Environmental Science

Working with the Earth

FIFTH EDITION

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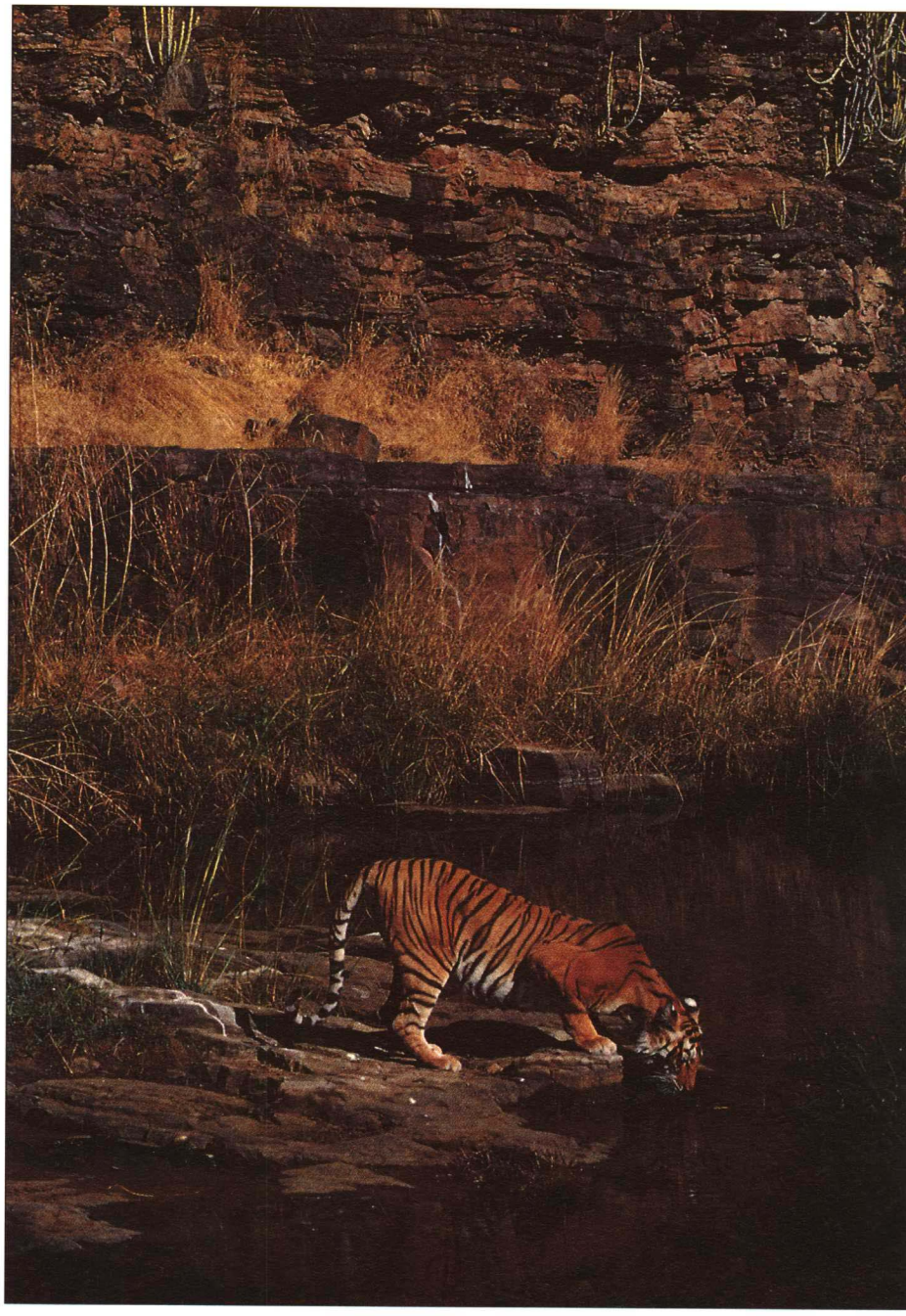

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PREFACE

For Instructors and Students

How I Became Involved In 1966 I heard a scientist give a lecture on the problems of overpopulation and environmental abuse. Afterward I went to him and said, "If even a fraction of what you have said is true, I will feel ethically obligated to give up my research on the corrosion of metals and devote the rest of my life to environmental issues. Frankly, I don't want to believe a word you have said, and I'm going into the literature to try to prove that your statements are either untrue or grossly distorted."

After six months of study I was convinced of the seriousness of these problems. Since then I have been studying, teaching, and writing about them. I have also attempted to live my life in an environmentally sound way—with varying degrees of success—by treading as lightly as possible on the earth (see pp. 511–512 for a summary of my own progress in attempting to work with nature). This book summarizes what I have learned in almost three decades of trying to understand environmental principles, connections, and solutions.

My Philosophy of Education I believe that our lifelong pursuit of knowledge should be guided by the following principles:

- Recognize that the primary aim of education should be to help us develop a respect for life.
- Question everything and everybody, as any good scientist does.
- Develop a list of principles, concepts, and rules to be used as guidelines in making decisions, and continually evaluate and modify this list as a result of experience.
- Recognize that the primary goal of education should be to learn how to sift through mountains of facts and ideas and find the few that are useful and worth knowing. We need an *Earth-wisdom revolution*, not an information revolution. Facts and numbers are merely stepping-stones to ideas, laws, concepts, principles, and connections. And most statistics and facts are human beings with the tears wiped off and living things whose lives we are threatening.
- Interact with what you read—as a way to make learning more interesting and effective. I do this by marking key sentences and paragraphs with a highlighter or pen. I put an asterisk in the margin next to something I think is important, and double asterisks next to something that I think is especially important. I write comments in the margins, such as *Beautiful, Confusing, Bull, Wrong,* and so on. I fold down the top corner of pages with highlighted passages and the top and bottom corners of especially important pages. This way, I can flip through a book and quickly review the key passages.

Key Features This book is designed to be used in introductory courses on environmental science. It treats environmental science as an *interdisciplinary* study, combining ideas and information from natural sciences (such as biology, chemistry, and geology) and social sciences (such as economics, politics, and ethics) to present a general idea of how nature works and how things are interconnected. This study of connections in nature examines how the environment is being used and abused—and what individuals can do to protect and improve it for themselves, for future generations, and for other living things.

This book is not just a description of the serious environmental problems we face. Instead, after each problem is discussed I list and discuss solutions to these problems—solutions proposed by a variety of scientists, environmental activists, and analysts—at global, national, local, and individual levels. Special boxes labeled *Solutions* give some of this information, along with entire chapter sections and subsections.

