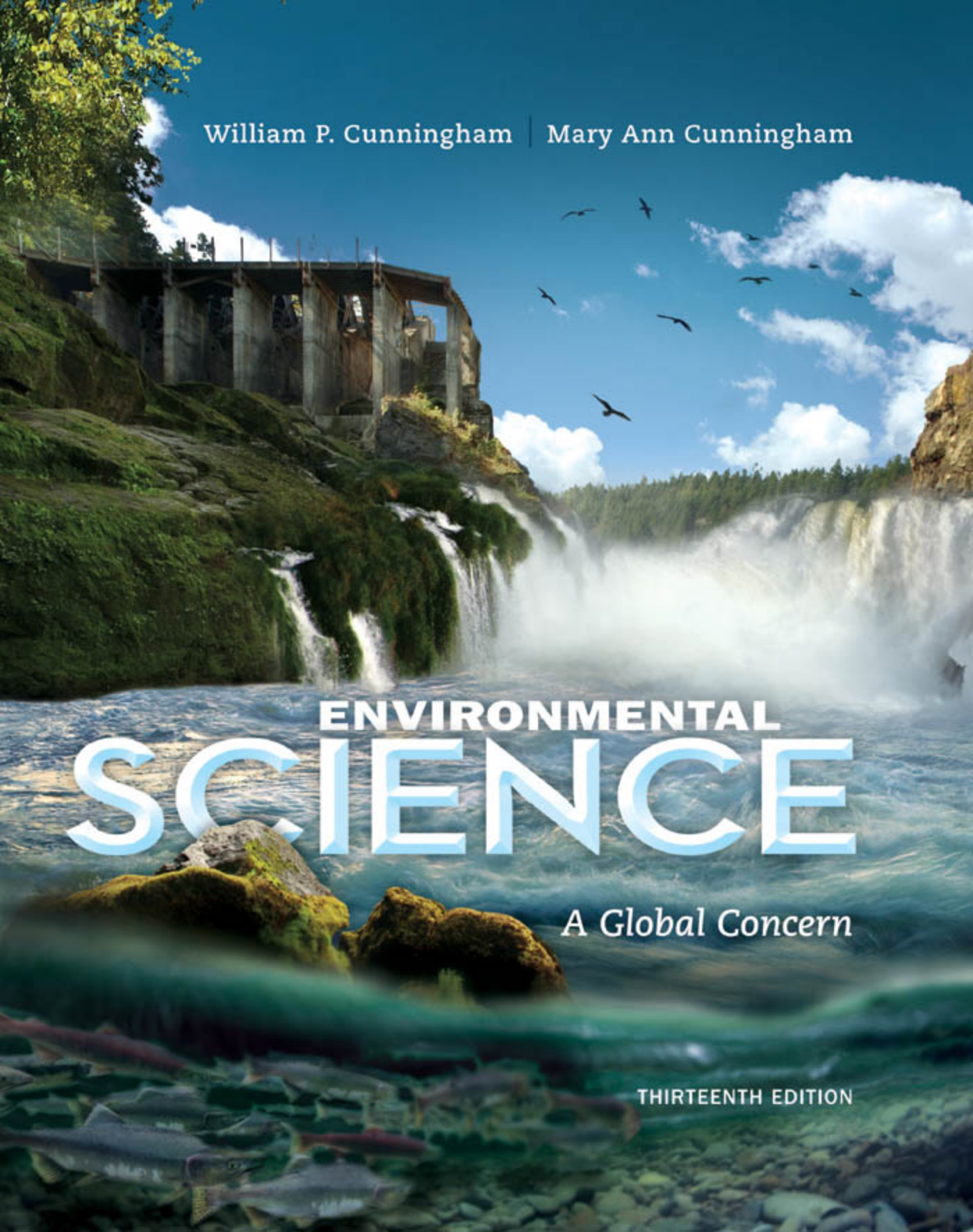
William P. Cunningham | Mary Ann Cunningham



ENVIRONMENTAL SCIENCE

A Global Concern

THIRTEENTH EDITION

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Environmental SCIENCE

A Global Concern

William P. Cunningham
University of Minnesota

Mary Ann Cunningham
Vassar College

Mc Graw Hill Education

ENVIRONMENTAL SCIENCE: A GLOBAL CONCERN, THIRTEENTH EDITION

1 2 3 4 5 6 7 8 9 0 DOW/DOW 1 0 9 8 7 6 5 4

ISBN 978–0–07–353254–7
MHID 0–07–353254–1

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Senior Content Licensing Specialist: *Lori Hancock*
Compositor: *Lachina Publishing Services*
Typeface: *10/12 Times LT Std*
Printer: *R. R. Donnelley*

Library of Congress Cataloging-in-Publication Data

Cunningham, William P.
Environmental science : a global concern / William P. Cunningham, University of Minnesota, Mary Ann Cunningham, Vassar College. – Thirteenth edition.
pages cm
Includes index.
ISBN 978–0–07–353254–7 — ISBN 0–07–353254–1 (hard copy : alk. paper) 1. Environmental sciences–Textbooks. I. Cunningham, Mary Ann. II. Title.
GE105.C86 2015
363.7–dc23

2013040969

www.mhhe.com

About the Authors

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

Mary Ann Cunningham is an associate professor of geography at Vassar College. A biogeographer with interests in landscape ecology, geographic information systems (GIS), and remote sensing, she teaches environmental science, natural resource conservation, and land-use planning, as well as GIS and remote sensing. Field research methods, statistical methods, and scientific methods in data analysis are regular components of her teaching. As a scientist and an educator, Mary Ann enjoys teaching and conducting research with both science students and nonscience 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 over a decade, and she has been coauthor of this book since its seventh edition. She is also coauthor of *Principles of Environmental Science* (now in its seventh edition) 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. With colleagues at Vassar she has published a GIS lab manual, *Exploring Environmental Science with GIS*, designed to provide students with an easy, inexpensive introduction to spatial and environmental analysis with GIS.

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

Professor Cunningham holds a bachelor's degree from Carleton College, a master's degree from the University of Oregon, and a Ph.D. from the University of Minnesota.

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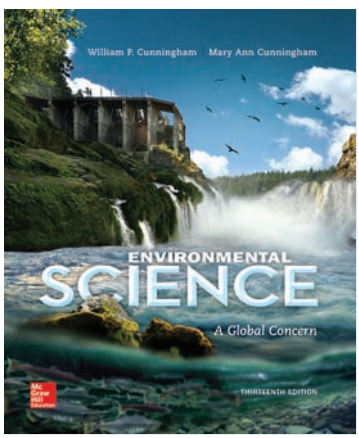
Preface

Environmental Science: a search for solution

The removal of a concrete dam on Washington State's Elwha River (front cover) represents a revolution in our imagination of how we can restore environmental systems. Nearly a century old, this was one of two dams built to power local lumber mills. But the dams destroyed migratory salmon runs and steelhead trout fisheries worth millions of dollars, disrupted the upland ecosystem, and devastated the traditional culture that depended on the fish and the river. As you can see on the cover of this book, the Elwha River dams have recently been removed, and the careful process of restoring the river, salmon migration, and the ecosystem has begun. (To read more see chapter 13, Restoration Ecology.)



New understanding of how ecosystems work has made this project a success. Better awareness of the economic and cultural value of healthy ecosystems has made this project possible. At the center of this revolution in thinking is the idea that we can restore ecosystems, and that ecosystem health benefits us all. This new commitment to stewardship of our environment, rather than simply bemoaning environmental damage, is one of the things that make environmental science an exciting field today.

Environmental science involves the systematic analysis of systems and how they function. The field is also concerned with the ways our policies and actions influence the systems on which we depend. We often follow shortsighted policies, degrading habitats and biodiversity or exploiting resources unsustainably, as in the case of dam building on the Elwha River. Better understanding of the multiple values of healthy ecosystems has led to the removal of this dam and many others. Here, as in many cases, an understanding of both policy and science was needed to discover a strategy for correcting past damages.

Your task, as you study environmental science, is to understand environmental systems and our dependence on them, and then to use that understanding to imagine new solutions to the environmental, social, or economic challenges we face today. As you read this book, you can discover many ways to engage with the issues and ideas involved in environmental science. 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.

We are surrounded by evidence of the progress we can make. Human population growth is slowing almost everywhere, as women's education and economic opportunity allow for small, well-cared-for families. New energy technologies now provide reliable alternatives to fossil fuels in many countries. Solar, wind, biomass, geothermal energy, and conservation could supply all the energy we need, if we chose to invest in them. 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. In the United States, there has been renewed respect for both science and the environment. Citizens and voters need to remain vigilant to protect the status of science in policy making, but experienced scientists have been appointed to government posts previously given to political appointees. Public support for environmental protection has been overwhelmingly enthusiastic. Grants and tax incentives, historically given to polluting industries, are now supporting more sustainable energy and millions of green jobs.

