CHAPTER 1

History, Philosophy, and Uses of Epidemiology

LEARNING OBJECTIVES

By the end of this chapter, you will be able to:

- Define the term *epidemiology*.
- Describe two ways in which epidemiology may be considered a liberal arts discipline.
- State the difference between description and analysis in epidemiology.
- Name three important landmarks in the history of epidemiology.
- List three uses of epidemiology.

CHAPTER OUTLINE

Introduction

As a member of contemporary society, you are besieged constantly with information about the latest health scare. One category of threats arises from infectious diseases, including infection with the human immunodeficiency virus (HIV), foodborne illness, Ebola viral disease, and the coronavirus disease 2019 (COVID-19) pandemic. The COVID-19 pandemic demonstrated how infectious disease threats can impact all aspects of society and touch each of our lives in profound ways. Chronic diseases represent another threat, including such health conditions as obesity, diabetes, and hypertension. Finally, we hear a great deal about the impact of adverse behaviors, such as the effects of smoking, binge drinking, and prescription drug abuse. In fact, threats such as these account for a devastating toll for the affected individual, our society, and the healthcare system. Especially vexing is the stream of information from media reports of epidemiologic research. These

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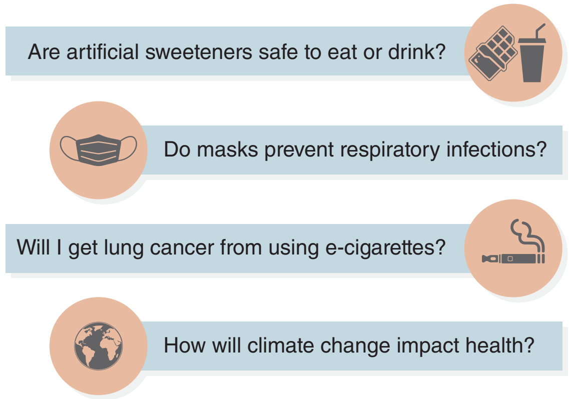

Figure 1.1 Examples of the types of questions that can be answered by epidemiologic research

pronouncements can be inconsistent, often are self-contradictory, and, in some cases, contribute to the spread of misinformation.

By exploring these threats to society, you will learn how epidemiology is an exciting field with many applications that help us to understand and contribute to solving today's health-related problems. (Refer to **Figure 1.1**.) For example, epidemiology can demonstrate the risks associated with cigarette smoking, as well as those related to exposure to secondhand cigarette smoke among nonsmokers. Epidemiology can also be used to examine whether electronic cigarettes are truly better for health than traditional cigarettes. Currently, youth violence such as bullying is an issue that confronts students, teachers, and administrators at schools. Epidemiologic research can identify factors related to such violence and suggest methods for its prevention. Other contributions of epidemiology include the identification of factors associated with obesity and substance abuse, both of which, as noted, are major societal issues. Epidemiology has a track record of helping to investigate these problems. Refer to **Table 1.1** for a list of important terms used in this chapter.

Epidemiology and Recent Epidemics

The COVID-19 pandemic provided just the latest example of an important applications of epidemiology, which is studying infectious disease epidemics. In addition to the COVID-19 pandemic, consider three other examples of infectious disease outbreaks and how they exemplify challenges to epidemiology: Ebola virus hemorrhagic fever, mpox, and intestinal illnesses.

Table 1.1 List of Important Terms Used in This Chapter

Analytic epidemiology	Morbidity
Descriptive epidemiology	Mortality
Demographic transition	Natural experiment
Determinant	Observational science
Disease management	Operations research
Distribution	Outcome
Epidemic	Pandemic
Epidemiologic transition	Population
Epidemiology	Quantification
Exposure	Risk
Interdisciplinary science	Risk factor
Miasmic theory of disease	

COVID-19 Pandemic

The first cases of COVID-19 were identified in Wuhan, China in late 2019. COVID-19 is caused by infection with the severe acute respiratory syndrome coronavirus 2 (SARS-Cov-2) virus. This was a new virus in humans and initial cases were linked to a large seafood and animal market in Wuhan. Subsequent cases had no link to the market, indicating person-to-person transmission of the disease. The disease is primarily spread through breathing in droplets or aerosol particles containing the SARS-CoV-2 virus that are suspended in the air. For many people, infection led to symptoms similar to other respiratory infections, including fever, cough, chills, and sore throat, although a significant proportion of people did not experience any symptoms of infection. For those who did experience symptoms, they ranged from mild to severe, and severe symptoms tended to be more common in people with underlying health conditions.[1]

From the initial cases in Wuhan, the infection rapidly spread throughout the world and impacted the lives of billions of people. As of July 10, 2023, the World Health Organization estimates a total of more than 670 million confirmed cases and 6.9 million global deaths linked to COVID-19, including more than 1 million deaths in the United States alone (refer to **Figure 1.2**).[1] Deaths in the United States have come in multiple waves as new variants have emerged and immunity from previous infection or vaccination has waned. The number of confirmed cases is expected to be an underestimate as an unknown proportion of infections did not result in any symptoms. Epidemiology contributed to efforts to limit

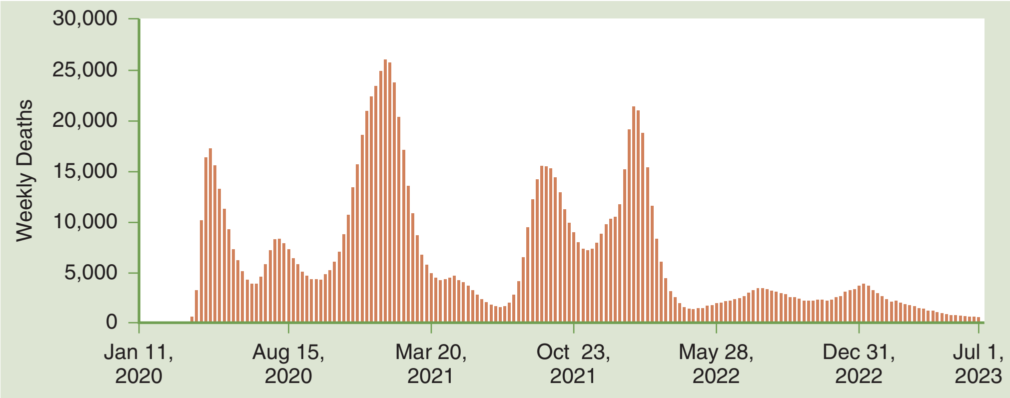

Figure 1.2 COVID-19 deaths in the United States over time, 2020–2023

Centers for Disease Control and Prevention. COVID Data Tracker. Available at: https://covid.cdc.gov/covid-data-tracker/#trends_weeklydeaths_select_00. Accessed July 10, 2023.

the impact of the COVID-19 pandemic by helping to identify groups at highest risk for infection to prioritize prevention efforts and evaluating the success of these efforts such as social distancing and mask wearing.

Ebola Virus Hemorrhagic Fever

Infection with the Ebola virus results from direct contact with blood or bodily fluids. Ebola is not an airborne condition like COVID-19, nor is it transmitted through indirect means, such as food and water. The infection—which can produce severe headaches, gastrointestinal symptoms, and bleeding—causes a high proportion of fatalities. The largest outbreak in history descended upon West Africa in 2014. (See infographic in **Figure 1.3**.) By April 13, 2016, a total of 28,652 cases had been reported in Africa. Approximately two out of every five people infected with Ebola virus died. When the Ebola outbreak exploded in 2014, public health officials scrambled to meet the challenge. Epidemiologic methods contributed to bringing this massive outbreak under control and to preparing and planning for future Ebola outbreaks. A subsequent outbreak of Ebola did occur in the Democratic Republic of Congo in 2018, infecting 3,470 people and killing almost two-thirds of them. This was the first outbreak of Ebola in which a vaccine was widely deployed and appeared to be effective at reducing the impact of the disease.[2]

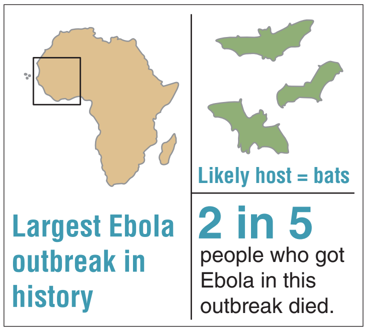

Figure 1.3 Ebola outbreak in West Africa

Centers for Disease Control and Prevention. Infographic: West Africa Ebola Outbreak. Available at: http://www.cdc.gov/vhf/ebola/pdf/west-africa-outbreak-infographic.pdf. Accessed July 10, 2023.

MPox (formerly known as monkeypox)

MPox is a disease that results from infection with the mpox virus. The virus was initially discovered in 1958 and the first documented human cases were recorded in 1970. Prior to an outbreak in 2022, mpox had primarily been a rare disease reported most frequently in Central and Western Africa. In 2022, cases of mpox began to emerge in different places in the world with greater frequency than previously observed. On July 23, 2022 the World Health Organization (WHO) declared the outbreak of mpox a Public Health Emergency of International Concern and a United States Public Health Emergency was declared on August 4, 2022. During the outbreak more than 30,000 mpox cases were reported in the United States alone. Epidemiology played a key role in rapidly identifying sexual contact among gay, bisexual, and other men who have sex with men (MSM) as the primary risk factor for infection and that certain marginalized communities were disproportionately impacted. These findings allowed for rapid deployment of an effective vaccine and other preventative efforts that quickly brought the outbreak under control.

Intestinal Illness

Intestinal illnesses caused by infections have an important impact on population and individual health, particularly those linked to foodborne sources. Foodborne illness outbreaks are most often associated with *Escherichia coli* and *Salmonella* bacteria and provide excellent examples of conditions that can be researched and brought under control though the application of epidemiologic methods.

