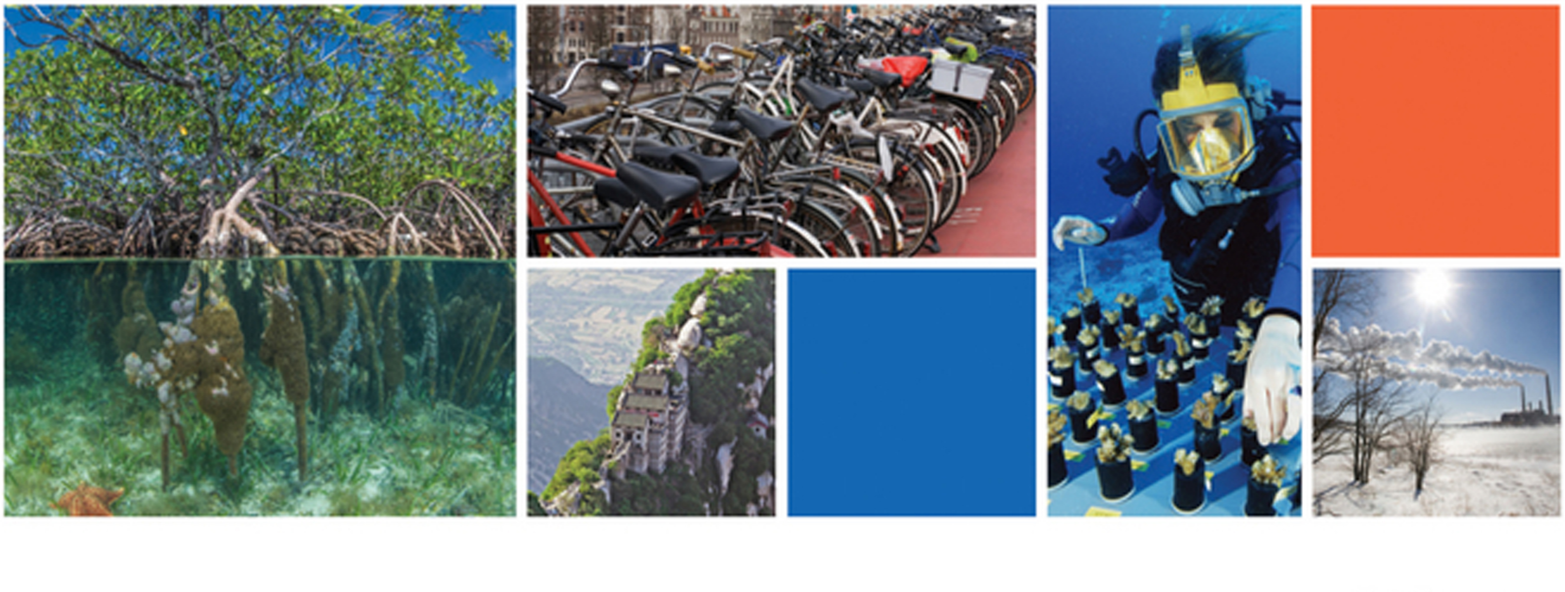
VISUALIZING Environmental Science

FIFTH EDITION

DAVID M. HASSENZAHL • MARY CATHERINE HAGER • LINDA R. BERG



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ENVIRONMENTAL SCIENCE

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David M. Hassenzahl
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WILEY

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This book was set in Baskerville by codeMantra, and printed and bound by Quad/Graphics. The cover was printed by Quad/Graphics.

ePUB ISBN: 9781119279167

The inside back cover will contain printing identification and country of origin if omitted from this page. In addition, if the ISBN on the back cover differs from the ISBN on this page, the one on the back cover is correct.

Printed in the United States of America
10 9 8 7 6 5 4 3 2 1

Preface

How Is Wiley Visualizing Different?

Wiley Visualizing differs from competing textbooks by uniquely combining two powerful elements: visual pedagogy integrated with a comprehensive text, and the inclusion of interactive multimedia through "WileyPLUS Learning Space." Together these elements deliver rigorous content using methods that engage students with the material. Each key concept is supported by supporting data, images, text, and diagrams that are crafted to maximize student learning.

(1) Visual Pedagogy. Wiley Visualizing is based on decades of research on the use of visuals in learning.[1] Using the cognitive theory of multimedia learning, which is backed up by hundreds of empirical research studies, Wiley's authors select relevant visualizations and graphical displays of information for their texts that specifically support students' thinking and learning, then organize the updated content to integrate the new knowledge with prior knowledge. Visuals and text are conceived and planned together in ways that clarify and reinforce major concepts while allowing students to understand the details. This commitment to distinctive and consistent visual pedagogy sets Wiley Visualizing apart from other textbooks.

(2) Interactive Multimedia. Wiley Visualizing is based on the understanding that learning is an active process of knowledge construction. *Visualizing Environmental Science, Fifth Edition* is therefore tightly integrated with multimedia activities provided in "WileyPLUS Learning Space."

Wiley Visualizing Is Designed As a Natural Extension of How We Learn

Visuals, comprehensive text, and learning aids are integrated to display facts, concepts, processes, and principles more effectively than words alone can. To understand why the Wiley Visualizing approach is effective, it is first helpful to understand how we learn.

1. Our brain processes information using two channels: visual and verbal. Our *working memory* holds information that our minds process as we learn. In working memory we begin to make sense of words and pictures, and build verbal and visual models of the information.
2. When the verbal and visual models of corresponding information are connected in working memory, we form more comprehensive, or integrated, mental models.
3. When we link these integrated mental models to our prior knowledge, which is stored in our *long-term memory*, we build even stronger mental models. When an integrated mental model is formed and stored in long-term memory, real learning begins.

