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# *Environmental Science*

A GLOBAL



*sixth edition*

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SIXTH EDITION

# *Environmental Science*



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## ENVIRONMENTAL SCIENCE: A GLOBAL CONCERN, SIXTH EDITION

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In the cover photo, Kavavow Kiguktak, an Inuit hunter from the village of Grise Fiord on Ellesmere Island high in the Canadian arctic, jumps across ice floes as he hunts seals on the Arctic Ocean. He depends on experience, courage, and traditional knowledge to find his way through this dangerous, constantly shifting environment. As remote and exotic as Kav's life may seem to most of us, he also is interconnected to the modern world. In 1999, the government of Canada transferred two million square kilometers of land back to the Inuit people. Commercial air routes and modern telecommunications now connect the widely dispersed residents of the vast new territory of Nunavut.

But links to the outside world also bring problems to these northern people. Alcoholism, AIDS, and suicide are the main killers of Inuit people between 15 and 35 years old. Air pollutants from cities and industries in Europe, Russia, China, and North America drift northward into the Arctic. During the winter, the industrial smog in remote areas of Nunavut can be higher than in London or New York. Furthermore, as contaminants accumulate and are concentrated in arctic food webs, they reach toxic levels in the fish, seals, and sea birds eaten by the Inuit.

This photo provides a good metaphor for our global environmental situation. Like Kav, we face dangerous, rapidly changing environmental conditions. It will take courage, knowledge, and effort to find our way out of our current environmental dilemmas. I hope you'll find information and inspiration in this book to help in your journey toward a better, safe, more equitable world.

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# Preface

A GLOBAL CONCERN

## 危机

The Chinese ideogram for “crisis” combines the character *wei*, meaning danger, with the character *ji*, denoting opportunity. This is a good description of our global environment

situation. We are dangerously close to pushing biological communities and biophysical processes beyond the point from which they can recover. At the same time, our greatly increased understanding of the natural world and how it works gives us an opportunity to repair the damage we have caused and to find new, more efficient, and more environmentally friendly ways of providing the goods and services we need. British ecologist Norman Myers points out that the current generation of students has the advantage of being the first in history to have the information, resources, and motivation to do something to solve our environmental crisis. Unfortunately, he adds, if solutions to some of our most pressing problems aren’t found quickly, this generation also may be the last to have a chance to do so.

I hope that you will find this book a valuable source of information about our global environment, as well as an inspiration for solutions to the dilemmas we face. Everyone has a role to play in this endeavor. Whether as students, educators, researchers, activists, or consumers, each of us can find ways to contribute in solving our common problems.

## WHO MAKES UP THE AUDIENCE FOR THIS TEXT?

This book is intended for use in a one- or two-semester course in environmental science, human ecology, or environmental studies at the college or advanced placement high school level. Because most students who will use this book are freshman or sophomore non-science majors, I have tried to make the text readable and accessible without technical jargon or a presumption of prior science background. At the same time, enough data and depth are presented to make this book suitable for many upper-division classes and a valuable resource for students who will keep it in their personal libraries after their formal studies are completed.

## WHY DID I WRITE THIS BOOK?

I have taught aspects of environmental science in a variety of settings for about 40 years. Although the earliest of these classes focused primarily on natural history and conservation, I found my interests and concerns changing in the 1970s. Two broad areas of environmental science that seemed important to me weren’t covered in the existing textbooks. One of these is global concerns. We live in an highly interconnected world; the coal burned in China, or the nuclear waste dumped in the ocean by Russia, or the pesticides used on farm crops in Central America affect all of us. The other area is environmental justice and the human dimensions of environmental issues. Although my original interests in the environment were primarily wilderness and wildlife issues, the Civil Rights Movement of the 1960s opened my eyes to the conditions in inner cities and the role of economics, health, policy, and law in environmental concerns. Ecology remains the heart of environmental science, but students also need to know something about the roles of human institutions and social sciences to be educated environmental citizens. It’s gratifying to see that since the first edition of this book was published in 1990, concerns about environmental ethics and social justice are appearing in other textbooks as well.

## WHY THIS COVER PHOTO?

I’m especially pleased with the cover photograph of this edition of *Environmental Science*. It shows Kavavow Kiguktak, an Inuk hunter jumping across ice floes as he looks for seals off the coast of Ellesmere Island in Canada’s high arctic. In spite of the extremely harsh conditions they face, the Inuit people have used traditional knowledge and a strong ethic of cooperation and sharing to live in harmony with their environment for thousands of years. Cultural traditions inform Kav about how many seals he can take from the common pool resource, the respect he must show his prey, and how he shares his catch with other members of his community. He depends on experience and courage to find his way across the constantly shifting ice floes.



In several ways, this image also serves as a good metaphor for our current environmental issues. As he jumps from one ice block to the next in the ever-shifting ice pack, Kav is constantly looking ahead, evaluating risks and opportunities, and making reasoned judgments. He faces great danger—a fall into the frigid ocean could be fatal—but the ice also provides an opportunity to move far out from the shore as he hunts. Simply standing still just isn't an option in this situation; Kav must keep moving to stay afloat. In much the same way, it takes courage, foresight, and nimble footwork for us to find a way out of the complex, constantly changing environmental problems we now face. We can't simply remain where we are, but must use every skill at our disposal to find a safe path to the future.

Although he lives in a remote and exotic part of the world, Kav is affected by events occurring far away. As a resident of the new territory of Nunavut, he is participating in a bold new experiment in self-rule and self-determination. New job opportunities are opening up for First Nations people as they take control of their ancestral territory. During the brief arctic summer, Kav, for instance, is a seasonal ranger at the remote Ellesmere National Park. In the summer of 1998, I made a two-week backpacking trip to this harsh, but beautiful landscape (see figure 15.9). One of the main attractions of hiking there is the opportunity to see arctic animals such as the white wolves, musk ox, Perry caribou, narwhal, polar bears, and arctic hares, all of which have had so little contact with humans that they are generally unafraid of us. Unfortunately, there seems to be a widespread decline in many of these arctic species. The cause isn't known for certain, but one suspicion is that global climate change coupled with pollution carried by wind currents from industrial centers far to the south may be playing a role. While a disappointment to visitors, this decline could be devastating for residents like Kav who try to maintain traditional ways of life.