E. coli Infections

This bacterial agent produces mild to severe diarrhea with bloody stools. Severe infections can cause acute kidney dysfunction. Two outbreaks of foodborne infection with *E. coli* bacteria were linked to Chipotle Mexican Grill restaurants. The first, in October 2015, resulted in 55 reported cases. In December 2015, a second episode was associated with five reported cases. The Centers for Disease Control and Prevention (CDC) used genetic fingerprinting techniques to type the strain of *E. coli* that was involved.[3] More recent outbreaks of foodborne infection with *E. coli* bacteria have been linked to consuming lettuce, including a multi-state outbreak in 2018 that led to more than 200 cases and 5 deaths.[4]

Salmonellosis

Foodborne salmonellosis is an infection caused by *Salmonella* bacteria. This agent can produce gastrointestinal symptoms (cramping, diarrhea, and fever) that begin 12 to 72 hours after initial infection. The majority of patients recover without treatment, although some endure life-threatening consequences.

A major outbreak that occurred in 2008 is particularly interesting. It affected more than 1,400 people and is believed to have contributed to 2 deaths.[5] Cases appeared in 43 states, most frequently in Texas, Arizona, and Illinois. The source of contamination was mysterious. All patients were affected with an uncommon strain of *Salmonella* Saintpaul, which had a distinctive genetic fingerprint. Initially, epidemiologic investigations implicated raw tomatoes. The public was advised not to eat red plum (red Roma) and round red tomatoes, which were suspected of being the implicated vehicle of infection. This news was indeed disturbing as tomatoes are generally considered healthful and are used extensively in many popular items of the American diet, including salads, ketchup, spaghetti sauce, pizza, and salsa. Despite this diligent work, the origin of the bacteria that sickened so many people was never definitively linked to tomatoes. Eventually, the CDC discovered that the source of the *Salmonella* outbreak was jalapeño and serrano peppers from Mexico.

More recent outbreaks of *Salmonella* illnesses have been linked to different sources, such as contact with small mammals as pets, including guinea pigs and hedgehogs.[6] In 2020, contact with backyard poultry was blamed for more than 1,700 cases of *Salmonella* illness, leading to 333 hospitalizations and 2 deaths.[7] Cases of *Salmonella* illness linked to backyard poultry exposure were reported in all 50 states.

The Concept of an Epidemic

What is meant by the term *epidemic*? An **epidemic** refers to the occurrence within a population and geographic area of cases of a health-related event or behavior that exceeds normal, expected levels.[8] The aforementioned *Salmonella* outbreak illustrates a foodborne-disease episode that reached epidemic proportions. Individual *Salmonella* cases may arise sporadically; usually, such occurrences are not epidemics but instead represent background cases. However, because in the 2008 outbreak a large number of people across the United States were affected with an unusual strain of *Salmonella* bacteria, the *Salmonella* outbreak could be considered an epidemic. Similarly, the Zika virus epidemic in Brazil, the Ebola virus scare in West Africa, and the *E. coli* outbreak associated with a U.S. chain restaurant are additional examples of epidemics.

Figure 1.4 demonstrates the concept of an epidemic in the case of the annual occurrence of a hypothetical disease. The "normal expectancy" is six cases per year. In five years, 2018, 2021, 2022, 2026 and 2027, the occurrence of the disease was in excess of normal expectancy. For these conditions (for example, influenza mortality), when the number of cases exceeds the background rate, an epidemic may be suspected.

You should be aware that in some instances, a single case of a disease represents an epidemic. With respect to a new occurrence of an infectious disease not previously found in an area or the occurrence of an infectious disease that has long been absent, a single or small number of cases of that disease would be regarded as an epidemic. At present, examples of infrequently occurring diseases in the United States are measles and polio. A small outbreak of measles, polio, or other infrequently occurring infectious disease requires the immediate attention of public health officials and would be treated as an epidemic. As a matter of fact, an outbreak of 125 cases of measles occurred at a California Disney theme park between December 2014 and February 2015.

The use of the word "epidemic" is not limited to communicable diseases. The term is applied to chronic diseases and other conditions as well. Illustrations are the "epidemic of obesity," the "epidemic of diabetes," or the "epidemic of drug overdose deaths."

Related to the term epidemic is **pandemic**, defined as "[a]n epidemic occurring worldwide, or over a very wide area, crossing international boundaries, and usually affecting a large number of people."[8]

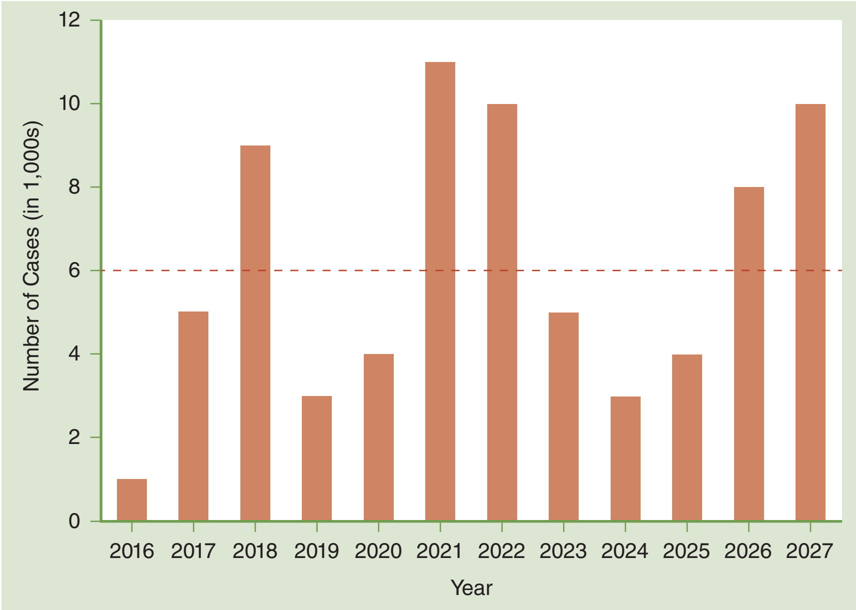

Figure 1.4 Annual occurrence, normal expectancy, and epidemic frequency of a hypothetical disease

The COVID-19 pandemic and the 1918 influenza pandemic are the most well-known examples of this concept, but periodic, less severe global influenza epidemics (such as swine flu of 2009) are also classified as pandemics.

The previous discussion leads to the question: What is the scope of epidemiology? This chapter will begin with a definition of the term epidemiology and illustrate how the study of epidemiology imparts skills that are useful in a variety of pursuits. As part of this exploration, the author will highlight the key historical developments in epidemiology and demonstrate how these developments have influenced the philosophy and practice of epidemiology. Some of these historical developments include concerns of the ancient Greeks about diseases caused by the environment, the observations of Sir Percival Pott on scrotal cancer among chimney sweeps in England, the work of John Snow on cholera, and modern work on the etiology of chronic diseases.

Epidemiology is one of the basic sciences of public health. Epidemiologic methods are applied to a variety of public health–related fields: health education, healthcare administration, tropical medicine, and environmental health. Epidemiologists quantify health outcomes by using statistics. They formulate hypotheses, and they explore causal relationships between exposures and health outcomes. A special concern of the discipline is causality: Do research findings represent cause-and-effect associations or are they merely associations? A simple example of a causal association would be whether a specific contaminated food such as lettuce caused an outbreak of gastrointestinal disease. A more complex example is whether there is a causal association between smoking during the teenage years and the subsequent development of lung cancer later in life.

Although the foregoing examples of the applications of epidemiology are primarily disease related, epidemiology is a body of methods that have general applicability to many fields. Two examples that are not disease related are firearm-related violence among youth and bullying in high schools.

The United States stands out compared to other countries regarding the toll of firearm-related violence on children. In the United States, firearm-related mortality is the leading cause of death in those 19 years of age and younger, resulting in more than 4,000 deaths per year.[9] Firearms are responsible for more than 5 deaths per 100,000 people 19 years of age and younger, which is more than five times higher than the next closest country (Canada, 0.8 death per 100,000 people 19 years of age and younger).[9]

The impact of firearm-related violence on children is an epidemic in the United States and trends in firearm-related mortality are increasing (refer to **Figure 1.5**). This trend is distinct from other similar countries that have seen a decrease in the impact of firearm-related mortality in children.[9] The impact of firearm-related violence is not felt equally by all groups in the United States, as African American children have higher rates of mortality than all other racial groups and have also experienced some of the steepest increases over time.

