ESSENTIAL PUBLIC HEALTH

Series Editor: Richard Riegelman

Essentials of Environmental Health

THIRD EDITION

Robert H. Friis

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Cover Image (Title Page, Part Opener, Chapter Opener):
© Jean-Luc Rivard/EyeEm/Getty Images
Printing and Binding: LSC Communications
Cover Printing: LSC Communications

Library of Congress Cataloging-in-Publication Data
Names: Friis, Robert H., author.
Title: Essentials of environmental health / Robert H. Friis.
Description: Third edition. | Burlington, MA: Jones & Bartlett Learning, [2019] | Includes bibliographical references and index.
Identifiers: LCCN 2017058190 | ISBN 9781284123975 (paperback)
Subjects: LCSH: Environmental health.
Classification: LCC RA565 .F75 2019 | DDC 362.1—dc23
LC record available at https://lccn.loc.gov/2017058190

6048

Printed in the United States of America
22 21 20 19 18 10 9 8 7 6 5 4 3 2 1

To C.A.F.

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Prologue

Dr. Robert Friis' *Essentials of Environmental Health* was the first text in the *Essential Public Health* Series. In the decade since the first edition was published, the importance of environmental health has been brought to the world's attention by crises and challenges ranging from oil spills to climate change, and from lead in water to pandemic influenza to Zika.

The third edition of *Essentials of Environmental Health* builds upon the previous editions. It keeps up with the changes in environmental health to produce a state-of-the-art introductory text. The third edition has been updated extensively to reflect the rapidly changing context of the environmental health field. Many new charts and figures have been added. Examples of new topics in this edition are the following:

- *Healthy People 2020* environmental objectives
- Expanded coverage of climate change
- Current status of population growth
- Mushroom poisoning
- Cap-and-trade policies in California
- Zika virus infection
- Lead contamination of water supply in Flint, Michigan
- Colony collapse disorder among honey bees
- Fukushima Daiichi Nuclear Power Plant
- Changing distribution of unintentional injury deaths

Dr. Friis also has produced a comprehensive set of ancillary materials accessible in the Navigate 2 Advantage package that accompanies this text. These resources provide the most recent information to broaden students' knowledge of environmental health. They also provide faculty with resources to challenge students and deepen their understanding of environmental health.

The *Essential Public Health* Series now includes over 20 books covering the full range of introductory texts. Dr. Friis has also authored *Epidemiology 101* as part of the series. *Epidemiology 101* is a core undergraduate public health text and a key component of the "101" approach to undergraduate public health education that also includes *Public Health 101* and *Global Health 101*. *Essentials of Environmental Health* has rapidly become a core text as well, key to a comprehensive curriculum in public health.

Dr. Friis brings to all his writing in environmental health and epidemiology a lifetime commitment to teaching, a personal connection to students as they begin their study of public health, and an impressive ability to clearly present complex subjects. I know that you will enjoy and benefit from this text.

Richard Riegelman, MD, MPH, PhD
Series Editor—Essential Public Health

Preface

When you follow the media, dramatic pictures and accounts of chemical spills, industrial fires, and other environmental disasters are not unusual. If you read the newspaper, surf the Internet, watch television, or merely observe what is happening around you, you will become aware of the environmental threats that are occurring on a worldwide scale. Since the publication of the first edition of *Essentials of Environmental Health* in 2007, our awareness of how threats to the environment endanger the survival of all life on the planet has continued to grow.

Within the past decade, public debate about global warming—a controversial topic—has escalated. Some worldwide climate changes such as extreme weather events have been attributed to global warming. The devastation caused by the August 2005 Hurricane Katrina in New Orleans was particularly moving. Other examples of extreme climate variations are increases in desertification in some parts of the world; at the same time, other areas such as Pakistan and China have experienced periodic massive flooding, for example, during the summer of 2010. In 2017, hurricanes devastated Puerto Rico and other Caribbean islands as well as Texas and Florida on the United States mainland.

As a consequence of the warming of the earth's temperature, mountain glaciers, masses of ice in Greenland, and glaciers and sea ice in the Arctic and Antarctic regions have been melting. Everyone should be concerned about the potential impact of these dramatic trends and incidents on the global physical environment and the health and survival of the world's population. At the same time, a hopeful attitude is warranted because of the progress that has been made in protecting environmental quality.

I have always been interested in the environment, especially the impact of rapid growth in California, my home state. During my lifetime, I have witnessed the conversion of pastoral northern California farmlands and orchards into densely populated urban zones with consequential environmental degradation. Although destruction of Brazilian rainforests is a focus of environmental advocates, wide swaths of the redwood forests of northern California and the wooded areas of the Pacific Northwest also are impacted by deforestation and are in need of protection.

In addition to urbanization in my home state, rapid population growth has also been a global phenomenon. In my travels over the past decades, I have observed this phenomenon in Mexico and some parts of Europe. One example is the transformation of small cities in Baja, California into booming metropolises. Another example is the residential and commercial development that now fill the open, snow-covered fields that I traipsed through as a student in western Germany on the way to language classes. Despite urban growth, German cities have adopted exemplary programs for urban planning and recycling solid wastes. Other northern European countries, such as Sweden, have implemented development policies that preserve open space and encourage citizens to use public transportation. Member states of the European Union have been leaders in the development of wind and solar power, alternative fuels such as biodiesel, and energy-saving technologies.

Increasing population and development pressures affect southern Europe as well. As a result of water overdraft, some European cities along the Mediterranean have had salt water intrude into their public water supplies. When I first traveled to Europe as a student, I was impressed with the fact that people used bottled water instead of tap water, and later I began to understand why—most of the time, the tap water simply was not as palatable as bottled water. Nowadays, however, it is also common for people in the United States to tote around bottles of "prestige water," perhaps because of their fear of contaminants and microbes that may be present in the tap water. (In most cases, this fear is unwarranted because the quality of municipal tap water is highly regulated.)

Back in California, we now know that because of the introduction of toxic chemicals and pesticides, sewage contamination, and overfishing, our once abundant fisheries are declining and fishing must be limited. For example, it was once possible to consume fresh abalone, but now this delicious crustacean is almost unavailable from the wild due to excessive human predation. Seafood lovers are advised not to

consume certain species of fish, which may be contaminated with mercury and other harmful substances.

During the spring and summer of 2010, a catastrophe at the *Deepwater Horizon* oil rig off the Louisiana coast caused the largest marine oil spill up to that time—about 5 million barrels. Aside from the immediate impact on wildlife and the fishing and tourism industries, the long-term environmental effects will require years to be ascertained. This catastrophe has called into question the safety of offshore oil drilling operations and focused attention on the adverse environmental consequences of oil extraction in general.

Still another concern is the impact of environmental factors on the safety of the global food supply. During late summer 2010, millions of eggs produced in the midwestern United States and sold widely by supermarket chains were found to be contaminated with *Salmonella* bacteria. Inspection of the poultry farms revealed that chickens were raised in despicable environmental conditions, which could contribute to the proliferation of *Salmonella* contamination. Within the past decade, other foodborne disease outbreaks in the United States have been associated with tomatoes (*Salmonella*) as well as lettuce and ground beef (*Escherichia coli*). Noteworthy is the increasing internationalization of the world's food supply—adulterated and unsafe foodstuffs produced in one country can be shipped globally and threaten all of humanity. An example is the melamine-contaminated baby formula manufactured in China.

Since 2010, environmental issues have continued to command our attention. Global political conflicts and war have been an impetus for migration to the European Union and North America. Migration impacts the environment and taxes the resources of host countries. Another continuing issue is the lack of clean water in many countries. Unsafe water provides an avenue for the transmission of cholera, amebiasis, and other deadly waterborne scourges. Often, many of the same countries that do not have reliable water supplies also lack sanitary toilet facilities.

An ongoing environmental topic involves the safety of nuclear power plants. In 2011, an earthquake and tsunami caused a meltdown of the Fukushima Daiichi Nuclear Reactor in northern Japan and release of radioactive materials into the surrounding area. This event followed the earlier meltdowns of the reactors at Three Mile Island in Pennsylvania (1979) and Chernobyl, Ukraine (1986).

The picture is not entirely bleak, however; much progress has been made in informing the public about environmental health hazards and introducing regulations and procedures for the control of these hazards. Notable are the use of unleaded fuels and catalytic converters in automobiles to control air pollution and lead contamination. Not only have important environmental protections such as these been implemented in the United States, they also have been adopted by European countries and elsewhere. Global recognition of the adverse impacts of climate change has led the world community, especially countries that are heavy users of fossil fuels, to formulate and adopt protocols that aim to reduce emissions of greenhouse gases.

Another example of a successful environmental policy that is now enforced in many parts of the world is the regulation of smoking in alcohol-serving establishments. This policy originated as California's Smokefree Bars Law, which controls occupational exposure to environmental tobacco smoke and also protects bar and restaurant patrons. At national and international levels, regulatory agencies conduct research and develop and enforce laws that control environmental health hazards. Although these efforts hold much promise for maintaining environmental quality, it must be kept in mind that policy and regulation are strongly influenced by the political process. Often economic considerations such as the need to maintain jobs and the prospect of increased taxation must be balanced against environmental protections.

This text addresses the important topics and methodological approaches in the environmental health field in order to provide a diversity of learners (from the beginning student to the experienced health professional) with an overview of the field. I believe that knowledge of environmental health issues can lead to an appreciation of humankind's connection with the earth and the precarious balance between human activities and environmental resources.

Robert H. Friis, PhD

Acknowledgments

My colleagues and students were extremely helpful in providing comments and background information necessary to complete this project. For the first edition of the text, I wish to thank the following former students: Ibtisam Khoury, Lillian Camacho, Sheetal Monga, Manohar Sukumar, and Heidi Burkey from California State University, Long Beach (CSULB); and Nada Hamade from the University of California, Irvine. Students helped with literature searches, reviewed written text materials, and provided feedback. I also acknowledge the contributions of Dr. Robert Phalen and Dr. Yee-lean Lee, University of California, Irvine; Dr. Jan Semenza, European Center for Disease Prevention and Control; Dr. Glenn Paulson, School of Public Health, University of Medicine and Dentistry of New Jersey; and Dr. Michelle Saint-Germain and Dr. Javier Lopez-Zetina, CSULB. These professional colleagues carefully reviewed chapters that were relevant to their areas of expertise.

For the second edition, I express my gratitude to the following students who helped with literature searches and review of the text: Sarah Long, Paula Griego, Jane Kil, and Dexter Dizon. For the third edition, I thank CSULB graduate student Nutan Kafle for her assistance with literature searches.

Also, I would like to thank anonymous reviewers whose insightful comments greatly enhanced the quality of this text. Mike Brown, Director of Product Management for Jones & Bartlett Learning, provided continued encouragement and motivation for completion of the project; Jones & Bartlett Learning staff offered much expertise. Finally, my wife, Carol Friis, was involved extensively with this project for all three editions—she provided detailed editorial comments, verified the accuracy of the references, and helped with many other aspects of the project. Without her support and assistance, completion of the text would not have been possible.

About the Author

Robert H. Friis, PhD, is Professor and Chair, emeritus, of the Department of Health Science at California State University, Long Beach (CSULB), and former Director of the CSULB-Veterans Affairs Medical Center, Long Beach, Joint Studies Institute. He is a past president of the Southern California Public Health Association. He serves or has served on the advisory boards of several health-related organizations, including the California Health Interview Survey. He previously retired from the University of California, Irvine, where he was an Associate Clinical Professor in the Department of Medicine, Department of Neurology, and School of Social Ecology. Dr. Friis is an epidemiologist by training and profession and has an enduring fascination with environmental health.

