

Richard T. Wright • Dorothy F. Boorse

Environmental **SCIENCE**

TOWARD A SUSTAINABLE FUTURE • 12E



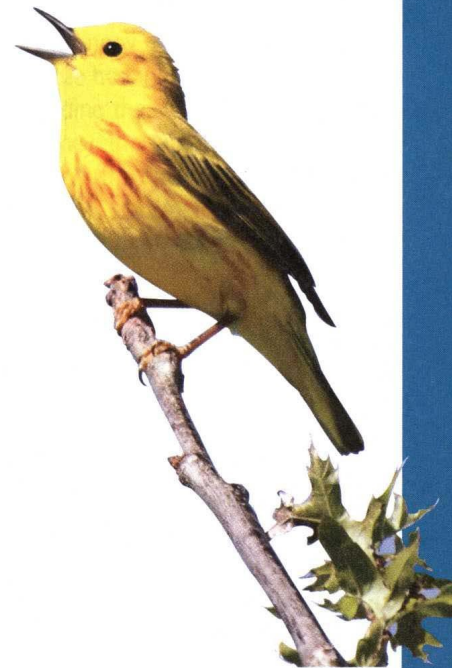
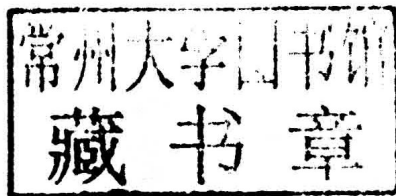
Environmental Science

Toward a Sustainable Future

TWELFTH EDITION

Richard T. Wright
Dorothy F. Boorse

Gordon College



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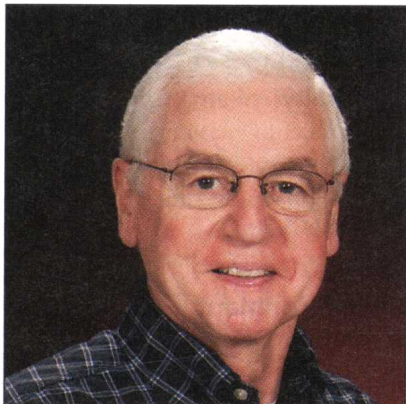
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ABOUT THE AUTHORS



Richard T. Wright is Professor Emeritus of Biology at Gordon College in Massachusetts, where he taught environmental science for 28 years. He earned a B.A. from Rutgers University and an M.A. and a Ph.D. in biology from Harvard University. For many years, Wright received grant support from the National Science Foundation for his work in marine microbiology, and in 1981, he was a founding faculty member of Au Sable Institute of Environmental Studies in Michigan, where he also served as Academic Chairman for 11 years. He is a Fellow of the American Association for the Advancement of Science, Au Sable Institute, and the American Scientific Affiliation. In 1996, Wright was appointed a Fulbright Scholar to Daystar University in Kenya, where he taught for two months. He is a member of many environmental organizations, including the Nature Conservancy, Habitat for Humanity, the Union of Concerned Scientists, and the Audubon Society, and is a supporting member of the Trustees of Reservations. He volunteers his services at the Parker River National Wildlife Refuge in Newbury, Massachusetts, and is an elder in First Presbyterian Church of the North Shore. Wright and his wife, Ann, live in Byfield, Massachusetts, and they drive a Toyota Camry hybrid vehicle as a means of reducing their environmental impact. Wright spends his spare time birding, fishing, hiking, and enjoying his three children and seven grandchildren.



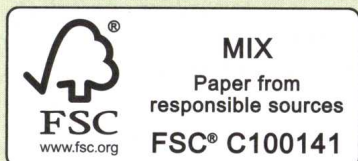
Dorothy F. Boorse is a professor of biology at Gordon College in Wenham, Massachusetts. Her research interest is in drying wetlands, such as vernal pools and prairie potholes, and in salt marshes. Her research with undergraduates has included wetland and invasive species projects. She earned a B.S. in biology from Gordon College, an M.S. in entomology from Cornell University, and a Ph.D. in oceanography and limnology from the University of Wisconsin–Madison. Boorse teaches, writes, and speaks about biology, the environment, ecological justice, and care of creation. She was recently an author on a report on poverty and climate change. In 2005, Boorse provided expert testimony on wildlife corridors and environmental ethics for a congressional House subcommittee hearing. Boorse is a member of a number of ecological and environmental societies, including the Ecological Society of America, the Society of Wetland Scientists, the Nature Conservancy, the Audubon Society, the New England Wildflower Society, and the Trustees of Reservations (the oldest land conservancy group in the United States). She and her family live in Beverly, Massachusetts. They belong to Appleton Farms, a CSA (community-supported agriculture) farm. At home, Boorse has a native plant garden and has planted two disease-resistant elm trees.

ABOUT OUR SUSTAINABILITY INITIATIVES

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PREFACE

We are now well into the second decade of the 21st century, and it is promising to be a crucial decade. Globally, major changes are taking place in the atmosphere and climate, the human population and its well-being, and the Earth's natural resources. We are still recovering from a major global economic recession, pointing to the reach of globalization; societies are reeling from disasters such as the Japanese tsunami, the Haitian earthquake, and the huge oil leak in the Gulf of Mexico; there is no letup in the accumulating evidence of climate change, brought on by increased fossil fuel burning; terrorism and conflict continue to grip the Middle East; and crises in food and agricultural production, brought on by heat waves and extended drought in the United States, are leading to greater numbers of hungry and impoverished people.