## WHAT'S NEW IN THIS EDITION?

The most difficult thing about writing a broad, introductory text like this is incorporating all the interesting and important material, keeping it current, and still resisting the temptation to let it grow to encyclopedic size. By careful pruning, I've managed to add significant new features to each edition of this book while still maintaining a reasonable length. I have had the good fortune in working on this revision to have more than one hundred reviews from colleagues at colleges and universities across North America. They've offered many useful criticisms and suggestions for improving the book. If you are one of those reviewers, you have my most sincere thanks.

### Two New Chapters

- A new introductory chapter presents suggestions to students about why environmental science is interesting and useful, how to study, how to prepare for tests, critical

thinking, and concept maps. These topics are presented in the beginning of the book so students can begin to use them immediately. This is the kind of information that most of us cover in the first lecture of a class. No other book goes into the *fundamentals of critical thinking theory and application* found here.

- The other new chapter, "Environmental Policy, Planning and Law," begins with a discussion of the policy cycle of agenda setting, problem definition, implementation, and evaluation by which public policy is established. The environmental law section defines statutory, case, and administrative law, a level of sophistication never before presented in an environmental science textbook. Also included are current concepts such as alternative dispute resolution, wicked problems, resilience in ecosystems and institutions, the precautionary principle, arbitration and mediation, and collaborative approaches to community-based planning. If our students are going to be educated environmental citizens, they need to know how these processes work.

### New Case Studies

Every chapter in this book begins with a case study designed to introduce the main topic and pique student interest. Three-quarters of these case studies are new to this edition and most are based on *very recent news stories* to emphasize the currency of environmental issues. All of them have been expanded from previous versions to be more substantive and meaningful. Overall, the total number of boxed readings have been reduced in this edition so that the remaining ones can be more substantial.

### More Environmental Ethics

Because critical thinking has been moved from chapter 2, "Environmental Ethics and Philosophy," to the new introductory chapter, space is now available to present environmental ethics in greater detail. Notice that this discussion takes a pluralist approach. There is no prescribed "earthmanship ethics" that divide the world into bipolar camps. A variety of worldviews and ethical perspectives are presented and students are invited to think for themselves. Similarly, the discussion of science isn't limited to positivist, reductionist approaches, but recognizes the validity of descriptive and interpretive sciences.

### New Information on Ecological Economics

Chapter 8, "Ecological Economics," has been revised to include a major new section on green business, eco-efficient economy, the Natural Step movement, and "design for the environment." These topics are both very current and are also positive examples of what we can do to improve environmental quality.

## Other Significant Changes

(A complete list of changes to this edition can be found on the accompanying website.)

- Data in tables, graphs, figures, and the text copy have been thoroughly updated.
- Chapter 9, “Environmental Health and Toxicology,” has a new treatment of infectious diseases that emphasizes emergent diseases and how drug resistance is selected for different microorganisms.
- Major revisions and corrections have been incorporated in chapter 16, “Environmental Geology,” including new information on earthquakes and flooding, and a new opening case study, “Earthquake in Turkey.”
- Chapter 17, “Air, Climate, and Weather,” has a helpful new illustration on how tornadoes form, and a new diagram and discussion on El Niño/Southern Oscillations.
- Chapters 19, “Water Use and Management,” and 20, “Water Pollution,” have been updated with new data and current information.
- Chapter 21, “Conventional Energy,” opens with a new case study about the potential for a vast new oil supply under and around the Caspian Sea and how that affects regional politics, including the war in Chechnya.
- An important section has been added to chapter 22, “Sustainable Energy,” on the current topics of fuel cells and hybrid gas/electric automobiles.
- Much new and/or corrected material appears in chapter 23, “Solid, Toxic, and Hazardous Waste,” such as international toxic shipping, and in chapter 25, “What Then Shall We Do?.” Chapter 25 now focuses much more succinctly than in the past on ways we can work individually and cooperatively to build a better world.

3. Strive to build free, just, participatory, and sustainable communities.
4. Secure peace and Earth’s abundance and beauty for present and future generations.

I hope the readers of this book will come to share those goals and to understand the reasons they are so important.

—William P. Cunningham

## RELATED TITLES OF INTEREST

1. *Field and Laboratory Activities Manual* (0-07-290913-7) by Enger and Smith.
2. *Annual Editions: Environment 99/00* (0-07-228498-6) Editor: John L. Allen.
3. *Taking Sides: Clashing Views on Controversial Environmental Issues* (0-07-303184-4) Editor: Theodore D. Goldfarb.
4. *Sources: Notable Selections in Environmental Studies* (0-07-303186-0) Editor: Theodore D. Goldfarb.
5. *The Dushkin Student Atlas of Environmental Issues* (0-697-36520-4) Editor: John Allen. University of Connecticut.
6. *Life Science Living Lexicon* (CD = 0-697-37993-0; Print = 0-697-12133-X) by William Marchuk.
7. *You Can Make a Difference: Be Environmentally Responsible* (0-07-292416-0) by Judy Getis.
8. *Environmental Ethics: Divergence and Convergence* (0-07-006180-7) by Botzler and Armstrong.
9. *Environmental Problem-Solving: A Case Study Approach* (0-07-027686-2) by Isobel W. Heathcote.
10. *Eyewitness World Atlas CD-ROM* (0-07-233220-4), published by Dorling-Kindersley.

## HOW IMPORTANT IS SUSTAINABILITY AND ENVIRONMENTAL CITIZENSHIP?

Ultimately the aims of this book are to foster attitudes of stewardship and environmental citizenship, and to encourage the goals of economic, ecological, and social sustainability. In the preamble to the United Nations Earth Charter, the authors declare, “In an increasingly interdependent world, it is imperative that we, the citizens of Earth, declare our responsibility to one another, the greater community of life, and future generations.” Among the principles proposed by the Earth Charter are:

1. Respect Earth and all life, recognize the interdependence and intrinsic value of all beings.
2. Care for the community of life in all its diversity as a responsibility shared by everyone.

