HOWARD FRUMKIN

EDITOR

ENVIRONMENTAL HEALTH

FROM GLOBAL TO LOCAL

THIRD EDITION

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Environmental Health

Environmental Health

From Global to Local

Third Edition

Howard Frumkin, Editor

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Published by Jossey-Bass
A Wiley Brand
One Montgomery Street, Suite 1000, San Francisco, CA 94104-4594—www.josseybass.com

Library of Congress Cataloging-in-Publication Data

Environmental health (Frumkin)
Environmental health : from global to local / [edited by] Howard Frumkin. — Third edition.
p. ; cm.
Includes bibliographical references and index.
ISBN 978-1-118-98476-5 (paperback), ISBN 978-1-118-98807-7 (pdf), ISBN 978-1-118-98806-0 (epub)
I. Frumkin, Howard, editor. II. Title.
[DNLM: 1. Environmental Health. 2. Environmental Exposure—prevention & control. 3. Environmental Medicine–methods. WA 30.5]
RA565
616.9'8—dc23

2015036497

Cover design by Wiley
Cover image: © Top Image: ©Cultura/Mischa Keijser/Getty; Bottom Image: ©Auffret Cline/EyeEm/

Printed in the United States of America
THIRD EDITION

PB Printing 10 9 8 7 6 5 4 3 2 1

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Dedication

I dedicate this book to my wife, Joanne, and to my children, Gabe and Amara.

Joanne—lover of truth, of science, and of narrative, who walks the talk, who is incapable of pretense or malice, and whose love is an incalculable gift.

Gabe and Amara—dedicated environmentalists, great lovers of the outdoors, hard-headed idealists, change agents, and two of the most wonderful people I know. They will make giant contributions to a safer, healthier, more sustainable, and more just world.

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An instructor's supplement is available at www.wiley.com/go/frumkin3e. Additional materials such as videos, podcasts, and readings can be found at www.josseybasspublichealth.com. Comments about this book are invited and can be sent to publichealth@wiley.com.

The Editor

Howard Frumkin has been dean, and professor of environmental and occupational health sciences, at the University of Washington School of Public Health since 2010. From 2005 to 2010, he held leadership roles at the U.S. Centers for Disease Control and Prevention, first as director of the National Center for Environmental Health and Agency for Toxic Substances and Disease Registry (NCEH/ATSDR), and later as special assistant to the CDC director for climate change and health. From 1990 to 2005, he was professor and chair of environmental and occupational health at Emory University's Rollins School of Public Health and professor of medicine at the Emory School of Medicine.

Dr. Frumkin trained in internal medicine, epidemiology, and occupational and environmental medicine. His research interests include public health aspects of the built environment, climate change, energy policy, and nature contact; toxic effects of chemicals; and environmental health policy. He is the author or coauthor of over 200 scientific journal articles and chapters, and his books, in addition to this one, include *Urban Sprawl and Public Health* (Island Press, 2004, coauthored with Lawrence Frank and Richard Jackson), *Emerging Illness and Society* (Johns Hopkins University Press, 2004, co-edited with Randall Packard, Peter Brown, and Ruth Berkelman), *Safe and Healthy School Environments* (Oxford University Press, 2006, co-edited with Robert Geller, Leslie Rubin, and Janice Nodvin), *Green Healthcare Institutions: Health, Environment, Economics* (National Academies Press, 2007, co-edited with Christine Coussens), and *Making Healthy Places: Designing and Building for Health, Well-Being, and Sustainability* (Island Press, 2011, co-edited with Andrew Dannenberg and Richard Jackson).

Dr. Frumkin has worked with many organizations active at the interface of human health and the environment. He has served on the boards of the Bullitt Foundation, the Children & Nature Network, the Seattle Parks Foundation, the Pacific Northwest Diabetes Research Institute, the U.S. Green Building Council, the Washington Global Health Alliance, Physicians for Social Responsibility, the Association of Occupational and Environmental Clinics, the American Public Health Association, and the National Environmental Education Foundation. He has served on the Executive Committee of the Regional Open Space Strategy for Central Puget Sound, on Procter & Gamble's Sustainability Expert Advisory Panel, on the National Toxicology Program Board of Scientific Counselors, on the National Research Council Committee on Sustainability Linkages in the Federal Government, on the Washington Department of Ecology Toxics Reduction Strategy Group, and on Seattle's Green Ribbon Commission. He has served on advisory boards for the Yale Climate and Energy Institute, the Wellcome Trust Sustaining Health initiative, the National Sustainable Communities Coalition, and the Center for Design and Health at the University of Virginia School of Architecture. As a member of the EPA's Children's Health Protection Advisory Committee, he chaired the Smart Growth and Climate Change work groups. A graduate of the Institute for Georgia Environmental Leadership, he was named 2004 Environmental Professional of the Year by the Georgia Environmental Council.

Dr. Frumkin was born in Poughkeepsie, New York. He received his AB degree from Brown University, his MD degree from the University of Pennsylvania, his MPH and DrPH degrees from Harvard University, his internal medicine training at the Hospital of the University of Pennsylvania and Cambridge Hospital, and his environmental and occupational medicine training at Harvard. He is board certified in internal medicine and in environmental and occupational medicine, and is a Fellow of the American College of Physicians, the American College of Occupational and Environmental Medicine, Collegium Ramazzini, and the Royal College of Physicians of Ireland. He is an avid cyclist, paddler, and hiker. He is married to radio journalist Joanne Silberner, and has two children—Gabe, a political campaign worker, and Amara, a health worker.

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Acknowledgments

In many religions and cultures teachers are revered. I honor that tradition, as well I should: I have been blessed with more superb teachers than I had any right to expect when I first marched off to school. They didn't know it, but they were all preparing me to envision this book and pull it together. One of the sweetest privileges of an editor—and there have been many—is the chance to thank them.

I express my deep and lasting gratitude to my high school teacher Barbara Leventer, who taught me that writing a research paper means specifying a hypothesis, organizing an outline, finding the right sources, and writing clearly (yes, that was all possible before the Internet!); my college teachers the late Ed Beiser, who taught me that there is no excuse for muddled thinking and unclear expression, and Steve Lyons and the late Hunter Dupree, who taught me the majesty and endless relevance of history; my medical school teachers Paul Stolley, who taught me the power of epidemiological data and who set a standard for principled advocacy, and the late John Eisenberg, who modeled a formidable combination of clinical excellence, astute policy analysis, and great kindness; my residency chief Bob Lawrence, who taught me that primary care extends from the bedside to the global commons; and my graduate school teachers Richard Monson, the late John Peters, and David Wegman, who taught me the interface of public health and the environment. Dick Jackson has been a mentor, thought partner, and friend since he arrived at the CDC 20 years ago.

I thank Dean Jim Curran and my colleagues and students at Emory University's Rollins School of Public Health, where I had the great good fortune to serve as a faculty member from 1990 to 2005, and where I edited the first edition of this textbook. I also thank my colleagues at the U.S. Centers for Disease Control and Prevention, where I directed the National Center for Environmental Health (NCEH) and the Agency for Toxic Substances and Disease Registry (ATSDR) from 2005 to 2010, and where I edited the second edition. And I thank my colleagues at the University of Washington School of Public Health, where I have served as dean since 2010. Two great universities and a great government agency have offered a wonderful career path, marked by intellectual stimulation, hard-working, dedicated colleagues, and dear friends. I thank my colleagues at other agencies, such as the Environmental Protection Agency and the National Institute of Environmental Health Sciences, and at organizations ranging from environmental and community groups to law firms to manufacturing companies, who have taught me more than I can say about the many facets of environmental health. Over the years I have especially appreciated my friends and colleagues at Physicians for Social Responsibility; the Institute of Medicine Roundtable on Environmental Health, Research, and Medicine; Atlanta's Clean Air Campaign; the EPA's Children's Health Protection Advisory Committee; the Association of Occupational and Environmental Clinics; the American Public Health Association; Sustainable Atlanta; the Children & Nature Network; the Bullitt Foundation; the Washington Global Health Alliance; the U.S. Green Building Council; the American Institute of Architects; and the Seattle Parks Foundation. Special gratitude to the members of my Green Reading Groups, first in Atlanta, and later in Seattle—perfect blends, both, of close friendship, intellectual curiosity, and environmental learning.

