Environment

SCIENCE, ISSUES, SOLUTIONS

Manuel Molles ▪ Brendan Borrell

BRIEF CONTENTS

	Preface	xiv
1	Introduction	1
2	Ecosystems and Economic Systems	31
3	Conservation of Endangered Species	59
4	Species and Ecosystem Diversity	93
5	Human Populations	125
6	Sustaining Water Supplies	155
7	Sustaining Terrestrial Resources	187
8	Sustaining Aquatic Resources	227
9	Fossil Fuels and Nuclear Energy	261
10	Renewable Energy	295
11	Environmental Health, Risk, and Toxicology	329
12	Solid and Hazardous Waste Management	357
13	Air, Water, and Soil Pollution	385
14	Global Climate Change	427
Appendix A	Basic Chemistry	A-1
Appendix B	The Rock Cycle: Product of a Dynamic Planet	B-1
Glossary		G-1
Index		I-1

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Manuel Molles
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To all people everywhere, and the web of life that sustains us

ABOUT THE AUTHORS

(Courtesy of Manuel Molles)

Manuel Molles

Manuel Molles is Professor Emeritus of Biology at the University of New Mexico, where he has been a member of the faculty and Curator for the Museum of Southwestern Biology since 1975. Presently, he and his wife Mary Anne live in a cabin in the mountains of La Veta, Colorado, where he writes full time and manages his 100-acre property. He received his Bachelor of Science degree in fisheries from Humboldt State University in 1971, and his Ph.D. in zoology from the University of Arizona in 1976. His dissertation topic was "Fish Species Diversity on Model and Natural Patch Reefs: Experimental Insular Biogeography." Manuel has taught and conducted ecological research in Latin America, the Caribbean, and Europe. He was awarded a Fulbright Research Fellowship to do research on river ecology in Portugal, and has been a visiting professor at the University of Coimbra, Portugal, at the Polytechnic University of Madrid, Spain, and at the University of Montana. Most recently, in 2014 Manuel was awarded the Ecological Society of America Eugene P. Odum Award for "Excellence in Ecology Education."

(Courtesy of Brendan Borrell)

Brendan Borrell

Brendan Borrell is a biologist and journalist who has written about science and the environment for dozens of outlets, including *Bloomberg Businessweek*, *Outside*, *Nature*, *New York Times*, *Scientific American*, and *Smithsonian*. His reporting at home and abroad has given him a firsthand view of some of the most pressing environmental issues of today. He has visited the phosphate mines of Morocco, followed a rhino hunt in South Africa, and taken a road trip through the expanding soy plantations of central Brazil. Brendan received his Ph.D. in Integrative Biology from the University of California, Berkeley, in 2006. For his dissertation research, he studied the evolution, ecology, and physiology of nectar feeding in the orchid bees of Costa Rica and Panama. His articles have received awards from the American Society for Journalists and Authors, and his reporting has been funded by the Alicia Patterson Foundation, the Pulitzer Center on Crisis Reporting, and the Mongabay Special Reporting Initiative.

WHY I WROTE THIS BOOK

I wrote this book because I am concerned about the future of wild places and the welfare of humanity, particularly the welfare of the next few generations who will inherit the world we leave.

I am motivated by a sense of urgency and mounting evidence that the time to establish a sustainable relationship with Earth is fast running out. The roots of these concerns about the environment developed early. I grew up on a family farm, where, from childhood, I was responsible for growing irrigated crops and raising a wide variety of livestock. There, husbanding animals and tilling soil, I grew to appreciate a well-run farm. However, my focus was not entirely on farming. There were wild places nearby where I was free to roam when my farm chores and schoolwork were done. Our farm overlooked the Merced River in central California at the transition between the flats of the Central Valley and the foothills of the Sierra Nevada. The headwaters of the Merced River drain Yosemite Valley, that long-ago haunt of John Muir.

My father trained me to do all the farm chores, but he also taught me to appreciate wild nature, especially the habits of birds—his first love. Likely because of these early influences, I would spend every available moment on or in the Merced River. However, my knowledge of the place where I grew up was not limited by what I saw in my ramblings, since my family had lived in the area since the mid-1800s. The stories of two great uncles who arrived in northern California as young boys in 1865, three years before Muir began living in Yosemite, were particularly exciting. Incredibly, one of them, Uncle Jim, was still active when I was a child. Those early days were, he said, a time of extensive wetlands and abundant wildlife, of rivers teeming with salmon, the ocean thick with whales, and most of the redwood forests still uncut. I never tired of those tales of what once was, but they also filled me with a deep sense of what had been lost in less than a century. However, I was also encouraged by the survival of unspoiled ecosystems near our farm, just an hour and a half drive from San Francisco, which we called The City and where I learned to value culturally rich urban environments.

My hope is that through this text, I can contribute in some small way to a sustainable balance between wild ecosystems, ecosystems managed for resource extraction, and urban ecosystems. It is my belief that a healthy future for humanity depends on achieving such a balance.

The core of what appears on these pages—the organization, topics, tone, and language—is inspired by what I have learned from the more than 10,000 students who attended my classes during my decades of teaching. Whether in the field, laboratory, or lecture hall, it was these students who taught me what in a subject is significant and how to communicate it. Through this text I hope to share a vision for sustainability with a new generation of students who will be the keepers of humanity's future.

I am also motivated by the feeling that my career would be incomplete without reaching out beyond my academic publications to write this textbook, which I have written while living in mountains surrounded by old growth, mixed conifer forest, abundant wildlife, and fishing for trout when I have a spare moment.