## ACKNOWLEDGMENTS

Many people have contributed in a variety of ways to each edition of this book. Mary Ann Cunningham provided advice and helpful suggestions throughout the writing process. She also has written a superb series of essays on current global environmental issues that appears on the web page world map. Laura Ragan wrote the initial draft of the case study about Chattanooga for chapter 24. Joel Burken of the University of Missouri provided information for the case study about arsenic in drinking water in India for chapter 20. I am particularly grateful to Amanda Woods McConney of Western Washington University, Jim Oris of Miami University of Ohio, Eric Anderson of the University of Wisconsin—Stevens Point, Jerry Hinckley of the College of Lake County, and Darby Nelson of Anoka Ramsey Community College, all of whom attended a

workshop that provided some extremely valuable insights for this edition. In addition, Amanda has written an excellent class activities and assessment guide that will be a great help for instructors teaching with this book. Jim has created a set of web-page lecture notes that make an outstanding template for environmental science courses. And Darby has written a thoughtful student study guide that will be exceptionally helpful in assisting students to study in an effective and efficient way. I remain grateful to Karen Warren of Macalester College from whom I learned most of what I know about critical thinking and environmental philosophy. Caroline Getty, a hiking companion in Ellesmere National Park, led me to the photography of Cherry and Brian Alexander that appears on the book cover.

I'm also indebted to all the students and teachers who have sent helpful suggestions, corrections, and recommendations for improving this book. Unfortunately, space didn't permit inclusion of all the excellent ideas that were provided. All have been saved, however, and will be helpful in future editions. I hope that those who read this edition will offer their advice and insights as well. Little of the vast range of material in this book represents my own personal research. All of us owe a great debt to the many scholars whose work forms the basis of our understanding of environmental science. We stand on the shoulders of giants. If errors persist in spite of my best efforts to root them out, I accept responsibility and ask for your indulgence.

I want to express my appreciation to the entire McGraw-Hill book team for their wonderful work in putting together this edition. Kathy Loewenberg oversaw the developmental stages and has made many creative contributions to this book. Mary Lee Harms was production project manager and kept everything running smoothly. Cathy Conroy did an excellent job of copyediting and spotting errors and inconsistencies. Connie Mueller found superb photographs. The folks at Precision Graphics did an excellent job of composition and page layout. Michelle Watnick and Marge Kemp have supported this project with their enthusiasm and creative ideas.

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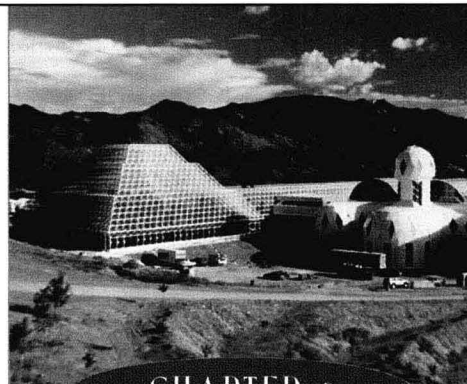
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# LEARNING AIDS

This book is designed to be useful as a self-education tool for students. To facilitate studying and encourage higher-level thinking, each chapter begins with a set of **Objectives** based on major concepts that students should master, and a listing of **ESP CD-ROM Topics** that are chapter-related. A short **Opening Story**, taken from recent news events, follows, setting the subject in context and illuminating the importance of the material to be discussed. **Key Terms**, indicated by boldface type, are defined in context where they are first used and are also listed in the **Glossary** for quick reference.



## CHAPTER 8

### Ecological Economics

Gentlemen, there is no more money. We shall have to start using our brains.

—Ernest Rutherford—

## IN DEPTH.

### Arsenic in Drinking Water

When we think of water pollution, we usually visualize sewage or industrial effluents pouring out of a discharge pipe, but there are natural toxins that threaten us as well. One of these is arsenic, a common contaminant in drinking water that may be poisoning millions of people around the world. Arsenic has been known since the fourth century B.C. to be a potent poison. It has been used for centuries as a rodenticide, insecticide, and weed killer, as well as a way of assassinating enemies. Because it isn't metabolized or excreted from the body, arsenic accumulates in hair and fingernails, where it can be detected long after death. Napoleon Bonaparte was found recently to have high enough levels of arsenic in his body to suggest he was poisoned.

Perhaps the largest population to be threatened by naturally occurring groundwater contamination by arsenic is in West Bengal, India, and adjacent areas of Bangladesh. Arsenic, in the form of insoluble salts, occurs naturally in

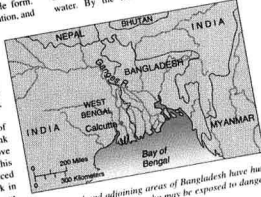
the bedrock that underlies much of this region. Under normal conditions, the groundwater stays relatively free of arsenic in a soluble form.

Rapid population growth, industrialization, and intensification of agricultural practices, however, have put increasing stresses on the limited surface water supplies of this region (see Chapter 19). Groundwater has all but replaced other water sources for most people in West Bengal, especially in the dry season.

In the 1960s, thousands of deep tube wells were sunk throughout the region to improve water supplies. Much of this humanitarian effort was financed by loans from the world bank in the name of human development.

At first, villagers were suspicious of well water, regarding it as unnatural and possibly evil. But as sur-

face water supplies diminished, many Bengali villages became more and more dependent on this new source of supposedly fresh, clean water. By the late 1980s, health workers



West Bengal and adjoining areas of Bangladesh have hundreds of millions of people who may be exposed to dangerous arsenic levels in well water.

