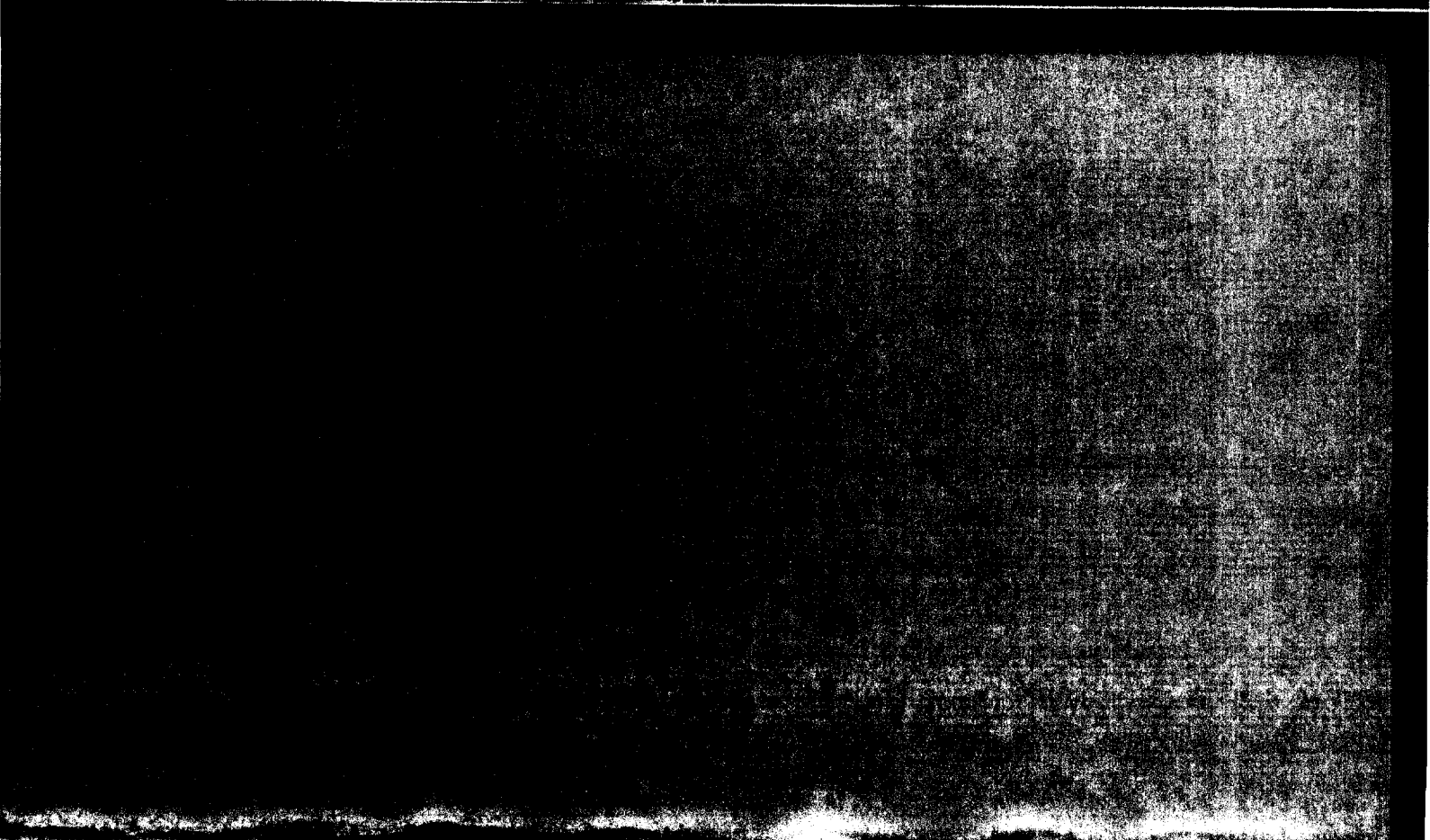
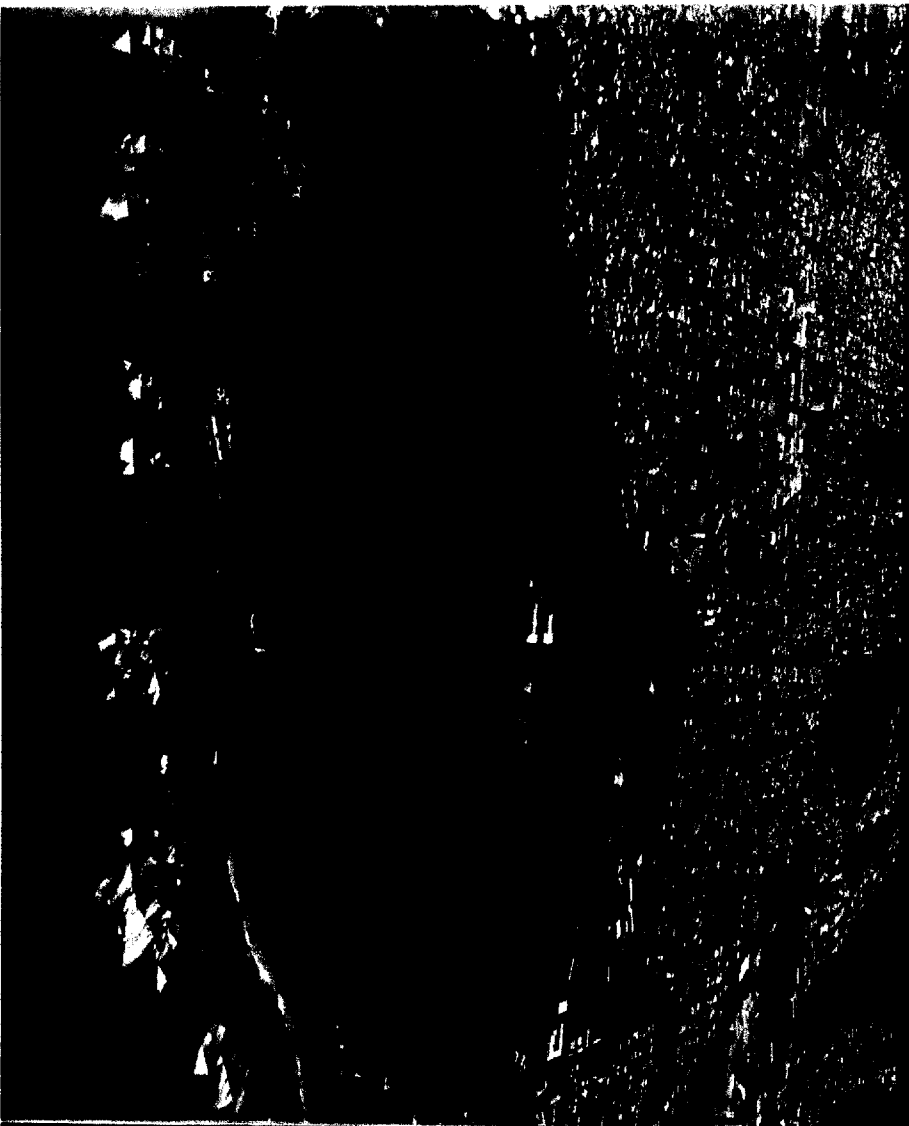