Manuel C. Molles
La Veta, Colorado

BRIEF CONTENTS

	Preface	xiv
1	Introduction	1
2	Ecosystems and Economic Systems	31
3	Conservation of Endangered Species	59
4	Species and Ecosystem Diversity	93
5	Human Populations	125
6	Sustaining Water Supplies	155
7	Sustaining Terrestrial Resources	187
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13	Air, Water, and Soil Pollution	385
14	Global Climate Change	427
Appendix A	Basic Chemistry	A-1
Appendix B	The Rock Cycle: Product of a Dynamic Planet	B-1
Glossary		G-1
Index		I-1

CONTENTS

Preface xiv


(Kelli-Ann Bliss/NOAA)

Chapter 1 Introduction 1

Science 4

1.1 Environment is everything 4

1.2 Science uses a formal method to gather evidence about how nature works 6

1.3 Scientific evidence can reduce uncertainty about natural phenomena 10

1.4 The integrity of science depends on following a strict code of ethical conduct 12

Issues 14

1.5 Human impact and environmental awareness began long ago 14

1.6 Human impact on the environment has become a global issue 19

Solutions 21

1.7 Environmental ethics extends moral responsibilities to the environment 21

1.8 Sustainability as a pragmatic solution to environmental woes 25

1.9 Environmental science provides a comprehensive framework for addressing environmental issues 26


(Jean Michel Labat/ Ardea.com)

Chapter 2 Ecosystems and Economic Systems 31

Science 34

2.1 Ecosystems and economic systems are built on matter 34

2.2 Energy makes matter move 36

2.3 Energy flows through ecosystems, while matter recycles 39

2.4 Economic systems and their currencies take several forms 43

Issues 46

2.5 Energy fuels, and limits, the economy 47

2.6 How we represent economic systems can have environmental consequences 48

2.7 Unregulated use of resources can lead to a "Tragedy of the Commons" 49

Solutions 50

2.8 Economics should include environmental costs and benefits 50

2.9 Property rights can lead to environmental preservation 52

2.10 Alternative paths to sustainability: Tragedy of the Commons revisited 53


(Jim Peaco, Yellowstone National Park, NPS)

Chapter 3 Conservation of Endangered Species 59

Science 62

3.1 Genetic diversity is essential to the evolution and survival of populations 62

3.2 Distribution and abundance are key indicators of population security 67

3.3 Populations change 68

3.4 The life history of a species influences its capacity to recover from disturbance 71

3.5 Species interactions define biological communities 73

Issues 76

3.6 Habitat destruction and alteration are the most serious threats to biodiversity 77

3.7 Invasive species threaten native species 78

3.8 Plant and wildlife trafficking are growing dangers to species 79

3.9 Pest and predator control have pushed species to the brink of extinction 80

Solutions 82

3.10 National laws and international treaties protect endangered species 82

3.11 Banning of a toxin and captive breeding brought peregrine falcons back from the brink of extinction 84

3.12 Population ecology provides a conceptual foundation for wolf restoration 84

3.13 Restoration of North American gray wolves has required working through conflict 85

3.14 Wild populations are sources of significant economic benefits 88

(Cheryl Jaworowski/USGS)

Chapter 4 Species and Ecosystem

Science 96

4.1 Species and ecosystem diversity are key elements of biodiversity 96

4.2 Geographic patterns and processes influence biodiversity 97

4.3 Some species influence biodiversity much more than others 103

4.3 Some species influence biodiversity much more than others 103

4.4 Ecological succession affects community composition and diversity 106

4.5 Global species richness results from a balance between speciation and extinction 108

Issues 110

4.6 Habitat fragmentation reduces biodiversity 110

4.7 Valuable services of ecosystems are threatened 112

4.8 Many invasive species harm ecosystems 113

Solutions 115

4.9 The number of protected areas has grown rapidly 116

4.10 Nongovernmental conservation complements governmental programs 117

4.11 Sustaining biodiversity and ecosystem services requires active management 118

4.12 Integrating conservation with local communities can help sustain protected areas 120

(Jorg Hackemann/Shutterstock)

Chapter 5 Human Populations 125

Science 128

5.1 Human population density varies significantly across Earth 128

5.2 The global population will grow into the middle of this century 130

5.3 The age structure of a population gives clues to its growth or decline 131

Issues 134

5.4 Fertility ranges greatly among countries and regions 134

5.5 Development varies widely among countries 136

5.6 Population growth and development generally increase environmental impact 137

5.7 Developmental differences between populations create migration pressures 139

Solutions 142

5.8 Most nations have national policies aimed at managing population growth 142

5.9 Human development is associated with lower fertility and reduced emigration 147

5.10 The challenge: Achieve high development and sustainable resource use 149

(NASA)

Chapter 6 Sustaining Water Supplies 155

Science 158

6.1 The hydrologic cycle moves water around Earth 158

6.2 The El Niño Southern Oscillation causes periods of dry years and wet years 161

Issues 162

6.3 Access to adequate water supplies as a human right 162

6.4 Humans already use most of the world's accessible freshwater supplies 164

6.5 Groundwater is being depleted faster than it is replenished 166

6.6 Managing water for human use threatens aquatic biodiversity 168

Solutions 173

6.7 Water conservation can increase water use efficiency substantially 173

6.8 Reclamation and recycling are saving water throughout the world 175

6.9 Desalination taps Earth's largest reservoir of water 178

6.10 Conservation and restoration can protect aquatic ecosystems and biodiversity 181


(Dudarev Mikhail/Shutterstock)

Chapter 7 Sustaining Terrestrial Resources 187

Science 190

7.1 Climate, biodiversity, and nutrients influence terrestrial primary production 190

7.2 Agriculture, forestry, and grazing systems are built on the natural biomes 193

7.3 Soil structure and fertility result from dynamic processes 194

Issues 198

7.4 Industrial agriculture, which increased production, came with environmental impacts 198

7.5 Common farming, grazing, and forestry practices deplete soils 199

7.6 Deforestation and some forestry management practices deplete soils and increase flooding danger 202

7.7 Irrigation can damage soils 205

7.8 Intensive agriculture can cause pollution and promote pesticide resistance 206

7.9 Genetically modified crops are sources of controversy and agricultural potential 209

Solutions 213

7.10 Investing in local farmers, while increasing genetic and crop diversity, may be a sustainable approach to feeding our growing population 213

7.11 Sustainable farming, forestry, and ranching practices can reduce soil losses and improve soil fertility 215

7.12 Sustainable irrigation requires careful management of water and salts 220

7.13 Integrated approaches to pest control can reduce pesticide pollution and evolution of pesticide resistance 221


(Bill Dewey, Taylor Shellfish Farms)

Chapter 8 Sustaining Aquatic Resources 227

Science 230

8.1 Commercial fish populations are heavily harvested and actively managed 230

8.2 Nutrient availability influences primary production in marine environments 232

8.3 El Niño and other large-scale climatic systems affect fisheries 236

Issues 237

8.4 Tragedy of the Commons: Intensive harvesting has resulted in overexploitation of many commercially important marine populations 237