Thank you to Karla Armenti, Kathlyn Barry, Darrell Norman Burrell, William Daniel, J. Aaron Hipp, Peter LaPuma, Susan West Marmagas, Camille Martina, Mary Kay O'Rourke, Anne Riederer, Lauren Savaglio, and Alfredo Vergara, who provided valuable feedback on the previous edition of this book, which helped greatly in designing changes for this edition.

I thank the chapter authors of this book, all of them highly expert and exceedingly busy people. They willingly shared their expertise and time (and gracefully tolerated my prodding and editing) to help compile the kind of book that we would all want to use in our own teaching. I am especially pleased that the authors include several graduate students and trainees, whose skill and energy bode well for the future of our field. I thank my editors at Jossey-Bass. The late Andy Pasternack, who edited the first two editions, was a friend, supporter, and mentor; his premature loss leaves a hole in the universe. Seth Schwartz ably succeeded Andy, bringing the same belief in this project, generous tolerance of delays, and discipline. Melinda Noack and Justin Frahm rounded out an all-star team at Jossey-Bass. And I thank copyeditor Elspeth MacHattie, a consummate professional, a pleasure to work with, and an enormous asset to this book.

I thank the staff who supported the preparation of the first and second editions of this book: Hope Jackson, Robin Thompson, Adrienne Tison, Erica Weaver, Rachel Wilson, and Suzanne Mason at Emory, and Cheryl Everhart at NCEH/ATSDR. And special thanks to JeShawna Schmidt, who supported me at the University of Washington in preparing this third edition, with her extraordinary combination of organizational skills, work ethic, grace, dedication, kindness, and optimism.

I had an unforgettable opportunity while preparing the third edition: a two-week academic residency at Villa Serbelloni, the Rockefeller Foundation's center in Bellagio, Italy. This sojourn exemplified the power of a physical setting—the indescribable beauty of Lake Como and of the facility itself—to inspire good work and to promote well-being. More importantly, it also exemplified the magic that occurs when people from diverse backgrounds and disciplines come together. My fellow residents hailed from South Africa, Kenya, India, and across the United States, and were working on housing, transportation, NGO governance, urban resiliency, literature, visual art, and dance—but all, in a real sense, were working on social change, dedicated to making the world a better place. I made lifelong friends, I learned from each of them, and they are all reflected in this book. I thank the Rockefeller Foundation for the privilege.

Finally, I acknowledge my beloved wife, best friend, and trusted consultant, Joanne Silberner, who silently, eloquently raised her eyebrows when I told her I had committed to another edition of this book, then supported me unstintingly throughout. Without her, nothing.

Potential Conflicts of Interest in *Environmental Health: From Global to Local*

In recent years, increasing attention has been focused on integrity in scientific publishing. Much of this concern has grown out of pharmaceutical research; in that arena, conflicts of interest are widespread (Friedman & Richter, 2004) and consequential; funding sources have been shown to predict research findings (Kjaergard & Als-Nielsen, 2002; Lexchin, Bero, Djulbegovic, & Clark, 2003; Smith, 2005; Lundh, Sismondo, Lexchin, Busuioc, & Bero, 2012). But pharmaceutical research is not the only vulnerable area; in environmental health, private interests may also collide with public good, so conflicts of interest must be recognized as a real concern in this field too (Michaels & Monforton, 2005; Sutton, Woodruff, Vogel, & Bero, 2011). In 2015, disclosures about an allegedly conflicted climate change researcher on the front page of the *New York Times*—nobody's ideal venue for such matters—reinforced this fact (Gillis, 2015; Gillis & Schwartz, 2015).

Conflicts of interest have been defined as "conditions in which professional judgment concerning a primary interest (such as a patient's welfare or the validity of research) tends to be unduly influenced by a secondary interest (such as financial gain)" (Thompson, 1993). Conflicts of interest, real or perceived, can derail the quest for truth, have a corrosive effect on scientific data (Bekelman, Li, & Gross, 2003; Rennie, 2010), and undermine public faith in science (Friedman, 2002; Kennedy, 2004; Lo & Field, 2009).

Importantly, the bias resulting from conflicts of interest may be subconscious, reflecting neither malfeasance nor even intent. Bias is a normal part of human cognition, and people are often unaware of their biases (Cain & Detsky, 2008; Young, 2009).

Conflicts of interest may be financial or nonfinancial. The financial variety is intuitively clear; as former *JAMA* editor Drummond Rennie wrote, "numerous studies have confirmed what we all know: money talks" (Rennie, 2010). The nonfinancial variety is not always as clear. These conflicts may be personal, political, religious, ideological, or careerist (Levinsky, 2002). The editors of *PLoS Medicine* described two examples (The PLoS Medicine Editors, 2008): the peer reviewer who disapproves of a particular research method for religious reasons, and who obstructs the publication of research using that method; and the editor who remains close to her former advisor, and who tilts toward accepting the advisor's paper.

Those who publish or report on science have increasingly tackled the challenge of conflicts of interest (Maurissen et al., 2005; Lo & Field, 2009). Transparency is a leading solution, recalling Justice Louis Brandeis's adage that "sunshine is the best disinfectant"—even if it is not always sufficient (Bero, Glantz, & Hong, 2005; Resnik & Elliott, 2013). The Committee on Publication Ethics (COPE, 2011), a forum for peer-reviewed journal editors and publishers, in its Code of Conduct, requires that "[r]eaders should be informed about who has funded research or other scholarly work and whether the funders had any role in the research and its publication and, if so, what this was." Similarly, the International Committee of Medical Journal Editors (ICMJE, 2014) expects authors to disclose both

"financial relationships with entities in the bio-medical arena that could be perceived to influence, or that give the appearance of potentially influencing," and "other [nonfinancial] relationships or activities that readers could perceive to have influenced, or that give the appearance of potentially influencing" an author's work. Accordingly, most medical journals now require disclosures of potential conflicts of interest when publishing papers. Such disclosures serve a purpose; they inform readers' views of what they read (Chaudhry, Shroter, Smith, & Morris, 2002; Kesselheim et al., 2012).

Disclosure has moved beyond the publication of research findings in journals. Many (but not enough) reports of scientific results in the popular media now mention funding sources (Cook, Boyd, Grossman, & Bero, 2007). Many universities require faculty to report potential conflicts of interest (Boyd & Bero, 2000). Disclosure is especially important in review papers (Michaels, 2009; Viswanathan et al., 2014). "Because analysis, interpretation, and synthesis, often of conflicting data, are important aspects of these papers," wrote one journal editor, "they are particularly susceptible to suspicions of bias, subconscious or otherwise" (DeMaria, 2004). The same, of course, is true for textbook chapters. But it is rare for textbooks to disclose potential conflicts of interest. This omission is curious given the wide readership of textbooks, the tendency of textbook chapters to present broad conclusions, and the fact that student readers, at an early stage of their training, may be more impressionable than discerning.