As a second example of using epidemiologic methods to address non-disease-related issues, **Exhibit 1.1**

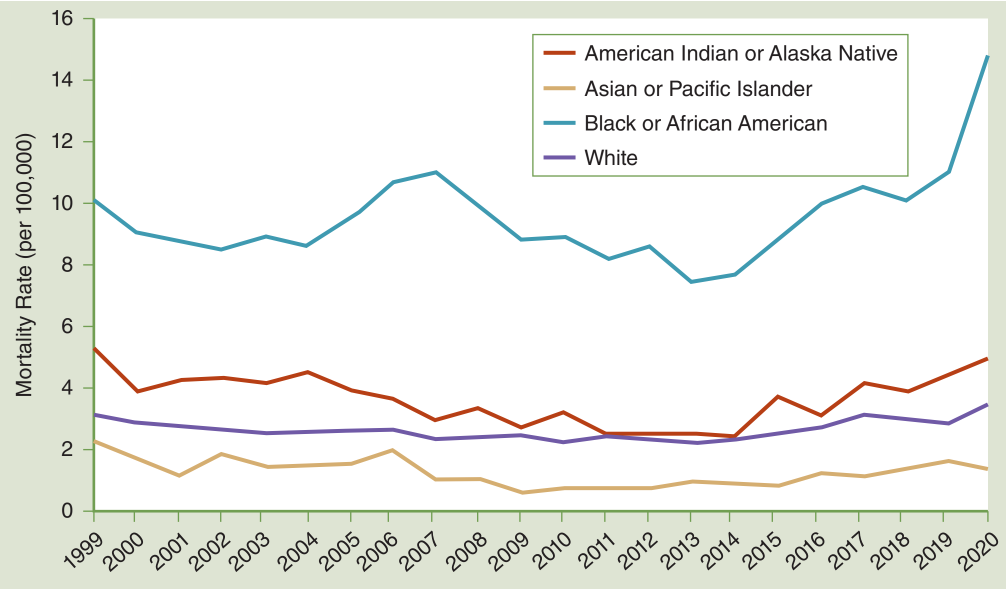

Figure 1.5 Firearm-related mortality rates by race and year, United States (19 years of age and younger)

Data from Centers for Disease Control and Prevention, National Center for Health Statistics. National Vital Statistics System, Mortality 1999-2020 on CDC WONDER Online Database, released in 2021. Data are from the Multiple Cause of Death Files, 1999-2020, as compiled from data provided by the 57 vital statistics jurisdictions through the Vital Statistics Cooperative Program. Available at: http://wonder.cdc.gov/ucd-icd10.html. Accessed July 10, 2023.

Exhibit 1.1 What Is Epidemiology About? The Example of Bullying in Schools

Bullying occurs with alarming frequency in the nation's schools. (Refer to **Table 1.2**.) It can take the form of cyberbullying and physical bullying. Any form of bullying torments victims and contributes to school avoidance.

Using data from the Youth Risk Behavior Survey, the CDC assessed the frequency of electronic bullying and bullying on school property among the nation's high school students. More than 15% of U.S. high school students reported being bullied electronically during the 12 months before the 2019 survey. Bullying tactics included the use of email, instant messaging, and texting.

A greater percentage of females than males were bullied; white females experienced the highest frequency of electronic bullying among ethnic/racial groups examined and individuals who identified as gay or bisexual experienced a frequency of bullying that was almost twice the frequency of their heterosexual counterparts.

Approximately one-fifth of high school pupils stated that they were bullied on school property. As was the case for cyberbullying, white females reported the highest frequency of school bullying among sex and racial/ethnic groups. Both forms of bullying were most common among ninth graders and declined in the later high school years.

Table 1.2 demonstrates an approach of epidemiology—comparing data according to the demographic characteristics (for example, sex, race/ethnicity, school year, and sexual identity) to identify population subgroups that experienced the highest frequency of bullying.

Table 1.2 Percentage of High School Students Who Were Electronically Bullied*† and Who Were Bullied on School Property* by Sex, Race/Ethnicity, Sexual Identity, and Grade—United States, Youth Risk Behavior Survey, 2019.

	Electronically Bullied					
	Female		Male		Total	
Category	*%*	*CI§*	*%*	*CI*	*%*	*CI*
Race/ethnicity						
White¶	25.3	(23.4–27.3)	12.0	(10.2–14.1)	18.6	(17.1–20.2)
Black¶	11.1	(8.9–13.7)	6.1	(4.5–8.3)	8.6	(7.4–10.0)
Hispanic	15.9	(13.5–18.7)	9.3	(7.3–11.8)	12.7	(11.1–14.5)

Grade						
9	21.3	(18.8–24.1)	11.9	(10.1–14.0)	16.5	(14.9–18.3)
10	21.1	(18.3–24.2)	11.0	(8.9–13.4)	16.0	(14.4–17.8)
11	20.3	(17.4–23.5)	8.6	(6.7–10.9)	14.4	(12.5–16.5)
12	18.6	(15.5–22.2)	11.9	(9.6–14.8)	15.4	(13.5–17.5)
Sexual Identity						
Heterosexual	19.1	(17.3–21.0)	9.9	(8.5–11.4)	14.1	(12.9–15.4)
Gay, lesbian, or bisexual	27.1	(23.7–30.7)	25.5	(18.7–33.8)	26.6	(23.3–30.2)
Total	20.4	(18.9–22.0)	10.9	(9.6–12.4)	15.7	(14.6–16.9)

Bullied on School Property						
	Female		**Male**		**Total**	
Category	*%*	*CI*[§]	*%*	*CI*	*%*	*CI*
Race/ethnicity						
White[¶]	28.3	(25.8–31.0)	18.0	(16.5–19.5)	23.1	(21.4–24.8)
Black[¶]	17.2	(13.9–21.1)	13.3	(10.7–16.4)	15.1	(13.1–17.4)
Hispanic	18.6	(16.5–20.8)	10.9	(8.2–14.3)	14.8	(12.8–17.1)
Grade						
9	27.0	(24.0–30.3)	18.0	(15.4–21.0)	22.4	(20.2–24.8)
10	25.3	(22.7–28.1)	17.4	(14.9–20.2)	21.3	(19.5–23.2)
11	21.2	(18.3–24.4)	12.4	(10.5–14.6)	16.9	(15.0–19.0)
12	20.5	(16.7–24.8)	12.8	(10.9–15.0)	16.7	(14.4–19.3)
Sexual Identity						
Heterosexual	20.8	(18.6–23.2)	14.0	(12.6–15.5)	17.1	(15.7–18.7)
Gay, lesbian, or bisexual	32.0	(28.6–35.7)	31.7	(25.7–38.4)	32.0	29.5–34.6
Total	23.6	(21.8–25.5)	15.4	(14.0–16.9)	19.5	(18.2–20.9)

*During the 12 months before the survey.
[†]Including being bullied through email, chat rooms, instant messaging, websites, or texting.
[§]95% confidence interval (CI).
[¶]Non-Hispanic.

Data from Centers for Disease Control and Prevention (CDC). 1991–2019 High School Youth Risk Behavior Survey Data. Available at: http://yrbs-explorer.services.cdc.gov. Accessed December 9, 2022.

provides information regarding school-related bullying, a topic of increasing public health and societal concern. Bullying can take the forms of cyberbullying and physical bullying. Alarmingly, between 15% and 20% of high school students experience cyber- and physical bullying, respectively.

The foregoing exhibit regarding violence in schools, specifically bullying, illustrates the potential applications of epidemiology for solving a broad range of problems that affect the health of populations. Specifically, epidemiology can be used as a research tool that seeks answers to the following types of questions with respect to these specific problems:

- What are the characteristics of victims and perpetrators of bullying?
- What school programs have been effective at reducing bullying both in school and online?
- What interventions might be proposed for the prevention of firearm-related violent acts and how successful are they likely to be?

Definition of Epidemiology

"**Epidemiology** is concerned with the distribution and determinants of health and diseases, morbidity, injuries, disability, and mortality in populations. Epidemiologic studies are applied to the control of health problems in populations."[10(p6)] The term epidemiology originates from the Greek: *epi* (upon) + *demos* (people) + *logy* (study of). The key characteristics of epidemiology are discussed next.

Population Focus

The unique focus of epidemiology is on the occurrence of health and disease in the population. The definition of a **population** is "[a]ll the inhabitants of a given country or area considered together. . . ."[8] The approach of focusing on the population contrasts with clinical medicine's concern with the individual; hence, epidemiology is sometimes called population medicine. Given examples of the *Salmonella* outbreak and violence in schools demonstrated epidemiologic investigations that were focused on entire population groups (such as the United States). A third example involves epidemiologic studies of lung disease. These investigations might examine the occurrence of lung cancer mortality across counties or among regional geographic subdivisions known as census tracts. Investigators might want to ascertain whether lung cancer mortality is higher in areas with higher concentrations of "smokestack" industries in comparison with areas that have lower levels of air pollution or are relatively free from air pollution. In contrast with the population approach used in epidemiology, the alternative approach of clinical medicine would be for the clinician to concentrate on the diagnosis and treatment of specific individuals for the sequelae of foodborne illnesses, injuries caused by school violence, and lung cancer.

Distribution

The term **distribution** implies that the occurrence of diseases and other health outcomes varies in populations, with some subgroups of the populations more frequently affected than others. Epidemiologic research identifies subgroups that have increased occurrence of adverse health outcomes in comparison with other groups. In our exploration of epidemiology, we will encounter many illustrations of differential distributions of health outcomes: for example, variations in the occurrence of cancer, heart disease, and asthma in populations. A recent example is the disparate impact of the COVID-19 pandemic, in which some groups were more likely to experience adverse outcomes than others. A higher prevalence of adverse health outcomes among some subgroups in comparison with the general population may be a reflection of a phenomenon known as health disparities, which draws attention to the critical importance of social determinants of health.

Determinants

A **determinant** is defined as "[a] collective or individual risk factor (or set of factors) that is causally related to a health condition, outcome, or other defined characteristic."[8] The term *risk factor* (an exposure that increases the probability of a disease or adverse health outcome) is discussed later in the chapter. Examples of determinants are biologic agents (e.g., bacteria and viruses), chemical agents (e.g., toxic pesticides and cancer-causing substances known as chemical carcinogens), and less-specific factors (e.g., stress and deleterious lifestyle practices).

Related to determinants are **exposures**, which pertain either to contact with a disease-causing factor or to the amount of the factor that impinges upon a group or an individual. Epidemiology searches for associations between exposures and health outcomes. Examples of exposures are contact with infectious disease agents through consumption of contaminated foods and environmental exposures to toxic chemicals, potential carcinogens, or air pollution. In other cases, exposures may be to biologic agents or to radiation, noise, or extremes of temperature. For the results of an epidemiologic research study to be valid, the level of exposure in a population must be defined carefully. The task of exposure assessment is not easily accomplished in many types of epidemiologic research.