In this book I use scientific laws, principles, and concepts to help us understand environmental and resource problems and the possible solutions to these problems, and how these concepts, problems, and solutions are connected. I have introduced only the concepts and principles necessary to understanding material in this book, and I have tried to present them simply but accurately. The key principles and concepts used in this textbook are summarized inside the back cover.

My aim is to provide a readable and accurate introduction to environmental science without the use of mathematics or complex scientific information. To

help make sure the material is accurate and up-to-date, I have consulted more than 10,000 research sources in the professional literature. In writing this book I have also profited from the more than 200 experts and teachers who have provided detailed reviews of the various editions of my other four books in this field (see list on pp. xiii–xv).

The book is divided into five major parts (see Brief Contents, p. xvii). After Parts I and II are covered, the rest of the book can be used in almost any order. For example, some instructors cover Part V, on Energy Resources, after Part II. Some find it useful to cover Part IV before Part III. In addition, most chapters and many sections within these chapters can be moved around or omitted to accommodate courses with different lengths and emphases. For example, some instructors move Chapter 7, which is on economics and politics, to Part I (as Chapter 3) or to the end of the book.

I have also written four other textbooks on environmental science—each with a different emphasis, organization, and length for use with various types of courses—*Living in the Environment*, 8th edition (701 pages, Wadsworth, 1994); *Resource Conservation and Management* (546 pages, Wadsworth, 1990); *Sustaining the Earth: An Integrated Approach* (325 pages, Wadsworth, 1994); and *Environment: Problems and Solutions* (150 pages, Wadsworth, 1994).

This book is an integrated study of environmental problems, connections, and solutions. The integrating themes in this book are *biodiversity and Earth capital, economics and environment, energy and energy efficiency, individual action and Earth citizens, politics and environmental laws, pollution prevention and waste reduction, population and exponential growth, science and technology, solutions and sustainability,* and *uncertainty and controversy* (see p. xvi).

After looking at the Brief Contents I urge you to look at the concepts and connections map inside the front cover. It is a summary of the key parts and concepts of environmental science and how they are connected to one another—in effect, a map of the book. I also suggest that you read the list of laws, concepts, and principles given inside the back cover. It is a two-page summary of the key ideas in this book.

I also relate the information in the book to the real world and to our individual lives, both in the main text and in various kinds of boxes sprinkled throughout the book. These include **(1) *Spotlights*** (21 in number) highlighting and giving further insights into environmental problems and concepts; **(2) *Case Studies*** (16) giving in-depth information about key issues; **(3) *Connections*** (19) showing how various environmental concepts, problems, and solutions are interrelated; **(4) *Pro/Con*** discussions (5) outlining both sides of controversial environmental issues; **(5) *Solutions*** (26) summarizing possible solutions to environmental problems or describing what individuals have done to help sustain the earth for us and all life; **(6) *Guest Essays*** (15) exposing readers to individual environmental researchers' or activists' points of view; and **(7) *Individuals Matter*** (15) giving examples of what we as individuals can do to help sustain the earth. More ways to evaluate individual lifestyles and campuses are given in *Green Lives, Green Campuses,* a supplement available with this book.

The book's 460 illustrations are designed to present complex ideas in understandable ways and to relate learning to the real world. They include 281 full-color diagrams (46 of them maps) and 179 carefully selected color photographs (17 of them satellite shots).

Major Changes in This Edition *This new edition is a major revision—the most extensive since the first edition was published.* Major changes include:

- Updating and revising material throughout the book. Because of rapid changes in data and information, a textbook in environmental science needs to be updated every two years.
- Improving readability by reducing sentence and paragraph length, omitting unnecessary details, and examining chapter organization and flow.
- Expanding the basic text from 470 pages to 540 pages to allow additional scientific content and many new topics. Instructors wanting shorter books covering this material can use *Sustaining the Earth: An Integrated Approach* (325 pages, Wadsworth, 1994) or *Environment: Problems and Solutions* (150 pages, Wadsworth, 1994).
- Adding brief *Earth Stories* at the beginning of each chapter to spark reader interest and provide useful information. Many describe what individuals have done to help us understand and work with the earth.
- Emphasizing solutions to environmental problems by adding 26 new *Solutions* boxes and adding sections and subsections on solutions within most chapters.
- Focusing on relationships among environmental concepts, problems, and solutions by adding 19 new *Connections* boxes and adding sections and subsections on connections within most chapters.
- Adding 19 new *Spotlights*, 6 new *Case Studies*, 8 new *Guest Essays*, 3 new *Individuals Matter* boxes, and 2 new *Pro/Con* boxes (see pp. x–xii).
- Introducing *concept mapping*. A concept map of the entire book (see inside front cover) has been developed and Appendix 4 shows students how to develop such maps. For instructors wishing to use this method for organizing and clarifying

ideas, an end-of-chapter question asks students to develop one or more concept maps for each chapter. Concept maps for each chapter are provided in the instructor's manual and are available as overhead transparencies.