8.5 Dams and river regulation have decimated migratory fish populations 241

8.6 Aquaculture can pollute aquatic environments and threaten wild fish populations 242

Solutions 245

8.7 Saving global fish stocks requires careful management and strong incentives 245

8.8 Biodiversity contributes to the productivity and stability of fisheries 248

8.9 River restoration may be a key to restoring decimated salmon populations 252

8.10 Aquaculture can provide high-quality protein with low environmental impact 254


(Dado Galdieri/Bloomberg via Getty Images)

Chapter 9 Fossil Fuels and Nuclear Energy 261

Science 264

9.1 Fossil fuels provide energy in chemical form 264

9.2 Power plants and vehicles burn fossil fuels to generate electricity and movement 270

9.3 Nuclear energy is released by atomic fission and fusion 272

Issues 274

9.4 Global energy use grows as energy shortages loom 274

9.5 Fossil fuel extraction and use can harm the environment 277

9.6 Nuclear power development comes with environmental costs 281

Solutions 284

9.7 New laws and technology are cleaning up the oil industry 284

9.8 Ecosystem restoration can mitigate the environmental impacts of fossil fuel extraction 286

9.9 Advances in nuclear power plant operation and design are aimed at improving safety 288

(Andrew Henderson/National Geographic Creative)

Chapter 10 Renewable Energy 295

Science 298

10.1 Solar energy can be used as a heat source and to generate electricity 298

10.2 Wind, water, and geothermal energy add to the renewable energy portfolio 302

10.3 Biomass fuels represent stored chemical energy 307

Issues 310

10.4 Solar power remains costly and can damage the environment 310

10.5 Wind turbines and transmission lines kill birds and bats 312

10.6 Hydroelectric development can have multiple environmental and social impacts 314

10.7 Biofuel development can reduce food supplies and harm the environment 315

Solutions 317

10.8 Smart solutions to issues associated with solar power are under development 317

10.9 Less damaging wind-generation strategies are under development 319

10.10 Downsizing can mitigate the impacts of hydroelectric development 321

10.11 Less damaging, more efficient biofuels are under development as alternatives to oil-based fuels 323

(fotog/Getty Images)

Chapter 11 Environmental Health, Risk, and Toxicology 329

Science 332

11.1 Chemical hazards include toxic substances and pollutants 332

11.2 Bacteria, viruses, and parasites are spread through the environment 334

Issues 339

11.3 Toxic substances move through the environment and can accumulate in large concentrations 339

11.4 Exposure to endocrine disruptors can affect the health of humans and other organisms 340

11.5 Misuse and overuse have promoted resistance to antibiotics and insecticides 342

11.6 Infectious diseases spill over from wild species and continue evolving to evade our defenses 344

Solutions 346

11.7 We assess risk both qualitatively and quantitatively 346

11.8 Risk management involves reducing environmental hazards and controlling disease 348

(USFWS photo by Susan White)

Chapter 12 Solid and Hazardous Waste Management 357

Science 360

12.1 The "waste" generated by economic systems does not occur in ecosystems 360

12.2 Waste has diverse sources and properties and varies with level of economic development 361

Issues 364

12.3 Municipal solid waste management is a growing problem 364

12.4 Hazardous waste generation is increasing and is often handled unsafely 367

12.5 New forms of hazardous waste are on the rise 369

12.6 Safe nuclear waste disposal requires long-term security 370

Solutions 373

12.7 Modern waste management emphasizes reduced disposal 373

12.8 Food waste and other biodegradable trash can be reduced and repurposed 374

12.9 Recycling and demanufacturing are critical to reducing waste 376

12.10 Safe and secure long-term disposal is the last resort 378


(Geoff Liesik/The Deseret News via AP)

Chapter 13 Air, Water, and Soil Pollution 385

Science 388

13.1 Industry releases pollutants 388

13.2 Humans produce a wide variety of pollutants 390

13.3 Atmospheric and aquatic transport eventually move pollutants around the planet 396

Issues 400

13.4 Air pollution exacts major health-related and economic tolls 400

13.5 Acid rain is a major source of damage to aquatic and terrestrial ecosystems 402

13.6 Persistent pollutants enter the human food chain 404

13.7 Organic matter and nutrient pollution can disrupt local and distant ecosystems 407

Solutions 409

13.8 Environmental regulation and international treaties have played important roles in reducing pollution in North America 409

13.9 Control measures have reduced emissions of pollutants and acid rain 412

13.10 New technologies can reduce indoor air pollution 415

13.11 Soils and sediments contaminated by hazardous wastes can be cleaned using a variety of techniques 416

13.12 There are many effective ways to reduce organic and nutrient pollution 419


(Jean-Louis Klein & Marie-Luce Hubert/ Science Source)

Chapter 14 Global Climate Change 427

Science 430

14.1 The atmosphere exerts key controls on planetary temperatures 431

14.2 Scientists began building the basis for understanding the greenhouse effect more than 200 years ago 432

14.3 Global temperatures and atmospheric CO_2 concentrations have varied cyclically 434

14.4 Atmospheric CO_2 appears to be the thermostat controlling global temperatures 437

Issues 440

14.5 Precise measurements reveal that fossil fuel burning is the main cause of increased atmospheric CO_2 levels 440

14.6 As CO_2 levels have risen in modern times, global temperatures have increased significantly 443

14.7 Rising temperatures have been accompanied by diverse changes in the Earth system 445

14.8 Climate change can lead to a wide range of societal costs 448

Solutions 452

14.9 Developing a road map to reduce carbon emissions 452

14.10 Reducing greenhouse gas emissions provides new economic opportunities 457

14.11 Restoring and enhancing carbon sinks could help balance the carbon budget 459

Appendix A Basic Chemistry A-1

Appendix B The Rock Cycle: Product of a Dynamic Planet B-1

Glossary G-1

Index I-1

A UNIQUE CHAPTER STRUCTURE

Each chapter is divided into three sections: Science, Issues, and Solutions.

"It clearly distinguishes between the science and political, social and economic choices required by the problems. It is more congenial to my teaching than any of my current or recent texts, period."

–BrianM ooney,
Johnson & Whales University

"I love this [science-issues-solutions] approach. Science is the tool that lays the foundation for what follows."

–BarryP erlmutter,
College of Southern Nevada

Central Question: How can we mitigate and adapt to the environmental and social impacts of climate change?

Explain the factors that control climate and global temperatures.

SCIENCE

(Jean-Louis Klein & Marie-Luce Hubert/Science Source)

Navigation bar clearly guides students through each chapter, using color to identify science, issues, solutions.