As a health department epidemiologist, he led investigations into environmental health problems such as chemical spills, air pollution, and foodborne illness. He has taught courses on epidemiology, environmental health, and statistics at universities in New York City and southern California. The topics of his research, publications, and presentations include tobacco use, mental health, chronic disease, disability, minority health, and psychosocial epidemiology.

Dr. Friis has been principal investigator or coinvestigator on grants and contracts from the University of California's Tobacco-Related Disease Research Program, the National Institutes of Health, and other agencies. This funding has supported investigations into topics such as tobacco control policies, geriatric health, depression in Hispanic populations, and infectious disease transmission in nursing homes. His academic interests have led him to conduct research in Mexico City and European countries. He has been a visiting professor at the Center for Nutrition and Toxicology, Karolinska Institute, Stockholm, Sweden; the Max Planck Institute, Munich, Germany; and the Medizinische Fakultät Carl Gustav Carus of the Dresden Technical University, Dresden, Germany. He reviews articles frequently for scientific journals and is on the international editorial board of *Public Health* and the *Journal of Public Health*. Dr. Friis is a fellow of the Royal Society of Public Health, lifetime member of the governing council of the Southern California Public Health Association, member of the Society for Epidemiologic Research, and member of the American Public Health Association. His awards include a postdoctoral fellowship for study at the Institute for Social Research, University of Michigan, and the Achievement Award for Scholarly and Creative Activity from California State University, Long Beach.

He is author/coauthor of the following texts published by Jones & Bartlett Learning:

- *Epidemiology for Public Health Practice*, with Thomas A. Sellers (editions one through five)
- *Essentials of Environmental Health* (editions one and two)
- *Epidemiology 101* (editions one and two)
- *Occupational Health and Safety for the 21st Century*

He is also the author/coauthor of texts on biostatistics and community/public health and is the editor of the *Praeger Handbook of Environmental Health*. Dr. Friis has helped to create online courses for several universities and other organizations.

Introduction

The purpose of this text is to inform the reader about the key areas of environmental health and instill awareness about the crucial role of the environment in the health of the planet and all living creatures. Organized according to three major domains—background, environmental disease agents, and applications—the text begins with background material and "tools of the trade" (environmental epidemiology, environmental toxicology, and environmental policy and regulation). The text then covers specific agents (e.g., microbial agents, toxic metals, pesticides, and ionizing and nonionizing radiation) of environmentally related diseases. Finally, applications and domains of environmental health are addressed (water and air quality, food safety, waste disposal, occupational health, and injuries).

This work is intended for graduate and undergraduate students who take environmental health courses in a variety of settings. Often, these courses are offered by schools of public health and health science departments. The text can also be used in online courses and instruction in intensive courses offered in a nontraditional format. Taking a nontechnical approach, the text should be accessible and interesting to students who have not had a great deal of previous introductory background, especially in the sciences. Nevertheless, the text should appeal to more advanced students as well. In order to generate interest in the subject matter, the author has included many examples and illustrations of environmental health issues. Text boxes throughout provide detailed information on selected topics. Other instructional aids are a list of learning objectives at the beginning of each chapter and study questions and exercises at the end.

A summary of the content of each chapter follows. Part I: Background of the Field, includes Chapters 1 through 4. Chapter 1 illustrates the role of environmental health in contemporary society, presents examples from the history of environmental health, and delimits the scope of the environmental health field; in addition, career opportunities are featured. Chapter 2 covers environmental epidemiology, one of the fundamental disciplines used in the study of environmental health. The subject of Chapter 3 is environmental toxicology, which, along with environmental epidemiology, is one of the key disciplines of the environmental health field. Chapter 4 focuses on environmental policy and regulation. Sometimes this content is placed near the end of environmental health texts. The author has elected to move it closer to the beginning because an appreciation of policy issues is crucial to the understanding of specific domains of environmental health. In addition, Chapter 4 contains extensive coverage of major environmental regulatory agencies and major US environmental health laws. It is important to cover these topics early in the text because references to agencies and laws are made in the chapters that follow. The reader may want to use this material for reference and consult it later while reading the remaining chapters.

The next group of chapters, Part II: Agents of Environmental Disease, Chapters 5 through 8, covers agents of environmental disease. The respective topics are zoonotic and vector-borne diseases, toxic metals and elements, pesticides and other organic chemicals, and ionizing and nonionizing radiation. Part III: Applications of Environmental Health, Chapters 9 through 14 deals with applications of environmental health: water quality, air quality, food safety, solid and liquid wastes, occupational health, and injuries.

Other components of the text are a glossary of key definitions and a list of abbreviations. For additional information and learning aids that reinforce the didactic content of the text, the author recommends that readers access the *Navigate 2 Advantage Access* online component. Some instructors enhance the learning experience by conducting field visits to environmentally relevant sites in the community (e.g., the municipal water plant). Other means to support the course are the use of videos and online resources.

Abbreviations

Term	Definition
APHIS	Animal and Plant Health Inspection Service (of USDA)
AQI	air quality index
ATSDR	Agency for Toxic Substances and Disease Registry
BHA	butylated hydroxyl anisole
BHT	butylated hydroxytoluene
BLL	blood lead level
BLS	Bureau of Labor Statistics
BRI	building-related illness
BSE	bovine spongiform encephalopathy
CAA	Clean Air Act
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act, 1980
CFR	case fatality rate
CFSAN	Center for Food Safety and Applied Nutrition
CHD	coronary heart disease
Ci	Curie
CNS	central nervous system
CO	carbon monoxide
COHb	carboxyhemoglobin
COPD	chronic obstructive pulmonary disease
Cr (VI)	hexavalent chromium
CTS	carpal tunnel syndrome
CWP	coal workers' pneumoconiosis
dB	decibel
DBPs	disinfection byproducts (of water)
DDT	dichlorodiphenyltrichloroethane
DES	diethylstilbestrol
DHF/DSS	dengue hemorrhagic fever/dengue shock syndrome
DHHS	Department of Health and Human Services
DNA	deoxyribonucleic acid
EBCLIS	EMF and Breast Cancer on Long Island Study
EDTA	ethylenediaminetetraacetic acid
EEA	European Environment Agency
EIA	environmental impact assessment
ELF	extremely low frequency radiation
EMF	electromagnetic field
EPA	U.S. Environmental Protection Agency
ETS	environmental tobacco smoke
EU	European Union
FAO	Food and Agricultural Organization (of United Nations)
FDA	Food and Drug Administration
FEMA	Federal Emergency Management Agency
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act, 1996
FoodNet	Foodborne Diseases Active Surveillance Network (of CDC)
FSIS	Food Safety and Inspection Service (of USDA)
FWS	Fish and Wildlife Service
GM	genetically modified
GRAS	generally recognized as safe
HACCP	hazard analysis of critical control points
HAV	hepatitis A virus
HBV	hepatitis B virus
HCV	hepatitis C virus
HIA	health impact assessment
HIV/AIDS	human immunodeficiency virus/acquired immunodeficiency syndrome
HPS	hantavirus pulmonary syndrome
HSEES	Hazardous Substances Emergency Events Surveillance (of ATSDR)
HUS	hemolytic uremic syndrome
IARC	International Agency for Research on Cancer
LD_{50}	lethal dose 50
MIC	methyl isocyanate
MM	malignant melanoma
MSD	musculoskeletal disorder
MSG	monosodium glutamate
MSHA	Mine Safety and Health Administration
MSW	municipal solid waste
NAAQS	National Ambient Air Quality Standards
NCHS	National Center for Health Statistics
NEPA	National Environmental Policy Act, 1969

NIEHS	National Institute of Environmental Health Sciences
NIH	National Institutes of Health
NIOSH	National Institute for Occupational Safety and Health
NMSC	non-melanoma skin cancer
NO_x	nitrogen oxides
NORA	National Occupational Research Agenda
NPL	National Priorities List
NRDC	Natural Resources Defense Council
NTOF	National Traumatic Occupational Fatalities Surveillance System
NTP	National Toxicology Program
O_3	ozone
OAQPS	Office of Air Quality Planning and Standards (of EPA)
OECD	European Organization for Economic Cooperation and Development
OPs	organophosphates
OR	odds ratio
OSCAR	Osteoporosis with Cadmium as a Risk Factor [study]
OSHA	Occupational Safety and Health Administration
PAHs	polycyclic aromatic hydrocarbons
PAYT	pay-as-you-throw
PCBs	polychlorinated biphenyls
PEP	post-exposure prophylaxis
PM	particulate matter
POPs	persistent organic pollutants
ppb	parts per billion
PPCPs	pharmaceutical and personal care products
PPE	personal protective equipment
ppm	parts per million
PSP	paralytic shellfish poison
RCRA	Resource Conservation and Recovery Act, 1976
RDD	radiological dispersal device
RF	radio frequency
RMSF	Rocky Mountain spotted fever
RR	relative risk
RVF	Rift Valley fever
SARA	Superfund Amendments and Reauthorization Act
SBS	sick building syndrome
SCE	sister chromatid exchange
SDWD	Safe Drinking Water Act
SI	System International
SMR	standardized mortality ratio
SO_2	sulfur dioxide
SPL	sound pressure level
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TCE	trichloroethylene
TFR	total fertility rate
TLV	threshold limit value
TSCA	Toxic Substances Control Act, 1976
UNEP	United Nations Environment Programme
USDA	U.S. Department of Agriculture
USGS	United States Geological Survey
USPHS	U.S. Public Health Service
UVR	ultraviolet radiation
vCJD	Creutzfeldt-Jakob disease, new variant
VHF	viral hemorrhagic fever
VOCs	volatile organic compounds
VSP	Vessel Sanitation Program (operated by CDC)
WHO	World Health Organization
WNV	West Nile virus

PART I

Background of the Field

CHAPTER 1

Introduction: The Environment At Risk

LEARNING OBJECTIVES

By the end of this chapter the reader will be able to:

- Describe how environmental health problems influence our lives.
- Discuss the potential impacts of population growth upon the environment.
- State a definition of the term *environmental health*.
- List at least five major events in the history of environmental health.
- Summarize employment opportunities in the environmental health field.

Introduction

This chapter will illustrate how the environment impacts the health of people and survival of every living being on the planet. You will learn about key terms used in environmental health and the scope of the field. The focus will be on distinguishing features of the field and the basic concepts, which are essential to this discipline. For example, one of these concepts is the relationship between world population growth and the environment. Another concept relates to historically significant environmental events and how they influenced the topics that are of current importance to the environmental health field. An additional topic involves employment classifications, career roles, and opportunities for environmental health workers. The chapter will conclude with an overview of the textbook: the roles of **environmental epidemiology** and **toxicology**, policy aspects of environmental health, examples of environmentally related agents and diseases, and specific content areas of environmental health such as air quality, water quality, food safety, and waste disposal.

Progress and Challenges in Protecting Our Environment

Although much progress has been made in protecting our environment, many lingering challenges confront humanity. Maintaining environmental quality is a pressing task for the 21st century. Often achievements in environment quality are limited primarily to the developed world, which has the financial wherewithal to address environmental health.

Improvement in environmental quality is an official goal of the US government, as articulated in *Healthy People 2020*. This goal (number 8, Environmental Health) is formatted as follows: "Promote health for all through a healthy environment."[1] A list of environmental objectives is shown in **TABLE 1.1**.