- Upgrading all diagrams to improve the color, add more detail, and give a more realistic 3-D effect.
- Adding 68 new color photos and 101 new diagrams and improving all previous diagrams.
- Adding 17 satellite photos of the earth.
- Adding 12 new maps and expanding a number of U.S. maps to include data on Canada, with the assistance of Daniel J. Boivin, Professor of Regional Planning, Université Laval, Quebec, Canada.
- Integrating the discussion of solid waste and hazardous waste into a new chapter (Chapter 13).
- Integrating the discussion of minerals and soil into one chapter (Chapter 12).
- Extensively rewriting and reorganizing Chapters 2, 7, 10, 16, 18, and the Epilogue (see Brief Contents, p. xvii).
- Providing new supplements, including an expanded *Instructor's Manual and Test Items*; a workbook supplement, *Green Lives, Green Campuses*; a *Laboratory Manual*; and *Environmental Articles*: more than 200 articles from which instructors can pick any number and have them bound as customized supplements for their courses.
- Greatly increasing the *scientific content* by adding or expanding material on more than 46 subjects, including: the nature of science and technology, limitations and misuse of science, half-life of radioisotopes, nature of life, five major kingdoms of organisms, importance of insects, amphibians, biodiversity, pyramids of numbers, pyramids of biomass, sulfur cycle, symbiotic relationships, interference competition, exploitation competition, energy flow in ecosystems, species interactions, feeding niches, coral reefs, thermal stratification and lake turnover, ecosystem diversity and stability, density-dependent and density-independent checks on population growth, r-strategists and K-strategists, survivorship curves, the origin of life and its diversity (chemical and biological evolution), adaptive radiation, inland wetlands, population dynamics in nature, mutations, adaptations, biological evolution and natural selection, ecological succession, structure and composition of the atmosphere, computer modeling and limits to growth, ecological land-use planning , geological hazards (earthquakes and volcanic eruptions), evaluation of models of possible global warming and ozone depletion, CFC substitutes, soil formation, humification and mineralization in soils, types of soil erosion (sheet, rill, and gully), riparian zones, toxicology and dose–response relationships, importance of spiders, lichens as air pollution indicators, toothed cetaceans and baleen whales, pollution and dissolved oxygen levels, waterborne diseases, mussel invaders in the Great Lakes, alien species in Australia, biological amplification of PCBs, bioremediation, perennial food crops, coyote problems, eucalyptus trees, the gray wolf, and "killer" bees.
- Adding more than 59 *new topics*, including: scientists' warning to humanity, Earth education, coral reef bleaching, population stabilization in Japan, population decline, computer models and limits to growth, ecocities, high-speed regional trains, land-use planning and control, the neem tree, population regulation in Thailand, the GATT trade agreement, getting political power, economic solutions to pollution and resource waste, types of economic systems, supply and demand, making sustaining the earth profitable, jobs and the environment, investing in the future, environmental investments by Germany, the anti-environmental movement, improving global environmental protection, the 1992 Rio Earth Summit, using regulation or market forces to control pollution, sustainable development, the Delaney clause, the asbestos controversy, floodplains and reducing the risks of flooding, cloud seeding and towing icebergs, mining with microbes, the materials revolution, resource exploitation, the Mining Law of 1872, Earthship houses, straw-bale houses, the diaper dilemma, recycled paper, paper made from kenaf, household hazardous materials and substitutes, the environmental justice movement, sustainable and optimum yields of fisheries, salmon ranching and farming, indigenous cultures and cultural extinction, the Everglades (problems and restoration), perennial crops, useful products from trees, rotation cycle of forest management, evaluation of monoculture forestry, metabolic reserve of rangeland grasses, wild game ranching, condition of the world's rangelands, riparian zones, the national trails system, reintroducing wolves to Yellowstone, effects of the ivory ban, exclusive economic zones, high seas in the oceans, and nuclear waste dumping in the former Soviet Union.

See pp. x–xii for a detailed summary of major changes for each chapter.

Welcome to Uncertainty, Controversy, and Challenge We will never have scientific certainty or agreement over what we should do about the complex environmental problems and challenges we face for several reasons:

- Instead of proof or certainty, science provides us with varying degrees of uncertainty (high, medium, low) about the validity of scientific data, hypotheses (tentative explanations), and theories (well-tested and widely accepted hypotheses). *Scientists can disprove things, but they can never prove anything—only show that certain ideas have a high degree of certainty.*
- Science advances through controversy as scientists argue about the validity of data and hypotheses with the goal of converting hypotheses to widely accepted scientific theories. What is important is not what scientists disagree on (the frontiers of knowledge still being developed and argued about) but what they generally agree on—the scientific consensus on theories, concepts, problems, and possible solutions.
- Despite considerable research, we still know relatively little about how nature works at a time when we are altering nature at an accelerating pace.

This built-in uncertainty and the complexity and importance of environmental issues to present and future generations of humans and other species make them highly controversial. Intense controversy also arises because environmental science is a dynamic blend of natural and social sciences that sometimes questions the ways we view and act in the world around us. This interdisciplinary attempt to mirror reality asks us to evaluate our worldviews, values, and lifestyles and our economic and political systems. This can often be a threatening process.

Many environmental books and articles overwhelm us with the problems we face without suggesting ways we might deal with these problems. This book is loaded with solutions suggested by scientists and environmentalists with a wide range of viewpoints and expertise.

Don't take the numerous possible solutions given in this book as gospel. They are given to encourage you to think critically and to make up your own mind. In deciding how to walk more gently on the earth, don't feel guilty about all of the things you are not doing. No one can even come close to doing all of these things, and you may disagree with some of the actions suggested by a diverse array of environmentalists. Pick out the things you are willing to do or agree with and then try to expand your efforts.

People with widely different worldviews, political persuasions, and ideas can work together to help sustain the earth, and that is what counts. We are all in this together, and we need to respect our differences and work together to find a rainbow of solutions to the problems and challenges we face.

Rosy optimism and gloom-and-doom pessimism are traps that usually lead to denial, indifference, and inaction. I have tried to avoid these two extremes and give a realistic—and yet hopeful—view of the future. My reading of history reveals that hope converted into action has been the driving force of our species. This book is filled with stories of individuals who have acted to help sustain the earth for us and all life, and whose actions inspire us to do better. It's an exciting time to be alive as we struggle to enter into a new relationship with the planet that is our only home.

Study Aids Each chapter begins with a few general questions to give you an idea of how the chapter is organized and what you will be learning. When a new term is introduced and defined, it is printed in **boldface type**. There is also a glossary of all key terms at the end of the book.

Factual recall questions (with answers) are listed at the bottom of most pages. You might cover the answer (on the right-hand page) with a piece of paper and then try to answer the question on the left-hand page. These questions are not necessarily related to the chapter in which they are found.

Each chapter ends with a set of questions designed to encourage you to think critically and apply what you have learned to your life. Some ask you to take sides on controversial issues and to back up your conclusions and beliefs. Individual and group projects also appear at the end of each chapter. These items are marked with an asterisk (*). Many additional projects are given in the *Instructor's Manual* and in the *Green Lives, Green Campuses* supplement available with this book.

Readers who become especially interested in a particular topic can consult the list of suggested readings for each chapter, given in the back of the book. Appendix 1 contains a list of publications to help keep up-to-date on the book's material, as well as a list of some key environmental organizations and government and international agencies.

Help Me Improve This Book Let me know how you think this book can be improved; and if you find any errors, please let me know about them. Most errors can be corrected in subsequent printings of this edition, rather than waiting for a new edition. Send any errors you find and your suggestions for improvement to Jack Carey, Biology Publisher, Wadsworth Publishing Company, 10 Davis Drive, Belmont, CA 94002. He will send them on to me.

