fifteenth Edition

ENVIRONMENTAL SCIENCE

A Global Concern



William P. Cunningham
Mary Ann Cunningham

FIFTEENTH EDITION

Environmental SCIENCE

A Global Concern

William P. Cunningham
University of Minnesota

Mary Ann Cunningham
Vassar College

ENVIRONMENTAL SCIENCE

This book is printed on acid-free paper.

1 2 3 4 5 6 7 8 9 LWI 24 23 22 21 20

ISBN 978-1-260-57510-1
MHID 1-260-57510-1

Cover Image: *Paul Souders/Getty Images*

logo applies to the text stock only

mheducation.com/highered

About the Authors

Source: Glow Images/SuperStock

© Tom Finkle

William P. Cunningham

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

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

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

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

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

Mary Ann Cunningham

© Tom Finkle

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

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

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

Source: imageBROKER/Alamy Stock Photo

Brief Contents

Contents

Source: imageBROKER/Alamy Stock Photo

List of Case Studies

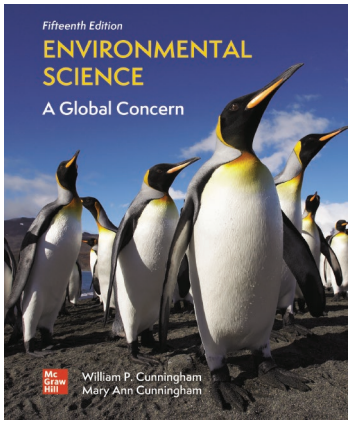
About the Cover

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

Preface

Environmental Science: A Search for Solutions

Environmental science focuses on understanding challenges that affect our lives, and on finding solutions to those challenges. Your decision to study environmental science is an important step. This field can help you find answers to some of the most important problems facing us today. Environmental science is an integrative field. It draws on diverse knowledge bases and skills to address issues: For example, preserving healthy ecosystems depends on strategies such as reducing greenhouse gas emissions, developing renewable energy systems, reducing pollution, improving social and environmental justice, improving sustainable farming systems, and reducing resource consumption.



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

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

Sustainable development is a central theme

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

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

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

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

What Sets This Book Apart?

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

Engaged and active learning

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

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

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

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

Quantitative reasoning and methods of science

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

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

A positive focus on opportunities

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

A balanced presentation for critical thinking

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

An integrated, global perspective

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

Google Earth™ placemarks

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

What's New in This Edition?

This edition has thoroughly updated data, figures, and tables, as well as 16 new opening case studies that reflect new developments in the field, and over a dozen new "Exploring Science" or "What Do You Think?" boxed readings. We have enhanced our focus on climate action and environmental action, something students in our classes find especially valuable. Brief "benchmark data"

tables provide reference values or comparisons that reflect key ideas in the chapter. Systematic discussions review topics such as uncertainty, graphing, statistics, experimental design, models, and systems. At the end of each chapter, we conclude with a new section, "Connecting the Dots," that draws together major themes of the chapter.

Specific chapter changes

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

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

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

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

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

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

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

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

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

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

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

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

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

new threats to U.S. national monuments from mining and other extractive industries.

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

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

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

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

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

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

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

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

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

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

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

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

Chapter 25 presents a new case study on the history of Earth Day. It is critical that students understand how we got to where we

are, and how public involvement with environmental issues has emerged. A new box discusses fossil fuel divestment debates at U.S. colleges and universities. We end the chapter with a review of sustainability as an overarching goal for environmental science.

Acknowledgments

We owe a great debt to the hardworking, professional team that has made this the best environmental science text possible. We express special thanks for editorial support to Michael Ivanov, PhD, and Jodi Rhomberg. We are grateful to Jessica Portz, Lora Neyens, Sherry Kane, Carrie Burger, Lorraine Buczek, and Tara McDermott, for their work in putting the book together, and marketing leadership by Noah Evans. We thank Tricia Lawrence for copyediting and Janet Robbins for excellent work on photographs.

The following individuals helped write and review learning goal–oriented content for LearnSmart for Environmental Science:

Central Washington University, Susan Kaspari
College of DuPage, Shamili Ajgaonkar Sandiford
Columbus State Community College, Morteza Javadi
Community College of Philadelphia, Christopher Murphy
Florida Atlantic University, Jessica Miles
Florida Gulf Coast University, Chad Evers
Georgia Southern University, J. Michelle Cawthorn
Indian Hills Community College, Chad V. Gatlin
John Tyler Community College, Joressia A. Beyer
Missouri State University, Kip R. Thompson
Moraine Valley Community College, Jennifer Kaye Sheppard
Northern Arizona University, Sylvester Allred
Ozarks Technical Community College, Michael S. Martin
Reading Area Community College, Heather A. Hinkle
Roane State Community College, Arthur C. Lee
Rock Valley Community College, Joseph E. Haverly
Rock Valley Community College, Megan M. Pease
Southeast Community College, Daniel D. Fogell
St. Cloud State University, Matthew Julius
State University of New York at Cortland, Noelle J. Relles
Temple College, Nathan Gardiner
The Community College of Baltimore County, Arthur C. Cage III
University of North Carolina Wilmington, Jeffery Hill
University of North Carolina at Chapel Hill, Trent McDowell
University of Wisconsin, Milwaukee, Tristan J. Kloss
University of Wisconsin, Milwaukee, Gina Seegers Szablewski
Waubonsee Community College, Dani Fischer
Winona State University, Jennifer L. Cochran

Input from instructors teaching this course is invaluable to the development of each new edition. Our thanks and gratitude go out to the following individuals who either completed detailed chapter reviews of *Environmental Science, A Global Concern,* fifteenth edition, or provided market feedback for this course.

