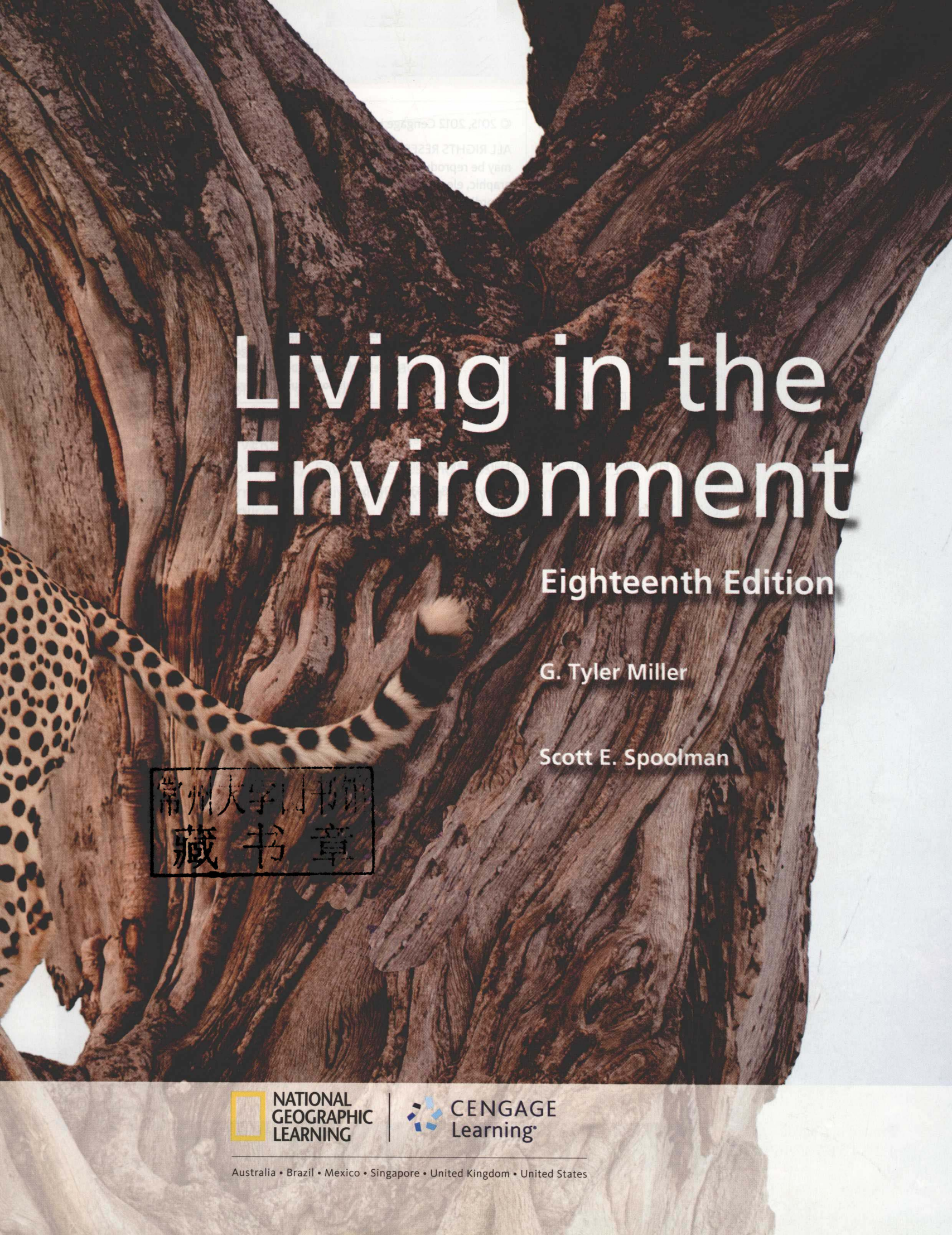


LIVING IN THE ENVIRONMENT

G. TYLER MILLER • SCOTT E. SPOOLMAN



The background of the cover is a close-up photograph of a large, weathered tree trunk with deeply textured, furrowed bark. A leopard's tail, with its characteristic black spots on a tan background, is draped across the left side of the trunk. A small, light-colored lizard is perched on the lower part of the trunk. The title 'Living in the Environment' is printed in a large, white, sans-serif font across the upper half of the image.

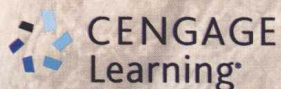
Living in the Environment

Eighteenth Edition

G. Tyler Miller

Scott E. Spoolman

常州大学图书馆
藏书章



Australia • Brazil • Mexico • Singapore • United Kingdom • United States

Living in the Environment, Eighteenth Edition**G. Tyler Miller, Scott E. Spoolman**

Senior Product Team Manager: Yolanda Cossio

Content Developer: Jake Warde

Content Coordinator: Shannon Holt

Product Assistant: Kellie Petruzzelli

Media Developer: Alexandria Brady

Executive Brand Manager: Nicole Hamm

Senior Market Development Manager: Tom Ziolkowski

Content Project Manager: Harold P. Humphrey

Senior Art Director: Pamela Galbreath

Manufacturing Planner: Karen Hunt

Senior Rights Acquisitions Specialist: Dean Dauphinais

Production Service: Dan Fitzgerald, Graphic World Inc.

Photo Researcher: Christina Ciaramella, PreMedia Global

Text Researcher: Melissa Tomaselli, PreMedia Global

Copy Editor: Graphic World Inc.

Illustrator: Patrick Lane, ScEYence Studios

Text and Cover Designer: Jeanne Calabrese

Cover and Title Page Image: © Frans Lanting/National
Geographic Creative

Compositor: Graphic World Inc.

© 2015, 2012 Cengage Learning

ALL RIGHTS RESERVED. No part of this work covered by the copyright herein may be reproduced, transmitted, stored, or used in any form or by any means, graphic, electronic, or mechanical, including but not limited to photocopying, recording, scanning, digitizing, taping, Web distribution, information networks, or information storage and retrieval systems, except as permitted under Section 107 or 108 of the 1976 United States Copyright Act, without the prior written permission of the publisher.

For product information and technology assistance, contact us at
Cengage Learning Customer & Sales Support, 1-800-354-9706.

For permission to use material from this text or product,
submit all requests online at **www.cengage.com/permissions.**

Further permissions questions can be e-mailed to
permissionrequest@cengage.com.

Library of Congress Control Number: 2013945510

Hardcover Edition:

ISBN-13: 978-1-133-94013-5

ISBN-10: 1-133-94013-7

Loose-leaf Advantage Edition:

ISBN-13: 978-1-285-19721-0

ISBN-10: 1-285-19721-6

Cengage Learning

200 First Stamford Place, 4th Floor
Stamford, CT 06902
USA

Cengage Learning is a leading provider of customized learning solutions with office locations around the globe, including Singapore, the United Kingdom, Australia, Mexico, Brazil, and Japan. Locate your local office at
www.cengage.com/global.

Cengage Learning products are represented in Canada by Nelson Education, Ltd.

To learn more about Cengage Learning Solutions, visit **www.cengage.com.**

Purchase any of our products at your local college store or at our preferred online store **www.cengagebrain.com.**



It's time to
give **YOU** something fresh.