In contrast to these and other disturbing trends, there are some changes that point to a brighter future. Renewable energy is ramping up swiftly in its share of the world's energy portfolio; many of the UN Millennium Development Goals (MDGs) are on track to be achieved by their target date of 2015; even though international accord on climate change is slow in coming, many countries are achieving major reductions in greenhouse gas emissions; death by tobacco use is being addressed in a global campaign; AIDS, tuberculosis, and malaria are on the defensive as public-health agencies expand treatment options and research; and population growth in the developing countries is continuing to decline.

The most profound change that must happen, and soon, is the transition to a sustainable civilization—one in which a stable human population recognizes the finite limits of Earth's systems to produce resources and absorb wastes, and acts accordingly. This is hard to picture at present, but it is the only future that makes any sense. If we fail to achieve it by our deliberate actions, the natural world will impose it on us in highly undesirable ways.

New to This Edition

To help implement our core values, we have made changes to the twelfth edition. The major changes are listed here, followed by a list of updates for each part and chapter. All of these changes were made in the hope of creating a book with a solid, rigorous framework that is also easily comprehensible.

- In this edition, Learning Objectives have been added to the beginning of each chapter. These objectives describe the knowledge or skills that students should have upon completing each chapter.
- The art program has been substantially updated. Each chapter features new photos and updated graphics.

- Content has been thoroughly updated: More than 45% of the research cited is from 2010 or later, and material has been carefully edited for currency.
- New Video Field Trips give students the chance to learn about wind power, invasive species, and campus sustainability in an all-new format.
- New Core Content and Data Analysis Coaching activities in MasteringEnvironmentalScience activities accompany the twelfth edition of the book.

Content Updates to the Twelfth Edition of *Environmental Science*

Part One—Framework for a Sustainable Future

Part One has a new opener that focuses on the vision of sustainability and the challenges facing us that are inconsistent with that vision. Chapter 1 (Science and the Environment) has a new opening story, the inspiring work of Rachel Carson and her seminal book, *Silent Spring*. Then, as we look at the state of the planet, we investigate the “environmentalist’s paradox,” where human well-being seems to be improving while the environment continues to decline. We then introduce the American environmental movement timeline, a new graphic that shows the major impacts of events, people, and policies. We continue with our three unifying themes (sustainability, sound science, and stewardship) and introduce hypothesis formation with a new essay, “When Oysters Became Canaries.” The final section in Chapter 1 explores social and environmental changes in the context of globalization. Chapter 2 (Economics, Politics, and Public Policy) explores the concepts of a green versus a brown economy and incorporates results from a new World Bank study that updates the “wealth of nations” concept the bank introduced earlier. A new essay (“California’s Green Economy”) illustrates beneficial environmental policy impacts, and other benefits of environmental policy are updated. Because of its time-sensitive content, the section on politics and the environment has been heavily rewritten. If we only had a crystal ball. . .

Part Two—Ecology: The Science of Organisms and Their Environment

Chapters 3–5 were reorganized in the last edition, and that organization has been maintained in this one, with topics flowing from basic to more complex, small to large, and species to ecosystems and humans. Chapter 3 (Basic Needs of Living Things) has new material on the sulfur cycle—another

geochemical cycle important to living things—and a new Sustainability essay (“Planetary Boundaries”). Chapter 4 (Populations and Communities) is somewhat reorganized and has additional material on Darwin’s finches in a new Sound Science box (“Studying Finches: The Life of a Scientist”). An example that allows students to calculate population growth has been moved from the main text into a Sound Science essay (“The Story Behind the Numbers: It’s a Wormy Project!”) to make the text more readable. Chapter 5 (Ecosystems: Energy, Patterns and Disturbance) begins with a new opener—the effects of an Icelandic volcano—and includes a new Sustainability essay (“Ecological Restoration: Aldo Leopold and the Shack on the Prairie”). More-modern ecological studies are described, including the LTER and NEON programs. Chapter 6 (Wild Species and Biodiversity) begins with a new opener on the Ganges River dolphin. Two new essays describe the return of the Lake Erie Water snake (Stewardship, “Lake Erie’s Island Snake Lady”) and the use of DNA in forensic wildlife science (Sound Science, “Using DNA to Catch Wildlife Criminals”). The section on protecting species was reorganized to cover topics from individual to international scales, and the section on the consequences of losing biodiversity was reorganized to tie into the values of biodiversity. Citizen science is highlighted with several examples. Chapter 7 (The Value, Use, and Restoration of Ecosystems) has a new opener on the Caribbean reef. The chapter was reorganized, with restoration and conservation moved to the end. The chapter has an even greater focus on ecosystem goods and services and two new essays (Sustainability, “How Much for That Irrigation Water?”, and Sound Science, “Restoration Science: Learning How to Restore”).

Part Three—The Human Population and Essential Resources

Part 3 begins with a new section opener about world population hitting 7 billion in October 2011. Chapter 8 (The Human Population) includes a new essay on calculating an ecological footprint (Stewardship, “Lessening Your Ecological Footprint”) and updated population profiles. The chapter returns throughout to three countries—Burkina Faso, Indonesia, and Sweden—which are introduced in the chapter opener. The section on the IPAT equation has been updated to include some newer concepts on calculating ecological impacts, and the concept of the GINI index of inequality is added to the chapter. Chapter 9 (Population and Development) has a new chapter opener on declining population growth rates in Thailand. The Stewardship essay on China (“Protecting People’s Options”) is expanded to include issues prior to the one-child policy and more information on human rights abuses. A new figure illustrates the concept of the speed of demographic change by contrasting different countries. The former chapter opener on Kerala, India, was updated and made into a Sustainability essay (“Looking at Change in India”). Chapter 10 (Water: Hydrologic Cycle and Human Use) has a new chapter opener on drought in China, a new essay on thermohaline circulation (Sound Science,