## Sediment

Rivers have always carried sediment to the oceans, but erosion rates in many areas have been greatly accelerated by human activities. As chapters 11 and 19 describe, some rivers carry astounding loads of sediment. Erosion and runoff from croplands contribute about 25 billion metric tons of soil, sediment, and suspended solids to world surface waters each year. Forests, grazing lands, urban construction sites, and other sources of erosion and runoff add at least 50 billion additional tons. This sediment fills lakes and reservoirs, obstructs shipping channels, clogs hydroelectric

canals, and creates drinking water problems in which insects take refuge as levels decline. Murky, cloudy water hinders swimming, boating, fishing, and other recreational activities. Sediment also can be beneficial. It makes purifying floodplain farm fields. Some river mouths create valuable delta for instance, builds up islands in the Mississippi, and is causing biological upturn in the Mississippi delta. Sediment also can be

## what do you think?

THE WORLD AROUND YOU

### Cultural Whaling in the Pacific Northwest

On May 17, 1999, for the first time in more than 70 years, members of the Makah tribe from Washington's Olympic peninsula struck and killed a gray whale. Using a mixture of modern technology and ancient traditions, nine men paddling a handmade cedar canoe drew close enough to harpoon the 20-ton whale, after which high-speed motorboats closed in to kill the wounded animal with a .50-caliber anti-tank rifle.

For months before the hunt, native people, animal rights groups, sea conservation societies, and members of the whale-watching industry had engaged in shouting matches, racial slurs, political maneuvering, media campaigns, and dangerous motorboat confrontations as each side tried to promote its own views. At issue is a complex mixture of international environmental policy, aboriginal culture and hunting rights, ethical values, commercial interests, and politics that is not easy to resolve. This case study presents a good opportunity for you to practice critical thinking skills.

For at least 1500 years the Makah people collected fish and shellfish and hunted for seals, whales, and sea otters along this section of fog-shrouded coast. The 1855 Treaty of Neah Bay recognized the right of the Makah people to hunt whales, the only such covenant in United States history. By the beginning of the twentieth century, however, commercial exploitation had driven nearly to extinction the whales, seals, otters, and fish on which the Makah once depended. Fewer than 2000 Pacific gray whales survived out of a historic population of about 30,000. By 1920, most Makah had given up their traditional subsistence culture and turned

to farming, logging, or factory jobs.

Since their protection under the Endangered Species Act and the International Whaling Ban, gray whales have made a remarkable and encouraging recovery. The population today is thought to be around 26,000 animals and is growing at about 2.5 percent per year. It may well have reached the carrying capacity of its habitat. In 1999 scientists estimated that about 800 whales died of starvation and disease during their 4000-mile migration from Baja California to the Arctic. A sustainable harvest might actually be beneficial for the whale population. When the species was removed from the U.S. endangered species list in 1994, the Makah announced their intention to resume whaling under their treaty rights. They consider this an important step in recovering their traditional culture and combating the poverty, drugs, alcoholism, violence, and despair that have afflicted their community. Reviving the rituals, discipline, and pride of whaling, they believe, could lead to a cultural renaissance for their people.

To anti-hunting groups, killing magnificent, intelligent, social animals like whales is tantamount to murder. In their view, calling for a sustainable harvest of whales is equivalent to establishing a sustainable level of genocide or torture. This isn't subsistence hunting, they claim, because the Makah haven't depended on whale meat for many years and don't need it now. To the Makah and their supporters from whaling nations such as Japan and Norway, on the other hand, it is hypocritical to condemn



Members of a Makah whaling crew set out in their handmade cedar canoe on a practice run. While hunting is central in the Makah culture, but is opposed by animal rights groups.

hunting marine mammals when most Americans happily eat the millions of cattle, pigs, sheep, and other animals slaughtered every year in commercial packing plants.

How would you approach this complex question? What information would you need to determine whether Indian claims for cultural traditions should take precedence over ethical rights of wild animals? Does the fact that native people have suffered economically and socially give them special standing? Should subsistence hunting be limited to traditional tools and people who have a demonstrated nutritional need? What information sources would you regard as reliable and authoritative in this situation? How would you decide whom or what to believe?

As you study environmental science, you will find that many of the dilemmas we face, like this question of hunting whales by native people, require a combination of scientific data and contextual sensitivity and empathy. Because humans are involved, questions of history, culture, ethics, and politics also come into play. How would you resolve this clash in world views? Can you suggest a compromise that might defuse this tense situation?

## OBJECTIVES

After studying this chapter, you should be able to:

- explain the difference between neoclassical and ecological economics and how each discipline views ecological processes and natural resources.
- distinguish between different types and categories of resources.
- understand how resource supply and demand affect price and technological progress.
- develop a position on limits to growth and economic carrying capacity of our environment.
- discuss internal and external costs, market approaches to pollution control, and cost-benefit analysis.
- define GNP and explain some alternative ways to measure values of natural resources and real social progress.
- analyze the role of business and some possible strategies for achieving future sustainability.

Above: Biosphere 2.

## ESSENTIAL STUDY PARTNER

The Essential Study Partner (ESP) CD-ROM that accompanies this textbook contains additional information on the following topics:

- classical, neoclassical, natural resource, and ecological economics: populations: economics: worldviews
- nonrenewable, renewable, and proven resources: populations: economics: resources
- privatization and cooperative management of resources: populations: economics: resources
- resource sustainability, technology, and conservation: populations: economics: sustainability
- environmental costs and the Index of Sustainable Economic Welfare (ISEW): populations: economics: sustainability
- cost-benefit analysis: populations: economics: sustainability

Case Studies, "In Depth" Boxes, and "What Do You Think?" Essays, many with "Ethical Considerations" attached, give students real-life examples to evaluate and a chance to practice critical thinking skills and formulate reasoned opinions. These boxes are carefully planned to build upon chapter content and are long enough to present important, real information.

The "What Can You Do?" Listings help students to learn that small, individual steps can make a real difference in affecting our environment.

Profiles of ordinary people in environmental careers are scattered throughout the text. Giving students models with whom they can identify will help them consider how they might pursue a career in an environmental area.

## PROFILE

### Fisheries Biologist

Robyn Angliss



Would you like a job that includes field surveys of whales and porpoises in Alaska and developing marine policy? Robyn Angliss has done both in her job at the United States National Marine Fisheries Service (NMFS). Although her title is fisheries biologist, Robyn specializes in mammals, especially marine mammals.