W E L C O M E T O...



MindTap™

Designed to support the way **YOU** learn and where you learn, MindTap is well beyond an eBook, assignments or digital supplement, a resource center website, a course delivery platform, or a Learning Management System.

**MindTap is the first in a new category—
The Personal Learning Experience.**



See for yourself.
View a MindTap demo at
www.cengage.com/mindtap.

“““

“This thing is awesome.
It's very, very easy to use.
Your book is right there
and has easy tabs to go
through. There are lots
of extra functions on the
side such as highlighting
... note taking ... it even
reads to you!”

Chris Baggett

Student, Arkansas Tech University



7 OUT OF 8

MindTap students would
recommend MindTap



ENGAGING LEARNERS TOGETHER

Cengage Learning and National Geographic are proud to present the National Geographic Learning Reader Series and enhanced core textbooks. These resources are brought to you through an exclusive partnership with the National Geographic Society, an organization that represents a tradition of amazing stories, exceptional research, first-hand accounts of exploration, rich content, and authentic materials.

Using the world-renowned content from the National Geographic Society, the Reader Series and core textbooks bring learning to life by featuring compelling images, media, and text from the Society. Through this engaging content, learners develop a clearer understanding of the world around them.

No organization presents this world, its people, places, and precious resources in a more compelling way than National Geographic. Through the Reader Series and core textbooks we honor the mission and tradition of the National Geographic Society – to inspire people to care about the planet.



Explore the partnership at: www.cengage.com/ngl

此为试读, 需要完整PDF请访问: www.ertongbook.com



Living in the Environment

Eighteenth Edition

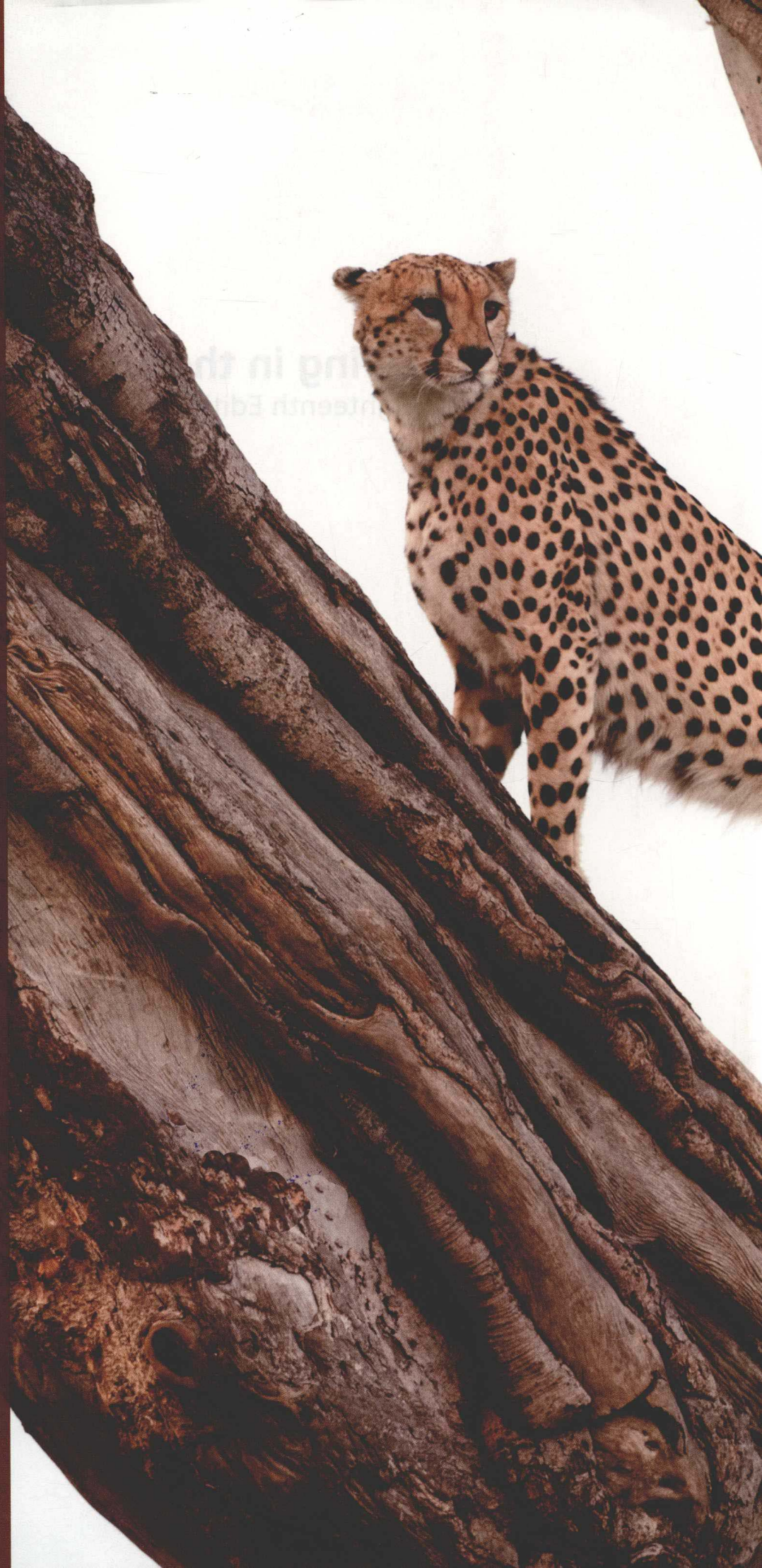
ABOUT THE COVER PHOTO

The cheetah is the world's fastest land mammal. Within a few seconds, it can run at speeds of as high as 105 kilometers per hour (65 miles per hour) for short periods of time. It uses this ability to chase down and kill gazelles, impalas, wildebeests, zebras, and hares on the open plains of southern Africa and parts of southwestern Asia where it lives.

The cheetah is built for the chase. It has large nostrils to maximize its air intake along with an enlarged heart and lungs. Its large tail acts as a sort of rudder to help it make quick, sharp turns in pursuit of fast prey. It typically kills a prey animal by tripping it and then biting the underside of its throat as it falls. Cheetahs hunt mostly during the middle of the day to avoid competing with other large predators like hyenas and lions that hunt mostly at night. They hide behind shrubs or rock outcroppings to get as close as possible to their prey and then chase them down in a burst of speed.

As many as three of every four cheetah cubs are killed during the first few weeks of their lives, mostly by leopards, lions, wild dogs, hyenas, and eagles. When the cubs are about 6 months old, their mothers capture live prey for them to practice killing. Cubs leave their mother after about 18 months. In the wild, adult cheetahs typically live for 8 to 10 years.

Now protected as a threatened species, cheetahs were once hunted for their spotted coats, and farmers killed them to try to protect their livestock. About 7,000 to 10,000 cheetahs now remain in the wild, in small isolated populations found mostly in 25 African countries. Because they thrive on large expanses of open land with abundant prey, they are threatened by the spread of ranches, farms, and other human settlements that have reduced their habitat by more than 90% since 1900. Also, poachers are still killing them for their coats. And according to scientists, because their population has dwindled, many cheetahs suffer from genetic defects due to inbreeding, which has lowered their resistance to disease, caused infertility, raised cub mortality rates, and made them more vulnerable to extinction.



