SECOND EDITION

THE Environment AND YOU

NORM CHRISTENSEN LISSA LEEGE

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About the Authors

Norm Christensen is professor emeritus and founding dean of Duke University's Nicholas School of the Environment. He earned his undergraduate and master's degrees in biology at California State University, Fresno, and his doctorate at the University of California, Santa Barbara. A central theme in Norm's career has been ecosystem change from both natural and human causes. His research includes studies of the causes and consequences of fire in grasslands, shrublands, and forests; of the impacts of human land use and land abandonment on ecosystem change and species conservation; and of the influence of global warming patterns on ecosystem change. Norm has worked on numerous national advisory committees, including the Interagency Taskforce on the Ecological Effects of the 1988 Yellowstone Fire, the Committee on Environmental Issues in Pacific Northwest Forest Management, the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management, and the U.S. Nuclear Waste Technical Review Board. He has served on the boards of The Conservation Fund, Resources for the Future, the Environmental Defense Fund, The Wilderness Society, and the North Carolina Nature Conservancy. He is a fellow in the American Association for the Advancement of Science and past president of the Ecological Society of America.

Undergraduate education, especially at the introductory level, has been an important part of Norm's career at Duke. He has been honored twice by the university with awards for distinguished undergraduate teaching. He was instrumental in the development of Duke's undergraduate program in environmental science and policy, and he has taught the introductory course for this program for over 15 years. This book is very much a product of these efforts and Norm's passion for connecting students with their environment.

Lissa Leege is a professor of biology and the founding director of the Center for Sustainability at Georgia Southern University. She earned her undergraduate degree in biology from St. Olaf College and received her Ph.D. in plant ecology at Michigan State University. Her ecological research concerns threats to rare plants, including the effects of fire and invasive species on endangered plant populations and communities. She has also conducted 20 years of research on the impacts of invasive pines on the sand dunes of Lake Michigan and the subsequent recovery of this system following invasive species removal. Lissa was instrumental in the development of an Interdisciplinary Concentration in Environmental Sustainability for undergraduates at Georgia Southern. Under her direction, the Center for Sustainability engages the campus in an annual *No Impact Week* and reaches the community with an annual GreenFest celebration, as well as a robust sustainability speaker series. Lissa is also involved with the environment on a statewide level as a member of the 2013 Class of the Institute for Georgia Environmental Leadership and a founding member of the Georgia Campus Sustainability Network. She serves on a local tree board and as a board member for Georgia Southern's Botanical Garden.

Lissa has taught non-majors environmental biology for 16 years with an emphasis on how students can contribute to environmental solutions. In 2006, she established an Environmental Service Learning project, through which thousands of environmental biology students have engaged in tens of thousands of hours of environmental service in the local community. Lissa was honored with both college and university service awards and has served as a faculty fellow in Service-Learning. She also teaches principles of biology, biology of plants, and graduate-level sustainability courses, as well as Study Abroad sustainability courses in Italy. Her contributions to this book have been inspired by her passion for engaging students in positive solutions to environmental problems.

Dedication

To Nicholas, Natalie, Noelle, Nicole, Riley, and all other of Earth's children. May we make decisions today that ensure the future beauty, diversity, and health of the environment on which they will depend.

To Micah and Emory, my constant joy and inspiration. I owe you the beautiful world I inherited, and it is my hope that education will motivate all kinds of students to take leadership and action in bringing about a bright and sustainable future.

Preface

It has been said that change is the only constant. For billions of years, Earth's environment and the organisms that inhabit it have been constantly changing. Over tens of millennia we, our species, have constantly changed; each generation's technologies, values, and understanding of its environment have differed from those that preceded it. As a consequence of those technologies and our growing numbers, we have changed Earth's environment more than any other species living now or in the past.

You and the world around you are the current manifestation of this process of inexorable change. The health and well-being of most of Earth's people have markedly improved over the past century but our impacts on Earth's environment have increased significantly. A century ago, our global population was fewer than 2 billion; today there are well over 7 billion of us. What's more, each of us today uses several times more resources and generates several times more waste than our century-ago ancestors. The effects on our environment are alarming. Resources such as water and petroleum are dwindling. Air pollution and water pollution have become commonplace. Rates of extinction among Earth's species are more than 10 times higher than in pre-industrial times, and Earth's climate is warming because of human-caused changes in the chemistry of its atmosphere.

These changes threaten the health of Earth's ecosystems and the well-being of many of its people; they directly affect you. These changes are unsustainable, but they are not inevitable. Sustainability and ecosystems are important themes throughout this book. Sustainable action and change require knowledge and understanding of the ecosystems upon which we depend. Yes, they are complex, but the key elements of ecosystem function and sustainability are beautifully simple. In an increasingly urban and technology-driven world, the connections between Earth's ecosystems and our well-being may seem distant, even irrelevant. But they are at all times immediate and compelling.

We have not downplayed the significant challenges presented by the variety of environmental issues that affect our lives because a balanced view of the challenges is needed. Naïve optimism is not likely to motivate substantial change in our actions and impacts, but neither is pessimism. We can all change the world in directions that are truly sustainable. We are convinced you will be part of that process of change. That confidence and conviction were the motivation for writing this book; hope was the inspiration.

Hallmark Features and New Innovations

A New Author

We welcome Lissa Leege to the author team of *The Environment and You.* Lissa teaches biology and environmental biology at Georgia Southern University and is the director of the university's Center for Sustainability. Lissa's passion for the environment and teaching, as well as her spirit of hope, have added new energy to the second edition.

A Focus on You

A hallmark of the first edition and further reinforced in the second is the importance of humans as agents of environmental change. The effects of those changes on human well-being continue to be a central theme in the second edition. *The Environment and You* emphasizes problem-solving and solutions that will enable you to make more informed choices on actions to support the well-being of humans and the health of the planet.

- ***Where You Live*** New to the second edition, this feature invites you to use primary data sources to explore environmental principles, issues, and sustainable solutions within the context of your local community. By answering the questions posed, you'll see how concepts and examples from your textbook can be applied to where you live and learn. This will not only satisfy your curiosity but also help you connect local discoveries to central themes of the chapters. Do you know, for example, what biome you live in (Chapter 7) or whether you share your local environment with an endangered species (Chapter 8)? Do you ever think about just how much water you use everyday (Chapter 11)? How about the size of your waste footprint (Chapter 17)? These are just a few of the questions you will explore.

- ***Seeing Solutions*** Problems need solutions and this feature highlights how individuals and groups around the world are using new approaches to solve environmental problems. Topics include a city that is investing in green space to solve problems associated with transportation, the local economy, and the health of its citizens (Chapter 16); a business that lessens its impact while improving profit and employee–community relations with a focus on the triple bottom line (Chapter 1); a group that supports increased educational opportunity for young women as a means to improve the health and well-being of their communities (Chapter 5); and efforts designed to support underdeveloped countries in dealing with the economic pressures of a changing world (Chapter 8).
- ***Agents of Change*** This feature showcases the efforts of college students and recent graduates who have taken action to produce sustainable environments and improve human well-being. It is intended to provide guidance and encouragement for any student with a similar drive to make the world a better place. The second edition features seven new inspiring Agents of Change, including Sol Weiner and Tom Clement, Guildford College (Chapter 2); Liz Brajevich, Michigan State University (Chapter 6); and Alex Freid, University of New Hampshire (Chapter 17).
- ***Real Questions*** We asked students around the country what they wanted to know and they responded with questions such as "Is climate change the reason for increased storms?" Their questions and our answers appear in the margins of every chapter.

Solid Coverage of Environmental Science

Our current understanding of environmental issues is built on a foundation of decades of careful research by generations of scientists. The second edition not only continues to provide many examples to help you understand the role science and scientific data can play in reducing uncertainty surrounding environmental issues but also engages you in the spirit of inquiry scientists use to ask questions and gather evidence to support predictions.

- ***Currency*** New discoveries are constantly occurring, and our understanding is quickly evolving in all areas of environmental science. Among the many updates to the second edition are recently revised United Nations forecasts for the growth of human populations, the latest information on changes in Earth's climate from the Intergovernmental Panel on Climate Change, and recent innovations in agriculture, energy conservation, and green building practices. This edition provides the most current synthesis of such changes in every environmental field.
- ***Motivation*** Each chapter opens with an essay about humans and their interaction with or understanding of the environment. From the long-abandoned statues of Easter Island (Chapter 1) to the present-day concerns of the Arctic Inuit (Chapter 9) or the principled attempt by some San Franciscans to return Hetch Hetchy Valley to its original state (Chapter 2), environmental science is full of interesting stories. These stories will help you connect to the scientific concepts introduced in each chapter.
- ***Applications and Examples*** *The Environment and You* provides numerous explanations of how scientists have found innovative ways to gather the evidence that supports current conclusions and enables informed predictions.
- ***Focus on Science*** This feature encourages you to think about the process of scientific inquiry and the different methods scientists use to gather evidence by highlighting the work of individual scientists and the contributions they have made. In the second edition, we have emphasized the strategies scientists use to conduct scientific research and added critical thinking questions that will spark class discussion and encourage you to think like a scientist.
- ***New Frontiers*** New to the second edition, this feature highlights interesting areas of environmental research as well as unique approaches to problem-solving. New Frontier features emphasize the complex interactions between new scientific discovery, ethics, and policy and ask you to consider the implications of the power science has to change the way we live and interact with the environment.

Organized for Learning

The Environment and You is organized to help students understand environmental science.

- Each lesson begins with a big idea so students always have a way to see the forest as well as the trees.
- Manageable amounts of information are organized by key concepts within modules, giving students complete lessons before moving on to the next topic.
- Important concepts are illustrated with clear, purposeful charts and graphs and supported with photographs that capture the essence of the concept being presented.

A new overall chapter organization in the second edition improves the continuity and connectivity between chapters and integrates complex key concepts with relevant environmental issues. Our new organization features the following:

- An integrated approach to ecosystem ecology, where complex biogeochemical cycles appear in context
- A single chapter on the geography of life that includes marine, aquatic, and terrestrial biomes

- A single chapter on water that offers a more cohesive approach, uniting coverage of the physical attributes of water with the discussion of issues related to water quality, conservation, and wastewater management

Supporting All Levels of Students

Students in introductory environmental science classes have vastly different levels of science background. *The Environment and You* is designed and written to serve that diversity.

- ***Self-assessment:*** Questions at the end of every module allow students to assess whether or not they have truly grasped a topic before they move on. Questions at the end of each chapter are designed to encourage synthesis of concepts and application to real situations.
- ***MasteringEnvironmentalScience™:*** Used by over a million science students, the Mastering platform is the most effective and widely used online tutorial, homework, and assessment system for the sciences. It motivates students to come to class prepared; provides students with personalized coaching and feedback; quickly monitors and displays student results; easily captures data to demonstrate assessment outcomes; and automatically grades assignments, including concept review activities, 3-D BioFlix® animation activities and quizzes, Graphit! activities, and chapter reading quizzes.