# Environmental Epidemiology

## *Principles and Methods*

---

Ray M. Merrill



# **Environmental Epidemiology**

## **Principles and Methods**

**Ray M. Merrill, PhD, MPH**

Professor of Biostatistics and Epidemiology  
Department of Health Science  
Brigham Young University  
Provo, Utah



**JONES AND BARTLETT PUBLISHERS**

*Sudbury, Massachusetts*

BOSTON TORONTO LONDON SINGAPORE

*World Headquarters*

Jones and Bartlett Publishers  
40 Tall Pine Drive  
Sudbury, MA 01776  
978-443-5000  
info@jpub.com  
www.jpub.com

Jones and Bartlett Publishers  
Canada  
6339 Orminda Way  
Mississauga, Ontario L5V 1J2  
Canada

Jones and Bartlett Publishers  
International  
Barb House, Barb Mews  
London W6 7PA  
United Kingdom

Jones and Bartlett's books and products are available through most bookstores and online booksellers. To contact Jones and Bartlett Publishers directly, call 800-832-0034, fax 978-443-8000, or visit our website [www.jpub.com](http://www.jpub.com).

Substantial discounts on bulk quantities of Jones and Bartlett's publications are available to corporations, professional associations, and other qualified organizations. For details and specific discount information, contact the special sales department at Jones and Bartlett via the above contact information or send an email to [specialsales@jpub.com](mailto:specialsales@jpub.com).

Copyright © 2008 by Jones and Bartlett Publishers, Inc.

All rights reserved. No part of the material protected by this copyright may be reproduced or utilized in any form, electronic or mechanical, including photocopying, recording, or by any information storage and retrieval system, without written permission from the copyright owner.

This publication is designed to provide accurate and authoritative information in regard to the Subject Matter covered. It is sold with the understanding that the publisher is not engaged in rendering legal, accounting, or other professional service. If legal advice or other expert assistance is required, the service of a competent professional person should be sought.

**Production Credits**

Publisher: Michael Brown	Cover Design: Kate Ternullo
Production Director: Amy Rose	Photo Research Manager and Photographer: Kimberly Porvin
Associate Editor: Karey Bircher	Photo Researcher: Timothy Renzi
Production Editor: Tracey Chapman	Cover Image: © Lisa Hoang/Shutterstock, Inc.
Production Assistant: Roya Millard	Printing and Binding: Malloy, Inc.
Marketing Manager: Sophie Fleck	Cover Printing: Malloy, Inc.
Manufacturing Buyer: Therese Connell	
Composition: Publishers' Design and Production Services, Inc.	

**Library of Congress Cataloging-in-Publication Data**

Merrill, Ray M.

Environmental epidemiology : principles and methods / Ray Merrill.

p. : cm.

Includes bibliographical references and index.

ISBN-13: 978-0-7637-4152-5 (pbk.)

ISBN-10: 0-7637-4152-3 (pbk.)

1. Environmental health. 2. Environmental monitoring. 3. Environmentally induced diseases—Epidemiology. I. Title.  
[DNLM: 1. Environmental Monitoring—methods. 2. Environmental Health. 3. Epidemiologic Factors. 4. Epidemiologic Methods. WA 670 M571e 2008]

RA566.M457 2008  
614.599—dc22

6048

2007031436

Printed in the United States of America  
11 10 09 08 07 10 9 8 7 6 5 4 3 2 1

# Conte

About the Author .....

Preface .....

**Concepts and Methods in Environmental Epidemiology** .....

Introduction to Environmental Epidemiology .....

Basic Elements of Research, Exposure, and Outcome Assessment .....

Monitoring Environmental Health .....

Epidemiologic Study Designs .....

Statistical Modeling and Inference .....

Causal Inference .....

**Environmental Epidemiology According to Person, Place, and Time** .....

Disease Clusters .....

Mapping and Geographic Information Systems .....

Time Series .....

**Applications of Environmental Epidemiology** .....

Indoor and Ambient Air Quality and Health .....

Soil and Food Contaminants and Health .....

CHAPTER 11

CHAPTER 10

SECTION III

CHAPTER 9

CHAPTER 8

CHAPTER 7

SECTION II

CHAPTER 6

CHAPTER 5

CHAPTER 4

CHAPTER 3

CHAPTER 2

CHAPTER 1

SECTION I

# Introduction to Environmental Epidemiology

## LEARNING OBJECTIVES

*After completing this chapter, you should be able to:*

1. Define environmental epidemiology.
2. Understand the full range of existing environments in environmental epidemiology.
3. Describe the “systems approach” for assessing environmental problems.
4. Describe the four processes of toxicokinetics and how they relate to environmental epidemiology.
5. Describe how human activity has interfered with selected matter cycles and has affected the environment and human health.
6. Identify ways environmental epidemiology contributes to public health.

## Introduction

A relation between the environment and human health has been observed for centuries. Hippocrates (460–377 BC), author of *Epidemic I*, *Epidemic III*, and *On Airs, Waters and Places*, made a connection between disease and environmental conditions, especially in relation to water and seasons.<sup>1</sup> He observed that different diseases occurred in different places and that malaria and yellow fever were most common in swampy areas. Some 2,000 years later, Bernardino Ramazzini (1633–1714), authored the first notable book on occupational health and industrial hygiene, *De morbis artificum diatribe* (*The Diseases of Workers*), published in 1700. In his work he identified several adverse health outcomes associated with chemicals, dust, metals, and other abrasive agents encountered by workers in various occupations.<sup>2–5</sup> For example, he described the dangers of lead poisoning from the glaze used by potters and the dangers of mercury exposure among mirror-makers, goldsmiths, and others. He observed that individuals in these occupations rarely reached old age, but if they did their health was often so bad that they prayed for death. Many of these workers had palsy of the neck and hands, loss of teeth, vertigo, asthma, and paralysis.

In 1775, Percival Pott described an increased risk of scrotal cancer in chimney sweeps, indicating that soot was the causal agent.<sup>6</sup> Later, John Snow (1813–1858) observed and recorded important environmental factors related to the course of cholera.<sup>7</sup> Snow showed that cholera was a waterborne disease that traveled in both surface and groundwater supplies.<sup>8,9</sup> Henry Burlin (1845–1912) observed that scrotal cancer was a more common disease among the English, attributing comparatively low levels in Scotland and America to the protective clothing worn by chimney sweeps in those places.<sup>10</sup> In current times, epidemiologic studies have identified numerous chemical exposures and industrial processes that are causally associated with human cancer.<sup>11</sup> For example, some industrial processes related to human bladder cancer are aluminum production, auramine manufacture, magenta manufacture, and rubber industry. The identified carcinogenic agents produced by these industrial processes include polycyclic aromatic hydrocarbons (PAHs), auramine, magenta, aromatic amine, and solvents.

A large body of research in recent years has greatly added to our understanding of how the environment can protect and sustain human life or contribute to disability and premature death. Some life-promoting features of the environment include

- soil for farming;
- water for drinking;
- air for breathing;

- the stratospheric ozone layer for protection against ultraviolet rays;
- space and facilities for recreation and exercise; and
- standards for food preparation, recycling, and disposal of waste.