How can you get work that takes you to beautiful places to study charismatic animals? Robyn was in her junior year of college and was thinking about a career in marine intertidal ecology when a friend invited her to be part of a summer field study in Prince William Sound, Alaska, to photograph whales and examine the effects of the Exxon Valdez oil spill on killer whales and humpback whales. Although the offer came just days before she was scheduled to go home for summer vacation, she accepted and headed north for a wilderness adventure. While working in Alaska, Robyn met the researcher from NMFS who was funding her project. The next fall, back in Seattle for her final year at the University of Washington, Robyn offered to volunteer for the NMFS researcher she met in Alaska to get some experience and to continue to learn more about marine wildlife. After a few months of volunteering, a part-time paid position became available, and by the time she graduated, Robyn was working full time as a biological technician (wildlife) at NMFS.

For three years, Robyn spent about the Alaska coast from Ketchikan to Point Barrow, gray, and beluga whales from the bow porpoise and killer whales from boats. In Seattle, she cataloged and analyzed photos, and wrote reports. While employed at NMFS, Robyn also worked on a masters of science thesis at the University of Washington, which she finished. Although she loved her job on the summer field work in Alaska, and the vast sea was involved, Robyn decided that ge-

ography and administration would be a good idea. She transferred to a job at NMFS headquarters in Washington, DC, where she worked on regulations to manage interactions between marine mammals and U.S. commercial fisheries, briefed staff members of the U.S. House and Senate on marine mammal issues, and held workshops on policy issues for scientists, environmental advocates, and representatives of the commercial fishing industry. Robyn enjoyed being involved in policy formulation and she feels that her improved understanding of the policy process and important legislation will be invaluable during her future career.

Currently, Robyn is back in Seattle as a fisheries biologist for NMFS. In addition to her continuing work on harbor seal populations in Alaska, she has recently been involved in a project on wildlife management funded by Yellowstone National Park. Ranchers who raise cattle on lands surrounding Yellowstone worry that bison migrating out of the park during the winter may carry brucellosis, a disease that causes cattle to abort their calves. Part of Robyn's duty is to analyze management alternatives designed to reduce the probability that bison will transmit the disease to cattle herds.

How could you get a job like Robyn's? A solid biology education

## SUMMARY

Any physical, biological, or chemical change in water quality that adversely affects living organisms or makes water unsuitable for desired uses can be considered pollution. Worldwide, the most serious water pollutants, in terms of human health, are pathogenic organisms from human and animal wastes. We have traditionally taken advantage of the capacity of ecosystems to destroy these organisms, but as population density has grown, these systems have become overloaded and ineffective. Effective sewage treatment systems are needed that purify wastewater before it is released to the environment.

In industrialized nations, toxic chemical wastes have become an increasing problem. Agricultural and industrial chemicals have been released or spilled into surface waters and are seeping into groundwater supplies. The extent of this problem is probably not yet fully appreciated.

Ultimately, all water ends up in the ocean. The ocean is so large that it would seem impossible for human activities to have a significant impact on it, but pollution levels in the ocean are increasing. Major causes of ocean pollution are oil spills from tanker barge pumping or accidents and oil well blowouts. Surface runoff and sewage outfalls discharge fertilizers, pesticides, organic nutrients, and toxic chemicals that have a variety of deleterious

effects on marine ecosystems. We usually think of eutrophication (increased productivity due to nutrient addition) as a process of inland waterways, but this can occur in oceans as well.

The major water pollutants in terms of quantity are silt and sediments. Biomass production by aquatic organisms, land erosion, and refuse discharge all contribute to this problem. Addition of salts and metals from highway and farm runoff and industrial activities also damage water quality. In some areas, draining swamps and tailings piles deliver sediment and toxic materials to rivers and lakes. Water pollution is a major source of human health problems. As much as 80 percent of all disease and some 25 million deaths each year may be attributable to water contamination.

Appropriate land-use practices and careful disposal of industrial, domestic, and agricultural wastes are essential for control of water pollution. Natural processes and living organisms have a high capacity to remove or destroy water pollutants, but these systems become overloaded and ineffective when pollution levels are too high. Municipal sewage treatment is effective in removing organic material from wastewater, but the sewage sludge is often contaminated with metals and other toxic industrial materials. Reducing the sources of these materials is often the best solution to our pollution problems.

## QUESTIONS FOR REVIEW

1. Define water pollution.
2. List eight major categories of water pollutants and give an example for each category.
3. Describe eight major sources of water pollution in the United States. What pollution problems are associated with each source?
4. What is *Pseudomonas* and why is it dangerous?
5. What is eutrophication? What causes it?
6. What are the origins and effects of siltation?
7. Describe primary, secondary, and tertiary processes for sewage treatment. What is the quality of the effluent from each of these processes?
8. Why do combined storm and sanitary sewers cause water quality problems? Why does separating them also cause problems?
9. What pollutants are regulated by the Clean Water Act? What goals does this act set for abatement technology?
10. Describe remediation techniques and how they work.

## QUESTIONS FOR CRITICAL THINKING

1. How precise is the estimate that 2 billion people lack access to clean water? Would it make a difference if the estimate is off by 10 percent or 50 percent?

2. How would you define adequate sanitation? Think of some situations in which people might have different definitions for this term.
3. Do you think that water pollution is worse now than it was in the past? What considerations go into a judgement like this? How do your personal experiences influence your opinion?
4. What additional information would you need to make a judgement about whether conditions are getting better or worse? How would you weigh different sources, types, and effects of water pollution?
5. Imagine yourself in a developing country with a severe shortage of clean water. What would you most miss if your water supply were suddenly cut by 90 percent?
6. Why has the EPA changed to total maximum daily pollution loads and watershed management? What are the major implications of this change?
7. Proponents of deep well injection of hazardous wastes argue that it will probably never be economically feasible to pump water out of aquifers more than 1 kilometer below the surface. Therefore, they say, we might as well use those aquifers for hazardous waste storage. Do you agree? Why or why not?
8. Under what conditions might sediment in water or cultural eutrophication be beneficial? How should we balance positive and negative effects?
9. Suppose that part of the silt in a river is natural and part is human-caused. Is one pollution better than the other?