New to the second edition of *Environmental Science and You*, Mastering has an expanded suite of activities designed to help your students practice concepts and develop scientific inquiry skills:

- *Process of Science activities* encourage your students to put scientific inquiry skills into action. These interactive activities guide them through current environmental research and help them understand concepts such as developing a hypothesis, making a prediction, understanding variables and independent variables, and more.
- *Global Connection activities* demonstrate the global relevance of local environmental issues and chapter themes. Your students will be able to draw comparisons between environmental issues in the United States and other countries such as water usage, air pollution, or species habitat loss.
- Expanded *Interpreting Graphs and Data* activities allow students to practice quantitative skills related to graph interpretation and analysis.

Additional *Video Field Trips* have been added to *MasteringEnvironmentalScience*. Assign these videos for use outside of class or use them in class to bring real issues to life. New to the second edition are a visit to a water desalination plant to see how one community is coping with water resource issues and an in-depth look at bee colony decline in the United States.

Acknowledgments

We accept all of the responsibilities of authorship for the second edition of *The Environment and You*, most particularly for any mistakes or flaws. But others deserve much of the credit for its development, organization, presentation, and production. As this project evolved over the course of several years, the Pearson Education publishing team and numerous environmental science colleagues provided much needed guidance and encouragement.

We are especially grateful to Alison Rodal, our acquisitions editor for this edition of *The Environment and You*. She was the catalyst for many of this edition's organizational changes and new features, and her contagious enthusiasm for this project motivated us at every stage. Chalon Bridges was executive editor for the first edition of *The Environment and You*, and many of her ideas for its content, organization, and presentation continue to be important in this edition.

Our development editor, Mary Hill, expertly and cheerfully guided us on this second edition journey, from start to finish. Mary has an exceptional eye for detail on matters ranging from grammar to module organization and layout to connections among chapters. Even more, we are awed by her nuanced understanding of so many facets of environmental science that informed her suggestions on substance and presentation. Her wonderful sense of humor sustained us throughout this process. Susan Teahan, Melissa Parkin, and Julia Osborne served as development editors for this book's first edition. We remain grateful to each one for important contributions to the creation of *The Environment and You*.

We thank Editor-in-Chief Beth Wilbur and Director of Development Deborah Gale who encouraged and facilitated this project in both its first and second editions, and Executive Editorial Manager Ginnie Simione Jutson for the second edition. In addition, we would not have been able to publish this project without the support from Editorial Director Adam Jaworski and President Paul Corey. Thank you for taking a risk on this project and for your ongoing collective leadership in science education.

Sophie Mitchell and her wonderful team at Dorling Kindersley Education helped craft and execute the original vision for the first edition of this project.

Program Manager Anna Amato very ably managed both the editorial and production processes. She deserves special credit for keeping all of us on track and on time.

Producing a book where text and art are created, designed, and arranged in tandem requires a highly collaborative approach to publishing. We are grateful to our production colleagues for overseeing and orchestrating this effort. David Zielonka led the production team that included Mae Lum and Laura Murray. Mark Ong and Tani Hasegawa were responsible for the page and cover design of this second edition, and Lindsay Bethoney oversaw the compositing of our text files to actual page layouts. We thank Kevin Lear of International Mapping for his leadership in the production of illustrations, graphs, and maps.

Special thanks go to Libby Reiser who was supplements project manager. Libby not only oversaw the production of all second edition supplements but also played a special role in bringing in new Agents of Change for the second edition. We remain grateful to Assistant Editor Rachel Bricker for her leadership in the development of the Agents of Change features in the first edition. We also thank Editorial Assistant Alison Cagle for so skillfully juggling various tasks to support the entire publishing team.

Special thanks to Content Producer Joe Mochnick for overseeing all details on the production of media for the new edition and for MasteringEnvironmentalScience, and to Tania Mlawer and Sarah Jensen for bringing their creativity and expertise to the development of our new MasteringEnvironmentalScience activities. Todd Brown ensured the smooth release of MasteringEnvironmentalScience for the second edition of the text.

We would also like to thank each contributing supplement author for the edition. Jacquelyn Jordan, Clayton State University, did a wonderful job carefully updating the Instructor's Guide. The Test Bank was written and assembled by Tanya Smutka, Inver Hills Community College, and David Serrano, Broward State College. David is also the author of the second edition PowerPoint presentations, carefully updating each chapter presentation to help give instructors a head start in planning each lecture. Justin St Julianna, Ivy Tech Community College, brought his perspective and expertise using media in his own teaching to our new Process of Science coaching activities. Reading Questions were crafted by Nilo Marin, Broward State College. We also thank Erica Kipp, Pace University, for her contribution to the updates in MasteringEnvironmentalScience resources for this edition.

After many years spent creating and crafting this book, there comes a time to pass the torch to marketing and sales. We are grateful to Christy Lesko, Director of Marketing, for her support of this text. Lauren Harp and Amee Mosley brought endless enthusiasm in promoting *The Environment and You*, communicating our vision to instructors all over the country, all with the support of Ami Sampat, Marketing Assistant. We are fortunate to have the support of the many sales representatives who work tirelessly to communicate our vision to faculty and ensure instructors' needs are satisfied. We thank them for their dedication and commitment!

Terrence Bensel, Brian Bovard, Robert Kingsolver, and Lester Rowntree made important contributions in the first edition to chapters on climate change, biodiversity, agriculture, energy, and waste management. Their detailed outlines provided road maps through sometimes unfamiliar territory, and many elements from their drafts of several of these chapters are part of the final product.

We owe much to our students at Duke and Georgia Southern Universities. In many ways, they helped shape the spirit and content of this text. They have been guinea pigs for each of its chapters and volunteered many editorial comments. The book is much the better for their input.

Over the years, each of us has had the benefit of working with wonderful mentors and colleagues, all the while being supported by our families. For each of us, individually, we want to thank those people who are so special to us.

Norm: My undergraduate and master's advisor Bert Tribbey passed along much knowledge and wisdom that appears in these pages, and he has long served as my primary role model for teaching excellence. My Duke colleagues William Chameides, Deborah Gallagher, Prasad Kasibhatla, Emily Klein, Randy Kramer, Marie Lynn Miranda, Joel Meyer, Lincoln Pratson, William Schlesinger, and Dean Urban were key sources of information and constructive criticism.

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Lissa: My Ph.D. advisor Peter Murphy was an excellent role model who always encouraged my love of teaching and ultimately inspired my desire to reach a wider audience. I am grateful to Georgia Southern University and the Department of Biology for providing me the educational leave I needed to pursue this project, and to my museum colleagues for opening my eyes to the exhilaration of teaching beyond my classroom.

I thank my parents for believing in my passion for sustainability and supporting my path. I owe much to my children Micah and Emory for the time they allowed me to dedicate to this book. I hope that they are proud of the outcome when I can finally say yes to the question, "Are you finished with the book yet, Mom?" Finally, I extend my deepest gratitude to my remarkably patient and supportive husband Frank D'Arcangelo, who encouraged me to follow this dream, even though it meant that he would need to be SuperDad even more often.

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Feldman, *Marist College;* Kevin Fermanich, *University of Wisconsin, Green Bay;* Linda Fitzhugh, *Gulf Coast College;* Laurie Fladd, *Trident Technical University;* Chris Fox, *Catonsville Community College;* Katie Gerber, *Santa Rosa Junior College;* Thaddeus Godish, *Ball State University;* James Goetz, *Kingsborough Community College;* Robert Goodman, *Citrus College;* Larry Gray, *Utah Valley University;* Peggy Green, *Broward Community College, North;* Joshua Grover, *Ball State University;* Kurt Haberyan, *Northwest Missouri State;* George Hagen, *Palo Alto College;* Nigel Hancock, *Long Beach City College;* Wendy Hartman, *Palm Beach Community College;* Kim Hatch, *Long Beach City College;* James Haynes, *State University of New York, Brockport;* Kathi Hopkins, *McClennan Community College;* James J. 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Winslow, *Bowling Green State University;* Don Wujek, *Oakland Community College, Auburn Hills;* Lori Zaikowski, *Dowling College;* Carol Zellmer, *California State University, Fresno;* Joseph Zurovchak, *Statue University of New York, Orange Community College.*

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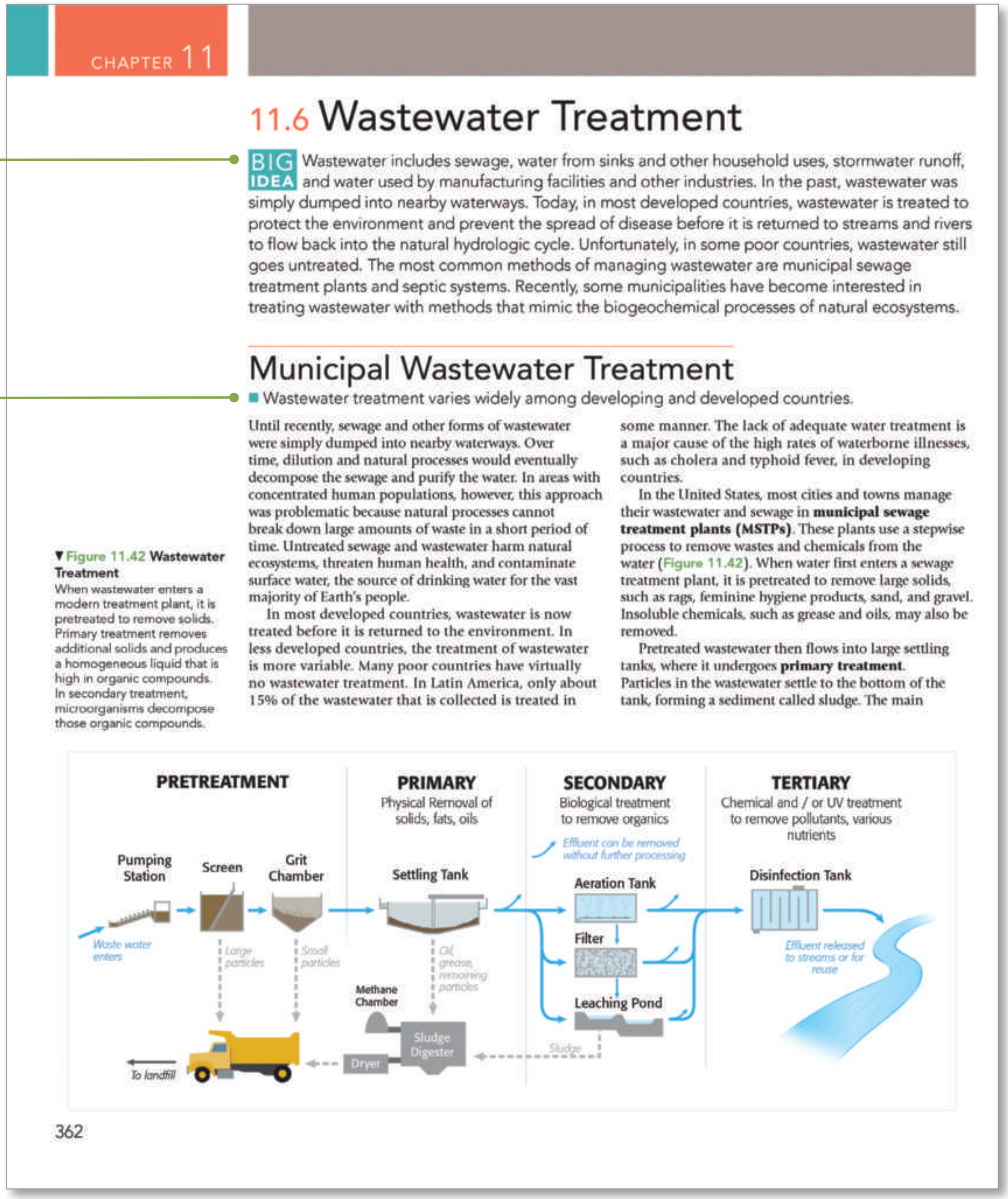
Stay Focused on the Big Ideas

The Environment and You strives to make navigating, focusing, and learning easier for students.