For Instructors

We wrote this book to help instructors achieve three important goals: *first*, to explain to their students the basics of environmental science; *second*, to help their students in using this scientific foundation to understand the environmental problems that we face and to evaluate possible solutions to them; and *third*, to inspire their students to make a difference in how we treat the earth on which our lives and economies depend, and thus in how we treat ourselves and our descendants.

We view environmental problems and possible solutions to them through the lens of *sustainability*—the integrating theme of this book. We believe that most people can live comfortable and fulfilling lives and that societies will be more prosperous and peaceful when sustainability becomes one of the chief measures by which personal choices and public policies are made. We introduce this book with a vision of such a more sustainable future in the Core Case Study of Chapter 1. Our belief in such a future is foundational to this textbook, and we consistently challenge students to work toward attaining it.


For this reason, we are happy to announce our new partnership with *The National Geographic Society*, which shares our goals, as reflected in its statement of purpose: *Inspiring people to care about the planet*. One result of this new collaboration is the addition of many stunning and informative photographs, numerous maps, and several new stories of National Geographic Explorers—people who are making a positive difference in the world. With these new tools, we continue to tell of the good news from various fields of environmental science, hoping to inspire young people to commit themselves to making our world a more sustainable place to live for their own and future generations.

What's New in This Edition?

- *Our new partnership with National Geographic* has given us access to hundreds of amazing photographs, numerous maps, and inspiring stories of *National Geographic Explorers*—people who are leading the way in environmental science, education, or entrepreneurial enterprises.
- *A stunning new design* with a National Geographic look that enhances visual learning.
- *Campus Sustainability boxes*: short descriptions about what selected U.S. colleges and universities are doing to make their institutions more sustainable. These stories are complemented by a new Core Case Study in Chapter 24 that summarizes several other such efforts.
- *Three social science principles of sustainability*. These complement the three scientific principles of sustainability that we have long used to explain how life on Earth has sustained itself for billions of years, and they act as guidelines for making a possible transition to more sustainable economies and societies.
- *New Core Case Studies* for 18 of the book's 25 chapters that serve as an integrating theme throughout each chapter. They bring important real-world stories to the forefront for use in applying those chapters' concepts and principles.
- *Two new end-of-chapter exercises: Doing Environmental Science and Global Environment Watch* research projects give students challenging new ways to apply the material.

Sustainability Is the Integrating Theme of This Book

Sustainability, a watchword of the 21st century for those concerned about the environment, is the overarching theme of this textbook. You can see the sustainability emphasis by looking at the Brief Contents (p. v).

Six principles of sustainability play a major role in carrying out this book's sustainability theme. These principles are introduced in Chapter 1. They are depicted in Figure 1-2 (p. 6), in Figure 1-5 (p. 9), and on the back cover of the student edition and are used throughout the book, with each reference marked in the margin by  (see pp. 62 and 218).

We use the following five major subthemes to integrate material throughout this book (see diagram on back cover of the student edition).

- **Natural Capital.** Sustainability depends on the natural resources and ecosystem services that support all life and economies. See Figures 1-3, p. 7, and 10-4, p. 220.
- **Natural Capital Degradation.** We describe how human activities can degrade natural capital. See Figures 1-7, p. 11, and 7-17, p. 160.
- **Solutions.** We present existing and proposed solutions to environmental problems in a balanced manner and challenge students to use critical thinking to evaluate them. See Figures 10-16, p. 227, and 18-26, p. 496.
- **Trade-offs.** The search for solutions involves trade-offs, because any solution requires weighing advantages against disadvantages. Our Trade-offs diagrams located in several chapters present the benefits and drawbacks of various environmental technologies and solutions to environmental problems. See Figures 12-19, p. 293, and 15-11, p. 383.
- **Individuals Matter.** Throughout the book, Individuals Matter boxes and some of the Case Studies describe what various scientists and concerned citizens (including several National Geographic Explorers) have done

to help us work toward sustainability (see pp. 82, 240, and 303). Also, a number of What Can You Do? diagrams describe how readers can deal with the problems we face (see Figures 9-12, p. 202, and 13-28, p. 341). Eight especially important things individuals can do are summarized in Figure 25-14 (p. 696).

Other Key Features of This Textbook

- **Up-to-Date Coverage.** Our textbooks have been widely praised for keeping users up to date in the rapidly changing field of environmental science. We have used thousands of articles and reports published in 2010–2013 to update the information and concepts in this book. Major new or updated topics include planetary boundaries that indicate ecological tipping points (Science Focus 3.3, p. 72); hydraulic fracturing (fracking) in oil and natural gas production and its harmful effects (pp. 379–380 and 383–385); and the rising threat of ocean acidification (Science Focus 11.2, p. 252), along with dozens of other important topics.
- **Concept-Centered Approach.** To help students focus on the main ideas, we built each major chapter section around a key question and one or two key concepts, which state the section's most important take-away messages. In each chapter, all key questions are listed at the front of the chapter, and each chapter section begins with its key question and concepts (see pp. 29 and 31). Also, the concept applications are highlighted and referenced throughout each chapter.
- **Science-Based Coverage.** Chapters 2–8 cover scientific principles important to the course and discuss how scientists work (see Brief Contents, p. v). Important environmental science topics are explored in depth in Science Focus boxes distributed among the chapters throughout the book (see pp. 94 and 203) and integrated throughout the book in various Case Studies (see pp. 238 and 256) and in numerous figures.
- **Global Perspective.** This book also provides a global perspective, first on the ecological level, revealing how all the world's life is connected and sustained within the biosphere, and second, through the use of information and images from around the world. This includes more than 80 maps in the basic text and in Supplement 6. Half of these maps are new and more than half of the new maps are from National Geographic. At the end of each chapter is a Global Environment Watch exercise that applies this global perspective (see p. 245).
- **Core Case Studies.** Each chapter opens with a Core Case Study (see pp. 190 and 278), which is applied throughout the chapter. These applications are indicated by the notation (**Core Case Study**) wherever they occur (see pp. 202, 281, and 301). Each chapter ends with a *Tying It All Together* box (see pp. 213 and 312), which connects the Core Case Study and other material in the chapter to some or all of the principles of sustainability.
- **Case Studies.** In addition to the 25 Core Case Studies, more than 70 additional Case Studies (see pp. 92, 200, and 331) appear throughout the book (and are listed in the Detailed Contents, pp. vi–xv). Each of these provides an in-depth look at specific environmental problems and their possible solutions. We also have included very brief descriptions of efforts on several college campuses to study or apply principles of sustainability in our new *Campus Sustainability* stories that appear in several of the book's chapters (see pp. 210 and 270).
- **Critical Thinking.** The Preface for Students (p. xxiii) describes critical thinking skills, and specific critical thinking exercises are used throughout the book in several ways:
 - As more than 100 *Thinking About* exercises that ask students to analyze material immediately after it is presented (see pp. 35 and 264).
 - In all *Science Focus* boxes.
 - In dozens of *Connections* boxes that stimulate critical thinking by exploring the often surprising connections related to environmental problems (see pp. 18 and 195).
 - In the captions of many of the book's figures (see Figures 3-15, p. 63, and 9-8, p. 198).
 - In end-of-chapter questions (see pp. 214 and 314).
- **Visual Learning.** With a new design heavily influenced by material from National Geographic and more than 400 photographs—two-thirds of them new and 20% of them from the archives of National Geographic—this is the most visually appealing environmental science textbook available (see Figures 3-21, p. 71; 7-16, p. 159; and 10-18, p. 229). Also new to this edition is the inclusion of more than 200 additional small photos as insets in various diagrams. Add in the more than 130 diagrams—34 of them new or improved in this edition—each designed to present complex ideas in understandable ways relating to the real world (see Figures 3-3, p. 54; 3-17, p. 66; and 4-2, p. 79), and you have one of the most visually informative textbooks available.
- **Flexibility.** To meet the diverse needs of hundreds of widely varying environmental science courses, we have designed a highly flexible book that allows instructors to vary the order of chapters and sections within chapters without exposing students to