American University, Priti P. Brahma
Antelope Valley College, Zia Nisani
Arizona Western College, Alyssa Haygood
Aurora University, Carrie Milne-Zelman
Baker College, Sandi B. Gardner
Baylor College, Heidi Marcum
Boston University, Kari L. Lavalli
Bowling Green State University, Daniel M. Pavuk
Bradley University, Sherri J. Morris
Broward College, Elena Cainas
Broward College, Nilo Marin
California Energy Commission, James W. Reede
California State University–East Bay, Gary Li
California State University, Natalie Zayas
Campbellsville University, Ogochukwu Onyiri
Central Carolina Community College, Scott Byington
Central State University, Omokere E. Odje
Clark College, Kathleen Perillo
Clemson University, Scott Brame
College of DuPage, Shamili Ajgaonkar Sandiford
College of Lake County, Kelly S. Cartwright
College of Southern Nevada, Barry Perlmutter
College of the Desert, Tracy Albrecht
College of the Desert, Candice Weber
College of the Desert, Kurt Leuschner
Columbia College, Jill Bessetti
Columbia College, Daniel Pettus
Community College of Baltimore County, Katherine M. Van de Wal
Connecticut College, Jane I. Dawson
Connecticut College, Chad Jones
Connors State College, Stuart H. Woods
Cuesta College, Nancy Jean Mann
Dalton State College, David DesRochers
Dalton State College, Gina M. Kertulis-Tartar
Deanza College, Dennis Gorsuch
East Tennessee State University, Alan Redmond
Eastern Oklahoma State College, Patricia C. Bolin Ratliff
Edison State College, Cheryl Black
Elgin Community College, Mary O'Sullivan

Erie Community College, Gary Poon
Estrella Mountain Community College, Rachel Smith
Farmingdale State College, Paul R. Kramer
Fashion Institute of Technology, Arthur H. Kopelman
Flagler College, Barbara Blonder
Florida State College at Jacksonville, Catherine Hurlbut
Franklin Pierce University, Susan Rolke
Galveston College, James J. Salazar
Gannon University, Amy L. Buechel
Gardner-Webb University, Emma Sandol Johnson
Gateway Community College, Ramon Esponda
Geneva College, Marjory Tobias
Georgia Perimeter College, M. Carmen Hall
Georgia Perimeter College, Michael L. Denniston
Gila Community College, Joseph Shannon
Golden West College, Tom Hersh
Gulf Coast State College, Kelley Hodges
Gulf Coast State College, Linda Mueller Fitzhugh
Holy Family University, Robert E. Cordero
Houston Community College, Yiyan Bai
Hudson Valley Community College, Daniel Capuano
Hudson Valley Community College, Janet Wolkenstein
Illinois Mathematics and Science Academy, C. Robyn Fischer
Illinois State University, Christy N. Bazan
Indiana University of Pennsylvania, Holly J. Travis
Indiana Wesleyan University, Stephen D. Conrad
James Madison University, Mary Handley
James Madison University, Wayne S. Teel
John A. Logan College, Julia Schroeder
Kentucky Community & Technical College System-Big Sandy District, John G. Shiber
Lake Land College, Jeff White
Lane College, Satish Mahajan
Lansing Community College, Lu Anne Clark
Lewis University, Jerry H. Kavouras
Lindenwood University, David M. Knotts
Longwood University, Kelsey N. Scheitlin
Louisiana State University, Jill C. Trepanier
Lynchburg College, David Perault
Marshall University, Terry R. Shank
Menlo College, Neil Marshall
Millersville University of Pennsylvania, Angela Cuthbert
Minneapolis Community and Technical College, Robert R. Ruliffson
Minnesota State College–Southeast Technical, Roger Skugrud
Minnesota West Community and Technical College, Ann M. Mills
Mt. San Jacinto College, Shauni Calhoun
Mt. San Jacinto College, Jason Hlebakos
New Jersey City University, Deborah Freile
New Jersey Institute of Technology, Michael P. Bonchonsky
Niagara University, William J. Edwards
North Carolina State University, Robert I. Bruck
North Georgia College & State University, Kelly West
North Greenville University, Jeffrey O. French
Northeast Lakeview College, Diane B. Beechinor
Northeastern University, Jennifer Rivers Cole
Northern Virginia Community College, Jill Caporale
Northwestern College, Dale Gentry
Northwestern Connecticut Community College, Tara Jo Holmberg
Northwood University Midland, Stelian Grigoras
Notre Dame College, Judy Santmire
Oakton Community College, David Arieti
Parkland College, Heidi K. Leuszler
Penn State Beaver, Matthew Grunstra
Philadelphia University, Anne Bower
Pierce College, Thomas Broxson
Purdue University Calumet, Diane Trgovcich-Zacok
Queens University of Charlotte, Greg D. Pillar
Raritan Valley Community College, Jay F. Kelly
Reading Area Community College, Kathy McCann Evans
Rutgers University, Craig Phelps
Santa Monica College, Dorna S. Sakurai
Shasta College, Morgan Akin
Shasta College, Allison Lee Breedveld
Southeast Kentucky Community and Technical College, Sheila Miracle
Southern Connecticut State University, Scott M. Graves
Southern New Hampshire University, Sue Cooke
Southern New Hampshire University, Michele L. Goldsmith
Southwest Minnesota State University, Emily Deaver
Spartanburg Community College, Jeffrey N. Crisp
Spelman College, Victor Ibeanusi
St. Johns River State College, Christopher J. Farrell
Stonehill College, Susan M. Mooney
Tabor College, Andrew T. Sensenig
Temple College, John McClain
Terra State Community College, Andrew J. Shella
Texas A&M University–Corpus Christi, Alberto M. Mestas-Nuñez

