ENVIRONMENTAL HEALTH

From Global to Local

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INTRODUCTION

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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?

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 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 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 defines environment, first, in a straightforward manner as “the circumstances, objects, or conditions by which one is surrounded.” The second definition it offers is more intriguing: “the complex of physical,
Introduction

As some miles of food stored the river? Is it or is there a river? Does it have the river? Do you or someone else smell the air? Has and killed us chemicals as pulling up that about the other ways? Here? Drink from the city wells above the people living millions and walk from the and lakes dry and is slightly pical regions, globe you’re environment, travel to the your risk of the or shortse in the next ill suffer from nighttime surrounded.”

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 constitution, crafted in 1948, of the World Health Organization (2005): “A state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity.” This broad definition goes well beyond the rather mechanistic view that prevails in some medical settings to include many dimensions of comfort and well-being.

Environmental health has been defined in many ways (see Box I.1). Some definitions make reference to the relationship between people and the environment, evoking an ecosystem concept, and others focus more narrowly on addressing particular environmental conditions. Some focus on abating hazards, and others focus on promoting health-enhancing environments. Some focus on physical and chemical hazards, and others extend more broadly to aspects of the social and built environments. In the aggregate the definitions in Box I.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.

Box I.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 [WHO], 2004).

“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, cited in U.S. Department of Health and Human Services [DHHS], 1998).

“Environmental health comprises those aspects of human health and disease that are determined by factors in the environment. It also refers to the theory and practice of assessing and controlling factors in the environment that can potentially affect health. It 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 developmental land use
and transport” (European Charter on Environment and Health; see WHO, Regional Office for Europe, 1990).

“Environmental health is the discipline that focuses on the interrelationships between people and their environment, promotes human health and well-being, and fosters a safe and healthful environment” (National Center for Environmental Health, cited in DHHS, 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 shelter 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, as the tsunami of 2004 reminded us.

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). 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 it is translated in the Revised Standard Version),

... 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.”

As interesting as it is to speculate about whether ancient dwellings suffered mold overgrowth, it is also interesting to consider the “unclean place outside the city”—an early hazardous waste site. Who hauled the wastes there, and what did that work do to 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 historian, “fostered the spread of diseases with crowded, dark, unventilated housing; unpaved streets mired in horse manure and littered with refuse; inadequate or nonexistent 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).

The industrial workplace—a place of danger and even horror—gave additional impetus to early environmental health. 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. Although the air, water, and soil near industrial sites could become badly contaminated, in ways that would be familiar to modern environmental professionals (Hurley, 1994; Tarr, 1996; Tarr, 2002), the most abominable conditions were usually found within the mines, mills, and factories.

Charles Turner Thackrah (1795–1833), a Yorkshire physician, developed an interest in the diseases he observed among the poor in the city of Leeds. In 1831, he described 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 the prevention of certain diseases, such as the elimination of lead as a glaze in the pottery industry and the use of ventilation and respiratory protection to protect knife grinders. Public outcry, and the efforts of early Victorian reformers such as Thackrah, led to passage 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, she documented links between toxic exposures and illness among miners, tradesmen, and factory workers, first in Illinois (where she directed the state's Occupational Disease Commission from 1910 to 1919) and later from an academic position at Harvard. Her books, including *Industrial Poisons in the United States* (1925) and *Industrial Toxicology* (1934), helped establish that workplaces could be microenvironments that threatened worker health.

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 certain environmental exposures. John Graunt (1620–1674), an English merchant and haberdasher, analyzed London’s weekly death records—the *ills
Introduction

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of mortality—and published his findings in 1662 as Natural and Political Observations Upon the Bills of Mortality. Graunt’s work was one of the first formal analyses of this data source and 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 Parliament to pass the Liverpool Sanitary Act of 1846, which created a sanitary code for Liverpool and a public health infrastructure to enforce it.

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 thirty-two, 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 report, Sanitary Conditions of the Labouring Population (1842), 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 applications of sanitary engineering—to protecting public health. As eloquently pointed out by Thomas McKeown (1979) more than a century later, these interventions were to do far more than medical care to improve public health and well-being during the industrial era.

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 observed 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 Three) and 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,” forged in response to industrialization: the idea that pristine environments were wholesome, healthful, and restorative to the human spirit.