On the other hand, some environmental contaminants can be life threatening, such as

- infectious agents (viruses, bacteria, fungi, parasites);
- environmental disruptions (e.g., floods, droughts, earthquakes, fires, tsunamis, mass movements, landslides);
- poor air quality (dusts, pollen, pollution);
- poor water quality (contaminants, inadequate water transport and treatment);
- negative human changes of the environment (global warming, ozone depletion, nuclear accidents, nuclear war, industrial accidents, hazardous material spills, oil spills); and
- social disruptions (ethnic violence, riots, urban fires due to arson, terrorism, bombings, conventional war, chemical/biological weapons).

Many of these environmental exposures are involuntary. For example, exposure to environmental tobacco smoke (also called secondhand smoke or passive smoke) in the home, the workplace, and in public places is often not a conscious choice. Children in particular are often innocent victims who are unable to choose to avoid environmental tobacco smoke. Infants exposed to environmental tobacco smoke are particularly susceptible to bronchitis and pneumonia.<sup>12</sup> In addition, exposed children are at increased risk of middle ear problems and exacerbated and new cases of coughing, wheezing, and asthma.<sup>12,13</sup>

In January 1993, the Environmental Protection Agency (EPA) declared that environmental tobacco smoke was a human carcinogen. Environmental tobacco smoke contains over 250 chemicals that are toxic or cancer causing, such as arsenic, ammonia, benzene, formaldehyde, hydrogen cyanide, and vinyl chloride.<sup>14</sup> The EPA estimates that environmental tobacco smoke contributes to approximately 3,000 lung cancer deaths each year.<sup>12</sup> In addition, a number of studies have linked environmental tobacco smoke with heart disease. A large cohort study involving over 32,000 women showed that constant exposure to environmental tobacco smoke almost doubles the risk of heart attack.<sup>15</sup> Environmental tobacco smoke can have a similar effect in nonsmokers as it does in smokers by causing carotid-wall thickening and compromised endothelial function, which promotes atherosclerosis (fatty buildup in the arteries) and subsequent heart disease.<sup>16</sup> In the United

States, exposure to environmental tobacco smoke increases the risk of coronary heart disease by approximately 30%, contributing to over 35,000 deaths each year.<sup>17</sup> Recent studies show that much of the cardiovascular system, including platelet and endothelial function, arterial stiffness, atherosclerosis, oxidative stress, inflammation, heart rate variability, energy metabolism, and increased infarct size, is highly sensitive to the toxins in environmental tobacco smoke.<sup>17</sup>

These epidemiologic findings linking environmental tobacco smoke with specific health problems were the impetus for several local, state, and federal authorities to enact public policies designed to protect the public from environmental tobacco smoke. In recent years, clean indoor air laws have been passed in many places. Information detailing smoking restrictions according to state is available elsewhere.<sup>18</sup>

Because many studies have focused on how human health is influenced by environmental factors, the term “environmental epidemiology” has surfaced. The purpose of this chapter is to define environmental epidemiology, identify existing environments in environmental epidemiology, present the “systems approach” to assessing environmental problems, and identify ways environmental epidemiology contributes to public health.

## Environmental Epidemiology

To understand the meaning of environmental epidemiology, first consider the meaning of environmental health. The World Health Organization (WHO) defines **environmental health** as those aspects of human health that are determined by physical, chemical, biological, social, and psychological factors in the environment.<sup>19</sup> This includes direct pathologic effects on health by chemicals, radiation, and biological agents as well as indirect effects on health from physical and psychosocial environments such as transportation, housing, socioeconomic status, and social networks. The WHO definition further states that environmental health is the theory and practice of assessing, correcting, controlling, and preventing those environmental factors that have a potentially harmful effect on human populations.<sup>19</sup> Considerable efforts in the United States and elsewhere go into assessment (monitoring and evaluation) of environmental factors associated with health, such as air quality, water quality, noise, solid-waste disposal, housing, occupational conditions, and unsanitary surroundings. On the basis of assessment information, environmental health services can more effectively prevent or reduce the health burden of illness associated with unsafe environmental factors.

In a book compiled by Last, the definition of **epidemiology** provided is “the study of the distribution and determinants of health-related states or events in specified populations, and the application of this study to control for health problems.”<sup>20</sup> **Health-related states or events** is used in the definition to capture the fact that epidemiology involves more than just the study of disease states (e.g., respiratory illness), but also includes the study of events (e.g., injury) and behaviors and conditions associated with health (e.g., hand washing). In addition, note that epidemiology is concerned with health-related states or events that occur in populations, not a specific individual. Epidemiologists direct their questions toward a selected population; for example, is there an excess of disease above what is expected in a specified population (**epidemic**) or is the frequency of disease what is normally expected (**endemic**)? When an epidemic is extensive, involving large regions, countries, or continents, it is referred to as a **pandemic** (Figure 1.1).

**Outbreak** carries the same definition as epidemic but is typically used when the event is confined to a more limited geographic area. In addition, the word “outbreak” may appear less alarming to the public than the word “epidemic.” Epidemiologists investigate outbreaks and health disparities in human populations by asking the following:

- Who are the people at greatest risk for disease? Men? Women? Older people? Younger people? People in a given community?
- Why are these people ill and not other people? Physical agent? Biologic agent? Chemical agent? Genetic factor? Lifestyle? Diet? Occupation?
- What is the illness observed? Heart disease? Cancer? Injury?
- How does the disease frequency change over time?
- How does the disease vary from place to place?
- Do disease cases have a given exposure in common?
- What is the strength of the relationship between an exposure and disease?
- How much disease could be avoided by eliminating the exposure?
- Does the totality of evidence provide support for a causal association?
- How can answers to these questions assist in controlling and preventing disease in the future?

It follows that **environmental epidemiology** is the study of distribution and determinants of health-related states or events in specified populations that are influenced by physical, chemical, biological, and psychosocial factors in the environment. It also involves the application of this study to prevent and control health problems. Its population focus and emphasis on identifying causal relations dis-