CHAPTER 14

Global Climate Change

Analyze the causes and impacts of a warming global climate.

ISSUES

Discuss the
that could m

SOLUTIONS

14.1–14.4 Science

Each chapter begins by explaining the basic science relevant to the chapter's topic, as a foundation for the coverage to follow.

14.5–14.8 Issues

Students draw upon the science coverage to get a better understanding of current environmental issues.

14.9–14.11 Solutions

Each chapter concludes by asking students to evaluate the success or failure of solutions (either implemented or proposed) for environmental problems in different parts of the world.

A CENTRAL QUESTION SETS THE LEARNING GOAL FOR THE CHAPTER

SOME CONSEQUENCES OF A WARMER EARTH

(Scott Hortop/Getty Images)

(John McColgan, Bureau of Land Management, Alaska Fire Service)

(USDA photo by Bob Nichols)

Heat waves are setting temperature records and impacting larger and larger areas around the world. High temperatures combined with drought have been conducive to large wildfires of unprecedented magnitude. Drought has had severe impacts on agricultural production in regions such as the midwestern United States.

Tracking Wildfires in the West

Raging fires and extreme weather events could become more common with a changing global climate

At 7 A.M. on June 23, 2012, a jogger was running along the Waldo Canyon Trail in the mountains above Colorado Springs, Colorado, when he smelled smoke. He veered off the trail to investigate and found a smoldering fire in the woods. After he reported the fire to the local sheriff's department, high winds and drought conditions in the forest caused the fire to spread over 600 acres in several hours' time, leading to evacuations of several nearby communities. By the time firefighters finally contained the Waldo Canyon Fire, two and a half weeks later, it had burned 7,384 hectares (18,247 acres) and 346 homes, killing two people. It ranked as the most destructive fire in Colorado's history, resulting in insurance claims of more than $450 million. Although the fire may have been started by an arsonist, another suspect has been singled out for its rapid spread and devastating impact: climate change.

That year, the wildfire season in the West came on the heels of a period of unrelenting heat. During the 12 months from August 2011 to July 2012, land temperatures in the 48 contiguous United States were the warmest in 117 years of record-keeping. Across Colorado, wildfires blackened nearly 67,000 hectares (165,000 acres) and destroyed over 600 homes. In Montana and New Mexico, they consumed another 529 homes. In Utah and Wyoming, they forced the shutdown of natural gas fields, interrupting the flow of critical energy supplies. All told, wildfires in the United States in 2012 burned more than 1.7 million hectares (4.1 million acres).

Abnormally high temperatures in the United States had other impacts as well. For instance, cattle had so little healthy pasture that the USDA allowed ranchers to graze their cattle on conservation lands set aside for erosion control and wildlife habitat. Approximately half of the nation's corn crop and one-third of the soybean crop had failed or were near failing—an episode that would play out in the global economy as an increase in food prices. Reduced farm income would hurt a wide range of businesses located in agricultural regions.

"Preservation of our environment is not a liberal or conservative challenge, it's common sense."

President Ronald Reagan, State of the Union address, January 1984)

Climate scientists modeling future climates believe that the summer of 2012 may provide a preview of some of the environmental and economic consequences of climate change. In fact, they have concluded that by mid-century, if present trends continue, the western United States would be subject to droughts worse than any occurring in the previous 1,000 years. Human action has played a significant role in changing Earth's climate, particularly by increasing the concentrations of gases in the atmosphere that trap the Sun's energy, leading to a temperature increase of almost 1°C since 1880. Climate scientists predict that climate change will include a higher frequency of heat waves, droughts, and other weather extremes along with the loss of the polar ice caps and a rise in sea level.

By the end of the 21st century, climate models suggest that the temperature of Earth's surface will rise another 2 to 3°C. "Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia," wrote the authors of the fifth assessment of the Intergovernmental Panel for Climate Change (IPCC), published in 2014. "It is extremely likely that human influence has been the dominant cause of the observed warming."

The good news is that once we recognize that we are significant contributors to climate change, there are steps we can take to reduce the problem. However, as we address this issue, we will need to avoid causing other forms of disruption, both environmental and economic.

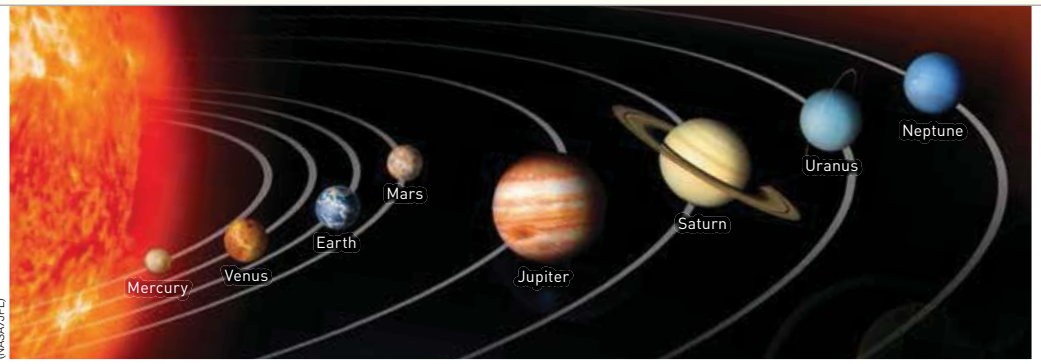
Central Question

How can we mitigate and adapt to the environmental and social impacts of climate change?

In each chapter, a case study introduces the student to the topic and establishes the overall learning goal for the chapter. This learning goal is called the Central Question.

"Using the Central Question as a theme through the chapter allows students to keep a focus on a thesis statement, tying together the supporting information. I find the Central Question very helpful in connecting concepts throughout the chapter."

–Terri Matiella, University of Texas, San Antonio



(NASA/JPL)

FIGURE 14.1 Mars, approximately 228 million kilometers (km) from the Sun, is the smallest of the three planets discussed here. Earth is approximately 78 million km closer to the Sun and twice the diameter of Mars. Venus is approximately the same size as Earth, around 40 million km, or 30%, closer to the Sun. However, the average temperature of Venus is more than 30 times higher than Earth's.

HOW CAN WE MITIGATE AND ADAPT TO THE ENVIRONMENTAL AND SOCIAL IMPACTS OF CLIMATE CHANGE?

The Central Question is visible on every spread of the chapter to help students keep it in mind as they read.