Supplements The following supplementary materials are available:

- *Instructor's Manual and Test Items*, written by Jane Heinze-Fry (Ph.D. in Science and Environmental Education). For each chapter, it has goals and objectives; one or more concept maps; key terms; teaching suggestions; multiple-choice test questions with answers; projects, field trips, and experiments; term-paper and report topics; and a list of audiovisual materials and computer software.
- *Green Lives, Green Campuses*, written by Jane Heinze-Fry. This workbook is designed to help students apply environmental concepts by investigating their lifestyles and by making an environmental audit of their campuses.
- *Laboratory Manual* written by C. Lee Rockett (Bowling Green State University) and Kenneth J. Van Dellen (Macomb Community College).
- A set of 50 color acetates and more than 400 black-and-white transparency masters for making overhead transparencies or slides of line art (including concept maps for each chapter), available to adopters.
- A special version of STELLA II software (a tool for developing critical thinking), together with an accompanying workbook, available to adopters.
- *Environmental Articles*, assembled by Jane Heinze-Fry. This is a collection of more than 200 articles that are indexed by topic and geographical location. Instructors may use the indexes to choose any combination of articles and have them bound as customized supplements for their courses. New articles will be added each year.
- *Watersheds: Classic Cases in Environmental Ethics* by Lisa H. Newton and Catherine K. Dillingham (Wadsworth, 1994). Nine readable case studies that amplify material in this textbook.
- *Environmental Ethics* by Joesph R. Des Jardins (Wadsworth, 1993). A very useful introduction.
- *Radical Environmentalism* by Peter C. List (Wadsworth, 1993). A series of readings on environmental politics and philosophy.

Annenberg/CPB Television Course This textbook is being offered as part of the Annenberg/CPB Project television series "Race to Save the Planet," a 10-part public television series and a college-level telecourse examining the major environmental questions facing the world today. The series takes into account the wide spectrum of opinion about what constitutes an environmental problem, as well as the controversies about appropriate remedial measures. It analyzes problems and emphasizes the successful search for solutions. The course develops a number of key themes that cut across a broad range of environmental issues, including sustainability, the interconnection of the economy and the ecosystem, short-term versus long-term gains, and the trade-offs involved in balancing problems and solutions.

A study guide and a faculty guide, both available from Wadsworth Publishing Company, integrate the telecourse and this text. The television program was developed as part of the Annenberg/CPB Collection.

For further information about available television course licenses and duplication licenses, contact PBS Adult Learning Service, 1320 Braddock Place, Alexandria, VA 22314-1698 (1-800-ALS-AL5-8).

For information about purchasing videocassettes and print material, contact the Annenberg/CPB Collection, P.O. Box 2284, South Burlington, VT 05407-2284 (1-800-LEARNER).

Acknowledgments I wish to thank the many students and teachers who responded so favorably to the eight editions of *Living in the Environment*, the four previous editions of *Environmental Science*, and the first edition of *Resource Conservation and Management* and who offered many helpful suggestions for improvement and corrected errors. I am also deeply indebted to the reviewers who pointed out errors and suggested many important improvements in this book. Any errors and deficiencies left are mine.

The members of Wadsworth's talented and dedicated production team, listed on the copyright page, have also made vital contributions. Their labors of love are also gifts to helping sustain the earth. I especially appreciate the competence and cheerfulness of Production Editors Karen Garrison and Vicki Friedberg and the superb inputs by two talented development editors, Mary Arbogast and Autumn Stanley. My thanks also go to Wadsworth's hard-working sales staff; to Kristin Milotich for her competence and cheerfulness in the midst of chaos; to George Dyke for superb copyediting; to Jane Heinze-Fry for her outstanding work on the *Instructor's Manual*, *Green Lives, Green Campuses*, and the *Environmental Articles;* and to C. Lee Rockett and Kenneth J. Van Dellen for developing the *Laboratory Manual* to accompany this book.

Special thanks go to Jack Carey, Biology Publisher at Wadsworth, for his encouragement, help, twenty-five years of friendship, and superb reviewing system. It helps immensely to work with the best and most experienced editor in college textbook publishing.

I also wish to thank Peggy Sue O'Neal, my spouse and best friend, for her love and support of me and the earth. I dedicate this book to her and to the earth that sustains us all.

G. Tyler Miller, Jr.

What's New in the Fifth Edition

PART I

HUMANS AND NATURE: AN OVERVIEW

1 Environmental Problems and Their Causes

1 color photo; 2 diagrams; opening Earth Story, "Living in an Exponential Age"; Section 1-1, "Living Sustainably"; 1 Spotlight; "World Scientists' Warning to Humanity"; Solutions, "Don't Kill the Goose"; 2 Guest Essays, "There Is No Crisis of Unsustainability," by Julian L. Simon and "Simple Simon Environmental Analysis," by Anne H. Ehrlich and Paul R. Ehrlich.

2 Cultural Changes, Worldviews, Ethics, and Sustainability

1 color photo; opening Earth Story, "2040 A.D.: Green Times on Planet Earth"; Sections 2-2 and 2-3 rewritten; Solutions, "Emotional Learning: Earth Wisdom"; expanded discussions of various types of worldviews; new discussion of Earth education; Guest Essay, "Launching the Environmental Revolution," by Lester R. Brown.

PART II

PRINCIPLES AND CONCEPTS

3 Matter and Energy Resources: Types and Concepts

1 color photo; opening Earth Story, "Saving Energy, Money, and Jobs in Osage, Iowa"; expanded discussion of nature of science and technology and limitations and misuse of science; new material on half-life of radioisotopes.

4 Ecosystems and How They Work

9 color photos; 7 diagrams; opening Earth Story, "Connections: Blowing in the Wind"; Connections, "Have You Thanked Insects Today?"; Connections, "The Mystery of the Vanishing Amphibians"; new discussions of nature of life, biodiversity, pyramids of numbers, pyramids of biomass, sulfur cycle, symbiotic relationships, interference competition, exploitation competition; expanded treatment of five major kingdoms, energy flow in ecosystems, species interactions, feeding niches, and commensalism.

5 Ecosystems: What Are the Major Types, and What Can Happen to Them?

13 color photos; 9 diagrams; opening Earth Story, "Earth Healing: From Rice Back to Rushes"; Spotlight, "The Kangaroo Rat: Water Miser and Keystone Species"; Case Study, "The Importance of Coral Reefs"; Connections, "Earth: The Just-Right, Resilient Planet"; new discussions of coral reef bleaching, lake turnover, ecosystem diversity and stability, density-dependent and density-independent checks on population growth, r-strategists and K-strategists, survivorship curves, origin of life and its diversity (chemical and biological evolution), adaptive radiation; expanded discussions of coral reefs, inland wetlands, population dynamics in nature, biological evolution and natural selection, and ecological succession; Guest Essay, "The Ecological Design Arts," by David W. Orr.

6 The Human Population: Growth, Urbanization, and Regulation

3 color photos; 14 diagrams; opening Earth Story, "Cops and Rubbers Day in Thailand"; Case Study, "The Graying of Japan"; 2 Solutions, "High-Speed Regional Trains" and "Is Your City Green? The Ecocity Concept in Davis, California"; new discussions of high-speed regional trains, population decline, computer modeling and limits to growth, land-use planning and control, and ecological land-use planning; expanded discussion of transportation and urban development; updating of population data.