TABLE 1.1 Objectives for *Healthy People 2020*—Environmental Health Goal: Promote Health for All through a Healthy Environment

Outdoor Air Quality
EH-1 Reduce the number of days the Air Quality Index (AQI) exceeds 100, weighted by population and AQI.
EH-2 Increase use of alternative modes of transportation for work.
EH-3 Reduce air toxic emissions to decrease the risk of adverse health effects caused by mobile, area, and major sources of airborne toxics.
Water Quality
EH-4 Increase the proportion of persons served by community water systems who receive a supply of drinking water that meets the regulations of the Safe Drinking Water Act.
EH-5 Reduce waterborne disease outbreaks arising from water intended for drinking among persons served by community water systems.
EH-6 Reduce per capita domestic water withdrawals with respect to use and conservation.
EH-7 Increase the proportion of days that beaches are open and safe for swimming.
Toxics and Waste
EH-8 Reduce blood lead levels in children.
EH-9 Minimize the risks to human health and the environment posed by hazardous sites.
EH-10 Reduce pesticide exposures that result in visits to a health care facility.
EH-11 Reduce the amount of toxic pollutants released into the environment.
EH-12 Increase recycling of municipal solid waste.
Healthy Homes and Healthy Communities
EH-13 Reduce indoor allergen levels.
EH-14 Increase the proportion of homes with an operating radon mitigation system for persons living in homes at risk for radon exposure.
EH-15 Increase the proportion of new single-family homes (SFH) constructed with radon-reducing features, especially in high-radon-potential areas.
EH-16 Increase the proportion of the Nation's elementary, middle, and high schools that have official school policies and engage in practices that promote a healthy and safe physical school environment.
EH-17 (Developmental) Increase the proportion of persons living in pre-1978 housing that has been tested for the presence of lead-based paint or related hazards.

EH-18 Reduce the number of U.S. homes that are found to have lead-based paint or related hazards.
EH-19 Reduce the proportion of occupied housing units that have moderate or severe physical problems.
Infrastructure and Surveillance
EH-20 Reduce exposure to selected environmental chemicals in the population, as measured by blood and urine concentrations of the substances or their metabolites.
EH-21 Improve quality, utility, awareness, and use of existing information systems for environmental health.
EH-22 Increase the number of States, Territories, Tribes, and the District of Columbia that monitor diseases or conditions that can be caused by exposure to environmental hazards.
EH-23 Reduce the number of public schools located within 150 meters of major highways in the United States.
Global Environmental Health
EH-24 Reduce the global burden of disease due to poor water quality, sanitation, and insufficient hygiene.

Modified from US Department of Health and Human Services. Office of Disease Prevention and Health Promotion. *Healthy People 2020*: Environmental Health. Available at: https://www.healthypeople.gov/2020/topics-objectives/topic/environmental-health/objectives. Accessed January 17, 2017.

According to *Healthy People 2020*:

> Humans interact with the environment constantly. These interactions affect quality of life, years of healthy life lived, and health disparities…. Maintaining a healthy environment is central to increasing quality of life and years of healthy life. Globally, nearly 25 percent of all deaths and the total disease burden can be attributed to environmental factors. Environmental factors are diverse and far reaching.… Poor environmental quality has its greatest impact on people whose health status is already at risk. Therefore, environmental health must address the societal and environmental factors that increase the likelihood of exposure and disease.[1]

Protecting the environment means creating a world in which the air is safe to breathe, the water is safe to drink, the land is arable and free from toxins, wastes are managed effectively, infectious diseases are kept at bay, and natural areas are preserved. **FIGURE 1.1** illustrates a beautifully maintained natural area in the United States. Crucial environmental dimensions also include the impacts of disasters, the built environment, and availability of nutritious foods.[1]

The requirements of a growing world population need to be balanced against the demands for environmental preservation. Although developed countries such as the United States have made substantial progress in clearing the air and reducing air pollution, significant challenges to the environment and human health remain. For example, among the current and persistent threats to the environment in the United States are the following: trash that fouls our beaches, hazardous wastes (including radioactive wastes) leaching from disposal sites, continuing episodes of air pollution, exposures to toxic chemicals, destruction of the land through deforestation, and global warming.

The hallmarks of environmental degradation are not difficult to find: Warning signs posted on beaches advise bathers not to enter ocean water that is unsafe because of sewage contamination. In some areas of the United States, drinking water is threatened by toxic chemicals

FIGURE 1.1 A natural ecosystem in the United States. Maintaining environmental quality is a pressing task for the 21st century.

that are leaching from disposal sites. Too many factories continue to belch thick, black smoke or emit unseen pollutants. Avoidance of air pollution, which at best insults our aesthetic senses and at worst endangers our health, is often impossible. Society's appetite for lumber and new housing to satisfy the burgeoning population has resulted in clear-cutting of forests and destruction of wildlife habitats in order to accommodate new habitations for humans. Continued use of fossil fuels contributes to poor air quality and climate change.

Pollution and population growth, often associated with adverse economic circumstances, are closely connected with environmental health. In his classic article, the late Professor Warren Winkelstein wrote that "the three P's—pollution, population, and poverty—are principal determinants of health worldwide. . . ."[2(p932)] The three P's are interrelated: Population growth is associated with poverty, and both poverty and population growth are associated with pollution.

An example of the first "P" is pollution from combustion of fossil fuels (e.g., petroleum and coal), which disperses greenhouse gases along with other pollutants into the atmosphere. This process is believed to be a cause of global warming that in turn may have wide-ranging adverse effects. One such effect is to advance the range of disease-carrying insects, bringing them into new geographic areas; for example, mosquito-borne diseases such as the West Nile virus and dengue fever may appear in areas that previously were free from these conditions. (Refer to the chapter on zoonotic and vector-borne diseases for more information.) The second "P" is population, which is growing exponentially in many parts of the world, especially the less-developed areas, and may result in a worldwide population of up to 10 to 12 billion people during the 21st century; the presence of so many people may exceed the carrying capacity (defined later in the chapter) of the earth by a factor of two. The third "P," poverty, is linked to population growth; poverty is one of the well-recognized determinants of adverse health outcomes.

A recent environmentally related adverse health outcome may be attributed, at least in part, to one of the three P's: population growth (which is associated with urban crowding). As a result of known and unknown environmental and other factors, threats to the human population periodically arise from infectious disease agents. (This topic is discussed in the chapter on zoonotic and vector-borne diseases.) For example, influenza viruses threaten the world's population from time to time. Environmental factors that are likely to advance the spread of influenza viruses include intensive animal husbandry practices needed to supply food to the world's growing population. These practices create extremely crowded conditions among food animals coupled with their close residential proximity to humans. Often such farm animals are treated with antibiotics that contribute to the proliferation of antibiotic resistant strains of bacteria.

Several years ago, public health officials became concerned about the possible occurrence of a human pandemic of avian influenza, caused by the avian influenza A (H5N1) virus. Large outbreaks of avian influenza occurred on poultry farms in Asia. Apparently, some transmission of the virus from birds to humans also occurred. The disease (called bird flu) produces a severe human illness that has a high fatality rate. Health officials were concerned that the virus might mutate, enabling human-to-human transmission; if human-to-human transmission of the virus erupted, a pandemic might result. Contributing to the possible epidemic transmission of influenza (and other communicable diseases) is the ability of human beings to travel rapidly from one area of the globe to another.

An example of a global outbreak of influenza was the pandemic caused by swine flu (H1N1 influenza). In 2009, swine flu spread through North America to other parts of the globe. The World Health Organization (WHO) declared a pandemic of influenza was underway.

Another example of a condition that threatens the human population as well as all life on earth is global climate change. **EXHIBIT 1.1** presents a case study of global climate change. More information on this topic appears in the chapter on air quality. Refer to **FIGURE 1.2** for ways climate change threatens your health.

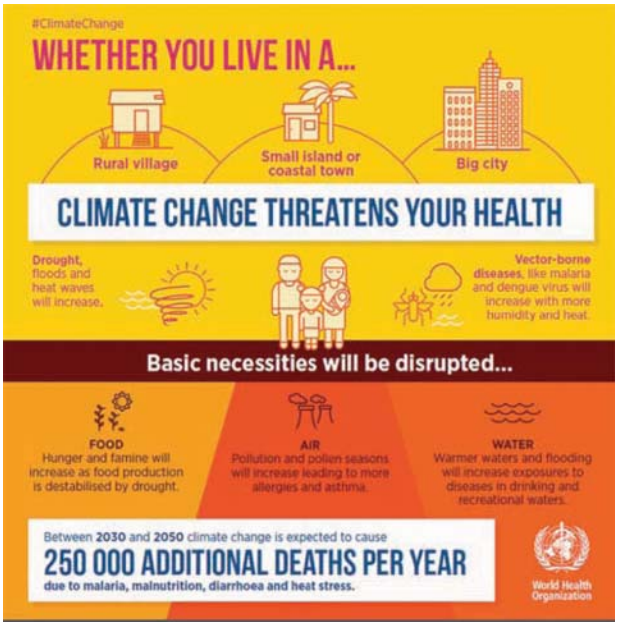


FIGURE 1.2 Climate change threatens your health.
Reproduced from World Health Organization. Climate change and human health. Available at: http://www.who.int/globalchange/mediacentre/events/climate-health-conference/climatechange-infographic2.jpg?ua=1. Accessed March 22, 2017.

EXHIBIT 1.1

Case Study: Climate Change: the Most Pressing Environmental Health Issue for the 21st Century

Two leading health bodies, a US governmental agency and a global health organization, have made the following declarations:

Climate change endangers human health, affecting all sectors of society, both domestically and globally. The environmental consequences of climate change, both those already observed and those that are anticipated, such as sea-level rise, changes in precipitation resulting in flooding and drought, heat waves, more intense hurricanes and storms, and degraded air quality, will affect human health both directly and indirectly. Addressing the effects of climate change on human health is especially challenging because both the surrounding environment and the decisions that people make influence health. For example, increases in the frequency and severity of regional heat waves—likely outcomes of climate change—have the potential to harm a lot of people.

—National Institute of Environmental Health Sciences

* * * * *

- "Climate change affects the social and environmental determinants of health—clean air, safe drinking water, sufficient food and secure shelter.
- Between 2030 and 2050, climate change is expected to cause approximately 250 000 additional deaths per year, from malnutrition, malaria, diarrhea, and heat stress.
- The direct damage costs to health (i.e., excluding costs in health-determining sectors such as agriculture and water and sanitation), is estimated to be between US$ 2–4 billion/year by 2030.
- Areas with weak health infrastructure—mostly in developing countries—will be the least able to cope without assistance to prepare and respond.
- Reducing emissions of greenhouse gases through better transport, food, and energy-use choices can result in improved health, particularly through reduced air pollution."

—World Health Organization

Modified and reproduced from Portier CJ, Thigpen TK, Carter SR, et al. *A Human Perspective on Climate Change*: A Report Outlining the Research Needs on the Human Health Effects of Climate Change. Research Triangle Park, NC: Environmental Health Perspectives/National Institute of Environmental Health Sciences; 2010; and World Health Organization. Climate change and health. June 2016. Available at: http://www.who.int/mediacentre/factsheets/fs266/en/. Accessed March 22, 2017

Significance of the Environment for Human Health

The environment is intimately connected with human health, illness, and mortality. For example, although figures on the role of environmental factors in global mortality vary considerably, the environment is undoubtedly a salient influence on human deaths. Some estimates from the 1990s placed the toll of the world's deaths caused by environmental factors at around 40%.[3] World Health Organization data from 2012 suggested that almost one-quarter of global deaths result from an unhealthy environment. Exposures to potentially hazardous agents such as microbes, toxic chemicals and metals, pesticides, and ionizing radiation account for many of the forms of environmentally associated morbidity (acute and chronic conditions, allergic responses, and disability) and mortality that occur in today's world. These environmentally related determinants are believed to be important for the development of chronic diseases such as cancer, although most chronic diseases are thought to be the result of complex interactions between environmental and genetic factors.[4] All human beings are affected in some way by exposure to environmental hazards associated with lifestyle: at work, at home, during recreation, or while traveling on the expressway. **TABLE 1.2** provides examples of the scope of disease burden associated with exposure to environmental hazards.