terms and concepts that could confuse them. We recommend that instructors start with Chapter 1, which defines basic terms and gives an overview of sustainability, population, pollution, resources, and economic development issues that are discussed throughout the book. This provides a springboard for instructors to use other chapters in almost any order. One often-used strategy is to follow Chapter 1 with Chapters 2–8, which introduce basic science and ecological concepts. Instructors can then use the remaining chapters in any order desired. Some instructors follow Chapter 1 with any or all of Chapters 23, 24, and 25 on environmental economics, politics, and worldviews, respectively, before proceeding to the chapters on basic science and ecological concepts. We provide a second level of flexibility in seven Supplements (see p. xv in the Detailed Contents and p. S1), which instructors can assign as desired to meet the needs of their specific courses. Examples include environmental history of the United States (Supplement 3), basic chemistry (Supplement 4), weather basics (Supplement 5), maps (Supplement 6, see Figure 5, p. S30, and Figure 6, p. S32), and basic environmental data and data analysis (Supplement 7, see Figure 7, p. S67, and Figure 10, p. S68).

- **In-Text Study Aids.** Each chapter begins with a list of *Key Questions* showing how the chapter is organized (see p. 401). When a new *key term* is introduced and defined, it is printed in boldface type, and all such terms are summarized in the glossary at the end of the book. More than 100 *Thinking About* exercises reinforce learning by asking students to think critically about the implications of various environmental issues and solutions immediately after they are discussed in the text (see p. 409). The captions of many figures contain similar questions that get students to think about the figure content (see Figure 16-16, p. 416). In their reading, students also encounter *Connections* boxes, which briefly describe connections between human activities and environmental consequences, environmental and social issues, and environmental issues and solutions (see p. 423). Finally, the text of each chapter wraps up with three *Big Ideas* (see p. 435), which summarize and reinforce three of the major take-away messages from each chapter, and a *Tying It All Together* section that relates the Core Case Study and other chapter content to the principles of sustainability (see p. 436). Again, this reinforces the main messages of the chapter along with the themes of sustainability to give students a stronger understanding of how it all ties together.

Each chapter ends with a *Chapter Review* section containing a detailed set of review questions that include all the chapter's key terms in bold type; *Critical Thinking* questions

that encourage students to think about and apply what they have learned to their lives; *Doing Environmental Science*—an exercise that will help students to experience the work of various environmental scientists; a *Global Environment Watch* exercise taking students to Cengage's GREENR site, where they can use this tool for interesting research related to chapter content; and a *Data Analysis* or *Ecological Footprint Analysis* problem built around ecological footprint data or some other environmental data set. (See pp. 436–439.) And at the end of the book, we have included a comprehensive glossary that includes definitions of all key terms as well as many other terms that are important to environmental science.

Supplements for Instructors

- **Environmental Science MindTap.** MindTap is a new personal learning experience that combines all your digital assets—readings, multimedia, activities, and assessments—into a singular learning path to improve student outcomes.
- **Instructor Companion Site.** Everything you need for your course in one place! This collection of book-specific lecture and class tools is available online via www.cengage.com/login. Access and download PowerPoint presentations, images, instructor's manual, videos, and more.
- **Cognero.** Cengage Learning Testing Powered by Cognero is a flexible, online system that allows you to do the following:
 - author, edit, and manage test bank content from multiple Cengage Learning solutions
 - create multiple test versions in an instant
 - deliver tests from your LMS, your classroom, or wherever you want
- **Transparencies.** Online Transparency Correlation Guide. This guide correlates the transparency set created for *Living in the Environment* 17e, *Environmental Science* 13e, *Sustaining the Earth* 10e, and *Essentials of Ecology* 6e to the new editions of these texts: *Living in the Environment* 18e, *Environmental Science* 14e, *Sustaining the Earth* 11e, and *Essentials of Ecology* 7e. To acquire the set of 250 printed transparencies and 250 electronic masters, please ask your local Cengage Learning Sales Representative or call 1-800-423-0563.
- **Aplia.** Aplia™ is a Cengage Learning online homework system dedicated to improving learning by increasing student effort and engagement. Aplia makes it easy for instructors to assign frequent online homework assignments. Aplia provides students with prompt and detailed feedback to help them learn as they work through the questions, and features interactive tutorials to fully engage them in learning course concepts. Automatic grading and powerful

assessment tools give instructors real-time reports of student progress, participation, and performance, and Aplia's easy-to-use course management features let instructors flexibly administer course announcements and materials online. With Aplia, students will show up to class fully engaged and prepared, and instructors will have more time to do what they do best. . . . teach.

- **BBC Videos for Environmental Science.** This large library of BBC clips are informative, short clips of current news stories on environmental issues from around the world. These clips are a great way to start a lecture or spark a discussion. Available on DVD with a workbook, on the PowerLecture DVD, and within MindTap.
- **Global Environment Watch.** Updated several times a day, the Global Environment Watch is a focused portal into GREENR—the Global Reference on the Environment, Energy, and Natural Resources—an ideal one-stop site for classroom discussion and research projects. This resource center keeps courses up to date with the most current news on the environment. Users get access to information from trusted academic journals, news outlets, and magazines, as well as statistics, an interactive world map, videos, primary sources, case studies, podcasts, and much more.
- **Virtual Field Trips in Environmental Issues.** This supplement brings the field to you, with dynamic panoramas, videos, photographs, maps, and quizzes covering important topics within environmental science. A case study approach covers the issues of keystone species, the role of climate change in extinctions, invasive species, the evolution of a species in relation to its environment, and an ecosystem approach to sustaining biodiversity. Students are engaged, interacting with real issues to help them think critically about the world around them.

Help Us Improve This Book or Its Supplements

Let us know how you think this book can be improved. If you find any errors, bias, or confusing explanations, please e-mail us about them at:

- mtg89@hotmail.com
- spoolman@tds.net

Most errors can be corrected in subsequent printings of this edition, as well as in future editions.

Acknowledgments

We wish to thank the many students and teachers who have responded so favorably to the 17 previous editions of *Living in the Environment*, the 14 editions of *Environmental Science*, the 10 editions of *Sustaining the Earth*, and the 6 editions of *Essentials of Ecology*, and who have corrected errors

and offered many helpful suggestions for improvement. We are also deeply indebted to the more than 300 reviewers, who pointed out errors and suggested many important improvements in the various editions of these three books.