7 Environmental Economics and Politics

Entire chapter rewritten; 1 color photo; 6 diagrams; opening Earth Story, "To Grow or Not to

Grow: Is That the Question?"; Case Study, "Kerala: Improving Life Quality Without Conventional Economic Growth"; 4 Spotlights, "GATT: Solution or Problem?," "Getting and Keeping Power: The Dark Side," "Browns vs. Greens: The Wise-Use Movement" and "What Is Good Environmental Management"; 3 Solutions, "Germany: Investing in the Future and the Earth," "Communicating with Elected Officials," and "Thinking for Tomorrow"; table evaluating economic solutions to pollution and resource waste; new discussions of types of economic systems, supply and demand, making sustaining the earth profitable, jobs and the environment, investing in the future, environmental investments by Germany, the anti-environmental movement, improving global environmental protection, and the 1992 Rio Earth Summit; expanded discussions of using regulation or market forces to control pollution, and sustainable development; Guest Essay, "If I Were President," by Jim Hightower.

8 Risk, Toxicology, and Human Health

1 color photo; 6 diagrams; opening Earth Story, "Smoking: The Big Killer"; Case Study, "The 1980 Eruption of Mt. St. Helens"; Solutions, "Reducing the Toll of Smoking"; 2 Connections: "Working Can Be Hazardous to Your Health" and "Sex Can Be Hazardous to Your Health"; new discussions of dose–response relationships (toxicology), geological hazards (earthquakes and volcanic eruptions); Guest Essay, "Public Confidence in Industry and Government: A Crisis in Environmental Risk Communication" by Vincent T. Covello.

PART III
RESOURCES: AIR, WATER, SOIL, MINERALS, AND WASTES

9 Air

4 color photos; 3 diagrams; opening Earth Story, "When Is a Lichen Like a Canary?"; Solutions, "A Market Approach to Pollution Control"; new discussions of mesosphere and thermosphere, asbestos controversy; updated discussion of health effects of air pollutants.

10 Climate, Global Warming, and Ozone Loss

Extensively revised and updated; 2 color photos; 8 diagrams; 2 cartoons; opening Earth Story, "2040 A.D.: Hard Times on Planet Earth"; Spotlight, "Denial Can Be Deadly"; Individuals Matter, "Ray Turner and His Refrigerator"; table evaluating CFC substitutes; new discussions of models of global warming and ozone loss, and of whether the ozone scare is a hoax; expanded discussion of what we know and don't know about possible global warming; updated discussion of possible effects of global warming.

11 Water

3 color photos; 8 diagrams; opening Earth Story, "Water Wars in the Middle East"; Solutions, "Rescuing a River"; Individuals Matter, "How to Save Water and Money"; new discussions of water's importance and unique physical and chemical properties, floodplains and reducing the risks of flooding, restoration of the Everglades, cloud seeding and towing icebergs, pollution and dissolved oxygen levels, alien invaders in the Great Lakes; table on waterborne diseases; updated and expanded discussion of James Bay water transfer project in Canada.

12 Minerals and Soil

New, integrated discussion of minerals and soil; 3 color photos; 4 diagrams; opening Earth Story, "The Great Terrain Robbery"; Case Study, "Desertification and Alien Species in Australia"; Connections, "The Importance of Plate Tectonics"; 4 Solutions, "Slowing Erosion in the United States," "Mining with Microbes," "Reforming the 1872 Mining Law," and "The Materials Revolution"; 2 Spotlights, "Extracting Coal" and "The Environment and the New Gold Rush"; table summarizing useful properties of soils related to soil texture; new discussions of the Mining Law of 1872, using microbes to extract minerals, new materials, humification and mineralization in soils, types of soil erosion (sheet, rill, and gully), desertification in Australia; expanded discussion of environmental impact of resource extraction.

13 Wastes: Reduction and Prevention

New chapter integrating and expanding discussions of solid waste and hazardous waste; 3 color photos; 1 diagram; opening Earth Story, "There Is No 'Away': The Love Canal Tragedy"; 3 Solutions, "Sailing Through Life in an Earthship," "Protecting Children from Lead Poisoning," and "Pollution Prevention Pays"; 3 Spotlights, "The Diaper Dilemma," "Recycled Paper Hype and Trade-offs," and "Superfund or

Superfailure?"; Pro/Con, "Is Deep-Well Disposal of Hazardous Waste a Good Idea?"; 2 tables, "Common Household Toxic and Hazardous Materials" and "Alternatives to Common Household Cleaning Products"; new discussions of recycling wastepaper, biological amplification of PCBs, grass-roots action against incinerators and landfills; expanded discussions of lead poisoning, hazardous waste options, reduction and reuse of solid waste, recycling of solid waste, bioremediation; Guest Essay, "Environmental Justice for All," by Robert D. Bullard.

PART IV

BIODIVERSITY: LIVING RESOURCES

14 Food Resources

2 color photos; 4 diagrams; opening Earth Story, "Perennial Crops on the Kansas Prairie"; Solutions, "Saving Children"; new discussions of sustainable and optimum yields of fisheries, salmon ranching and farming; expanded discussions of environmental effects of producing meat, cultivating more land; Guest Essay, "Mazunte: A Farming and Fishing Ecological Reserve in Mexico," by Alberto Ruz Buenfil.

15 Protecting Food Resources: Pesticides and Pest Control

2 color photos; opening Earth Story, "Along Came a Spider"; 2 Connections, "The Pesticide Treadmill" and "The Circle of Poison"; Spotlight, "The Delaney Clause"; expanded discussion of first- and second-generation pesticides.

16 Biodiversity: Sustaining Ecosystems

Extensive rewriting and reorganization; 8 color photos; 7 diagrams; 1 improved diagram; 1 cartoon; opening Earth Story, "How Farmers and Loud Monkeys Saved a Forest"; Pro/Con, "Monocultures or Mixed Cultures?"; 3 Connections, "Cultural Extinction," "What Should We Do About Coyotes?," and "Who's Afraid of the Big Gray Wolf?"; 2 Spotlights, "Ways to Harvest Trees" and "A Tree for All Seasons"; Solutions, "Kenaf: A Substitute for Paper"; new discussions of useful products from trees, the rotation cycle of forest management, an evaluation of monoculture forestry, the metabolic reserve of rangeland grasses, wild game ranching, condition of the world's rangelands, riparian zones, the national trails system; expanded discussions of road building and forests, sustainable management of public rangeland.

17 Biodiversity: Sustaining Wild Species

6 color photos; 4 diagrams; opening Earth Story, "The Passenger Pigeon: Gone Forever"; Connections, "Should All Sales of Elephant Ivory Be Banned?"; Spotlight, "Is There Really an Extinction Crisis?"; new discussions of "killer" bees, exclusive economic zones and high seas in the oceans; expanded discussion of habitat loss and fragmentation, toothed cetaceans and baleen whales.