“What’s New in the Water Cycle?”), and another on the connection between water, energy, and food (Stewardship, “The Energy/Water/Food Trade: Waste One, Waste Them All”). There is more material on impervious surfaces, extreme-distance transport of water, and the relationship of climate change and the water cycle. Chapter 11 (Soil: Foundation for Land Ecosystems) has a new chapter opener on the Dust Bowl as well as an essay on two-stage ditches in the American Midwest (Sustainability, “New Ditches Save Soil”). The effects of mining on soils, acid rain, soil and carbon storage, and nanoparticles are also added. Chapter 12 (The Production and Distribution of Food) was altered significantly, with an entirely new section on sustainable agriculture and cutting-edge agricultural techniques as well as a new chapter opener on urban agriculture. The chapter is organized around three ideas—production, environmental sustainability, and effective distribution—and with a new summary table on actions that increase or decrease food availability. The food pyramid has been updated with the new USDA food “plate.” Golden rice, the subject of the former chapter opener, was moved to a new Stewardship essay (“Golden Rice”). A new Sustainability essay (“Preventing Food Crises”) connects photographer Dorothea Lange and the Great Depression to modern food crises. Chapter 13 (Pests and Pest Control) has a new chapter opener on bedbugs, a new Sound Science essay on biofouling organisms (“Marine Fouling Organisms: Keeping One Step Ahead of the Barnacles”), and more information on stored product pests and on the decline of bees. The latter part of the chapter is reorganized to include policies regulating both pesticides and pests themselves, including more on the government agency APHIS and its role in monitoring pests. It should be mentioned that for all of these chapters, photos, graphics, and statistical data have been brought up to date.

Part Four—Harnessing Energy for Human Societies

Chapter 14 (Energy from Fossil Fuels) has a new part opener with bad news and good news and a new chapter opener on the Deepwater Horizon disaster in the Gulf of Mexico. A new figure plots the different kinds of power plants constructed in recent years, and a new energy flow scheme from Livermore Labs is employed. The discussion on oil sands is expanded, and the Keystone pipeline proposal is presented and illustrated. Natural gas and coal are given separate sections in this edition. Hydraulic fracturing (fracking) is explored, and mountaintop removal coal mining is presented under the heading “Mining Coal” (Section 14.4). Policy from the Recovery Act is added, and there is a new Sound Science essay (“Energy Returned on Energy Invested”). Chapter 15 (Nuclear Power) opens with the earthquake and tsunami that rocked northern Japan in March 2011, leading to the nuclear disaster at the Fukushima Daiichi power plant. This event is used as an illustration of the consequences of a loss-of-coolant accident. Yucca Mountain is revisited, and the President’s Blue Ribbon Commission report of 2011 is presented. The relicensing situation for U.S. nuclear power plants is reviewed, and global nuclear power is summarized. Chapter 16 (Renewable

Energy) opens with the latest on Cape Wind and a look at portable solar travel bags. Then follows a new section (“Strategic Issues”) that examines the issues surrounding calls for great changes in renewable energy, calls for achieving 80% of electricity by renewable sources within a few decades. The chapter highlights the utilities’ trend toward large photovoltaic installations and reviews work by MIT scientists that for the first time connects solar cell power to water oxidation under standard conditions, something that could pave the way to major energy gains.

Part Five—Pollution and Prevention

Chapter 17 (Environmental Hazards and Human Health) opens with a reference to the movie *Contagion* and moves from there to some controversial research on the avian flu virus, a disease that has the potential for great harm. The obesity epidemic in the United States is highlighted, with a new graphic on body mass index. ToxCast and the new IRIS system are discussed, and new information on the causation of asthma is added. A new Sound Science essay is “The Grisly Seven,” where neglected tropical diseases that affect millions are discussed. Chapter 18 (Global Climate Change) starts with a new opener on the threats of rising sea level to island populations. A new section on “The Atmosphere’s Control Knob” gives a perspective on the key importance of CO₂. Another new section is “Skeptics, Deniers, and Ethics,” where opposition to climate change is put into perspective. The major international climate conferences are summarized, and the gap between promised emission reduction pledges and what needs to be done is emphasized and illustrated. In Chapter 19 (Atmospheric Pollution), new material on ammonia points to the great importance of nitric acid in acid rain as sulfur dioxides are being brought under greater control. Mercury emissions are highlighted, and the new Mercury and Air Toxics Standards are presented as a highly important development in curbing pollution from older coal-burning power plants. Nitrous oxide is presented as the newly recognized key ozone-depleting substance of the 21st century. Chapter 20 (Water Pollution and Its Prevention) has new illustrations of sludge digesters and septic systems and documents changes in the Chesapeake Bay restoration efforts, ending with comments on partisan efforts in Congress to block EPA enforcement of water quality regulations. Chapter 21 (Municipal Solid Waste: Disposal and Recovery) has a new emphasis on composting, and single-stream recycling is described as the new trend in recycling. EPA’s waste management hierarchy is added as an illustration. The opening story has a new focus: installing solar arrays on closed landfills. The Internet is referenced as a great way to accomplish resale and reuse, and options for getting rid of e-waste are presented. Chapter 22 (Hazardous Chemicals: Pollution and Prevention) has a new opener on the controversial issue of endocrine disruptors and bisphenol A. A new section (“Evaluating New Chemicals”) illustrates the different approaches of TSCA and REACH in the United States and Europe. The many abandoned uranium mines on Navajo reservations provide a new example of environmental (in)justice.