It takes a village to produce a textbook, and the members of the talented production team, listed on the copyright page, have made vital contributions. Our special thanks go to development editor Jake Warde, production editors Hal Humphrey and Dan Fitzgerald, designer Pam Galbreath, copy editor Chris DeVito, compositor Craig Beffa, photo researcher Christina Ciaramella, artist Patrick Lane, media developer Alexandria Brady, assistant editor Alexis Glubka, product assistant Kellie Petruzzelli, and Cengage Learning's hardworking sales staff. Finally, we are very fortunate to have the guidance, inspiration, and unfailing support of Life Sciences Senior Product Team Manager Yolanda Cossio and her dedicated team of highly talented people who have made this and other book projects such a pleasure to work on.

G. Tyler Miller

Scott E. Spoolman

Guest Essayists

Guest essays by the following authors are available online:

M. Kat Anderson, ethnocologist with the National Plant Center of the USDA's Natural Resource Conservation Center; **Lester R. Brown**, president, Earth Policy Institute; **Alberto Ruz Buenfil**, environmental activist, writer, and performer; **Robert D. Bullard**, professor of sociology and director of the Environmental Justice Resource Center at Clark Atlanta University; **Michael Cain**, ecologist and adjunct professor at Bowdoin College; **Herman E. Daly**, senior research scholar at the School of Public Affairs, University of Maryland; **Lois Marie Gibbs**, director, Center for Health, Environment, and Justice; **Garrett Hardin**, professor emeritus (now deceased) of human ecology, University of California, Santa Barbara; **John Harte**, professor of energy and resources, University of California, Berkeley; **Paul G. Hawken**, environmental author and business leader; **Jane Heinze-Fry**, environmental educator; **Paul F. Kamitsuja**, infectious disease expert and physician; **Amory B. Lovins**, energy policy consultant and director of research, Rocky Mountain Institute; **Bobbi S. Low**, professor of resource ecology, University of Michigan; **John J. Magnuson**, Director Emeritus of the Center for Limnology, University of Wisconsin, Madison; **Lester W. Milbrath**, director of the research program in environment and society, State University of New York, Buffalo; **Peter Montague**, director, Environmental Research Foundation; **Norman Myers**, tropical ecologist and consultant in environment and development; **David W. Orr**, professor of environmental studies, Oberlin College; **Noel Perrin**, adjunct professor of environmental studies, Dartmouth College; **David Pimentel**, professor of insect ecology and agricultural sciences, Cornell University; **John Pichtel**,

Ball State University; **Andrew C. Revkin**, environmental author and environmental reporter for the New York Times; **Vandana Shiva**, physicist, educator, environmental consultant; **Nancy Wicks**, ecopioneer and director of Round Mountain Organics; and **Donald Worster**, environmental historian and professor of American history, University of Kansas.

Dr. Dean Goodwin and his colleagues Berry Cobb, Deborah Stevens, Jeannette Adkins, Jim Lehner, Judy Treharne, Lonnie Miller, and Tom Mowbray provided excellent contributions to the Data Analysis and Ecological Footprint Analysis exercises. Mary Jo Burchart of Oakland Community College wrote the in-text Global Environment Watch exercises.

Cumulative List of Reviewers

Barbara J. Abraham, Hampton College; Donald D. Adams, State University of New York at Plattsburgh; Larry G. Allen, California State University, Northridge; Susan Allen-Gil, Ithaca College; James R. Anderson, U.S. Geological Survey; Mark W. Anderson, University of Maine; Kenneth B. Armitage, University of Kansas; Samuel Arthur, Bowling Green State University; Gary J. Atchison, Iowa State University; Thomas W. H. Backman, Lewis-Clark State College; Marvin W. Baker, Jr., University of Oklahoma; Virgil R. Baker, Arizona State University; Stephen W. Banks, Louisiana State University in Shreveport; Ian G. Barbour, Carleton College; Albert J. Beck, California State University, Chico; Eugene C. Beckham, Northwood University; Diane B. Beechinor, Northeast Lakeview College; W. Behan, Northern Arizona University; David Belt, Johnson County Community College; Keith L. Bildstein, Winthrop College; Andrea Bixler, Clarke College; Jeff Bland, University of Puget Sound; Roger G. Bland, Central Michigan University; Grady Blount II, Texas A&M University, Corpus Christi; Lisa K. Bonneau, University of Missouri-Kansas City; Georg Borgstrom, Michigan State University; Arthur C. Borror, University of New Hampshire; John H. Bounds, Sam Houston State University; Leon F. Bouvier, Population Reference Bureau; Daniel J. Bovin, Université Laval; Jan Boyle, University of Great Falls; James A. Brenneman, University of Evansville; Michael F. Brewer, Resources for the Future, Inc.; Mark M. Brinson, East Carolina University; Dale Brown, University of Hartford; Patrick E. Brunelle, Contra Costa College; Terrence J. Burgess, Saddleback College North; David Byman, Pennsylvania State University, Worthington-Scranton; Michael L. Cain, Bowdoin College; Lynton K. Caldwell, Indiana University; Faith Thompson Campbell, Natural Resources Defense Council, Inc.; John S. Campbell, Northwest College; Ray Canterbury, Florida State University; Ted J. Case, University of San Diego; Ann Causey, Auburn University; Richard A. Cellarius, Evergreen State University; William U. Chandler, Worldwatch Institute; F. Christman, University of North Carolina, Chapel Hill; Lu Anne Clark, Lansing Community College; Preston

Cloud, University of California, Santa Barbara; Bernard C. Cohen, University of Pittsburgh; Richard A. Cooley, University of California, Santa Cruz; Dennis J. Corrigan; George Cox, San Diego State University; John D. Cunningham, Keene State College; Herman E. Daly, University of Maryland; Raymond F. Dasmann, University of California, Santa Cruz; Kingsley Davis, Hoover Institution; Edward E. DeMartini, University of California, Santa Barbara; James Demastes, University of Northern Iowa; Charles E. DePoe, Northeast Louisiana University; Thomas R. Detwyler, University of Wisconsin; Bruce DeVantier, Southern Illinois University at Carbondale; Peter H. Diage, University of California, Riverside; Stephanie Dockstader, Monroe Community College; Lon D. Drake, University of Iowa; Michael Draney, University of Wisconsin-Green Bay; David DuBose, Shasta College; Dietrich Earnhart, University of Kansas; Robert East, Washington & Jefferson College; T. Edmonson, University of Washington; Thomas Eisner, Cornell University; Michael Esler, Southern Illinois University; David E. Fairbrothers, Rutgers University; Paul P. Feeny, Cornell University; Richard S. Feldman, Marist College; Vicki Fella-Pleier, La Salle University; Nancy Field, Bellevue Community College; Allan Fitzsimmons, University of Kentucky; Andrew J. Friedland, Dartmouth College; Kenneth O. Fulgham, Humboldt State University; Lowell L. Getz, University of Illinois at Urbana-Champaign; Frederick F. Gilbert, Washington State University; Jay Glassman, Los Angeles Valley College; Harold Goetz, North Dakota State University; Srikanth Gogineni, Axia College of University of Phoenix; Jeffery J. Gordon, Bowling Green State University; Eville Gorham, University of Minnesota; Michael Gough, Resources for the Future; Ernest M. Gould, Jr., Harvard University; Peter Green, Golden West College; Katharine B. Gregg, West Virginia Wesleyan College; Paul K. Grogger, University of Colorado at Colorado Springs; L. Guernsey, Indiana State University; Ralph Guzman, University of California, Santa Cruz; Raymond Hames, University of Nebraska, Lincoln; Robert Hamilton IV, Kent State University, Stark Campus; Raymond E. Hampton, Central Michigan University; Ted L. Hanes, California State University, Fullerton; William S. Hardenbergh, Southern Illinois University at Carbondale; John P. Harley, Eastern Kentucky University; Neil A. Harriman, University of Wisconsin, Oshkosh; Grant A. Harris, Washington State University; Harry S. Hass, San Jose City College; Arthur N. Haupt, Population Reference Bureau; Denis A. Hayes, environmental consultant; Stephen Heard, University of Iowa; Gene Heinze-Fry, Department of Utilities, Commonwealth of Massachusetts; Jane Heinze-Fry, environmental educator; John G. Hewston, Humboldt State University; David L. Hicks, Whitworth College; Kenneth M. Hinkel, University of Cincinnati; Eric Hirst, Oak Ridge National Laboratory; Doug Hix, University of Hartford; S. Holling, University of British Columbia; Sue Holt, Cabrillo College; Donald Holtgrieve, California State