This third edition of *Environmental Health: From Global to Local*, continuing a practice begun in the second edition, has addressed this concern by asking each chapter author to report both real and perceived conflicts of interest. Following guidelines from a Natural Resources Defense Council workshop (Sass, 2009) and from the ICMJE (2014), each author was asked to disclose relationships occurring during the last three years, currently active, or reasonably anticipated to occur in the foreseeable future "with companies that make or sell products or services discussed in the chapter, companies that make or sell related products or services, and other pertinent entities with an interest in the topic, specifying the type of relationship." These relationships were defined as including (but not limited to)

- Grant support
- Employment (past, present, or firm offer of future)
- Stock ownership or options
- Payment for serving as an expert witness or giving testimony
- Personal financial interests on the part of the author, immediate family members, or institutional affiliations that might gain or lose financially through publication of the chapter
- Other forms of compensation, including travel funding, consultancies, honoraria, board positions, and patent or royalty arrangements
- Employment by a for-profit, nonprofit, foundation, or advocacy group

If it is important for authors to offer these disclosures to readers, it is even more important for the editor—who selects and curates all material in the book—to do so. During the three years prior to starting work on this book, and while doing the editing, in addition to my work as dean at the University of Washington School of Public Health, I held the following positions:

- Board member of the U.S. Green Building Council, which promotes green, healthy buildings (uncompensated)
- Board member of the Bullitt Foundation, a regional environmental grantmaker in the Pacific Northwest (uncompensated)

- Board member of the Seattle Parks Foundation, which promotes parks and park access in Seattle (uncompensated)
- Member of the American Institute of Architects Design & Health Leadership Group, which promotes healthy building design (uncompensated)
- Member of the American Association for the Advancement of Science Climate Science Panel, which provides public information on climate science (uncompensated)
- Member of the Yale Climate and Energy Institute External Advisory Board (uncompensated)
- Member of the Procter & Gamble Sustainability Expert Advisory Panel (honorarium paid to University of Washington)
- Member of several editorial boards, all uncompensated (*American Journal of Industrial Medicine*, *Salud Pública de México*, *Environmental Health Perspectives*, *American Journal of Preventive Medicine*, *ECOHEALTH*, *Annual Review of Public Health*, and *Ecopsychology*)

Each author's employment is shown in the author identification section, and disclosures of potential conflicts of interest appear at the bottom of the first text page of his or her chapter. I am not aware of another major textbook that has implemented such a policy. I hope this helps to ensure the integrity of every chapter in this book and becomes more common in scientific textbooks in coming years.

Howard Frumkin
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Environmental Health

Part 1

Methods and Paradigms

Chapter 1

Introduction to Environmental Health

Howard Frumkin

Key Concepts

Environmental health is the field of public health that addresses physical, chemical, biological, social, and psychosocial factors in the environment. It aims both to control and prevent environmental hazards and to promote health and well-being through environmental strategies.

People have always been concerned with environmental health, but the nature of their concerns has evolved with the transition from prehistoric, to agricultural, to industrial, to postindustrial life.

Many disciplines contribute to environmental health: epidemiology and toxicology, psychology and communications, urban planning and food science, law and ethics, and more.

Environmental health utilizes the geographic concept of spatial scales, from the global (with issues such as climate change), to the regional (air quality), to the local (neighborhood design), to the hyperlocal (ergonomics).

Environmental health thinking takes a systems approach, embracing complexity, and focusing on "upstream" factors as well as on "downstream" health impacts.

Please stop reading.

That's right. Close this book, just for a moment. Lift your eyes and look around. Where are you? What do you see?

Perhaps you're in the campus library, surrounded by shelves of books, with carpeting underfoot and the heating or air-conditioning humming quietly in the background. Perhaps you're home—a dormitory room, a bedroom in a house, a suite in a garden apartment, maybe your kitchen. Perhaps you're outside, lying beneath a tree in the middle of campus, or perhaps you're on a subway or a bus or even an airplane. What is it like? How does it feel to be where you are?

Dr. Frumkin's disclosures appear in the front of this book, in the section titled "Potential Conflicts of Interest in *Environmental Health: From Global to Local*."

Is the light adequate for reading? Is the temperature comfortable? Is there fresh air to breathe? Are there contaminants in the air—say, solvents off-gassing from newly laid carpet or a recently painted wall? Does the chair fit your body comfortably?

If you're inside, look outside. What do you see through the window? Are there trees? Buildings? Is the neighborhood noisy or tranquil? Are there other people? Are there busy streets, with passing trucks and busses snorting occasional clouds of diesel exhaust?

Now imagine that you can see even farther, to a restaurant down the block, to the nearby river, to the highway network around your city or town, to the factories and assembly plants in industrial parks, to the power plant in the distance supplying electricity to the room you're in, to the agricultural lands and forests some miles away. What would you see in the restaurant? Is the kitchen clean? Is the food stored safely? Are there cockroaches or rats in the back room? What about the river? Is your municipal sewage system dumping raw wastes into the river, or is there a sewage plant discharging treated, clean effluent? Are there chemicals in the river water? What about fish? Could you eat the fish? Could you swim in the river? Do you drink the water from the river?

As for the highways, factories, and power plant . . . are they polluting the air? Are the highways clogged with traffic? Are people routinely injured and killed on the roads? Are workers in the factories being exposed to hazardous chemicals or to noise or to machines that may injure them or to stress? Are trains pulling up to the power plant regularly, off-loading vast piles of coal? And what about the farms? Are they applying pesticides, or are they controlling insects in other ways? Are you confident that you're safe eating the vegetables that grow there? Drinking the milk? Are the farmlands shrinking as residential development from the city sprawls outward?

Finally, imagine that you have an even broader view. Floating miles above the Earth, you look down. Do you notice the hundreds of millions of people living in wildly differing circumstances? Do you see vast megacities with millions and millions of people, and do you see isolated rural villages three days' walk from the nearest road? Do you see forests being cleared in some places, rivers and lakes drying up in others? Do you notice that the Earth's surface temperature is slightly warmer than it was a century ago? Do you see cyclones forming in tropical regions, glaciers and icecaps melting near the poles?

OK, back to the book.

Everything you've just viewed, from the room you're in to the globe you're on, is part of your environment. And many, many aspects of that environment, from the air you breathe to the water you drink, from the roads you travel to the wastes you produce, may affect how you feel. They may determine your risk of being injured before today ends, your risk of coming down with diarrhea or shortness of breath or a sore back, your risk of developing a chronic disease in the next few decades, even the risk that your children or your grandchildren will suffer from developmental disabilities or asthma or cancer.

WHAT IS ENVIRONMENTAL HEALTH?

Merriam-Webster's Collegiate Dictionary first defines **environment** straightforwardly as "the circumstances, objects, or conditions by which one is surrounded." The second definition it offers is more intriguing: "the complex of physical, chemical, and biotic factors (as climate, soil, and living things) that act upon an organism or an ecological community and ultimately determine its form and survival." If our focus is on human health, we can consider the environment to be all the external (or nongenetic) factors—physical, nutritional, social, behavioral, and others—that act on humans.

A widely accepted definition of **health** comes from the 1948 constitution of the World Health Organization: "A state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity." This broad definition reaches well beyond blood pressure readings and X-ray results to include many dimensions of our lives: well-being, comfort, even happiness.

Environmental health has been defined in many ways (see Text Box 1.1). Some definitions evoke the relationship between people and the environment—a systems-based, ecological approach—while others focus more narrowly on addressing particular environmental conditions. Some focus on controlling hazards, while others focus on promoting health-enhancing environments. Some focus on physical and chemical hazards, while others extend more broadly to aspects of the social and built environments. In the aggregate the definitions in Text Box 1.1 make it clear that environmental health is many things: an interdisciplinary academic field, an area of research, and an arena of applied public health practice.

Text Box 1.1 Definitions of Environmental Health

"Environmental health comprises those aspects of human health, including quality of life, that are determined by physical, chemical, biological, social and psychosocial factors in the environment. It also refers to the theory and practice of assessing, correcting, controlling, and preventing those factors in the environment that can potentially affect adversely the health of present and future generations." (World Health Organization)

"Environmental health is the branch of public health that protects against the effects of environmental hazards that can adversely affect health or the ecological balances essential to human health and environmental quality." (Agency for Toxic Substances and Disease Registry)

"Environmental health includes both the direct pathological effects of chemicals, radiation and some biological agents, and the effects (often indirect) on health and well-being of the broad physical, psychological, social and aesthetic environment, which includes housing, urban development, land use, and transport." (European Charter on Environment and Health)

"Environmental health focuses on the health interrelationships between people and their environment, promotes human health and well-being, and fosters a safe and healthful environment." (National Association of City and County Health Officials)

Source: U.S. Department of Health and Human Services, 1998.