Part Six—Stewardship for a Sustainable Future

Chapter 23 (Sustainable Communities and Lifestyles) begins with a new story on renewal in Atlanta, Georgia, exploring the Atlanta BeltLine. A new paragraph examines the Rust Belt as a way of understanding urban blight. A new paragraph on “Fixing Suburbia” presents two recent books on how to repair suburban sprawl. Finally, the essay on Tangier Island is updated with reference to a meeting between the islanders and a farming community in Pennsylvania.

Coauthors

Like the global scene, the field of environmental science evolves and continues to change, and so has this text. The most significant change has been the work of a coauthor, Dr. Dorothy Boorse. Boorse began as coauthor in the eleventh edition, and in the twelfth, she has taken responsibility for half of the book (Chapters 1 and 3–13). For Wright, this has been an especially gratifying development, as Boorse was his student at Gordon College and is now back at the college as Professor of Biology. It has been a delight to work together on this edition.

Core Values

Environmental science stands at the interface between humans and Earth and explores the interactions and relations between them. This relationship will need to be considered in virtually all future decision making. This text considers a full spectrum of views and information in an effort to establish a solid base of understanding and a sustainable formula for the future. What you have in your hands is a readable guide and up-to-date source of information that will help you to explore the issues in more depth. It will also help you to connect them to a framework of ideas and values that will equip you to become part of the solution to many of the environmental problems confronting us.

In this new edition, we hope to continue to reflect accurately the field of environmental science; in so doing, we have constantly attempted to accomplish each of the following objectives:

- To write in a style that makes learning about environmental science both interesting to read and easy to understand, without overwhelming students with details;
- To present well-established scientific principles and concepts that form the knowledge base for an understanding of our interactions with the natural environment;
- To organize the text in a way that promotes sequential learning yet allows individual chapters to stand on their own;
- To address all of the major environmental issues that confront our society and help to define the subject matter of environmental science;

- To present the latest information available by making full use of resources such as the Internet, books, and journals; every possible statistic has been brought up to date;
- To assess options or progress made in solving environmental problems; and
- To support the text with excellent supplements for instructors and students that strongly enhance the teaching and learning processes.

Because we believe that learning how to live in the environment is one of the most important subjects in every student's educational experience, we have made every effort to put in their hands a book that will help the study of environmental science come alive.

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ACKNOWLEDGMENTS

More than 30 years ago, Bernard Nebel published the first edition of this text. He did it because he was frustrated with existing environmental science texts and was convinced he could produce a more readable and effective book—and he did! By the fourth edition, Richard Wright joined Nebel and collaborated for two more editions. From the seventh to tenth editions, Wright was responsible for the text, and now with the eleventh and twelfth editions, there are once again two authors. This is a good development, one that is already adding richness and a new voice to many of the chapters. We are deeply indebted to Nebel for his diligent work in developing the text and producing successive editions. We offer this new edition of the book as our contribution to the students who are now well into this new century, in the hope that they will join us in helping to bring about the environmental revolution—the transition to a sustainable society—that must come, we hope sooner rather than later.

Although the content and accuracy of this text are the responsibility of the authors, it would never have seen the light of day without the dedicated work of many other people. We want to express our heartfelt thanks to all those at Pearson Education who have contributed to the book in so many ways.

We salute our editor, Alison Rodal, for her encouragement in helping us reorganize and write this new edition. Our developmental and project editor, Leata Holloway, worked closely with us on every aspect of the book; thank

you, Leata, for your good contributions. Katie Ostler at Element LLC was our production editor, keeping us focused on the details of transforming manuscript into a finished product. We are grateful to Gina Cheselka for her management and guidance and to Lee Ann Doctor for her work on the media. We'd also like to thank Lauren Harp for her help in marketing the text. Thanks also go to Jennifer Nonenmacher and Peter Jardim, photo researchers.

In addition, we thank Todd Tracy, Ed Zalisko, Trixi Beeker, Kayla Rihani, Thomas Pliske, and Heidi Marcum for their work on MasteringEnvironmentalScience and other text supplements.

I (Richard Wright) wish to offer some very personal thanks to my wife, Ann, who has been my companion since the beginning of my work in biology and has provided the emotional base and care without which I would be far less of a person and a biologist. Her love and patience have sustained me in immeasurable ways.

I (Dorothy Boorse) would like to thank my husband, Gary, my biggest supporter. I am also very thankful to my mentors—particularly Richard Wright, who has known me for years and helped me inestimably, and Calvin DeWitt of the University of Wisconsin–Madison, who has been one of the foremost figures in motivating young people to care about the environment and ethics.

Finally, it is our hope that this book can inspire a new generation to work toward bringing healing to a Creation suffering from human misuse.

Richard T. Wright

Dorothy F. Boorse

DEDICATION

This edition is dedicated to the memory of Wangari Muta Maathai (1940–2011) tireless advocate for the environment. Maathai became the voice of modern Africa, a voice of hope and strength protecting the environment for the next generation. We take pride in dedicating this edition to her memory.

Maathai became the first eastern African woman to get a PhD when she received a Doctorate in Anatomy from the University College of Nairobi, (now the University of Nairobi) where she also began her teaching career. There, she became an advocate for women's rights and the environment. She was convinced environmental degradation was the root of many of Kenya's problems. She served in Kenya's Parliament, became an assistant minister for Environment and Natural Resources and served international organizational roles. She is best known for founding the Green Belt Movement, an effort to help solve unemployment and deforestation while empowering women. To date, the organization has planted more than 47 million trees in Kenya.

Maathai received many international awards. She was a prolific author and frequent speaker. In 2004, she became the first African woman to receive the Nobel Peace Prize. It was the first awarded for work in protecting the natural world as a route to promoting justice and peace.