Businesses, too, recognize the opportunities in conservation, recycling, producing nontoxic 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. College and university students are finding new ways to organize, network, and take action to protect the environment they will inherit (see chapter 25).

Ecologist Norman Meyers has said, "The present has a unique position in history. Now, as never before, we have technical, political, and economic resources to solve our global environmental crisis. And if we don't do it now, it may be too late for future generations to do so." How might you develop your skills and interests to help in this project to make the world better.

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.

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** web site. **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 lecture, discussion 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?

New pedagogical features include key concepts and section reviews for each major section in a chapter, quantitative reasoning questions, and an exciting new art program that provides outstanding graphic explanation of ideas and issues. Data and concepts are updated throughout. This edition is closely tied to online resources in **Connect**, which support teaching, studying, and grading. Resources on Connect include figures, animations, movie clips, data analysis exercises, online quizzes, and course management software.

Specific changes to chapters

- **Learning to Learn** has a new boxed essay that explores critical reading of the news ("How Do You Tell the News from the Noise?"), as well as revised discussions of critical and analytical thinking strategies.
- **Chapter 1** includes an enhanced discussion of sustainable development, including principles such as managing common resources and accounting for ecosystem services. An updated case study highlights alternative energy in China. This chapter also emphasizes ways that all students, regardless of their interests, can use their particular skill sets to contribute to environmental problem solving.
- **Chapter 2** provides new figures that bring ecological cycles and relationships to life, as well as emphasizing processes of scientific investigation.
- **Chapter 3** includes an expanded discussion of the nitrogen cycle, with a table showing common forms of nitrogen, which reinforces both the opening case study and the data analysis exercise on the Chesapeake environmental report card. Enhanced discussions of material cycles also support subsequent chapters, such as agriculture and water pollution.
- **Chapter 4** has a new case study on Darwin's finches in the Galapagos Islands. This essay demonstrates the evidence for evolution and shows that evolution continues to be an important biological process today.
- **Chapter 5** has a new Exploring Science box that focuses on how to interpret climate graphs, in order to differentiate climate regions and biomes. A new Data Analysis exercise reinforces this theme with online climate graphs for different regions.
- **Chapter 6** begins with a revised case study on population biology of the overfished bluefin tuna. An Exploring Science reading continues this discussion by examining how we study population viability in a hard-to-study species like the bluefin.
- **Chapter 7** includes a new opening case study on Brazil's dramatic decline in fertility rates. Brazil and other developing areas are revolutionizing our understanding of the dynamics of global population growth. World demographic data have been updated to the latest available information. A new data analysis feature investigates population data with the revolutionary data visualization tools of GapMinder.org.
- **Chapter 8** opens with an updated case study on the dangers of bisphenol A (BPA). The discussion of global disease burden is updated to reflect recent successes in reducing major infectious diseases. Nearly all figures are new or revised.
- **Chapter 9** includes updated data on hunger, nutrition, and obesity. We explore why food costs are rising despite falling farm income, the economics of food production and agricultural subsidies, and why increases in food production, including innovations in genetically modified crops, often fail to address the problem of hunger——for example, 80 percent of U.S. corn is used for fuel and livestock feed, while soy is largely used for industrial oils.
- **Chapter 10** updates discussions of soil erosion, erosion control, soil characteristics, and irrigation. We have expanded the discussion of fertilizer use and overuse, including anhydrous ammonia. The discussion of pesticides includes neonicotinoid insecticides, recently banned in Europe because of concern over collapsing pollinator populations. New UN studies of sustainable techniques for improving global food production are discussed.
- **Chapter 11** has an added discussion on the importance of climate change in habitat loss, as well as mercury impacts on populations. New highlights address controversial invasive species challenges, including feral cats, rats, tamaris, and barred owls invading spotted owl habitat.
- **Chapter 12** provides two new Exploring Science boxes highlighting the ways indigenous peoples are using technology, such as satellite images and smart phones, to map and combat deforestation. The discussion of tropical deforestation is expanded to include new developments in forest losses from palm oil production, as well as recent pledges to stop some deforestation.
- **Chapter 13** has a new opening case study focusing on restoration of the Elwha River and its salmon, a landmark case in ecosystem restoration. The history, goals, and techniques of ecological restoration projects are reexamined in light of recent disasters as well as climate change.
- **Chapter 14** opens with a new case study on mountaintop removal mining. Revised discussions of basic earth processes give greater focus to production of earth resources, including oil and coal. New diagrams explain the origins of these two important resources. Discussions of resource extraction processes and environmental effects are updated, as are explanations of mass extinctions and earth hazards.
- **Chapter 15** has updated data and figures on climate processes, atmospheric circulation, and climate change, our most pressing global issue. New figures show processes and data. Reviews of climate accords and carbon trading also reflect recent events.
- **Chapter 16** includes new data on air pollution–related deaths in Beijing and other Chinese cities. This complements the opening case study on the London smog event of 1952, which helped lead to modern air pollution controls. In addition to discussions of new pollutants, including CO_2 and

halogens, we present updated findings on economic benefits of the Clean Air Act.

- **Chapter 17** discusses Australian adaptation to the most serious drought in a millennium, in a new What Do You Think? essay. Data and discussions of water resources and North American drought conditions are updated.
- **Chapter 18** highlights new developments in water pollution, including growing nutrient contamination from midwestern agriculture (in opening case study); chemical contaminants of emerging concern, such as the antimicrobial agent triclosan; the challenges of bottled water; and improvements in clean water access in China and India. A new Exploring Science box examines inexpensive water purification strategies that now provide clean water to millions in the developing world.
- **Chapter 19** opens with a new case study on an Arkansas oil pipeline spill and its implications for shipment of Canadian tar sands oil. Throughout the chapter, new figures and text update the discussion of energy resources, including the relative efficiency of different sources and new questions about coal consumption, increases in U.S. oil production, questions about the economics of nuclear power, and the implications of new and alternative oil and gas reserves (fracking) for energy policy.
- **Chapter 20** has updated discussions of energy conservation and sustainable energy options for individuals, including passive and zero-energy houses and plug-in hybrid vehicles. We report on rapidly falling prices for solar energy and increasing production, as well as policy alternatives regarding these energy sources. We examine arguments about how renewable energy could supply all our energy if we invested in them now.
- **Chapter 21** includes expanded discussion of current waste management alternatives, including questions of incineration and biogas (methane) production. Waste reduction, reuse, and recycling are emphasized. Challenges in managing and funding hazardous waste cleanup, including Superfund projects, are also updated.
- **Chapter 22** provides updated figures and data on trends in urbanization, one of the most dramatic changes of our time, with some of the most widespread environmental impacts and opportunities.
- **Chapter 23** provides an updated discussion of scarcity, management of common property, and cost externalization. The chapter also has expanded discussions of ecological economics, including ecosystem services and accounting for natural capital.
- **Chapter 24** includes a number of pedagogical updates regarding environmental policy, as well as updated figures.
- **Chapter 25** concludes the book with expanded discussions of what students can do to address challenges and issues in environmental science. A new What Do You Think? reading discusses college divestment from fossil fuel–producing corporations, a movement that has raised new questions for universities, colleges, and cities. A new focus on environmental citizenship complements a revised examination of green consumerism.

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 Michelle Vogler and Jodi Rhomberg. We are grateful to the excellent production team led by Vicki Krug and marketing leadership by Matthew Garcia. We thank Wendy Nelson for copyediting and LouAnn Wilson for excellent work on photographs.

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

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University of North Carolina at Chapel Hill, Trent McDowell
University of Wisconsin, Milwaukee, Tristan J. Kloss

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*, thirteenth 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
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McGraw-Hill's ConnectPlus™

McGraw-Hill's Connect Plus (www.mcgrawhillconnect.com) is a web-based assignment and assessment platform that gives students the means to better connect with their coursework, with their instructors, and with the important concepts that they will need to know for success now and in the future. The following resources are available in Connect:

- Auto-graded assessments
- LearnSmart, an adaptive diagnostic and learning tool
- SmartBook, an adaptive reading experience
- Powerful reporting against learning outcomes and level of difficulty
- The full textbook as an integrated, dynamic eBook, which instructors can also assign
- Data Analysis exercises to improve critical-thinking skills
- Base Map and Google Earth exercises
- An extensive Case Studies Library
- McGraw-Hill Tegrity Campus, which digitally records and distributes your lectures with a click of a button
- Instructor resources, such as an instructor's manual, PowerPoints and test banks.