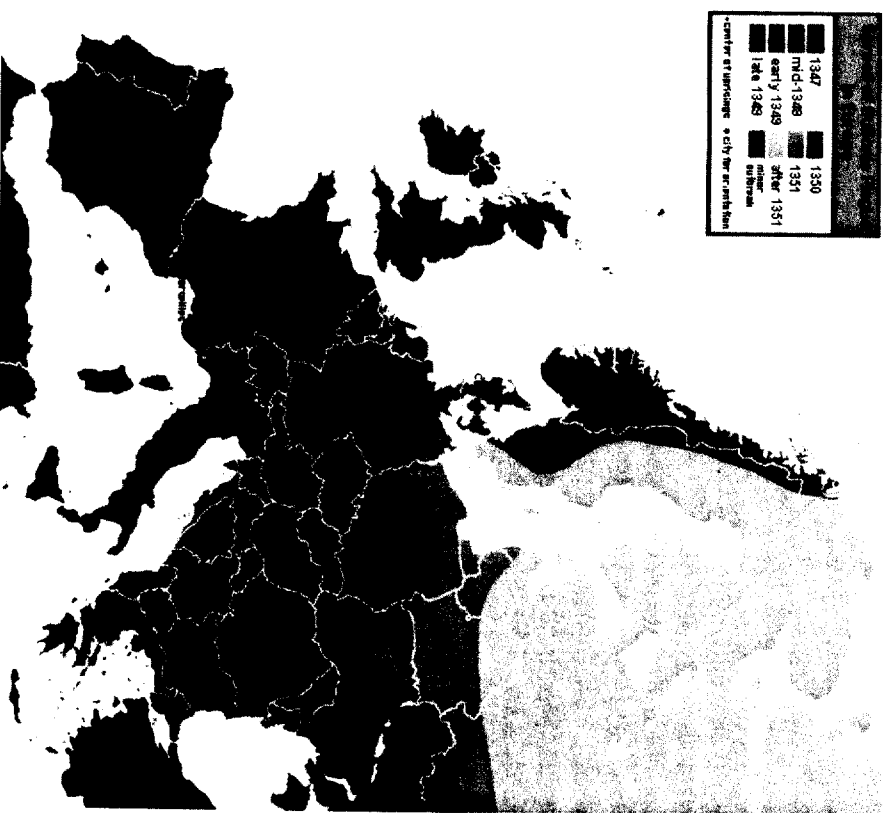


FIGURE 1.1 The spread of the plague throughout Europe from 1346 through 1353. (Source: Courtesy of Matich, 2007.)<sup>21</sup>

tinguishes it from environmental health, which is more comprehensive. It seeks to clarify the relation between environmental factors and human health by focusing on specified populations or communities. It is based on the observation that most diseases are not random occurrences, but rather are related to environmental factors that vary according to population subgroups, place, and time. Environmental epidemiologic studies are concerned not only with those who get a disease, but also with those who do not, and in identifying why the two groups differ.

Prior to the second half of the twentieth century, environmental epidemiology focused on disease-causing infectious agents or pathogens and factors such as water quality and supply systems, waste control, and food quality. Supplying safe water, appropriate disposal of waste, and regulation of food handling are environmental measures that have considerably reduced morbidity and mortality levels in many developed parts of the world. Increasing life expectancy and a movement from infectious to chronic disease as the primary cause of disease and death have motivated a change in focus of environmental epidemiology to chemicals and physical agents that have a relatively large impact on chronic illness. These agents include particulate matter, pesticides, radiation, metals, and volatile organic compounds. Epidemiologic studies have shown that particulate matter, especially fine particles, can cause premature death, respiratory-related hospitalization, aggravated asthma, acute respiratory symptoms, chronic bronchitis, decreased lung function, and work and school absences;<sup>22</sup> pesticides can cause birth defects, nerve damage, and cancer;<sup>23</sup> radiation can cause burns and radiation sickness, premature aging, cancer, and death;<sup>24</sup> metals such as lead can cause damage to the nervous system, kidneys, brain, and red blood cells;<sup>25</sup> and volatile organic compounds can cause eye and respiratory tract irritation, headaches, dizziness, visual disorders, memory impairment, and cancer.<sup>26</sup> Environmental epidemiology also examines the effects of social disruptions (e.g., ethnic violence, war, acts of terrorism, and natural disasters) on disease and death.

## The Environment

In a medical sense, the **environment** reflects the aggregate of those external conditions and influences affecting the life and development of an organism.<sup>27</sup> John Last defined “environment” for the International Epidemiological Association as “[a]ll that which is external to the human host.”<sup>28</sup> The environment may be thought of as physical, biological, social, cultural, and so on, any or all of which can influence health status of populations. Environment has also been presented by how it is associated with human health. Some of the different existing ideas on environments and their perspectives on the interaction with health include:

1. **The inner versus outer environment.** The inner body is protected from outside contaminants by three barriers: the skin, the gastrointestinal tract, and the lungs. When contaminants do penetrate these barriers, the body fortunately has protective mechanisms (e.g., vomiting, diarrhea, detoxification

in the liver, excretion through the kidneys, and coughing). The lungs represent the most susceptible barrier and are considered the most important pathway for environmental contaminants. Consider that the average adult breathes approximately 800 cubic feet (20 cubic meters) or approximately 50 pounds of air each day.<sup>29</sup>

2. **The personal versus ambient environment.** This definition contrasts an environment where a person has control (e.g., diet, smoking, sexual behavior, and alcohol consumption) with the ambient environment where they have little or no control (e.g., food additives, pollution, and industrial products).<sup>29</sup> Many chronic conditions have been largely associated with personal environment. For example, 70% or more of cancer deaths are attributed to diet, smoking, and reproductive and sexual behavior.<sup>30</sup>

3. **The solid, liquid, and gaseous environments.** Routes of human exposure to contaminants are through solid, liquid, and gaseous environments.<sup>29</sup> Soil, food, water, and air are key environments to our existence, and each is subject to contamination. Chemical and biological contaminants can be absorbed in the body through the lungs, gastrointestinal tract, or skin. Common forms of transmission include the air, water, soil, and food. Airborne transmission occurs when droplets or dust particles carry hazardous chemicals (e.g., carbon monoxide, ozone, lead) or biological agents/pathogens (virus, bacteria, fungus) through the air to infect a susceptible host. Waterborne transmission occurs when a harmful chemical or biological agent/pathogen, such as cholera or shigellosis, is carried in drinking water, swimming pools, streams, or lakes. Soilborne contamination occurs when either solid or liquid hazardous substances mix with soil. Soil contaminants may be physically or chemically attached to soil particles or trapped in spaces between soil particles. Soil may become contaminated by hazardous substances that fall out of the air or by contaminated water as it flows over or through it. Foodborne transmission occurs by consuming foods or beverages contaminated by biological agents and poisonous chemicals. The most common foodborne infections are caused by salmonella, listeria, toxoplasma, Norwalk-like viruses, campylobacter, and E. coli O157:H7. It is estimated that foodborne diseases cause approximately 76 million illnesses, 325,000 hospitalizations, and 5,000 deaths each year in the United States.<sup>31,32</sup>

4. **The physical, chemical, biological, and psychosocial environments.** The environment may also be considered according to the avenue or

mechanism by which it affects people.<sup>29</sup> Physical, biological, chemical, and psychosocial aspects of the environment are shown in Table 1.1.

In a broad sense, the study of environmental epidemiology requires consideration of all these definitions of environment and their interrelationship. However, the study of the environment may be restricted by person (e.g., children), place (e.g., workplace, to indoors or outdoors), or time (e.g., summer). It may also be restricted to environments that can be modified.<sup>33</sup> Environmental health interventions typically attempt to modify only the physical, biological, and chemical environments, and corresponding behaviors (e.g., hand washing).