IMPROVED! Big Idea Summaries start each lesson so you can easily keep sight of the big picture as well as the supporting details for each module and topic.

Big Idea Statements clearly summarize the learning objective for each topic.

NEW! Improved chapter organization strengthens the connections between chapters and integrates key concepts with relevant environmental issues. Highlights include a more cohesive approach to water-related issues, an integrated discussion of ecosystem ecology, and a revised chapter on the geography of life.



CHAPTER 11

11.6 Wastewater Treatment

BIG IDEA Wastewater includes sewage, water from sinks and other household uses, stormwater runoff, and water used by manufacturing facilities and other industries. In the past, wastewater was simply dumped into nearby waterways. Today, in most developed countries, wastewater is treated to protect the environment and prevent the spread of disease before it is returned to streams and rivers to flow back into the natural hydrologic cycle. Unfortunately, in some poor countries, wastewater still goes untreated. The most common methods of managing wastewater are municipal sewage treatment plants and septic systems. Recently, some municipalities have become interested in treating wastewater with methods that mimic the biogeochemical processes of natural ecosystems.

Municipal Wastewater Treatment

Wastewater treatment varies widely among developing and developed countries.

Until recently, sewage and other forms of wastewater were simply dumped into nearby waterways. Over time, dilution and natural processes would eventually decompose the sewage and purify the water. In areas with concentrated human populations, however, this approach was problematic because natural processes cannot break down large amounts of waste in a short period of time. Untreated sewage and wastewater harm natural ecosystems, threaten human health, and contaminate surface water, the source of drinking water for the vast majority of Earth's people.

In most developed countries, wastewater is now treated before it is returned to the environment. In less developed countries, the treatment of wastewater is more variable. Many poor countries have virtually no wastewater treatment. In Latin America, only about 15% of the wastewater that is collected is treated in some manner. The lack of adequate water treatment is a major cause of the high rates of waterborne illnesses, such as cholera and typhoid fever, in developing countries.

In the United States, most cities and towns manage their wastewater and sewage in **municipal sewage treatment plants (MSTPs)**. These plants use a stepwise process to remove wastes and chemicals from the water (Figure 11.42). When water first enters a sewage treatment plant, it is pretreated to remove large solids, such as rags, feminine hygiene products, sand, and gravel. Insoluble chemicals, such as grease and oils, may also be removed.

Pretreated wastewater then flows into large settling tanks, where it undergoes **primary treatment**. Particles in the wastewater settle to the bottom of the tank, forming a sediment called sludge. The main

▼ Figure 11.42 **Wastewater Treatment**
When wastewater enters a modern treatment plant, it is pretreated to remove solids. Primary treatment removes additional solids and produces a homogeneous liquid that is high in organic compounds. In secondary treatment, microorganisms decompose those organic compounds.

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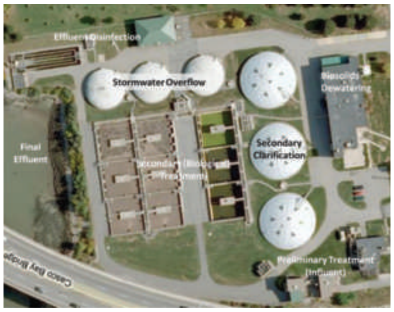
purpose of primary treatment is to produce a relatively homogeneous liquid that can be treated biologically and a sludge that can be processed separately. In many developing countries, municipalities return wastes to the environment after primary treatment.

In **secondary treatment**, bacteria and other microorganisms are used to break down the organic material dissolved in the wastewater. In most treatment plants, secondary treatment takes place in aerated tanks and basins. Some facilities use membranes or gravel filters to further separate solid and liquid wastes (Figure 11.43).

Some treatment plants also use **tertiary treatment** to remove inorganic nutrients from wastewater. In this stage of treatment, wastewater is passed through sand and charcoal filters to remove residual solids and toxins. Next, the water is stored in human-made ponds or lagoons where microorganisms remove significant amounts of dissolved nitrogen and phosphorus. Finally, the water is disinfected with chlorine, ozone, or ultraviolet radiation to reduce the number of microorganisms.

Solid wastes, or sludge, accumulate at each step in this treatment process. Most often, sludge is subjected to digestion by microorganisms, which reduce the volume of organic matter and the number of disease-causing microbes. Sludge is then dried so that it can be transported and disposed of off-site. Usually, it is dumped into landfills or spread onto open land. However, a growing number of treatment plants convert sludge into pellets that can be used as fertilizers; these pellets are often sold to local gardeners and farmers.

In place of traditional MSTPs, some communities are beginning to use natural or constructed wetlands to purify wastewater that has had primary treatment. Wetlands are very effective at purifying water (see Module 7.7). As water slowly percolates through wetland soils, solid materials are filtered out and microbes decompose the organic matter. Nutrients, such as nitrogen and phosphorus, and contaminants, such as heavy metals, are adsorbed by soil particles or taken up by plants and stored in their tissues.



◄ Figure 11.43 **Your Neighborhood MSTP**
Communities use different components of wastewater treatment depending on their needs. This aerial view of a wastewater treatment plant in Portland, Maine shows primary and secondary treatment.

Manageable-sized lessons are organized by modules to give you a brief yet complete understanding before moving on to the next topic.

QUESTIONS 11.6

1. Describe what happens in primary, secondary, and tertiary treatment of wastewater.
2. Explain how an on-site septic system operates.

For additional review, go to **MasteringEnvironmentalScience**

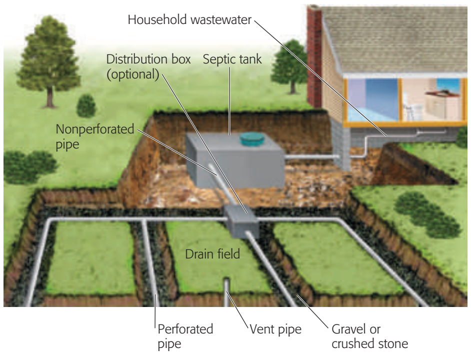
End-of-module questions prompt you to check your understanding at the end of each module.

On-Site Wastewater Treatment

■ If properly maintained, septic systems can isolate waste and protect water supplies.

In less densely populated areas, households often rely on **septic systems** to treat their wastewater and sewage. In these systems, sewage and household wastewater flow to an underground septic tank outside the home. Solids settle to the bottom of the tank where microorganisms begin to break down the waste. Wastewater flows to a series of perforated, underground pipes through which it is released into a **leach field**, where microorganisms in the soil finish breaking down the waste materials (Figure 11.44). Periodically, the solids that settle in the septic tank need to be pumped out and disposed of in a landfill.

Nearly 25% of the households in the United States rely on septic systems to treat their wastewater. When properly maintained, septic systems are an effective means of isolating wastes and protecting water supplies. Maintenance includes monitoring leach fields and occasional pumping of septic tanks. However, about 10% of these systems are not functioning properly. In communities where soil conditions prevent effective leaching, failure rates may exceed 70%. The U.S. EPA reports that failed septic systems are the third most common cause of groundwater contamination.



▲ Figure 11.44 **Household Septic System**
Rural wastewater is often treated in on-site septic systems. Wastewater flows into the septic tank, where solid materials are decomposed. Liquid wastes flow out of the tank and into a system of perforated pipes in the leach field, where dissolved organic chemicals are broken down by microbes.

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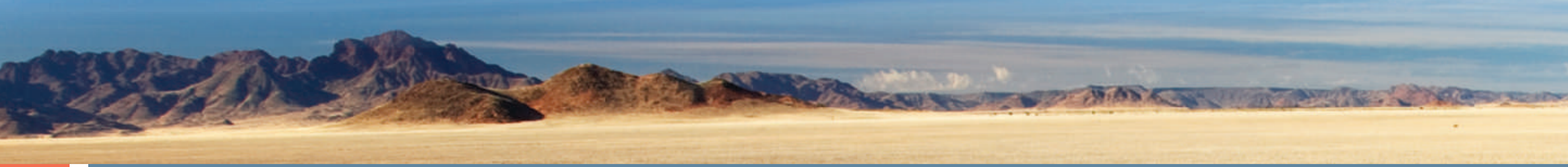


Find Inspiration in Seeking Solutions to Problems

Co-authors Norm Christensen and Lissa Leege offer a fresh approach by emphasizing problem solving and scalable solutions that inspire students to make more informed choices to support the well-being of humans and the planet.