Maathai died of cancer in 2011. Her whole life, featured in the documentary film *Taking Root: The Vision of Wangari Maathai*, was dedicated to the poor and the land. In her Nobel acceptance speech, she said, “Today we are faced with a challenge that calls for a shift in our thinking, so that humanity stops threatening its life-support system. We are called to assist the Earth to heal her wounds and in the process heal our own—indeed, to embrace the whole creation in all its diversity, beauty and wonder.”

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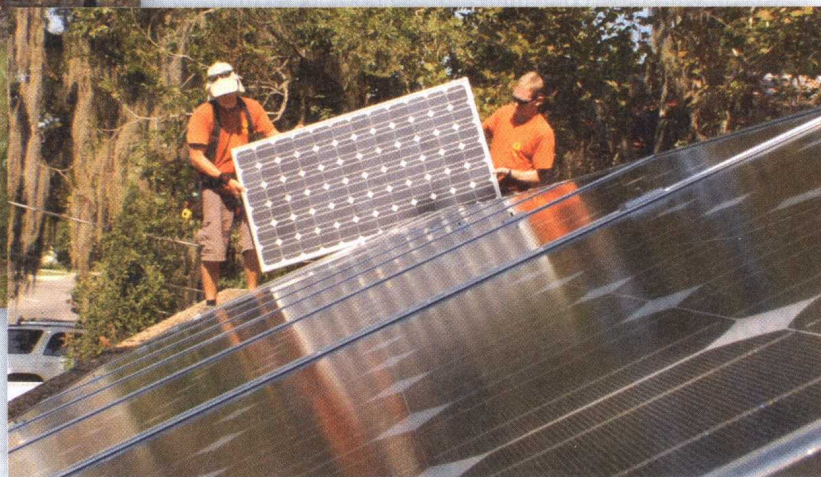
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Chapter 15: Nonrenewable Energy and E... Current Events: Baffled About Fracking? You're Not Alone (5/13/2011) Resources

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Current Events: Baffled About Fracking? You're Not Alone (5/13/2011)

Read this New York Times article and then answer the questions.

[Baffled About Fracking? You're Not Alone \(5/13/2011\)](#)

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Part A

Which of the following is true?

- Drilling is done before fracking.
- Drilling and fracking are the same thing.
- Fracking and drilling are done at the same time.
- Fracking is done before drilling.

Submit My Answers Give Up

Part B

Fracking is done to obtain which of the following?

- oil
- coal
- natural gas
- water

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UPDATED! Current Events Quizzes are regularly updated and connect recent news articles to course topics.

The New York Times

Baffled About Fracking? You're Not Alone

By MIKE SORAGHAN
Published: May 13, 2011

Hydraulic fracturing, or "fracking," got a clean bill of health this week in the first scientific look at the safety of the oil and production practice.

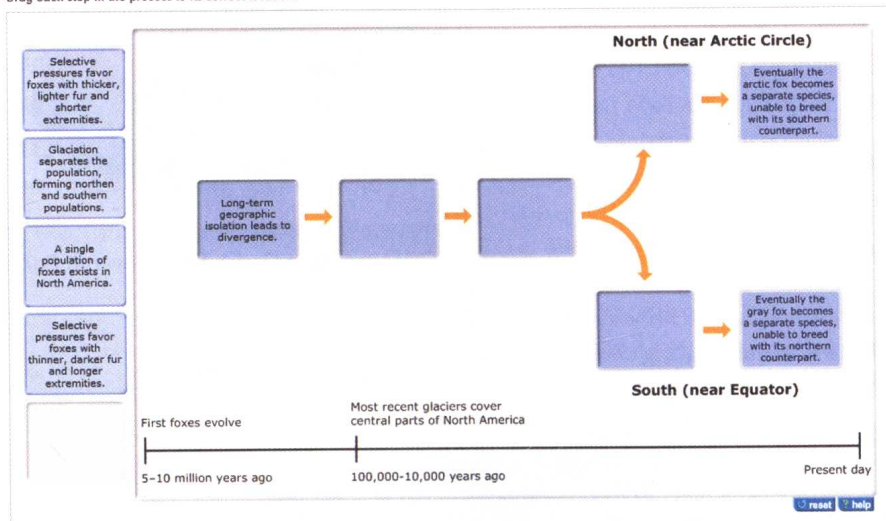
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Concept Review: Allopatric Speciation

Part A

The arctic fox and gray fox evolved from the same species over thousands of years. Can you place these steps in the process of allopatric speciation along the timeline? Drag each step in the process to its correct location.



Submit My Answers Give Up

Try Again

You labeled 5 of 5 targets incorrectly. Recall that a single population is the precondition for allopatric speciation. Where on the timeline should this precondition be located?

EXPANDED! Concept Review Activities guide you through complex content with specific wrong answer feedback. New assignment options cover core topics in the environmental science course and include data analysis activities.