The effort our brains put forth to make sense of instructional information is called *cognitive load*. There are two kinds of cognitive load: productive cognitive load, such as when we're engaged in learning or exert positive effort to create mental models, and unproductive cognitive load, which occurs when the brain is trying to make sense of needlessly complex content or when information is not presented well. The learning process can be impaired when the amount of information to be processed exceeds the capacity of working memory. Well-designed visuals and text with effective pedagogical guidance can reduce the unproductive cognitive load in our working memory.

[1] Mayer, R.E. (Ed.) 2005. *The Cambridge Handbook of Multimedia Learning*. New York: Cambridge University Press.

Wiley Visualizing Is Designed for Engaging and Effective Learning

The visuals and text in *Visualizing Environmental Science, Fifth Edition* are specially integrated to present complex processes in clear steps and with compelling representations, organize related pieces of information, and integrate related information sources. This approach, along with the use of interactive multimedia, minimizes unproductive cognitive load and helps students engage with the content. When students are engaged, they are storing information in long-term memory, and thinking critically about both new information and their previous beliefs. This leads to better thinking, greater knowledge, and ultimately academic success.

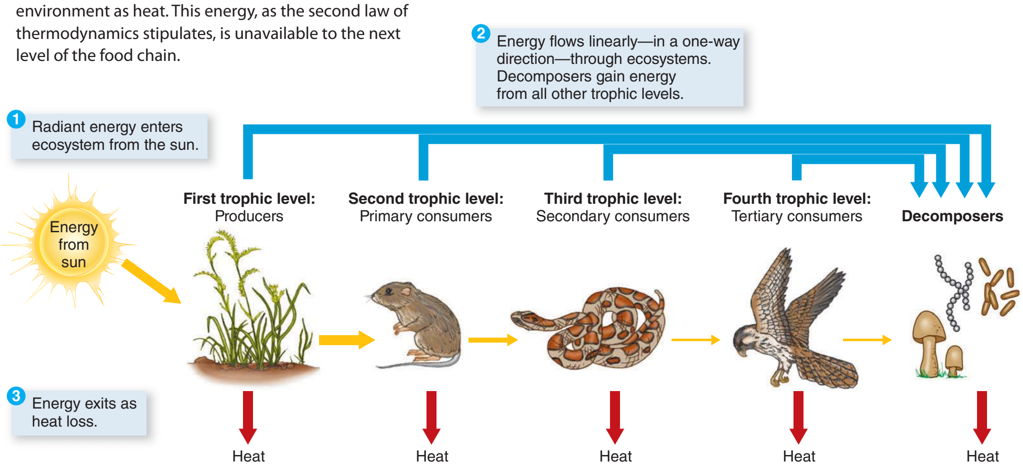
Research shows that well-designed visuals, integrated with comprehensive text, can improve the efficiency with which a learner processes information. In this regard, SEG Research, an independent research firm, conducted a national, multisite study evaluating the effectiveness of Wiley Visualizing. Its findings indicate that students using Wiley Visualizing products (both print and multimedia) were more engaged in the course, exhibited greater retention throughout the course, and made significantly greater gains in content area knowledge and skills, as compared to students in similar classes that did not use Wiley Visualizing.[2]

PROCESS DIAGRAM

THE PLANNER

Energy flow through a food chain • Figure 5.5

Much of the energy acquired by a given level of a food chain is used and escapes into the surrounding environment as heat. This energy, as the second law of thermodynamics stipulates, is unavailable to the next level of the food chain.



Think Critically Which level of consumers gains the lowest percentage of the sun's original energy input per organism consumed? Why?

[2] SEG Research. 2009. "Improving Student-Learning with Graphically-Enhanced Textbooks: A Study of the Effectiveness of the Wiley Visualizing Series." Available online at www.segmeasurement.com.

What Is the Organization of This Book?

We begin *Visualizing Environmental Science 5e* with an introduction of the environmental dilemmas we face in our world today, emphasizing particularly how unchecked population growth and economic inequity complicate our ability to solve these problems. We stress that solutions rest in understanding the science underlying these problems. They also require creativity and diligence at all levels, from individual commitment to international cooperation. Indeed, a key theme integrated throughout the fifth edition is the local to global scales of environmental science. We offer concrete suggestions that students can adopt to make their own difference in solving environmental problems, and we explain the complications that arise when solutions are tackled on a local, regional, national, or global scale.

Yet *Visualizing Environmental Science 5e* is not simply a checklist of "to do" items to save the planet. In the context of an engaging visual presentation, we offer solid discussions of such critical environmental concepts as sustainability, conservation and preservation, and risk analysis. We weave the threads of these concepts throughout our treatment of ecological principles and their application to various ecosystems, the impacts of human population change, and the problems associated with our use of the world's resources. We particularly instruct students in the importance of ecosystem services to a functioning world, and the threats that restrict our planet's ability to provide such services.

This text is intended to provide introductory content primarily for nonscience undergraduate students. The accessible format of *Visualizing Environmental Science 5e*, coupled with our assumption that students have little prior knowledge of environmental sciences, allows students to easily make the transition from jumping-off points in the early chapters to the more complex concepts they encounter later. With its interdisciplinary presentation, which mirrors the nature of environmental science itself, this book is appropriate for use in one-semester and one-quarter environmental science courses offered by a variety of departments, including environmental studies and sciences, biology, ecology, agriculture, earth sciences, and geography.

Visualizing Environmental Science 5e is organized around the premise that humans are inextricably linked to the world's environmental dilemmas. Understanding how different parts of Earth's systems change, and how those changes affect other parts and systems, prepares us to make better choices as we deal with environmental problems we encounter everyday in the media and our lives.