With ConnectPlus, instructors can deliver assignments, quizzes, and tests online. Instructors can edit existing questions and author entirely new problems; track individual student performance—by question, by assignment; or in relation to the class overall—with detailed grade reports; integrate grade reports easily with Learning Management Systems (LMS), such as WebCT and Blackboard; and much more.

By choosing Connect, instructors are providing their students with a powerful tool for improving academic performance and truly mastering course material. Connect allows students to practice important skills at their own pace and on their own schedule. Importantly, students' assessment results and instructors' feedback are all saved online, so students can continually review their progress and plot their course to success.

LearnSmart™

No two students are alike. Why should their learning paths be? LearnSmart uses revolutionary adaptive technology to build a learning experience unique to each student's individual needs. It starts by identifying the topics a student knows and does not know. As the student progresses, LearnSmart adapts and adjusts the content based on his or her individual strengths, weaknesses, and confidence, ensuring that every minute spent studying with LearnSmart is the most efficient and productive study time possible.

LearnSmart also takes into account that everyone will forget a certain amount of material. LearnSmart pinpoints areas that a student is most likely to forget and encourages periodic review to ensure that the knowledge is truly learned and retained. In this way, LearnSmart goes beyond simply getting students to memorize material—it helps them truly retain the material in their long-term memory. Want proof? Students who use LearnSmart are 35 percent more likely to complete their class, are 13 percent more likely to pass their class, and improve their performance by a full letter grade. To learn more, log on to http://learnsmartadvantage.com.

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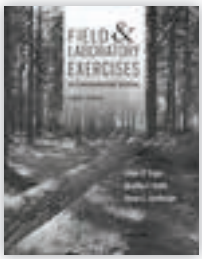
Additional Materials in Environmental Science

Students of environmental science and other disciplines, as well as the general reader, will find these unique guides invaluable to their understanding of current world countries and events.

Field and Laboratory Exercises in Environmental Science, Eighth Edition, by Enger, Smith, and Lionberger, 978-0-07-759982-9

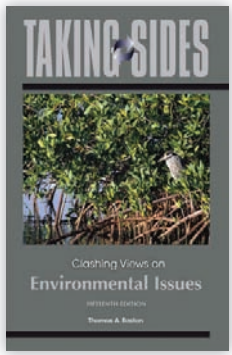


The major objectives of this manual are to provide students with hands-on experiences that are relevant, easy to understand, applicable to the student's life, and presented in an interesting, informative format. Ranging from field and lab experiments to social and personal assessments of the environmental impact of human activities, this manual presents something for everyone, regardless of the budget or facilities of each class. These labs are grouped by categories that can be used in conjunction with any introductory environmental textbook.

Annual Editions: Environment, by Richard Eathorne, 978-0-07-351562-5

Revised annually for more than 32 years, this text provides convenient, inexpensive access to current articles selected from some of the most respected magazines, newspapers, and journals published today. Instructional features include an annotated table of contents, a correlation guide to main textbooks, a topic guide for all articles, Internet references by unit for additional research, learning outcomes, and critical-thinking questions. An instructor resource guide with test materials is available for download, as well as a practical guide for *Using Annual Editions in the Classroom*.

Taking Sides: Clashing Views on Environmental Issues by Tom Easton; 978-0-07-351451-2



Revised bi-annually for more than 30 years, this text is a debate-style reader designed to introduce students to controversies in environmental policy and science. The readings present arguments by leaders in the field and have been selected for their liveliness and substance. Instructional features include an annotated table of contents, a correlation guide to main textbooks, a topic guide for all articles, Internet references by unit, learning outcomes, critical-thinking questions, and "Is There Common Ground?" questions to guide further research. An instructor resource guide with test materials is available for download, as well as a practical guide for *Using Taking Sides in the Classroom*.

Classic Edition Sources: Environmental Studies, by Tom Easton; 978-0-07-352764-2

This collection brings together more than 40 selections of enduring intellectual value—classic articles, reviews, book excerpts, and research studies—that help define the study of the environment and our current understanding of it. These readings represent almost 150 years of ecological thought and application, with dates of publication rang-

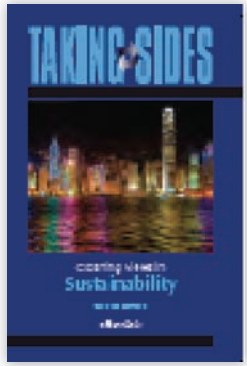
ing from 1864 to the present. Instructional features include an annotated table of contents, a correlation guide to main textbooks, a topic guide for all articles, Internet references by unit to facilitate further research. An instructor resource guide with test materials is available for download.

Annual Editions: Sustainability by Nicholas Smith-Sebasto, 978-0-07-352869-4

This new addition to the *Annual Editions* series provides carefully selected articles from the most respected magazines, newspapers, and journals published today. This volume contains interesting, well-illustrated readings by environmentalists, educators, researchers, scientists, and writers that provide perspective on the emerging field of sustainability. Instructional features include an annotated table of contents, a correlation guide to main textbooks, a topic guide for all articles, internet references by unit for additional research, learning outcomes, and critical thinking questions. An instructor resource guide with test materials is available for download as well as a practical guide for *Using Annual Editions in the Classroom*.

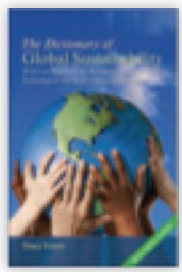
Taking Sides: Sustainability by Robert Taylor, 978-0-07-351453-6

This new addition to the *Taking Sides* series introduces students to controversies in the emerging field of sustainability. The text



presents arguments by policy analysts, scientists, economists, and environmentalists that have been selected for their liveliness and substance. Instructional features include: an annotated table of contents, a correlation guide to main textbooks, a topic guide for all articles, internet references by unit, learning outcomes, critical thinking questions, and "Is There Common Ground?" questions to guide further research. An Instructor Resource Guide with test materials is available for download as well as a practical guide for *Using Taking Sides in the Classroom*.

The Dictionary of Global Sustainability by Tracy Green, 978-0-07-351452-9



This textbook serves as a quick reference guide to students and professionals seeking a better understanding of sustainability concepts. The volume provides nearly 2,800 key terms in this emerging field, as well as a listing of organizations and scholarly and trade journals—domestic and international—that will lead the reader to valuable research materials. It includes case studies that examine sustainability projects from around the world designed to illustrate the theory and practice of environmental, economic, technological, and social aspects of sustainability.

Guided Tour

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

Restoration of the Elwha River and Its Salmon

Rising high in the mountains of Olympic National Park, the Elwha River cascades 72 km (45 miles) down to the Strait of Juan de Fuca. For centuries, prodigious runs of six species of Pacific salmon and steelhead supported the culture and livelihood of the indigenous S'Klallam Nation. In 1910, despite tribal protests, the 33-m tall (108 ft) lower Elwha dam was built to provide electricity for local lumber mills, and 14 years later another dam, twice as high, was added at Glines Canyon, 15 km (9 miles) upstream. Because either dam had a fish ladder to allow salmon to pass, these structures closed off the entire upstream spawning ground to migratory fish. Annual runs that once included more than 400,000 fish—with some individual king salmon larger than 45 kg (100 pounds)—were reduced to just a few thousand fish clustered in the lower 8 km (5 mi) of the river. A fishery once valued at $10 million per year was largely eliminated.

Impounding the river didn't just affect fish and the humans dependent on them. The entire ecosystem was diminished. Research shows that decomposing salmon carcasses provide essential nutrients for the entire aquatic and riparian systems. As much as half the forest biomass was dependent on nutrients brought in by the fish. Furthermore, the dams stopped sediment movement down the river. This starved beaches and enhanced coastal erosion. The Army Corps of Engineers has spent hundreds of millions of dollars every year to protect beaches and local harbors from erosion.

In 1968 the S'Klallam tribe and several environmental groups opposed relicensing of the dams, citing salmon losses, environmental damage, flooding of sacred tribal sites, and safety concerns about the aging structures. Furthermore, they pointed out, the dams were located within the Olympic National Park, where it's illegal to have commercial hydroelectric projects. Congressional hearings and debates dragged on for the next 24 years, but in 1992 Congress passed a law, which President George W. Bush signed, appropriating $325 million for removal of the dams and restoration of the river to suitable salmon habitat.

Still another two decades passed before deconstruction of the Elwha dam began, in 2011. A year later demolition started at the higher Glines Canyon Dam. But how do you safely remove such large dams without releasing catastrophic mudslides from the 34 million m^3 of soft sediments stored behind them? These are the largest dams ever removed in the United States and an important test of our ability to restore damaged river ecosystems.