Tusculum College, Kimberly Carter
University of Akron, Nicholas D. Frankovits
University of Denver, Shamim Ahsan
University of Kansas, Kathleen R. Nuckolls
University of Miami, Kathleen Sullivan Sealey
University of Missouri at Columbia, Douglas C. Gayou
University of Missouri–Kansas City, James B. Murowchick
University of Nebraska, James R. Brandle
University of North Carolina Wilmington, Jack C. Hall
University of North Texas, Samuel Atkinson
University of Tampa, Yasoma Hulathduwa
University of Tennessee, Michael McKinney
University of Utah, Lindsey Christensen Nesbitt
University of Wisconsin–Stevens Point, Holly A. Petrillo
University of Wisconsin–Stout, Charles R. Bomar
Valencia College, Patricia Smith
Vance Granville Community College, Joshua Eckenrode
Villanova University, Lisa J. Rodrigues
Virginia Tech, Matthew Eick
Viterbo University, Christopher Iremonger
Waubonsee Community College, Dani DuCharme
Wayne County Community College District, Nina Abubakari
West Chester University of Pennsylvania, Robin C. Leonard
Westminster College, Christine Stracey
Worcester Polytechnic Institute, Theodore C. Crusberg
Wright State University, Sarah Harris

Mc Graw Hill connect®

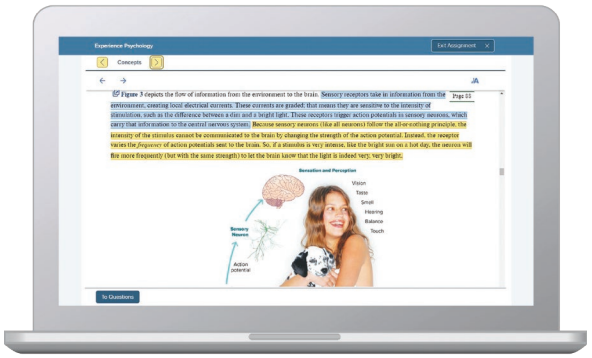
FOR INSTRUCTORS

You're in the driver's seat.

Want to build your own course? No problem. Prefer to use our turnkey, prebuilt course? Easy. Want to make changes throughout the semester? Sure. And you'll save time with Connect's auto-grading too.

65%

Less Time Grading



Laptop: McGraw-Hill; Woman/dog: George Doyle/Getty Images

They'll thank you for it.

Adaptive study resources like SmartBook® 2.0 help your students be better prepared in less time. You can transform your class time from dull definitions to dynamic debates. Find out more about the powerful personalized learning experience available in SmartBook 2.0 at **www.mheducation.com/highered/connect/smartbook**

Make it simple, make it affordable.

Connect makes it easy with seamless integration using any of the major Learning Management Systems—Blackboard®, Canvas, and D2L, among others—to let you organize your course in one convenient location. Give your students access to digital materials at a discount with our inclusive access program. Ask your McGraw-Hill representative for more information.

Padlock: Jobalou/Getty Images

Solutions for your challenges.

A product isn't a solution. Real solutions are affordable, reliable, and come with training and ongoing support when you need it and how you want it. Our Customer Experience Group can also help you troubleshoot tech problems—although Connect's 99% uptime means you might not need to call them. See for yourself at **status.mheducation.com**

Checkmark: Jobalou/Getty Images

SUPPORT AT every step

FOR STUDENTS

Effective, efficient studying.

Connect helps you be more productive with your study time and get better grades using tools like SmartBook 2.0, which highlights key concepts and creates a personalized study plan. Connect sets you up for success, so you walk into class with confidence and walk out with better grades.

Study anytime, anywhere.

Download the free ReadAnywhere app and access your online eBook or SmartBook 2.0 assignments when it's convenient, even if you're offline. And since the app automatically syncs with your eBook and SmartBook 2.0 assignments in Connect, all of your work is available every time you open it. Find out more at **www.mheducation.com/readanywhere**

> ***"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

Calendar: owattaphotos/Getty Images

No surprises.

The Connect Calendar and Reports tools keep you on track with the work you need to get done and your assignment scores. Life gets busy; Connect tools help you keep learning through it all.