## The Systems Approach

A primary goal in environmental epidemiology is to understand how human health problems may arise from environmental factors. An accurate and comprehensive evaluation requires a "systems approach" where the health problem is related to the complexity of environmental exposures. The word "systems" is defined as "a group of interrelated, interacting, or interdependent constituents forming a complex whole."<sup>34</sup> The **systems approach** in environmental epidemiology considers the fact that environmental exposures may derive from multiple sources, they may enter the body through multiple routes, and elements in the environment can change over time because of constant interaction, altering the degree to which

**TABLE 1.1** Mechanisms by which the environment influences human health

<b>Physical stresses</b>	Excessive heat, cold, and noise; radiation (electromagnetic, ultrasound, microwave, x-irradiation); vehicular collisions; workplace injuries; climate change; ozone depletion; housing; and so on
<b>Chemical</b>	Drugs, acids, alkali, heavy metals (lead and mercury), poisons (arsenic), and some enzymes
<b>Biological</b>	Disease-causing infectious agents or pathogens (viruses, bacteria, fungi, parasites)
<b>Psychosocial milieu</b>	Families and households, socioeconomic status, social networks and social support, neighborhoods and communities, formal institutions, and public policy

Source: Adapted from Moeller, 1992, pp. 6-7.<sup>29</sup>



they are harmful. Understanding the source and nature of environmental contaminants, ways people are exposed, and dose effects often require the combined efforts of epidemiologists, biologists, toxicologists, respiratory physiologists, and public health officials. According to Moeller, viewing a health problem in its entirety through a systems approach involves:

1. Determining the source and nature of each environmental contaminant or stress.
2. Assessing how and in what form it comes into contact with people.
3. Measuring the health effect.
4. Applying controls when and where appropriate.<sup>29</sup>

With the assistance of experts such as air pollution engineers, industrial hygienists, chemists, and quality-control personnel, health standards are then established, monitoring and assessment carried out, and actions taken to reduce contaminants when they exceed specified standards.

## Toxicokinetics

**Toxicokinetics** is an area of study of how a substance enters the body and the course it takes while in the body. The name originates from kinetics, which means movement, and the study of movement of toxic substances. Toxicokinetics involves four processes:

1. Absorption—entrance of the substance into the body. When a substance is ingested or inhaled, it is still considered outside the body until it crosses cellular barriers in the gastrointestinal tract or lungs. Absorption can also be through the skin, implants, conjunctival instillations (eye drops), and suppositories. Hence, there is a distinction between the exposure dose (outside dose) and the absorbed dose (internal dose). For a substance to enter the body, cell membranes (cell walls) must be penetrated. Cell membranes are designed to prevent foreign invaders or substances from entering into bodily tissue.
2. Distribution—movement of the substance from where it enters the body to other sites in the body (e.g., liver, blood and lymph circulation, kidney, lung). After a substance passes the lining of the skin, lung, or gastrointestinal tract, it enters the fluid surrounding the cells of that organ (interstitial fluid) versus fluid inside the cells (intracellular fluid). Interstitial fluid rep-

resents about 15% of body weight and intracellular fluid about 40% of body weight. A toxicant can leave the interstitial fluid in three ways: entering cells of local tissue, entering blood capillaries and the body's blood circulatory system, and entering the lymphatic system. Once in the circulatory system, a chemical can be excreted, stored, biotransformed into metabolites, its metabolites excreted or stored, or it or its metabolites can interact or bind with cellular components.

3. Biotransformation—transformation produced by the body of the substance into new chemicals (metabolites). Biotransformation is essential to survival. It is the process by which absorbed nutrients (food, oxygen, etc.) are transformed into substances required by the body to function normally. While most chemicals undergo biotransformation, the extent to which this is done depends on the storage or excretion of the chemical and its metabolites, the dose level, frequency, and route of exposure. The body is efficient at biotransforming body wastes or chemicals that are not normally produced or expected into water-soluble metabolites excreted into bile and excreted from the body. Biotransformation that metabolizes a substance to lower toxicity is called detoxification. However, it is possible for metabolites to be more toxic (bioactivation). When the metabolite interacts with cellular macromolecules such as DNA, serious health effects (cancer, birth defects) may arise.
4. Excretion—ejection of the substance or metabolites from the body. Toxicants or their metabolites may be ejected from the body through feces, urine, or expired air.

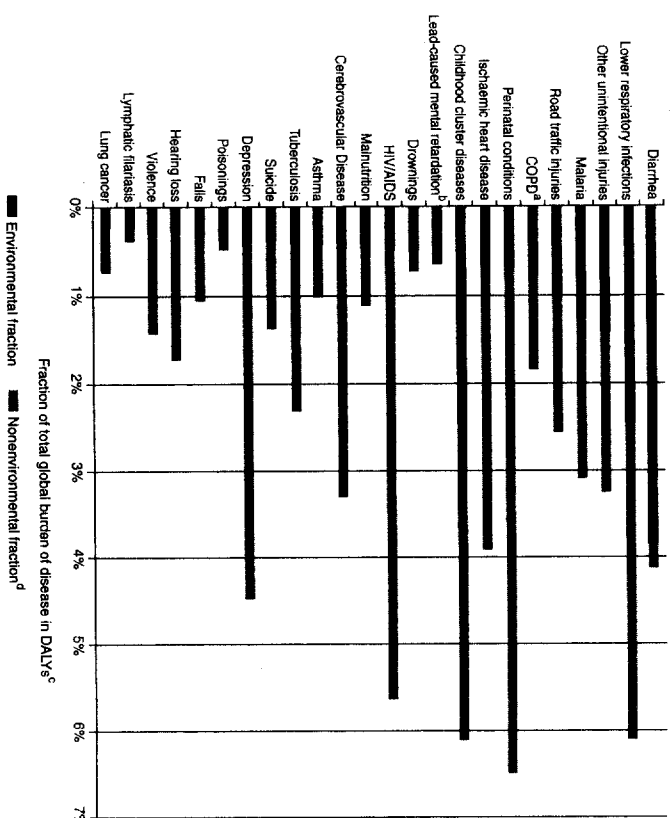
Factors influencing the toxicity severity of a substance that enters the body include route of exposure; duration of exposure; concentration of exposure; rate and amount absorbed; distribution and concentrations within the body; efficiency by which the body changes the substance and the metabolites produced; ability of the substance or metabolites to pass through cell membranes and affect cell components; duration and amount of the substance or metabolites in body tissues; and rate, amount, and site of departure of the substance or metabolites from the body. For example, poor absorption of a highly toxic substance may be less dangerous than a substance with low toxicity but high absorption. Further, two substances of similar toxicity and absorption may pose different hazards, depending on whether biotransformation results in a more toxic metabolite for one versus the other substance.<sup>35</sup>

**Polycyclic aromatic hydrocarbons (PAHs)** consist of over 100 different chemicals formed during incomplete burning of coal, oil and gas, garbage, tobacco, or charbroiled meat. Some PAHs are manufactured (e.g., coal tar, crude oil, creosote, and roofing tar). Some are used in medicine or used in making pesticides, dyes, and plastics. The Department of Health and Human Services has determined that some PAHs are carcinogenic. People who have breathed or touched mixtures of PAHs over extended periods of time have developed cancer. Points of absorption include the gastrointestinal tract, lungs, and skin by, for example, eating grilled or charred meat; breathing air containing PAHs from cigarette smoke, vehicle exhaust, or asphalt roads; or drinking contaminated water or milk. In the body, PAHs are transformed into chemicals that can attach to substances in body tissues or blood.<sup>36</sup>

## The Role of Environmental Epidemiology in Public Health

Environmental epidemiologic research has linked several diseases with environmental factors and has allowed researchers to quantify the public health burden of disease attributed to the environment. Accordingly, environmental factors influence more than 80% of the diseases regularly reported to the WHO. Globally, an estimated 24% of the burden of disease (healthy life years lost) and an estimated 23% of premature deaths have been associated with environmental factors. In children ages 0–14 years, 36% of the disease burden is attributed to environmental factors. Diseases with the strongest absolute burden related to modifiable environmental factors are diarrhea (94%); lower respiratory infections (20%; 42% in developing countries); workplace hazards, radiation, and industrial accidents (44%); and malaria (42%).<sup>33</sup> Diseases with the largest environmental contribution worldwide are presented in Figure 1.2. An estimate of the fraction of cancer deaths occurring in the United States each year that are caused by toxic occupational exposures is 10%.<sup>37</sup> Cigarette smoke is the most common chemical carcinogen, accounting for as many as 40% of all cancer deaths.<sup>38</sup>

Environmental epidemiologic information can provide a means for meeting public health objectives aimed at protecting and improving the health and well-being of human populations. Epidemiologic findings contribute to preventing and controlling health-related states or events by providing useful information for directing public health policy and planning, as well as informing individuals about adverse health behaviors.