THE EVOLUTION OF ENVIRONMENTAL HEALTH

Human concern for environmental health dates from ancient times, and it has evolved and expanded over the centuries.

Ancient Origins

The notion that the environment could have an impact on comfort and well-being—the core idea of environmental health—must have been evident in the early days of human existence. The elements can be harsh, and we know that our ancestors sought respite in caves or under trees or in crude shelters they built. The elements can still be harsh, both on a daily basis and during extraordinary events; think of

the Indian Ocean earthquake and tsunami of 2004, Hurricanes Katrina and Rita in 2005 and Sandy in 2012, the Sichuan earthquake of 2008, the Nepal earthquake of 2015, and the ongoing droughts in Australia and California.

Our ancestors confronted other challenges that we would now identify with environmental health. One was food safety; there must have been procedures for preserving food, and people must have fallen ill and died from eating spoiled food. Dietary restrictions in ancient Jewish and Islamic law, such as bans on eating pork, presumably evolved from the recognition that certain foods could cause disease. Another challenge was clean water; we can assume that early peoples learned not to defecate near or otherwise soil their water sources. In the ruins of ancient civilizations from India to Rome, from Greece to Egypt to South America, archeologists have found the remains of water pipes, toilets, and sewage lines, some dating back more than 4,000 years (Rosen, 1958/1993). Still another environmental hazard was polluted air; there is evidence in the sinus cavities of ancient cave dwellers of high levels of smoke in their caves (Brimblecombe, 1988), foreshadowing modern indoor air concerns in homes that burn biomass fuels or coal.

An intriguing passage in the biblical book of Leviticus (14:33–45) may refer to an environmental health problem well recognized today: mold in buildings. When a house has a "leprous disease" (as the Revised Standard Version translates this passage),

> . . . then he who owns the house shall come and tell the priest, "There seems to me to be some sort of disease in my house." Then the priest shall command that they empty the house before the priest goes to examine the disease, lest all that is in the house be declared unclean; and afterward the priest shall go in to see the house. And he shall examine the disease; and if the disease is in the walls of the house with greenish or reddish spots, and if it appears to be deeper than the surface, then the priest shall go out of the house to the door of the house, and shut up the house seven days. And the priest shall come again on the seventh day, and look; and if the disease has spread in the walls of the house, then the priest shall command that they take out the stones in which is the disease and throw them into an unclean place outside the city; and he shall cause the inside of the house to be scraped round about, and the plaster that they scrape off they shall pour into an unclean place outside the city; then they shall take other stones and put them in the place of those stones, and he shall take other plaster and plaster the house. If the disease breaks out again in the house, after he has taken out the stones and scraped the house and plastered it, then the priest shall go and look; and if the disease has spread in the house, it is a malignant leprosy in the house; it is unclean. And he shall break down the house, its stones and timber and all the plaster of the house; and he shall carry them forth out of the city to an unclean place.

Can we conclude that mold grew within warm, damp ancient dwellings? And what was that "unclean place outside the city"—an early hazardous waste site? Who hauled the wastes there, and did that work undermine their health?

Still another ancient environmental health challenge, especially in cities, was rodents. European history was changed forever when infestations of rats in fourteenth-century cities led to the Black Death (Zinsser, 1935; Herlihy and Cohn, 1997; Cantor, 2001; Kelly, 2005). Modern cities continue to struggle periodically with infestations of rats and other pests (Sullivan, 2004), whose control depends in large part on environmental modifications.

Industrial Awakenings

Modern environmental health further took form during the age of industrialization. With the rapid growth of cities in the seventeenth and eighteenth centuries, **sanitarian** issues rose in importance. "The urban environment," wrote one public health historian, "fostered the spread of diseases with crowded, dark, unventilated housing; unpaved streets mired in horse manure and littered with refuse; inadequate or nonexisting water supplies; privy vaults unemptied from one year to the next; stagnant pools of water; ill-functioning open sewers; stench beyond the twentieth-century imagination; and noises from clacking horse hooves, wooden wagon wheels, street railways, and unmuffled industrial machinery" (Leavitt, 1982, p. 22).

The provision of clean water became an ever more pressing need, as greater concentrations of people increased both the probability of water contamination and the impact of disease outbreaks. Regular outbreaks of cholera and yellow fever in the eighteenth and nineteenth centuries (Rosenberg, 1962) highlighted the need for water systems, including clean source water, treatment including filtration, and distribution through pipes. Similarly, sewage management became a pressing need, especially after the provision of piped water and the use of toilets created large volumes of contaminated liquid waste (Duffy, 1990; Melosi, 2000; also see Chapter 16 and Text Box 4.2 in Chapter 4).

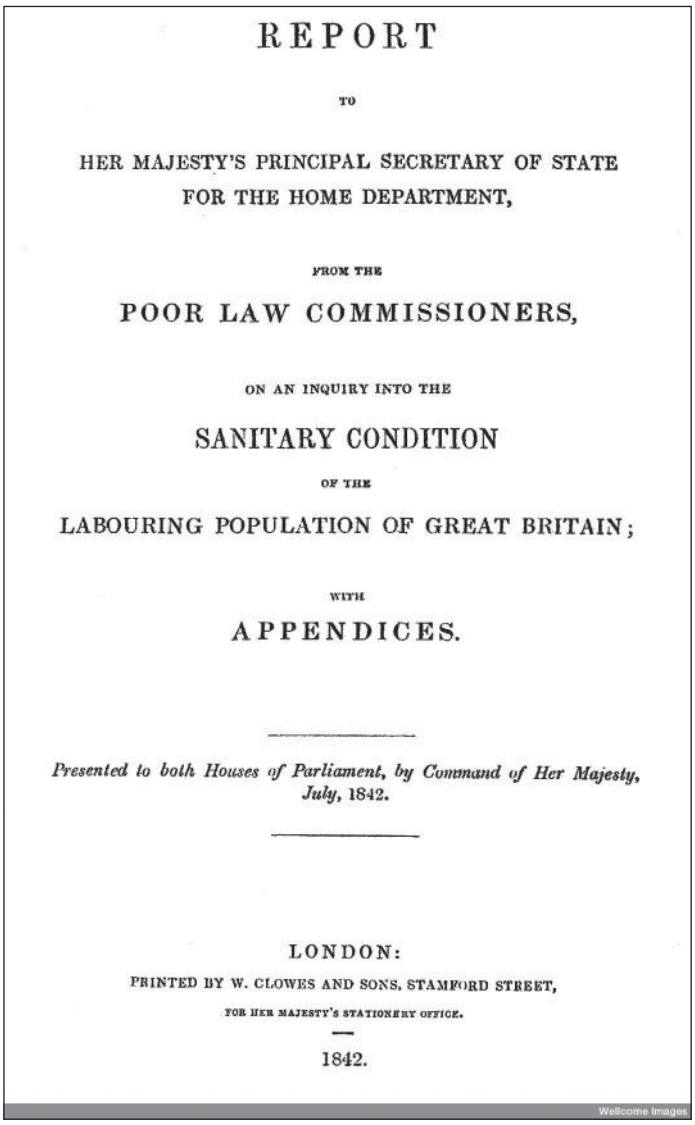
The industrial workplace—a place of danger and even horror—gave additional impetus to early environmental health efforts. Technology advanced rapidly during the late eighteenth and nineteenth centuries, new and often dangerous machines were deployed in industry after industry, and mass production became common. In communities near industrial facilities, the air, water, and soil could become badly contaminated in ways that would be familiar to modern environmental professionals (Tarr, 1996, 2002), but the most abominable conditions were usually found within the mines, mills, and factories themselves. Workers became the proverbial canaries in the coal mines.