## what can you do?

### Tips for Staying Healthy

- Eat a balanced diet with plenty of fresh fruits, vegetables, legumes, and whole grains. Wash fruits and vegetables carefully. They may well have come from a country where pesticides and sanitation laws are lax.
- Use unsaturated oils such as olive or canola rather than hydrogenated or semisolid fats such as margarine.
- Cook meats and other foods at temperatures high enough to kill pathogens; clean utensils and cutting surfaces; store food properly.
- Wash your hands frequently. You transfer more germs from hand to mouth than any other means of transmission.
- When you have a cold or flu, don't demand antibiotics from your doctor—they aren't effective against viruses.
- If you're taking antibiotics, continue for the entire time prescribed—quitting as soon as you feel well is an ideal way to select for antibiotic-resistant germs.
- Practice safe sex.
- Don't smoke and avoid smoky places.
- If you drink, do so in moderation. Never drive when your reflexes or judgment are impaired.
- Exercise regularly: walk, swim, jog, dance, garden. Do something you enjoy that burns calories and maintains flexibility.
- Get enough sleep. Practice meditation, prayer, or some other form of stress reduction.
- Make a list of friends and family who make you feel more alive and happy. Spend time with one of them at least once a week.

react with specific cellular components to kill cells. Because of this specificity, they often are harmful even in dilute concentrations. For instance, is a protein found in castor beans and one of the most toxic organic compounds known. Three hundred picograms (trillionths of a gram) injected intravenously is enough to kill an average mouse. A lethal dose of dioxin, which often are claimed to be the most toxic substances known. Table 9.3 shows some of the most toxic elements of greatest concern to the EPA.

Allergens are substances that activate the immune system. Some allergens act directly as antigens; that is, they are recognized as foreign by white blood cells and stimulate the production of specific antibodies. Other allergens act indirectly by binding to other materials and changing their structure or chemistry so they become antigenic and cause an immune response.

Formaldehyde is a good example of a toxic chemical that is a powerful sensitizer. It is both directly and indirectly allergenic. Some people who are exposed to formaldehyde in plastics,

TABLE 9.3 Toxic Chemicals in the United States Causing the Greatest Risk to Human Health

Benzene	Methyl ethyl ketone
Cadmium	Methyl isobutyl ketone
Carbon tetrachloride	Nickel
Chloroform	Tetrachloroethylene
Chromium	Toluene
Cyanides	Trichloroethane
Dichloromethane	Trichloroethylene
Lead	Xylene(s)
Mercury	

Source: Data from Environmental Protection Agency.

wood products, insulation, glue, fabrics, and a variety of other products become hypersensitive not only to formaldehyde itself but also to many other materials in their environment, sometimes called the "sick building" syndrome. These individuals may have to go to great lengths to protect themselves from these allergenic substances.

Immune system depressants are pollutants that seem to suppress the immune system rather than activate it. Little is known about how this occurs or which chemicals are responsible. Immune system failure is thought to have played a role, however, in widespread deaths of seals in the North Atlantic and of dolphins in the Mediterranean. These dead animals generally contain high levels of pesticide residues, polychlorinated biphenyls (PCBs), and other contaminants, that may disrupt normal endocrine hormone function (see What Do You Think, chapter 12) and make them susceptible to a variety of opportunistic infections. Similarly, some humans with "sick house" syndrome or other environmental illnesses seem to have defective immune responses. Demonstrating a clear cause-and-effect relationship in these cases usually is difficult, however.

Neurotoxins are a special class of metabolic poisons that specifically attack nerve cells (neurons). The nervous system is so important in regulating body activities that disruption of its activity is especially fast-acting and devastating. Different types of neurotoxins act in different ways. Heavy metals such as lead and mercury kill nerve cells and cause permanent neurological damage. Anesthetics (ether, chloroform, halothane, etc.) and chlorinated hydrocarbons (DDT, Dieldrin, Aldrin) disrupt nerve cell membranes and carbamates (carbamyl, zeneb, maneb) inhibit acetylcholinesterase, an enzyme that regulates signal transmission between nerve cells and the tissues or organs they innervate (for example, muscle). Most neurotoxins are both extremely toxic and fast-acting.

Mutagens are agents, such as chemicals and radiation, that damage or alter genetic material (DNA) in cells. This can lead to birth defects if the damage occurs during embryonic or fetal growth. Later in life, genetic damage may trigger neoplastic (tumor) growth.

## PART TWO Population, Economics, Policy, and Health

At the end of each chapter, a **Summary** and a set of **Questions for Review** provide an opportunity for students to test their understanding of the material just covered, while **Questions for Critical Thinking** are designed to stimulate creative, analytical thinking and to serve as a springboard for class discussions. **Additional Information on the Internet** lists important chapter topics for which there are hyperlinks, available on the accompanying website, to help students with study and research.

10. Suppose that you own a lake but it is very polluted. An engineer offers options for various levels of cleanup. As you increase water quality, you also increase costs greatly. How clean would you want the water to be—fishable, swimmable, drinkable—and how much would you be willing to pay to achieve your goal? Make up your own numbers. The point is to examine your priorities and values.