Outcomes

The definition of **outcomes** is "[a]ll the possible results that may stem from exposure to a causal factor. . . ."[8] The outcomes examined in epidemiologic research range from specific infectious diseases to disabling conditions, unintentional injuries, psychiatric illnesses, chronic diseases, and conditions associated with personal behavior and lifestyle. These outcomes may be expressed as types and measures of **morbidity** (illnesses due to a specific disease or health condition) and **mortality** (causes of death). Accurate clinical assessments of outcomes are vitally important to the quality of epidemiologic research and the strength of inferences that can be made. Without such assessments, it would not be possible to replicate the findings of research.

Quantification

Epidemiology is a quantitative discipline. The term **quantification** refers to the counting of cases of illness or other health outcomes such as mortality. Quantification means the use of statistical measures to describe the occurrence of health outcomes and to measure their association with exposures. The field of descriptive epidemiology quantifies variation of diseases and health outcomes according to subgroups of the population.

Control of Health Problems

Epidemiology aids with health promotion, alleviation of adverse health outcomes (e.g., infectious and chronic diseases), and prevention of disease. Epidemiologic methods are applicable to the development of needs assessments, the design of prevention programs, the formulation of public health policies, and the evaluation of the success of such programs. Epidemiology contributes to health policy development by providing quantitative information that can be used by policy makers.

The Evolving Conception of Epidemiology as a Liberal Art

Epidemiology is often considered to be a biomedical science that relies on a specific methodology and high-level technical skills.[11] Nevertheless, epidemiology in many respects is also a "low-tech" science that can be appreciated by those who do not specialize in this field.[12] The following text box lists skills acquired through the study of epidemiology; these skills enlarge one's appreciation of many academic fields: laboratory sciences, mathematics, the social sciences, history, and literature.

Skills acquired through training in epidemiology

1. Use of the interdisciplinary approach
2. Use of the scientific method
3. Enhancement of critical-thinking ability
   a. Reasoning by analogy and deduction
   b. Problem solving
4. Use of quantitative and computer methods
5. Communication skills

The Interdisciplinary Approach

Epidemiology is an **interdisciplinary science**, meaning that it uses information from many fields. Here are a few examples of the specializations that contribute to epidemiology and the types of input that they make:

- Mathematics and biostatistics (for quantitative methods)
- History (for historical accounts of disease and early epidemiologic methods)
- Sociology (social determinants of disease)
- Demography and geography (population structures and location of disease outbreaks)
- Behavioral sciences (models of disease; design of health promotion programs)
- Law (examining evidence to establish causality; legal bases for health policy)

Many of the issues of importance to contemporary society do not have clearly delineated disciplinary boundaries. For example, prevention of school violence requires an interdisciplinary approach that draws on information from sociology, behavioral sciences, and the legal profession. In helping to develop solutions to the problem of school violence, epidemiology leverages information from mathematics (e.g., statistics on the occurrence of violence), medicine (e.g., treatment of victims of violence), behavioral and social sciences (e.g., behavioral and social aspects of violence), and law (legal basis for development of school-related antiviolence programs). Through the study of epidemiology, one acquires an appreciation of the interdisciplinary approach and a broader understanding of a range of disciplines.

Use of the Scientific Method

Epidemiology is a scientific discipline that makes use of a body of research methods similar to those used in the basic sciences and applied fields, including biostatistics. The work of the epidemiologist is driven by theories, hypotheses, and empirical data. The scientific method employs a systematic approach and objectivity in evaluating the results of research. Comparison groups are used to examine the effects of exposures. Epidemiology uses rigorous study designs, which include cross-sectional, ecologic, case-control, and cohort studies.

Enhancement of Critical-Thinking Ability

Critical-thinking skills include the following: reasoning by analogy, making deductions that follow from a set of evidence, and solving problems. We will learn that epidemiologists use analogical reasoning to infer disease causality. Suppose there are two similar diseases. The etiology of the first disease is known, but the etiology of the second disease is unknown. By analogy, one can reason that the etiology of the second disease must be similar to that of the first.

Also, epidemiologists gather descriptive information on the occurrence of diseases and use this information to develop hypotheses regarding specific exposures that might have been associated with those diseases. Finally, epidemiologists are called into action to solve problems—for example, trying to control foodborne disease outbreaks caused by *Salmonella* and *E. coli*, or slowing epidemic diseases such as COVID-19, Ebola virus disease, and MPox (formerly called monkeypox).

Use of Quantitative and Computer Methods

Biostatistics is one of the core disciplines most closely linked to epidemiology. Because of the close linkage between the two fields, epidemiology and biostatistics are housed in the same academic department in some universities. Through your training in epidemiology, you will acquire quantitative skills, such as tabulating numbers of cases, making subgroup comparisons, and mapping associations between exposures and health outcomes. In research and agency settings, epidemiologists use computers to store, retrieve, and process health-related information and to perform these types of analyses. An intriguing development is the field of "big data," which processes massive reservoirs of data from sources that include social media and commercial transactions. Those who become tech savvy may be able to detect patterns that help to discern the presence and determinants of epidemics as well as risk factors for infectious and chronic diseases.

Communication Skills

As a core discipline of public health, epidemiology is an applied field. Information from epidemiologic analyses can be used to control diseases, improve the health of the community, evaluate intervention programs, and inform public policy. One of the skills needed by applied epidemiologists is the ability to disseminate information that could be useful for controlling health problems and improving the health status of the population. A developing part of communication skills is the use of data visualization approaches to display information in a way that allows for clear communication, understanding, and action.

Application of Descriptive and Analytic Methods to an Observational Science

In examining the occurrence of health and disease in human populations, researchers almost always are prohibited from using experimental methods because of ethical issues, such as potential harm to subjects. Studies of the population's health present a challenge to epidemiologic methods. First and foremost, epidemiology is an **observational science** that capitalizes on naturally occurring situations in order to study the occurrence of disease. Thus, in order to study the association of cigarette smoking with lung diseases, epidemiologists might examine and compare the frequency of lung cancer and other lung diseases among smokers and nonsmokers.

Descriptive Epidemiology

From past history until the present era, epidemiologists have implemented descriptive epidemiology (and descriptive epidemiologic studies) as one of the fundamental applications of the field.[13] The term **descriptive epidemiology** refers to epidemiologic studies that are concerned with characterizing the amount and distribution of health and disease within a population. Health outcomes are classified according to the variables of person, place, and time. Examples of person variables are demographic characteristics such as sex, age, and race/ethnicity. Place variables denote geographic locations that can be defined both widely and narrowly, ranging from a specific country or countries, areas within countries, neighborhoods within a city, or even down to the level of specific seating arrangements within a restaurant. Illustrations of time variables are a decade, a year, a month, a week, a day, or even hours in some outbreaks of foodborne illness. These studies, which aid in the development of hypotheses, set the stage for subsequent research that examines the etiology of disease.

Analytic Epidemiology

Analytic epidemiology examines causal (etiologic) hypotheses regarding the association between exposures and health conditions. The field of analytic epidemiology proposes and evaluates causal models for etiologic associations and studies them empirically. "Etiologic studies are planned examinations of causality and the natural history of disease. These studies have required increasingly sophisticated analytic methods as the importance of low-level exposures is explored and greater refinement in exposure–effect relationships is sought."[14(p945)] Note that the natural history of disease refers to the time course of disease from its beginning to its final clinical endpoints. For more information, see the chapter on epidemiology and screening for disease.

One approach of analytic epidemiology is to take advantage of naturally occurring situations or events to test causal hypotheses. These events are referred to as **natural experiments**, defined as "[n]aturally occurring circumstances in which subsets of the population have different levels of exposure to a hypothesized causal factor in a situation resembling an actual experiment. The presence of people in a particular group is typically nonrandom."[8] An example of a natural experiment is the work of John Snow, discussed later in this chapter. Many past and ongoing natural experiments are relevant to environmental epidemiology. When new public health–related laws and regulations are introduced, their implementation becomes similar to natural experiments that could be explored in epidemiologic research. For example, epidemiologists could study whether motor vehicle laws that limit texting while driving reduce the frequency of automobile crashes, or if changes in opioid prescribing practices impact the number of annual overdose deaths. Other examples of natural experiments that have evolved from laws are the addition of fluoride to the public water supply to prevent tooth decay and the use of mask mandates during the COVID-19 pandemic.

History of Epidemiology and Development of Epidemiologic Principles

The discipline of epidemiology originated as early as classical antiquity (before about 500 CE), and later during the medieval period, which was marked by bubonic plague epidemics in Europe. The Renaissance was the era of Paracelsus, a toxicologist, and John Graunt, a pioneering compiler of vital statistics. During the eighteenth and nineteenth centuries, breakthroughs occurred in the development of a vaccination against smallpox and the formulation of epidemiologic methods. The period from the beginning of the twentieth century to the present has seen a rapid growth in epidemiology. Two of the achievements of this period were identification of smoking as a cause of cancer and eradication of smallpox.

The Period of Classical Antiquity (before 500 CE)

Hippocrates (460 BCE–370 BCE)

The ancient Greek authority Hippocrates contributed to epidemiology by departing from superstitious reasons for disease outbreaks. Until Hippocrates's time, supernatural explanations were used to account for the diseases that ravaged human populations. In about 400 BCE, Hippocrates suggested that environmental factors such as water quality and the air were implicated in the causation of diseases. He authored the historically important book, *On Airs, Waters, and Places*. Hippocrates's work and the writings of many of the ancients did not delineate specific known agents involved in the causality of health problems, but referred more generically to air, water, and food. In this respect, early epidemiology shares with contemporary epidemiology the frequent lack of complete knowledge of the specific agents of disease, especially those associated with chronic diseases.