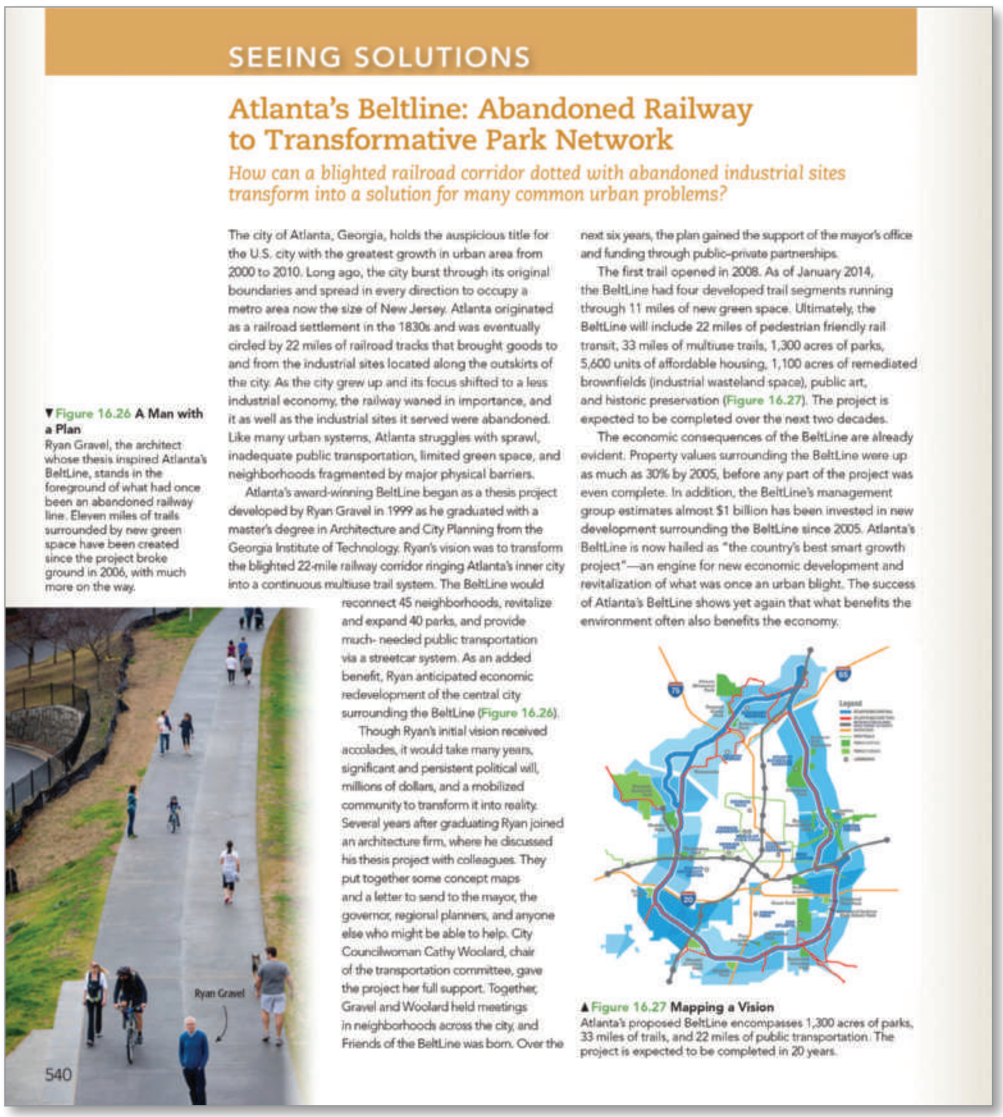
UPDATED!
Seeing Solutions
demonstrates how an organization or community has come together to tackle an environmental problem.

NEW! Where You Live
activities invite you to use primary data sources to explore environmental principles, issues, and sustainable solutions in your local community.

Where YOU LIVE **Where does your water come from?**

Your home has both a street address and a watershed address. Using EPA data, determine in which watershed your home is located.

- What is your watershed called? Where does the water that runs off your street ultimately end up? What upstream rivers lead into your watershed, and what downstream rivers take its water to the ocean?
- Using EPA data for your watershed (impaired water), characterize the water quality in a stream or river near your home.
- What are the most important factors influencing that quality?



SEEING SOLUTIONS

Atlanta's Beltline: Abandoned Railway to Transformative Park Network

How can a blighted railroad corridor dotted with abandoned industrial sites transform into a solution for many common urban problems?

The city of Atlanta, Georgia, holds the auspicious title for the U.S. city with the greatest growth in urban area from 2000 to 2010. Long ago, the city burst through its original boundaries and spread in every direction to occupy a metro area now the size of New Jersey. Atlanta originated as a railroad settlement in the 1830s and was eventually circled by 22 miles of railroad tracks that brought goods to and from the industrial sites located along the outskirts of the city. As the city grew up and its focus shifted to a less industrial economy, the railway waned in importance, and it as well as the industrial sites it served were abandoned. Like many urban systems, Atlanta struggles with sprawl, inadequate public transportation, limited green space, and neighborhoods fragmented by major physical barriers.

Atlanta's award-winning BeltLine began as a thesis project developed by Ryan Gravel in 1999 as he graduated with a master's degree in Architecture and City Planning from the Georgia Institute of Technology. Ryan's vision was to transform the blighted 22-mile railway corridor ringing Atlanta's inner city into a continuous multiuse trail system. The BeltLine would reconnect 45 neighborhoods, revitalize and expand 40 parks, and provide much- needed public transportation via a streetcar system. As an added benefit, Ryan anticipated economic redevelopment of the central city surrounding the BeltLine (Figure 16.26).

Though Ryan's initial vision received accolades, it would take many years, significant and persistent political will, millions of dollars, and a mobilized community to transform it into reality. Several years after graduating Ryan joined an architecture firm, where he discussed his thesis project with colleagues. They put together some concept maps and a letter to send to the mayor, the governor, regional planners, and anyone else who might be able to help. City Councilwoman Cathy Woolard, chair of the transportation committee, gave the project her full support. Together, Gravel and Woolard held meetings in neighborhoods across the city, and Friends of the BeltLine was born. Over the next six years, the plan gained the support of the mayor's office and funding through public-private partnerships.

The first trail opened in 2008. As of January 2014, the BeltLine had four developed trail segments running through 11 miles of new green space. Ultimately, the BeltLine will include 22 miles of pedestrian friendly rail transit, 33 miles of multiuse trails, 1,300 acres of parks, 5,600 units of affordable housing, 1,100 acres of remediated brownfields (industrial wasteland space), public art, and historic preservation (Figure 16.27). The project is expected to be completed over the next two decades.

The economic consequences of the BeltLine are already evident. Property values surrounding the BeltLine were up as much as 30% by 2005, before any part of the project was even complete. In addition, the BeltLine's management group estimates almost $1 billion has been invested in new development surrounding the BeltLine since 2005. Atlanta's BeltLine is now hailed as "the country's best smart growth project"—an engine for new economic development and revitalization of what was once an urban blight. The success of Atlanta's BeltLine shows yet again that what benefits the environment often also benefits the economy.

▼ Figure 16.26 A Man with a Plan
Ryan Gravel, the architect whose thesis inspired Atlanta's BeltLine, stands in the foreground of what had once been an abandoned railway line. Eleven miles of trails surrounded by new green space have been created since the project broke ground in 2006, with much more on the way.

Ryan Gravel

▲ Figure 16.27 Mapping a Vision
Atlanta's proposed BeltLine encompasses 1,300 acres of parks, 33 miles of trails, and 22 miles of public transportation. The project is expected to be completed in 20 years.

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AGENTS OF CHANGE

Water Conservation Competition

Martin Fugueroa is majoring in biology with an emphasis on Human Biology and a minor in sustainability. During his sophomore year at University of California, Merced, Martin Figueroa created the Water Conservation Competition—a month-long water battle between the 14 dorms on campus, which challenges students to reduce their water use. Students can view their daily usage throughout the competition on an online, real-time dashboard that Martin developed with a local technology company. Martin continues to host this competition, which conserves over a million of gallons of water each year.

How did you first get the idea for the UC Merced Water Battle?

UC Merced is located in one of the driest climates in California—the Central Valley, a region also famous for its rich agriculture. When I arrived on campus my freshman year, I noticed a drastic difference in the landscape—parts of the campus had amazing grass and green lands, while other sections were arid and dry. The difference is all due to water resources.

On my drive home to Los Angeles, I observed the large tubes required to pump water to the drier regions of California; just above these were billboards calling for more water resources in the Central Valley. This sparked my desire to learn about where our water originates and how it is distributed.

I then enrolled in a course on sustainability and current environmental issues. This class inspired me to take action on my campus and influence administrators to implement new sustainability standards. My water conservation efforts started out as a campaign, which developed into a competition in the hopes of increasing student participation and awareness. I wanted students to think about water and how our usage impacts the future of our planet.

What steps did you take to create the competition?

The first step was getting approval and support from campus administrators, water stakeholders, and sustainability and housing departments, who would then give me access to facilities and meters needed to track the water usage. I then contacted Aquacue, a water technology company, to help create the water battle dashboard where students can view their water usage in real-time, as well as notify us about leaks. This dashboard greatly increased student participation and allowed students to visually understand their impact.

I also assembled a committee of administrators, stakeholders, and two student groups, Green Campus and Engineers for a Sustainable World. With the help of several classes and professors, we created marketing materials including flyers, short films, commercials, and QR codes, which link students to the water dashboard. Social media provided a great forum for students to encourage their dorm-mates to reduce water consumption, while also fueling competition among the dorms. We kicked off the competition with several tabling events where students could ride our amazing bike blender, drink a free smoothie, and learn about the ways students can conserve water.

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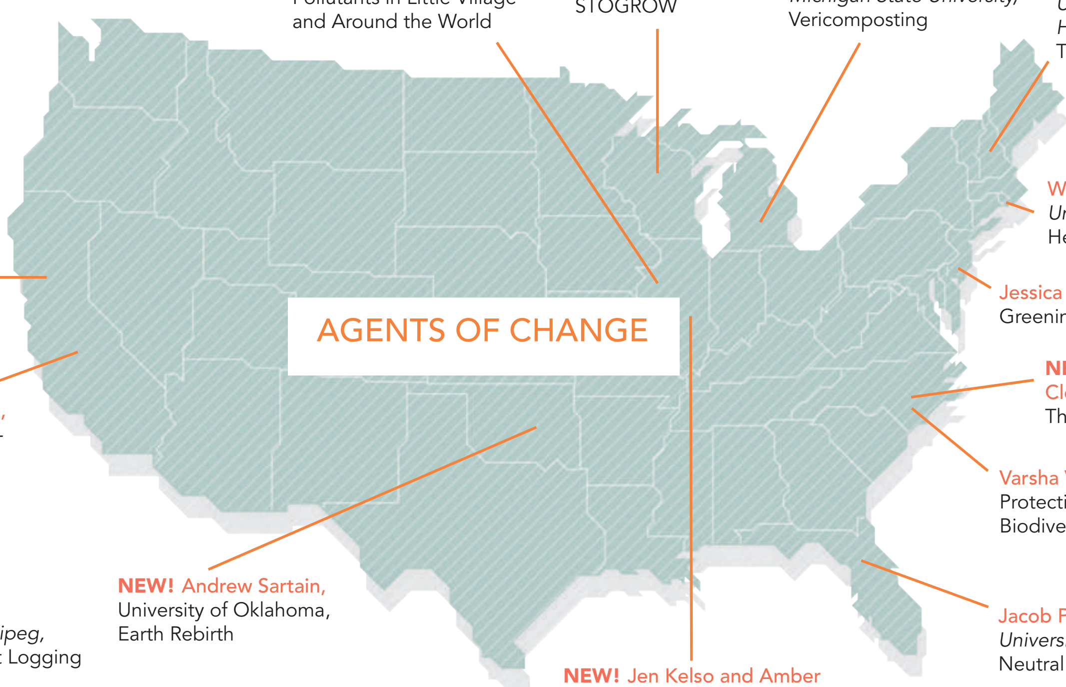
UPDATED!
Agents of Change showcase inspiring college students and recent graduates who are taking action to develop sustainable environments and improve human well-being. Seven Agents of Change stories are new to the second edition.