Vulnerable Subgroups of the Population

The elderly, persons with disabilities and chronic diseases, pregnant women, and children are more likely to be affected by environmental hazards than are members of the general population. With respect to age, research from WHO underscored the differential effects of environmental influences across the life course.[5] Age groups most likely to be impacted are children younger than 5 years, children as old as 10 years to a lesser degree, and older adults from 50 to 75 years.

TABLE 1.2 The Scope of Environmental Health Problems in the World and the United States

- The World Health Organization (WHO) estimated that in 2012, approximately 12.6 million deaths across the globe (23% of all deaths) were linked to environmental sources.[a]
- The US Environmental Protection Agency reported that in 2015, industry released 881 million pounds (400 million kilograms) of toxic chemicals into the air and water (690 million pounds [313 million kilograms] into the air and 191 million pounds [87 million kilograms] into the water). On the positive side, a declining trend in the release of these chemicals occurred between 2005 and 2015.[b]
- Elevated blood levels of lead continue to be an important problem in the United States, with children living in at least 4 million households that expose them to excessive amounts of lead.[c]
- The number of people with asthma in the United States increased to 8% of the population in 2009; environmental factors such as tobacco smoke and air pollution are asthma triggers.[d]
- "Strong evidence exists that industrial chemicals widely disseminated in the environment are important contributors to… the global, silent pandemic of neurodevelopmental toxicity."[e]
- "Using air quality standards established by WHO, experts have estimated that 1.3 billion of the world's urban inhabitants breathe air that exceeds these quality standards."[f]
- Environmental factors are thought to contribute significantly to various forms of cancer, including cervical cancer, prostate cancer, and breast cancer.

Data from:
[a]Prüss-Üstün A, Wolf J, Corvalan CF, et al. Preventing disease through healthy environments. Geneva, Switzerland: World Health Organization; 2016.
[b]US Environmental Protection Agency. Introduction to the 2015 TRI national analysis. Available at: https://www.epa.gov/sites/production/files/2017-01/documents/tri_na_2015_complete_english.pdf. Accessed June 29, 2017.
[c]Centers for Disease Control and Prevention. Lead home page. Available at: https://www.cdc.gov/nceh/lead. Accessed June 30, 2017.
[d]Centers for Disease Control and Prevention. Vital signs. Asthma in the US. Available at: https:// www.cdc.gov/vitalsigns/asthma/index.html. Accessed June 30, 2017.
[e]Grandjean P, Landrigan PJ. Neurobehavioural effects of developmental toxicity. *Lancet Neurol*. 2014;13(3):330-338.
[f]Butterfield PG. Upstream reflections on environmental health: An abbreviated history and framework for action. *Advances in Nursing Science*. 2002;25:34.

Children represent an especially vulnerable group with respect to exposure to hazardous materials, including pesticides and toxic chemicals. Their immune systems and detoxifying organs are still developing and are not fully capable of responding to environmental toxins.[6] Children may be exposed more often than adults to toxic chemicals in the ambient outdoor air and in the soil because they spend more time outside.[7,8]

Environmental Health and the Developing World

Residents of developing countries suffer far more from problems associated with environmental degradation than do those who live in developed countries; this observation holds true despite the fact that developed countries are highly industrialized and disseminate vast quantities of pollutants into the environment from industrial processes and motor vehicles. In comparison with developing countries, wealthy nations provide better access to medical care and are better able to finance pollution controls.

In the developing world, the pursuit of natural resources has caused widespread deforestation of tropical rain forests and destruction of wildlife habitat. Although these two issues have been the focus of much publicity, less widely publicized environmental hazards such as water contamination, air pollution, unsanitary food, and crowding take a steep toll in both morbidity and mortality in developing countries.[9]

One region of the world that at present confronts serious environmental threats is Asia. Many of the countries in this region are experiencing declines in the amount of forest land, unintentional conversion of arable land to desert, and rising levels of pollution. In order to meet the demands of the rapidly increasing populations of South Asia, rural farmers clear forests and cultivate land that erodes easily and eventually becomes useless for agriculture.[10] **Runoff** from the land contributes to water pollution. The world's most populous country, China, faces many challenging environmental problems including water shortages in the northwest; severe air pollution in major cities, such as Beijing; and increasing desertification.[11]

Environmental Risk Transition

The term **environmental risk transition** has been used to characterize changes in environmental risks that happen as a consequence of economic development in the less-developed regions of the world. Environmental risk transition is characterized by the following circumstances:

In the poorest societies, household risks caused by poor food, air, and water quality tend to dominate. The major risks existing in developing countries today are of this type—diarrhea is attributable to poor water/sanitation/hygiene, acute respiratory diseases to poor housing and indoor air pollution from poor quality household fuels, and malaria to poor housing quality, although all are of course influenced by other factors as well (malnutrition in particular). . . . As these problems are brought under control, a new set tends to be created at the regional and global level through long-term and long-range pollutants, such as acid rain precursors, ozone-depleting chemicals, and greenhouse gases.[12(p38)]

Population and the Environment

Currently increasing at a geometric rate, the human population threatens to overwhelm available resources; some areas of the world face periodic food scarcity and famine. A number of factors have contributed to population growth, including increases in fertility and reductions in mortality. One of the consequences of population growth has been to encourage the conversion of large rural and forested areas of the earth into cities. Urbanization is linked to numerous adverse implications for the health of populations, including increasing rates of morbidity and mortality. Refer to the following text box, which discusses the consequences of continued population growth.

HOMO SAPIENS—A SUICIDAL SPECIES?

Largely as a result of human action, profound changes are occurring in our environment. . . . The basic cause of almost all of these problems is the world's large and growing human population, which consumes so much energy and produces such large quantities of toxic wastes. . . . Environmental changes, if accompanied by economic and political instability, could lead to the collapse of organized health services. In an era of scarcities of food, water, and other resources, and of a threat to survival, priorities should be reassessed.[13(pp121,123)]

Population Growth Trends

The human population has grown exponentially over the past 200 years and reached 6 billion in June 1999.[14] By 2017, this number reached 7.5 billion. The current trend is for world population growth to continue at a high rate, as noted in the following passage:

> Every day we share the earth and its resources with 250,000 more people than the day before. Every year there are another 90 million mouths to feed. That is the equivalent of adding a city the size of Philadelphia to the world population every week; a Los Angeles every two weeks; a Mexico every year; and a United States and Canada every three years.[15(p30)]

FIGURE 1.3 characterizes this burgeoning growth for a single year—2002. During that year the world population increased by 2⅓ persons per second, or 141 persons per minute. This annual growth rate would be equivalent to a Boeing 737 jetliner carrying a new group of 141 passengers each minute.

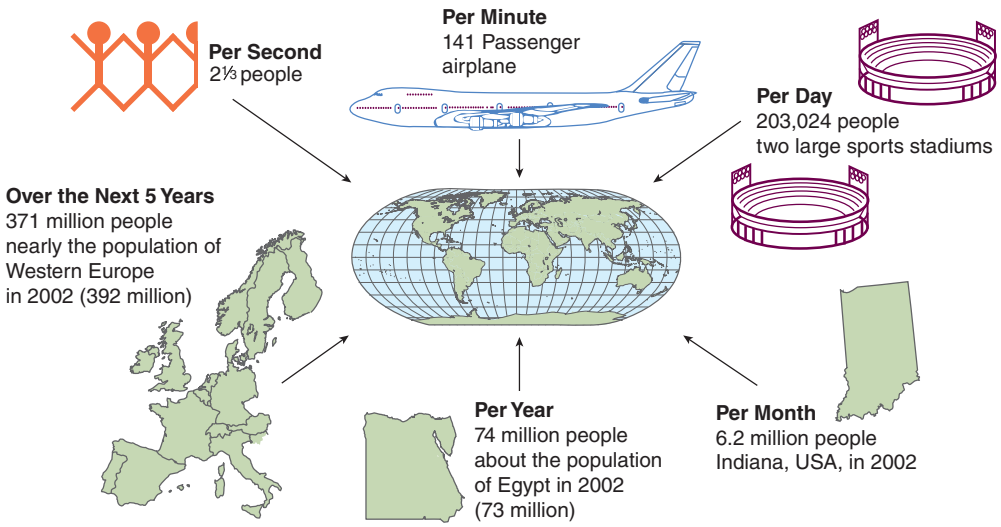


FIGURE 1.3 Net additions to the world: 2002. In 2002, the world gained 2⅓ people per second.
Modified from US Census Bureau. International Population Reports WP/02. *Global Population Profile: 2002*. Washington, DC: US Government Printing Office; 2004:14.

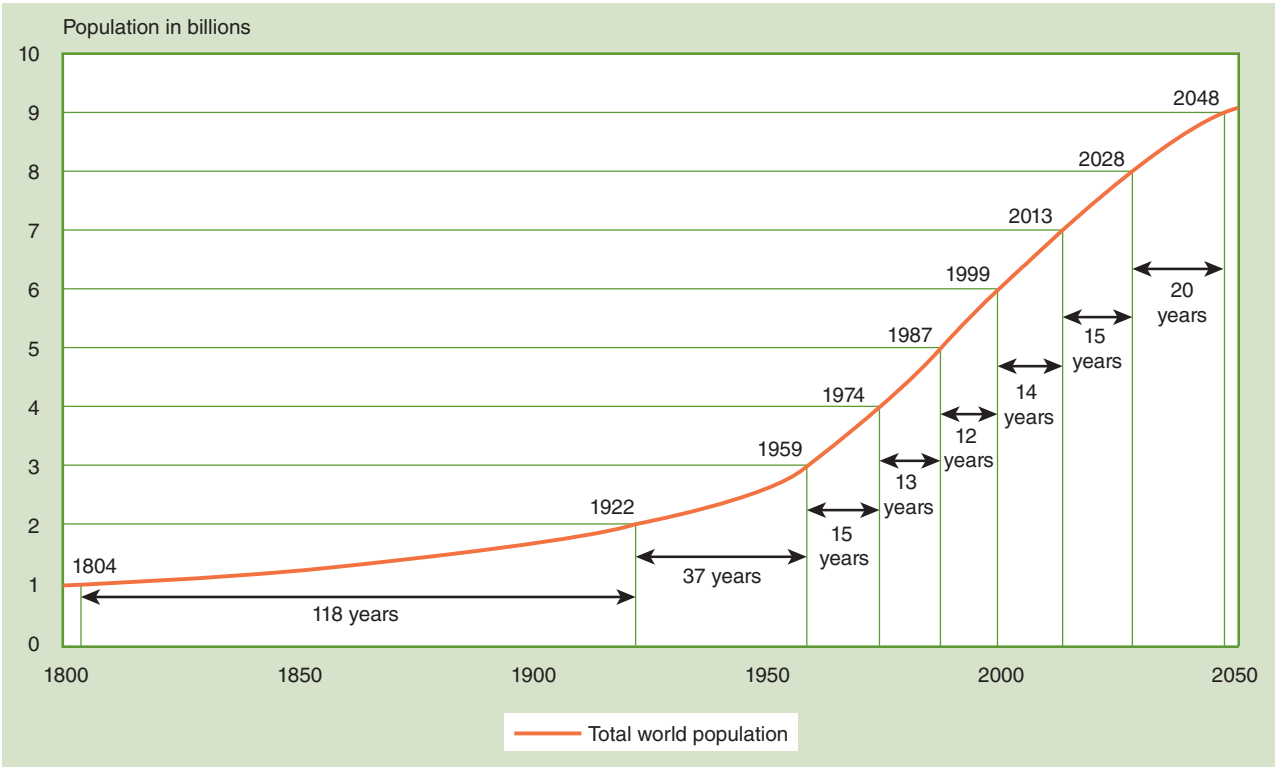


FIGURE 1.4 Time to successive billions in world population: 1800 to 2050.
Reproduced from US Census Bureau, International Population Reports WP/02. *Global Population Profile: 2002*. Washington, DC: US Government Printing Office; 2004:11.