University, Hayward; Michelle Homan, Gannon University; Michael H. Horn, California State University, Fullerton; Mark A. Hornberger, Bloomsburg University; Marilyn Houck, Pennsylvania State University; Richard D. Houk, Winthrop College; Robert J. Huggett, College of William and Mary; Donald Huisinigh, North Carolina State University; Catherine Hurlbut, Florida Community College at Jacksonville; Marlene K. Hutt, IBM; David R. Inglis, University of Massachusetts; Robert Janiske, University of South Carolina; Hugo H. John, University of Connecticut; Brian A. Johnson, University of Pennsylvania, Bloomsburg; David I. Johnson, Michigan State University; Mark Jonasson, Crafton Hills College; Zoghul Kabir, Rutgers, New Brunswick; Agnes Kadar, Nassau Community College; Thomas L. Keefe, Eastern Kentucky University; David Kelley, University of St. Thomas; William E. Kelso, Louisiana State University; Nathan Keyfitz, Harvard University; David Kidd, University of New Mexico; Pamela S. Kimbrough; Jesse Klingebiel, Kent School; Edward J. Kormondy, University of Hawaii-Hilo/West Oahu College; John V. Krutilla, Resources for the Future, Inc.; Judith Kunofsky, Sierra Club; E. Kurtz; Theodore Kury, State University of New York at Buffalo; Troy A. Ladine, East Texas Baptist University; Steve Ladochy, University of Winnipeg; Anna J. Lang, Weber State University; Mark B. Lapping, Kansas State University; Michael L. Larsen, Campbell University; Linda Lee, University of Connecticut; Tom Lege, Idaho Department of Fish and Game; Maureen Leupold, Genesee Community College; William S. Lindsay, Monterey Peninsula College; E. S. Lindstrom, Pennsylvania State University; M. Lippiman, New York University Medical Center; Valerie A. Liston, University of Minnesota; Dennis Livingston, Rensselaer Polytechnic Institute; James P. Lodge, air pollution consultant; Raymond C. Loehr, University of Texas at Austin; Ruth Logan, Santa Monica City College; Robert D. Loring, DePauw University; Paul F. Love, Angelo State University; Thomas Lovering, University of California, Santa Barbara; Amory B. Lovins, Rocky Mountain Institute; Hunter Lovins, Rocky Mountain Institute; Gene A. Lucas, Drake University; Claudia Luke, University of California, Berkeley; David Lynn; Timothy F. Lyon, Ball State University; Stephen Malcolm, Western Michigan University; Melvin G. Marcus, Arizona State University; Gordon E. Matzke, Oregon State University; Parker Mauldin, Rockefeller Foundation; Marie McClune, The Agnes Irwin School (Rosemont, Pennsylvania); Theodore R. McDowell, California State University; Vincent E. McKelvey, U.S. Geological Survey; Robert T. McMaster, Smith College; John G. Merriam, Bowling Green State University; A. Steven Messenger, Northern Illinois University; John Meyers, Middlesex Community College; Raymond W. Miller, Utah State University; Arthur B. Millman, University of Massachusetts, Boston; Sheila Miracle, Southeast Kentucky Community & Technical College; Fred Montague, University of Utah; Rolf Monteen, California Polytechnic

State University; Debbie Moore, Troy University Dothan Campus; Michael K. Moore, Mercer University; Ralph Morris, Brock University, St. Catherine's, Ontario, Canada; Angela Morrow, Auburn University; William W. Murdoch, University of California, Santa Barbara; Norman Myers, environmental consultant; Brian C. Myres, Cypress College; A. Neale, Illinois State University; Duane Nellis, Kansas State University; Jan Newhouse, University of Hawaii, Manoa; Jim Norwine, Texas A&M University, Kingsville; John E. Oliver, Indiana State University; Mark Olsen, University of Notre Dame; Carol Page, copy editor; Bill Paletski, Penn State University; Eric Pallant, Allegheny College; Charles F. Park, Stanford University; Richard J. Pedersen, U.S. Department of Agriculture, Forest Service; David Pelliam, Bureau of Land Management, U.S. Department of the Interior; Murray Paton Pendarvis, Southeastern Louisiana University; Dave Perault, Lynchburg College; Rodney Peterson, Colorado State University; Julie Phillips, De Anza College; John Pichtel, Ball State University; William S. Pierce, Case Western Reserve University; David Pimentel, Cornell University; Peter Pizor, Northwest Community College; Mark D. Plunkett, Bellevue Community College; Grace L. Powell, University of Akron; James H. Price, Oklahoma College; Marian E. Reeve, Merritt College; Carl H. Reidel, University of Vermont; Charles C. Reith, Tulane University; Erin C. Rempala, San Diego City College; Roger Revelle, California State University, San Diego; L. Reynolds, University of Central Arkansas; Ronald R. Rhein, Kutztown University of Pennsylvania; Charles Rhyne, Jackson State University; Robert A. Richardson, University of Wisconsin; Benjamin F. Richason III, St. Cloud State University; Jennifer Rivers, Northeastern University; Ronald Robberecht, University of Idaho; William Van B. Robertson, School of Medicine, Stanford University; C. Lee Rockett, Bowling Green State University; Terry D. Roelofs, Humboldt State University; Daniel Ropek, Columbia George Community College; Christopher Rose, California Polytechnic State University; Richard G. Rose, West Valley College; Stephen T. Ross, University of Southern Mississippi; Robert E. Roth, Ohio State University; Dorna Sakurai, Santa Monica College; Arthur N. Samel, Bowling Green State University; Shamili Sandiford, College of DuPage; Floyd Sanford, Coe College; David Satterthwaite, I.E.E.D., London; Stephen W. Sawyer, University of Maryland; Arnold Schecter, State University of New York; Frank Schiavo, San Jose State University; William H. Schlesinger, Ecological Society of America; Stephen H. Schneider, National Center for Atmospheric Research; Clarence A. Schoenfeld, University of Wisconsin, Madison; Madeline Schreiber, Virginia Polytechnic Institute; Henry A. Schroeder, Dartmouth Medical School; Lauren A. Schroeder, Youngstown State University; Norman B. Schwartz, University of Delaware; George Sessions, Sierra College; David J. Severn, Clement Associates; Don Sheets, Gardner-Webb University; Paul Shepard,