**FIGURE 1.2** Prevalent diseases associated with the environment. (Source: from Pruss-Ustun & Corvalan, 2006.)<sup>33</sup>

<sup>a</sup> Abbreviations: COPD = Chronic obstructive pulmonary disease.  
<sup>b</sup> Lead-caused mental retardation is defined in the WHO list of diseases for 2002, accessed at: [www.who.int/injury](http://www.who.int/injury).  
<sup>c</sup> DALYs represents a weighted measure of death, illness, and disability.  
<sup>d</sup> For each disease the fraction attributable to environmental risks is shown in black. Gray plus black represents the total burden of disease.

Public health policy and planning, and individual health decision making should benefit from answers to the following questions:

- What is the extent of the public health problem?
- Who is at greatest risk?
- Where is the health problem greatest?
- When is the health problem greatest?
- What is the likely cause of the health problem?
- What is the natural history of the health problem?
  - susceptibility stage (types of exposure capable of causing disease among susceptible hosts)
  - presymptomatic stage (length of time in the subclinical phase, description of the pathologic changes that occur during this phase)

- symptomatic stage (type of symptoms that characterize the disease)
- outcome stage (probability of recovery, disability, or death associated with different levels of the disease)
- Are prevention and control programs available that are efficacious (i.e., produce desired effect among those who participate in the program)?
- Are prevention and control programs available that are effective (i.e., produce benefits among those who are offered the program; good compliance)?

Some examples of how environmental epidemiologic information influenced public health decisions and policy are provided here.

### *Example 1: E. Coli O157:H7 Outbreak Associated with Contaminated Alfalfa Sprouts*

During the last week of June 1997, the Michigan Department of Community Health observed an increase in laboratory reports of *E. coli* O157:H7 infection. Over two times the number of infected cases were reported than in the previous month. The increase in cases continued into July. Thirty-eight cases of confirmed O157:H7 infections meeting the case definition from 10 counties in the lower peninsula of Michigan are shown in Figure 1.3. Epidemiologic investigation linked the increased occurrence of illness to consumption of contaminated alfalfa sprouts.<sup>39</sup>

In response, the implicated seed lot discontinued distribution to sprouting companies. Approximately 6,000 pounds of seed were removed from the marketplace. The state Division of Food and Drugs held meetings to explain to seed growers the importance of protecting alfalfa and other seeds used in sprouting from possible contamination. Television and radio announcements were made about the risk of contaminated sprouting seeds. In addition, the Center for Food Safety and Quality Enhancement began working with the sprout industry to find ways to make sprouts safer for consumption.<sup>39</sup>

### *Example 2: E. Coli O157:H7 Outbreak Associated with Contaminated Spinach*

In the fall of 2006, an extensive investigation of an *E. coli* O157:H7 outbreak involving 205 confirmed cases and three deaths found the cause to be contaminated Dole-brand baby spinach grown in California. Some potential environmental risk factors were identified, including contamination near the presence of wild

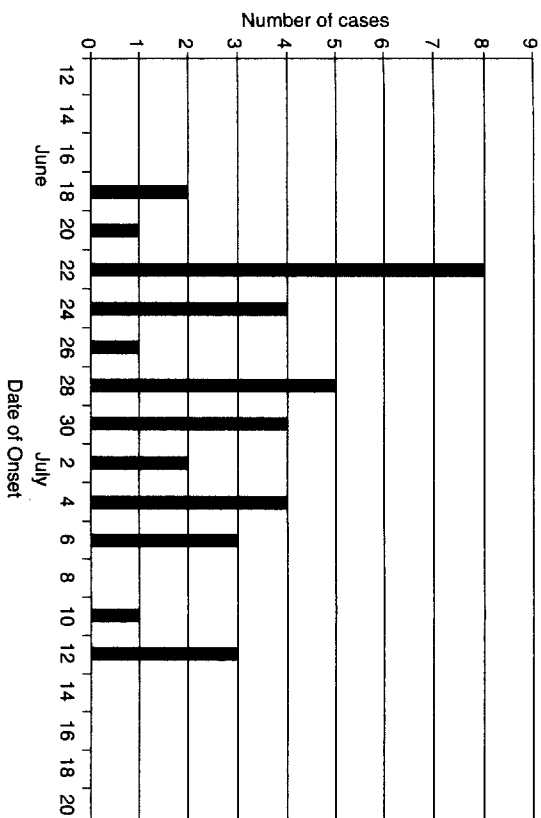


FIGURE 1.3 Number of persons with *E. coli* O157:H7 infection in Michigan by date, June 15–July 15, 1997. (Source: CDC Case Study, 2002.)<sup>39</sup>

pigs and surface waterways exposed to feces from cattle and wildlife. In response to this and other outbreaks, the U.S. Food and Drug Administration (FDA) announced an initiative called "Leafy Greens."<sup>40</sup> This initiative focuses on produce, contamination agents, and related public health concerns. In addition, the FDA has provided recommendations on ways to prevent microbial contamination while processing fresh-cut produce in its publication called "Guide to Minimize Microbial Food Safety Hazards of Fresh-cut Fruits and Vegetables." The FDA also advises consumers to wash all produce thoroughly before eating. Although this would not have prevented the *E. coli* outbreak involving spinach, it can reduce the risk of contamination from several other sources.

### *Example 3: Environmental Changes and Health*

Changes in the environment caused by human interference in matter cycles has resulted in adverse effects to health. Humans have caused environmental problems by interfering with the **hydrological cycle**, the **nitrogen cycle**, the **phosphorous**

TABLE 1.2 Matter cycles and pollution

Cycles	Human Interference	Environmental Problems
Hydrological cycle	Removal of large quantities of freshwater from rivers, lakes, and groundwater supplies Because of vegetation removal, rainwater washes away and no longer infiltrates	Depletion of groundwater Vegetation removed  Groundwater supplies are not restored Groundwater becomes salinated Risk of flooding enhanced Soil erosion increase Landslides increase
	Water quality is compromised because of added nutrients and contaminants	Disruption of ecological processes that usually purify the water
Nitrogen cycle	Fuel combustion releases nitrogen oxides	Nitrous oxide is a greenhouse gas that causes the earth's temperature to increase; can react with ozone to break down the stratospheric ozone layer
	Nitrogen dioxide may react with hydrogen to form nitric acid	Nitric acid causes acid deposition, which damages trees, vegetation, and marine ecosystems
Phosphorous cycle	Removal of phosphates in certain locations to apply to farmland as fertilizers	Because the phosphate supply is mobile, in these locations phosphate levels become too high in surrounding land/soils and groundwater, when crops do not absorb all phosphates, the phosphates end up in water and settle in lakes and reservoirs; the result is eutrophication, which means that water is so rich of nutrients that certain water plants (e.g., green algae) grow extensively; the water then becomes depleted of the oxygen supply causing oxygen-dependent fish and organisms to die and nonoxygen dependent bacteria to thrive