The lower Elwha was structurally unsound due to age and defective construction. It wasn't safe to simply blow it up, so a diversion channel was dug around the dam to lower water levels in the reservoir behind it. Once all the water was drained away, controlled blasting destroyed the dam. The higher Glines Canyon dam was more stable, so jackhammers and diamond saws operating from a floating barge on the upstream side gradually removed large concrete chunks, which were lifted by cranes to trucks waiting above the dam. Final demolition of both dams was completed in 2013.

The big job of restoring the river valley to its original condition still remained. Ecologists worried that high banks of soft sediment could still slump into the river and bury gravel streambeds critical for spawning habitat. To control sediment and aid restoration of streamside vegetation, Park Service employees collected and saved native seeds to revegetate and stabilize the old lakebed and stream banks. Fortunately, ground cover established quickly, and stream bank erosion was far less than had been feared. Invasion by non-native plants also was minimal.

But can we bring back the once fabulous migratory salmon runs? Biologists are hopeful. Before the dams were removed, they captured native Elwha River fish, to be kept in hatcheries and nearby streams until they could be reintroduced into the river. Because the many small feeder streams that provide habitat for juvenile salmon are mostly within the National Park, they're already in good condition. Within a few months following removal of the dams, some wild salmon made their way up the turbid river and spawned. Once restocking with hatchery fish has been completed, it's hoped that salmon runs will once again be restored to the 400,000 fish that once migrated up the river.

Restoration ecology is a new, exciting, and experimental field that applies ecological principles to healing natural systems like the Elwha River. Full restoration of an entire ecosystem is a staggering task, but even small steps can make a remarkable difference. And we're finding that nature can be more resilient and robust than we might imagine. In this chapter, we'll examine a number of other cases in which people are working to repair damage and rehabilitate, remediate, or restore ecosystems.

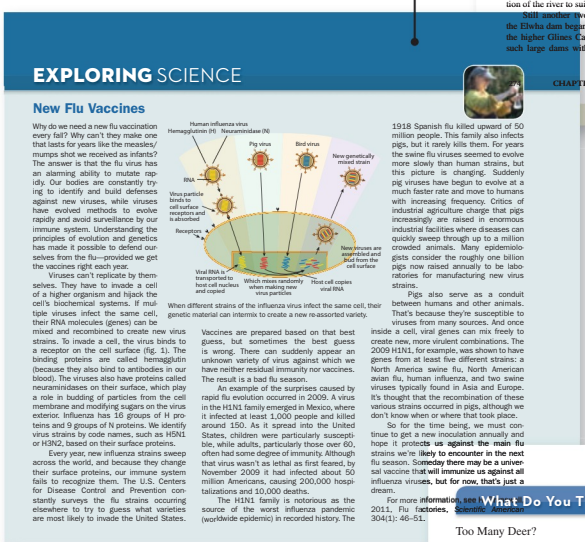
FIGURE 13.1 After dam demolition in 2013, the Elwha River rushes through its canyon. Restoration of the entire ecosystem remains a challenge, but salmon are already returning to the river.

CHAPTER 13 Restoration Ecology

http://www.mhhe.com/cunningham13e

Exploring Science

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



EXPLORING SCIENCE

New Flu Vaccines

Why do we need a new flu vaccination every fall? Why can't they make one that lasts for years like the measles/mumps shot we received as infants? The answer is that the flu virus has an alarming ability to mutate rapidly. Our bodies are constantly trying to identify and build defenses against new viruses, while viruses have evolved methods to evolve rapidly and avoid surveillance by our immune system. Understanding the principles of evolution and genetics has made it possible to defend ourselves from the flu—provided we get the vaccines right each year.

Viruses can't replicate by themselves. They have to invade a cell of a higher organism and hijack the cell's biochemical systems. If multiple viruses infect the same cell, their RNA molecules (genes) can be mixed and recombined to create new virus strains. To invade a cell, the virus binds to a receptor on the cell surface (fig. 1). The binding proteins are called hemagglutin (because they also bind to antibodies in our blood). The viruses also have proteins called neuraminidases on their surface, which play a role in budding of particles from the cell membrane and modifying sugars on the virus exterior. Influenza has 16 groups of H proteins and 9 groups of N proteins. We identify virus strains by code names, such as H5N1 or H3N2, based on their surface proteins.

Every year, new influenza strains sweep across the world, and because they change their surface proteins, our immune system fails to recognize them. The U.S. Centers for Disease Control and Prevention constantly surveys the flu strains occurring elsewhere to try to guess what varieties are most likely to invade the United States.

When different strains of the influenza virus infect the same cell, their genetic material can intermix to create a new re-assorted variety.

Vaccines are prepared based on that best guess, but sometimes the best guess is wrong. There can suddenly appear an unknown variety of virus against which we have neither residual immunity nor vaccines. The result is a bad flu season.

An example of the surprises caused by rapid flu evolution occurred in 2009. A virus in the H1N1 family emerged in Mexico, where it infected at least 1,000 people and killed around 150. As it spread into the United States, children were particularly susceptible, while adults, particularly those over 60, often had some degree of immunity. Although that virus wasn't as lethal as first feared, by November 2009 it had infected about 50 million Americans, causing 200,000 hospitalizations and 10,000 deaths.

The H1N1 family is notorious as the source of the worst influenza pandemic (worldwide epidemic) in recorded history. The 1918 Spanish flu killed upward of 50 million people. This family also infects pigs, but it rarely kills them. For years the swine flu viruses seemed to evolve more slowly than human strains, but this picture is changing. Suddenly pig viruses have begun to evolve at a much faster rate and move to humans with increasing frequency. Critics of industrial agriculture charge that pigs increasingly are raised in enormous industrial facilities where diseases can quickly sweep through up to a million crowded animals. Many epidemiologists consider the roughly one billion pigs now raised annually to be laboratories for manufacturing new virus strains.

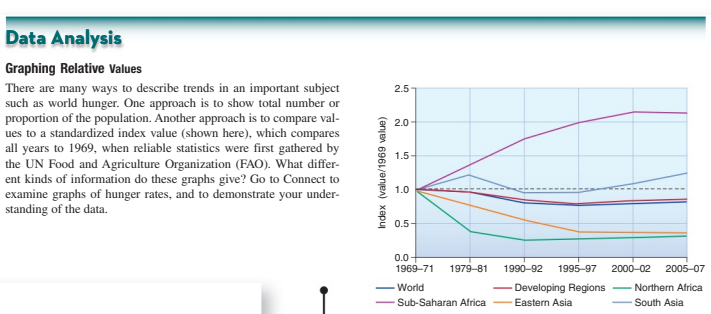
Pigs also serve as a conduit between humans and other animals. That's because they're susceptible to viruses from many sources. And once inside a cell, viral genes can mix freely to create new, more virulent combinations. The 2009 H1N1, for example, was shown to have genes from at least five different strains: a North America swine flu, North American avian flu, human influenza, and two swine viruses typically found in Asia and Europe. It's thought that the recombination of these various strains occurred in pigs, although we don't know when or where that took place.

So for the time being, we must continue to get a new inoculation annually and hope it protects us against the main flu strains we're likely to encounter in the next flu season. Someday there may be a universal vaccine that will immunize us against all influenza viruses, but for now, that's just a dream.

For more information, see Scientific American, 2011, Flu factories, 304(1): 46–51.

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

Graphing Relative Values

There are many ways to describe trends in an important subject such as world hunger. One approach is to show total number or proportion of the population. Another approach is to compare values to a standardized index value (shown here), which compares all years to 1969, when reliable statistics were first gathered by the UN Food and Agriculture Organization (FAO). What different kinds of information do these graphs give? Go to Connect to examine graphs of hunger rates, and to demonstrate your understanding of the data.

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 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 (518/km^2). 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. Other species are diminished as well. Many small mammals and ground-dwelling birds begin to disappear when deer populations reach 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. Every year some 40,000 collisions with motor vehicles cause $80 million in property damage. 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. Disputes arise between those who love to watch deer and their neighbors who want to exterminate them all.

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, 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 often die after relocation.

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.

If you were a wildlife biologist charged with managing the deer herd in your state, 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?

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

Learning Outcomes

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

Learning Outcomes

After studying this chapter, you should be able to:

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

Section Reviews

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

Section Review

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

Conclusion

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

Conclusion

The potential location of biological communities is determined in large part by climate, moisture availability, soil type, geomorphology, and other natural features. Understanding the global distribution of biomes, and knowing the differences in who lives where and why, are essential to the study of global environmental science. Human occupation and use of natural resources are strongly dependent on the biomes found in particular locations. We tend to prefer mild climates and the highly productive biological communities found in temperate zones. These biomes also
and overuse.
characteristics that allow
h as seasonal tropical for-
ognizing these adaptations
or survival in those biomes.