Central Question: How can we mitigate and adapt to the environmental and social impacts of climate change?

14.1–14.4 Science	14.5–14.8 Issues	14.9–14.11 Solutions	Answer the Central Question:
• What affect does the atmosphere have on planetary temperatures? • How did scientists learn about the greenhouse effect and its role on Earth? • How do global temperatures and CO_2 concentrations vary over time? • Which atmospheric factor exerts the most control over global temperatures and how do we know?	• What is the primary cause of increased CO_2 levels and how do we know? • What global physical effect results from rising CO_2 levels? • What types of changes on Earth have accompanied rising global temperatures? • What societal costs have resulted from climate change?	• What tactics can we take to reducing carbon emissions? • What new economic opportunities may arise from reducing greenhouse gas emissions? • What role do carbon sinks play in balancing the carbon budget?	

At the end of each chapter, students create an Active Summary as a recap of the Science, Issues, and Solutions sections presented in the chapter; it also prepares them to answer the Central Question.

"This layout has great value in terms of encouraging students to read, and it also requires the student to answer questions along the way that feed back into the Central Question. This lends itself to a curriculum based more on concepts and discussion rather than simple fact recitation."

–Megan Lahti, Arizona Western College

A Focus on Solutions

The topics and issues in environmental science can leave students feeling hopeless and powerless about environmental issues. Because of the unique chapter structure, this text emphasizes solutions—what has been done (and how well it worked) and what more can be done (and how science can help us implement it).

14.9–14.11 Solutions

(AP Photo/Danny Wilcox Frazier)

(Greg Gibson/AP Photo)

(Mark Henley/Panos Pictures)

Empowering Students

Following the Solutions section of each chapter, students work through a list of activities they might try in order to directly engage with environmental science issues and feel that their experience counts.

Climate Change and You

Many consider climate and atmospheric change to be the most serious environmental challenge that our species has ever faced. Massive releases of greenhouse gases resulting from the activity of a growing human population have already warmed Earth and threaten to radically disrupt the entire biosphere. The challenges posed by climate change put our collective life and economic support systems at risk. In the face of such a challenge, what can an individual do?

☐ ***Follow the science.***

Although climate scientists are in overwhelming agreement on climate change and its causes, the deniers of climate change science present competing conclusions on the present state and dynamics of Earth's climate, as well as the societal and environmental stakes. The best way to sort your way through these competing narratives is to build on what you have learned in this course by following developments in published science, paying particular attention to data associated with global temperatures, storm intensities, depth and frequencies of drought, sea level rise, and so forth.

☐ ***Conserve energy.***

Collectively, we can alter the amount of energy produced simply by conserving energy. Energy utilities report that conservation by consumers has already reduced energy demand in both the United States and Europe. A first step is to make sure that your residence is well insulated. If possible, you can also set your thermostat to reduce energy used for heating in winter (no higher than 68° F) and cooling in summer (no cooler than 78° F). Save energy by walking or bicycling whenever practical and safe, or use public mass transport. If you operate a motor vehicle, you can try to maximize fuel economy by choosing a fuel-efficient one and keeping it well maintained.

☐ ***Support efforts to reduce greenhouse gas emissions.***

As a citizen, you can use your voice and vote to support transitioning to renewable energy sources and reducing greenhouse gas production. You can support local, regional, and national programs fostering conservation agriculture and forestry practices that help sustain these natural carbon sinks. You can also support legislation that levels a cost on carbon emissions associated with power production and other industrial activity. As a consumer, you can go one step further and support clean energy initiatives offered by your local electrical utility.

☐ ***Become involved.***

In ways large and small, we can all be a force for constructive change. After completing this course in environmental science, you should have a broader understanding of the science, issues, and potential solutions to today's environmental challenges. More important, you are better prepared to expand that base of knowledge far beyond where it is now. As you do so, let your informed voice be heard where appropriate and become involved individually and with organizations that reflect your knowledge and understanding of the most pressing environmental issues, whether they be related to climate change or the many other issues surveyed in this text. In the end, because these issues reflect what we do or have done to the environment of our planet, all are interrelated.

"This [science-issues-solutions framework] allows students to understand the basis for the issues, and then helps them look toward the future with a sense of hopefulness and optimism [that] these issues can be addressed, instead of leaving them with a sense of 'doom and gloom.'"

–TerriM atiella,
University of Texas, San Antonio

Critical Thinking and Problem Solving

Think About It questions after each chapter section ask students to analyze what they've just read and apply it to new situations.

Margin questions throughout the chapter help students engage with the issues and can serve as lecture or discussion prompts.

Critical Analysis

Critical Analysis questions at the end of each chapter require students to apply higher-level Bloom's skills to environmental issues and solutions.

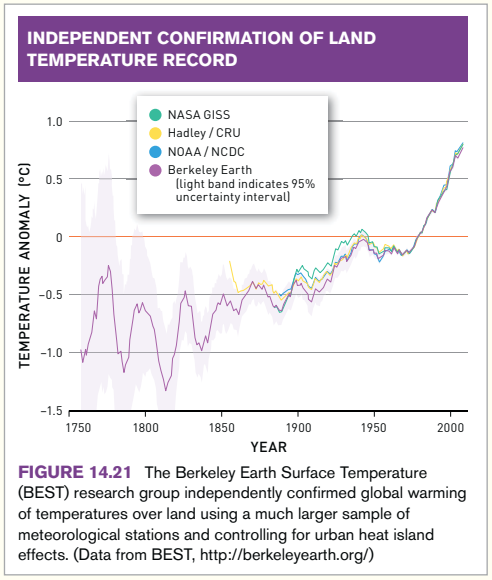


FIGURE 14.21 The Berkeley Earth Surface Temperature (BEST) research group independently confirmed global warming of temperatures over land using a much larger sample of meteorological stations and controlling for urban heat island effects. (Data from BEST, http://berkeleyearth.org/)

A focus on data in each chapter builds quantitative skills and mathematical reasoning.