TABLE 1.2 Matter cycles and pollution (continued)

Cycles	Human Interference	Environmental Problems
	Deforestation	The rain washes phosphates away, causing the ground to become unproductive; it takes considerable time for phosphate supplies to be restored because phosphate comes from weathering rocks and oceanic sediments
Sulfur cycle	Humans are responsible for 90% of sulfur salts found on the earth, primarily formed during industrial process (coal combustion, petroleum refining, and melting)	Sulfur compounds (sulfuric acid, sulfur dioxide, and hydrogen sulfide) cause acid deposition on water and soil, influencing life in the soil and water and causing a disturbance to natural processes
Carbon cycle	Deforestation	Removal of trees and plants that absorb carbon dioxide
	Industrial processes (coal and oil combustion)	Carbon emissions to the atmosphere; uptake of excessive carbon dioxide in the atmosphere cannot be taken up by trees, plants, and oceans fast enough; carbon dioxide is a greenhouse gas that causes the earth's temperature to increase
	Extensive burning of fossil fuels, which consist of dead organic matter	Depleting fossil fuel supplies, which take a very long time to restore

Source: Adapted from Lemtech, 2006.<sup>41</sup>

**cycle, the sulfur cycle, and the carbon cycle.** A summary of ways humans interfere with these cycles is presented in Table 1.2.

Environmental changes in the climate and stratospheric ozone have prompted investigations of potential health consequences. Good health depends on continued stability and functioning of that part of the earth and its atmosphere that supports life. Climate change may affect human health through increased temperatures and temperature-related illness and death; extreme weather events; air pollution; food and water shortages; and a rise in waterborne, foodborne, vectorborne, and rodentborne diseases. Stratospheric ozone depletion can adversely affect life through

increased exposure to ultraviolet radiation. In response, the United Nations Framework Convention on Climate Change (UNFCCC) has taken steps to reduce greenhouse gas emissions and respond to the impacts of climate change.<sup>42</sup> On December 11, 1997, the **Kyoto Protocol** strengthened the UNFCCC by setting standards for greenhouse gas emissions among countries ratifying the protocol.<sup>43</sup> In 1987, the **Montreal Protocol** on Substances That Deplete the Ozone Layer was signed as an international treaty to protect stratospheric ozone by stopping the emission of halocarbon gases and other substances.<sup>44</sup>

Once causal associations are established between environmental factors and human health, public health assessment can be employed to monitor exposure and health-related conditions in the population. Public health surveillance makes possible the identification of individuals and populations at greatest risk for disease and of where the public health problem is greatest.<sup>45</sup> Public health intervention programs can then be developed and effectively evaluated. In addition, people can be warned about the negative effects of certain environmental exposures and alter their conditions and behaviors accordingly.

## Key Issues

1. Environmental epidemiology is the study of the distribution and determinants of health-related states or events in specified populations that are influenced by physical, chemical, biological, and psychosocial factors in the environment. It also involves the application of this study to prevent and control health problems.
2. The population focus of environmental epidemiology and emphasis on identifying causal relationships distinguishes it from environmental health, which is more comprehensive.
3. Environmental epidemiology should consider a full range of existing environments: the inner versus outer environment; the personal versus ambient environment; the solid, liquid, and gaseous environments; the chemical, biological, physical, and socioeconomic environments.
4. The systems approach in environmental epidemiology considers the fact that environmental exposures may derive from multiple sources, they may enter the body through multiple routes, and elements in the environment can change over time because of constant interaction, altering the degree to which they are harmful. Viewing a health problem in its entirety through a systems approach involves: (1) determining the source and nature of each

environmental contaminant or stress; (2) assessing how and in what form it comes into contact with people; (3) measuring the health effect; and (4) applying controls when and where appropriate.

5. Toxicokinetics is an area of study of how a substance enters the body and the course it takes while in the body. Toxicokinetics involves four processes: absorption, distribution, biotransformation, and excretion.
6. Changes in the environment caused by human interference in matter cycles (hydrological cycle, the nitrogen cycle, the phosphorous cycle, the sulfur cycle, and the carbon cycle) have resulted in environmental problems and adverse affects to human health.
7. Epidemiologic findings contribute to preventing and controlling health-related states or events by providing useful information for directing public health policy and planning, as well as informing individuals about adverse health behaviors.

## Exercises

### Key Terms

*Define the following terms.*

Carbon cycle  
Endemic  
Environment  
Environmental epidemiology  
Environmental health  
Epidemic  
Epidemiology  
Health-related states or events  
Hydrological cycle  
Kyoto Protocol  
Montreal Protocol  
Nitrogen cycle  
Outbreak  
Pandemic  
Phosphorous cycle  
Polycyclic aromatic hydrocarbons  
Sulfur cycle

## Systems approach

The inner versus outer environment

The personal versus ambient environment

The physical, chemical, biological, and psychosocial environments

The solid, liquid, and gaseous environments

Toxicokinetics

## Study Questions

- 1.1. Define environmental epidemiology.
- 1.2. Describe the primary purpose of environmental epidemiology.
- 1.3. What was the original focus of environmental epidemiology, and how has it changed since the mid-twentieth century?
- 1.4. Compare inner versus outer and personal versus ambient environments.
- 1.5. Identify and discuss routes of exposure in the environment.
- 1.6. Identify and give examples of ways that the environment can influence health.
- 1.7. What is the systems approach for assessing environmental problems?
- 1.8. How is toxicokinetics related to a systems approach?
- 1.9. Describe some of the environmental problems related to human interference with the hydrological cycle, the nitrogen cycle, the phosphorous cycle, the sulfur cycle, and the carbon cycle.
- 1.10. How does environmental epidemiology contribute to public health?

## References

1. Jones WHS. (translation). *Hippocrates, Vol. I*. London: William Heinemann; 1923:71–137.
2. Cumston CG. *An Introduction to the History of Medicine*. New York, NY: Alfred A. Knopf; 1926.
3. Garrison FH. *History of Medicine*. Philadelphia, PA: Saunders; 1926.
4. Rosen G. *A History of Public Health*. New York: MD Publications; 1958.
5. Seelig MG. *Medicine: An Historical Outline*. Baltimore: Williams & Wilkins; 1925.
6. Port R. *Chirurgical Observations*. Vol 3. London: Hawes L, Clark W, Collins R; 1775:177–183.
7. Snow J. *On the Mode of Communication of Cholera*. 2nd ed. 1855. Reproduced by Commonwealth Fund, New York; 1936.