Oceans cover over 70 percent of the earth's surface, yet we know relatively little about them. Some marine biomes, such as coral reefs, can be as biologically diverse and productive as any terrestrial biome. 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. Still, it is possible for us to protect these living communities. The opening case study of this chapter illustrates how people can work together to protect and even restore the biological communities on which they depend. Perhaps we can find similar solutions in other biologically rich but endangered biomes.

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 buy shade-grown, fair-trade coffee and cocoa. How much of a premium would you pay for these products? What factors would influence how much you would pay?
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 habitat. 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

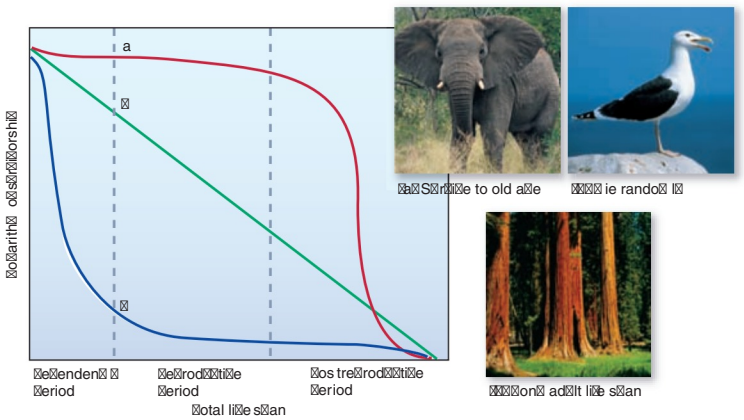
Compare the "hot spot" map in figure 11.4 with the biomes map in figure 5.2 on p. 101. Which of the "hot spots" has the largest number of endemic species? Which has the least? Can you detect any patterns when you compare these two maps?

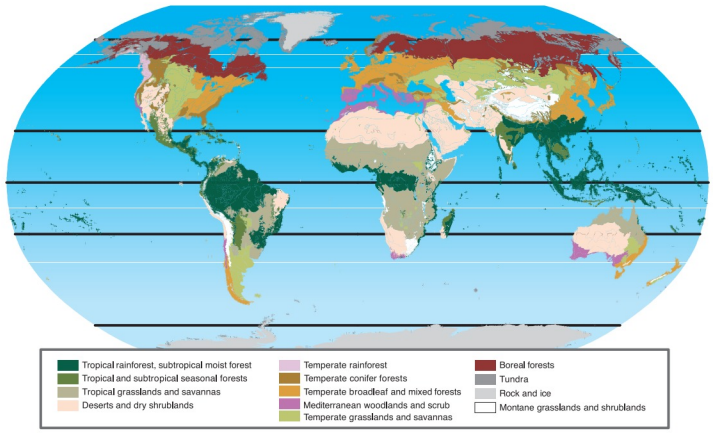
Quantitative Reasoning

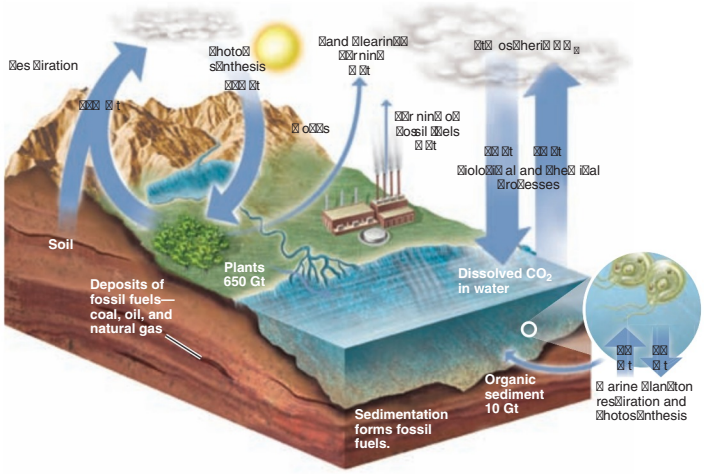
Quantitative reasoning questions in the text push students to evaluate data and graphs they have read about. Attention to statistics, graphing, graph interpretation, and abundant up-to-date data are some of the resources available to help students practice their skills with data interpretation.

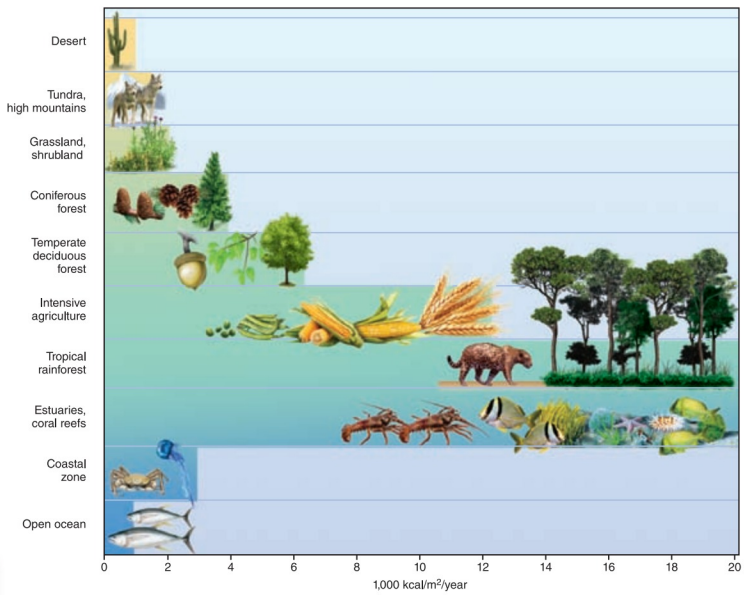
Relevant Photos and Instructional Art Support Learning

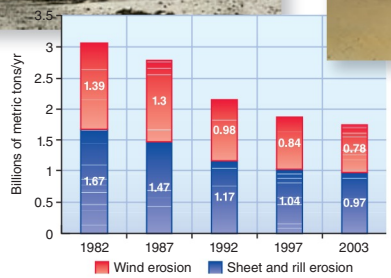
High-quality photos and realistic illustrations display detailed diagrams, graphs, and real-life situations.











Introduction
Learning to Learn

▲Learning to learn is a lifelong skill.

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 Honestly assess the strengths and weaknesses of your current study skills.

L.3 Be prepared to apply critical and reflective thinking in environmental science.

L.4 Avoid logical errors and fallacies.

"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

Why Study Environmental Science?

Welcome to environmental science. We hope you'll enjoy learning about the material presented in this book, and that you'll find it both engaging and useful. There should be something here for just about everyone, whether your interests are in basic ecology, natural resources, or the broader human condition. You'll see, as you go through the book, that it covers a wide range of topics. It defines our environment, not only the natural world, but also the built world of technology, cities, and machines, 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.

You'll find that many issues discussed here are part of current news stories on television or in newspapers. Becoming an educated environmental citizen will give you a toolkit of skills and attitudes that will help you understand current events and be a more interesting person. Because this book contains information from so many different disciplines, you will find connections here with many of your other classes. Seeing material in an environmental context may assist you in mastering subject matter in many courses, as well as in life after you leave school.

FIGURE L.1 What does it all mean? Studying environmental science gives you an opportunity to develop creative, reflective, and critical thinking skills.

One of the most useful skills you can learn in any of your classes is critical thinking—a principal topic of this chapter. Much of the most important information in environmental science is highly contested. Facts vary depending on when and by whom they were gathered. For every opinion there is an equal and opposite opinion. How can you make sense out of this welter of ever-changing information? The answer is that you need to develop a 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.

There is much to be worried about in our global environment. Evidence is growing relentlessly that we are degrading our environment and consuming resources at unsustainable rates. Biodiversity is disappearing at a pace unequaled since the end of the age of dinosaurs 65 million years ago. Irreplaceable topsoil erodes from farm fields, threatening global food supplies. Ancient forests are being destroyed to make newsprint and toilet paper. Rivers and lakes are polluted with untreated sewage, while soot and smoke obscure our skies. Even our global climate seems to be changing to a new regime that could have catastrophic consequences.