## KEY TERMS

- atmospheric deposition 448
- best available, economically achievable technology (BAT) 469
- best practicable control technology (BPT) 469
- biochemical oxygen demand (BOD) 450
- coliform bacteria 449
- cultural eutrophication 450
- dissolved oxygen (DO) content 450
- effluent sewerage 467
- eutrophic 450
- nonpoint sources 448
- oligotrophic 450
- oxygen sag 450
- point sources 448
- red tide 451
- secondary treatment 467
- tertiary treatment 467
- thermal pulse 455
- total maximum daily loads (TMDL) 456

## ADDITIONAL INFORMATION ON THE INTERNET

Visit our website at <http://www.mhhe.com/environmentalcience/> for specific information about each of the topics below:

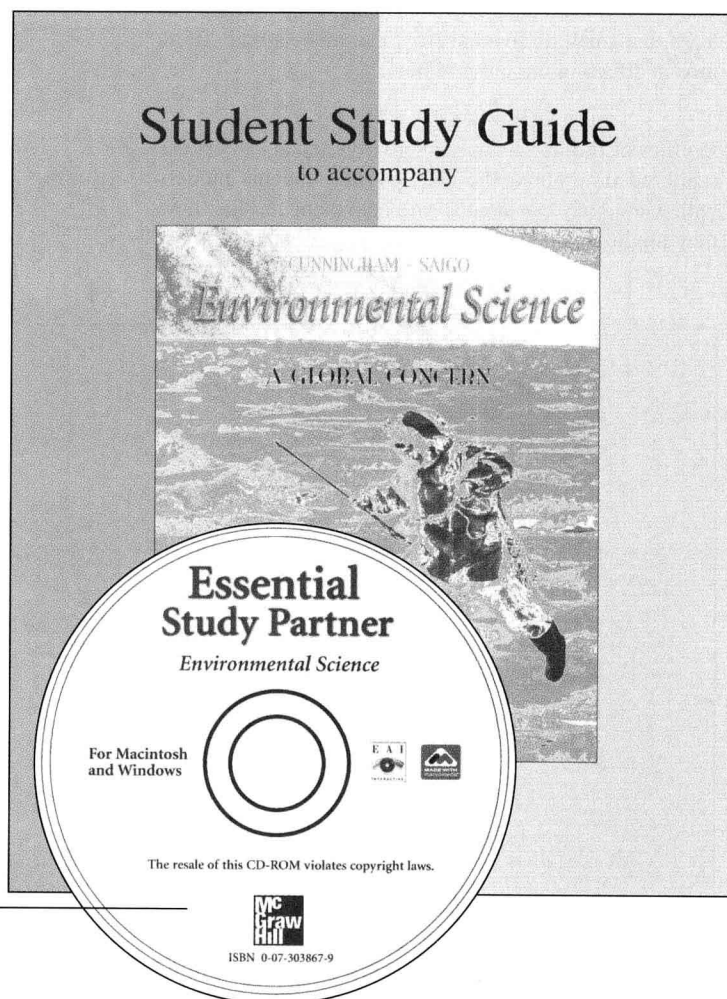
- Hogwatch: Water Pollution and Industrial Farming
- Plesteria, the Deadly Dinoflagellate
- Office of Water, Environmental Protection Agency
- Campaigns to Clean Up European rivers
- International Rivers Network: linking human rights and environmental protection.
- The EPA Office of Wetlands, Oceans, and Watersheds
- "Red Tides" and Harmful Algal Blooms (Woods Hole Oceanographic Institute)
- NOAA Office of Response and Restoration: oil spill remediation
- Coral Reef Bleaching
- Water Quality in the U.S. by State
- EPA Drinking Water Quality Standards
- Ground Water Quality
- Water and Waste International



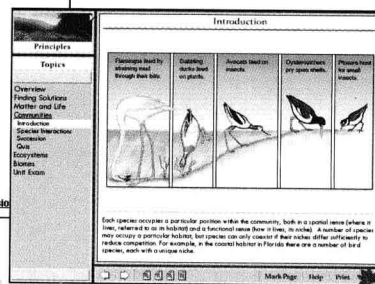
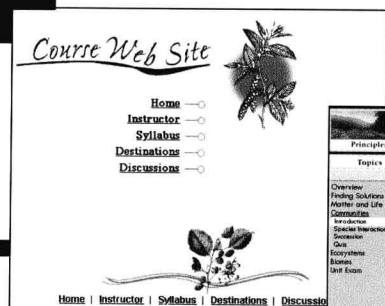
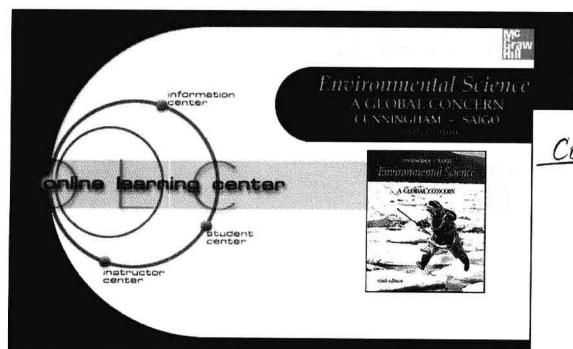
# SUPPLEMENTS

1. **Class Activities and Assessment Guide (CAAG).** Proper assessment is critical to your grading system, and this brand new (free) ancillary for instructors reflects the most recent studies of assessment and ways that students learn. Available in print, or on the website, key components of this invaluable text include:
  - a “Resource Locator” that pulls together appropriate material from numerous sources to help instructors get the most out of every chapter
  - a variety of classroom activities, all cross-referenced in the Resource Locator and complete with assessment guides
  - guidelines for constructing a good test
  - Bloom’s taxonomy for identifying levels of questions
  - objective test questions with answers
  - short answer/essay questions with assessment guides
2. **Computerized Testing Software** offers the objective test questions that are in the CAAG in electronic format for ease in class testing and grading.
3. A set of **100 Transparencies** is available to users of the text. These acetates include key figures from the text, including new art from this edition.
4. **Environmental Science and Ecology Visual Resource Library (VRL) CD-ROM.** This classroom presentation CD includes images from an ecology text and two environmental science textbooks, plus hundreds of photographs.
5. The **Student Study Guide** is completely reworked for this edition, linked to the ESP and to the Online Learning Center, and includes activities based on both of these resources. The student study guide is available in print and on the website.

The **Essential Study Partner (ESP)** CD-ROM is a student tutorial CD containing high-quality 3-D animations, interactive study activities, illustrated overviews of key topics in environmental science, and self-quizzes and exams for each important unit.