PART V

ENERGY RESOURCES

18 Solutions: Energy Efficiency and Renewable Energy

Extensively rewritten and reorganized; 2 color photos; 14 diagrams; opening Earth Story, "Houses That Save Energy and Money "; Spotlight, "Net Energy: The Only Energy That Really Counts"; 2 Solutions, "Light Up Your Life, Help the Earth, and Save Money" and "Straw-Bale Houses"; expanded discussion of improving energy efficiency.

19 Nonrenewable Energy Resources

1 color photo; 4 diagrams; opening Earth Story, "Bitter Lessons from Chernobyl"; Individuals Matter, "How to Save Energy and Money"; new discussions of nuclear waste dumping in the former Soviet Union, Energy Policy Act of 1992; Guest Essay, "Technology Is the Answer (But What Was the Question?)" by Amory B. Lovins.

Epilogue Living Sustainably

Extensively revised.

Guest Essayists and Reviewers

Guest Essayists The following are the authors of Guest Essays:

Lester R. Brown, President, Worldwatch Institute; **Alberto Ruz Buenfil**, environmental activist, writer, and performer; **Robert D. Bullard**, Professor of Sociology, University of California, Riverside; **Vincent T. Covello**, Professor of Environmental Sciences, School of Public Health, and Director, Center for Risk Communication, Columbia University; **Anne H. Ehrlich**, Senior Research Associate, Department of Biological Sciences, Stanford University; **Paul R. Ehrlich**, Bing Professor of Population Studies, Stanford University; **Lois Marie Gibbs**, Director, Citizens' Clearinghouse for Hazardous Wastes; **Garrett Hardin**, Professor Emeritus of Human Ecology, University of California, Santa Barbara; **Jim Hightower**, populist, author, and radio commentator; **Amory B. Lovins**, Energy Policy Consultant and Director of Research, Rocky Mountain Institute; **Jessica Tuchman Mathews**, Vice President, World Resources Institute; **Peter Montague**, Senior Research Analyst, Greenpeace, and Director, Environmental Research Foundation; **Norman Myers**, consultant in environment and development; **David W. Orr**, Professor of Environmental Studies, Oberlin College; **David Pimentel**, Professor of Entomology, Cornell University; **Julian L. Simon**, Professor of Economics and Business Administration, University of Maryland.

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Integrating Themes

Ten themes are used to integrate the material in this book. You might think of them as connecting threads woven through the material. To follow each thread use the page numbers listed after each theme.

Biodiversity and Earth Capital

Economics and Environment

Energy and Energy Efficiency

Individual Action and Earth Citizens

Politics and Environmental Laws

Pollution Prevention and Waste Reduction

Population and Exponential Growth

Science and Technology

Solutions and Sustainability

Uncertainty and Controversy

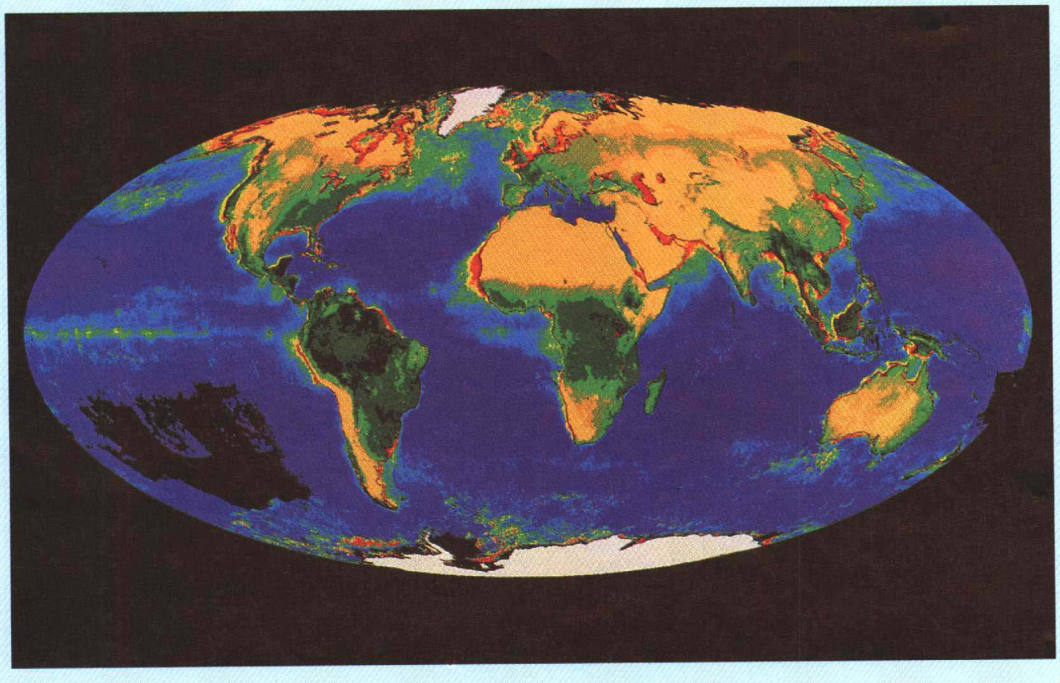
Working with the Earth: A Student's Visual Guide Through this Book

With the emergence of the environment as one of today's most pressing and controversial concerns, the interdisciplinary field of environmental science is becoming increasingly important and interesting. I assume that is one of the reasons why you are enrolled in this course.

In this fifth edition of **Environmental Science,** I try to present basic and easily understandable scientific principles to show you how various parts of Earth's life support systems, environmental problems, and possible solutions are connected and how all of us can do many things to help sustain the earth. The new subtitle for this edition, **Working with the Earth,** emphasizes this perspective.

The many changes in this edition of **Environmental Science** were made with you, the student, in mind. The art program is entirely new and includes many illustrations and photographs that are more three-dimensional, colorful, detailed, and useful. I've tried to make my writing clearer and more personal so you can enjoy the process of learning. And because I wanted to make sure that the information was as current, accurate, and scientifically sound as possible, I've added more scientific content. I've consulted well over 10,000 research sources in the professional literature, and I've listened to the more than 200 experts who have reviewed the material in this and earlier editions.

For the past 27 years, I've devoted my full time to studying, teaching, and writing about the environment and its connections. As you might imagine, environmental science is a passion that has changed my life. It is my hope that this book will change yours, or at the very least, challenge you to question your assumptions, think problems through, and begin to lead more environmentally responsible lives. The material that follows will enhance your ability to use and learn from this book.