From the origin of the species *Homo sapiens* (assumed to be about 250,000 years ago) to CE 1800, the population of the world grew by 1 billion individuals.[16] From 1800 to 1922 (122 years), the population added another 1 billion persons. Since 1922, the population has increased at a phenomenal rate: Another billion persons were added after 37 years, 15 years, and 13 years, respectively. Only 12 years elapsed before an additional billion persons were added between 1987 and 1999. See **FIGURE 1.4**.

Another perspective on population growth is the time that it takes for the population to double. From 1931 to 1974 (a 43-year interval), the earth's population doubled; it is projected to double again during approximately the same interval (1974 to 2018).[17] Estimates suggest that the world's population will reach 8 billion persons between the years 2018 and 2028.

In 1950, the world's five most populous countries were China, India, the United States, Russia, and Japan; at the turn of the 21st century, Russia and Japan were replaced by Indonesia and Brazil. In 2050, India will become the world's most populous country; China will fall to second place, the United States will remain in third place, Indonesia will be in fourth place, and Brazil will be replaced by Nigeria.

Around the 1960s, annual rates of population increase topped out at slightly more than 2% (an 81 million absolute increase annually since the 1980s).[18] Demographers project that the human population eventually may stabilize at a size—about 10 billion persons—that is about three quarters larger than it was around 2000.

Population Dynamics

The term **population dynamics** refers to the ever-changing interrelationships among the set of variables that influence the demographic makeup of populations as well as the variables that influence the growth and decline of population sizes. Among the factors that relate to the size as well as the age and sex composition of populations are fertility, death rates, and migration.

Fertility

One of the measures of fertility is the **completed fertility rate (total fertility rate)**, which is the "[n]umber of children a woman has given birth to when she completes childbearing."[19(p2)] In the United States, the completed fertility rate in 2012 was around 2.0 children per woman;[19] the natural population replacement rate is estimated to be around 2.1. (See the breaking news box about the decline in fertility).

During the baby boom era at the end of the 1950s, the US fertility rate exceeded 3.5 births per woman. Presently, western European countries have low fertility rates; also, the rates are declining in most regions of the developing world.[20] The United States, Canada, Japan, South Korea, Thailand, China, and many countries in

BREAKING NEWS:

"The US fertility rate fell [in 2016] to the lowest point since record keeping started more than a century ago, according to statistics released by the Centers for Disease Control and Prevention." (CNN, August 11, 2016). The general fertility rate (total number of births per 1,000 women aged 15–14) declined to 62.0 in the fourth quarter of 2016. In comparison, the general fertility rate was 118.0 in 1960.

Europe are at or below the replacement rate for fertility. Despite the declines in fertility rates in some Asian countries to levels approaching replacement rates, the populations in these countries will continue to increase because of births among the large cohort of persons of childbearing age who were born when fertility rates were high. Those individuals form a substantial proportion of the population in China and other rapidly industrializing countries. However, the overall trend is for the world's population to age and be composed of increasing numbers of older individuals.

In comparison with the developed world, the fertility rates are considerably higher (at about 4.0 births per woman) in many Asian countries, Latin American countries, and African countries. In the future, their relatively higher fertility rates will enable these regions of the developing world to claim the largest population sizes. (See **FIGURE 1.5**.)

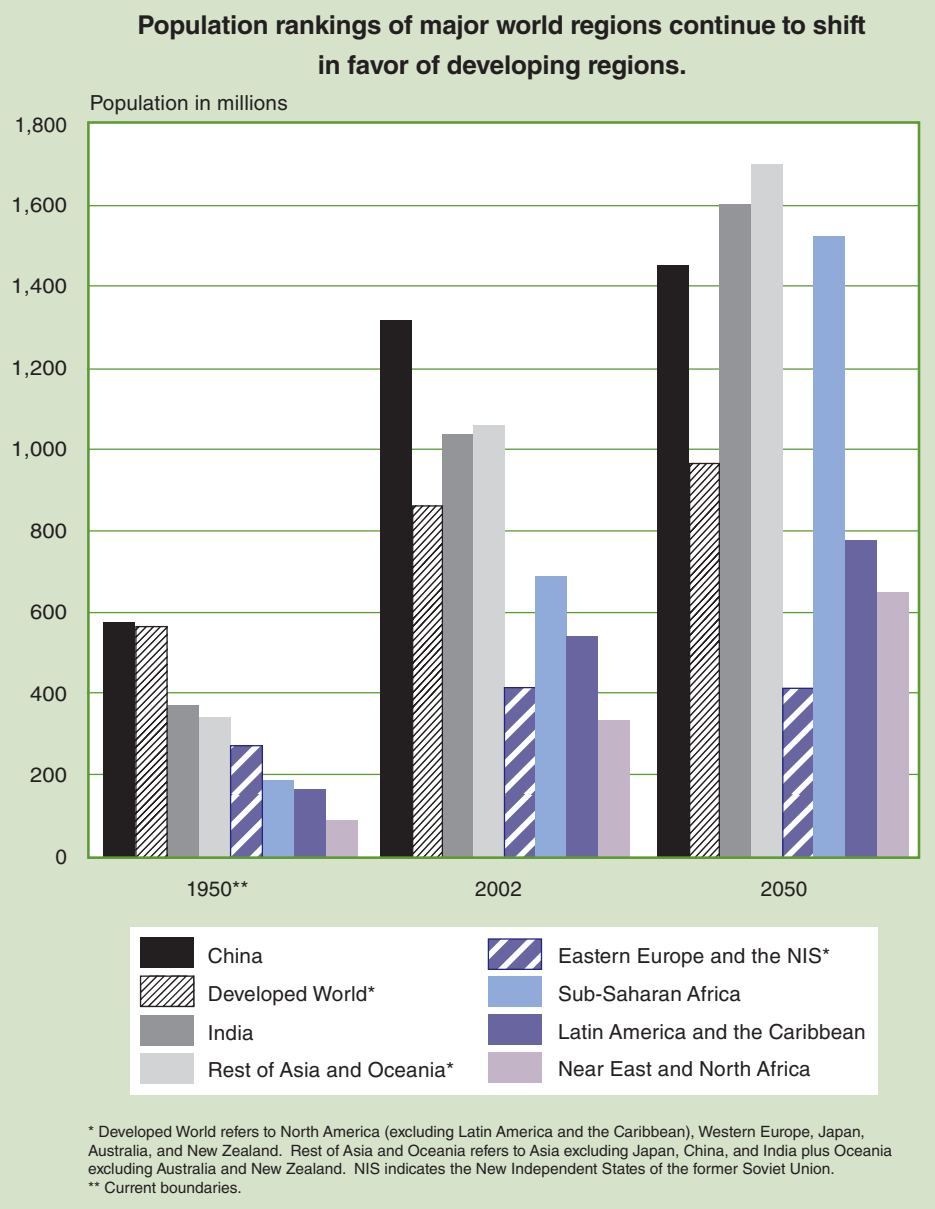


FIGURE 1.5 Regional distribution of global population: 1950, 2002, and 2050.

Reproduced from US Census Bureau. International Population Reports WP/02. *Global Population Profile: 2002*. Washington, DC: US Government Printing Office; 2004:12.

MORTALITY TERMS

Burden of disease is defined as "[t]he impact of disease in a population. An approach to the analysis of health problems, including loss of healthy years of life." One measure of the burden of disease is disability-adjusted life years (DALYs).

Life expectancy (expectation of life) refers to "[t]he average number of years an individual is expected to live if current mortality rates continue to apply." *Life expectancy at birth* is the "[a]verage number of years a newborn baby can be expected to live if current mortality trends continue."

Disability-adjusted life years (DALYs) refer to "adjustment of life expectancy to allow for long-term disability as estimated from official statistics." "A DALY lost is a measure of the burden of disease on a defined population."

Porta M, ed. *A Dictionary of Epidemiology*. 6th ed. New York, NY: Oxford University Press; 2014.

Mortality

Mortality has declined markedly over time in both industrialized and less-developed countries. Adult mortality and infant and child mortality have demonstrated downward trends. Declining mortality in the developed world began approximately 200 years ago; in the developing world, substantial declines in mortality have occurred more recently during the past 50 years or so. The reduction in mortality has been accomplished through measures that have included public health improvements, famine control, and increased availability of drugs and vaccines. Some additional terms related to mortality are burden of disease, life expectancy, and disability-adjusted life years. (Refer to the text box.)

Migration

Migration has continued to feed global population growth; more than 1 billion of the world's residents are migrants. Census estimates indicate that by the year 2050, the US population will grow by another 100 million and that about one-third of this growth will be from migration. Persons who migrate tend to cluster in a limited group of 10 countries. In 2015, the three leading countries for receiving international migrants were the United States, Germany, and the Russian Federation.[21] Reasons for migration include the search for economic betterment; a large proportion of those who relocate are migrant workers. Forced migration (forcible displacement of persons) is a means of escaping from persecution for religious and political reasons and to obtain relief from unstable conditions in one's home country. Toward the conclusion of 2015, more than 65 million persons were displaced. Many were refugees from Syria, Afghanistan, and Somalia.[21]

Demographic Transition

Demographic transition is the alteration over time in a population's fertility, mortality, and makeup.[14] (Note that demographic transition theory does not include the effects of migration upon the age and sex composition of a population.) According to the demographic transition theory, developed societies have progressed through three stages that have affected their age and sex distributions.

The three phases can be demonstrated by hypothetical population pyramids, which are graphs that show the distribution of a population according to age and sex. Examples of the population pyramids at stages 1 through 3 are shown in **FIGURE 1.6**. Stage 1 characterizes a population at the first stage of demographic transition when most of the population is young and fertility and mortality rates are high; overall, the population remains small. Stage 2 shows a drop in mortality rates that occurs during the demographic transition; at this stage fertility rates remain high, and there is a rapid increase in population, particularly among the younger age groups. In comparison with the narrow triangular shape of the population distribution at stage 1, this population pyramid also is triangular in shape but has a wider base. Stage 3 reflects dropping fertility rates that cause a more even distribution of the population according to age and sex.

Epidemiologic Transition

The term **epidemiologic transition** is used to describe a shift in the pattern of morbidity and mortality from causes related primarily to infectious and communicable diseases to causes associated with chronic, degenerative diseases. The epidemiologic transition accompanies the demographic transition. The epidemiologic transition already has taken place in the populations of most developed countries (a process that required approximately one century) but has not occurred yet in many developing countries.

One reflection of the epidemiologic transition is the growing burden of chronic, degenerative diseases, especially in developed countries and to a lesser extent in developing countries, as a consequence of population aging. Chronic, degenerative diseases include cardiovascular diseases, cancer, neuropsychiatric conditions, and injuries; these conditions are becoming the major causes of disability and premature death in many nations. Nevertheless, in developing countries communicable and infectious diseases remain the leading causes of morbidity and mortality.