The Modern Era

The modern field of environmental health dates from the mid-twentieth century, and perhaps 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 the Second World War. 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. 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 1964, "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" (Carson, 1963 [2005]).

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 occupational groups and showed that asbestos could cause a fibrosing lung disease, lung cancer, mesothelioma, and other neoplasms. Outbreaks of cancer in industrial workplaces—lung cancer in a chemical plant near Philadelphia due to bischloromethyl ether (Figueroa, Raszkowski, and Weiss, 1973; Randall, 1977), hepatic hemangiosarcoma in a vinyl chloride polymerization plant in Louisville (Creech and 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 (Epstein, 1982).

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 achieve the removal of lead from gasoline, population blood lead levels plummeted, an enduring public health victory. 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 and others, 1994), and human observations such as an apparent decrease in sperm counts (Carlson, Giwercman, Keiding, and Skakkebaek, 1992; Swan, Elkin, and 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 Two) and other insights resulted from long-term epidemiological
research (see Chapter Three). 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; Mazur, 1998); Times Beach, Missouri, famous for its unprecedented dioxin levels; Toms River, New Jersey, and Woburn, Massachusetts, where municipal drinking water was contaminated with organic chemicals; “Mount Dioxin,” a defunct wood treatment plant in Pensacola, Florida; and others—raised concerns about many health problems, from nonspecific symptoms to immune dysfunction to cancer to birth defects. 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 (Kurzman, 1987; Dhara and Dhara, 2002; Moro and Lapierre, 2002).

Even as the awareness of chemical hazards grew, supported by advances in toxicology and epidemiology, environmental health during the second half of the twentieth century was developing in a different direction altogether: environmental psychology. As described in Chapter Five, 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. He 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 and Wilson, 1993; Kellert, 1997). 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. Ancient wisdom in many cultures had recognized the interrelationships 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 One). 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 and 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 (Rappaport and others, 1999; McMichael, 2001; Aron and Patz, 2001; Martens and McMichael, 2002; Alcamo and others, 2003; Waltner-Toews, 2004; Brown, Grootjans, Ritchie, and Townsend, 2005). Ecological analysis was also applied to specific areas relevant to human health. For example, there were advances in medical botany (Lewis and Elvin-Lewis, 2003; van Wyk and Wink, 2004), in the understanding of biodiversity and its value to human health (Grifo and Rosenthal, 1997), and in the application of ecology to clinical medicine (Aguirre and others, 2002; Ausubel with Harpignies, 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 clinical 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 Thirty-Five). 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 Seven). Finally, a wide range of alternative and complementary approaches 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 (Randolph, 1976, 1987; Rea, 1992–1998).
Environmental health policy also emerged rapidly. With the promulgation of environmental laws beginning in the 1960s, legislators at the federal and state levels created agencies and assigned them new regulatory responsibilities (see Chapter Thirty-Three). 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. Ironically, the new environmental regulations created a schism in the environmental health field. Responsibility for environmental health regulation had traditionally belonged to health departments, but this was now transferred to the new environmental departments. At the federal level, the U.S. Environmental Protection Agency (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 estranged from each other.

Environmental regulatory agencies increasingly attempted to ground their rules in evidence, using quantitative risk assessment techniques (see Chapter Thirty-Two). 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.

At the dawn of the twenty-first century, then, the environmental health field had moved well beyond its traditional sanitary functions. Awareness of chemical toxicity had 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—were better and better recognized. In practical terms, clinical services in environmental health had developed, and regulation had advanced through a combination of political action and scientific evidence.

**Emerging Issues**

Environmental health is a dynamic, evolving field. As the twenty-first century unfolds, traditional sanitary functions remain critically important, and chemical hazards will continue to be a focus of scientific and regulatory attention. 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 and Foster, 2000; see also Chapter Eight). Historians have observed that environmental justice represents a profound shift in the history of environmentalism (Shabecoff, 1993; Gottlieb, 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 on Earth Day, 1970, and the third wave was the emergence of large, “inside-the-beltway” environmental organizations such as the Sierra Club, 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 justice. The vision of environmental justice—eliminating disparities in economic opportunity, healthy environments, and health—is one that resonates with public health priorities. It emphasizes that environmental health extends well beyond technical solutions to hazardous exposures to include human rights and equity as well. It is likely that 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 (see Chapter Eight). Children make up another susceptible population, for several reasons (see Chapter Twenty-Eight). They eat more food, drink more water, and breathe more air per unit of body weight than adults do and are therefore heavily exposed to any contaminants in these media. 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 exposures risks, both in the workplace and in the general environment, due both to disproportionate exposures (for example, in health care jobs) and to unique susceptibilities (for example, 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 the 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 is being introduced by 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 Two). Advances in data analysis techniques have supported innovative epidemiological analyses and the use of large databases. In particular the use of geographic information systems (GISs) has yielded new insights on the spatial distribution of environmental exposures and diseases (see Chapter Thirty-One). Perhaps the most promising scientific advances are occurring at the molecular level, in the linked fields of genomics, toxicogenomics, and proteomics (Schmidt, 2003; Mattes and others, 2004; Pesch and others, 2004; Pognan, 2004; Waters and Fostel, 2004; see also Chapter Six). 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. Scientific advances related to environmental health will have profound effects on the field in coming decades.