Three-year composite of satellite data on Earth's primary productivity. This is one of 17 satellite photographs in this edition.

NEW "EARTH STORIES"

Each chapter opens with an "Earth Story" to introduce you to related material and spark your interest. These stories, illustrated with exciting photographs or drawings, provide useful information. Many describe what individuals have already done to help sustain the earth, offering you inspiration and hope for the future.

3 Matter and Energy Resources: Types and Concepts

Saving Energy, Money, and Jobs in Osage, Iowa

Osage, Iowa (population about 4,000), has become the energy-efficiency capital of the United States. It began in 1974 when easygoing Wes Birdsall, general manager of Osage Municipal Gas and Electric Company, started going door-to-door preaching. He wanted the townspeople to save energy and reduce their natural gas and electric bills. The utility would save money, too, by not having to add a new power plant.

Wes started his crusade by telling homeowners about the importance of insulating walls and ceilings and of plugging of leaky windows and doors. He also advised people to replace their incandescent light bulbs with more efficient fluorescent bulbs and to turn down the temperature on water heaters and wrap them with insulation—an economic boon to the local hardware and lighting stores. Wes also suggested saving water and fuel by installing low-flow shower heads.

He stepped up his campaign by offering to give every building in town a free thermogram—an infrared scan that shows where heat escapes (Figure 3-1). When people could see the energy (and money) hemorrhaging out of their buildings, they took action to plug these leaks—again helping the local economy.

Since 1974 the town has cut its natural gas consumption by 45%; no mean feat in a place where winter temperatures can plummet to –103°C (–80°F). In addition, the utility company saved enough money to prepay all its debt, accumulate a cash surplus, and cut inflation-adjusted electricity rates by a third (which attracted two new factories). Furthermore, each household saves more than $1,000 per year. This money supports jobs, and most of it circulates in the local economy. Before the energy-efficiency revolution, about $1.2 million a year went out of town—usually out of state—to buy energy. What are your local utility and community doing to improve energy efficiency and stimulate the local economy?

Figure 3-1 An infrared photo showing heat loss around the windows, doors, roofs, and foundations (red, white, and yellow colors) of houses and stores in Plymouth, Michigan. Wes Birdsall provided similar thermograms made for houses in Osage, Iowa. The average U.S. house has heat leaks and air infiltration equivalent to leaving a window wide open during the heating season. Because of poor design, most U.S. office buildings and houses waste about half the energy used to heat and cool them. Americans pay about $300 billion a year for this wasted heat—more than the entire annual military budget. (VANSCAN® Continuous Mobile Thermogram by Daedalus Enterprises, Inc.)

NEW CONNECTIONS BOXES

Above all, environmental science is the study of connections in nature. Throughout the main text and in 19 Connections boxes, I've tried to show how environmental concepts, problems, and solutions are related.

CONNECTIONS

Bats: A Bad Rap

Despite their variety (950 species) and worldwide distribution, bats have several traits that expose them to extinction because of human activities. Many bats nest in huge cave colonies, which become vulnerable to destruction when people block the caves' entrances. And once the population of a bat species falls below a certain level, it may not recover because of its slow reproductive rate.

Bats play significant ecological roles and are also of great economic importance. Some bat species help control many crop-damaging insects and other pest species, such as mosquitoes and rodents (Figure 17-10). About 70% of all bat species feed on night-flying insects, making them the primary controls for such insects.

Other species of bats eat pollen; still others eat certain fruits. Bats with this kind of specialized feeding are the chief pollinators for certain trees, shrubs, and other plants; they also spread plants throughout tropical forests by excreting undigested seeds. If these keystone species are eliminated from an area, dependent plants will disappear. U.S. examples of bat-pollinated species are the giant saguaro cactus (Figure 4-11) and agaves (plants of the desert Southwest used in making fiber rope and tequila). In Southeast Asia, a cave-dwelling, nectar-eating bat species is the only known pollinator of durian trees, whose fruit is worth $120 million per year. If you enjoy bananas, cashews, dates, figs, avocados, or mangos, you can thank bats. Research on bats has contributed to the development of birth control and artificial insemination methods, and testing of drugs, studies of disease resistance and aging, vaccine production, and development of navigational aids for the blind.

People mistakenly fear bats as filthy, aggressive, rabies-carrying, bloodsuckers. But most bat species are harmless to people, livestock, and crops. In the United States only 10 people have died of bat-transmitted disease in four decades of record keeping. More Americans die each year from falling coconuts. Only three species of bats (none of them found in the United States) feed on blood, mostly that of cattle or wild animals. These bat species can be serious pests to domestic livestock but rarely affect humans.

Because of unwarranted fears of bats and misunderstanding of their vital ecological roles, several species have been driven to extinction, and others, such as the ghost bat (Figure 17-9), are endangered or threatened. We need to see bats as valuable allies, not as enemies.

G. B. Barnard/N.T. Photo Library

Figure 17-10 Endangered ghost bat carrying a mouse in tropical northern Australia. This carnivorous night-feeding bat is harmless to people. Bats are considered keystone species in many ecosystems because of their roles in pollinating plants, dispersing seeds, and controlling insect and rodent populations.

NEW CONCEPT MAPPING

I've used a diagram or "concept map" to summarize the key concepts and show connections for the entire book (see the inside front cover). Appendix 4 shows you how to construct these diagrams on your own.

are threatened with extinction, mostly because of habitat loss and fragmentation.

Commercial Hunting and Poaching Today subsistence hunting (for food) is rare because of the decline in hunting-and-gathering societies (Connections, p. 428). Sport hunting is closely regulated in most countries, and game species are endangered only where protective regulations do not exist or are not enforced.

However, a combination of habitat loss, legal commercial hunting, and illegal commercial hunting (poaching) has driven many species, such as the American bison (Case Study, p. 461) to or over the brink of extinction (Figures 17-6 and 17-7). Bengal tigers are in trouble because a tiger fur sells for $100,000 in Tokyo. A mountain gorilla is worth $150,000 and a chimpanzee $50,000; an ocelot skin, $40,000; an Imperial

Robert and Linda Mitchell

Figure 17-11 Endangered ring-tailed lemur in Madagascar. Lemurs are the oldest distant relative of the human species. The 30 species of lemurs on this island are found nowhere else in the wild. Half of them are endangered.

Is Your City Green?—The Ecocity Concept in Davis, California

SOLUTIONS

In a sustainable and ecologically healthy city—called an *ecocity* or *green city*—matter and energy resources are used efficiently, and far less pollution and waste are produced than in conventional cities. Emphasis is on pollution prevention, reuse, recycling, and efficient use of energy and matter resources. Per capita solid waste is greatly reduced, and 60% of what is produced is recycled, composted, or reused. An ecocity takes advantage of locally available energy sources and requires that all buildings, vehicles, and appliances meet high energy-efficiency standards.