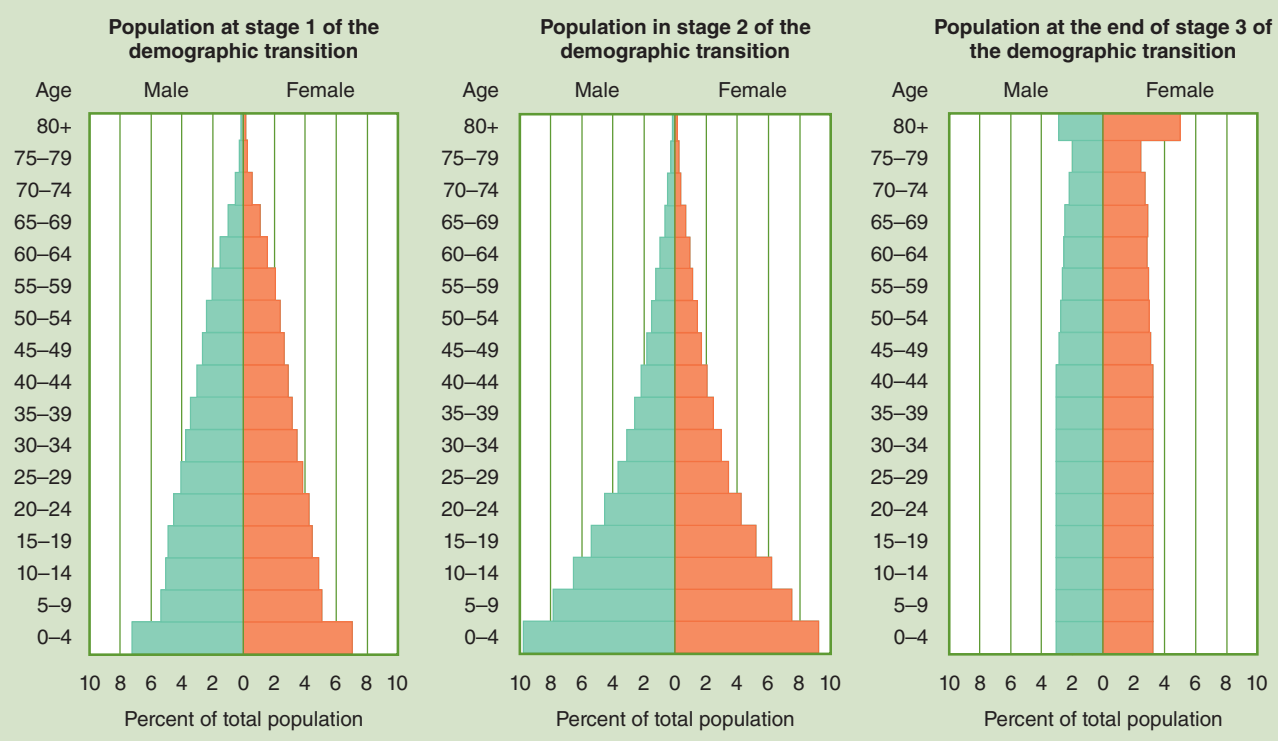


FIGURE 1.6 The demographic transition in three stages of age and sex composition: stage 1 (left), stage 2 (middle), and stage 3 (right).
Reproduced from Kinsella K, He W. US Census Bureau. International Population Reports P95/09-1. *An Aging World: 2008*. Washington, DC: US Government Printing Office; 2009:20.

Consequences of Population Increases

Rapid growth of the world's population contributes to the deterioration of the environment through widespread depletion of natural resources and by causing the levels of air, water, and other forms of pollution to increase. Also, the resources available per person decrease as the total number of individuals on the planet continues to increase geometrically. Consequently, population growth is a determinant of the number of persons who live in poverty. In already crowded regions, an even larger population means that the size of most people's living spaces must decline and population density must increase. Population density and associated urban crowding are dimensions of environmental degradation associated with increases in the spread of infectious and communicable diseases.

Unless significant technological innovations can be introduced, merely feeding the world's hungry population will become problematic. Many developing countries, where population growth rates are among the highest in the world, are reaching the limit of their abilities to provide for the economic and social needs of their citizens. The United Nations Secretariat states that:

> …excessive population pressure in specific geographical areas can pose serious ecological hazards, including soil erosion, desertification, dwindling supplies of firewood, deforestation and the degradation of sources of fresh water. Often the link between population pressure and those types of environmental stress is the growth in the relative and absolute number of persons living in poverty. The result is marginalization of small-scale farmers and pressure on larger numbers to migrate from distressed areas. In many cases the result is also the prevalence of environmentally related diseases.[22(p32)]

The effects of rapid growth of the world's population include:

- Urbanization
- Overtaxing carrying capacity (defined later in this chapter)
- Food insecurity
- Loss of biodiversity

Urbanization and the Environment

The past two centuries have seen a rapid increase in the number of cities over the entire globe.[23] The proportion of urban residents has increased from about 5% in 1800 to 50% in 2000 and is expected to reach about 66% by 2030.[22] **FIGURE 1.7** illustrates the growth of the world's urban population between 1975 and 2015 for low- and middle-income countries in comparison with high-income countries. Although the

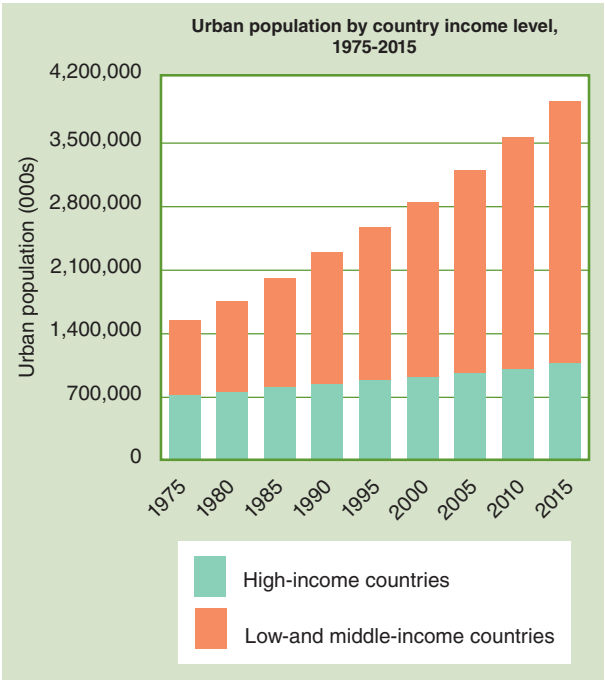


FIGURE 1.7 Urban population by country income level, 1975-2015 (1.84% total annual urban population growth between 2015 and 2020).
Reproduced from World Health Organization. *Urban population growth*. Available at: http://who.int/gho/urban_health/situation_trends/urban_population_growth/en/index1.html. Accessed July 2, 2017.

proportion of urban residents has increased in both categories, a relatively larger growth in the number of urban residents is projected to occur among low-income countries. This trend is apparent in the figure and is forecast to continue into the future. On average, the total urban population will grow by 1.84% annually between 2015 and 2020. (See Figure 1.7.)

The factors that lead to urbanization include industrialization, availability of food, employment opportunities, lifestyle considerations, and escape from political conflict.[23] Tied to increases in urbanization are numerous adverse health impacts, particularly in developing countries. Among the most important causes of morbidity and early death in urban environments of developing countries are environmentally related diseases and accidents.[24] According to McMichael:

> Large cities in the least developed countries typically combine the traditional environmental health problems of poverty, particularly respiratory and enteric infections, with those of poor quality housing and unregulated industrialization. Residents therefore are often at **risk** from diseases and injuries associated with poor sanitation, unsafe drinking water, dangerous roads, polluted air, indoor air pollution and toxic wastes.[23(p1119)]

The following text box lists hazards associated with the urban environment.

Megacities

The term **megacity** denotes an urbanized area that has 10 million or more inhabitants; in 2016, there were 31 megacities that contained slightly more than 6.8% of the world's population.[25] Examples of megacities and their respective 2016 populations (in millions) are Tokyo (38.1), Shanghai (24.5), Mumbai (formerly known as Bombay; 21.4), Sao Paulo (21.3), and Mexico City (21.2). The two megacities in the United States are New York (18.6) and Los Angeles (12.3).

HAZARDS TO HEALTH WITHIN THE URBAN ENVIRONMENT

1. Biological pathogens or pollutants within the human environment that impair human health—including pathogenic agents and their vectors (and reservoirs); for instance, the many pathogenic microorganisms in human excreta, airborne pathogens (for instance, those responsible for acute respiratory infections and tuberculosis), and disease vectors such as malaria-carrying (*Anopheline*) mosquitoes
2. Chemical pollutants within the human environment, including those added to the environment by human activities (e.g., industrial wastes) and chemical agents present in the environment independent of human activities
3. The availability, cost, and quality of natural resources on which human health depends—for instance, food, water, and fuel
4. Physical hazards (e.g., high risks of flooding in houses and settlements built on floodplains or of mud slides or landslides for houses on slopes)
5. Aspects of the built environment with negative consequences on physical or psychosocial health (e.g., overcrowding, inadequate protection against noise, inadequate provision of infrastructure, services, and common areas)
6. Natural resource degradation (e.g., of soil and water quality) caused by wastes from city-based producers or consumers that impacts on the health/livelihoods of some urban dwellers
7. National/global environmental degradation with more indirect but long-term influences on human health

Modified and reproduced with permission from Satterthwaite D. The impact on health of urban environments. *Environ Urban*. 1993;5:88.

FIGURE 1.8 Street scene in a crowded megacity (Mexico City).

Megacities have major influences upon the environment in a number of ways (e.g., demands for energy, potable water, construction materials, food, sewage processing, and solid waste disposal). **FIGURE 1.8** shows street life in a crowded megacity.

Carrying Capacity

Carrying capacity is "[t]he maximum number of individuals that can be supported sustainably by a given environment."[26] Both human and nonhuman populations may be threatened with disastrous consequences when available resources are exhausted. "Like a bacterial colony in a culture medium, we are susceptible to depletion of nutriments and to poisoning by our own waste products."[15(p123)]

Animal Populations

In the animal kingdom, the carrying capacity of an environment governs population size. In nature, the factors of food availability, reproductive behavior, and infectious diseases tend to keep animal populations in check. An example of an animal population kept in check by food availability follows: The U.S. Coast Guard shipped 29 reindeer to St. Matthew Island in the Bering Sea during the World War II era.[26] The deer were intended as a source of meat for personnel on the island; however, no deer were ever culled and all 29 remained when the war ended. An abundance of deer fodder was available on the island. By the early 1960s, the original deer population had swelled to 6,000 animals. Soon afterward, as a result of overgrazing and depletion of food sources for the deer, the population—having declined to fewer than 50 animals in 1966—faced extinction.

In a given area, the growth of animal populations appears to be sequenced according to the following characteristic patterns:

> "Logistic growth, responding to immediate negative feedback, as carrying capacity is approached
>
> Domed or capped growth, responding to deferred negative feedback but necessitating a period of excess mortality
>
> Irruptive growth, with a chaotic post-crash pattern."[18(p978)]

Human Populations

The factors that lead to the crash of animal populations are similar to those that could threaten the survival of the human race. Human life is not possible without adequate food, breathable air, and safe water. Agricultural land must continue to be arable. There needs to be a diversity of plant and animal species. If these components of the human life support system are disrupted by overpopulation of the planet, the species *Homo sapiens* could suffer a population crash. This outcome would be in line with Malthusian predictions.

In 1798, Thomas Malthus authored *First Essay on Population*, which theorized that the human population had the potential to grow exponentially.[16] According to this scenario, the population could outstrip available resources. Malthus suggested that "positive checks" for excessive population growth rates were epidemics of disease, starvation, and population reduction through warfare. The growth of the population could be constrained also through "preventive checks" such as not allowing people to marry.

Endangerment of the human population through ecological damage is not far fetched: Previous history has recorded incidents of decimation and collapse of civilizations that were associated with disruption of the environment. It is believed that approximately 5,000 years ago, Mesopotamia, a renowned ancient civilization, declined as a result of agricultural practices that caused soil erosion, buildup of salt in the soil, and the filling of irrigation channels with silt.[27] During medieval times, crowded cities of Europe were devastated by plague and other infectious diseases. In the interval between the 13th and 16th centuries, global temperatures declined by approximately 1°C (1.8°F), contributing to the decimation of societies that were located in the far north (e.g., Viking settlements in Greenland).