- Chapters 1 through 4 establish the groundwork for understanding the environmental issues we face, how science can inform our decisions from the individual to global scales, how environmental sustainability and human values play a critical role in addressing these issues, how the environmental movement developed over time and was shaped by economics, and how environmental threats from many sources create health hazards that must be evaluated.
- Chapters 5, 6, and 7 present the intricacies of ecological concepts in a human-dominated world, including energy flow and the cycling of matter through ecosystems, and the various ways that species interact and divide resources. Gaining familiarity with these concepts allows students to better appreciate the variety of terrestrial and aquatic ecosystems that are then introduced, and to develop a richer understanding of the implications of human population change for the environment.
- The remaining 11 chapters deal with the world's resources as we use them today and as we assess their availability and impacts for the future. These issues cover a broad spectrum, including the sources and effects of air pollution, climate and global atmospheric change, freshwater resources, causes and effects of water pollution, the ocean and fisheries, mineral and soil resources, land resources, agriculture and food resources, biological resources, solid and hazardous waste, and nonrenewable and renewable energy resources. Recognizing the importance of the global ocean to environmental issues, we are particularly pleased to dedicate an entire chapter to a discussion of ocean processes and resources.

New to This Edition

In this edition, the authors have further developed graphical representations of information. This includes additional graphs and tables throughout the text. Each chapter opens with a representative story that includes prose, compelling imagery, and a visual display of information. A challenging question about the story engages the reader in the chapter's topic.

To actively encourage students to synthesize and apply content, "Sustainable Citizen" questions at the end of each chapter challenge students to examine how their own practices and beliefs might affect the local and global environment, or be applied to implementing solutions to environmental problems. A few examples of new material in this edition include:

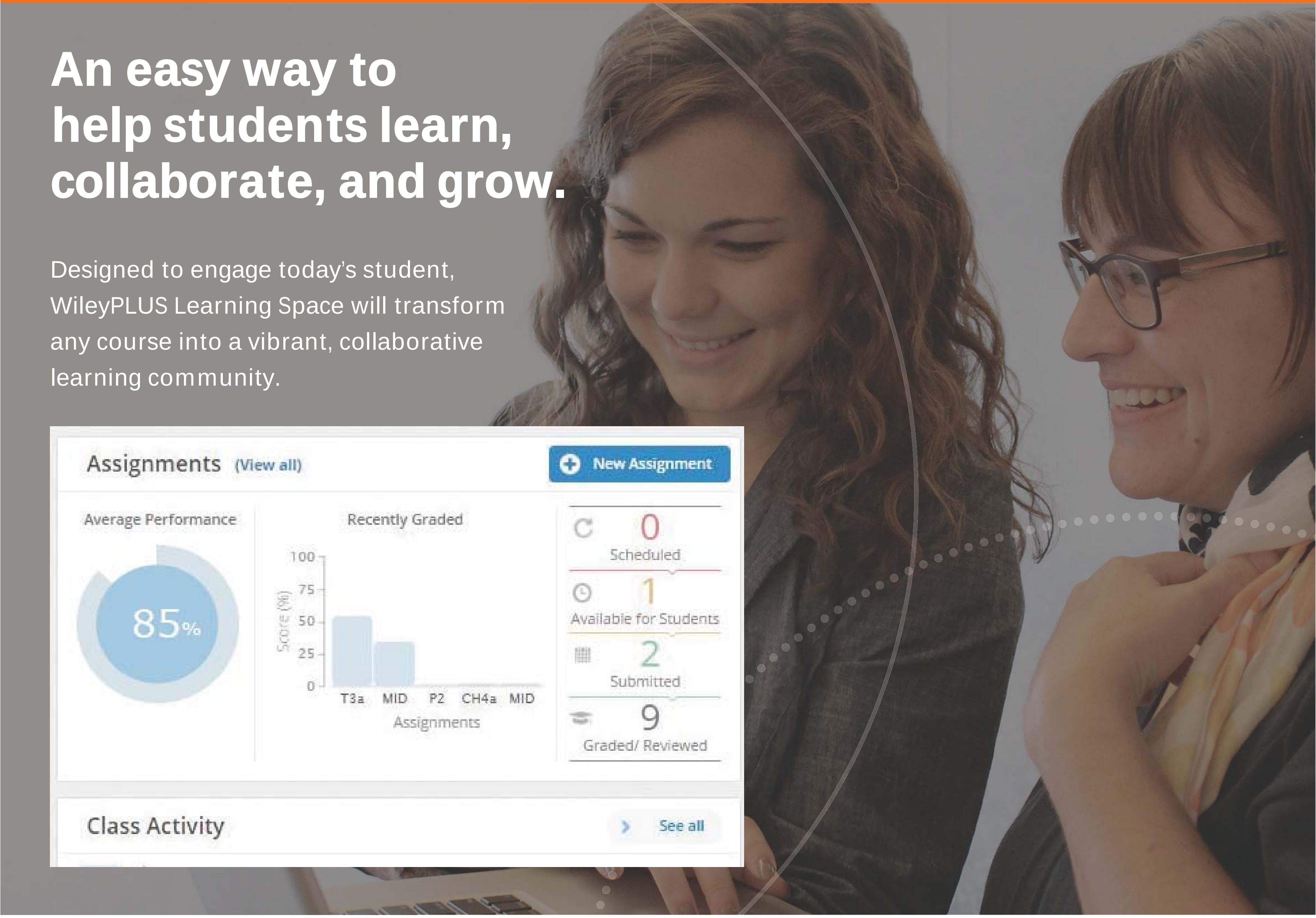
- A greatly updated chapter on food resources, to reflect increased awareness of the impact of the environment on food production and food production on the environment.
- A new chapter opener on the energy embedded in every vehicle on the road.
- An EnviroDiscovery feature exploring the idea of deep retrofits to reduce the energy demand of a residence.
- Chapter-wide updates evaluating human impacts on the ocean and global fisheries, and assessing efforts to preserve and protect marine resources.
- A new chapter opener exploring a groundbreaking approach to wildlife conservation in Africa.
- New WileyPLUS Learning Space course. WileyPLUS Learning Space is an online teaching and learning platform that helps students learn, collaborate, and grow, and helps instructors diagnose student progress, facilitate engagement, and measure outcomes.
- New Interactive Graphics (three to five per chapter). Interactive Graphics engage students by presenting processes, relationships, data, and layers in a dynamic fashion, all controllable by the student. Instead of skipping quickly over static images, students explore Interactive Graphics in ways that allow them to see how the parts relate to the whole, visualize data, build processes, and relate elements to each other.