A comprehensive **Website** (<http://www.mhhe.com/environmentalscience/>) offers numerous resources for both students and instructors in the form of our Online Learning Center. Features include chapter-related hyperlinks, interactive lecture notes, answers to critical thinking questions, study questions, case studies, practice quizzing, key term flashcards, PageOut—our web page design tool, animations, current global environmental issues, and much more.



# The Online Learning Center

Your Password to Success

[www.mhhe.com/environmentalscience](http://www.mhhe.com/environmentalscience) (click on cover)

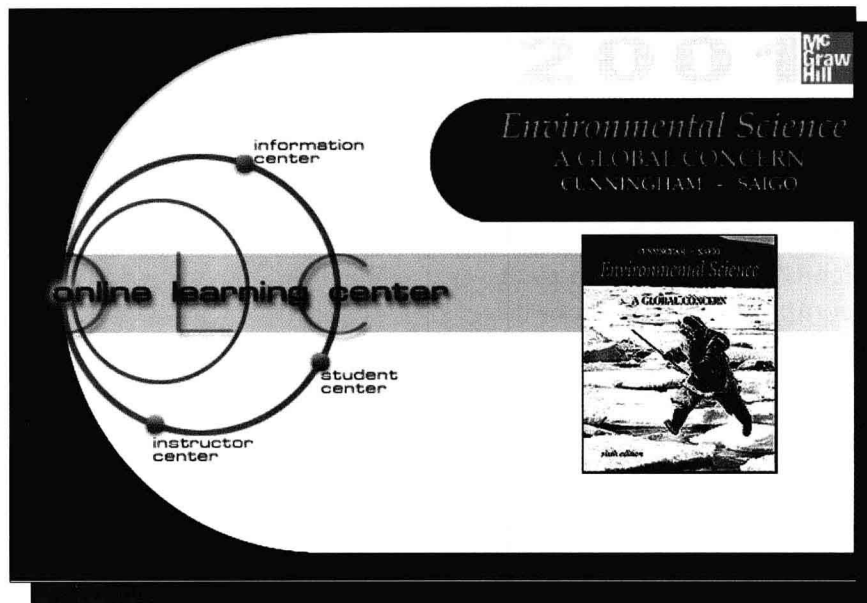
This text-specific website allows students and instructors from all over the world to communicate. Instructors can create a more interactive course with the integration of this site, and students will find tools such as practice quizzing, key term flashcards, case studies, global environmental issues, and chapter-related hyperlinks, that will help them improve their grades.

## Student Resources

- Study questions
- Practice quizzing
- Hyperlinks to chapter topics
- Case studies
- Global environmental issues
- Key term flashcards

## Instructor Resources

- Class activities and assignment guide
- Links to related websites to expand on particular topics
- Interactive lecture outlines
- Case studies
- Test item file
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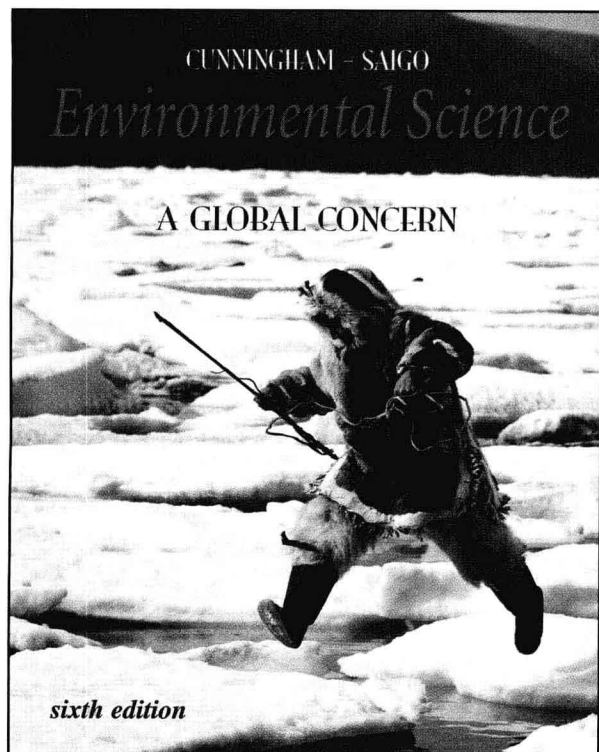
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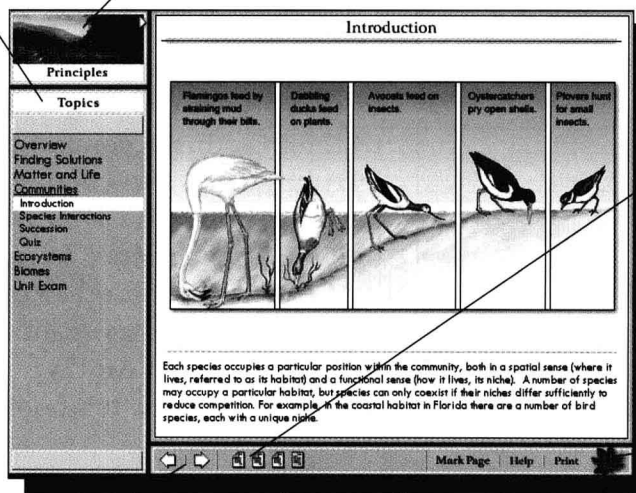


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The topic menu contains an interactive list of the available topics. Clicking on any of the listings within this menu will open your selection and will show the specific concepts presented within this topic. Clicking any of the concepts will move you to your selection. You can use the UP and DOWN arrow keys to move through the topics.

The unit pop-up menu is accessible at any time within the program. Clicking on the current unit will bring up a menu of other units available in the program.



To the right of the arrows is a row of icons that represent the number of screens in a concept. There are three different icons, each representing different functions that a screen in that section will serve. The screen that is currently displayed will highlight yellow and visited ones will be checked.

The activity icon represents an interactive learning activity.

Along the bottom of the screen you will find various navigational aids. At the left are arrows that allow you to page forward and backward through text screens or interactive exercise screens. You can also use the LEFT and RIGHT arrows on your keyboard to perform the same function.

The page icon represents a page of informational text.

The film icon represents an animation screen.

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