Marisol Becerra, *DePaul University,* Mapping Pollutants in Little Village and Around the World

NEW! Hillary King, *St. Olaf College,* STOGROW

NEW! Eliza Barjbich, *Michigan State University,* Vericomposting

NEW! Alex Fried, *University of New Hampshire,* Trash 2 Treasure



Rachel Barge, *University of California–Berkeley,* Green Initiative Fund

NEW! Martin Figueroa, *University of California–Merced,* Water Battle

Will Perez, *Brown University,* Taking Public Health to Rural Haiti

Jessica Franzini, *Stockton College,* Greening Urban Spaces

NEW! Sol Weiner and Tom Clement, *Guildford College,* The Making of *Swine Country*

Varsha Vijay, *Duke University,* Protecting a Unique Biodiversity Hotspot

ALSO FEATURED: Robin Bryan, *University of Winnipeg,* Campaign Against Logging

NEW! Andrew Sartain, University of Oklahoma, Earth Rebirth

NEW! Jen Kelso and Amber White, *Loyola University of Chicago,* Biodiesel Project

Jacob Perritt-Cravey, *University of Florida,* Carbon-Neutral Football Games

Easily Access Current, Accurate Science Information

Our current understanding of environmental issues is built on a foundation of decades of careful research by generations of scientists. This important work is discussed throughout the Second Edition.

NEW! Critical thinking questions can spark class discussion and help you develop inquiry skills and an understanding of scientific discovery.

UPDATED! Focus on Science essays highlight the research of individual scientists and show how scientific research increases understanding of environmental issues.

FOCUS ON SCIENCE

Adapting to Rising Seas

How effective is the conservation of natural habitat as an adaptation strategy to sea level rise and increased storm severity?

Rising sea level and increased storm activity and flooding pose ever-increasing threats to coastal communities around the world. These threats are compounded by rapid population growth and sprawling development in coastal cities. The traditional approach to protect coastal towns has been construction of sea walls and other "hardened" structures. More recently, greater emphasis has been placed on the conservation and restoration of natural habitats such as coral and oyster reefs, sea grass beds, and coastal forests and wetlands that buffer coastlines from waves and storm surges. We know these conservation strategies are effective at particular locations. Katie Arkema and her colleagues at Stanford University Natural Capital Project were interested in determining the value of such conservation practice applied on a large scale, across the entire coast of the United States (Figure 9.45).

▲ **Figure 9.45 Ecosystem Services** Katie Arkema is interested in finding ways to quantify nature's benefits to people and applying that information to the management of coastal and marine ecosystems.

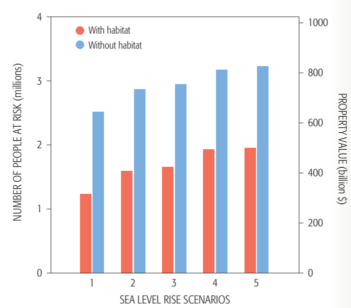
1. What physical features of a coastline might increase risks associated with sea level rise?
2. Was the effect of habitat protection consistent among the sea level rise scenarios? Explain your conclusion.
3. How might coastal counties use this information to plan future land use?

Arkema and her team used a combination of *data synthesis* and *ecological models* to address this question. They began by calculating a hazard *index* for each square kilometer of the U.S. coastline based on the physical features that influence water movement, the types of natural coastal habitats at current sea levels, and the likelihood of coastal storms. They then calculated hazard indices based on five sea level scenarios, and for coastlines with or without natural coastal habitat.

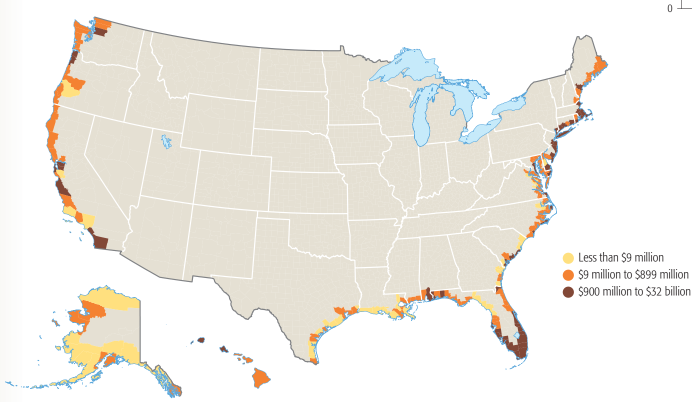
Scenario 1 represented current conditions and scenario 2 approximated sea level change expected in a *Sustainable World* future. Scenarios 3, 4, and 5 represented sea level rise with successively greater warming, with 5 corresponding to changes expected under the *Business as Usual* trajectory for global warming. They also mapped data on human populations and property values for each square kilometer of coastline. By overlaying these maps, Arkema was able to convert hazard indices to more direct measures of imperiled human life and property damage.

As expected, the number of people and the amount of property at risk increased with increasing rates of sea level rise (Figure 9.46). The presence of natural coastal habitat diminished those risks by at least 40% in each scenario on a national scale. At least as important, Arkema and her colleagues have produced the first national map indicating where conservation and restoration of reefs, wetlands, and coastal forests have the greatest potential to protect human life and property in coastal communities (Figure 9.47).

Source: Arkema K.K. 2013. Coastal habitats shield people and property from sea-level rise and storms. *Nature: Climate Change* 3: 913–918.



▲ **Figure 9.46 With and Without Habitat** Bar graphs indicate the number of people and property value at risk nationally. Across all five sea level change scenarios, natural coastal habitats such as reefs, wetlands, and coastal forests substantially diminish risks to life and property in coastal communities.



◄ **Figure 9.47 Where It Matters Most** The color for each coastal county indicates the total property value for which coastal habitats reduce exposure to storms and sea level rise under sea level rise scenario 4. Coastal habitats protect the greatest value and number of people in New York, Florida, and California.

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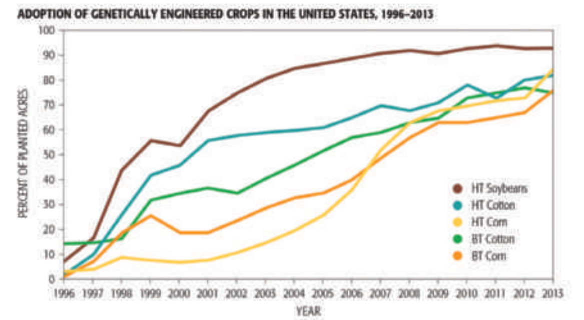
The most **current, accurate data** and research is presented throughout the text, and citations are provided so you can locate the sources of scientific information.



▲ Figure 12.40 **Genetically Modified Crops Crowd the Fields**
GMO corn, cotton, and soybeans have crowded out all other varieties in the United States. More than 90% of these plants are now genetically modified, mostly for resistance to pests and herbicides.

Source: Data from USDA, Economic Research Service and National Agricultural Statistics Service

MODULE 9.4

9.4 Consequences of Global Warming

BIG IDEA The changes caused by global warming vary from region to region. In some places, increasing temperatures have been accompanied by higher rainfall amounts. In others, they have brought drought. Winters have become milder and shorter in Earth's middle latitudes, and dry seasons have grown longer in some parts of the tropics. Glaciers and ice sheets are melting worldwide. Warming is causing sea levels to rise. Taken together, these changes are having a significant impact on the flora and fauna of many ecosystems.

Drier and Wetter

■ Global warming is producing wetter conditions in some places and drought in others.

The effects of rising temperatures on precipitation vary geographically. Rainfall has increased significantly in eastern North and South America, as well as in most parts of Europe and Asia. In contrast, sub-Saharan Africa, the Mediterranean region, and western North America have been drier. Since 1970, longer and more intense droughts—as measured by decreased precipitation and higher temperatures—have affected wide areas of the tropics and subtropics. At the same time, there has been a worldwide increase in the frequency of rainstorms that result in flooding, even in areas where total annual rainfall has declined (Figure 9.24). Warm air holds more moisture (see Module 3.6).

In regions in which rain is highly seasonal, such as sub-Saharan Africa, global warming appears to be changing the length of wet and dry periods. This is a matter of special concern because food production depends on the length of wet seasons. Based on current trends and climate models, growing seasons are expected to become shorter over most of sub-Saharan Africa, with the exception of lands very near the equator.

There is evidence that global warming is influencing drought cycles. For example, the El Niño/La Niña/Southern Oscillation is caused by changes in the temperature of surface waters in the equatorial Pacific Ocean. When waters off the west coast of South and Central America are cold, drought is much more common in the southwestern United States. Some climatologists think that since 1970 the length and intensity of El Niño and La Niña events have been outside the range of natural variability. Although climate models predict that such changes will occur, most scientists feel that it is not clear that they are actually underway.

Questions from real students appear throughout the text, along with brief, scientifically accurate responses from authors Norm Christensen and Lissa Leege.

Q *Is climate change the reason for increased storms and global disturbances?*
Ciara Tyce,
Georgia Southern University

Norm: A Climate scientists are generally careful not to attribute a particular weather event to global warming. However, increased frequency and intensity of storms and heat waves is consistent with climate model predictions.


▲ Figure 9.24 **Deluges and Droughts**
Ⓐ In 2013, torrential rains impacted crop production across much of upstate New York. Ⓑ In 2014, extreme drought in California meant farmers could not grow crops on hundreds of thousands of acres. Global warming may have contributed to both situations.

New Frontiers discussions emphasizes the complex interactions between new scientific discovery, ethics, and policy.

New **FRONTIERS**

Revving up Severe Weather?

Ocean temperature is an important factor in the development of tropical storms and hurricanes, and ocean temperatures have increased between 0.25 °C and 0.5 °C (0.45–0.9 °F) over the past century. Warmer sea surface temperatures appear to be associated with the observed increase in the number and strength of tropical storms in the Pacific Ocean. For example, Typhoon Haiyan, which hit the Philippines in 2013, was one of the strongest tropical storms ever recorded. But trends in the Atlantic Ocean are far less clear. The very significant damage from Hurricane Sandy in 2012 was largely a consequence of a combination of sea level rise (see the next section) and poorly managed coastal development (see Module 18.2).

Debate continues regarding the effects of global warming on past and current storm patterns, but there is consensus among scientists that continued sea surface warming will very likely increase the frequency and severity of tropical storms in the future. How much evidence do you believe we need in order to take strong action to mitigate the effects of future strong storms? How much of the risk associated in living in coastal areas should be the responsibility of property owners versus the government?