8. Snow on Cholera. Part 1. Available at: <http://www.uic.edu/spb/prepare/courses/chsc400/resources/snowcase1.htm>. Accessed April 4, 2007.
9. Snow on Cholera. Part 2. Available at: <http://www.uic.edu/spb/prepare/courses/chsc400/resources/snowcase2.htm>. Accessed April 4, 2007.
10. Waldron HA. A brief history of scrotal cancer. *Br J Ind Med*. 1983;40:390–401.
11. International Agency for Research on Cancer. *Overall evaluations of carcinogenicity: an updating of IARC monographs*. Vols 1–42. IARC Monographs Supplement 7. Geneva IARC; 1987.
12. Environmental Protection Agency. The health effects of exposure to second-hand smoke. Available at: <http://www.epa.gov/smokefree/healtheffects.html>. Accessed April 5, 2007.
13. Office of Environmental Health Hazard Assessment. Health effects of exposure to environmental tobacco smoke: Final report, approved at the panel's June 24, 2005 meeting. Available at: [http://www.oehha.ca.gov/air/environmental\\_tobacco/2005etrfinal.html](http://www.oehha.ca.gov/air/environmental_tobacco/2005etrfinal.html). Accessed April 5, 2007.
14. Health and Human Services. The health consequences of involuntary exposure to tobacco smoke: A report of the surgeon general. Available at: <http://www.surgeongeneral.gov/library/secondhandsmoke/>. Accessed April 5, 2007.
15. Kawachi I, Colditz GA, Speizer FE, et al. A prospective study of passive smoking and coronary heart disease. *Circulation*. 1997;95:2374–2379.
16. Otsuka R, Watanabe H, Kirata K. Acute effects of passive smoking on the coronary circulation in healthy young adults. *JAMA*. 2001;286:436–441.
17. Barnoya J, Glantz SA. Cardiovascular effects of second hand smoke. *Circulation*. 2005;111:2684–2698.
18. American Lung Association. Tobacco control. Available at: <http://slat.lungusa.org/>. Accessed April 5, 2007.
19. World Health Organization. Protection of the human environment. Available at: <http://www.who.int/phe/en/>. Accessed September 22, 2006.
20. Last JM, ed. *A Dictionary of Epidemiology*. 3rd ed. New York, NY: Oxford University Press; 1995.
21. Matich J. *The Great Plague*. Available at: <http://www.urbanedpartnership.org/target/bridges/greatplague.html>. Accessed April 5, 2007.
22. Environmental Protection Agency. Health and environmental effects of particulate matter. Available at: <http://www.epa.gov/ttncaal/naagfin/pmhhealth.html>. Accessed April 5, 2007.
23. Environmental Protection Agency. Pesticides and food: health problems pesticides may pose. Available at: <http://www.epa.gov/pesticides/food/risks.htm>. Accessed April 5, 2007.
24. Environmental Protection Agency. Understanding radiation. Health effects. Available at: [http://www.epa.gov/radiation/understand/health\\_effects.htm#whatkind](http://www.epa.gov/radiation/understand/health_effects.htm#whatkind). Accessed April 5, 2007.
25. Environmental Protection Agency. Private drinking water wells. Human health. Available at: <http://www.epa.gov/safewater/privatewells/health.html>. Accessed April 5, 2007.

26. Environmental Protection Agency. Indoor air quality. An introduction to indoor air quality: organic gases (volatile organic compounds—VOCs). Available at: <http://www.epa.gov/iaq/voc.html>. Accessed April 5, 2007.
27. *Stedman's Medical Dictionary for the Health Professions and Nursing*. 5th ed. New York: Lippincott, Williams & Wilkins; 2005.
28. Last JM, ed. *A Dictionary of Epidemiology*. 4th ed. New York, NY: Oxford University Press; 2001.
29. Moeller DW. *Environmental Health*. Cambridge, MA: Harvard University Press; 1992.
30. Doll R, Peto R. The causes of cancer: Quantitative estimates of avoidable risks of cancer in the United States today. *J Natl Cancer Inst*. 1981;66(6):1191–1309.
31. Tybor PJ, Hurst WC, Reynolds AE, Schuler G. Preventing chemical food-borne illness. Available at: <http://pubs.caes.uga.edu/caespubs/pubcd/b1042-w.html>. Accessed September 22, 2006.
32. Mead PS, Slutsker L, Dietz V, et al. Food-related illness and death in the United States. 1999. Available at: <http://www.cdc.gov/ncidod/eid/vol5no5/mead.htm>. Accessed September 22, 2006.
33. Pruss-Ustun A, Corvalan C. Preventing disease through healthy environments. Towards an estimate of the environmental burden of disease. Geneva, Switzerland: WHO Press. Available at: [http://www.who.int/quantifying\\_ehimpacts/publications/preventingdisease/en/print.html](http://www.who.int/quantifying_ehimpacts/publications/preventingdisease/en/print.html). Accessed September 22, 2006.
34. *Webster's Ninth New Collegiate Dictionary*. Springfield, MA: Merriam-Webster Inc; 1991.
35. National Library of Science. Toxicology tutor II: toxicokinetics. Available at: <http://sis.nlm.nih.gov/enviro/toxwuor/Tox2/amenu.htm>. Accessed June 10, 2007.
36. Agency for Toxic Substances and Disease Registry. ToxFAQs: polycyclic aromatic hydrocarbons (PAHs). U.S. Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry. Available at: <http://www.atsdr.cdc.gov/tfacts69.pdf>. Accessed June 10, 2007.
37. Cole P. Cancer and occupation: status and needs of epidemiologic research. *Cancer*. 1977;39:1788–1791.
38. Landrigan PJ, Markowitz SB, Nicholson WJ. Cancer prevention in the workplace. In: Greenwald P, Kramer BS, Weed DL, eds. *Cancer Prevention and Control*. New York, NY: Marcel Dekker Inc; 1995:393–410.
39. Centers for Disease Control and Prevention (CDC) Case Study. A multistate outbreak of *E. coli* O157:H7 infection. Available at: <http://www2a.cdc.gov/epicasestudies/graphics/ecoli.pdf>. Accessed August 23, 2006.
40. Investigation of an *Escherichia coli* O157:H7 outbreak associated with Dole pre-packaged spinach. Available at: <http://www.dhs.ca.gov/ps/fdb/local/PDF/2006%20Spinach%20Report%20Final%20redacted%20no%20photosfigures.PDF>. Accessed April 4, 2007.
41. Lennetech. Matter cycles and pollution. Available at: <http://www.lennetech.com/matter-cycles-pollution.htm>. Accessed June 11, 2007.
42. United Nations Framework Convention on Climate Change. The United Nations Framework Convention on Climate Change: Essential Background. 2006. Available at: [http://unfccc.int/essential\\_background/convention/items/2627.php](http://unfccc.int/essential_background/convention/items/2627.php). Accessed October 17, 2006.
43. United Nations Framework Convention on Climate Change. Kyoto Protocol. Available at: [http://unfccc.int/kyoto\\_protocol/background/items/3145.php](http://unfccc.int/kyoto_protocol/background/items/3145.php). Accessed November 25, 2006.
44. Alternative Fluorocarbons Environmental Acceptability Study. Available at: [http://www.afcas.org/montreal\\_protocol.html](http://www.afcas.org/montreal_protocol.html). Accessed October 17, 2006.
45. Teutsch SM, Churchill RE. *Principles and Practices of Public Health Surveillance*. 2nd ed. New York: Oxford University Press; 2000.