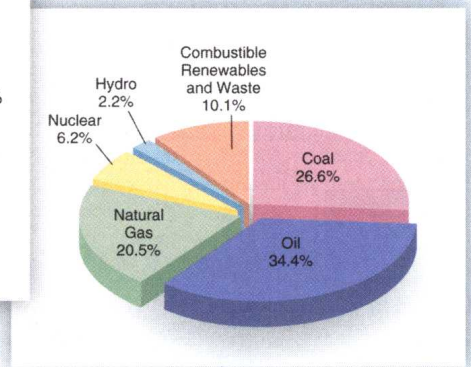
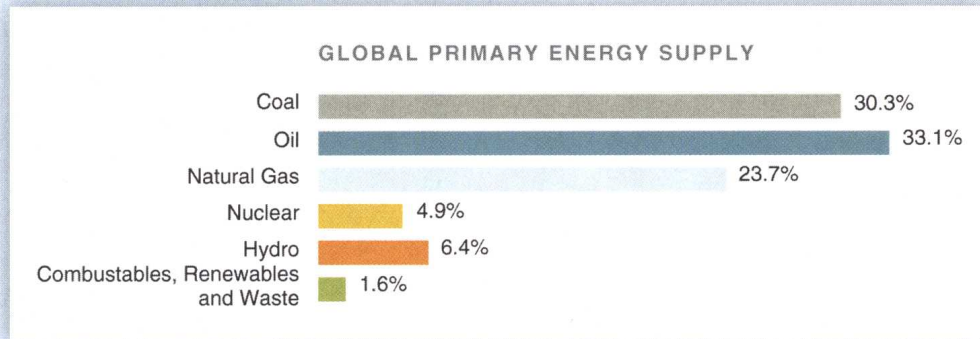
Additional Study Tools in MasteringEnvironmentalScience®

- **The Pearson eText** gives you access to the text whenever and wherever you can access the Internet. The eText pages look exactly like the printed text, and include powerful interactive and customization functions.
- **Self Study Area** offers a 24/7 study resource.
- **GraphIt! Activities** help you explore the data behind environmental issues and research.
- **Reading Quizzes** help you stay on track with your reading assignments and test your understanding of the content.

New to the Twelfth Edition

A revitalized art program makes the text more visually appealing and accessible with images and figures that teach more clearly. Learning Objectives also introduce you to important concepts that you should know.

NEW! Twelfth Edition



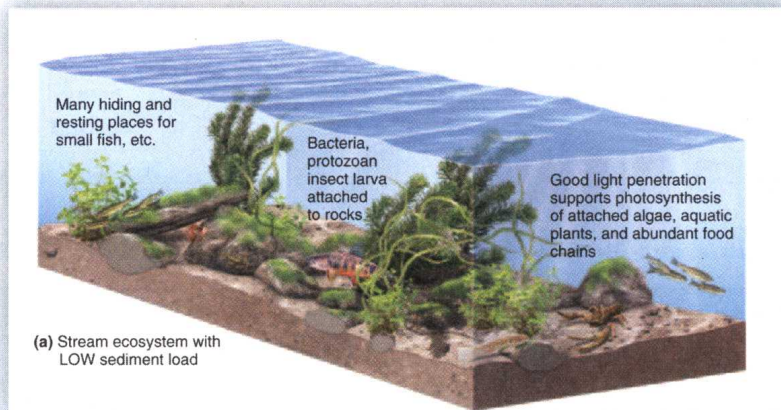
IMPROVED! Bar Graphs and Data Figures are more visually appealing and easier to interpret.

Corresponding Graph from Eleventh Edition

NEW! Twelfth Edition

LEARNING OBJECTIVES

- 1. Economics and the Environment:** Describe how economic activity relates to environmental goods and services, and differentiate between green and brown economies.
- 2. Resources in a Sustainable Economy:** Summarize the components of the wealth a nation draws on to establish and maintain an economy, and identify new efforts to measure true economic progress.
- 3. Environmental Public Policy:** Explain the kinds of policies employed to regulate the use of natural resources and deal with pollution, and describe a typical policy life cycle.
- 4. Benefit-Cost Analysis of Environmental Public Policy:** Discuss how benefit-cost analysis is applied to environmental policy regulations, and give examples of the impact of regulations.
- 5. Politics and the Environment:** Assess the role played by partisan politics in recent environmental public policy.



Corresponding Figure from Eleventh Edition

NEW! Learning Objectives open each chapter to introduce key concepts that you should understand at the conclusion of the chapter.

BRIEF CONTENTS

PART ONE

Framework for a Sustainable Future 1

- 1 Science and the Environment 2
- 2 Economics, Politics, and Public Policy 23

PART TWO

Ecology: The Science of Organisms and Their Environment 49

- 3 Basic Needs of Living Things 50
- 4 Populations and Communities 75
- 5 Ecosystems: Energy, Patterns, and Disturbance 101
- 6 Wild Species and Biodiversity 129
- 7 The Value, Use, and Restoration of Ecosystems 158

PART THREE

The Human Population and Essential Resources 186

- 8 The Human Population 187
- 9 Population and Development 216
- 10 Water: Hydrologic Cycle and Human Use 239
- 11 Soil: The Foundation for Land Ecosystems 266
- 12 The Production and Distribution of Food 289
- 13 Pests and Pest Control 317

PART FOUR

Harnessing Energy for Human Societies 342

- 14 Energy from Fossil Fuels 343
- 15 Nuclear Power 369
- 16 Renewable Energy 392

PART FIVE

Pollution and Prevention 414

- 17 Environmental Hazards and Human Health 415
- 18 Global Climate Change 441
- 19 Atmospheric Pollution 472
- 20 Water Pollution and Its Prevention 506
- 21 Municipal Solid Waste: Disposal and Recovery 532
- 22 Hazardous Chemicals: Pollution and Prevention 551