Charles Turner Thackrah (1795–1833), a Yorkshire physician, became interested in the diseases he observed among the poor in the city of Leeds. In 1831, he catalogued many work-related hazards in a short book with a long title: *The Effects of the Principal Arts, Trades and Professions, and of Civic States and Habits of Living, on Health and Longevity, with Suggestions for the Removal of Many of the Agents which Produce Disease and Shorten the Duration of Life*. In it he proposed guidelines for preventing certain diseases, such as eliminating lead as a glaze in the pottery industry and using ventilation and respiratory protection to protect knife grinders. Public outcry and the efforts of early Victorian reformers such as Thackrah led to passage, in the U.K., of the Factory Act in 1833 and the Mines Act in 1842. Occupational health did not blossom in the United States until the early twentieth century, pioneered by the remarkable Alice Hamilton (1869–1970). A keen firsthand observer of industrial conditions, with a powerful social conscience, she documented links between toxic exposures and illness among miners, tradesmen, and factory workers, first in Illinois (where she directed that state's Occupational Disease Commission from 1910 to 1919) and later from an academic perch at Harvard (as that university's first female professor). Her books, including, in 1925, *Industrial Poisons in the United States* and, in 1934, *Industrial Toxicology*, helped to establish that workplaces could be dangerous environments for workers.

A key development in the seventeenth through nineteenth centuries was the quantitative observation of population health—the beginnings of epidemiology. With the tools of epidemiology, observers could systematically attribute certain diseases to particular environmental exposures (as explored in Chapter 4). John Graunt (1620–1674), an English merchant and haberdasher, realized that London's weekly death records—the "bills of mortality"—were a treasure trove of information. He analyzed them, and published his findings in 1662 as *Natural and Political Observations Upon the Bills of Mortality*.

Graunt's work was a pioneering example of demography. Almost two centuries later, when the British Parliament created the Registrar-General's Office (now the Office of Population Censuses and Surveys) and William Farr (1807–1883) became its compiler of abstracts, the link between vital statistics and environmental health was forged. Farr made observations about fertility and mortality patterns, identifying rural-urban differences, variations between acute and chronic illnesses, and seasonal trends, and implicating certain environmental conditions in illness and death. Farr's 1843 analysis of mortality in Liverpool led the British Parliament to pass the Liverpool Sanitary Act of 1846, which created a sanitary code for Liverpool and a public health infrastructure to enforce it.

FIGURE 1.1 Title Page of Chadwick's Groundbreaking 1842 Report



REPORT

TO

HER MAJESTY'S PRINCIPAL SECRETARY OF STATE
FOR THE HOME DEPARTMENT,

FROM THE

POOR LAW COMMISSIONERS,

ON AN INQUIRY INTO THE

SANITARY CONDITION

OF THE

LABOURING POPULATION OF GREAT BRITAIN;

WITH

APPENDICES.

Presented to both Houses of Parliament, by Command of Her Majesty, July, 1842.

LONDON:
PRINTED BY W. CLOWES AND SONS, STAMFORD STREET,
FOR HER MAJESTY'S STATIONERY OFFICE.
1842.

Wellcome Images

Source: Wellcome Trust, Wellcome Images.

If Farr was a pioneer in applying demography to public health, his contemporary Edwin Chadwick (1800–1890) was a pioneer in combining social epidemiology with environmental health. At the age of 32, Chadwick was appointed to the newly formed Royal Commission of Enquiry on the Poor Laws, and helped reform Britain's Poor Laws. Five years later, following epidemics of typhoid fever and influenza, he was asked by the British government to investigate sanitation. His classic 1842 report, *Sanitary Conditions of the Labouring Population* (Figure 1.1), drew a clear link between living conditions—in particular overcrowded, filthy homes, open cesspools and privies, impure water, and miasmas—and health, and made a strong case for public health reform. The resulting Public Health Act of 1848 created the Central Board of Health, with power to empanel local boards that would oversee street cleaning, trash collection, and water and sewer systems. As sanitation commissioner, Chadwick advocated such innovations as urban water systems, toilets in every house, and transfer of sewage to outlying farms where it could be used as fertilizer (Hamlin, 1998). Chadwick's work helped establish the role of public works—essentially sanitary engineering—in protecting public health.

These achievements are profoundly important to public health. As eloquently pointed out by Thomas McKeown (1979) more than a century later, environmental health interventions were to do far more than medical care to improve public health and well-being during the industrial era. A recent economic analysis (Cutler & Miller, 2005) notes that from 1900 to 1940, infant mortality rates fell by 62%, total mortality fell by 40%, and life expectancy rose from 47 to 63 years—and that clean water alone accounted for three

quarters of the decline in infant mortality, and over 40% of the decline in total mortality. Another analysis (Lee, 2007) attributes much of the decline in infant mortality during the same era to pasteurization of milk. These victories are well worth remembering at a time when some public health actions, including those in environmental health, are tinged with ideological controversy (see Text Box 1.2).

The physician John Snow (1813–1858) was, like William Farr, a founding member of the London Epidemiological Society. Snow gained immortality in the history of public health for what was essentially an environmental epidemiology study. During an 1854 outbreak of cholera in London, he documented a far higher incidence of disease among people who lived near or drank from the Broad Street pump than among people with other sources of water. He persuaded local authorities to remove the pump handle, and the epidemic in that part of the city soon abated. (There is some evidence that it may have been ending anyway, but this does not diminish the soundness of Snow's approach.) Environmental epidemiology was to blossom during the twentieth century (see Chapter 4), supplemented by the development of geospatial information late in the century (see Chapter 5), and was to provide some of the most important evidence needed to support effective preventive measures.

Finally, the industrial era led to a powerful reaction in the worlds of literature, art, and design. In the first half of the nineteenth century, Romantic painters, poets, and philosophers celebrated the divine and inspiring forms of nature. In Germany painters such as Caspar David Friedrich (1774–1840) created meticulous images of the trees, hills, misty valleys, and mercurial light of northern Germany, based on a close observation of nature, and in England Samuel Palmer (1805–1881) painted landscapes that combined straightforward representation of nature with religious vision. His countryman John Constable (1776–1837) worked in the open air, painting deeply evocative English landscapes. In the United States, Hudson River School painters, such as Thomas Cole (1801–1848), took their inspiration from the soaring peaks and crags, stately waterfalls, and primeval forests of the northeast. At the same time, the New England transcendentalists celebrated the wonders of nature. "Nature never wears a mean appearance," wrote Ralph Waldo Emerson (1803–1882) in his 1836 paean, *Nature*. "Neither does the wisest man extort her secret, and lose his curiosity by finding out all her perfection. Nature never became a toy to a wise spirit. The flowers, the animals, the mountains, reflected the wisdom of his best hour, as much as they had delighted the simplicity of his childhood." Henry David Thoreau (1817–1862), like Emerson a native of Concord, Massachusetts, rambled from Maine to Cape Cod and famously lived in a small cabin at Walden Pond for two years, experiences that cemented his belief in the "tonic of wildness." And America's greatest landscape architect, Frederick Law Olmsted (1822–1903), championed bringing nature into cities. He designed parks that offered pastoral vistas and graceful tree-lined streets and paths, intending to offer tranquility to harried people and to promote feelings of community. These and other strands of cultural life reflected yet another sense of environmental health, arising in response to industrialization: the idea that pristine environments were wholesome, healthful, and restorative to the human spirit. This dimension is explored in Chapter 25.

Text Box 1.2 Environmental Health: Common Good or Nanny State?

Political scientists, economists, and other scholars have long noted the tension between **individualism** and **collectivism**. Individualists emphasize personal independence, autonomy, and liberty, while collectivists emphasize the value of group norms and action—not only in promoting the **common good** but also in achieving social justice and in providing social support and identity. In recent years political discourse in the

(Continued)

(Continued)

United States (dating from the presidency of Ronald Reagan), Great Britain (dating from Margaret Thatcher's time as prime minister), and other countries, has tilted toward individualism, signaling a mistrust of collective action and especially of government action. President Reagan famously declared, in his first inaugural speech, "Government is not the solution to our problem; government is the problem."