Learning for everyone.

McGraw-Hill works directly with Accessibility Services Departments and faculty to meet the learning needs of all students. Please contact your Accessibility Services office and ask them to email accessibility@mheducation.com, or visit **www.mheducation.com/about/accessibility** for more information.

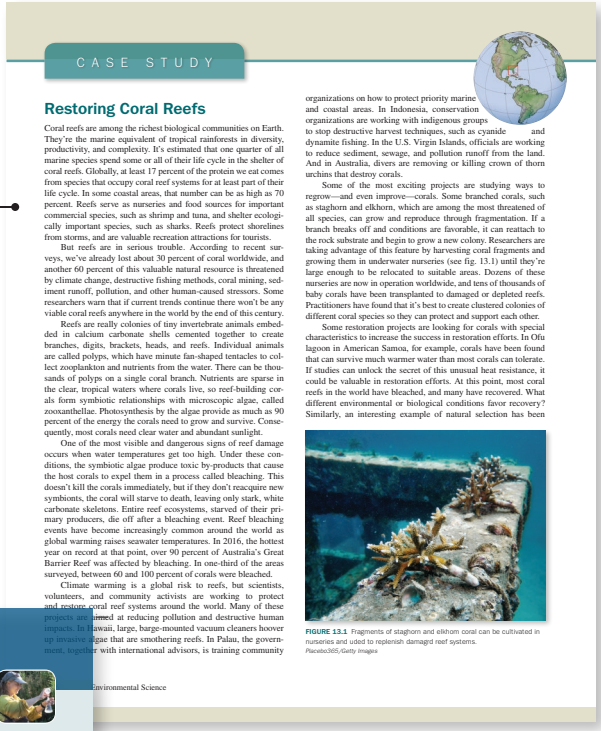
Top: Jenner Images/Getty Images, Left: Hero Images/Getty Images, Right: Hero Images/Getty Images

Key Elements

A global perspective is vital to learning about environmental science.

Case Studies

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



CASE STUDY

Restoring Coral Reefs

Coral reefs are among the richest biological communities on Earth. They're the marine equivalent of tropical rainforests in diversity, productivity, and complexity. It's estimated that one quarter of all marine species spend some or all of their life cycle in the shelter of coral reefs. Globally, at least 17 percent of the protein we eat comes from species that occupy coral reef systems for at least part of their life cycle. In some coastal areas, that number can be as high as 70 percent. Reefs serve as nurseries and food sources for important commercial species, such as shrimp and tuna, and shelter ecologically important species, such as sharks. Reefs protect shorelines from storms, and are valuable recreation attractions for tourists.

But reefs are in serious trouble. According to recent surveys, we've already lost about 30 percent of coral worldwide, and another 60 percent of this valuable natural resource is threatened by climate change, destructive fishing methods, coral mining, sediment runoff, pollution, and other human-caused stressors. Some researchers warn that if current trends continue there won't be any viable coral reefs anywhere in the world by the end of this century.

Reefs are really colonies of tiny invertebrate animals embedded in calcium carbonate shells cemented together to create branches, digits, brackets, heads, and reefs. Individual animals are called polyps, which have minute fan-shaped tentacles to collect zooplankton and nutrients from the water. There can be thousands of polyps on a single coral branch. Nutrients are sparse in the clear, tropical waters where corals live, so reef-building corals form symbiotic relationships with microscopic algae, called zooxanthellae. Photosynthesis by the algae provide as much as 90 percent of the energy the corals need to grow and survive. Consequently, most corals need clear water and abundant sunlight.

One of the most visible and dangerous signs of reef damage occurs when water temperatures get too high. Under these conditions, the symbiotic algae produce toxic by-products that cause the host corals to expel them in a process called bleaching. This doesn't kill the corals immediately, but if they don't reacquire new symbionts, the coral will starve to death, leaving only stark, white carbonate skeletons. Entire reef ecosystems, starved of their primary producers, die off after a bleaching event. Reef bleaching events have become increasingly common around the world as global warming raises seawater temperatures. In 2016, the hottest year on record at that point, over 90 percent of Australia's Great Barrier Reef was affected by bleaching. In one-third of the areas surveyed, between 60 and 100 percent of corals were bleached.

Climate warming is a global risk to reefs, but scientists, volunteers, and community activists are working to protect and restore coral reef systems around the world. Many of these projects are aimed at reducing pollution and destructive human impacts. In Hawaii, large, barge-mounted vacuum cleaners hoover up invasive algae that are smothering reefs. In Palau, the government, together with international advisors, is training community

organizations on how to protect priority marine and coastal areas. In Indonesia, conservation organizations are working with indigenous groups to stop destructive harvest techniques, such as cyanide and dynamite fishing. In the U.S. Virgin Islands, officials are working to reduce sediment, sewage, and pollution runoff from the land. And in Australia, divers are removing or killing crown of thorn urchins that destroy corals.

