CHAPTER

1

Foundations of Epidemiology

OBJECTIVES

After completing this chapter, you will be able to:

- Define epidemiology.
- Define descriptive epidemiology.
- Define analytic epidemiology.
- Identify some activities performed in epidemiology.
- Explain the role of epidemiology in public health practice and individual decision making.
- Define epidemic, endemic, and pandemic.
- Describe common source, propagated, and mixed epidemics.
- Describe why a standard case definition and adequate levels of reporting are important in epidemiologic investigations.
- Describe the epidemiology triangle for infectious disease.
- Describe the advanced epidemiology triangle for chronic diseases and behavioral disorders.
- Define the three levels of prevention used in public health and epidemiology.
- Understand the basic vocabulary used in epidemiology.

In recent years, the important role of epidemiology has become increasingly recognized. Epidemiology is a core subject required in public health and health education programs; it is a study that provides information about public health problems and the causes of those problems. This information is then used to improve the health and social conditions of people. Epidemiology has a population focus in that epidemiologic investigations are concerned with the collective health of the people in a community or population under study. In contrast, a clinician is concerned for the health of an individual. The clinician focuses on treating and caring for the patient, whereas the epidemiologist focuses on identifying the source or exposure of disease, disability or death, the number of persons exposed, and the potential for further spread. The clinician treats the patient based on scientific knowledge, experience, and clinical judgment, whereas the epidemiologist uses descriptive and analytical epidemiologic methods to provide information that will ultimately help determine the appropriate public health action to control and prevent the health problem.

Epidemiology is defined as the study of the distribution and determinants of health-related states or events in human populations and the application of this study to the prevention and control of health problems.[1] The word epidemiology is based on the Greek words epi, a prefix meaning "on, upon, or befall"; demos, a root meaning "the people"; and logos, a suffix meaning "the study of." In accordance with medical terminology, the suffix is read first and then the prefix and the root. Thus, the word epidemiology taken literally refers to the study of that which befalls people. As such, epidemiology is commonly referred to as the basic science or foundation of public health.

Epidemiology involves sound methods of scientific investigation. Epidemiologic investigations involve descriptive and analytic methods which draw on statistical techniques for describing data and evaluating hypotheses, biological principles, and causal theory. Both descriptive and analytic epidemiology are discussed at length in later chapters. Briefly, descriptive epidemiology involves characterization of the distribution of health-related states or events. Analytic epidemiology involves finding and quantifying associations, testing hypotheses, and identifying causes of health-related states or events.[2]

Evaluating the distribution of disease means to identify the frequency and pattern of health-related states or events among people in the population. Frequency refers to the number of health-related states or events and their relationship with the size of the at-risk population. Typically, the number of cases or deaths is more meaningful when considered in reference to the size of the corresponding population, especially when comparing risks of disease among groups. For example, despite differences in population sizes across time or among regions, meaningful comparisons can be made of the burden of HIV/AIDS by using proportions or percentages. In 2007, the estimated percentage of adults 15 to 49 years of age with HIV/AIDS was 5.0% in sub-Saharan Africa, 0.3% in the Middle East and North Africa, 0.3% in South and Southeast Asia, 0.1% in East Asia, 0.4% in Oceania, 0.5% in Latin America, 1.0% in the Caribbean, 0.9% in Eastern Europe and Central Asia, 0.3% in Western and Central Europe, and 0.6% in North America.[3]

Pattern refers to describing health-related states or events by who is experiencing the health-related state or event (person), where the occurrence of the state or event is highest or lowest (place), and when the state or event occurs most or least (time). In other words, epidemiologists are interested in identifying the people involved and why these people are affected and not others, where the people are affected and why in this place and not others, and when the state or event occurred and why at this time and not others.

For example, in 1981 the Centers for Disease Control and Prevention (CDC) reported that five young men went to three different hospitals in Los Angeles, California with confirmed *Pneumocystis carinii* pneumonia. These men were all identified as homosexuals.[4]

On July 27, 1982, this illness was called AIDS, and in 1983, the Institut Pasteur in France found the human immunodeficiency virus, which causes AIDS.[5]

Identifying the determinants or determining factors of health-related states or events is a primary function of epidemiology. A cause is a specific event, condition, or characteristic that precedes the health outcome and is necessary for its occurrence. An adverse health outcome can be prevented by eliminating the exposure. If an environmental exposure is required for the health outcome to occur, the causative factor is "necessary." If the health-related state or event always occurs because of the exposure, the causative factor is "sufficient." For example, a mother's exposure to rubella virus (Rubivirus) is necessary for rubella to occur; however, exposure to rubella virus is not sufficient to cause rubella because not everyone infected develops the disease.