Finally, recognizing the educational value of integrating text with graphics and imagery, we have focused on improving the quality of process diagrams and have continued to revise our art program, layout, and design to provide students with a visually stunning, content-rich, image-based learning experience.

WileyPLUS Learning Space

An easy way to help students learn, collaborate, and grow.

Designed to engage today's student, WileyPLUS Learning Space will transform any course into a vibrant, collaborative learning community.



Identify which students are struggling early in the semester.

Educators assess the real-time engagement and performance of each student to inform teaching decisions. Students always know what they need to work on.

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Measure outcomes to promote continuous improvement.

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Instructor's Support

Instructor's Manual *(Available in WileyPLUS and on the book companion site)*

Answers to the Think Critically, Interpreting Data, Concept Check, Global–Local, and Critical and Creative Thinking questions that appear in the printed text are available in an Instructor's Manual created by John LaMassa, of Iona College. There is also an In-Class Activities Instructor's Manual available for each chapter.

Test Bank *(Available in WileyPLUS and on the book companion site)*

Many visuals from the textbook are also included in the Test Bank by Keith Hench of Kirkwood Community College. The Test Bank has approximately 1400 test items, with at least 25% of them incorporating visuals from the book. The test items include multiple choice, true/false, text entry, and essay questions that test a variety of comprehension levels.

Clicker Questions *(Available in WileyPLUS Learning Space and on the book companion site)*

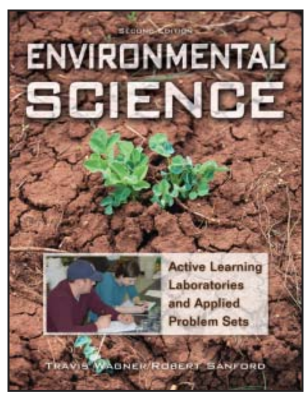
Clicker questions, written by Julie Weinert, of Southern Illinois University, Carbondale, are available as Microsoft Word files, and can be converted to appropriate clicker formats upon request.

Lecture PowerPoints, Image PowerPoints, and Image Gallery

A complete set of highly visual PowerPoint presentations—one per chapter—authored by Erica Kipp, of Pace University, and Janet Wolkenstein, of Hudson Valley Community College, is available to enhance classroom presentations. Tailored to the text's topical coverage and learning objectives, these presentations are designed to convey key text concepts, illustrated by embedded text art.

All photographs, figures, maps, and tables from the text are available within an Image Gallery as jpgs and PowerPoints, and can be used as you wish in the classroom. These electronic files allow you to easily incorporate images into your own PowerPoint presentations as you choose, or to create your own handouts.

ALSO AVAILABLE



Environmental Science: Active Learning Laboratories and Applied Problem Sets, 2e by Travis Wagner and Robert Sanford, both of the University of Southern Maine, presents specific labs that use natural and social science concepts and encourages a "hands-on" approach to evaluating the impacts from the environmental/human interface. The laboratory and ***homework activities are designed to be low cost and to reflect a sustainable approach*** in both practice and theory. *Environmental Science: Active Learning Laboratories and Applied Problem Sets, 2e* is available as a stand-alone, in a package with, or customized with *Visualizing Environmental Science 5e*. Contact your Wiley representative for more information.

Climate Change: What the Science Tells Us by Charles Fletcher discusses the most recent research focusing on the causes and effects of climate change and offers strategies to help learners understand why and how scientists have come to this conclusion. This book can be packaged or customized with *Visualizing Environmental Science, 5e*.

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Special Thanks

We are extremely grateful to the many members of the editorial and production staff at John Wiley and Sons who guided us through the challenging steps of developing this book. Their tireless enthusiasm, professional assistance, and endless patience smoothed the path as we found our way. We thank in particular Sponsoring Editor Jennifer Yee, who expertly directed the revision with a steady hand; Clay Stone, Senior Marketing Manager, for a superior marketing effort; and Mili Ali, Market Solutions Assistant, for her attention to detail throughout our revision process. Thanks also to Development Editor Melissa Edwards Whelan and Associate Product Designer Lauren Elfers for their skilled and insightful work in developing our *WileyPLUS* course as well as the other media components. Thanks to Developmental Editor/Art Developer Kathy Naylor for her invaluable help in keeping our editorial efforts on track and her dedication to developing new graphics. We also thank John Duval, Production Editor, and Trish McFadden, Senior Production Editor, for helping us through the production process. We thank Senior Photo Editor Mary Ann Price for her unflagging, always swift work in researching and obtaining many of our text images. We thank Tom Nery for our striking interior design and for our stunning new cover. Thank you to Petra Recter, Vice President and Director, for providing guidance and support to the rest of the team throughout the revision.