Middle Ages (approximately 500–1450 CE)

Black Death

Of great significance for epidemiology is the Black Death, which occurred between 1346 and 1352 and claimed up to one-third of the population of Europe at the time (20 to 30 million out of 100 million people). The Black Death was thought to be an epidemic of bubonic plague, a bacterial disease caused by *Yersinia pestis*. (Refer to **Figure 1.6** for a drawing of plague victims.) Bubonic plague is characterized by painful swellings of the lymph nodes (buboes) in the groin and elsewhere in the body. Other symptoms often include fever and the appearance of black splotches on the skin. (Refer to **Figure 1.7**.) Untreated, bubonic plague kills up to 60% of its victims. The bites of fleas harbored by rats and some other types of rodents can transmit plague.

Renaissance (approximately 1200–1699 CE)

Paracelsus (1493–1541)

Paracelsus was one of the founders of the field of toxicology, a discipline that is used to examine the toxic effects of chemicals found in environmental venues such as the workplace. Active during the time of da Vinci and Copernicus, Paracelsus advanced toxicology during the

Figure 1.6 Black Death

© National Library of Medicine.

early sixteenth century. Among his contributions were several important concepts: the dose-response relationship, which refers to the observation that the effects of a poison are related to the strength of its dose, and the notion of target organ specificity of chemicals.

John Graunt (1620–1674)

In 1662, John Graunt published *Natural and Political Observations Mentioned in a Following Index, and Made Upon the Bills of Mortality*. This work recorded descriptive characteristics of birth and death data, including seasonal variations, infant mortality, and excess male over female mortality. Graunt is said to be the first to employ quantitative methods to describe population vital statistics by organizing mortality data in a mortality table. Because of his contributions to vital statistics, Graunt has been called the Columbus of statistics.

Eighteenth Century (1700–1799 CE)

Ramazzini (1633–1714)

Bernardino Ramazzini is regarded as the founder of the field of occupational medicine.[15] He created elaborate descriptions of the manifestations of occupational

Figure 1. 7 This patient presented with symptoms of plague that included gangrene of the right foot, causing necrosis (tissue death) of the toes

Centers for Disease Control and Prevention. Public Health Image Library, ID# 4139. Available at: http://phil.cdc.gov/phil/home.asp. Accessed February 6, 2016.

diseases among many different types of workers.[16] His descriptions covered a plethora of occupations, from miners to cleaners of privies to fabric workers. The father of occupational medicine is also considered to be a pioneer in the field of ergonomics, by pointing out the hazards associated with postures assumed in various occupations. Ramazzini authored *De Morbis Artificum Diatriba* (Diseases of Workers), published in 1700. His book highlighted the risks posed by hazardous chemicals, dusts, and metals used in the workplace.

Sir Percival Pott (1714–1788)

Sir Percival Pott, a London surgeon, is thought to be the first individual to describe an environmental cause of cancer. In 1775, Pott made the astute observation that chimney sweeps had a high incidence of scrotal cancer in comparison with male workers in other occupations.[17] He argued that chimney sweeps were prone to this malady as a consequence of their contact with soot.

In a book titled *Chirurgical Observations Relative to the Cataract, the Polypus of the Nose, the Cancer of the Scrotum, the Different Kinds of Ruptures, and the Mortification of the Toes and Feet*, Pott developed a chapter called "A Short Treatise of the Chimney Sweeper's Cancer." This brief work of only 725 words is noteworthy because it was the first time that an environmental cause of cancer was clearly described and indirectly identified the first known carcinogen. Pott provided a detailed account of the link between chimney sweeping and scrotal cancer and concluded exposure to soot was to blame.[18]

Following his conclusions about the relationship between scrotal cancer and chimney sweeping, Pott established an occupational hygiene control measure—the recommendation that chimney sweeps bathe once a week.

Edward Jenner (1749–1823)

In 1798, Jenner's findings regarding his development of a vaccine that provided immunity to smallpox were published. Jenner had observed that dairymaids who had been infected with cowpox (transmitted by cattle) were immune to smallpox. The cowpox virus, known as the vaccinia virus, produces a milder infection in humans than does the smallpox virus. Jenner created a vaccine by using material from the arm of a dairymaid, Sarah Nelmes, who had an active case of cowpox. In 1796, the vaccine was injected into the arm of an 8-year-old boy, James Fipps, who was later exposed to smallpox and did not develop the disease. Concluding that the procedure was effective, Jenner vaccinated other children, including his own son. **Figure 1.8** displays an 1802 cartoon by British satirist James Gillray. The cartoon implied that people who were vaccinated would become part cow.

Nineteenth Century (1800–1899 CE)

John Snow and Cholera in London during the Mid-Nineteenth Century

Over the centuries, cholera has inspired great fear because of the dramatic symptoms and mortality that it causes. Cholera is a potentially highly fatal disease marked by profuse watery stools, called rice water stools. The onset of cholera is sudden and marked by painless diarrhea that can progress to dehydration and circulatory collapse. Severe, untreated cholera outbreaks can kill more than half of affected cases. At present, the cause of cholera is known (the bacterium *Vibrio cholerae*) and the level of fatality is often less than 1% when the disease is treated. One of the methods for transmission of cholera is through ingestion of contaminated water (see **Figure 1.9**).

Figure 1. 8 The cow pock—or—the wonderful effects of the new inoculation

Drawing by James Gillray, 1802. Reprinted from National Institutes of Health, National Library of Medicine. Smallpox: A Great and Terrible Scourge. Available at: http://www.nlm.nih.gov/exhibition/smallpox/sp_vaccination.html. Accessed February 6, 2016.

Figure 1.9 Typical water supply that is contaminated with *Vibrio cholerae*, the infectious disease agent for cholera

Centers for Disease Control and Prevention. Public Health Image Library, ID# 1940. Available at: http://phil.cdc.gov/phil/home.asp. Accessed February 6, 2016.

John Snow (1813–1858), an English anesthesiologist, innovated several of the key epidemiologic methods that remain valid and in use today. In recognition of his groundbreaking contributions, many epidemiologists consider Snow to be the father of the field. For example, Snow believed that the disease cholera was transmitted by contaminated water and was able to demonstrate this association. In Snow's time, the mechanism for the causation of infectious diseases such as cholera was largely unknown. The Dutchman Anton van Leeuwenhoek had used the microscope to observe microorganisms (bacteria and yeast). However, the connection between microorganisms and disease had not yet been ascertained. One of the explanations for infectious diseases was the **miasmatic theory of disease**, which held that "… disease was transmitted by a miasma, or cloud, that clung low on the surface of the earth."[19(p11)] This theory was applied to malaria, among other diseases.

Snow noted that an outbreak of "Asiatic" cholera had occurred in India during the early 1800s. Snow wrote, "The first case of decided Asiatic cholera in London, in the autumn of 1848, was that of a seaman named John Harnold, who had newly arrived by the Elbe steamer from Hamburgh, where the disease was prevailing."[20(p3)] Cholera then began to appear in London.

During the mid-1800s, Snow investigated a cholera outbreak in London. A section of London, designated the Broad Street neighborhood (now part of the Soho district), became the focus of Snow's detective work (refer to the map shown in **Figure 1.10**). His procedures for investigating the cholera outbreak demonstrated several important innovations (summarized in the text box titled "John Snow, MD, the forerunner of modern epidemiologists").

Here is Snow's graphic description of the cholera outbreak that occurred in 1849:

> The most terrible outbreak of cholera which ever occurred in this kingdom, is probably that which took place in Broad Street, Golden Square, and the adjoining streets, a