Food Insecurity and Famine

The term **food insecurity** refers to a situation in which supplies of wholesome foods are uncertain or may have limited availability. Food insecurity and famine may occur when the carrying capacity in a

particular geographic area is exceeded. An illustration of the effect of exceeding the carrying capacity in a local geographic area is the occurrence of a local subsistence crisis, which follows when the ability of land and available water to produce food are overtaxed.[18] In theory, low nutritional levels that accompany local subsistence crises may cause population mortality to increase so that mortality is brought into balance with fertility, stabilizing the population size. Periodically, food insecurity is a reality in some developing regions. For example, food insecurity endangers as much as one-third of Africa, and the prognosis for increasing the food supply in some African countries is poor.[27]

Loss of Biodiversity

The word *biodiversity* is formed from the combination of *biological* and *diversity*. An adequate definition of biodiversity is not readily available. Nevertheless, the term **biodiversity** generally refers to the different types and variability of animal and plant species and ecosystems in which they live.[28] With respect to a particular geographic area, biodiversity involves diversity in the genes of a population of a given species, diversity in the number of species, and diversity in habitats. Biodiversity is considered to be an essential dimension of human health.[29]

The dramatic human population growth during the past few decades and concomitant increases in urbanization and industrialization have caused the physical environment to be degraded substantially; one of the consequences of unchecked population growth is hypothesized to be accelerated loss of biodiversity. Human activities are thought to be related to the spread of harmful insect vectors, extinctions of species, and loss of flora; some of these plants and trees could be the source of valuable commodities such as new pharmaceuticals. Ultimately, loss of biodiversity may pose a danger to food production as a result of the growth in numbers of invasive species and the eradication of helpful plants and insects. An example of the loss of biodiversity is the destruction of tropical rain forests that has culminated in the extinction of some flowering plants that may have had future medical value.[29]

Definitions Used in the Environmental Health Field

The Environment

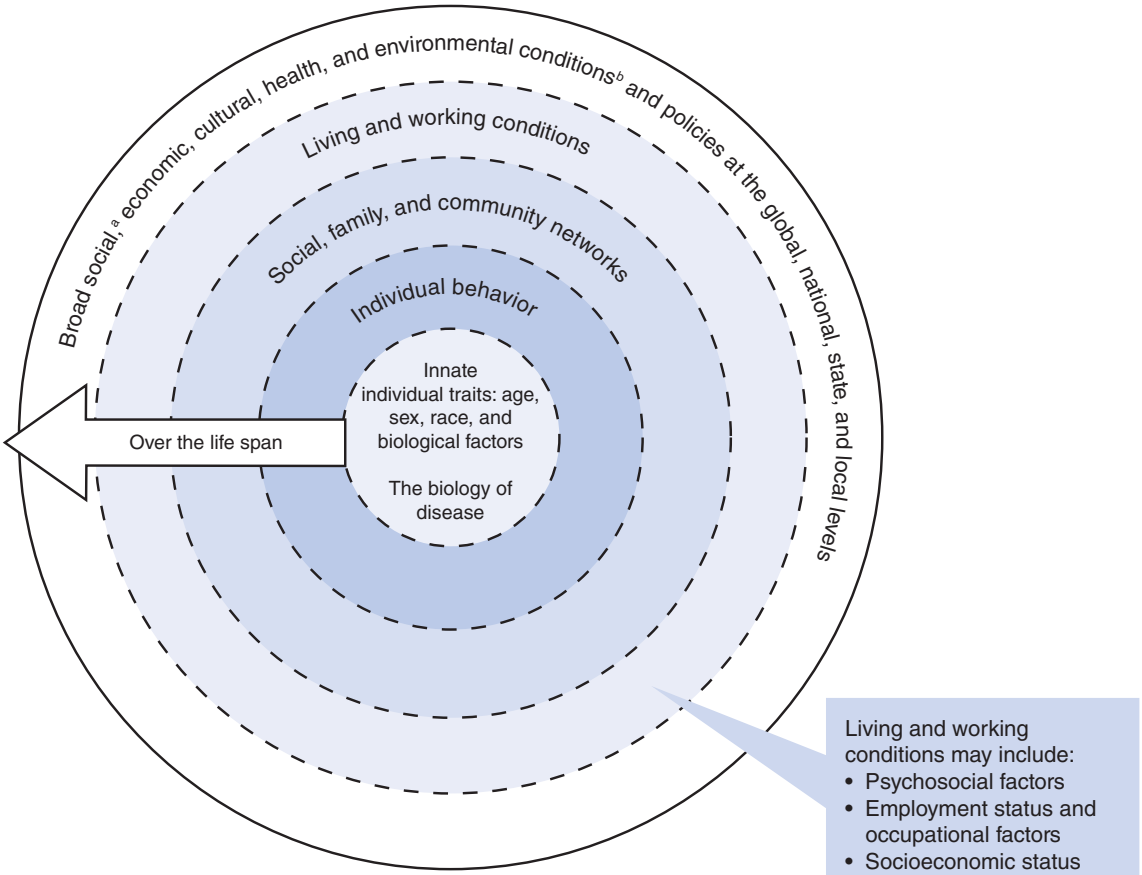
The term **environment** refers to "the complex of physical, chemical, and biotic factors (as climate, soil, and living things) that act upon an organism or an ecological community and ultimately determine its form and survival."[30] This definition pertains to the physical environment. Examples of physical environmental factors (as noted previously) that affect human health include toxic chemicals, metallic compounds, ionizing and nonionizing radiation, and physical and mechanical energy. These factors will be discussed in more detail later in the text.

The term *environment* captures the notion of factors that are external to the individual, as opposed to internal factors such as genetic makeup. In contrast to the physical environment, described in the foregoing definition, the **social environment** encompasses influences upon the individual that arise from societal and cultural factors. Among the major determinants of health are the environment (physical and social), personal lifestyle factors, constitutional factors such as heredity and human biology, and healthcare systems dimensions such as access to and quality of medical care and methods for organization of healthcare systems.[31] A model that describes these aspects of health is the **ecological model**, which proposes that the determinants of health (environmental, biological, and behavioral) interact and are interlinked over the life course of individuals. (Refer to **FIGURE 1.9**.) From the model it may be inferred that the environment is one component of many interacting dimensions that affect the health of populations.

Ecological System (Ecosystem)

Ecosystems are one of the important dimensions of life in the biosphere. All life on earth survives in the biosphere, which consists of the atmosphere and the earth's surface and oceans. The biosphere covers a narrow range from about 6 miles (9.6 kilometers) above the earth to the surface of the earth to the deepest ocean trenches, some of which are 36,000 feet deep (about 11,000 meters). One of the crucial aspects of the earth's biosphere is energy flow; the ultimate source of energy for all living beings on earth is the sun. Energy flows from the sun in the form of electromagnetic radiation (e.g., ultraviolet radiation, infrared radiation, and visible light). Only a small percentage of the energy produced by the sun impinges upon the earth. Plants absorb some portions of the sun's electromagnetic radiation and convert them into nutrients and oxygen via the process known as photosynthesis. This energy is then transferred to other life forms through the food chain, for example, via herbivores that eat the plants themselves or carnivores that eat other animals.

"An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional



[a] Social determinants include, but are not limited to: economic inequality, urbanization, mobility, cultural values, attitudes and policies related to discrimination and tolerance on the basis of race, gender, and other differences.
[b] Other conditions at the national level might include major sociopolitical shifts, such as recession, war, and governmental collapse.
[c] The built environment includes transportation, water and sanitation, housing, and other dimensions of urban planning.

FIGURE 1.9 The ecological model of population health.

Modified and reproduced with permission from *Who Will Keep the Public Healthy? Educating Public Health Professionals for the 21st Century*, © 2003 by the National Academy of Sciences, courtesy of the National Academies Press, Washington, D.C., p. 33; and from Dahlgren G, Whitehead M. *Policies and Strategies to Promote Social Equity in Health*. Stockholm, Sweden: Institute for Futures Studies; 1991.

unit. Humans are an integral part of ecosystems. Ecosystems vary enormously in size: a temporary pond in a tree hollow and an ocean basin can both be ecosystems."[32(p3)] The interconnected components of an **ecosystem** are in a steady state; disrupting one of the components can disrupt the entire ecosystem. **FIGURE 1.10** suggests that the health of the ecosystem is associated with the health of human beings as well as that of domestic animals and wildlife.

Survival of the human population depends upon ecosystems, which aid in supplying clean air and water as part of the earth's life support system.[33] Ecosystems are being degraded with increasing rapidity because of human environmental impacts such as urbanization and deforestation. Degradation of ecosystems poses environmental dangers such as loss of the oxygen-producing capacity of plants and loss of biodiversity.

Environmental Health

The field of **environmental health** has a broad focus and includes a number of subspecializations. For example, occupational health often is regarded as a topic that is closely allied with environmental health and is a subset of broader environmental health concerns. Consequently, in view of its broad reach, the term *environmental health* does not have a single definition, nor is it easy to define. According to the World Health Organization:

> Environmental health addresses all the physical, chemical, and biological factors external to a person, and all the related factors impacting behaviours. It encompasses the assessment and control of those environmental factors that can potentially affect health. It is targeted towards preventing disease and creating health-supportive environments.[34]

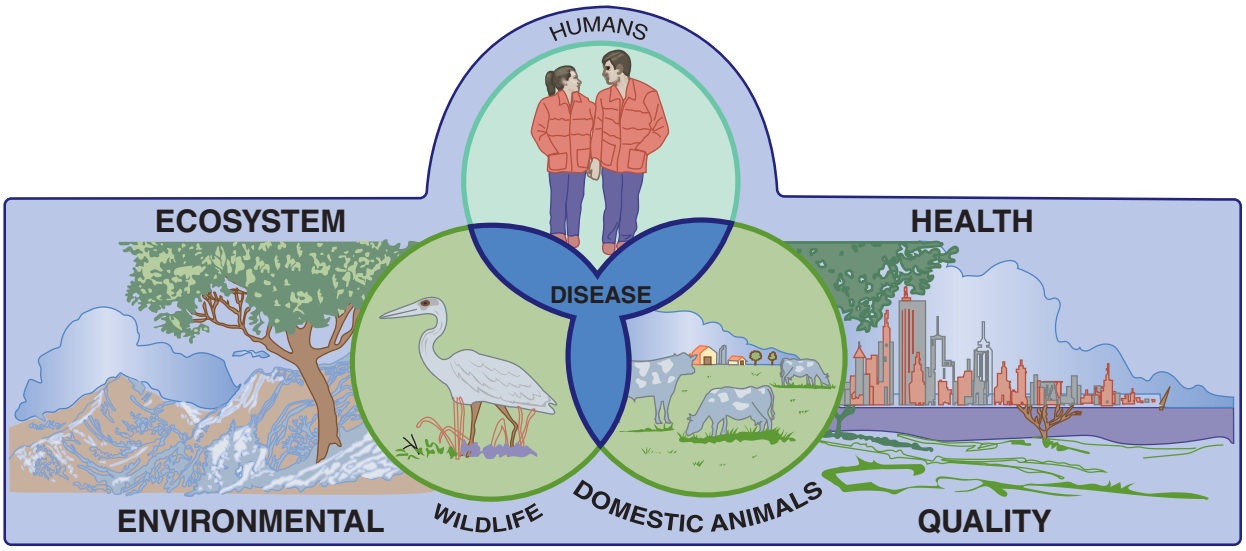


FIGURE 1.10 Ecosystem health.
Reproduced from Friend M. *Disease Emergence and Reemergence. The Wildlife-Human Connection*. Reston, VA: US Geological Survey, Circular 1285, p. 131. Illustration by John M. Evans.

Historical Background

This section presents a brief review of environmental health history, categorized as follows: ancient history, occupational health (contributions from about 1500 to the mid-1800s), and environmental history post-1800. **FIGURE 1.11** summarizes some of the highlights in environmental health history.