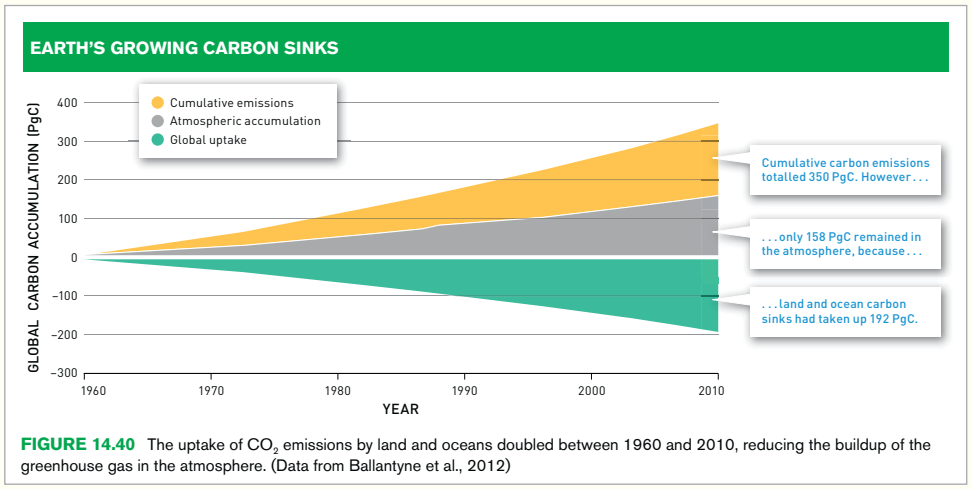


FIGURE 14.40 The uptake of CO_2 emissions by land and oceans doubled between 1960 and 2010, reducing the buildup of the greenhouse gas in the atmosphere. (Data from Ballantyne et al., 2012)

LaunchPad

LaunchPad gives instructors everything they need to quickly set up a course, shape the content of their syllabus, craft presentations and lectures, assign and assess homework, and guide the progress of individual students and the class as a whole. Meanwhile, LaunchPad is the students' one-stop shop for class preparation, homework, and exam prep.

Instructor Resources

The new standard in online course management, LaunchPad makes it easier than ever to create interactive assignments, track online homework, and access a wealth of extraordinary teaching and learning tools. Fully loaded with our customizable e-Book and all student and instructor resources, the LaunchPad is organized around a series of prebuilt LaunchPad units—carefully curated, ready-to-use collections of material for each chapter of *Environment: Science, Issues, and Solutions.*

LECTURE TOOLS

Lecture Slides

These slides combine art, classroom discussion questions, and descriptions of key concepts from the book for classroom presentation.

Layered Slides

Slides for select figures deconstruct key concepts, sequences, and processes in a step-by-step format, allowing instructors to present complex ideas in clear, manageable parts.

Optimized Art (Jpegs and layered slides)

Infographics are optimized for projection in large lecture halls and split apart for effective presentation.

Clicker Questions

Designed as interactive in-class exercises, these questions reinforce core concepts and uncover misconceptions.

ASSESSMENT

Activities use a game-like interface to guide students through a series of questions tailored to their individual level of understanding.

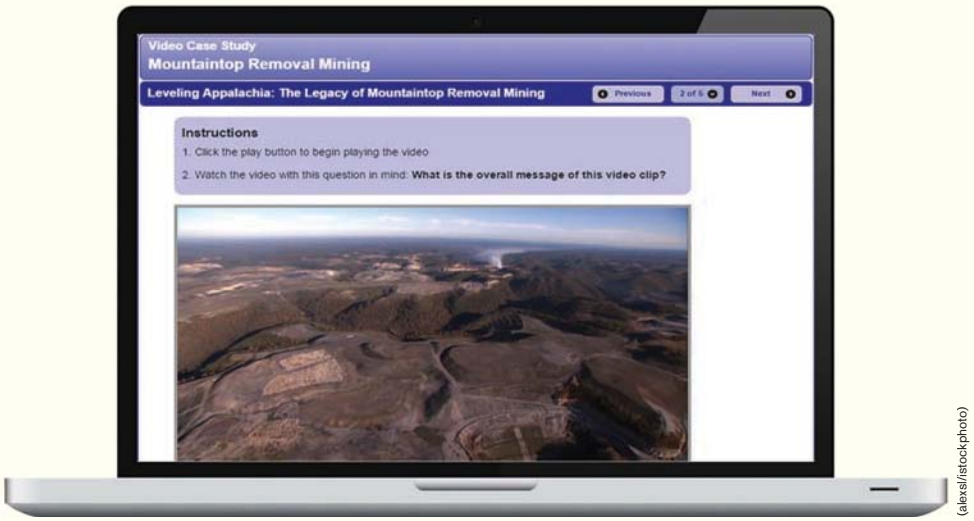
Videos

Videos from an array of trusted sources bring the stories of the book to life and make the material meaningful to students. Each video includes assessment questions to gauge student understanding.

Test Bank

A collection of questions, organized by chapter, presented in a sortable, searchable platform. The Test Bank features multiple-choice questions and uses infographics and graphs from the book.

Student Resources



(alexsl/istockphoto)

Student resources reinforce chapter concepts and give students the tools they need to succeed in the course. All student resources are organized and can be found in the LaunchPad.

LaunchPad macmillan learning Students have access to a variety of study tools in the LaunchPad, along with a complete online version of the textbook. Carefully curated LaunchPad Units provide suggested learning paths for each chapter in the text.

LearningCurve macmillan learning This set of formative assessment activities uses a game-like interface to guide students through a series of questions tailored to their individual level of understanding. A personalized study plan is generated based on their quiz results. LearningCurve is available to students in the LaunchPad.

Graphing Tutorials

Students build and analyze graphs, using their critical thinking skills to predict trends, identify bias, and make cause-and-effect connections.

Video Case Studies

Videos from an array of trusted sources bring the stories of the book to life and allow students to apply their environmental, scientific, and information literacy skills. Each video includes questions that engage students in the critical thinking process.

Key Term Flashcards

Interactive flashcards can help students drill and learn the most important terms in each chapter.

Critical Thinking Activities

Assignable activities engage students in the material and inspire critical thinking based on content from the textbook.

Environment and Your Activities

Activities prompt students to get directly involved in environmental science issues in their lives and communities.

Reviewers

We extend our deep appreciation to the following instructors who reviewed, tested, and advised on the book manuscript at various stages.