Some of the most exciting projects are studying ways to regrow—and even improve—corals. Some branched corals, such as staghorn and elkhorn, which are among the most threatened of all species, can grow and reproduce through fragmentation. If a branch breaks off and conditions are favorable, it can reattach to the rock substrate and begin to grow a new colony. Researchers are taking advantage of this feature by harvesting coral fragments and growing them in underwater nurseries (see fig. 13.1) until they're large enough to be relocated to suitable areas. Dozens of these nurseries are now in operation worldwide, and tens of thousands of baby corals have been transplanted to damaged or depleted reefs. Practitioners have found that it's best to create clustered colonies of different coral species so they can protect and support each other.

Some restoration projects are looking for corals with special characteristics to increase the success in restoration efforts. In Ofu lagoon in American Samoa, for example, corals have been found that can survive much warmer water than most corals can tolerate. If studies can unlock the secret of this unusual heat resistance, it could be valuable in restoration efforts. At this point, most coral reefs in the world have bleached, and many have recovered. What different environmental or biological conditions favor recovery? Similarly, an interesting example of natural selection has been

FIGURE 13.1 Fragments of staghorn and elkhorn coral can be cultivated in nurseries and used to replenish damaged reef systems.
Placebo365/Getty Images

Environmental Science

Exploring Science

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

EXPLORING SCIENCE

Say Hello to Your 90 Trillion Little Friends

Have you ever thought of yourself as a biological community or an ecosystem? Researchers estimate that each of us has about 90 trillion bacteria, fungi, protozoans, and other organisms living in or on our bodies. And the viruses inside those commensal species increase our biodiversity by another order of magnitude. The largest group—around 2 kg worth—inhabit your gut, but there are thousands of species living in every orifice, gland, pore, and crevice of your anatomy. Although the 10 trillion or so mammalian cells make up more than 95 percent of the volume of your body, they represent less than 10 percent of all the cell types that occupy that space.

Because most of the other species with which we coexist are microorganisms, we call the collection of cells that inhabit us our microbiome. The species composition of your own microbial community will be very similar to that of other people and pets with whom you live, but each of us has a unique collection of species that may be as distinctive as our fingerprints.

As is the case in other species interactions, these relationships can be mutualistic, symbiotic, commensal, or predatory. We used to think of all microorganisms as germs to be eliminated as quickly and thoroughly as possible. Current research suggests, however, that many of our fellow travelers are beneficial, perhaps even indispensable, to our good health and survival.

Your microbiome is essential, for example, in the digestion and absorption of nutrients. Symbiotic bacteria in your gut supply essential nutrients (important amino acids and short-chain fatty acids), vitamins (such as K and some B varieties), hormones and

FIGURE 1 *Lactobacillus* bacteria are part of the normal flora of human intestine and are often used as probiotic supplements. These intestinal bacteria help crowd out pathogens, aid in digestion, and supply your body with essential nutrients.
Kateryna Kon/Shutterstock

communicate with, and modulate, your immune and metabolic systems. They help exclude pathogens by competing with them for living space, or by creating an environment in which harmful species can't grow or prosper.

The inhabitants of different organs can have important roles in specific diseases. Oral bacteria, for example, have been implicated in cardiovascular disease, pancreatic cancer, rheumatoid arthritis, and preterm birth, among other things. Symbionts in the lung have been linked to cystic fibrosis and chronic obstructive pulmonary disease (COPD). And the gut community seems to play a role in obesity, diabetes, colitis, susceptibility to infections, allergies, and other chronic problems. A healthy biome seems to be critical in controlling chronic inflammation that triggers many important long-term diseases.

As is true in many ecosystems, the diver-

a community rich in good microbes will not only help you resist infection by pathogens but will allow faster recovery after a catastrophic event. People in primitive or rustic societies who eat a wide variety of whole grains, raw fruits and vegetables, and unprocessed meat or dairy products tend to have a much greater species variety than those of us who have a diet full of simple sugars and highly processed foods. Widespread use of antibiotics to treat illnesses, as well as chronic low levels of antimicrobials, preservatives, and stabilizers in our food, toothpaste, soap, and many other consumer products also limits diversity in our symbiotic community.

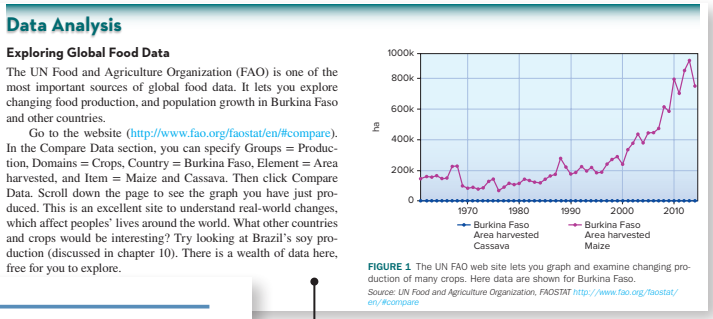
A growing problem in many places is antibiotic-resistant, hospital-acquired infections. One of the most intractable of these is *Clostridium difficile*, or *C. diff*, which infects 250,000 and kills 14,000 Americans every year. An effective treatment for this superpathogen is a fecal transplant. A sample of the microbiome from a healthy person is implanted either directly through a feeding tube into the patient's stomach or in frozen, encapsulated pellets of feces that are delivered orally. In one trial, 18 of 20 patients who received fecal transplants recovered from *C. diff*.