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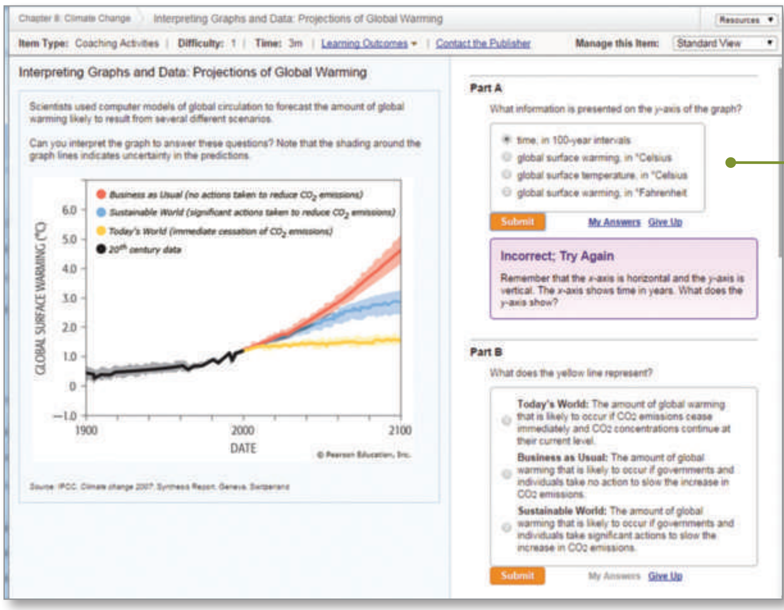
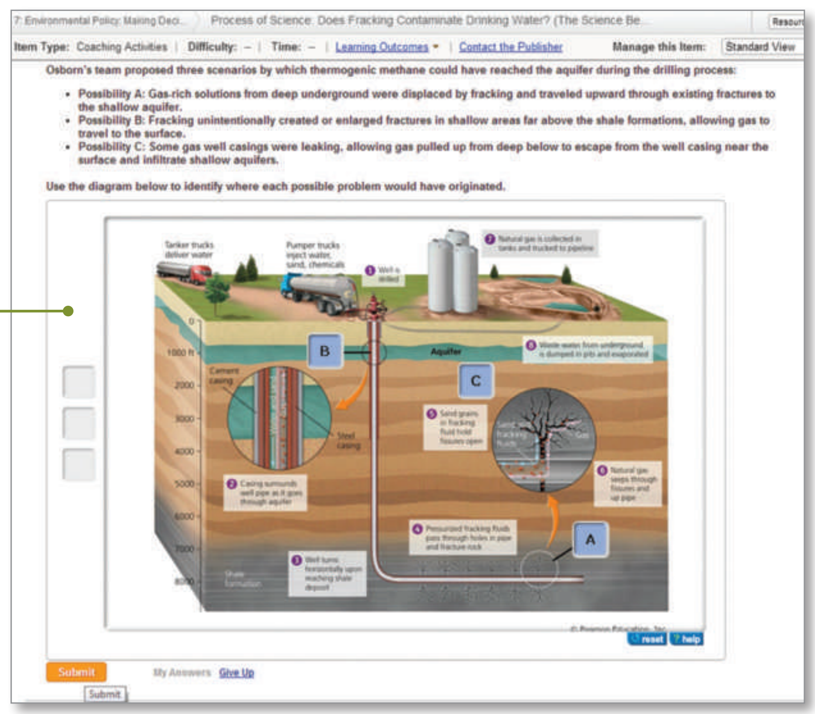
Learn and Practice with New Online Activities

MasteringEnvironmentalScience® is an online homework, tutorial, and assessment system that helps you quickly master concepts both in and outside the classroom. This book and MasteringEnvironmentalScience work together to create a classroom experience that makes teaching and learning more efficient and enjoyable.

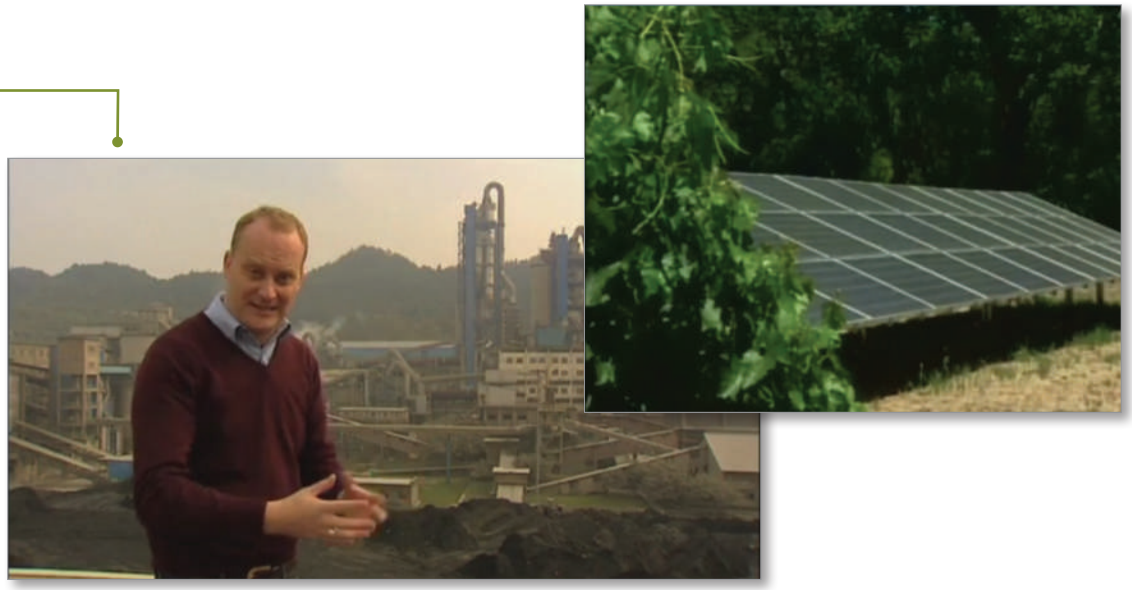


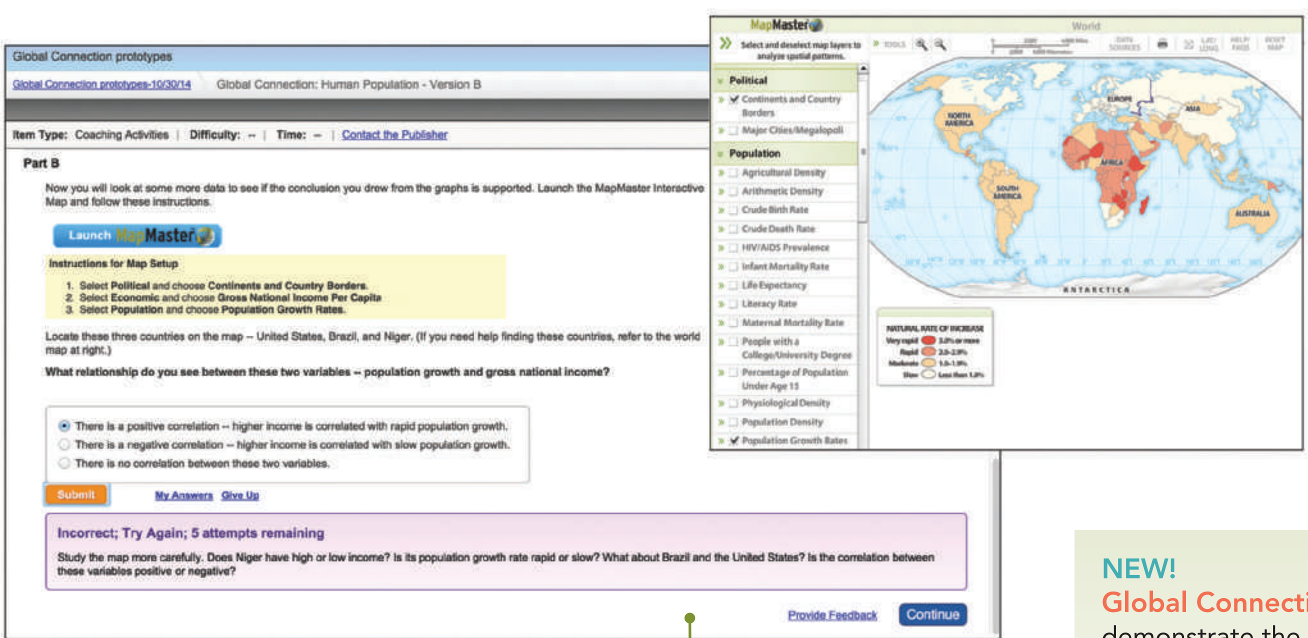
EXPANDED! Interpreting Graphs and Data questions help you practice basic quantitative analysis skills.

NEW! Process of Science activities show you how to put scientific inquiry skills into action.



NEW!
Everyday Environmental Science videos, produced by the BBC, introduce you to connections between environmental science topics and real world issues. Instructors can show film footage in class, during class lectures, or assign as homework in MasteringEnvironmentalScience to engage students in learning about environmental science topics.





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MasteringEnvironmentalScience®

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- Now available on smartphones and tablets.
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- Fully accessible (screen-reader ready).
- Configurable reading settings, including resizable type and night-reading mode.
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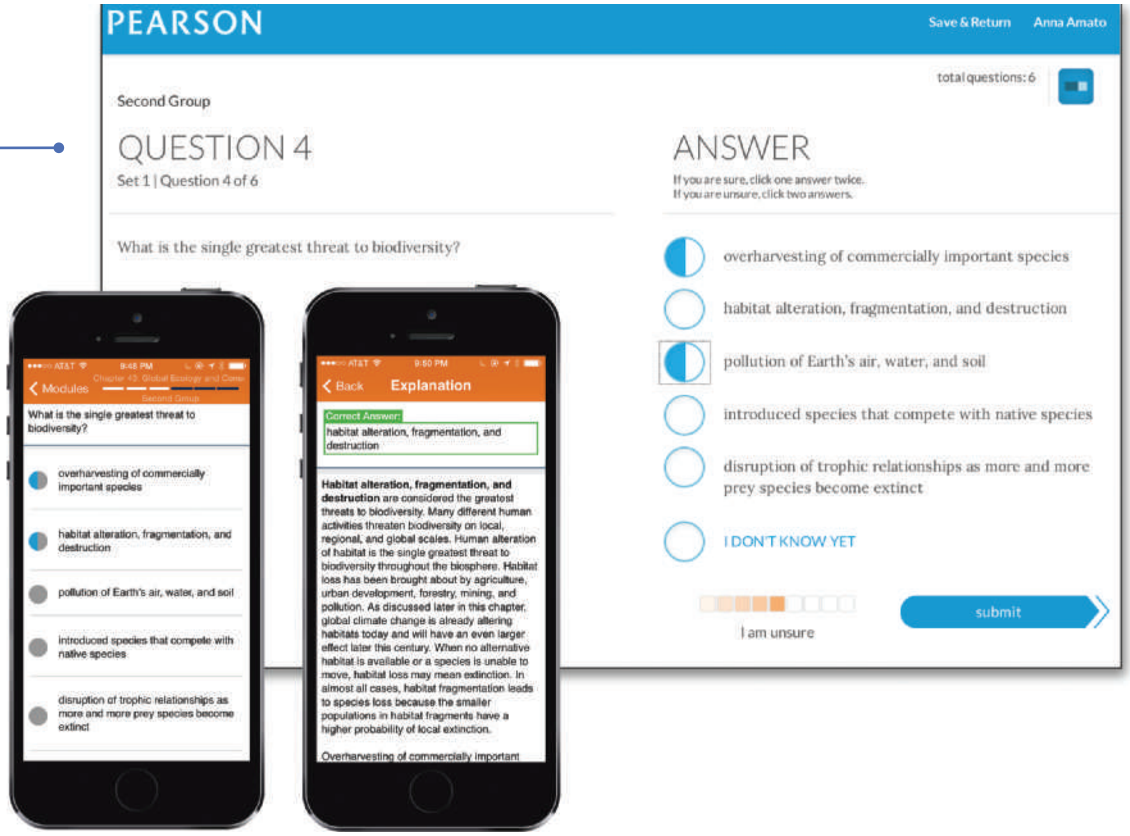