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

The world population is currently just over six billion and is expected to plateau at something like nine billion during the twenty-first century (see Chapter Ten). 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, 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; see also
Chapter Twelve). Global climate change, which results in large part from increasing energy use (see Chapter Fifteen), will threaten health in many ways, from infectious disease risks to heat waves to severe weather events (see Chapter Eleven). As more of the world’s population is concentrated in dense urban areas, features of the urban environment—noise, crowding, vehicular and industrial pollution—will come to be important determinants of health (United Nations Centre on Human Settlements, 2001; see also Chapter Sixteen). And with integration of the global economy—the complex changes known as globalization—hazards will cross national boundaries (Ives, 1985; see also Chapter Thirteen), trade agreements and market forces will challenge and possibly undermine national environmental health policies (Low, 1992; Sand, 1992; Runge, 1994; Brack, 1998; Victor, Raustiala, and Skolnikoff, 1996), and global solutions to environmental health challenges will increasingly be needed.

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 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 landmark 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, 2003].

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 permit improvement in 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. Some of the most compelling thinking in environmental health in recent years offers social and technical paths to sustainable development (Hawken, Lovins, and Lovins, 1999; Brown, 2001, 2003; McDonough and Braungart, 2002; Ehrlich and Ehrlich, 2004; Brown, Grootjans, Ritchie, and Townsend, 2005). 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 from 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 them 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 air pollution or water pollution enforcement. At the global level such problems as climate change require responses on a national and international scale. These are crafted by professionals in organizations such as the Intergovernmental Panel on Climate Change. So useful
Introduction

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 nine chapters, we address specific issues, beginning with global scale problems in Chapters Ten to Thirteen, moving to regional scale problems in Chapters Fourteen to Eighteen, and ending with local problems in Chapters Nineteen to Twenty-Eight. The final eight chapters describe the practice of environmental health, ranging from tools such as geographic information systems to activities such as risk communication and health care services.

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 at an environmental advocacy group would recognize himself or herself 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 protect the respiratory health of asthmatic children living downwind if she includes sophisticated emissions controls. The transportation planner who enables people to walk instead of drive also protects public health by helping 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 village once again performed a rescue, just as they were commenting 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 midafternoon all were exhausted. Finally, the flow of victims stopped, and the villagers collapsed, huffing and puffing, in the town square.
At that moment one of the villagers strode whistling into the town square, 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 challenged 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 with that old footbridge upstream. I walked up to it, 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.”

Box 1.2: A Prevention Poem

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.

“Twas a dangerous cliff, as they freely confessed, though to walk near its crest was so pleasant;
But over its terrible edge there had slipped a duke, and full many a peasant;
So the people said something would have to be done, but their projects did not at all tally.
Some said: “Put up a fence round the edge of the cliff;” Some, “An ambulance down in the valley.”
But the cry for the ambulance carried the day, for it spread through the neighboring city.
A fence may be useful or not, it is true, but each heart became brimful of pity,
For those who slipped over that dangerous cliff; and dwellers in highway and alley,
Gave pounds or gave pence, not to put up a fence, but an ambulance down in the valley.
“For the cliff is all right if you’re careful,” they said, “And if folks even slip and are dropping,
It isn’t the slipping that hurts them so much as the shock down below when they’re stopping.”
So day after day as those mishaps occurred, quick forth would those rescuers sally,
To pick up the victims who fell off the cliff with the ambulance down in the valley.
Then an old sage remarked, “It’s a marvel to me that people gave far more attention
Introduction

To repairing results than to stopping the cause, when they'd much better aim at prevention.