Pitzer College and Claremont Graduate School; Michael P. Shields, Southern Illinois University at Carbondale; Kenneth Shiovitz; F. Siewert, Ball State University; E. K. Silbergold, Environmental Defense Fund; Joseph L. Simon, University of South Florida; William E. Sloey, University of Wisconsin, Oshkosh; Robert L. Smith, West Virginia University; Val Smith, University of Kansas; Howard M. Smolkin, U.S. Environmental Protection Agency; Patricia M. Sparks, Glassboro State College; John E. Stanley, University of Virginia; Mel Stanley, California State Polytechnic University, Pomona; Richard Stevens, Monroe Community College; Norman R. Stewart, University of Wisconsin, Milwaukee; Frank E. Studnicka, University of Wisconsin, Platteville; Chris Tarp, Contra Costa College; Roger E. Thibault, Bowling Green State University; Nathan E. Thomas, University of South Dakota; William L. Thomas, California State University, Hayward; Shari Turney, copy editor; John D. Usis, Youngstown State University; Tinco E. A. van Hylckama, Texas Tech University; Robert R. Van Kirk, Humboldt State University; Donald E. Van Meter, Ball State University; Rick Van Schoik, San Diego State University; Gary Varner, Texas A&M University; John D. Vitek, Oklahoma State University; Harry A. Wagner, Victoria College; Lee B. Waian, Saddleback College; Warren C. Walker, Stephen F. Austin State

University; Thomas D. Warner, South Dakota State University; Kenneth E. F. Watt, University of California, Davis; Alvin M. Weinberg, Institute of Energy Analysis, Oak Ridge Associated Universities; Brian Weiss; Margery Weitkamp, James Monroe High School (Granada Hills, California); Anthony Weston, State University of New York at Stony Brook; Raymond White, San Francisco City College; Douglas Wickum, University of Wisconsin, Stout; Charles G. Wilber, Colorado State University; Nancy Lee Wilkinson, San Francisco State University; John C. Williams, College of San Mateo; Ray Williams, Rio Hondo College; Roberta Williams, University of Nevada, Las Vegas; Samuel J. Williamson, New York University; Dwina Willis, Freed-Hardeman University; Ted L. Willrich, Oregon State University; James Winsor, Pennsylvania State University; Fred Witzig, University of Minnesota at Duluth; Martha Wolfe, Elizabethtown Community and Technical College; George M. Woodwell, Woods Hole Research Center; Todd Yetter, University of the Cumberland; Robert Yoerg, Belmont Hills Hospital; Hideo Yonenaka, San Francisco State University; Brenda Young, Daemen College; Anita Závodská, Barry University; Malcolm J. Zwolinski, University of Arizona.

For Students

Students who can begin early in their lives to think of things as connected, even if they revise their views every year, have begun the life of learning.

Mark Van Doren

Why Is It Important to Study Environmental Science?

Welcome to **environmental science**—an *interdisciplinary* study of how the earth works, how we interact with the earth, and how we can deal with the environmental problems we face. Because environmental issues affect every part of your life, the concepts, information, and issues discussed in this book and the course you are taking will be useful to you now and throughout your life.

Understandably, we are biased, but *we strongly believe that environmental science is the single most important course that you could take*. What could be more important than learning about the earth's life-support system, how our choices and activities affect it, and how we can reduce our growing environmental impact? Evidence indicates strongly that we will have to learn to live more sustainably by reducing our degradation of the planet's life-support system. We hope this book and the learning opportunities available to you online will inspire you to become involved in this change in the way we view and treat the earth, which sustains us, our economies, and all other living things.

You Can Improve Your Study and Learning Skills

Maximizing your ability to learn involves trying to *improve your study and learning skills*. Here are some suggestions for doing so:

- **Develop a passion for learning.**
- **Get organized.**
- **Make daily to-do lists.** Put items in order of importance, focus on the most important tasks, and assign a time to work on these items. Shift your schedule as needed to accomplish the most important items.
- **Set up a study routine in a distraction-free environment.** Study in a quiet, well-lit space. Take breaks every hour or so. During each break, take several deep breaths and move around; this will help you to stay more alert and focused.
- **Avoid procrastination.** Do not fall behind on your reading and other assignments. Set aside a particular time for studying each day and make it a part of your daily routine.
- **Make hills out of mountains.** It is psychologically difficult to read an entire book, read a chapter in a book, write a paper, or cram to study for a test.

Instead, break these large tasks (mountains) down into a series of small tasks (hills). Each day, read a few pages of a book or chapter, write a few paragraphs of a paper, and review what you have studied and learned.

- **Ask and answer questions as you read.** For example, "What is the main point of a particular subsection or paragraph?" "How does it relate to the key question and key concepts addressed in each major chapter section?"
- **Focus on key terms.** Use the glossary in your textbook to look up the meaning of terms or words you do not understand. This book shows all key terms in **bold** type and lesser, but still important, terms in *italicized* type. The MindTap online edition of this text provides direct links to definitions for all bold-type terms. The *Chapter Review* questions at the end of each chapter also include the chapter's key terms in bold. Flash cards for testing your mastery of key terms for each chapter are available on the website for this book, or you can make your own.
- **Interact with what you read.** You could highlight key sentences and paragraphs and make notes in the margins. You might also mark important pages that you want to return to. The MindTap edition supports extensive note-taking features.
- **Review to reinforce learning.** Before each class session, review the material you learned in the previous session and read the assigned material.
- **Become a good note taker.** Learn to write down the main points and key information from any lecture using your own shorthand system. Review, fill in, and organize your notes as soon as possible after each class.
- **Check what you have learned.** At the end of each chapter, you will find review questions that cover all of the key material in each chapter section. We suggest that you try to answer each of these questions after studying each chapter section.
- **Write out answers to questions to focus and reinforce learning.** Write down your answers to the critical thinking questions found in the *Thinking About* boxes throughout the chapters, in many figure captions, and at the end of each chapter. These questions are designed to inspire you to think critically about key ideas and connect them to other ideas and to your own life. Also, write down your answers to all chapter-ending review questions. Additional quizzes can be found online as well. Save your answers for review and test preparation.
- **Use the buddy system.** Study with a friend or become a member of a study group to compare notes, review material, and prepare for tests. Explaining

something to someone else is a great way to focus your thoughts and reinforce your learning. Attend any review sessions offered by instructors or teaching assistants.

- **Learn your instructor's test style.** Does your instructor emphasize multiple-choice, fill-in-the-blank, true-or-false, factual, or essay questions? How much of the test will come from the textbook and how much from lecture material? Adapt your learning and studying methods to this style.
- **Become a good test taker.** Avoid cramming. Eat well and get plenty of sleep before a test. Arrive on time or early. Calm yourself and increase your oxygen intake by taking several deep breaths. (Do this also about every 10–15 minutes while taking the test.) Look over the test and answer the questions you know well first. Then work on the harder ones. Use the process of elimination to narrow down the choices for multiple-choice questions. For essay questions, organize your thoughts before you start writing. If you have no idea what a question means, make an educated guess. You might earn some partial credit and avoid getting a zero. Another strategy for getting some credit is to show your knowledge and reasoning by writing something like this: "If this question means so and so, then my answer is _____."
- **Take time to enjoy life.** Every day, take time to laugh and enjoy nature, beauty, and friendship.