Trees and plants adapted to the local climate and soils are planted throughout the ecocity to provide shade and beauty, to reduce pollution and noise, and to supply habitats for wildlife. Abandoned lots and polluted creeks are cleaned up and restored. Nearby forests, grasslands, wetlands, and farms are preserved instead of being devoured by urban sprawl. Much of an ecocity's food comes from nearby organic farms, solar greenhouses, community gardens, and gardens on rooftops and in yards and window boxes.

An ecocity is a people-oriented city—not a car-oriented city. Its residents are able to walk or bike to most places, including work, and to take low-polluting mass transit. It is designed, retrofitted, and managed to provide a sense of community built around cooperative and vibrant neighborhoods.

The ecocity concept is not a futuristic dream. The citizens and elected officials of Davis, California—a city of about 40,000 people about 130 kilometers (80 miles) northeast of San Francisco—committed themselves in the early 1970s to making it an ecologically sustainable city.

City building codes encourage the use of solar energy for water and space heating. All new homes must meet high standards of energy efficiency, and when an existing home changes hands, the buyer must bring it up to the energy conservation standards for new homes. In Davis's Village Homes—America's first solar neighborhood—houses are heated by solar energy (Figure 6-24). They face into a common open space reserved for people and bicycles; cars are restricted to streets, which are located only on the periphery of the development. The neighborhood also has orchards, vineyards, and a large community garden. Since 1975 the city has cut its use of energy for heating and cooling in half.

Davis has a solar power plant; some of the electricity it produces is sold to the regional utility company. Eventually the city plans to generate all of its own electricity.

The city discourages the use of automobiles and encourages the use of bicycles by closing some streets to automobiles, by building bike lanes on major streets, and by building bicycle paths. Any new housing tract must have a separate bike lane, and some city employees are given bikes. As a result, 28,000 bicycles account for 40% of all in-city transportation, and less land is needed for parking spaces. This heavy dependence on the bicycle is aided by the city's warm climate and flat terrain.

Davis limits the type and rate of its growth, and it maintains a mix

problems and save money in the long run. Finally, it's difficult to get municipalities in the same general area to cooperate in planning efforts. Thus an ecologically sound development plan in one area may be disrupted by unsound development in nearby areas.

Making Urban Areas More Livable and Sustainable Since most people around the world now live, or will live, in urban areas, improving the quality of urban life is an urgent priority—and a few cities have started to do it (Solutions, above). Here are some ways various analysts have proposed to make urban areas more sustainable:

Economic Development and Population Regulation

- Reduce population growth rates (Section 6-5).
- Reduce the flow of people from rural to urban areas by increasing investments and social services in rural areas and by not giving higher food, energy, and other subsidies to urban dwellers than to rural dwellers.
- Recognize that increased urbanization and urban density is better than spreading people out over the countryside, which would destroy more of the planet's biodiversity. The primary problem is not urbanization, but our failure to make cities more sustainable and livable.
- Maintain employment and plug dollar drains from local economies by setting up "buy local" programs, greatly improving energy efficiency (p. 40), and instituting extensive recycling, reuse, and pollution prevention programs.

Q: What greenhouse gas is being emitted to the atmosphere in the largest quantity from human activities?

NEW SOLUTIONS BOXES

In addition to describing environmental problems, this new edition emphasizes more than ever before solutions to these problems. In each of 26 Solutions boxes, a new feature in this edition, I've highlighted a particular environmental problem and offered you possible ways to solve it. There are also sections and subsections of Solutions within most chapters.

Factual Recall Questions

Factual recall questions appear at the bottom of most left-hand pages so you can test your knowledge. Answers appear on the facing page.

The Kangaroo Rat: Water Miser and Keystone Species

SPOTLIGHT

The kangaroo rat (Figure 5-8) is a remarkable mammal that has mastered the art of water conservation in its desert environment. As the desert's chief seed eater, it is also a keystone species that helps support other desert species. By consuming seeds it helps keep desert shrubland from becoming grassland.

This rodent comes out of its burrow only at night, when the air is cool and water evaporation has slowed. Its main source of food is dry seeds, which it quickly stuffs into its cheek pouches. After a night of foraging, it returns to its burrow and empties its cache of seeds.

In the cool burrow the seeds soak up water exhaled in the rodent's breath. When the rodent eats these seeds it gets this water back. It does not drink water; its water comes from recycled moisture in the seeds it eats and from water produced when the sugars in the seeds undergo aerobic respiration. Some of the water vapor in the rat's breath condenses on a cool inside surface of the nose and diffuses back to its body. Kangaroo rats have no sweat glands, so they don't lose water by perspiration. In addition, they save water by excreting hard, dry feces and thick, nearly solid urine from their super-efficient kidneys.

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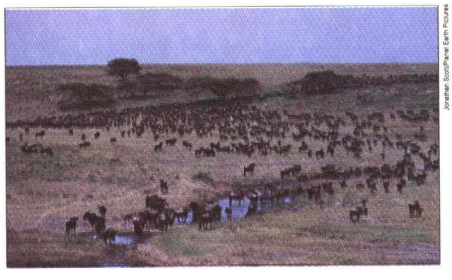
Figure 5-8 This nocturnal kangaroo rat of the California desert is an expert in water conservation. It is also a keystone species because it consumes such vast quantities of seeds, which prevents desert shrubland from becoming grassland.



Jonathan Scott/Planet Earth Pictures

Figure 5-9 Serengeti tropical savanna in Tanzania, Africa, an example of one type of tropical grassland. Most savannas consist of grasslands punctuated by stands of deciduous shrubs and trees, which shed their leaves during the dry season and thus avoid excessive water loss. More large, hoofed, plant-eating mammals (ungulates), such as the herd of wildebeest shown here, live in this biome than anywhere else.

Polar grasslands, or *arctic tundra*, occur just south of the Arctic polar ice cap (Figure 5-3). During most of the year these treeless plains are bitterly cold, swept by frigid winds, and covered with ice and snow. Winters are long and dark, and the low average annual precipitation falls mostly as snow. This biome is carpeted with a thick, spongy mat of low-growing plants (Figure 5-13). Most of the annual growth of these plants occurs during the summer, when sunlight shines almost around the clock.

Q: What percentage of the world's population own cars?

SPOTLIGHTS

I've included 21 Spotlights (19 new to this edition) to highlight and provide you with further insights into key environmental problems and concepts. This one, "The Kangaroo Rat: Water Miser and Keystone Species," discusses how this desert animal is an expert at conserving water. It also explains how this mammal keeps desert shrubland from becoming grassland.