In environmental health, as in many fields of public health, collective action is essential—so much so that public health has been defined as "collective action for sustained population-wide health improvement" (Beaglehole, Bonita, Horton, Adams, & McKee, 2004). Zoning for healthy neighborhoods, fuel efficiency and air quality regulations for clean air, and food inspections and standards for wholesome food are examples of concerted government action that protects public health. Critics regard some such government actions as paternalistic and restrictive of individual liberty. They warn of the **nanny state** (Calman, 2009; Wiley, Berman, & Blanke, 2013).

There are strong moral and practical arguments for collective action in environmental health, not least the fact that preventing disease and promoting health often require action well beyond the scope of personal behavior (Minkler, 1999; Chokshi & Stine, 2013). Individuals cannot on their own achieve clean air, clean water, safe roads, walkable neighborhoods, or reduced carbon emissions. A rich legal tradition in the United States supports the role of government in promoting public health; examples include *Jacobson* v. *Massachusetts* (1905), in which the U.S. Supreme Court upheld a city's right to compel smallpox vaccination (Parmet, Goodman, & Farber, 2005), and *Euclid* v. *Ambler* (1926), in which the Supreme Court upheld a local zoning ordinance, based in part on protecting public health (Schilling & Linton, 2005). More generally, environmental health efforts are embedded in the larger concept of the common good—a concept with a lengthy history and a compelling contemporary role (Etzioni, 2004, 2015). Balancing the common good with individual rights remains a fascinating challenge in public health and public policy.

The Modern Era

The modern field of environmental health dates from the mid-twentieth century, and no landmark better marks its launch than the 1962 publication of Rachel Carson's *Silent Spring*. *Silent Spring* focused on DDT, an organochlorine pesticide that had seen increasingly wide use since World War II. Carson had become alarmed at the ecosystem effects of DDT; she described how it entered the food chain and accumulated in the fatty tissues of animals, how it indiscriminately killed both target species and other creatures, and how its effects persisted for long periods after it was applied. She also made the link to human health, describing how DDT might increase the risk of cancer and birth defects (see Text Box 6.4 in Chapter 6). One of Carson's lasting contributions was to place human health in the context of larger environmental processes. "Man's attitude toward nature," she declared in 1963, "is today critically important simply because we have now acquired a fateful power to alter and destroy nature. But man is a part of nature, and his war against nature is inevitably a war against himself . . . . [We are] challenged as mankind has never been challenged before to prove our maturity and our mastery, not of nature, but of ourselves" (*New York Times*, 1964).

The recognition of chemical hazards was perhaps the most direct legacy of *Silent Spring*. Beginning in the 1960s, Irving Selikoff (1915–1992) and his colleagues at the Mount Sinai School of Medicine intensively studied insulators and other worker populations and showed that asbestos could cause asbestosis (a fibrosing lung disease), lung cancer, mesothelioma, and other cancers. Outbreaks of cancer in industrial workplaces—lung cancer in a chemical plant near Philadelphia due to bis-chloromethyl ether (Figueroa, Raszkowski, & Weiss, 1973; Randall, 1977), hemangiosarcoma of the liver in a vinyl chloride polymerization plant in Louisville (Creech & Johnson, 1974), and others—underlined the risk

of carcinogenic chemicals. With the enormous expansion of cancer research, and with effective advocacy by such groups as the American Cancer Society (Patterson, 1987), environmental and occupational carcinogens became a focus of public, scientific, and regulatory attention.

But cancer was not the only health effect linked to chemical exposures. Herbert Needleman (1927–), studying children in Boston, Philadelphia, and Pittsburgh, showed that lead was toxic to the developing nervous system, causing cognitive and behavioral deficits at levels far lower than had been appreciated. When this recognition finally helped to achieve the removal of lead from gasoline, population blood lead levels plummeted, an enduring public health victory—and one that may even have helped reduce crime levels twenty years later (Nevin, 2007). Research also suggested that chemical exposures could threaten reproductive function. Wildlife observations such as abnormal genitalia in alligators in Lake Apopka, Florida, following a pesticide spill (Guillette et al., 1994) and human observations such as an apparent decrease in sperm counts (Swan, Elkin, & Fenster,1997) suggested that certain persistent, bioaccumulative chemicals (persistent organic pollutants, or POPs) could affect reproduction, perhaps by interfering with hormonal function. Emerging evidence showed that chemicals could damage the kidneys, liver, and cardiovascular system and immune function and organ development.

Some knowledge of chemical toxicity arose from toxicological research (see Chapter 6) and other insights resulted from epidemiological research (see Chapter 4). But catastrophes—reported first in newspaper headlines and only later in scientific journals—also galvanized public and scientific attention. The discovery of accumulations of hazardous wastes in communities across the nation—Love Canal in Niagara Falls, New York (Gibbs, 1998); Times Beach, Missouri, famous for its unprecedented dioxin levels; Toms River, New Jersey (Fagin, 2013); Woburn, Massachusetts (Harr, 1996), where municipal drinking water was contaminated with organic chemicals; "Mount Dioxin," a defunct wood treatment plant in Pensacola, Florida; Anniston, Alabama, where residents (especially black residents) were exposed to intolerable levels of PCBs (Spears, 2014); and many others—raised concerns about many health problems, from learning disabilities to immune dysfunction to cancer to birth defects. Mercury contamination of Minamata Bay, Japan, and the resulting burden of neurological illness riveted world attention, spurred by the heart-wrenching photographs of Eugene Smith (Smith & Smith, 1975) (Figure 1.2). And acute disasters, such as the isocyanate release that killed hundreds and sickened thousands in Bhopal, India, in 1984, made it clear that industrialization posed real threats of chemical toxicity (Dhara & Dhara, 2002; Lapierre & Moro, 2002).

FIGURE 1.2 A Victim of Minamata Disease Being Bathed: Photograph by W. Eugene Smith

In tandem with the growing awareness of chemical hazards, environmental health during the second half of the twentieth century was developing along another promising line: *environmental psychology*. As described in Chapter 9, this field arose as a subspecialty of psychology, building on advances in perceptual and cognitive psychology. Scholars such as Stephen Kaplan and Rachel Kaplan at the

University of Michigan carried out careful studies of human perceptions and of reactions to various environments. An important contribution to environmental psychology was the theory of biophilia, first advanced by Harvard biologist E. O. Wilson in 1984. Wilson defined **biophilia** as "the innately emotional affiliation of human beings to other living organisms." He pointed out that for most of human existence, people have lived in natural settings, interacting daily with plants, trees, and other animals. As a result, Wilson maintained, affiliation with these organisms has become an innate part of human nature (Wilson, 1984). Other scholars extended Wilson's concept beyond living organisms, postulating a connection with other features of the natural environment—rivers, lakes, and ocean shores; waterfalls; panoramic landscapes and mountain vistas (Kellert & Wilson, 1993; see Chapter 25). Environmental psychologists studied not only natural features of human environments but also such factors as light, noise, and way-finding cues to assess the impact of these factors. They increasingly recognized that people responded to various environments, both natural and built, in predictable ways. Some environments were alienating, disorientating, or even sickening, whereas others were attractive, restorative, and even salubrious.

A third development in modern environmental health was the continued integration of ecology with human health, giving rise to a field called *ecohealth*. Ancient wisdom in many cultures had recognized the relationships between the natural world and human health and well-being. But with the emergence of formal complex systems analysis and modern ecological science, the understanding of ecosystem function advanced greatly (see Chapter 2). As part of this advance the role of humans in the context of ecosystems was better and better delineated. On a global scale, for example, the concept of *carrying capacity* (Wackernagel & Rees, 1995) helped clarify the impact of human activity on ecosystems and permitted evaluation of the ways ecosystem changes, in turn, affected human health and well-being (Aron & Patz, 2001; McMichael, 2001; Alcamo et al., 2003; Waltner-Toews, 2004; Brown, Grootjans, Ritchie, & Townsend, 2005; Rayner & Lang, 2012). Ecological analysis was also applied to specific areas relevant to human health. For example, there were advances in medical botany (Lewis & Elvin-Lewis, 2003; van Wyk & Wink, 2004), in the understanding of biodiversity and its value to human health (Chivian & Bernstein, 2008), and in the application of ecology to clinical medicine (Aguirre, Ostfeld, Tabor, House, & Pearl, 2002; Ausubel, 2004). These developments, together, reflected a progressive synthesis of ecological and human health science, yielding a better understanding of the foundations of environmental health.