PART SIX

Stewardship for a Sustainable Future 573

- 23 Sustainable Communities and Lifestyles 574

Appendix A
Environmental Organizations A-1

Appendix B
Units of Measure B-1

Appendix C
Some Basic Chemical Concepts C-1

Glossary G-1

Index I-1

CONTENTS

PREFACE	xiii
---------	------

PART ONE

Framework for a Sustainable Future	1
---	----------

1 Science and the Environment	2
1.1 A Paradox: What Is the Real State of the Planet?	4
Population Growth and Human Well-Being	4
Ecosystem Goods and Services	5
Global Climate Change	6
■ Sound Science When Oysters Became Canaries	8
Loss of Biodiversity	8
1.2 Environmental Science and the Environmental Movement	9
Environmental Science	9
The Environmental Movement	9
1.3 Three Unifying Themes	11
Sustainability	12
Sound Science	13
Stewardship	17
■ Stewardship Exploring a Stewardship Ethic	19
1.4 Moving Toward a Sustainable Future	19
Social Changes	20
Environmental Changes	20
A New Commitment	20

Revisiting the Themes	21
Review Questions	21
Thinking Environmentally	22
Making a Difference	22

2 Economics, Politics, and Public Policy	23
---	-----------

2.1 Economics and the Environment	25
Relationships Between Economic Development and the Environment	25
Economic Systems	25
International Trade and the World Trade Organization	27
The Need for a Sustainable Economy	28
2.2 Resources in a Sustainable Economy	29
Measuring the Wealth of Nations	30
New Work by the World Bank	31
Measuring True Economic Progress	31
Resource Distribution	33
2.3 Environmental Public Policy	34
The Need for Environmental Public Policy	34
Policy in the United States	35
Policy Options: Market or Regulatory?	35
Public Policy Development: The Policy Life Cycle	36
Economic Effects of Environmental Public Policy	38
2.4 Benefit-Cost Analysis of Environmental Public Policy	40
External Costs	40
■ Sustainability California's Green Economy	41
Environmental Regulations Impose Real Costs	41
The Benefits of Environmental Regulation	42
Cost-Effectiveness Analysis	44
Progress	44
2.5 Politics and the Environment	44
Political Parties and the Battle for Control	45
Mid-Term Blues	46
Citizen Involvement	46
Revisiting the Themes	47
Review Questions	47
Thinking Environmentally	48
Making a Difference	48



PART TWO

Ecology: The Science of Organisms and Their Environment 49

3	Basic Needs of Living Things	50
3.1	Organisms in Their Environment	51
	The Hierarchy of Ecology	51
3.2	Environmental Factors	55
	Optimums, Zones of Stress, and Limits of Tolerance	55
3.3	Matter in Living and Nonliving Systems	56
	Basic Units of Matter	57
	Four Spheres	57
	Organic Compounds	59
3.4	Matter and Energy	61
	Energy Basics	61
	Energy Changes in Organisms	63
	One-Way Flow of Energy	66
3.5	The Cycling of Matter in Ecosystems	66
	The Carbon Cycle	66
	The Phosphorus Cycle	67
	The Nitrogen Cycle	68
	The Sulfur Cycle	70
	■ Sustainability Planetary Boundaries	71
	Comparing the Cycles	71
	Revisiting the Themes	73
	Review Questions	73
	Thinking Environmentally	74
	Making a Difference	74
4	Populations and Communities	75
4.1	Dynamics of Natural Populations	76
	Population Growth Curves	76
	Biotic Potential Versus Environmental Resistance	77
	■ Sound Science The Story Behind the Numbers: It's a Wormy Project!	78
4.2	Limits on Populations	80
	Density Dependence and Density Independence	80
	Critical Number	81
4.3	Community Interactions	81
	Predation	82
	Competition	85
	Mutualism	86
	Commensalism	88
4.4	Evolution as a Force for Change	88
	■ Sound Science Studying Finches: The Life of a Scientist	89
	Selective Pressure	90
	Adaptations to the Environment	90
	Drifting Continents	94
4.5	Implications for Human Management	96
	Introduced Species	96
	■ Sound Science The Biological Detective: The Case of Spotted Knapweed	98
	Revisiting the Themes	99
	Review Questions	99
	Thinking Environmentally	100
	Making a Difference	100



5	Ecosystems: Energy, Patterns, and Disturbance	101
5.1	Characteristics of Ecosystems	103
	Trophic Levels, Food Chains, and Food Webs	103
	Trophic Categories	103
5.2	The Flow of Energy in Ecosystems	108
	The Fate of Food	108
	Energy Flow and Efficiency	108
	Aquatic Systems	108
5.3	From Ecosystems to Global Biomes	109
	The Role of Climate	109
	Microclimate and Other Abiotic Factors	112
5.4	Ecosystem Responses to Disturbance	115
	Ecological Succession	115
	Disturbance and Resilience	117
5.5	Human Values and Ecosystem Sustainability	119
	■ Sustainability Ecological Restoration: Aldo Leopold and the Shack on the Prairie	120
	Appropriation of Energy Flow	120
	Involvement in Nutrient Cycling	121
	Value of Ecosystem Capital	121
	Can Ecosystems Be Restored?	122
	The Future	124
	Managing Ecosystems	124
	■ Stewardship Ecosystem Stakeholders	125
	Revisiting the Themes	126
	Review Questions	127
	Thinking Environmentally	127
	Making a Difference	128
6	Wild Species and Biodiversity	129
6.1	The Value of Wild Species and Biodiversity	130
	Biological Wealth	130
	Two Kinds of Value	131
	Sources for Food and Raw Materials	132
	Sources for Medicine	133
	Recreational, Aesthetic, and Scientific Value	133
	Value for Their Own Sake	134