You Can Improve Your Critical Thinking Skills

Critical thinking involves developing skills to analyze information and ideas, judge their validity, and make decisions. Critical thinking helps you to distinguish between facts and opinions, evaluate evidence and arguments, and take and defend informed positions on issues. It also helps you to integrate information and see relationships and to apply your knowledge to dealing with new and different problems, as well as to your own lifestyle choices. Here are some basic skills for learning how to think more critically.

- **Question everything and everybody.** Be skeptical, as any good scientist is. Do not believe everything you hear and read, including the content of this textbook, without evaluating the information you receive. Seek other sources and opinions.
- **Identify and evaluate your personal biases and beliefs.** Each of us has biases and beliefs taught to us by our parents, teachers, friends, role models, and our own experience. What are your basic beliefs, values, and biases? Where did they come from? What assumptions are they based on? How sure are you that your beliefs, values, and assumptions are right and why?

According to the American psychologist and philosopher William James, "A great many people think they are thinking when they are merely rearranging their prejudices."

- **Be open-minded and flexible.** Be open to considering different points of view. Suspend judgment until you gather more evidence, and be willing to change your mind. Recognize that there may be a number of useful and acceptable solutions to a problem and that very few issues are either black or white. Try to take the viewpoints of those you disagree with. Understand that there are trade-offs involved in dealing with any environmental issue, as you will learn in reading this book.
- **Be humble about what you know.** Some people are so confident in what they know that they stop thinking and questioning. To paraphrase American writer Mark Twain, "It's what we know is true, but just ain't so, that hurts us."
- **Find out how the information related to an issue was obtained.** Are the statements you heard or read based on firsthand knowledge and research or on hearsay? Are unnamed sources used? Is the information based on reproducible and widely accepted scientific studies or on preliminary scientific results that may be valid but need further testing? Is the information based on a few isolated stories or experiences or on carefully controlled studies that have been reviewed by experts in the field involved? Is it based on unsubstantiated and dubious scientific information or beliefs?
- **Question the evidence and conclusions presented.** What are the conclusions or claims based on the information you're considering? What evidence is presented to support them? Does the evidence support them? Is there a need to gather more evidence to test the conclusions? Are there other, more reasonable conclusions?
- **Try to uncover differences in basic beliefs and assumptions.** On the surface, most arguments or disagreements involve differences of opinion about the validity or meaning of certain facts or conclusions. Scratch a little deeper and you will find that many disagreements are based on different (and often hidden) basic assumptions concerning how we look at and interpret the world around us. Uncovering these basic differences can allow the parties involved to understand one another's viewpoints and to agree to disagree about their basic assumptions, beliefs, or principles.
- **Try to identify and assess any motives on the part of those presenting evidence and drawing conclusions.** What is their expertise in this area? Do they have any unstated assumptions, beliefs, biases, or values? Do they have a personal agenda? Can they

benefit financially or politically from acceptance of their evidence and conclusions? Would investigators with different basic assumptions or beliefs take the same data and come to different conclusions?

- **Expect and tolerate uncertainty.** Recognize that scientists cannot establish absolute proof or certainty about anything. However, the reliable results of science have a high degree of certainty.
- **Check the arguments you hear and read for logical fallacies and debating tricks.** Here are six of many examples of such debating tricks: *First*, attack the presenter of an argument rather than the argument itself. *Second*, appeal to emotion rather than facts and logic. *Third*, claim that if one piece of evidence or one conclusion is false, then all other related pieces of evidence and conclusions are false. *Fourth*, say that a conclusion is false because it has not been scientifically proven (scientists never prove anything absolutely, but they can often establish high degrees of certainty). *Fifth*, inject irrelevant or misleading information to divert attention from important points. *Sixth*, present only either/or alternatives when there may be a number of options.
- **Do not believe everything you read on the Internet.** The Internet is a wonderful and easily accessible source of information that includes alternative explanations and opinions on almost any subject or issue—much of it not available in the mainstream media and scholarly articles. Blogs of all sorts have become a major source of information, even more important than standard news media for some people. However, because the Internet is so open, anyone can post anything they want to some blogs and other websites with no editorial control or review by experts. As a result, evaluating information on the Internet is one of the best ways to put into practice the principles of critical thinking discussed here. Use and enjoy the Internet, but think critically and proceed with caution.
- **Develop principles or rules for evaluating evidence.** Develop a written list of principles to serve as guidelines for evaluating evidence and claims. Continually evaluate and modify this list on the basis of your experience.
- **Become a seeker of wisdom, not a vessel of information.** Many people believe that the main goal of their education is to learn as much as they can by gathering more and more information. We believe that the primary goal is to learn how to sift through mountains of facts and ideas to find the few *nuggets of wisdom* that are especially useful for understanding the world and for making decisions. This book is full of facts and numbers, but they are useful only to the extent that they lead to an understanding of key ideas, scientific laws, theories, concepts, and connections. The major

goals of the study of environmental science are to find out how nature works and sustains itself (*environmental wisdom*) and to use *principles of environmental wisdom* to help make human societies and economies more sustainable, more just, and more beneficial and enjoyable for all. As writer Sandra Carey observed, “Never mistake knowledge for wisdom. One helps you make a living; the other helps you make a life.”

To help you practice critical thinking, we have supplied questions throughout this book, found within each chapter in brief boxes labeled *Thinking About*, in the captions of many figures, and at the end of each chapter. There are no right or wrong answers to many of these questions. A good way to improve your critical thinking skills is to compare your answers with those of your classmates and to discuss how you arrived at your answers.

Use the Learning Tools We Offer in This Book

We have included a number of tools throughout this textbook that are intended to help you improve your learning skills and apply them. First, consider the *Key Questions* list at the beginning of each chapter section. You can use these to preview a chapter and to review the material after you’ve read it.

Next, note that we use three different special notations throughout the text. Each chapter opens with a **Core Case Study**, and each time we tie material within the chapter back to this core case, we note it in bold, colored type as we did in this sentence. You will also see two icons appearing regularly in the text margins. When you see the *sustainability* icon, you will know that you have just read something that relates directly to the overarching theme of this text, summarized by our six **principles of sustainability**, which are introduced in Figures 1-2, p. 6, and 1-5, p. 9, and which appear on the back cover of the student edition. The *Good News* icon appears near each of many examples of successes that people have had in dealing with the environmental challenges we face.

We also include several brief *Connections* boxes to show you some of the often surprising connections between environmental problems or processes and some of the products and services we use every day or some of the activities we partake in. These, along with the *Thinking About* boxes scattered throughout the text (both designated by the *Consider This...* heading), are intended to get you to think carefully about activities and choices we take for granted and how they might be affecting the environment.

At the end of each chapter, we list what we consider to be the *three big ideas* that you should take away from the chapter. Following that list in each chapter is a *Tying It All Together* box. This feature quickly reviews the Core Case Study and how chapter material relates to it, and it explains how the principles of sustainability can be