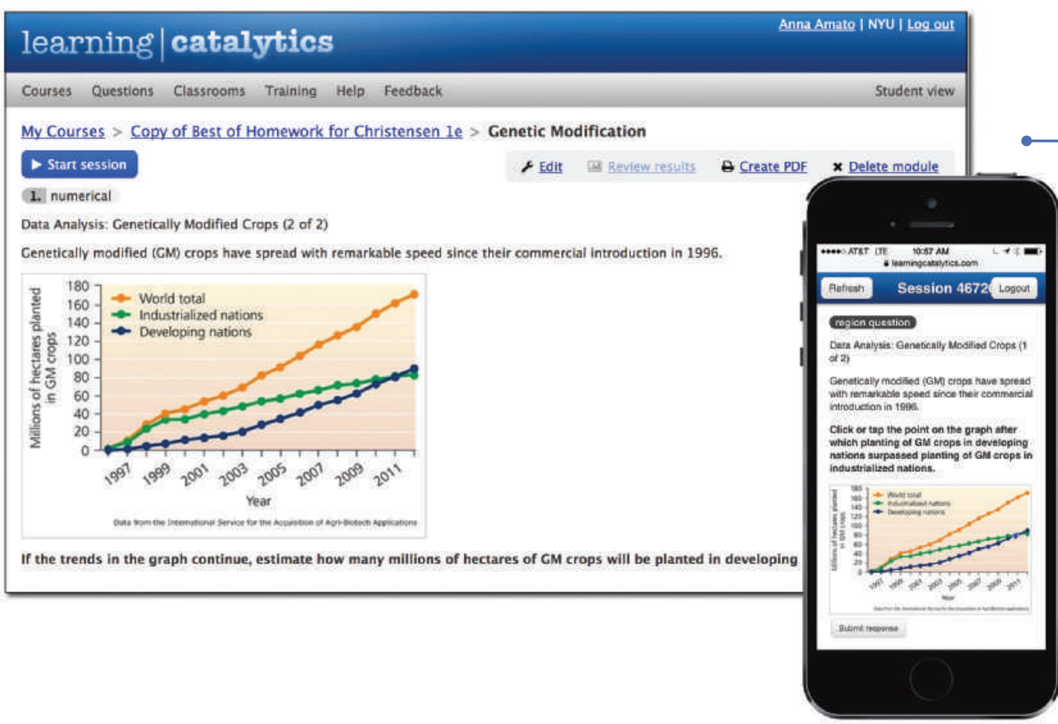

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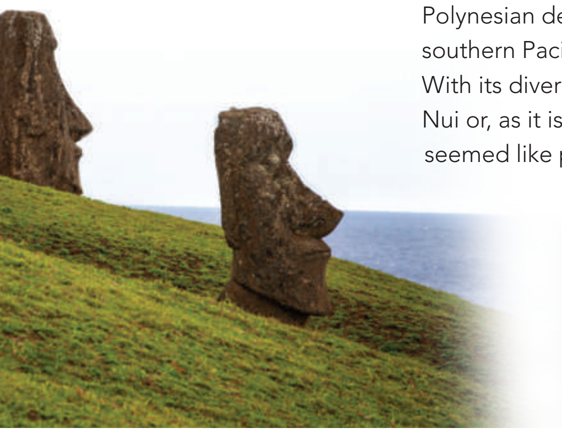
Learning Catalytics questions expand the possibilities for student engagement. The bring-your-own device classroom intelligence system allows instructors deliver a wide range of auto-gradable or open-ended questions that test content knowledge and build critical thinking skills.

Environment, Sustainability, and Science

1

It Takes a Community

Can we collaborate, plan, and act for a sustainable future?



▲ **Figure 1.1 Easter Island**
Hundreds of iconic moai, massive religious statues, testify to a once-robust Rapa Nui community and culture. It is thought that, in the 1600s, the island's few remaining trees were used to transport the moai to the island's perimeter.

Sometime between A.D. 700 and 1100, people of Polynesian descent colonized a remote island in the southern Pacific Ocean, 3,500 km (2,180 mi) west of Chile. With its diverse forests and productive coastal waters, Rapa Nui or, as it is popularly known, Easter Island must have seemed like paradise to these first inhabitants. In just a few of centuries, these people, also called Rapa Nui, developed an advanced culture with writing and religion, and their population grew to 15,000 to 20,000 (**Figure 1.1**). But by the time of Dutch explorer Jacob Roggeveen's arrival in 1722, Rapa Nui had been deforested, 21 tree species were extinct, and no tree taller than 10 feet remained. Unable to build seaworthy boats and having decimated the island's land and seabird populations, only 2,000 to 3,000 Rapa Nui remained, eking out a meager living by farming the island's infertile soils.

The Rapa Nui saga is seen by many historians and ecologists as a classic example of the *tragedy of the commons*. The tragedy, first described in 1968 by philosopher Garret Hardin, is the decline and destruction of the natural resources—forests, wildlife, water, and so on—that are shared in common by members of a community. Cooperation, planning, and regulation among community members could avert this tragedy and sustain such resources indefinitely. But, Hardin argued, cooperative behavior diminishes the net benefit that individual members of the community can obtain by uncontrolled exploitation. In the end, individual greed wins out over community cooperation, and commonly shared resources are overexploited.

We, too, live on an island (**Figure 1.2**), and possible parallels to the Rapa Nui story are compelling. We share a great many natural resources in common with 7.3 billion other individuals. Supplies of many of those resources are diminishing. Each year, for example, 0.2% of Earth's forests are permanently lost and more than 1% are severely degraded. Nearly a third of marine fish stocks are in decline. The species extinction rate is thought to be 1,000 times greater than in pre-human times. We are polluting critical common resources such as the air we breathe and water we drink. Earth's ecosystems can renew most of these resources, but this would require cooperation, planning, and action among community members.

Are we, too, doomed to the tragedy of the commons? Many environmental scientists believe strongly that we are not. Economist Elinor Ostrom was certainly a vocal champion for this view (**Figure 1.3**). Although she acknowledged that common resources are often overexploited, she also saw numerous cases where they had been and continue to be sustainably managed. The tragedy of the commons, she argued, is an oversimplification, and community members are not necessarily trapped by their greed. Nor are they unwilling to invest time and energy to agree on sustainable resource management strategies.

Ostrom and her colleagues chronicled numerous examples of community success, including sustainable management of fisheries by the Seri people of northwest Mexico and long-term stewardship of forests by

◄ **Figure 1.2 Home Sweet Home**
It is obvious from this photo of Earth rising over the lifeless surface of our moon that we, too, live on an island. Earth is, so far as we know, the only inhabited and inhabitable place in our solar system. Its resources are finite, but most are renewable if they are used at sustainable rates.

communities in Nepal (**Figure 1.4**). She also pointed to successful community collaboration on much larger scales such as the Montreal Protocol, an international program that has successfully limited emissions of chemicals that degrade Earth's protective ozone layer.

Ostrom compared these situations to ones where the tragedy of the commons prevailed, and she identified key characteristics of resources, governance, and communities that lead to sustainable management of common resources.

The condition of the resource is very important. When resources become severely exhausted, there are few incentives to manage them sustainably. Therefore, early action is important. Community action is more likely the more important a resource is to the community.

Choice and voice were important governance characteristics shared by sustainable communities. The more options for management, the better, and community members should have equal say in deciding which options to pursue.

▲**Figure 1.3 A Sustainability Optimist**
Elinor Ostrom was convinced that individuals in communities can sustainably manage their resources through collaborative, collective action. Her innovative studies earned her the 2009 Nobel Prize in Economics.

Sustainable communities share three important characteristics. The first is knowledge; the more communities know and understand about essential resources, the more likely it is that they will collaborate to conserve them. The second is leadership; individuals committed to the future of the community and its resources are essential. The third is what Ostrom called social capital; sustainable communities share a vision for the future, and they share values that shape the means of reaching that future.

Ostrom's key community characteristics appear throughout *The Environment and You*. This includes knowledge and understanding of Earth's ecosystems and our impacts on them. It also includes abundant examples of sustainable actions to reduce or eliminate those impacts. Most important, we demonstrate ways that you as individuals can put these actions into practice. We are certain that you will find many reasons to share Ostrom's belief in the potential for sustainable communities at local, regional, and global levels.

- *What is sustainability?*
- *What are the characteristics of sustainable systems?*
- *What is an ecosystem?*
- *What key characteristics do Earth's ecosystems share?*
- *Why are uncertainty and science important to the sustainable management of systems?*
- *What important questions remain for a sustainable future?*

◄**Figure 1.4 Sustainable Communities**
Ⓐ The Seri people have sustainably fished and farmed along the coast of the Sea of Cortez for over 2,000 years. Community members share a commitment to the well-being of their community and the resources that support it. Ⓑ For tens of generations, Nepali farmers have sustainably managed their agricultural fields alongside forest ecosystems. These communities understand that intact diverse forests provide fuelwood, timber, and wildlife, and they also control erosion and support pollinators for their crops.

1.1 Environment and Sustainability

BIG IDEA In Earth's long history, no organism has had a greater effect on the environment than have humans. Our ability to appropriate Earth's resources has been a major factor in the rapid growth in our numbers. Over the past century, we have come to understand that our actions have significant consequences for the well-being of the community of all living things and for ourselves in particular. This understanding is the basis for human actions and behaviors that are mindful of essential environmental processes, economically feasible, and fair to all people now and in the future. These are the key prerequisites for a sustainable future.