Let us stop at its source all this mischief," cried he; "Come, neighbors and friends, let us rally;

If the cliff we will fence, we might also dispense with the ambulance down in the valley."

"Oh he's a fanatic," the others rejoined; "Dispense with the ambulance? Never! He'd dispense with all charities too if he could. No, no! We'll support them forever!

Aren't we picking up folks just as fast as they fall? And shall this man dictate to us? Shall he?

Why should people of sense stop to put up a fence while their ambulance works in the valley?"

But a sensible few who are practical too, will not bear with such nonsense much longer.

They believe that prevention is better than cure; and their party will soon be the stronger.

Encourage them, then, with your purse, voice, and pen, and (while other philanthropists daily)

They will scorn all pretense and put a stout fence on the cliff that hangs over the valley.

Better guide well the young than reclaim them when old, for the voice of true wisdom is calling;

To rescue the fallen is good, but 'tis best to prevent other people from falling;

Better close up the source of temptation and crime than deliver from the dungeon or galley;

Better put a strong fence 'round the top of the cliff, than an ambulance down in the valley.

Upstream thinking has helped identify the root causes of many public health problems (also see Box 1.2), and this is nowhere more true than in environmental health. Environmental hazards sometimes originate far from the point of exposure. Imagine that you inhale a hazardous air pollutant. It may come from motor vehicle tailpipes, from power plants, from factories, or from any combination of these. As for the motor vehicle emissions, the amount of driving people do in your city or town reflects urban growth patterns and available transportation alternatives, and the pollutants generated by people's cars and trucks vary with available technology and prevailing regulations. As for the power plants,
the amount of energy they produce reflects the demand for energy by households and businesses in the area they serve, and the pollution they emit is a function of how they produce energy (are they coal, nuclear, or wind powered?), the technology they use, and the regulations that govern their operations. Hence a full understanding of the air pollutants you breathe must take into account urban growth, transportation, energy, and regulatory policy, among other upstream determinants. This book contains chapters on many of the upstream forces that affect environmental health, including population growth, transportation, and energy.

These ideas are at the core of a useful model created by the World Health Organization (Figure I.1) (WHO, Regional Office for Europe, 2004). The DPSEEA (driving forces—pressures—state—exposure—effects—actions) model was developed as a tool both for analyzing environmental health hazards and for designing indicators useful in decision making. The driving forces are the factors that motivate environmental health processes. In our air pollution example, these factors might include population growth; consumer preferences for energy-consuming homes, appliances, and vehicles; and sprawl that requires driving long distances. The driving forces result in pressures on the environment, such as the emission of oxides of nitrogen, hydrocarbons, particulate matter, and other air pollutants. These emissions, in turn, modify the state of the environment,

**FIGURE I.1. THE DPSEEA MODEL.**

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*Source: WHO, Regional Office for Europe, 2004.*
accumulating in the air and combining to form additional pollutants such as ozone. However, this deterioration in the state of the environment does not invariably threaten health; human exposure must occur. In the case of air pollutants, exposure occurs when people are breathing when and where the air quality is low. (Some people, of course, sustain higher exposures than others; an outdoor worker, an exercising athlete, or a child at play receives relatively higher doses of air pollutants than a person in an air-conditioned office.) The hazardous exposure may lead to a variety of health effects, acute or chronic. In the case of air pollutants, these effects may include coughing and wheezing, asthma attacks, heart attacks, and even early death.

Finally, to eliminate or control environmental hazards and protect human health, society may undertake a wide range of actions, targeted at any of the upstream steps. For example, protecting the public from the effects of air pollution might include encouraging energy conservation to reduce energy demand and designing live-work-play communities to reduce travel demand (addressing driving forces); providing mass transit or bicycle lanes to reduce driving, requiring emissions controls on power plants, or investing in wind turbines to reduce emissions from coal-fired power plants (addressing pressures); requiring low-sulfur fuel (addressing the state of the environment); warning people to stay inside when ozone levels are high (addressing exposures); and providing maintenance asthma medications (addressing health effects). The most effective long-term actions, however, are those that are preventive, aimed at eliminating or reducing the forces that drive the system (see Chapter Twenty-Nine). This theme is universal in public health, applying both to environmental hazards and to other health hazards.

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Introduction

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Introduction


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