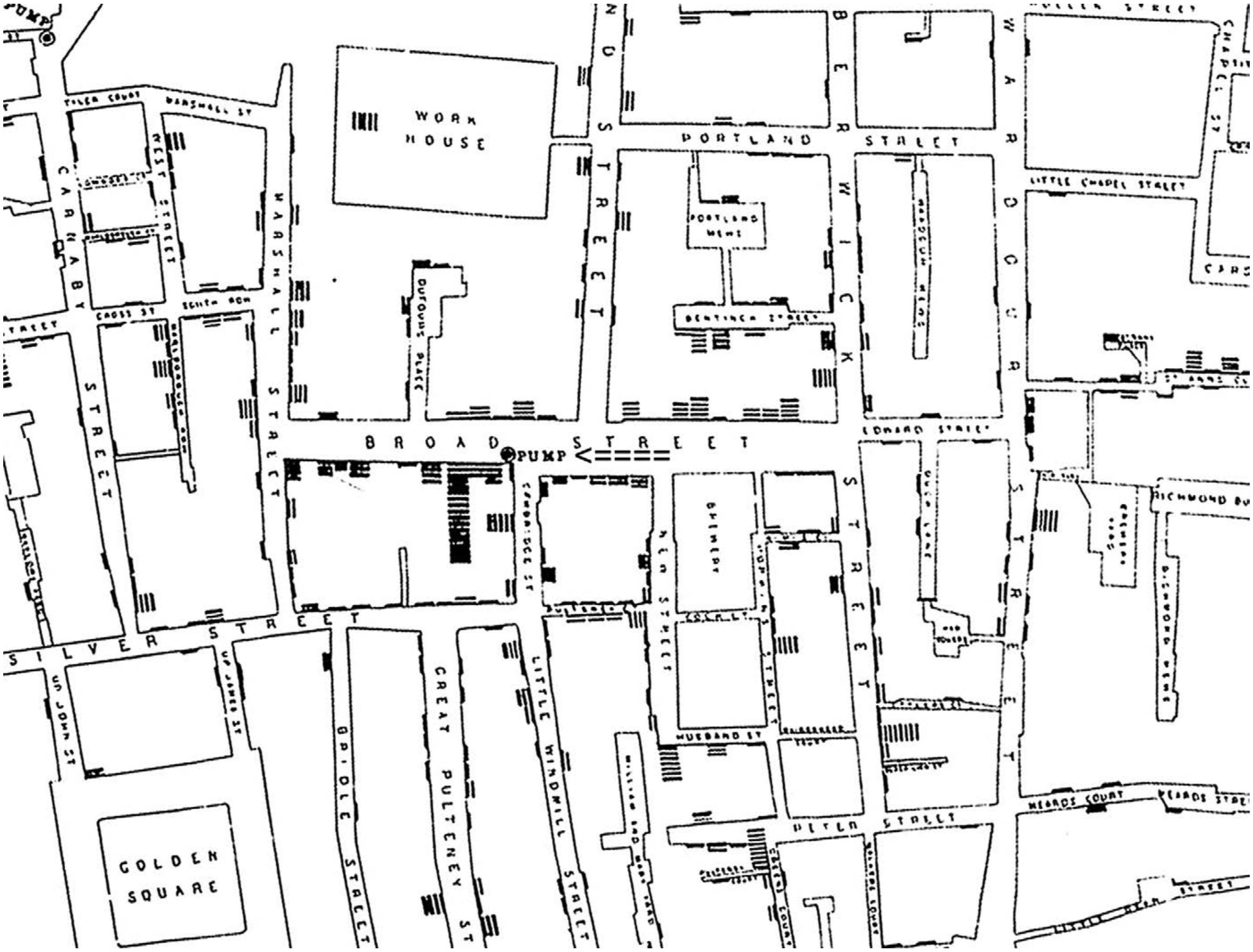

Figure 1.10 Map of cholera cases in the Broad Street, London area. Each case is indicated by a short line

Reprinted from Snow J. *Snow on Cholera*. Cambridge, MA: Harvard University Press; 1936. Reprinted by Hafner Publishing Company, © 1965.

few weeks ago.... The mortality in this limited area probably equals any that was ever caused in this country, even by the plague; and it was much more sudden, as the greater number of cases terminated in a few hours.... Many houses were closed altogether, owing to the death of the proprietors; and, in a great number of instances, the tradesmen who remained had sent away their families: so that in less than six days from the commencement of the outbreak, the most afflicted streets were deserted by more than three-quarters of their inhabitants."[20(p38)]

Snow's pioneering approach illustrated the use of both descriptive and analytic epidemiology. One of his first activities was to plot the cholera deaths in relation to a pump that he hypothesized was the cause of the cholera outbreak. Each death was shown on the map (Figure 1.10) as a short line. An arrow in the figure points to the location of the Broad Street pump. "As soon as I became acquainted with the situation and the extent of this irruption of cholera, I suspected some contamination of the water of the much-frequented street-pump in Broad Street, near the end of Cambridge Street;... On proceeding to the spot, I found that nearly all the deaths had taken place within a short distance of the pump."[20(pp38–39)] The handle of the pump was later removed—a public health measure to control the outbreak. In Snow's time, many European cities took water for domestic use directly from rivers, which often were contaminated with microorganisms. (Refer to **Figure 1.11**, which suggests that pumps that dispensed river water were sources of deadly contamination.)

Figure 1.11 Death lurks at the pump

John Snow, MD, the forerunner of modern epidemiologists

Snow's contributions to epidemiology included the following:

- Powers of observation and written expression
- Application of epidemiologic methods
  - Mapping (spot maps)
  - Use of data tables to describe infectious disease outbreaks
- Participation in a natural experiment
- Recommendation of a public health measure to prevent disease (removal of the pump handle; see text)

Snow also conducted a natural experiment: Two water companies, the Lambeth Company and the Southwark and Vauxhall Company, provided water in such a manner that adjacent houses could receive water from two different sources. In 1852, one of the companies, the Lambeth Company, relocated its water sources to a section of the Thames River that was less contaminated. During a later cholera outbreak in 1854, Snow observed that a higher proportion of residents who used the water from the Southwark and Vauxhall Company developed cholera than did residents who used water from the Lambeth Company. The correspondence between changes in the quality of the water supply and changes in the occurrence of cholera became known as a natural experiment.

Data from the outbreak of 1854 are presented in **Table 1.3**. The Lambeth Company provided cleaner water than the Southwark and Vauxhall Company. "The mortality in the houses supplied by the Southwark and Vauxhall Company was therefore between eight and nine times as great as in the houses supplied by the Lambeth Company…."[20(p86)]

Here is a second example of Snow's contributions to epidemiology. In addition to utilizing the method

Table 1.3 The Proportion of Deaths per 10,000 Houses—Cholera Epidemic of 1854

	Number of Houses	Deaths from Cholera	Deaths in Each 10,000 Houses
Southwark and Vauxhaul Company	40,046	1,263	315
Lambeth Company	26,107	98	37
Rest of London	256,423	1,422	59

Reprinted from Snow J. *Snow on Cholera*. Cambridge, MA: Harvard University Press; 1936; reprinted by Hafner Publishing Company © 1965:86.

of natural experiment, Snow provided expert witness testimony on behalf of industry with respect to environmental exposures to potential disease agents.[21] Snow attempted to extrapolate from the health effects of exposures to high doses of environmental substances to the effects of exposure to low doses. On January 23, 1855, a bill was introduced in the British Parliament called the Nuisances Removal and Diseases Prevention Amendments bill. This bill was a reform of Victorian public health legislation that followed the 1854 cholera epidemic.[21] The intent of the bill was to control release into the atmosphere of fumes from operations such as gas works, silk-boiling works, and bone-boiling factories. Snow contended that these odiferous fumes were not a disease hazard in the community.[22] The thesis of Snow's argument was that deleterious health effects from the low levels of exposure experienced in the community were unlikely, given the knowledge about higher-level exposures among those who worked in the factories. Snow argued that the workers in the factories were not suffering any ill health effects or dying from the exposures. Therefore, it was unlikely that the much lower exposures experienced by the members of the larger community would affect their health.

William Farr (1807–1883)

A contemporary of John Snow, William Farr assumed the post of "Compiler of Abstracts" at the General Register Office (located in England) in 1839 and held this position for 40 years. Among Farr's contributions to public health and epidemiology was the development of a more sophisticated system for codifying medical conditions than that which was previously in use. Also noteworthy is the fact that Farr used data such as census reports to study occupational mortality in England. In addition, he explored the possible linkage between mortality rates and population density, showing that both the average number of deaths and births per 1,000 living persons increased with population density (defined as number of persons per square mile).

Robert Koch (1843–1910)

The German physician Robert Koch (**Figure 1.12**) verified that a human disease was caused by a specific living organism. He isolated the bacteria that cause anthrax (*Bacillus anthracis*) and cholera (*V. cholerae*). One of his most famous contributions was identifying the cause of tuberculosis (*Mycobacterium tuberculosis*). This work was described in 1882 in *Die Aetiologie der Tuberkulose*. Koch's four postulates to demonstrate the

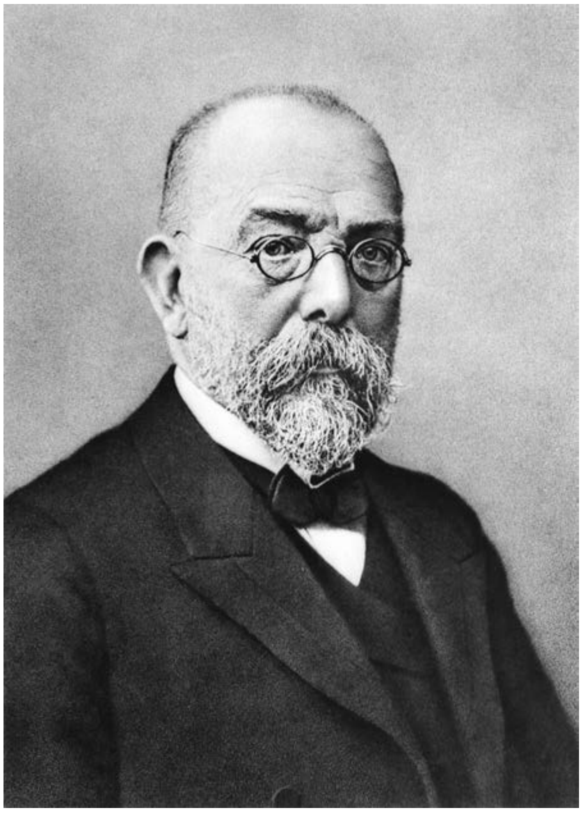

Figure 1.12 Robert Koch

association between a microorganism and a disease were formatted as follows:

1. The organism must be observed in every case of the disease.
2. It must be isolated and grown in pure culture.
3. The pure culture must, when inoculated into a susceptible animal, reproduce the disease.
4. The organism must be observed in, and recovered from, the experimental animal.[23]

Alice Hamilton (1869–1970)

Alice Hamilton was a pioneer in the field of occupational epidemiology and, in 1919, was the first woman hired to the faculty of the Harvard Medical School, serving as an assistant professor in the new Department of Industrial Medicine. Her expertise was in toxicology and her research interests focused on occupational health and the dangerous effects of industrial metals and chemical compounds on the human body. In 1912, she directed a statewide examination of occupational diseases in the United States, particularly focused on lead exposure. Over the course of her career, she identified health problems related to a number of industrial activities, including metal smelting and munitions manufacturing. Her public health efforts were commemorated by the U.S. Postal Service in 1955 with a 55-cent stamp.[24]

Early Twentieth Century (1900–1940 CE)

Pandemic Influenza

Also known as the Spanish flu, this pandemic raged from 1918 to 1919 and killed 50 to 100 million people globally. Estimates suggest that one-third of the world's population, which then was 1.5 billion, became infected and developed clinically observable illness. Instead of primarily attacking the young and the elderly as is usually the situation with influenza, the Spanish flu took a heavy toll on healthy young adults. One hypothesis is that the influenza virus interacted with respiratory bacteria, causing numerous deaths from bacterial pneumonias. The death rate was so high that morgues were overflowing with bodies awaiting burial. Adequate supplies of coffins and the services of morticians were unavailable. To handle the influx of patients, special field hospitals were set up. (See **Figure 1.13**.)