The Environment and You

Environmental science and ecology explore the interactions of humans with the natural environment.

You may use the word *environment* to describe where you are and everything around you. Scientists have a more specific definition: the **environment** is all of the physical, chemical, and biological factors and processes that determine the growth and survival of an organism or a community of organisms. The long list of all the factors that make up your environment would include the gases in the air you breathe and the many life forms that nourish and are nourished by you. **Environmental science** studies all aspects of the environment.

Ecology is the branch of environmental science that focuses on the abundance and distribution of organisms in relation to their environment. Earth's environments have sustained living organisms for at least 3.8 billion years; they have sustained members of our own species for well over 100,000 years. Throughout this time, Earth's environments and the communities of organisms that depend on them have been constantly changing.

▲ **Figure 1.5 The Frontier**
This painting by Albert Bierstadt of seemingly unending wilderness is typical of many 19th-century depictions of American landscapes.

◀ **Figure 1.6 Too Many Uses?**
Rapid population growth in the United States following World War II placed increasing demands on public lands for timber resources and for other ecosystem services such as grazing, recreation, and the protection of water supplies.

Defining Sustainable Actions

■ Our understanding of sustainable behavior has changed through time.

The concept of sustainability is central to environmental science. But what does it mean to be sustainable? Over the last 150 years, we have viewed this concept in different ways.

A century and a half ago, the human use of resources, such as wildlife and fisheries, was determined largely by our needs or perceived needs. Earth's forest resources appeared to be inexhaustible, and wildlife was abundant (Figure 1.5). Rivers, lakes, and coastal waters were teeming with fish. We were fully confident of the environment's capacity to produce an abundance of resources and to absorb and process our wastes. And why not? The world's population was only about 1 billion people, and the population of the United States was less than 75 million. (Today, over 7 billion people inhabit this planet; more than 300 million live in the United States.)

As human populations and their demand for resources grew, supplies of resources began to dwindle. Between 1920 and 1940, the number of scientific studies of the environment increased greatly. With new knowledge, resource managers began to appreciate the need to align the demand for resources with their supply. In forestry, this included strategies to plant and regrow trees after harvest and to protect them from the threats of pests and fire. In fisheries, this meant establishing catch limits and artificially stocking lakes and streams. These actions helped to sustain the supply of resources.

By 1950, there were 2.5 billion people in the world and 152 million in the United States. As the demand for resources increased, conflicts skyrocketed. In the United States, for example, growth in housing increased the demand for wood from national forests. At the same time, there was increased public interest in using those forests for recreation, for supporting wildlife, and for protecting water supplies. People argued over which use of forest resources should be given priority. To be sustainable, management policies had to recognize the different demands on the environment and its resources. Policies also had to address the conflicts among humans who valued those resources differently. For example, in the management of U.S. national forests there are strongly held values associated with commercial timber management, the provision of clean water, and the conservation of species that have often been in conflict (Figure 1.6).

Where YOU LIVE **What resources does your national forest provide?**
Find the nearest national forest to your home by searching the web for "U.S. national forest" and the name of your state. What important natural resources and public benefits does your forest provide? What potential conflicts might there be among these uses?

▲ **Figure 1.7 Sustainability as a Commitment to the Future**
The 1987 UN Commission on Sustainability was chaired by Norwegian prime minister Gro Brundtland.

▼ **Figure 1.8 A World of Change**
This is a composite satellite image of Earth at night. Imagine how it might have looked a century ago. How will it change over the next century? The changes in these lights represent changes in Earth's ecosystems, in human values and technologies, and in our environmental impacts.

In its 1987 report, *Our Common Future*, the United Nations Commission on Sustainability declared, "At its most basic level, sustainability means meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Figure 1.7). This declaration added a critical element of time to our concept of sustainability—sustainable management has its eye on the needs of the future.

The UN Commission on Sustainability was concerned with maintaining **human well-being**, a multifaceted concept that includes life's basic necessities, such as food and shelter, as well as good health, social stability, and personal freedom. Their report noted that the factors necessary to ensure human well-being may change from one generation to the next. Thus, sustainability is not a process of maintaining the status quo. Instead, the commission argued that sustainability is maintaining the ability to accommodate three important sources of change.

1. The world is changing. Earth's environments undergo constant change, sometimes in regular daily and seasonal cycles and sometimes in more complicated patterns. Environmental change is both inevitable and essential.

2. We are changing. Successive generations of humans have developed and used ever-changing technologies to extract and use resources. Humans also pass their knowledge about their environment and its resources from one generation to the next. As a consequence, our needs for ecosystem goods and services are constantly changing. The value we place on these goods and services changes, too.

3. We are changing the world. No other organism has ever shaped its environment to the extent that we have. Our use of technologies, such as fire and agriculture, has allowed our numbers to increase and has changed the world. Our increasing numbers have extended our influence (Figure 1.8). Our increasing use of technology has had even greater consequences.

Today we are at a unique moment in history. At no previous time has Earth supported so many humans. At no previous time has overall human well-being been better. We can point with gratitude to actions by previous generations that have helped us meet our current needs, such as the development of agricultural technologies and the establishment of national forests and parks. But we can also identify actions by our ancestors that have impoverished our world. In many regions, poor agricultural practices have permanently diminished soil fertility. Overexploitation has left us with mere snippets of the once vast ancient forests.

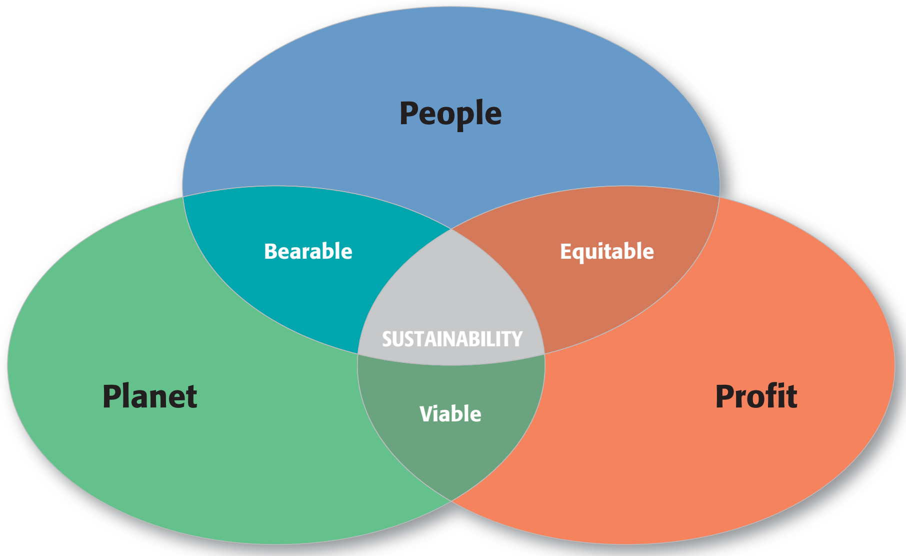
Although average well-being among humans is high, variation in well-being is high as well. In developed countries such as the United States, clean water is taken for granted and obesity is all too common. Yet more than one-fifth of Earth's people lack access to clean water and suffer from malnutrition. This disparity has led the United Nations and other world leaders to broaden the definition of sustainability to include the concept of equity. In this context, **sustainability** means meeting the needs of the present *in an equitable and fair fashion* without compromising the ability of future generations to meet their own needs. This is the definition that we will use throughout this text. (It should be noted, however, that scholars and decision makers are not in agreement on what constitutes "equitable and fair.")

Does this definition of sustainability seem too focused on humans? If so, remember that Earth's environments were self-sustaining for billions of years before our time. If we were to disappear tomorrow, they would eventually recover from our impacts. Our present and future well-being depends heavily on how we treat all of Earth's life and environments. But it also depends on actions that are economically feasible and fair to all people, now and in the future.

Planet, People, and Profit: The Triple Bottom Line

■ Sustainability lies at the intersection of environmental, social, and economic success.

For years, the environmentally minded have insisted on the importance of including the environment in the measurement of profit in business but struggled to develop an accounting system to include these external costs. In 1994, John Elkington, the founder of a British consultancy, SustainAbility, developed the concept of the **triple bottom line (TBL)**. TBL is an accounting framework by which corporations, nonprofit organizations, and even governments can measure three dimensions of performance: environmental, social, and economic. According to TBL thinking, the intersection of these three dimensions is the only sustainable path for the future (Figure 1.9). Also referred to as the "3 P's"—planet, people, and profit—TBL incorporates the dimension of "planet" or environment, as measured by output of pollutants, conservation of endangered species, waste production, energy use, and so on. The social dimension, or "people," includes such measures as human health and well-being, equity (including the difference in salary between top executives and the lowest-paid workers), access to social resources, and benefit to the community. The economic dimension, or "profit," is the only measure that has been traditionally evaluated.



▲ Figure 1.9 **The Triple Bottom Line**
The intersection of these three dimensions is the path to sustainability. Profit without people or planet is short sighted, with no future human or environmental capital to draw from. Environment without people or profit does not support human well-being or allow for economic growth. A focus on the social dimension without accounting for the dimensions of planet or profit does not allow for the preservation of long-term environmental capital or sustaining incomes.

Reporting the TBL presents a challenge for any organization, in that each dimension is measured in different units. How can the value of pollution that was never emitted be measured in dollars? What is the value of a healthy and happy workforce and a community supported by the businesses therein? Despite the challenges of measurement, TBL is gaining popularity among corporations, nonprofits, and governments, so much so that many have shifted their business models to evaluate and improve all three areas. What is motivating this shift? According to MIT/Sloan Management Review's 2011 Sustainability & Innovation Global Executive Study and Research Project, consumer preferences, legislative pressure, and resource scarcity are the most important drivers of this change toward a new business model. In addition, investors are looking more carefully at sustainability practices before supporting corporations.

Of nearly 3,000 global corporations surveyed in 2011, 31% reported that conserving environmental capital for the future and placing value in their communities and workforce has actually increased their profits. For example, Campbell Soup Company invested significantly in water efficiency measures, resulting in a savings of 1 billion gallons of water during 2008–2013 and a 15–20% return on investment (money saved due to the improvements). The bottom line is that corporations that incorporate the TBL into their business model also stand to increase their economic profit.

There is much we can learn from the past to help us ensure a sustainable world for the next generation. Yet in many important respects, that generation will be quite different from all earlier generations. By all indications, it will include over 9 billion people. Those people will use technologies and have expectations that we can hardly imagine. If the management of our resources today is to be truly sustainable, we must be very generous in our projection of future needs. The ecosystem concept described next provides a foundation for defining sustainable behavior and actions.

QUESTIONS 1.1

1. Describe how human understanding of sustainable actions has changed over the past century.
2. What kinds of change must be included in our understanding of sustainability?
3. Describe the three dimensions of the TBL. How is each important to sustainability?

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