Identifying causal associations is complex and typically requires making a "judgment" based on the totality of evidence, such as a valid statistical association, time sequence of events, biologic credibility, and consistency among studies. A step towards understanding causation is to identify relevant risk factors. A risk factor is a behavior, environmental exposure, or inherent human characteristic that is associated with an important health condition.[6] In other words, a risk factor is a condition that is associated with the increased probability of a health-related state or event. For example, smoking is a risk factor for chronic diseases such as heart disease, stroke, and several cancers (including cancers of the oral cavity and pharynx, esophagus, pancreas, larynx, lung and bronchus, urinary bladder, kidney and renal pelvis, and cervix).[7–10] A risk factor is typically not sufficient to cause a disease, but other contributing factors, such as personal susceptibility, are also required before a disease occurs.

The term "health-related states or events" is used in the definition of epidemiology to capture the fact that it involves more than just the study of disease (e.g., cholera, influenza, pneumonia); it also includes the study of events (e.g., injury, drug abuse, and suicide) and of behaviors and conditions associated with health (e.g., physical activity, nutrition, seat belt use, and provision and use of health services).

Epidemiology not only involves the study of the distribution and determinants of health-related states or events in human populations, but it also involves the application of this study to the prevention and control of health problems. Results of epidemiologic investigations can provide public health officials with information related to who is at greatest risk for disease, where the disease is most common, when the disease occurs most frequently, and what public health programs might be most effective. Such information may lead to more efficient resource allocation and to more appropriate application of health programs designed to educate and prevent and control disease. Epidemiologic information can also assist individuals in making informed decisions about their health behavior.

ACTIVITIES IN EPIDEMIOLOGY

An epidemiologist studies the occurrence of disease or other health-related events in specified populations, practices epidemiology, and controls disease.[1] Epidemiologists may be involved in a range of activities, such as:

- Identifying risk factors for disease, injury, and death
- Describing the natural history of disease
- Identifying individuals and populations at greatest risk for disease
- Identifying where the public health problem is greatest
- Monitoring diseases and other health-related events over time

- Evaluating the efficacy and effectiveness of prevention and treatment programs
- Providing information that is useful in health planning and decision making for establishing health programs with appropriate priorities
- Assisting in carrying out public health programs
- Being a resource person
- Communicating public health information

The interdependence of these activities is evident. For example, carrying out an intervention program requires clearance from an institutional review board and often other organizations and agencies. As is also the case for funding agencies, these groups require quantifiable justification of needs and of the likelihood of success. This presupposes that the risk factors are known, that there is an understanding of the natural history of the disease, and that there are answers to the questions of person, place, and time, as well as some evidence of the probable success of the intervention. Being a resource person in this process requires a good understanding of the health problem as it relates to the individual and community; the rationale and justification for intervention, along with corresponding goals and objectives; and an ability to communicate in a clear and concise manner.[11] All of this implies a good understanding of epidemiologic methods.

In their professional work, epidemiologists may focus on specific areas, such as epidemiologic methods, infectious disease, chronic disease, oral and dental health epidemiology, pharmacoepidemiology, psychiatric epidemiology, social epidemiology, environmental epidemiology, reproductive epidemiology, and more. Training for these various focus areas is broad; nevertheless, the training required in each of the areas typically includes statistics and medicine.

Epidemiologists are employed by the appropriate health agencies at all levels of local, state, and federal government. They find careers in healthcare organizations, private and voluntary health organizations, hospitals, military organizations, and private industry. Epidemiologists are also employed by universities and medical schools to teach and/or conduct research.

ROLE OF EPIDEMIOLOGY IN PUBLIC HEALTH PRACTICE

Epidemiologic information plays an important role in meeting public health objectives aimed at promoting physical, mental, and social well-being in the population. Epidemiologic findings contribute to preventing and controlling disease, injury, disability, and death by providing information that leads to informed public health policy and planning as well as individual health decision making. Some useful information provided to health policy officials and individuals through epidemiology is listed in **Table 1-1**.

Public health assessment identifies if, where, and when health problems occur and serves as a guide to public health planning, policy making, and resource allocation. The state of health of the population should be compared with the availability, effectiveness, and efficiency of current health services. Most areas of the United States have surveillance systems that monitor the morbidity and mortality of the community by person, place, and time. Public health surveillance has been defined as the ongoing systematic collection, analysis, interpretation, and dissemination of health data.[12] Surveillance information about disease epidemics, breakdowns in vaccination or prevention programs, and health disparities among special populations is important for initiating and guiding action.