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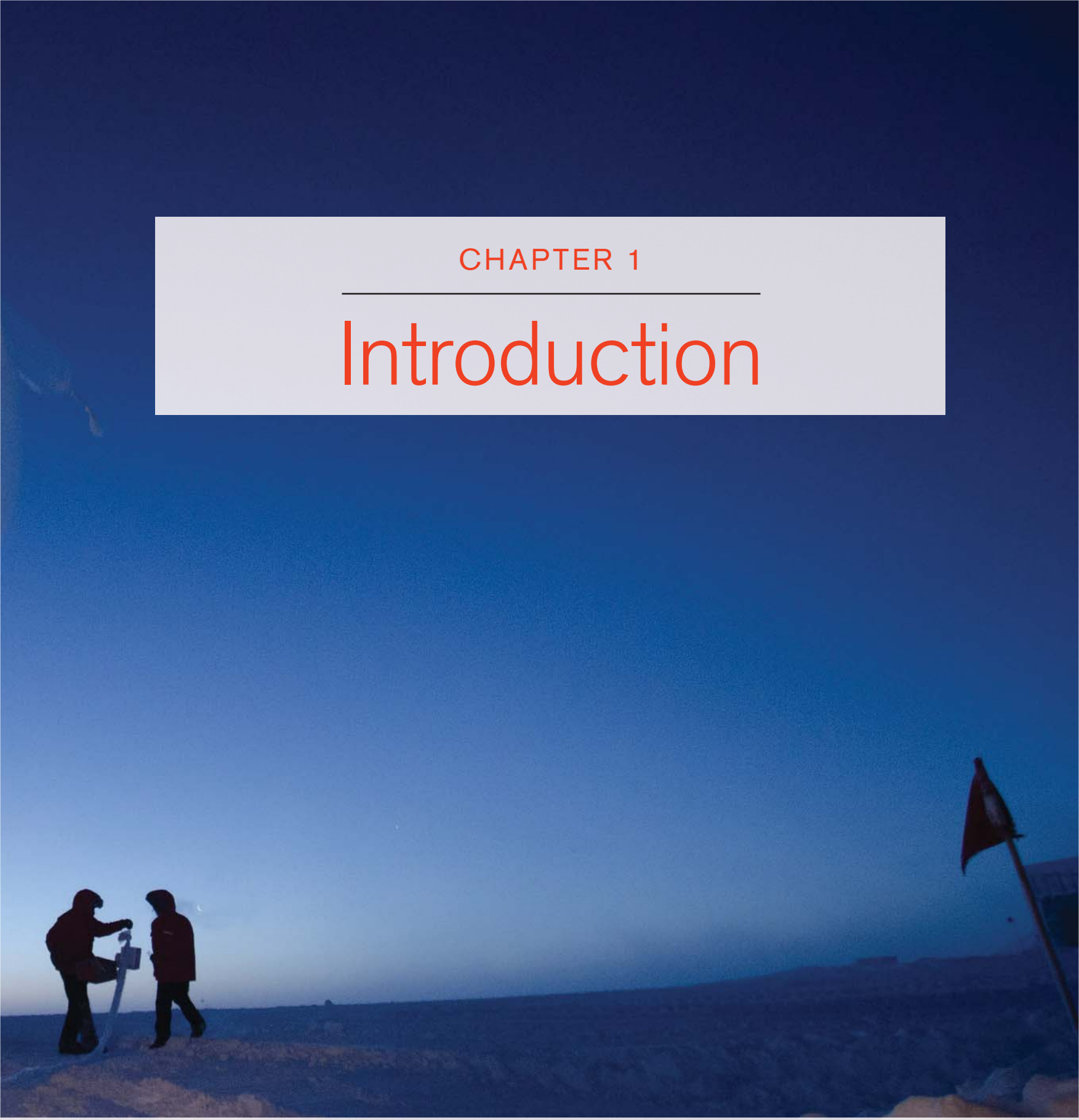
Central Question: How do science and values help address environmental issues?

Explain what makes up the environment, what science is, and how science can address uncertainty.

(Kelli-Ann Bliss/NOAA)

SCIENCE



CHAPTER 1

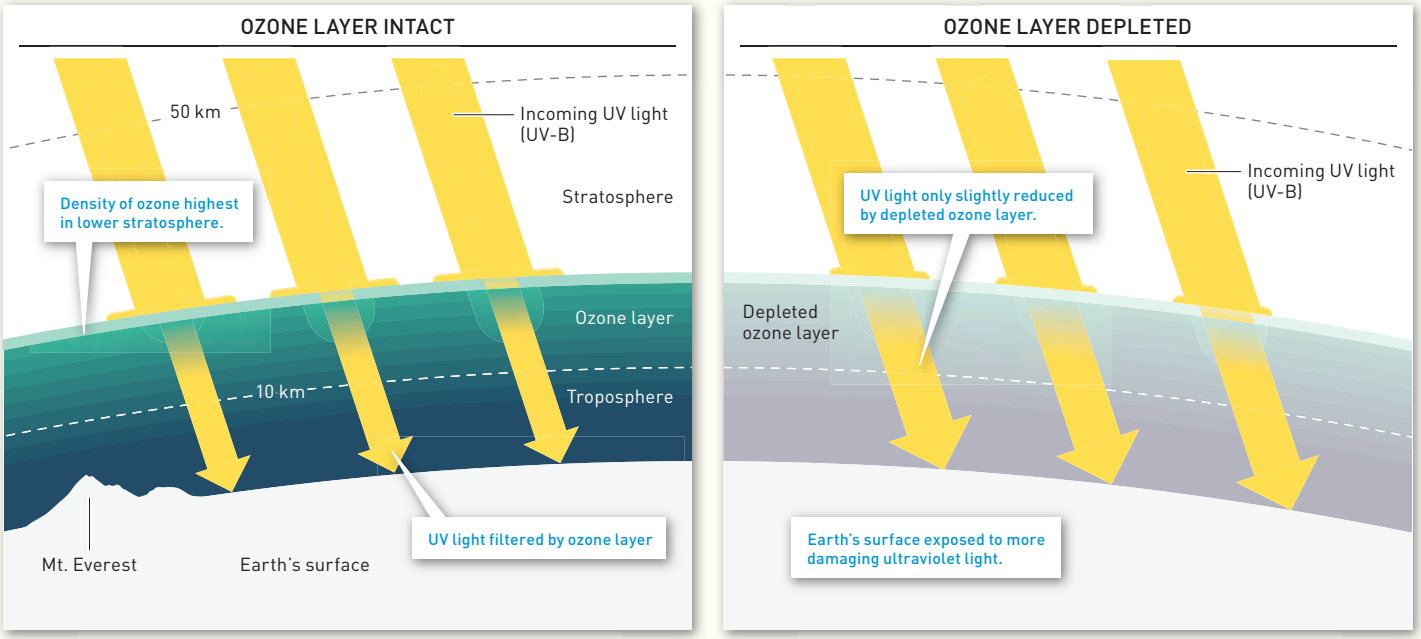
Introduction

Analyze the global environmental impact of humans.