About the Authors

Photo by Jason A. Halley. Courtesy of California State University, Chico

David M. Hassenzahl is the Dean of the College of Natural Sciences at the California State University at Chico. An internationally recognized scholar of sustainability and risk analysis, his research focuses on incorporating scientific information and expertise into public decision. He holds a B.A. in Environmental Science and Paleontology from the University of California at Berkeley, and a Ph.D. from Princeton University's Woodrow Wilson School. His efforts in climate change education have been supported by the National Science Foundation, and recognition of his work includes the Society for Risk Analysis Outstanding Educator Award and the UNLV Foundation Distinguished Teaching Award. Dr. Hassenzahl is a Senior Fellow of the National Council for Science and the Environment, a Fellow of the Society for Risk Analysis, and president of the Association of Environmental Studies and Sciences. Prior to his academic career, Dr. Hassenzahl worked in the private sector as an environmental manager, and as an inspector for the (San Francisco) Bay Area Air Quality Management District.

Mary Catherine Hager is a professional science writer and editor specializing in life and earth sciences. She received a double-major B.A. in environmental science and biology from the University of Virginia and an M.S. in zoology from the University of Georgia. Ms. Hager worked as an editor for an environmental consulting firm and as a senior editor for a scientific reference publisher. For more than 20 years she has written and edited for environmental science, biology, and ecology textbooks for high school and college. Additionally, she has published articles in environmental trade magazines and edited federal and state reports addressing wetlands conservation issues. Her writing and editing pursuits are a natural outcome of her scientific training and curiosity, coupled with her love of reading and effective communication.

Linda R. Berg is an award-winning teacher and textbook author. She received a B.S. in science education, an M.S. in botany, and a Ph.D. in plant physiology from the University of Maryland. Dr. Berg taught at the University of Maryland—College Park for 17 years and at St. Petersburg College in Florida for 8 years. She has taught introductory courses in environmental science, biology, and botany to thousands of students and has received numerous teaching and service awards. Dr. Berg is also the recipient of many national and regional awards, including the National Science Teachers Association Award for Innovations in College Science Teaching, the Nation's Capital Area Disabled Student Services Award, and the Washington Academy of Sciences Award in University Science Teaching. During her career as a professional science writer, Dr. Berg has authored or co-authored numerous editions of several leading college science textbooks. Her writing reflects her teaching style and love of science.

Contents in Brief

Contents

InSight Features

These multipart visual presentations focus on a key concept or topic in the chapter.

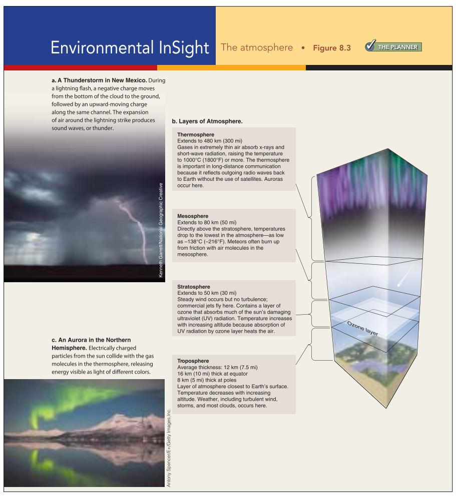
Chapter 1
Population Growth and Poverty • Environmental Exploitation

Chapter 2
A Plan for Sustainable Living

Chapter 3
Economics and the Environment

Chapter 4
Bioaccumulation and Biomagnification

Chapter 5
Symbiotic Relationships



Chapter 6
How Climate Shapes Terrestrial Biomes • Evidence for Evolution

Chapter 7
Demographics of Countries

Chapter 8
The Atmosphere

Chapter 9
The Effects of Global Climate Change • The Ozone Layer • The Effects of Acid Deposition

Chapter 10
Water Conservation

Chapter 11
Ocean Currents • Human Impacts on the Ocean

Chapter 12
Soil Conservation

Chapter 13
Tropical Deforestation • National Parks

Chapter 14
World Hunger • Impacts of Industrialized Agriculture

Chapter 15
Threats to Biodiversity • Efforts to Conserve Species

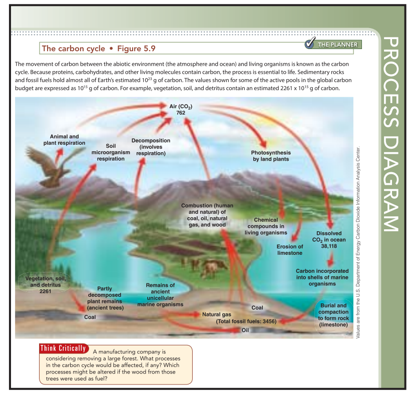
Chapter 16
Recycling in the United States

Chapter 17
The *Exxon Valdez* and *Deepwater Horizon* Oil Spills

Chapter 18
Wind Energy

Process Diagrams

These series or combinations of figures and photos describe and depict a complex process.