At the same time, we have better tools and knowledge than any previous generation to do something about these crises. Worldwide public awareness of—and support for—environmental protection is at an all-time high. Over the past 50 years, human ingenuity and enterprise have brought about a breathtaking pace of technological innovations and scientific breakthroughs. We have learned to produce more goods and services with less material. The breathtaking spread of communication technology makes it possible to share information worldwide nearly instantaneously. Since World War II, the average real income in developing countries has doubled; malnutrition has declined by almost one-third; child death rates have been halved; average life expectancy has increased by 30 percent; and the percentage of rural families with access to safe drinking water has risen from less than 10 percent to almost 75 percent.

The world's gross domestic product has increased more than tenfold over the past five decades, but the gap between the rich and poor has grown ever wider. More than a billion people now live in abject poverty without access to adequate food, shelter, medical care, education, and other resources required for a healthy, secure life. The challenge for us is to spread the benefits of our technological and economic progress more equably and to find ways to live sustainably over the long run without diminishing the natural resources and vital ecological services on which all life depends. We've tried to strike a balance in this book between enough doom and gloom to give you a realistic view of our problems, and enough positive examples to give hope that we can discover workable solutions.

What would it mean to become a responsible environmental citizen? What rights and privileges do you enjoy as a member of the global community? What duties and responsibilities earn us the rights and privileges of citizenship? In many chapters of this book you will find practical advice on things you can do to conserve resources and decrease adverse environmental impacts. Ethical perspectives are an important part of our relationship to the environment and the other people with whom we share it. The discussion of ethical principles and worldviews in chapter 2 is a key section of this book. We hope you'll think about the ethics of how we treat our common environment.

Clearly, to become responsible and productive environmental citizens, each of us needs a basis in 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."

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 have I gotten myself into?" you are probably wondering as you begin to read this book. "Will environmental science be worth my while? Do I have a chance to get a good grade?" The answers to these questions depend, to a large extent, on you and how you decide to apply yourself. Expecting to be interested and to do either well or poorly in your classes often turns out to be a self-fulfilling prophecy. As Henry Ford once said, "If you think you can do a thing, or think you can't do a thing, you're right." Cultivating good study skills can help you to reach your goals and make your experience in environmental science a satisfying and rewarding one. The purpose of this introduction is to give you some tips to help you get off to a good start in studying. You'll find that many of these techniques are also useful in other courses and after you graduate, as well.

Another thing 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. You might be someone who loves science, but many people consider science unfamiliar and intimidating. To do well in this class, it will help to identify the ways that science connects with your interests and with the things you like to do. 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.

Most people think science is the domain of specialists in lab coats. But in fact science is practiced by all kinds of people in all kinds of ways, every day, including you. Basically, science is just about trying to figure out how things work. Understanding some basic ideas in science can be very empowering: learning to look for evidence and to question your assumptions is a life skill; 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. A lot of people think science is foreign, but it belongs to all of us, and this book is about helping you see how a better understanding of science can make the world more understandable and interesting for you.

Environmental science, as you can see by skimming through the table of contents of this book, is a complex, transdisciplinary field that draws from many academic specialties. It is loaded with facts, ideas, theories, and confusing data. It is also a dynamic, highly contested subject. Topics such as environmental contributions to cancer rates, potential dangers of pesticides, or when and how much global warming may be caused by human activities are widely disputed. Often you will find distinguished and persuasive experts who take completely opposite positions on any particular question. It will take an active, organized approach on your part to make sense of the arguments and ideas you'll encounter here. And it will take critical, thoughtful reasoning to formulate your own position on the many controversial theories and ideas in environmental science. Learning to learn will help you keep up-to-date on important issues after you leave this course. Becoming educated voters and consumers is essential for a sustainable future.

Develop good study habits

Many students find themselves unprepared for studying in college. In a survey released a decade ago by the Higher Education Research Institute, more than two-thirds of high school seniors nationwide reported studying outside of class less than one hour per day. Nevertheless, because of grade inflation, nearly half those students claim to have an A average. It comes as a rude shock to many to discover that the study habits they developed in high school won't allow them to do as well—or perhaps even to pass their classes—in college. Many will have to triple or even quadruple their study time. In addition, they need urgently to learn to study more efficiently and effectively.

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. Answer the questions in table L.1 as a way of assessing where you are as you begin to study environmental science and where you need to work to improve your study habits.

One of the first requirements for success is to set clear, honest, attainable goals for yourself. Are you willing to commit the time and effort necessary to do well in this class? Make goals for yourself in terms that you can measure and in time frames within which you can see progress, and adjust your approach if it isn't taking you where you want to go. Be positive but realistic. It's more effective to try to accomplish a positive action than to avoid a negative one. When you set your goals, use proactive language that states what you want rather than negative language about what you're trying to avoid. It's good to be optimistic, but setting impossibly high standards will only lead to disappointment. Be objective about the obstacles you face and be willing to modify your goals if necessary. As you gain more experience and information, you may need to adjust your expectations either up or down. Take stock from time to time to see whether you are on track to accomplish what you expect from your studies. In environmental planning, this is called adaptive management.

One of the most common mistakes many of us make is to procrastinate and waste time. Be honest, are you habitually late for meetings or in getting assignments done? Do you routinely leave your studying until the last minute and then frantically cram the

Table L.1 Assess Your Study Skills
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 strong is your commitment to be successful in this class?
_____ How well do you manage your time (e.g., do you always run late or do you complete assignments on time)?
_____ Do you have a regular study environment that reduces distraction and encourages concentration?
_____ How effective are you at reading and note-taking (e.g., do you remember what you've read; can you decipher your notes after you've made them)?
_____ Do you attend class regularly and listen for instructions and important ideas? Do you participate actively in class discussions and ask meaningful questions?
_____ Do you generally read assigned chapters in the textbook before attending class or do you wait until the night before the exam?
_____ Are you usually prepared before class with questions about material that needs clarification or that expresses your own interest in the subject matter?
_____ How do you handle test anxiety (e.g., 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?

night before your exams? If so, you need to organize your schedule so that you can get your work done and still have a life. Make a study schedule for yourself and stick to it. Allow enough time for sleep, regular meals, exercise, and recreation so that you will be rested, healthy, and efficient when you do study. Schedule regular study times between your classes and work. Plan some study times during the day when you are fresh; don't leave all your work until late night hours when you don't get much done. Divide your work into reasonable sized segments that you can accomplish on a daily basis. Plan to have all your reading and assignments completed several days before your exams so you will have adequate time to review and process information. Carry a calendar so you will remember appointments and assignments.

Establish a regular study space in which you can be effective and productive. It might be a desk in your room, a carrel in the library, or some other quiet, private environment. Find a place that works for you and be disciplined about sticking to what you need to do. If you get in the habit of studying in a particular place and time, you will find it easier to get started and to stick to your tasks. Many students make the mistake of thinking that they can study while talking to their friends or watching TV. They may put in many hours but not really accomplish much. On the other hand, some people think most clearly in the anonymity of a crowd. The famous philosopher Immanuel Kant found that he could think best while wandering through the noisy, crowded streets of Königsberg, his home town.

How you behave in class and interact with your instructor can have a big impact on how much you learn and what grade you get. Make an effort to get to know your instructor. She or he is probably not nearly as formidable as you might think. Sit near the front of the room where you can see and be seen. Pay attention and ask questions that show your interest in the subject matter. Practice the skills of good note-taking (table L.2). 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. If you think of yourself as a good student and act like one, you may well get the benefit of the doubt when your grade is assigned.

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.2). You will get a valuable perspective on whether you're getting the main points and understanding an adequate amount by

Table L.2 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.*

FIGURE L.2 Cooperative learning, in which you take turns explaining ideas and approaches with a friend, can be one of the best ways to comprehend material.

comparing. It's an old adage 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.

Recognize and hone your learning styles

Each of us has ways that we learn most effectively. Discovering techniques that work for you and fit the material you need to learn is an important step in reaching your goals. Do any of the following fit your preferred ways of learning?

- **Visual Learner:** understands and remembers best by reading, looking at photographs, figures, and diagrams. Good with maps and picture puzzles. Visualizes image or spatial location for recall. Uses flash cards for memorization.
- **Verbal Learner:** understands and remembers best by listening to lectures, reading out loud, and talking things through with a study partner. May like poetry and word games. Memorizes by repeating item verbally.
- **Logical Learner:** understands and remembers best by thinking through a subject and finding reasons that make sense. Good at logical puzzles and mysteries. May prefer to find patterns and logical connections between items rather than memorize.
- **Active Learner:** understands and remembers best those ideas and skills linked to physical activity. Takes notes, makes lists, uses cognitive maps. Good at working with hands and learning by doing. Remembers best by writing, drawing, or physically manipulating items.