Ancient History

Negative human impacts on the environment are thought to have begun many thousands of years ago. One of the initial targets of human activity was forests, which were cut down for use as timber and burned to clear land for agriculture and human settlements. Deforestation subsequently led to soil erosion that caused rivers and bays to be fouled with silt.

The observations, insights, and writings of the ancient Greeks are noteworthy for the history of environmental health.[35] Around the 5th century BCE, the ancient Greek philosophers had developed the concept of the relationship between environmental factors and human health; instead of advocating for the workings of supernatural factors and the belief that magic potions would have curative powers, their philosophical position linked the influence of environment to disease.

Hippocrates, who lived between 460 and 370 BCE, often is referred to as "the father of medicine." (See **FIGURE 1.12**.) Hippocrates emphasized the role of the environment as an influence on people's health and health status in his work titled *On Airs, Waters, and Places* (ca 400 BCE). The Greek philosopher proposed that environmental and climatic factors such as the weather, seasons, and prevailing winds; the quality of air, water, and food; and one's geographic location were influential in causing changes in human health. He espoused the doctrine of maintaining equilibrium among the body's four humors, known as yellow bile, black bile, phlegm, and blood; imbalance among the four humors caused by environmental influences led to the onset of infectious diseases.

Many of the principles identified by Hippocrates regarding the impact of the environment on human health and disease remain credible despite the great increases in medical knowledge that have occurred since Hippocrates' time.[35] For example, now it is known that polluted water is associated with many types of waterborne infections (e.g., cholera and cryptosporidiosis [discussed later in this text]). Consistent with the belief that air is a factor in diseases is the origin of the term *malaria* (bad air), a disease that is carried by airborne mosquitoes that dwell in standing pools of water.

For many years, people have known about the harmful effects of heavy metals.[36] Hippocrates identified the toxic properties of lead.[37] The toxic properties of sulfur and zinc were pointed out by the Roman scholar Pliny the Elder (CE 29–79) during the 1st century CE; Pliny invented a mask constructed from the bladder of an animal for protection against dusts and metal fumes. During the 2nd century CE, the renowned Greek physician Galen (CE 129–200) outlined the pathological aspects of lead toxicity and

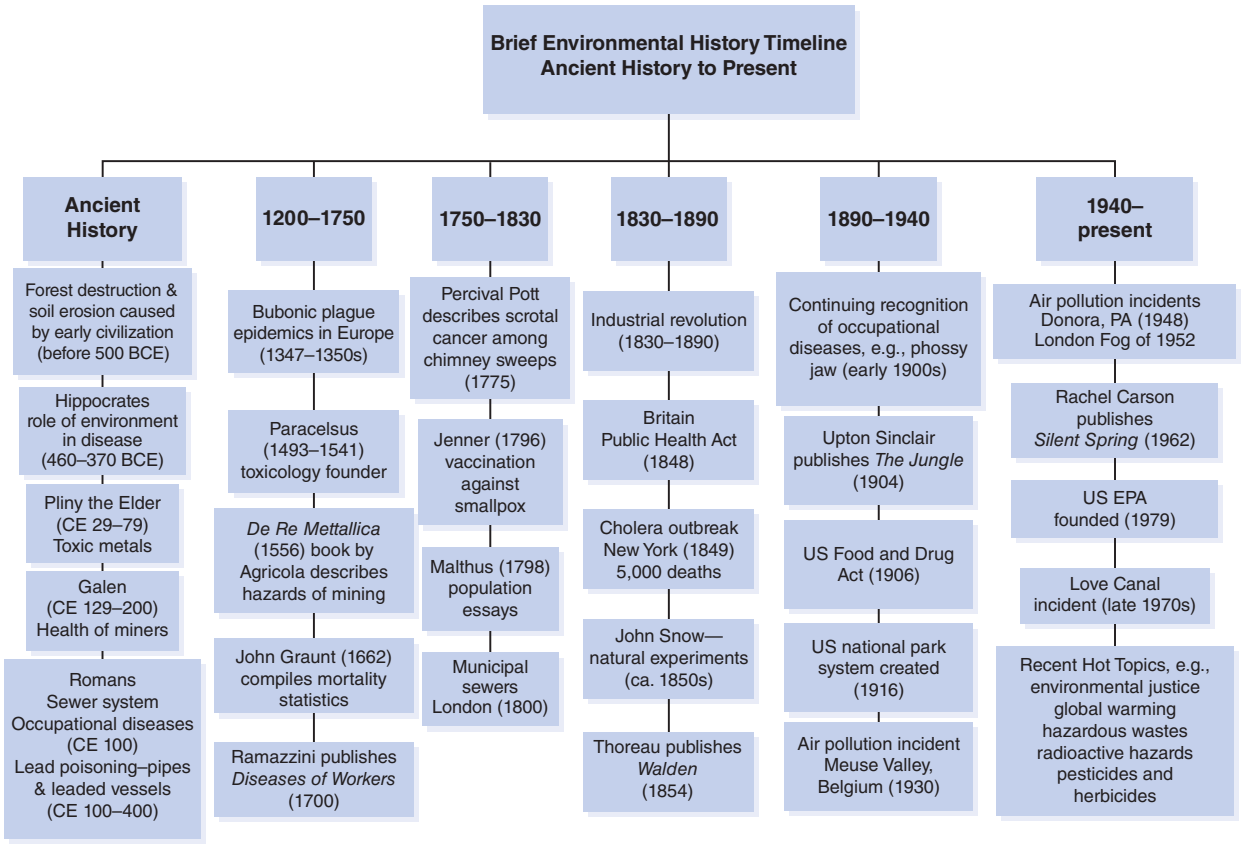


FIGURE 1.11 Brief environmental history time line: ancient history to the present.

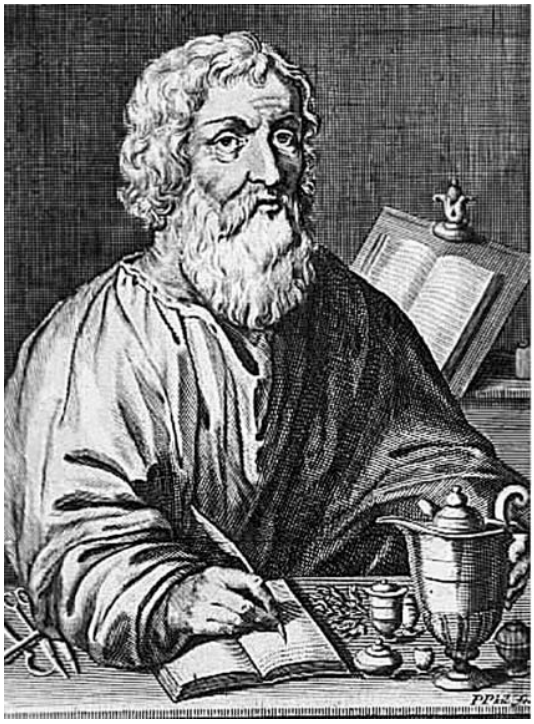


FIGURE 1.12 Hippocrates.
Courtesy of US National Library of Medicine, National Institutes of Health. History of medicine division. Available at: http://ihm.nlm.nih.gov/luna/servlet/view/search?q=B014553. Accessed July 1, 2017.

suggested that mists from acids could endanger the health of copper miners.[37]

The ancient Romans developed the first infrastructure for maintaining public health. Among their innovations were systems for the transport of water and sewage, heating devices for water and for rooms, and communal baths.[38,39] Beginning about 500 BCE, the Etruscans constructed a sewer called the Cloaca Maxima in Rome. As the city grew, a system of aqueducts that supplied fresh water and a web of sewers called cloacae were installed.

The Romans brought many of these innovations to their settlements all over Europe. Roman aqueducts and baths can been seen today in many parts of Europe. An example of the Roman baths at Baden-Baden, Germany is shown in **FIGURE 1.13**. The Romans used lead pipes to supply the homes of the affluent, who probably suffered from chronic lead poisoning. After the decline of their empire (possibly due, in part, to chronic lead poisoning), many of the hygiene-related contributions of the Romans were forgotten; for several centuries, the European world endured the abhorrent sanitary conditions of the medieval era, with its periodic outbreaks of epidemics of plague, cholera, and other pestilence.

FIGURE 1.13 Roman baths at Baden-Baden, Germany.

Occupational Health (Contributions from About 1500 to the Mid-1800s)

The field of occupational health has made numerous contributions to environmental health history. From about 1500 to the mid-1800s, recognition grew regarding the contribution of occupationally related exposures to adverse health conditions. There are many examples of explorations of the impacts of unsafe and hazardous working environments on the health of workers, especially the effects of exposures to toxic metals and hazards that occurred among miners. Among the historically important figures in occupational health were Paracelsus (1493–1541), Agricola (1494–1555), Bernardino Ramazzini (1633–1714), Percival Pott (1714–1788), and Alice Hamilton (1869–1970). See the chapter on environmental toxicology for information on Paracelsus, the chapter on environmental epidemiology for information about Percival Pott, and the chapter on occupational health for a discussion of Agricola, Ramazzini, and Hamilton; the chapter on occupational health also provides information on other historically important individuals in the field of occupational health.

Although his contributions were not limited specifically to occupational health, John Graunt (one of the early compilers of vital statistics data) published *Natural and Political Observations Made upon the Bills of Mortality* in 1662. Sometimes Graunt is referred to as the Columbus of statistics because his book made a fundamental contribution by attempting to demonstrate the quantitative characteristics of birth and death data.

Environmental History Post-1800

Just before the commencement of the 1800s, Jenner (in 1796) devised a method for vaccinating against smallpox; in 1798, Malthus wrote his well-known essays on population, mentioned earlier in this chapter. The history of environmental health since 1800 may be classified into three major eras:[40] the first wave of environmental concern (19th century to mid-20th century), the second wave of environmental awareness (mid-20th century to the 1980s), and the third period of environmental concern (1980s to the present).

The period of approximately 1850 to 1950 was marked by growing awareness of existing threats to public health from unsanitary conditions, detrimental social conditions, and hazardous work environments. For example, a common employment practice in Europe was the use of child labor. This era coincided approximately with the Industrial Revolution and marked the introduction of public health reforms to improve environmental conditions. In 1800, construction began on sewers that served the city of London. The British Parliament enacted the Public Health Act in 1848 to promote clean water and control infectious diseases. There were major outbreaks of cholera, including an outbreak in New York City in 1849 that killed 5,000 people.

About the same time, John Snow hypothesized that sewage-contaminated water was associated with cholera and conducted a "natural experiment" to demonstrate the cause of an outbreak in the present Soho district of London. John Snow (1813–1858) was an English anesthesiologist who innovated several of the key epidemiologic methods that remain valid and in use today. In Snow's time, the mechanism for the causation of infectious diseases was largely unknown. The Dutchman Anton van Leeuwenhoek (1632–1723) had used the microscope to observe microorganisms (bacteria and yeast). However, the connection between microorganisms and disease had not yet been ascertained. During Snow's time, one of the explanations for infectious diseases such as cholera was the miasmic theory of disease, which alleged that illnesses were caused by clouds of noxious matter. Snow rejected the miasmatic theory and showed the connection between polluted water and cholera. Because of his pioneering work, Snow is regarded as an icon in the history of public health and continues to be influential during the 21st century. (More information about Snow's work is provided in the chapter on environmental epidemiology.)

In the United States, Lemuel Shattuck published the 1850 *Report on the Sanitary Conditions of Massachusetts*. Shattuck argued for the creation of a state health department and local health boards. Among other issues, Shattuck's report dealt in detail with the topic of environmental sanitation and its connection with health. Although not implemented by the state legislature at the time, Shattuck's proposed recommendations were extremely farsighted and innovative and became a major influence in the development of subsequent public health practice. Ultimately, years later,