Chapter 1
The Scientific Method • Addressing Environmental Problems

Chapter 2
Cascading Responses of Increased Carbon Dioxide Through the Environment

Chapter 3
Environmental Impact Statements

Chapter 4
Four Steps for Risk Assessment

Chapter 5
Energy Flow Through a Food Chain • Food Web at the Edge of an Eastern U.S. Deciduous Forest • The Carbon Cycle • The Hydrologic Cycle • The Nitrogen Cycle • The Sulfur Cycle • The Phosphorus Cycle

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Darwin's Finches • Primary Succession on Glacial Moraine • Secondary Succession on an Abandoned Field in North Carolina

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Chapter 9
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Chapter 10
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Chapter 11
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Chapter 12
The Rock Cycle

Chapter 13
Role of Forests in the Hydrologic Cycle

Chapter 14
Energy Inputs in Industrialized Agriculture • Genetic Engineering

Chapter 16
Mass Burn, Waste-to-Energy Incinerator • Integrated Waste Management

Chapter 17
Petroleum Refining • Nuclear Fission • Pressurized Water Reactor

Chapter 18
Active Solar Water Heating

1 The Environmental Challenges We Face

A RAPIDLY CHANGING WORLD

Over three billion years ago, just before the first life forms arose, Earth's surface and climate were inhospitable by modern standards, but contained abundant raw materials. Early life forms used the sun's energy to exploit Earth's resources. Over Earth's history, organisms have shaped the landscape, altered the global climate, and modified the chemical makeup of the ocean and soils. The environments found around the globe now reflect billions of years of change, and those environments will continue to change.

Today, humans are the dominant agent of environmental change on our planet, altering it more rapidly and in more ways than any other species ever has. We have developed technology to venture into space, allowing us a view of the uniqueness of our planet in the solar system (see photograph). However, our burgeoning population is overwhelming Earth's regenerative capacity. We have transformed forests, prairies, watersheds, ocean fisheries, and deserts. We consume ever-increasing amounts of Earth's abundant but finite resources—rich topsoil, clean water, and breathable air. Our activities have disrupted habitats of thousands upon thousands of other species. In 2015, the International Union for the Conservation of Nature classified 22,784 species worldwide as threatened (see insert).

Our activities impact Earth systems, including climate and nutrient cycles, from the local to the global level. What remains unclear is Earth's capacity to support a high quality of life for the billions of people who live on it now and will be born in the future. Making choices and policies to ensure human well-being requires that we understand Earth systems and how we change them.

Based on data from International Union for Conservation of Nature 2015. Red List of Endangered Species.

NASA/NG Image Collection

CHAPTER OUTLINE

CHAPTER PLANNER

- ❑ Study the picture and read the opening story.
- ❑ Scan the Learning Objectives in each section:
  p. 4 ❑ p. 12 ❑ p. 16 ❑ p. 20 ❑
- ❑ Read the text and study all figures and visuals. Answer any questions.

Analyze key features

- ❑ Environmental InSight, p. 5 ❑ p. 13 ❑
- ❑ EnviroDiscovery 1.1, 1.2, p. 8 ❑ p. 22 ❑
- ❑ Process Diagram, p. 19 ❑ p. 21 ❑
- ❑ Case Study 1.1, p. 23
- ❑ Stop: Answer the Concept Checks before you go on:
  p. 11 ❑ p. 12 ❑ p. 20 ❑ p. 21 ❑

End of Chapter

- ❑ Review the Summary and Key Terms.
- ❑ Answer What is happening in this picture?
- ❑ Answer the Critical and Creative Thinking Questions.

Human Impacts on the Environment

LEARNING OBJECTIVES

1. **Distinguish** among highly developed countries, moderately developed countries, and less developed countries.
2. **Relate** human population size to natural resources and resource consumption.
3. **Describe** the three factors that are most important in determining human impact on the environment.

The satellite photograph in **Figure 1.1a** is a portrait of about 450 million people. The tiny specks of light represent cities, and the great metropolitan areas, such as New York City along the northeastern seacoast, are ablaze with light. This represents the most significant factor impacting the health of Earth's environment: a large and growing human population.

In 2015 the human population as a whole passed 7.3 billion individuals, and this growth has been very rapid. In 1960 the human population was only 3 billion (**Figure 1.1b**). By 1975 there were 4 billion people, and by 1987 there were 5 billion. The more than 7 billion people who currently inhabit our planet consume vast quantities of food and water, occupy or farm much of the most productive land, use a great deal of energy and raw materials, and produce much waste.

Despite most countries' involvement with family planning, population growth rates don't change overnight. Several billion people will be added to the world in the 21st century, so even if we remain concerned about population and even if our solutions are very effective, the coming decades may very well see many problems.

Globally, about 1.5 billion individuals live in multidimensional **poverty** (**Figure 1.1c**). While poverty can be measured by income alone, multidimensional poverty includes such factors as income, access to education, and local environmental quality. Poverty is associated with a short life expectancy, illiteracy, and inadequate access to health services, safe water, and balanced nutrition. Worldwide, poverty is decreasing, but remains sensitive to environmental degradation.

> **poverty** A condition in which people are unable to meet their basic needs for food, clothing, shelter, education, or health.
>
> **highly developed countries** Countries with complex industrialized bases, low rates of population growth, and high per person incomes.

The world population may stabilize toward the end of the 21st century, driven by policy and cultural factors. Population experts at the Population Reference Bureau have noticed a decrease in the fertility rate worldwide to a current average of 2.5 children per woman, and the fertility rate is projected to continue to decline in coming decades.

The fertility rate varies from country to country, from 1.7 in highly developed countries to 4.5 in some of the least developed countries. Population experts have made various projections for the world population at the end of the 21st century, from about 7.7 billion to 10.6 billion, depending primarily on how fast the fertility rate decreases.

No one knows whether Earth can support so many people indefinitely. Finding ways for it to do so represents one of the greatest challenges of our times. Among the tasks to be accomplished is feeding a world population considerably larger than today's without destroying the biological communities that support life on our planet. The quality of life available to our children and grandchildren will depend to a large extent on our ability to develop a sustainable system of agriculture to feed the world's people.