A fourth feature of modern environmental health was the expansion of health care services related to environmental exposures. Occupational medicine and nursing had been specialties in their respective professions since the early twentieth century, with a traditional focus on returning injured and ill workers to work and, to some extent, on preventing hazardous workplace exposures. In the last few decades of the twentieth century, these professional specialties incorporated a public health paradigm, drawing on toxicological and epidemiological data, using industrial hygiene and other primary prevention approaches, and engaging in worker education (see Chapter 21). In addition, the occupational health clinical paradigm was broadened to include general environmental exposures. Clinicians began focusing on such community exposures as air pollutants, radon, asbestos, and hazardous wastes, emphasizing the importance of taking an environmental history, identifying at-risk groups, and providing both treatment and preventive advice to patients. Professional ethics expanded to recognize the interests of patients (both workers and community members) as well as those of employers, and in some cases even the interests of unborn generations and of other species (see Chapter 10). Finally, a wide range of alternative and complementary approaches—some well outside the mainstream—arose in occupational and environmental health care. For example, an approach known as clinical ecology postulated that

overloads of environmental exposures could impair immune function, and offered treatments including "detoxification," antifungal medications, and dietary changes purported to prevent or ameliorate the effects of environmental exposures (Rea, 1992–1998).

Environmental health policy also emerged rapidly. With the promulgation of environmental laws beginning in the 1960s, federal and state officials created agencies and assigned them new regulatory responsibilities. These agencies issued rules that aimed to reduce emissions from smokestacks, drainpipes, and tailpipes; control hazardous wastes; and achieve clean air and water. Although many of these laws were oriented to environmental preservation, the protection of human health was often an explicit rationale as well. (Indeed, the mission of the U.S. Environmental Protection Agency, or EPA, is "to protect human health and the environment.") Ironically, the new environmental regulations created a schism in the environmental health field. Responsibility for environmental health regulation had traditionally rested with health departments, but this was now transferred to newly created environmental agencies. At the federal level, the EPA assumed some of the traditional responsibilities of the Department of Health, Education, and Welfare (now Health and Human Services), and corresponding changes occurred at the state level. Environmental regulation and health protection became somewhat uncoupled from each other.

Environmental regulatory agencies increasingly attempted to ground their rules in evidence, using quantitative risk assessment techniques (see Chapter 27). This signaled a sea change in regulatory policy. The traditional approach had been simpler; dangerous exposures were simply banned. For example, the 1958 Delaney clause, an amendment to the 1938 Federal Food, Drug, and Cosmetic Act, banned carcinogens in food. In contrast, emerging regulations tended to set permissible exposure levels that took into account anticipated health burdens, compliance costs, and technological feasibility. Moreover, regulations tended to assign the burden of proof of toxicity to government regulators. As the scientific and practical difficulties of this approach became clear in the late twentieth century, an alternative approach emerged: assigning manufacturers the burden of proving the safety of a chemical. Based philosophically in the **precautionary principle** (see Chapter 26), this approach was legislated in Europe as part of the European Union's REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) initiative, which entered into force in 2007 (European Commission, 2009). It has not, for the most part, been implemented in U.S. toxics law (see Chapter 6).

In the twenty-first century, then, while traditional sanitarian functions remain essential, the environmental health field has expanded well beyond its origins. Awareness of chemical toxicity has advanced rapidly, fueled by discoveries in toxicology and epidemiology. At the same time, the complex relationships inherent in environmental health—the effects of environmental conditions on human psychology, and the links between human health and ecosystem function—are better and better recognized. In practical terms, clinical services in environmental health have developed, and regulation has advanced through a combination of political action and scientific evidence.

Emerging Issues

Environmental health is a dynamic, evolving field. Looking ahead, we can identify at least five trends that will further shape environmental health: environmental justice, a focus on susceptible groups, scientific advances, global change, and moves toward sustainability.

Beginning around 1980, African American communities identified exposures to hazardous waste and industrial emissions as matters of racial and economic justice. Researchers documented that these exposures disproportionately affected poor and minority communities, a problem that was aggravated by

disparities in the enforcement of environmental regulations. The modern **environmental justice** movement was born, a fusion of environmentalism, public health, and the civil rights movement (Bullard, 1994; Cole & Foster, 2000; see also Chapter 11). Historians have observed that environmental justice represents a profound shift in the history of environmentalism (Gottlieb, 1993; Shabecoff, 1993; Dowie, 1995). This history is commonly divided into waves. The first wave was the conservation movement of the early twentieth century, the second wave was the militant activism that blossomed in 1970 on the first Earth Day, and the third wave was the emergence of large, "inside-the-beltway" environmental organizations such as the Environmental Defense Fund, the League of Conservation Voters, and the Natural Resources Defense Council, which had gained considerable policy influence by the 1980s. Environmental justice, then, represents a fourth wave, one that is distinguished by its decentralized, grassroots leadership, its demographic diversity, and its emphasis on human rights and distributive justice. The vision of environmental justice—eliminating disparities in economic opportunity, environmental exposures, and health—is one that resonates with public health priorities. It emphasizes that environmental health extends well beyond the control of hazardous exposures to include human rights and equity as well. This vision will be an increasingly central part of environmental health in coming decades.

Environmental justice is one example of a broader trend in environmental health—a *focus on susceptible groups*. For many reasons, specific groups may be especially vulnerable to the adverse health effects of environmental exposures. In the case of poor and minority populations, these reasons include disproportionate exposures, limited access to legal protection, limited access to health care, and in some cases compromised baseline health status. Children make up another susceptible population, for several reasons; they eat more food, drink more water, and breathe more air per unit of body weight than adults do and are therefore more heavily exposed to any contaminants in these media (Landrigan & Etzel, 2014). Children's behavior—crawling on floors, placing their hands in their mouths, and so on—further increases their risk of exposure. With developing organ systems and immature biological defenses, children are less able than adults to withstand some exposures. And with more years of life ahead of them, children have more time to manifest delayed toxic reactions. These facts have formed the basis for research and public health action on children's environmental health.

Women bear some specific environmental exposure risks, both in the workplace and in the general environment, due both to disproportionate exposures (e.g., in health care jobs) and to unique susceptibilities (e.g., to reproductive hazards). Elderly people also bear some specific risks, and as the population ages, this group will attract further environmental health attention. For example, urban environments will need to take into account the limited mobility of some elderly people and provide ample sidewalks, safe street crossings, and accessible gathering places to serve this population. People with disabilities, too, require specific environmental health attention to minimize the risks they face. In coming decades environmental health will increasingly take account of susceptible groups as the risks they face and their needs for safe, healthy environments become better recognized.

A third set of emerging issues in environmental health grows out of *scientific advances*. In toxicology better detection techniques have already enabled us to recognize and quantify low levels of chemical exposure and have supported major advances in the understanding of chemical effects (see Chapter 6). Innovative toxicological approaches, including physiologically based pharmacokinetic modeling (PBPK) and high-throughput computational techniques, offer rapid insights into chemical toxicity. Advances in data collection and analysis techniques have supported innovative epidemiological analyses. In particular the use of geographic information systems (GISs) has yielded new insights on the spatial distribution of environmental exposures and diseases (see Chapter 5). The use of large databases—the "big data" revolution—has also enabled highly innovative analyses. Perhaps

the most promising scientific advances are occurring at the molecular level, in the linked fields of genomics, toxicogenomics, epigenetics, and proteomics (see Chapter 7). New genomic tools such as microarrays (or gene chips) have enabled scientists to characterize the effects of chemical exposures on the expression of thousands of genes. Databases of genetic responses, and the resulting protein and metabolic pathways, will yield much information on the effects of chemicals and on the variability in responses among different people. Big data are also increasingly available from other data sources—smartphones that track travel patterns, social media, online searches, customer loyalty cards, charge card purchases, wearable devices that track activity and health parameters, and more. While these sources raise profound privacy concerns, **reality mining** can provide unprecedented insights into exposures, preferences, behaviors, and health outcomes across populations (Pentland, Lazer, Brewer, & Heibeck, 2009; Eagle & Greene, 2014). Scientific advances related to environmental health—from molecular biology to information science—will have profound effects on the field in coming decades.