Discovery of Penicillin

Scottish researcher Alexander Fleming (1881–1955) discovered the antimicrobial properties of the mold *Penicillium notatum* in 1928. This breakthrough led to development of the antibiotic penicillin, which became available toward the end of World War II.

Figure 1.13 Emergency hospital during influenza epidemic, Camp Funston, Kansas

The Contemporary Era (1940 to the present)

The Framingham Heart Study (1948–present)

Begun in 1948, this pioneering research project is named for Framingham, Massachusetts, where, initially, a random sample of 6,500 persons 30 to 59 years of age participated. Subsequent groups of people have participated in the study, including the children and grandchildren of the original study participants. The results from this study continue to provide important information about many aspects of health, including advancements in the epidemiology of heart disease and the key role of exercise and nutrition in preventing disease development.

Smoking and Health

Following World War II, an increase in deaths attributed to lung cancer was observed in vital statistics data. At this time, a growing body of evidence suggested that cigarette smoking was linked to lung cancer as well as other forms of morbidity and mortality. In 1964, the U.S. Surgeon General released *Smoking and Health*,[25] which asserted that cigarette smoking is a cause of lung cancer in men and is linked to other disabling or fatal diseases. Epidemiologic methods and studies contributed critical information to this report.

William Carter Jenkins (1949–2019)

William Carter Jenkins earned master's degrees in biostatistics and public health and a doctorate in epidemiology (refer to **Figure 1.14**). In the 1960s, he was one of the first African American epidemiologists recruited to serve at the National Center for Health Statistics, a branch of the U.S. Public Health Service. His career was motivated by the pursuit of social justice, and one of the defining moments of his career was his work to expose and put an end to the Tuskegee syphilis study. His work contributed to the end of the study in 1972 and subsequent efforts to get an official apology from the U.S. government, which was provided by President Bill Clinton in 1997. His experiences with this study led to him devoting the remainder of his career to addressing racism and injustice in health care, including recognizing the disproportionate impact of acquired immunodeficiency syndrome (AIDS) on Black men in the early stages of the AIDS crisis.[26]

Smallpox Eradication (1977)

As noted previously, Jenner pioneered development of a smallpox vaccine during the 1800s. Smallpox is an incurable disease caused by a virus. One form of the virus, variola major, produces a highly fatal infection in unvaccinated populations. Because of a highly effective surveillance and vaccination program that was intensified during the late 1960s, the ancient scourge of smallpox was brought under control. The last known naturally acquired case was reported in Somalia in 1977.

Figure 1.14 William Carter Jenkins (1949–2019)

Other Recent Contributions

Other recent contributions of epidemiology include helping to identify HIV as the virus that causes AIDS, helping to discover the association between the human papillomavirus and cervical cancer, evaluating the success of prevention activities and approaches during the COVID-19 pandemic, responding to threats from emerging infectious diseases, and assessing the impact of the sugary food consumption on health.

Brief Overview of Current Uses of Epidemiology

Epidemiologists are indebted to J.N. Morris,[27] who published a list of seven uses of epidemiology; Morris's original formulation has continued to be relevant to the modern era. Five of these uses are shown in the following text box:

Uses of Epidemiology

Among the principal uses of epidemiology are the following:

- Historical use: Study the history of the health of populations.
- Community health use: Diagnose the health of the community.
- Health services use: Study the working of health services.
- Risk assessment use: Estimate individuals' risks of disease, accident, or defect.
- Disease causality use: Search for the causes of health and disease.

Morris JN. *Uses of Epidemiology.* 3rd ed. Edinburgh, UK: Churchill Livingstone; 1975:262–263.

Historical Use

The historical use of epidemiology documents the patterns, types, and causes of morbidity and mortality over time. Since the early 1900s, in developed countries the causes of mortality have shifted from those related primarily to infectious and communicable diseases to chronic (non-communicable) conditions. This use is illustrated by changes over time in the causes of mortality in the United States. For example, **Figure 1.15** shows the decline in the rate of influenza and pneumonia mortality between 1900 and 2013. Mortality from infectious diseases rose sharply during the influenza pandemic of 1918 and then resumed its downward trend. In the early 1980s, mortality from infectious diseases increased again because of the impact of HIV disease, but mortality from HIV disease subsequently declined once better treatments became available. Since the year 2000, the leading causes of death in the United States have consistently been chronic diseases, with heart disease and cancer resulting in the most deaths per year. The number of deaths from unintentional injuries has been steadily increasing over the last decade, largely related to the epidemic of drug overdose deaths. In 2020, COVID-19 was responsible for more deaths than any cause except for heart disease and cancer, providing another example of the continued importance of communicable diseases on population health.[28]

The term **epidemiologic transition** describes a shift in the patterns of morbidity and mortality from causes related primarily to infectious and communicable diseases to causes associated with chronic, degenerative diseases. The epidemiologic transition coincides with the **demographic transition**, a shift from high birth rates and death rates found in agrarian societies to much lower birth and death rates in developed countries. **Figure 1.16** shows the stage of epidemiologic transition across the top and the stage of demographic transition across the bottom. These two kinds of transition parallel one another over time. The figure is subdivided into four segments: pre, early, late, and post. Refer to the figure for the definitions of these stages. At present, the United States is in the posttransition stage, which is dominated by diseases associated with personal behavior, adverse lifestyle, and emerging infections.

Community Health Use

Morris described the use of epidemiology to assess the health of communities, which includes measuring the distribution of health and disease in terms of incidence, prevalence, disability and mortality.[27]

Examples of characteristics that affect the health of the community are age and sex distributions, racial/ethnic makeup, socioeconomic status, employment and unemployment rates, access to healthcare services, population density, and residential mobility. These variables are reflected in a wide range of outcomes: life expectancy, social conditions, and patterns of morbidity and mortality. Concerning for the field of epidemiology and public health professionals is the impact of demographic and socioeconomic

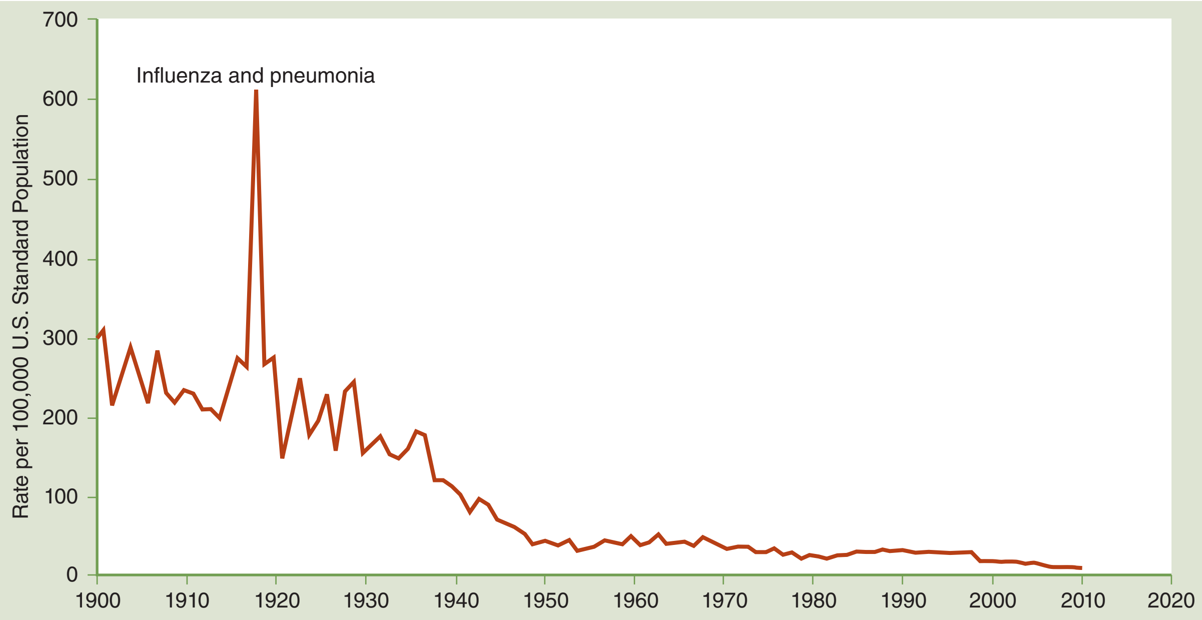

Figure 1.15 Rate* of influenza and pneumonia mortality, by year—United States, 1900–2013

*Age-adjusted

Chong Y, Tejada Vera B, Lu L, Anderson RN, Arias E, Sutton PD. *Deaths in the United States, 1900–2013.* Hyattsville, MD: National Center for Health Statistics; 2015. Available at: https://blogs.cdc.gov/nchs-data-visualization/deaths-in-the-us/. Accessed November 17, 2016.