A factor as important as population size is a population's level of **consumption**, which is the human use of material and energy. Consumption is intimately connected to a country's **economic growth**, the expansion in output of a nation's goods and services. The world's economy is growing at an enormous rate, yet this growth is unevenly distributed across the nations of the world.

The Gap Between Rich and Poor Countries

Generally speaking, countries are divided into rich (the "haves") and poor (the "have-nots"). Rich countries are known as **highly developed countries**. The United States, Canada, most of Europe, and Japan, which represent about

Environmental InSight

Population growth and poverty • Figure 1.1

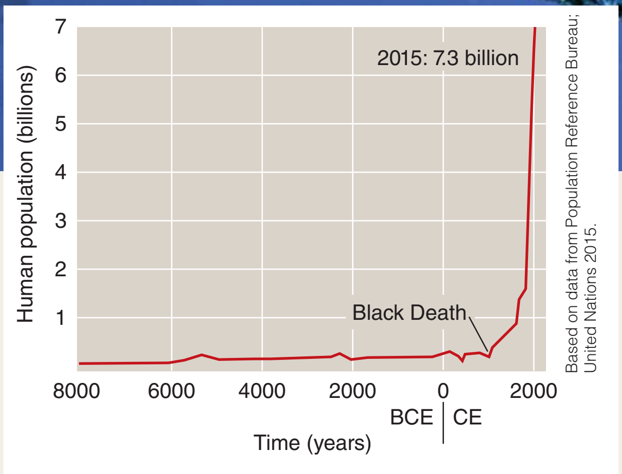
THE PLANNER

Earth Imaging/Stone/Getty Images

a. Satellite View of North America at Night.
This image shows most major cities and metropolitan areas in the United States, Mexico, and Canada.

GLOBAL LOCAL

Many of the world's poor people lack access to adequate sanitation, cooking and heating fuel, clean drinking water, health care, suitable housing, and enough food. Which two of these inadequacies would be most critical for poor people in a developing country like India? For poor people in a highly developed country like the United States? Are your answers different? Why or why not?



b. Human Population Growth.
It took thousands of years for the human population to reach 1 billion (in 1800). In 2015, Earth's human population surpassed 7 billion. (Black Death refers to a devastating disease, probably bubonic plague, that decimated Europe and Asia in the 14th century.)

M. Lourdes Siracuza Cappi/mlsiraci/Flickr/Getty Images Inc

c. Poverty.
While Brazil's economy has developed substantially over the past decade, many residents continue to live in deep poverty in favelas (slums) like this one near São Paulo. Note the luxury hotels in the background.

Consumption of natural resources • Figure 1.2

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a. A typical Japanese family, from Tokyo, with their possessions. People in highly developed countries consume a disproportionate share of natural resources.

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b. A typical Mexican family, from Guadalajara, with their possessions. Economic development in this moderately developed country has allowed many people to enjoy a middle-class lifestyle. Other Mexicans live in poverty, however.

18 percent of the world's population, are highly developed countries (Figure 1.2a).

Poor countries, in which about 82 percent of the world's population live, fall into two subcategories: moderately developed and less developed. Turkey, South Africa, Thailand, and Mexico are examples of **moderately developed countries** (MDCs) (Figure 1.2b). People living in MDCs have fewer opportunities for income, education, and health care than people living in highly developed countries.

Examples of **less developed countries** (LDCs) include Haiti, Bangladesh, Rwanda, Laos, Ethiopia, and Mali (Figure 1.2c). Cheap, unskilled labor is abundant in LDCs, but capital for investment is scarce. To improve their economic conditions, many LDCs must borrow money from banks in highly developed countries. Most economies of LDCs are agriculturally based, often relying on only one or a few crops. As a result, crop failure or a low world market value for that crop is catastrophic to the economy. Hunger, disease, and illiteracy are common in LDCs.

moderately developed countries Countries with medium levels of industrialization and per person incomes lower than those of highly developed countries.

less developed countries Countries with low levels of industrialization, very high rates of population growth, very high infant mortality rates, and very low per person incomes relative to highly developed countries.

Population, Resources, and the Environment

Inhabitants of the United States and other highly developed countries consume many more resources per person than do citizens of developing countries. This high rate of resource consumption affects the environment at least as much as the rapid population growth that is occurring in other parts of the world. China and India, the world's most populous countries, include many of the world's poorest people, a growing middle class, and a few of the world's wealthiest people. Both countries have growing populations and expanding economies.

We can make two useful generalizations about the relationships among population growth, consumption of natural resources, and environmental degradation. First, the amount of resources essential to an individual's survival is small, but rapid population growth (often found in developing countries) tends to overwhelm and deplete a country's soils, forests, and other natural resources. Second, in highly developed nations, individual demands

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c. A typical family from Kouakourou, Mali, with all their possessions. The rapidly increasing number of people in less developed countries overwhelms their natural resources, even though individual resource requirements may be low.

on natural resources are far greater than the requirements for mere survival. To satisfy their desires as well as their basic needs, many people in more affluent nations deplete resources and degrade the global environment through increased consumption of energy (through such uses as heating, transportation, and manufacturing), material goods (such as cars, televisions, and cellular phones), and agricultural products (including food, animal feed, and wood products). An increase in urban agriculture in highly developed countries is an example of a local solution to this sort of problem (see *EnviroDiscovery* 1.1).

Types of Resources When examining the effects of population on the environment, it is important to distinguish between nonrenewable and renewable natural resources. **Nonrenewable resources** include minerals (such as silicon, iron, and copper) and fossil fuels (coal, oil, and natural gas). Natural processes do not replenish nonrenewable resources within a reasonable duration on the human timescale. Fossil fuels, for example, take millions of years to form.

nonrenewable resources Natural resources that are present in limited supplies and are depleted as they are used.