Moving from the molecular scale to the global scale, a fourth set of emerging environmental health issues relates to *global change*. This broad term encompasses many trends, including population growth, climate change, urbanization, changing patterns of energy use, and the increasing integration of the world economy (Friedman, 2008). These trends will shape environmental health in many ways.

The global population now exceeds 7 billion and is expected to plateau at roughly 9 to 10 billion during the twenty-first century (see Chapter 3). Most of this population growth will occur in developing nations, and much of it will be in cities. Not only this population growth but also the increasing per capita demand for resources such as food, energy, and materials will strain the global environment (Heinberg, 2007; Brown, 2011), in turn affecting health in many ways. For example, environmental stress and resource scarcity may increasingly trigger armed conflict, an ominous example of the links between environment and health (Homer-Dixon, 1999; Klare, 2001). Global climate change, which results in large part from increasing energy use (see Chapter 14), will threaten health in many ways, from infectious disease risks to heat waves to severe weather events (see Chapter 12). As more of the world's population is concentrated in dense urban areas, features of the urban environment—noise, crowding, processed foods, vehicular and industrial pollution—will increasingly shape health (see also Chapter 15). And with integration of the global economy—through the complex changes known as globalization—hazards increasingly cross national boundaries, trade agreements and market forces challenge and possibly undermine national environmental and health policies (Gleeson & Friel, 2013; Walls, Smith, & Drahos, 2015), and global solutions to environmental health challenges will increasingly be needed (Labonté, Schrecker, Packer, & Runnels, 2009).

Sustainability has been a part of the environmental health vernacular since the 1980s. In 1983, the United Nations formed the World Commission on Environment and Development to propose strategies for sustainable development. The commission, chaired by then Norwegian prime minister Gro Harlem Brundtland, issued its landmark report, *Our Common Future*, in 1987. The report included what has become a standard definition of sustainable development: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." In 1992, several years after the publication of *Our Common Future*, the United Nations Conference on Environment and Development (UNCED), commonly known as the Earth Summit, convened in Rio de Janeiro. This historic conference produced, among other documents, the Rio Declaration on Environment and Development, a blueprint for sustainable development. The first principle of the Rio declaration placed environmental health at the core of sustainable development: "Human beings are at

the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature" (United Nations, 1992).

Like environmental justice the concept of sustainable development blends environmental protection with notions of fairness and equity. As explained on the Web site of the Johannesburg Summit, held ten years after the Earth Summit:

> The Earth Summit thus made history by bringing global attention to the understanding, new at the time, that the planet's environmental problems were intimately linked to economic conditions and problems of social justice. It showed that social, environmental and economic needs must be met in balance with each other for sustainable outcomes in the long term. It showed that if people are poor, and national economies are weak, the environment suffers; if the environment is abused and resources are over consumed, people suffer and economies decline. The conference also pointed out that the smallest local actions or decisions, good or bad, have potential worldwide repercussions [United Nations Department of Economic and Social Affairs, 2006].

The concept of sustainability has emerged as a central theme, and challenge, not only for environmentalism but for environmental health as well. In the short term, sustainable development will improve the living conditions and therefore the health of people across the world, especially in the poor nations. In the long term, sustainable development will protect the health and well-being of future generations. As described in Chapter 3, some of the most compelling thinking in environmental health in recent years offers social and technical paths to sustainable development (Hawken, Lovins, & Lovins, 1999; Brown, 2001; McDonough & Braungart, 2002; Brown et al., 2005; Institute of Medicine, 2013). These approaches build on the fundamental links among health, environment, technological change, and social justice. Ultimately, they will provide the foundation for lasting environmental health.

SPATIAL SCALES, FROM GLOBAL TO LOCAL

The concept of **spatial scale** is central to many disciplines, from geography to ecology to urban planning. Some phenomena unfold on a highly local scale—ants making a nest, people digging a septic tank. Some phenomena spread across regions—the pollution of a watershed from an upstream factory, the sprawl of a city over a 100-mile diameter. And some phenomena, such as climate change, are truly global in scale. Al Gore, in describing environmental destruction in his 1992 book, *Earth in the Balance*, borrowed military categories to make this point, distinguishing among "local skirmishes," "regional battles," and "strategic conflicts."

Spatial scale is important not only in military and environmental analysis but also in environmental health. Some environmental factors that affect health operate locally, and the environmental health professionals who address these factors work on a local level; think of the restaurant and septic tank inspectors who work for the local health department or the health and safety officer at a manufacturing facility. Other environmental factors affect health at a regional level, and the professionals who address these problems work on a larger spatial scale; think of the state officials responsible for enforcement of air pollution or water pollution regulations. Global problems such as climate change require responses on the national and international scales. These responses are crafted by professionals in organizations such as the World Health Organization and the Intergovernmental Panel on Climate Change. So useful is the concept of spatial scales in environmental health that it provides the framework for this book. After introducing the methods and paradigms of environmental health in the first eleven chapters, this

book addresses specific issues, beginning with global scale problems in Chapter 12, moving to regional scale problems in Chapters 13 to 16, and ending with local problems in Chapters 17 to 25. The final three chapters (Chapters 26 to 28) describe the practice of environmental health, focusing on such efforts as risk assessment and communication.

It is clear that environmental health professionals work on different spatial scales, but it is not always so clear who is an environmental health professional. Certainly, the environmental health director at a local health department; the director of environment, health, and safety at a manufacturing firm; an environmental epidemiology researcher at a university; or a physician working for an environmental advocacy group would self-identify and be recognized by others as an environmental health professional. But many other people work in fields that have an impact on the environment and human health. The engineer who designs power plants helps to protect the respiratory health of asthmatic children living downwind if she plans for effective emissions controls. The transportation planner who enables people to walk instead of drive also protects public health by helping to promote physical activity and clean up the air. The park superintendent who maintains urban green spaces may contribute greatly to the well-being of people in his city. In fact much of environmental health is determined by "upstream" forces that seem at first glance to have little to do with environment or health.

THE FORCES THAT DRIVE ENVIRONMENTAL HEALTH

Public health professionals tell the emblematic story of a small village perched alongside a fast-flowing river. The people of the village had always lived near the river, they knew and respected its currents, and they were skilled at swimming, boating, and water rescue. One day they heard desperate cries from the river and noticed a stranger being swept downstream past their village. They sprang into action, grabbed their ropes and gear, and pulled the victim from the water. A few minutes later, as they rested, a second victim appeared, thrashing in the strong current and gasping for breath. The villagers once again performed a rescue. Just as they were remarking on the coincidence of two near drownings in one day, a third victim appeared, and they also rescued him. This went on for hours. Every available villager joined in the effort, and by mid-afternoon all were exhausted. Finally, the flow of victims stopped, and the villagers collapsed, exhausted, along the waterfront.

Just at that moment another villager strode whistling into town, relaxed and dry. He had not been seen since the first victims were rescued and had not helped with any of the rescues. "Where were you?" his neighbors demanded of him. "We've been pulling people out of the river all day! Why didn't you help us?"

"Ah," he replied. "When I noticed all the people in the river, I thought there must be a problem upstream. I walked up to that old footbridge, and sure enough, some boards had broken and there was a big hole in the walkway. So I patched the hole, and people stopped falling through." (See Text Box 1.3.)

Text Box 1.3 A Prevention Poem: A Fence or an Ambulance

Like the story of the villagers who saved drowning victims, this poem emphasizes that prevention may lie with root causes. These root causes are often environmental, like the hole in the village's bridge or, in this case, an unguarded cliff edge (See Figure 1.3).

(Continued)