Similarly, c
plants from lea
mice that rece
from obese mi
ome may even
When microbes
mice are transp
timid mice, th
adventurous.

So, it may

Google Earth

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



Data Analysis

Exploring Global Food Data

The UN Food and Agriculture Organization (FAO) is one of the most important sources of global food data. It lets you explore changing food production, and population growth in Burkina Faso and other countries.

Go to the website (http://www.fao.org/faostat/en/#compare). In the Compare Data section, you can specify Groups = Production, Domains = Crops, Country = Burkina Faso, Element = Area harvested, and Item = Maize and Cassava. Then click Compare Data. Scroll down the page to see the graph you have just produced. This is an excellent site to understand real-world changes, which affect peoples' lives around the world. What other countries and crops would be interesting? Try looking at Brazil's soy production (discussed in chapter 10). There is a wealth of data here, free for you to explore.

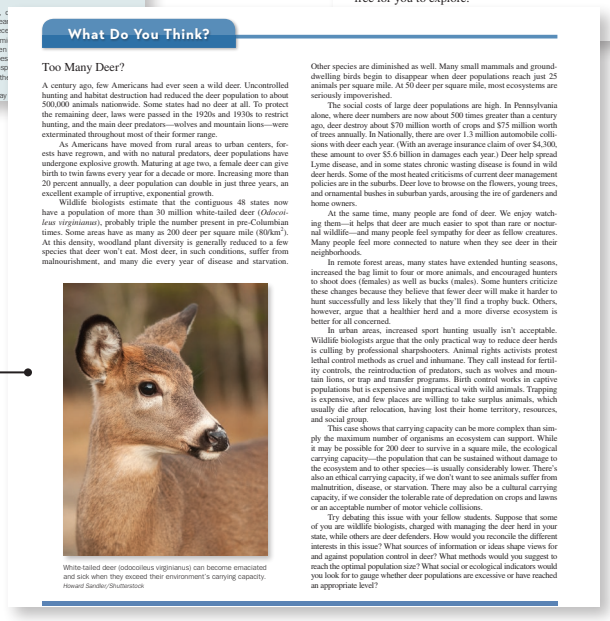
FIGURE 1 The UN FAO web site lets you graph and examine changing production of many crops. Here data are shown for Burkina Faso.
Source: UN Food and Agriculture Organization, FAOSTAT http://www.fao.org/faostat/en/#compare

Data Analysis

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

What Do You Think?

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



What Do You Think?

Too Many Deer?

A century ago, few Americans had ever seen a wild deer. Uncontrolled hunting and habitat destruction had reduced the deer population to about 500,000 animals nationwide. Some states had no deer at all. To protect the remaining deer, laws were passed in the 1920s and 1930s to restrict hunting, and the main deer predators—wolves and mountain lions—were exterminated throughout most of their former range.

As Americans have moved from rural areas to urban centers, forests have regrown, and with no natural predators, deer populations have undergone explosive growth. Maturing at age two, a female deer can give birth to twin fawns every year for a decade or more. Increasing more than 20 percent annually, a deer population can double in just three years, an excellent example of irruptive, exponential growth.

Wildlife biologists estimate that the contiguous 48 states now have a population of more than 30 million white-tailed deer (*Odocoileus virginianus*), probably triple the number present in pre-Columbian times. Some areas have as many as 200 deer per square mile (80/km²). At this density, woodland plant diversity is generally reduced to a few species that deer won't eat. Most deer, in such conditions, suffer from malnourishment, and many die every year of disease and starvation.

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

Other species are diminished as well. Many small mammals and ground-dwelling birds begin to disappear when deer populations reach just 25 animals per square mile. At 50 deer per square mile, most ecosystems are seriously impoverished.

The social costs of large deer populations are high. In Pennsylvania alone, where deer numbers are now about 500 times greater than a century ago, deer destroy about $70 million worth of crops and $75 million worth of trees annually. In Nationally, there are over 1.3 million automobile collisions with deer each year. (With an average insurance claim of over $4,300, these amount to over $5.6 billion in damages each year.) Deer help spread Lyme disease, and in some states chronic wasting disease is found in wild deer herds. Some of the most heated criticisms of current deer management policies are in the suburbs. Deer love to browse on the flowers, young trees, and ornamental bushes in suburban yards, arousing the ire of gardeners and home owners.

At the same time, many people are fond of deer. We enjoy watching them—it helps that deer are much easier to spot than rare or nocturnal wildlife—and many people feel sympathy for deer as fellow creatures. Many people feel more connected to nature when they see deer in their neighborhoods.

In remote forest areas, many states have extended hunting seasons, increased the bag limit to four or more animals, and encouraged hunters to shoot does (females) as well as bucks (males). Some hunters criticize these changes because they believe that fewer deer will make it harder to hunt successfully and less likely that they'll find a trophy buck. Others, however, argue that a healthier herd and a more diverse ecosystem is better for all concerned.

In urban areas, increased sport hunting usually isn't acceptable. Wildlife biologists argue that the only practical way to reduce deer herds is culling by professional sharpshooters. Animal rights activists protest lethal control methods as cruel and inhumane. They call instead for fertility controls, the reintroduction of predators, such as wolves and mountain lions, or trap and transfer programs. Birth control works in captive populations but is expensive and impractical with wild animals. Trapping is expensive, and few places are willing to take surplus animals, which usually die after relocation, having lost their home territory, resources, and social group.