The list in Table L2 represents only a few of the learning styles identified by educational psychologists. How can you determine which approaches are right for you? Think about the one thing in life that you most enjoy and in which you have the greatest skills. What hobbies or special interests do you have? How do you learn new material in that area? Do you read about a procedure in a book and then do it, or do you throw away the manual and use trial and error to figure out how things work? Do you need to see a diagram or a picture before things make sense, or are spoken directions most memorable and meaningful for you? Some people like to learn by themselves in a quiet place where there are no distractions, while others need to discuss ideas with another person to feel really comfortable about what they're learning.

Sometimes you have to adjust your preferred learning style to the specific material you're trying to master. You may be primarily a verbal learner, but if what you need to remember for a particular subject is spatial or structural, you may need to try some visual learning techniques. Memorizing vocabulary items might be best accomplished by oral repetition, while developing your ability to work quantitative problems should be approached by practicing analytical or logical skills.

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? Does the evidence presented adequately 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? What additional information would you need in order to make an informed judgment about this subject, and how might you go about obtaining that information or making that judgment?

A study technique developed by Frances Robinson and called the SQ3R method (table L.3) can be a valuable aid in improving your reading comprehension. Start your study session with a *survey* of the entire chapter or section you are about to read so you'll have an idea of how the whole thing fits together. What are the major headings and subdivisions? Notice that there is usually a hierarchical organization that gives you clues about the relationship between the various parts. This survey will help you plan your strategy for approaching the material. Next, *question* what the main points are likely to be in each of the sections. Which parts look most important or interesting? Ask yourself where you should invest the most time and effort. Is one section or topic likely to be more relevant to your particular class? Has your instructor emphasized any of the topics you see? Being alert for important material can help you plan the most efficient way to study. The key terms at the beginning of each major section will give you clues to the most important messages in that section.

After developing a general plan, begin active reading of the text. Read in small segments and stop frequently for reflection and to make notes. Don't fall into a trance in which the words

Table L.3 The SQ3R Method for Studying Texts
Survey
Preview the information to be studied before reading.
Question
Ask yourself critical questions about the content of what you are reading.
Read
Conduct the actual reading in small segments.
Recite
Stop periodically to recite to yourself what you have just read.
Review
Once you have completed the section, review the main points to make sure you remember them clearly.

swim by without leaving any impression. Highlight or underline the main points, but be careful that you don't just paint the whole page yellow. If you highlight too much, nothing will stand out. Try to distinguish what is truly central to the argument being presented. Make brief notes in the margins that identify main points. This can be very helpful in finding important sections or ideas when you are reviewing. 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? Does this relate to my own personal experiences or previous knowledge? Are there details or ideas that need clarification or elaboration?

As you read, stop periodically to *recite* the information you've just acquired. Summarize the information in your own words to be sure that you really understand and are not just depending on rote memory. This is a good time to have a study group (fig. L.3). Taking turns to summarize and explain material really helps you internalize it. If you don't have a study group and you feel awkward talking to yourself, you can try writing your summary. Finally, *review* the section. Did you miss any important points? Do you understand things differently the second time through? This is a chance to think critically about the material. Do you agree with the conclusions suggested by the authors? Can you think of alternative explanations for the same evidence? As you review each section, think about how this may be covered on the test. Put yourself in the position of the instructor. What would be some good questions based on this material? Don't try to memorize everything but try to anticipate what might be the most important points.

After class, compare your lecture notes with your study notes. Do they agree? If not, where are the discrepancies? Is it possible that you misunderstood what was said in class, or does your instructor differ with what's printed in the textbook? Are there things that your instructor emphasized in lecture that you missed in your pre-class reading? This is a good time to go back over the readings to reinforce your understanding and memory of the material.

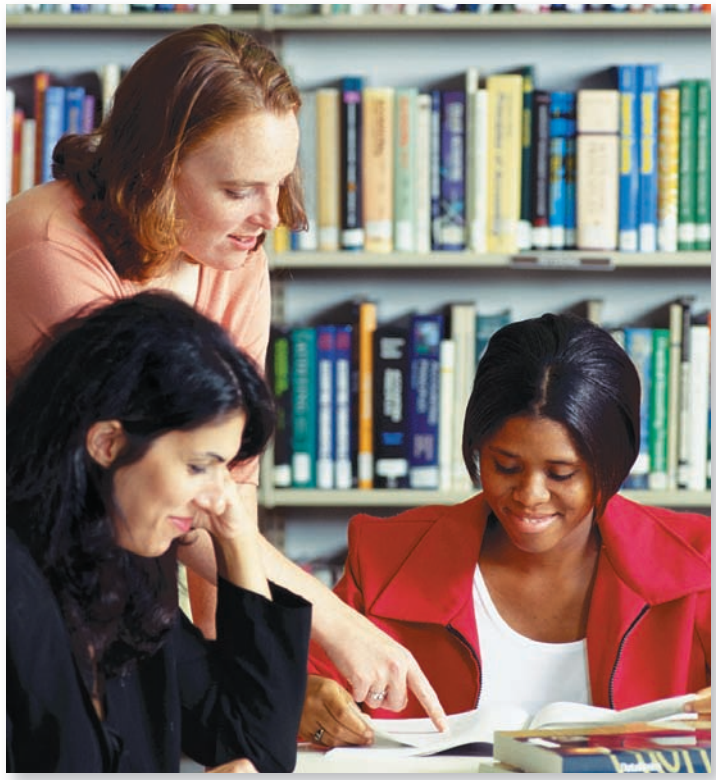


FIGURE L.3 Explaining ideas to your peers is an excellent way to test your knowledge. If you can teach it to someone else, then you probably have a good grasp of the material.

Will this be on the test?

Students often complain that test results don't adequately reflect what they know and how much they've learned in studying. It may well be that test questions won't cover what you think is important or use a style that appeals to you, but you'll probably be more successful if you adapt yourself to the realities of your instructor's test methods rather than trying to force your instructor to accommodate to your preferences. One of your first priorities in studying, therefore, should be to learn your instructor's test style. Are you likely to have short-answer objective questions (multiple choice, true or false, fill in the blank) or does your instructor prefer essay questions? If you have an essay test, will the questions be broad and general or more analytical? You should develop a very different study strategy 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. Unless you have a photographic memory, you won't be able to remember every detail. What's most important? What's the big picture? If you see how pieces of the course fit together, it will all make more sense and be easier to remember. As you read and review, ask yourself what might be some possible test questions in each section. If you're likely to have factual questions, what are the

most significant facts in the material you've read? Memorize some benchmark figures. Just a few will help a lot. Pay special attention to tables, graphs, and diagrams. They were chosen because they illustrate important points.

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 7.1 *billion* people, not thousands, millions, or trillions. Highlight facts and figures in your lecture notes about which your instructor seemed especially interested. There is a good chance you'll see those topics again on a test. 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 314 million residents. The populations of the European Union is slightly larger, India is about three times as large, and China is more than four times as large. Be sure you're familiar with the boldface key terms in the textbook. Vocabulary terms make good objective questions. The "Section Review" at the end of each major heading provides a short quiz about major points that you should understand after reading the material.

A number of strategies can help you be successful in test-taking. Look over the whole test at the beginning and first answer the questions you know well, then tackle the harder ones. On multiple-choice tests, find out whether there is a penalty for guessing. Use the process of elimination to narrow down the possible choices and improve the odds for guessing. Often you can get hints from the context of the question or from other similar questions. Notice that the longest or most specific answer often is right while those that are vague or general are more likely wrong. Be alert for absolutes (such as *always*, *never*, *all*), which could indicate wrong choices. Qualifiers (such as *sometimes*, *may*, or *could*), on the other hand, often point to correct answers. Exactly opposite answers may indicate that one of them is correct.

If you anticipate essay questions, practice writing one- or two-paragraph summaries of major points in each chapter. Develop your ability to generalize and to make connections between important facts and ideas. Notice that the Critical Thinking and Discussion Questions at the end of each chapter are open-ended topics that can work well either for discussion groups or as questions for an essay test. You'll have a big advantage on a test if you have some carefully thought-out arguments for and against the major ideas presented in each chapter. If you don't have any idea what a particular essay question means, you often can make a transition to something you do understand. Look for a handle that links the question to a topic you are prepared to answer. Even if you have no idea what the question means, make an educated guess. You might get some credit. Anything is better than a zero. Sometimes if you explain your answer, you'll get at least some points. "If the question means such and such, then the answer would be _____" may get you partial credit.