6.2	Biodiversity and Its Decline	136
	How Many Species?	136
	The Decline of Biodiversity	136
	Reasons for the Decline	138
	Consequences of Losing Biodiversity	144
	■ Stewardship Lake Erie's Island Snake Lady	144
	Moving Forward	145
6.3	Saving Wild Species	145
	The Science of Conservation	145
	Individuals and Corporations	146
	Nonprofit Efforts	146
	Governments: Local, State, and National Policies	147
	Protecting Endangered Species	148
	■ Sound Science Using DNA to Catch Wildlife Criminals	151
	Seeing Success	152
6.5	Protecting Biodiversity Internationally	153
	International Developments	153
	Stewardship Concerns	154
	Revisiting the Themes	156
	Review Questions	156
	Thinking Environmentally	157
	Making a Difference	157
7	The Value, Use, and Restoration of Ecosystems	158
7.1	Ecosystem Capital	159
	Ecosystems as Natural Resources	161
7.2	Consumption and Production	162
	Conservation Versus Preservation	162
	Patterns of Human Use of Natural Ecosystems	163
	■ Sustainability How Much for That Irrigation Water?	164
7.3	Biomes and Ecosystems Under Pressure	167
	Forest Ecosystems	167
	Ocean Ecosystems	171
	■ Sound Science Restoration Science: Learning How to Restore	173
7.4	Protection and Restoration	178
	Public and Private Lands in the United States	178
	Ecosystem Restoration	181
	Final Thoughts	182
	Revisiting the Themes	184
	Review Questions	184
	Thinking Environmentally	185
	Making a Difference	185

PART THREE

The Human Population and Essential Resources **186**

8	The Human Population	187
8.1	Humans and Population Ecology	188
	<i>r</i> - or <i>K</i> Strategists	189
	Revolutions	190
	Do Humans Have a Carrying Capacity?	193



8.2	Population and Consumption: Different Worlds	194
	Rich Nations, Middle-Income Nations, Poor Nations	194
	Moving Up: Good News	196
	Population Growth in Rich and Poor Nations	196
	Different Populations, Different Problems	198
	■ Stewardship Lessening Your Ecological Footprint	200
8.3	Consequences of Population Growth and Affluence	201
	Countries with Rapid Growth	201
	Countries with Affluence	204
8.4	Projecting Future Populations	204
	Population Profiles	205
	Predicting Populations	206
	■ Sound Science Are We Living Longer?	209
	Population Momentum	211
	The Demographic Transition	212
	Revisiting the Themes	214
	Review Questions	214
	Thinking Environmentally	215
	Making a Difference	215
9	Population and Development	216
9.1	Predicting the Demographic Transition	217
	Different Ways Forward	217
	Looking at the Data	218
	Competing Ideas	218
	■ Sustainability Looking at Change in India	219
	Large and Small Families	220
9.2	Promoting Development	223
	Millennium Development Goals	224
	■ Stewardship Protecting People's Options	225
	World Agencies at Work	227
	The Debt Crisis	229
	Development Aid	230

9.3 A New Direction: Social Modernization	231	11.3 Soil Conservation	283
Improving Education	231	Helping Individual Landholders	283
Improving Health	232	■ Sound Science Sustainable Agriculture	
Family Planning	233	Research with Farmer Experimenters	284
Employment and Income	234	■ Sustainability New Ditches Save Soil	285
Resource Management	235	Public Policy and Soils	286
Putting It All Together	236	Revisiting the Themes	287
Revisiting the Themes	237	Review Questions	287
Review Questions	237	Thinking Environmentally	288
Thinking Environmentally	238	Making a Difference	288
Making a Difference	238		
		12 The Production and Distribution of Food	289
10 Water: Hydrologic Cycle and Human Use	239	12.1 Crops and Animals: Major Patterns of Food Production	290
10.1 Water: A Vital Resource	240	Subsistence Agriculture in the Developing World	290
10.2 Hydrologic Cycle: Natural Cycle, Human Impacts	241	The Development of Modern Industrialized Agriculture	291
Evaporation, Condensation, and Purification	241	The Green Revolution	293
Precipitation	243	Animal Farming and Its Consequences	295
Groundwater	244	Biofuels and Food Production	296
Loops, Pools, and Fluxes in the Cycle	245	12.2 From Green Revolution to Gene Revolution	297
Human Impacts on the Hydrologic Cycle	246	The Promise	297
■ Sound Science What's New in the Water Cycle?	249	The Problems	299
10.3 Water: Getting Enough, Controlling Excess	249	■ Stewardship Golden Rice	301
Sources	250	The Policies	301
Surface Waters	253	12.3 Food Distribution and Trade	302
Groundwater	255	Patterns in Food Trade	303
10.4 Water Stewardship: Supply and Public Policy	256	The Global Food Crisis	303
Capturing Runoff	257	■ Sustainability Preventing Food Crises	304
Tapping More Groundwater	257	Food Security	305
Desalting Seawater	258	12.4 Hunger, Malnutrition, and Famine	306
Using Less Water	258	Malnutrition versus Hunger	306
■ Stewardship The Energy/Water/Food Trade: Waste One, Waste Them All	260	Food Advice in the United States	307
Public-Policy Challenges	261	Extent and Consequences of Hunger	307
Revisiting the Themes	263	Root Cause of Hunger	308
Review Questions	264	Famine	308
Thinking Environmentally	264	Hunger Hot Spots	310
Making a Difference	265	Food Aid	310
		The Goal Is Zero, the Way There is Complex	311
		12.5 The Future: Feeding the World as We Approach 2030 – 2050	311
		Future Prospects	311
		More Green Revolution	312
		Sustainable Agriculture	312
		Revisiting the Themes	315
		Review Questions	315
		Thinking Environmentally	316
		Making a Difference	316
		13 Pests and Pest Control	317
		13.1 The Need for Pest Control	318
		Types of Pests and the Importance of Pest Control	318
		Different Philosophies of Pest Control	320
		13.2 Chemical Treatment: Promises and Problems	321