ISSUES

Discuss how personal views affect how we address environmental problems and the goal of sustainability.

SOLUTIONS



The protective effects of the stratospheric ozone layer and the effects of ozone depletion.

A Growing Impact

With the discovery of a hole in the ozone layer, the impact of a growing human population became more apparent than ever.

Polar bears are drowning in the Arctic Ocean! The Amazonian rain forest is being cleared for soybeans and cattle ranches! Another oil well has blown out in the Gulf of Mexico! It seems that every day a new and shocking environmental tragedy appears in the headlines. Environmental activists argue that we're one step away from apocalypse, while politicians and businessmen hem and haw about the true impact of these kinds of events and who bears responsibility.

Amid heated debates over the most pressing environmental issues of the 21st century, it's sometimes difficult to separate the science from spin. Are people who deny that humans are changing the climate honestly questioning the evidence or are they seeking to delay action? And do environmental activists ever consider the impact that restrictive environmental regulations would have on the economy and the livelihoods of people?

As we shall learn in this text, such controversies and philosophical dilemmas over environmental issues are nothing new. In fact, it may be easier to understand the current debates around climate change and offshore oil drilling by looking deeply at one of the most frightening news headlines in the recent past: "Hole Found in Earth's Atmosphere!" The year was 1985 and British researchers working in the Antarctic had measured a major reduction in ozone levels in the upper atmosphere. **Ozone,** a molecule made up of three oxygen atoms, is considered a pollutant in the lower atmosphere, but it performs a critical role in the upper atmosphere, shielding against potentially harmful **ultraviolet,** or **UV, light** from the Sun.

ozone A molecule made up of three oxygen atoms; considered a pollutant in the lower atmosphere, but in the upper atmosphere it shields against potentially harmful rays from the Sun.

ultraviolet (UV) light Shorter-wavelength, higher-energy rays from the Sun that can damage living tissue.

"Science cannot resolve moral conflicts, but it can help to more accurately frame the debates about those conflicts."

Heinz Pagels, physicist and science writer, *Dreams of Reason: The Computer and the Rise of the Sciences of Complexity* (1988)

Ultraviolet light, which has shorter wavelengths and higher energy than visible light, can damage living tissue, as anyone who has ever been sunburned knows. Consequently, an ozone hole would lead to problems in human health, such as increased incidence of skin cancer and cataracts, agricultural problems, such as damage to crops, and ecological problems, such as harm to the abundant marine life around the Antarctic. Although the evidence for the ozone hole was debated for years, the science was eventually settled, and governments took action to solve the problem. The ozone hole tapped into deeper fears about how the activities of humans may be impacting the environment, foreshadowing many of the challenges we're faced with today.

The depletion of Earth's ozone layer was not the first sign of human impact on the environment. However, it was a clear and dramatic indication that human impact had achieved truly global proportions. Immediately, questions swirled around the discovery. What had produced the hole in Earth's protective shield? How serious was the situation and could anything be done to repair the protective ozone layer? Addressing these questions would require contributions from the fields of science, medicine, communication media, politics, international diplomacy, national and international law, and many more. Addressing the unresolved environmental issues in the early 21st century will inevitably require the application of not only science, but also human values. As we explore the central question of Chapter 1, we'll return repeatedly to the example of the ozone hole because it reveals the entire process of how science shapes our societies.

Central Question

How do science and values help address environmental issues?

(Kelli-Ann Bliss/NOAA)

1.1–1.4 Science

Is food a chemical factor in the environment, a biological factor, or both? What does your answer imply about the classification of environmental factors?

Because of our origins as hunters and subsistence farmers, humans have long been interested in the relationship between organisms and their environment. Even, today, with a larger fraction of the world's population living in cities and working in jobs as diverse as driving a taxi or programming computer software, we recognize that our impact on the environment extends to the entire planet and those historical interests assume a new urgency. But just what is "environment"?

1.1 Environment is everything

The **environment** consists of both the **biotic** and **abiotic** factors that affect an organism. Biotic factors are the living components of the environment. Abiotic factors include the physical and chemical components of the environment. In environments where humans have significant influences, we must also consider cultural components (Figure 1.1).

Think of the "feel" of a misty morning compared to the direct rays of the summer Sun. That's your physical, abiotic environment, which includes factors such as temperature, humidity, and cloud cover, which affects the intensity of sunlight. The physical environment also includes factors that play themselves out over time, such as seasonal changes in temperature or day length. It also includes noise, such as the cock-a-doodle-doo of a rooster, the roar of a freeway at rush hour, or the pinging of underwater sonar.

Furthermore, abiotic factors include the chemicals found in the environment. When you drink a glass of water, with its dissolved oxygen, minerals, and pollutants, you are ingesting a piece of the chemical environment. The chemical environment includes the composition of air, water, and soil. The number, kinds, and concentrations of pollutants the air may contain, as well as the odors in your surroundings, are part of your chemical environment, as are the nutrients in the food you eat (Figure 1.2). A plant's chemical environment includes all the nutrients in the soil or surrounding water, as well as the gases in the surrounding air and soil.

Chemical and physical factors are often closely intertwined, and these relationships are at the center of many of today's environmental problems. For example, scientists discovered that when we released refrigerant chemicals known as chlorofluorocarbons (CFCs) into the environment, we thinned stratospheric ozone. This, in turn, changed the physical environment at the Earth's surface by permitting more UV light to pass through the atmosphere. Conversely, altering a physical factor can change important aspects of the chemical environment. For instance, increasing the temperature of a pond will reduce the concentration of oxygen that the pond water can hold. Chemical and physical factors have direct and indirect influences on the biological environment.

A scientific study of the New York City subway system that began in 2013 mapped out species of bacteria found on everything from the turnstiles to the benches to the garbage cans. Pathomap, as the study is called, is a partial record of the **biological environment** faced by commuters each and every day. More generally, your biological environment will include all the viral or bacterial diseases you've contracted during your life and

environment The physical, chemical, and biological conditions that affect an organism.

biotic Living components of the environment.

abiotic Physical and chemical components of the environment.

biological environment The kinds and diversity of pathogens, predators, parasites, and competitors with which an organism interacts.