Does your instructor like thought-provoking questions? Does she/he expect you to be able to interpret graphs or to draw inferences from a data table? Might you be asked to read a paragraph and describe what it means or relate it to other cases you've covered in the class? If so, you should practice these skills. Making up and sharing these types of questions with your study group can greatly increase your understanding of the material as well as improve your performance on exams. Writing a paragraph answer for each of the Critical Thinking and Discussion Questions could be a very good way to study for an essay test.

Concentrate on positive attitudes and building confidence before your tests. If you have fears and test anxiety, practice relaxation techniques and visualize success. Be sure you are rested and well prepared. You certainly won't do well if you're sleep-deprived and a bundle of nerves. Often the worst thing you can do is to stay up all night to cram your brain with a jumble of data. Being able to think clearly and express yourself well may count much more than knowing a pile of unrelated facts. Review your test when it is returned to learn what you did well and where you need to improve. Ask your instructor for pointers on how you might have answered the questions better. Carefully add your score to be sure you got all the points you deserve. Sometimes graders make simple mathematical errors in adding up points.

Section Review

1. What is your strongest learning style?
2. What are the five techniques of 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. In a rapidly moving field such as environmental science, facts and explanations change constantly. It's often said that in six years approximately half the information you learn from this class will be obsolete. During your lifetime you will probably change careers four to six times. Unfortunately, we don't know which of the ideas we now hold will be outdated or what qualifications you will need for those future jobs. 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.

Even in our everyday lives most of us are inundated by a flood of information and misinformation. Competing claims and contradictory ideas battle for our attention. The rapidly growing complexity of our world and our lives intensifies the difficulties in knowing what to believe or how to act. Consider how the communications revolution has brought us computers, e-mail, cell phones, mobile faxes, pagers, the World Wide Web, hundreds of channels of satellite TV, and direct mail or electronic marketing that overwhelm us with conflicting information. We have more choices than we can possibly manage, and know more about the world around us than ever before but, perhaps, understand less. How can we deal with the barrage of often contradictory news and advice that inundates us?

To complicate our difficulty in knowing what to believe, distinguished authorities disagree vehemently about many important topics. A law of environmental science might be that for any expert there is always an equal and opposite expert. How can you decide what is true and meaningful in such a welter of confusing information? Is it simply a matter of what feels good at the moment or supports our preconceived notions? Or are there ways to use logical, orderly, creative thinking procedures to reach decisions?

By now, most of us know not to believe everything we read or hear (fig. L.4). "Tastes great . . . Low, low sale price . . . Vote for me . . . Lose 30 pounds in 3 weeks . . . You may already be a winner . . . Causes no environmental harm . . . I'll never lie to you . . . Two out of three doctors recommend . . ." More and more of the information we used to buy, elect, advise, judge, or heal has been created not to expand our knowledge but to sell a product or advance a cause. It would be unfortunate if we become cynical and apathetic due to information overload. It does make a difference what we think and how we act.

Approaches to truth and knowledge

A number of skills, attitudes, and 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?" In this section, we'll look more closely at critical and reflective thinking as a foundation for your study of environmental science. We hope you will apply these ideas consistently as you read this book.

As figure L.5 suggests, critical thinking is central in the constellation of thinking skills. It challenges us to examine theories, facts, and options in a systematic, purposeful, and responsible manner. It shares many methods and approaches with other methods of reasoning but adds some important contextual skills, attitudes, and dispositions. Furthermore, it challenges us to plan methodically and to assess the process of thinking as well as the implications of our decisions. 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. Professor Karen J. Warren of Macalester College identifies ten steps in critical thinking (table L.4).

Notice that many critical thinking processes are self-reflective and self-correcting. This form of thinking is sometimes called "thinking about thinking." It is an attempt to plan rationally how to analyze a problem, to monitor your progress while you are doing it, and to evaluate how your strategy worked and what you have learned when you are finished. It is not critical in the sense of finding fault, but it makes a conscious, active, disciplined effort to be aware of hidden motives and assumptions, to uncover bias, and to recognize the reliability or unreliability of sources (see What Do You Think?, p. 9).

FIGURE L.4 "There is absolutely no cause for alarm at the nuclear plant!"
Source: *© Tribune Media Services. Reprinted with permission.*

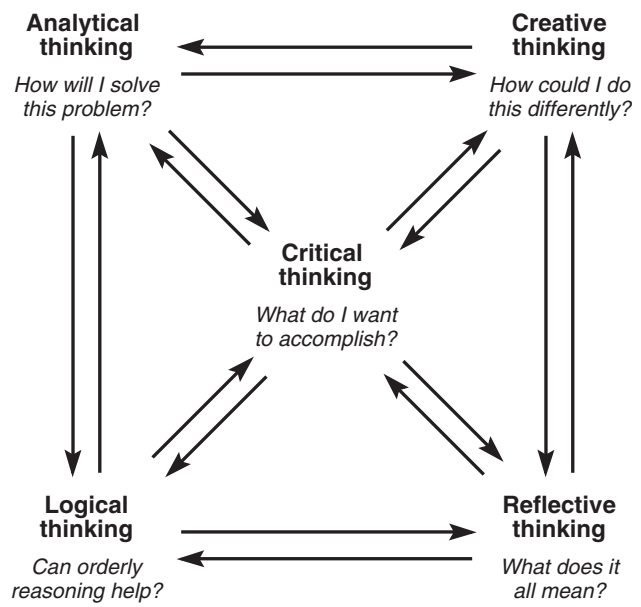


FIGURE L.5 Different approaches to thinking are used to solve different kinds of problems or to study alternate aspects of a single issue.

What Do You Think?

How Do You Tell the News from the Noise?

With the explosion of cable channels, web logs (blogs), social networks, and e-mail access, most of us are interconnected constantly to a degree unique in history. There were at least 150 million blogs on the Web in 2010, and 15,000 new ones are added every day. More than a billion people are linked in social networks. Every day several billion e-mails, tweets, text messages, online videos, and Facebook postings connect us to one another. Handheld devices make it still easier to surf the Web, watch videos, or link to friends. In 2010 there were 4.6 billion mobile phones in the world, or enough for two-thirds of humanity to have one.

There are many benefits from social networks and rapid communication. They were instrumental in bringing about democratic revolutions in the Middle East. And they help people find others with compatible interests or talents. Whatever you want to discuss or learn about, you can probably find a group on the Internet. You may be the only person in your community fascinated by a particular topic, but elsewhere in the world there are others just like you. Together you make a critical mass that justifies a publication or an affinity group. But there's a darker side of this specialization and narrowing focus. Many people use their amazing degree of interconnection not so much to be educated, or to get new ideas, as to reinforce their existing beliefs. A study on the State of the Media by the Center for Journalistic Excellence at Columbia University[1] concluded that the news is becoming increasingly partisan and ideological. Rumors and outright lies fly through the net at light speed. Conspiracy theorists and political operatives spread sensational accusations that are picked up and amplified in the echo chambers of modern media. Newscasters find they don't have to aim at mass markets any more. With so many channels available, they can cater to a narrow sector of the population and give them just what they want to hear.

One effect of separate conversations for separate communities has been the growth of hyperpartisan news programing, which increasingly involves attack journalism. Commentators often ridicule and demean their opponents rather than weighing ideas or reporting objective facts and sources, because shouting matches are exciting 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. Visual images seem more immediate and believable: after all, pictures don't lie—although they can give a very selective view of the truth. Many topics, such as policy issues, don't make good visuals, and therefore never make it into TV coverage. 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. As consumers of instantaneous communication, we often don't have time to seek evidence, but depend more on gut instincts, which often means simply our prejudices and preconceived notions.

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 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.

How can you detect bias in a blog or news report? Ask yourself (or your friends) these questions as you practice critical thinking, look for bias, and make sense out of what you see and hear.

1. What political positions are represented? Are they overt or covert?
2. Are speakers discussing facts and rational ideas, or are they resorting to innuendo, name-calling, character assassination, and ad hominem attacks? When people start calling each other Nazi or communist (or both), civil discourse has probably come to an end.
3. What special interests might be involved here? Who stands to gain presenting a particular viewpoint? Who is paying for the message?
4. What sources are used as evidence in this communication? How credible are they?
5. Are facts or statistics cited in the presentation? Are they credible? Are citations provided so you can check the sources?
6. Is the story one-sided, or are alternate viewpoints presented? If it is one-sided, does it represent majority opinion? Does that matter?
7. 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?
8. Are the arguments presented based on facts and logic, or are they purely emotional appeals?

How many of the critical thinking steps above do you use regularly, as you interpret information from the television or the Internet? How many news sources do you rely on for information? Is it just one, or do you seek out views from multiple sources? What motivates you to do this? What kinds of factors influence the ways you form your opinions on the news?

[1]The State of the News Media 2004 available at http://www.journalism.org.