This case shows that carrying capacity can be more complex than simply the maximum number of organisms an ecosystem can support. While it may be possible for 200 deer to survive in a square mile, the ecological carrying capacity—the population that can be sustained without damage to the ecosystem and to other species—is usually considerably lower. There's also an ethical carrying capacity, if we don't want to see animals suffer from malnutrition, disease, or starvation. There may also be a cultural carrying capacity, if we consider the tolerable rate of depredation on crops and lawns or an acceptable number of motor vehicle collisions.

Try debating this issue with your fellow students. Suppose that some of you are wildlife biologists, charged with managing the deer herd in your state, while others are deer defenders. How would you reconcile the different interests in this issue? What sources of information or ideas shape views for and against population control in deer? What methods would you suggest to reach the optimal population size? What social or ecological indicators would you look for to gauge whether deer populations are excessive or have reached an appropriate level?

Learning Outcomes

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

Learning Outcomes

After studying this chapter, you should be able to:

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

Section Reviews

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

Section Review

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

Connecting the Dots

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

Connecting the Dots

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

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

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

Critical Thinking and Discussion Questions

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

Critical Thinking and Discussion Questions

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

What Can You Do?

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

What Can You Do?

Controlling Pests

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

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

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

Quantitative Reasoning

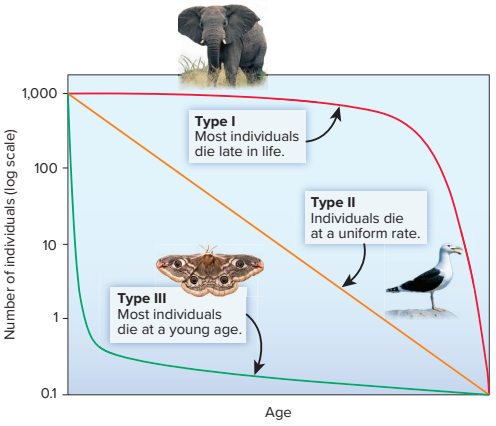
Compare the estimates of known and threatened species in table 11.1. Are some groups overrepresented? Are we simply more interested in some organisms, or are we really a greater threat to some species?

Quantitative Reasoning

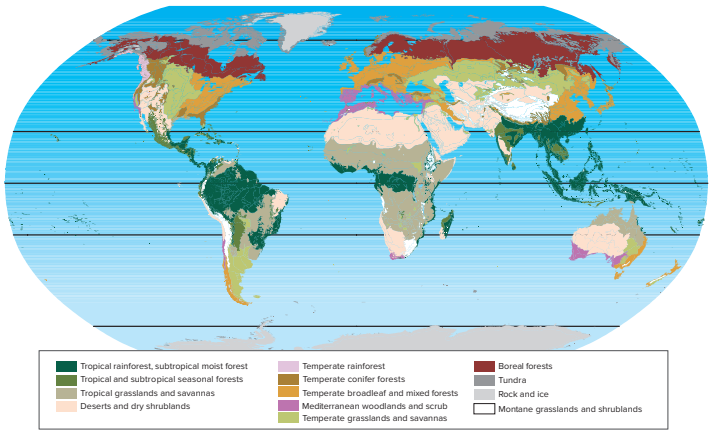
Quantitative reasoning questions in the text push students to evaluate data and graphs they have read about. Attention to statistics, graphing, graph interpretation, and abundant up-to-date data are some of the resources available to help students

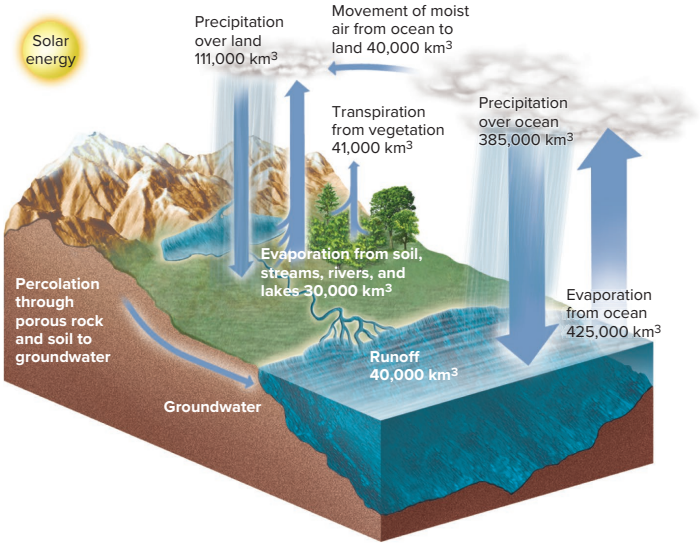
Relevant Photos and Instructional Art Support Learning