In addition to a nation's population and its level of resource use, several other factors affect the way nonrenewable resources are used—including how efficiently the resource is extracted and processed and how much of it is required or consumed. Nonetheless, the inescapable fact is that Earth has a finite supply of nonrenewable resources that sooner or later will be exhausted. In time, technological advances may help find or develop substitutes for nonrenewable resources. Slowing the rate of population growth and resource consumption will help us buy time to develop such alternatives.

Some examples of **renewable resources** are trees, fishes, fertile agricultural soil, and fresh water. Nature replaces these resources fairly rapidly, on a scale of days to decades. Forests, fisheries, and agricultural land are particularly important renewable resources in developing countries because they provide food. Indeed, many people in developing countries are subsistence farmers who harvest just enough food for their families to survive.

renewable resources Resources that are replaced by natural processes and that can be used forever, provided they are not overexploited in the short term.

Rapid population growth can cause renewable resources to be overexploited. For example, large numbers of poor people must grow crops on land—such as mountain slopes or tropical rain forests—that is poorly suited for farming. Although this practice may provide a short-term solution to the need for food, it does not work in the long run because when these lands are cleared for farming, their agricultural productivity declines rapidly and severe environmental deterioration occurs. Renewable resources, then, are *potentially* renewable. They must be used in a manner that allows natural processes time to replace or replenish them.

The effects of population growth on natural resources are particularly critical in developing countries. The economic growth of developing countries is frequently tied to the exploitation of their natural resources, often for export to highly developed countries. Developing countries are faced with the difficult choice of exploiting natural resources to provide for their expanding populations in the short term (that is, to pay for food or to cover debts) or conserving those resources for future generations. It is instructive to note that the economic growth and development of the United States and of other highly developed nations came about through the exploitation—and, in some cases, the destruction—of their resources. Continued growth and development in highly developed countries now relies significantly on the importation of these resources from less developed countries.

Poverty is tied to the effects of population pressures on natural resources and the environment. Poor

EnviroDiscovery 1.1

Green Roofs

Green roof

The Jacob K. Javits Convention Center is one of many buildings in New York City with a living green roof.

A roof that is completely or partially covered with vegetation and soil is known as a *green roof*. Also called *eco-roofs*, green roofs can provide several environmental benefits. For one thing, the plants and soil are effective insulators, reducing heating costs in winter and cooling costs in summer. The rooftop mini-ecosystem filters pollutants out of rainwater and reduces the amount of stormwater draining into sewers. In urban areas, green roofs provide wildlife habitat, even on the tops of tall buildings. A city with multiple green roofs provides "stepping stones" of habitat that enable migrating birds and insects to pass unharmed through the city. Green roofs can also be used to grow vegetable and fruit crops and to provide an outdoor refuge for people living or working in the building. Green roofs allow urban systems to more closely resemble the natural systems they have replaced and provide resources that would otherwise have to be brought in.

Green roofs may be added to existing buildings, but it is often easier and less expensive to install them in new buildings. Modern green roofs, which are designed to support the additional weight of soil and plants, consist of several layers that hold the soil in place, stop plant roots from growing through the rooftop, and drain excess water, thereby preventing leaks. New York City is one of many cities that have increasing numbers of green roofs (see photograph). One of the largest individual green roofs in the United States is on the Ford Motor Company Plant in Dearborn, Michigan.

communities in developing countries find themselves trapped in a vicious cycle of poverty. They use environmental resources for short-term gain (that is, to survive), but this exploitation degrades the resources and diminishes long-term prospects of economic development.

Population Size and Resource Consumption

Resource issues are clearly related to population size: At a given level of consumption, a larger population consumes more resources and causes more environmental damage than does a smaller population. However, not all people consume the same amounts of resources. Consumption patterns vary across different populations within a single country and among the different regions of the world.

Variation in consumption is associated with economic status, geography (especially whether people live in rural, suburban, or urban areas), culture, and other social and personal factors. A resident of a city who walks to work, rarely eats meat, owns few belongings, and has a small, well-insulated home may consume a fraction of the resources as a resident of nearby suburbs.

Consumption is both an economic and a social act. Consumption provides the consumer with a sense of identity as well as status among peers. The media, including the advertising industry, promote consumption as a way to achieve happiness. We are encouraged to spend, to consume.

People in highly developed countries can be extravagant and wasteful consumers; their use of resources is greatly out of proportion to their numbers. A single child born in a highly developed country such as the United States causes a greater impact on the environment and on resource depletion than perhaps 20 children born in a developing country. Many natural resources are needed to provide the automobiles, air conditioners, disposable diapers, cell phones, DVD players, computers, clothes, newspapers, athletic shoes, furniture, books, and other "comforts" of life in highly developed nations. Thus, the disproportionately large consumption of resources by the United States and other highly developed countries affects natural resources and the environment as much as or more than the population explosion in the developing world.

Highly developed nations represent less than 20 percent of the world's population, yet they consume significantly more than half of its resources. According to the Worldwatch Institute, highly developed countries account for the lion's share of total resources consumed:

- 86 percent of aluminum used
- 76 percent of timber harvested
- 68 percent of energy produced
- 61 percent of meat eaten
- 42 percent of the fresh water consumed

These nations also generate 75 percent of the world's pollution and waste (**Figure 1.3**).

Consumption • Figure 1.3

American consumption is actively promoted in Times Square advertisements. Highly developed nations, such as the United States, consume more than 50 percent of the world's resources, produce 75 percent of its pollution and waste, and represent only 18 percent of its total population.

Raga Jose Fuste/Prisma/SuperStock