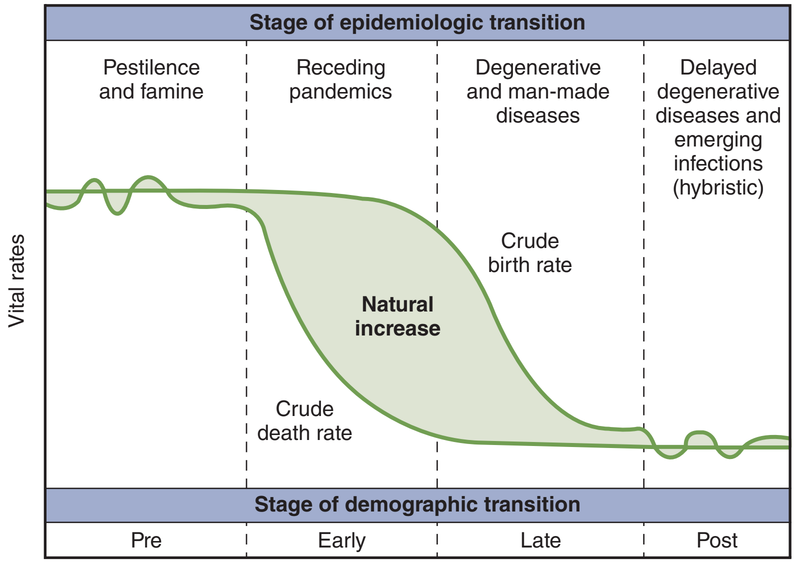

Figure 1.16 Demographic/epidemiologic transition framework

Reprinted from Rockett IRH. Population and health: an introduction to epidemiology, 2nd ed. *Population Bulletin*, December 1999;54(4):9. Reprinted with permission of Population Reference Bureau.

factors on health disparities observed in many communities. The communities where people live are very salient for adverse health outcomes and, conversely, a healthy life.

Health Services Use

Morris also proposed that epidemiology could be used to determine how well health services were working in a community and how they could be improved."[27]

Operations research is defined as a type of study of the placement of health services in a community and the optimum utilization of such services. Epidemiology helps to provide quantitative information regarding the availability and cost of healthcare services. Epidemiologic studies aid planners in determining what services are needed in the community and what services are duplicated unnecessarily. Provision of healthcare services is exceedingly costly for society. Epidemiologic methods can provide inputs into cost-benefit analyses, which balance cost issues against quality of services in order to maximize cost effectiveness. Epidemiologic findings are relevant to the current era of managed care through **disease management**; this term refers to a method of reducing healthcare costs by providing integrated care for chronic conditions (e.g., heart disease, hypertension, and diabetes). Since the implementation of the 2010 Affordable Care Act, epidemiologic methods have been critical to the ongoing assessment of healthcare quality and efficiency.

Risk Assessment Use

According to Morris, epidemiology could be used to estimate individual risks of diseases or other health outcomes based on group experiences and suggest ways to reduce these risks [27]

Risk is "[t]he probability of an adverse or beneficial event in a defined population over a specified time interval."[8] A **risk factor** is an exposure that is associated with a disease, morbidity, mortality, or another adverse health outcome. For example, cigarette smoking increases the risk of developing certain forms of cancer, including lung cancer. Epidemiologic studies provide quantitative measurements of risks to health through a methodology known as risk assessment, which is one of the major cornerstones of health policy development.

Disease Causality Use

With respect to this use, Morris indicated that epidemiology could be used to investigate the causes of health and disease.[27]

The search for causes of disease and other health outcomes is one of the most important uses of epidemiology. In order to assess potential causal associations, epidemiologists need to consider a set of causal criteria, such as the strength of association between exposure and health outcome and whether the exposure preceded the health outcome temporally. Descriptive epidemiologic studies can suggest hypotheses to be studied and possible associations can be evaluated by analytic study designs. These analytic study designs include case-control and cohort studies, as well as natural experiments, clinical trials, and community trials. We will learn that study designs, whether observational or analytic, can be arranged in a hierarchy according to our confidence in the validity of the information that they provide.

Conclusion

Epidemiologists study the occurrence of diseases and health outcomes in populations. Findings from epidemiologic research are reported frequently in the popular media. For example, disease outbreaks such as those caused by foodborne illnesses often command public attention. Chapter 1 defined some of the terms that are used to describe disease outbreaks, discussed the scope and applications of epidemiology, and presented information on its interdisciplinary composition. Epidemiologic methods are applicable to many types of health-related issues, from infectious diseases to violence in schools. Although many people consider epidemiology to be essentially a medical subject, it is also a liberal arts discipline in many respects. Epidemiology provides training in generally applicable skills such as critical-thinking ability and use of the scientific method.

Epidemiology is primarily an observational science that involves describing the occurrence of disease in populations (descriptive epidemiology) and researching the etiology of diseases (analytic epidemiology). The history of epidemiology extends over many centuries, beginning during classical antiquity at the time of the ancient Greeks. Subsequent historical events included the identification of infectious disease agents and Snow's employment of methods that remain relevant today, for example, case mapping and data tabulation. Recent history has included eradication of smallpox, development of improved procedures to control chronic diseases, and responding to new and emerging infectious diseases. Some uses of epidemiology are documenting trends in health and disease, diagnosing the health of the community, and identifying needed health services.

WRAP-UP

Study Questions and Exercises

1. Define the following terms:
   a. Epidemic
   b. Pandemic
   c. Epidemiology
2. Name and discuss three of the key characteristics of epidemiology.
3. In what respects does epidemiology differ from clinical medicine?
4. What are some examples of risk factors for disease that you experience in your life? Be sure to define what is meant by a risk factor.
5. Check your local library or go online to find works of literature that describe epidemics and epidemic detective work. A recommended title is Berton Roueché's classic, *The Medical Detectives* (New York, NY: Penguin Books; 1991). This work describes "Eleven Blue Men" and other fascinating episodes of medical investigations. Another recommended title is Lydia Kang and Nate Petersen's *Patient Zero: A Curious History of the World's Worst Diseases* (New York, NY: Workman Publishing Company; 2021).
6. Distinguish between the descriptive and analytic approaches to epidemiology.
7. The following list shows individuals who contributed to the history of epidemiology. Describe each of their contributions.
   a. Hippocrates
   b. John Graunt
   c. Sir Percival Pott
   d. Alice Hamilton
   e. Alexander Fleming
8. Discuss four uses of epidemiology. For each use, give examples that were not mentioned in the text. Rank the uses according to their importance for public health.
9. Find an article in the popular media (either in the print media or online) that illustrates one or more uses of epidemiology. Write a one-page summary of the article and highlight the uses of epidemiology that are relevant to the topic presented. If you are enrolled in a class, be prepared to discuss the article in the class.
10. How could epidemiology be used to research and develop solutions to the problems of electronic bullying and bullying on school campuses? In what sense are the events an appropriate topic for epidemiologic investigation? Why do you think a greater percentage of females than males report electronic bullying?
11. New outbreaks of disease erupt periodically in the United States and elsewhere around the globe. Some of these conditions are familiar, whereas others are entirely new. List at least three outbreaks of disease that have happened in the last 6 months. If you are enrolled in a class, create an online forum in which you catalog recent and current epidemics.
12. What are your objectives for studying epidemiology? What skills do you hope to acquire? How will this information help you to advance your career in public health? Demonstrate ways in which this course can help you with your present position, regardless of whether it is connected with the health field.
13. The COVID-19 pandemic, Ebola virus scare, and foodborne illnesses associated with a restaurant chain are examples of challenges to epidemiology. Compare the similarities and differences among these events. State at least one general principle that you can distill from these episodes.
14. What would be the response of epidemiologists to a single case of a long absent infectious disease (e.g., smallpox), should it happen in New York City? Describe the circumstances under which a single case of a disease is considered to be an epidemic.
15. Illustrate four ways in which epidemiology contributes as the basic science of public health.
16. John Snow removed the handle from the pump featured in the Broad Street cholera epidemic. Using your own ideas, state why or why not this was an effective public health intervention.
17. Describe John Snow's natural experiment. Based on your own knowledge, discuss at least two contemporary examples of natural experiments that have been implemented within the past decade.
18. In your own opinion, why do you think many public health professionals regard John Snow as the father of epidemiology? Provide three reasons to support your position.

19. Using your own ideas, define the terms Black Death and Spanish flu and state why these events were historically significant for epidemiology.
20. In your opinion, under what present-day circumstances could Edward Jenner conduct his experiments with smallpox vaccinations? Do you think that any of his procedures would be prohibited in a modern research study?
21. In what ways was the COVID-19 pandemic similar to previous global disease pandemics such as the Black Death and Spanish flu? In what ways was it different?
22. Name three contemporary achievements of epidemiology. Discuss how the historical context of epidemiology helped to make them possible.
23. As noted previously, epidemiology studies the distribution of diseases in populations. Conduct a discussion in your class or an online forum in which you cite examples of the differential distributions of adverse health outcomes among various subgroups of the American population and explanations for their occurrence.

Young Epidemiology Scholars (YES) Exercises

The Young Epidemiology Scholars: Competitions website provides links to teaching units and exercises that support instruction in epidemiology. The YES program, discontinued in 2011, was administered by the College Board and supported by the Robert Wood Johnson Foundation. The exercises continue to be available at the following website: http://yes-competition.org/yes/teaching-units/title.html. The following exercises relate to topics discussed in this chapter and can be found on the YES competitions website.

History of epidemiology

1. McCrary F, Stolley P. Examining the Plague: An Investigation of Epidemics Past and Present.
2. McCrary F, St. George DMM. Mortality and the Trans-Atlantic Slave Trade.
3. McCrary F, Baumgarten M. Casualties of War: The Short- and Long-Term Effects of the 1945 Atomic Bomb Attacks on Japan.

Uses of epidemiology

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