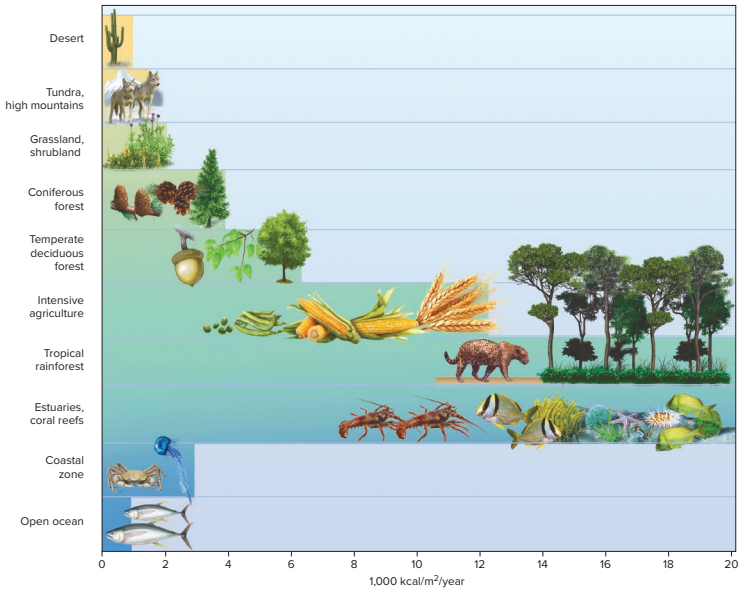
High-quality photos and realistic illustrations display detailed diagrams, graphs, and real-life situations.



Digital Vision/Getty Images
Stockbyte
simon22/123RF

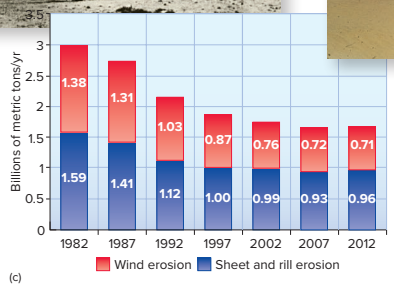






(a)

(b)



(c)

Source: a -b. USDA Natural Resources Conservation Service

Introduction
Learning to Learn

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

Learning Outcomes

After studying this introduction, you should be able to:

- **L.1** Form a plan to organize your efforts and become a more effective and efficient student.
- **L.2** Apply critical and reflective thinking in environmental science.
- **L.3** Identify logical errors, persuasive tricks, and biases used in popular media.
- **L.4** Describe issues that motivate you and consider ways they connect to environmental science.

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

– Peter Kropotkin

CASE STUDY

How can I do well in environmental science?

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

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

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

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

What are good study habits?

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

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

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

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

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

Table L.1 Learning Skills—Taking Notes

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

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

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

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

How can you use this textbook effectively?

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

1. *Survey* the entire chapter or section you are about to read, so you can see how it fits together. What are the major headings and subdivisions?
2. 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 figure L.5 suggests, critical thinking is central in the constellation of thinking skills. Thinking critically can help us discover hidden ideas and means, develop strategies for evaluating reasons and conclusions in arguments, recognize the differences between facts and values, and avoid jumping to conclusions.

How do you tell the news from the noise?

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

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

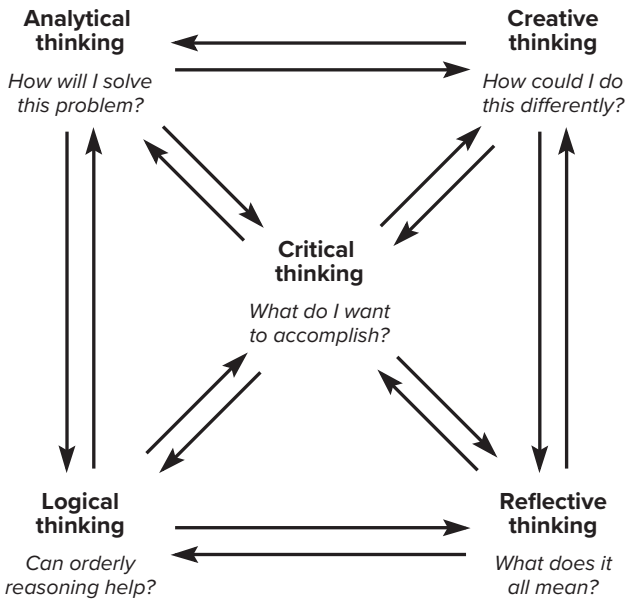


FIGURE L.5 Different approaches to thinking are used to solve different kinds of problems or to study alternate aspects of a single issue.

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

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

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

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

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

Applying critical thinking

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

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

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

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

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

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

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

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

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

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

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

Section Review

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

Connecting the Dots

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

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

1 Understanding Our Environment

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

Learning Outcomes

After studying this chapter, you should be able to:

- **1.1** Explain what environmental science is, and how it draws on different kinds of knowledge.
- **1.2** Identify some early thinkers on environment and resources, and contrast some of their ideas.
- **1.3** Describe sustainable development and its goals.
- **1.4** Explain core concepts in sustainable development.
- **1.5** Identify ways in which ethics and faith might promote sustainability and conservation.

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

– Wangari Maathai (1940–2011)

Winner of 2004 Nobel Peace Prize

CASE STUDY

Sustainable Development Goals for Kibera

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

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

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

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

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

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

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

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

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