Accurate assessment requires standard case definitions and adequate levels of reporting. A standard set of criteria, or **case definition**, ensures that cases are consistently diagnosed,

TABLE 1-1 Types of Epidemiologic Information Useful for Influencing Public Health Policy and Planning and Individual Health Decisions

1. Public health assessment
   - Surveillance
   - Identifying who is at greatest risk for experiencing the public health problem
   - Identifying where the public health problem is greatest
   - Identifying when the public health problem is greatest
   - Monitoring potential exposures over time
   - Monitoring intervention-related health outcomes over time
2. Finding causes of disease
   - Identifying the primary agents associated with disease, disorders, or conditions
   - Identifying the mode of transmission
   - Combining laboratory evidence with epidemiologic findings
3. Completing the clinical picture
   - Identifying who is susceptible to disease
   - Identifying the types of exposures capable of causing disease
   - Describing the pathologic changes that occur, the stage of subclinical disease, and the expected length of this subclinical phase of the disease
   - Identifying the types of symptoms that characterize the disease
   - Identifying probable outcomes (recovery, disability, or death) associated with different levels of the disease
4. Evaluating the program
   - Identifying the efficacy of the public health program
   - Measuring the effectiveness of the public health program

regardless of where or when they were identified and who diagnosed the case. Higher levels of reporting ensure accurate representation of the health problem; however, even low levels of reporting can provide important information as to the existence and potential problems of a given health state or event.

When evaluating a prevention or control program, both the efficacy and the effectiveness of the program should be considered. Although these terms are related, they have distinct meanings. **Efficacy** refers to the ability of a program to produce a desired effect among those who participate in the program compared with those who do not.[3,13] **Effectiveness**, on the other hand, refers to the ability of a program to produce benefits among those who are offered the program.[3,13] For example, suppose a strict dietary intervention program is designed to aid in the recovery process of heart attack patients. If those who comply with the program have much better recoveries than those who do not, the program is efficacious; however, if compliance is low because of, for example, the amount, cost, and types of foods involved in the program, the program is not effective. Similarly, a physical activity program involving skiing could be efficacious, but the cost of skiing and the technical skills associated with it may make it ineffective in the general public. Finally, it must be taken into account that the administration of some interventions might require the presence of individuals with advanced medical training and technically advanced equipment. In certain communities, a lack of available health resources may limit the availability of such programs, making them ineffective even though they may be efficacious.

EPIDEMICS, ENDEMICS, AND PANDEMICS

Historically, epidemiology was developed in order to investigate epidemics of infectious disease. An **epidemic** is the occurrence of cases of an illness, specific health-related behavior, or other health-related events clearly in excess of normal expectancy in a community or region.[1] Public health officials often use the term outbreak, which is used synonymously with epidemic but actually refers to an epidemic confined to a localized area.[6] An epidemic may result from exposure to a common source at a point in time or through intermittent or continuous exposure over days, weeks, or years. An epidemic may also result from exposure propagated through gradual spread from host to host. It is possible for an epidemic to originate from a common source and then, by secondary spread, be communicated from person to person.

The word "**endemic**" refers to the ongoing, usual, or constant presence of a disease in a community or among a group of people; a disease is said to be endemic when it continually prevails in a region.[1] For example, although influenza follows a seasonal trend with the highest number of cases in the winter months, it is considered endemic if the pattern is consistent from year to year. A **pandemic** is an epidemic affecting or attacking the population of an extensive region, country, or continent.[1]

Several epidemics of cholera have been reported since the early 1800s. In 1816, an epidemic of cholera occurred in Bengal, India and then became pandemic as it spread across India, extending as far as China and the Caspian Sea before receding in 1826.[14] Other cholera epidemics that also became pandemic involved Europe and North America (1829–1851), Russia (1852–1860), Europe and Africa (1863–1875), Europe and Russia (1899–1923), and Indonesia, El Tor, Bangladesh (India), and the Union of Soviet Socialist Republics (1961–1966).[14] Examples of case reports of cholera, provided by John Snow, along with descriptions of two cholera epidemics investigated by Snow, are presented in Case Study I: Snow on Cholera (Appendix I).

In the United States, cholera is now classified as an endemic disease. From 1992 to 1999, the annual numbers of cases reported were 103, 25, 39, 23, 4, 6, 17, and 6, respectively.[15] Other examples of diseases classified now as endemic in the United States include botulism, brucellosis, and plague.

Epidemics are often described by how they spread through the population. Two primary types of infectious-disease epidemics are common-source and propagated epidemics. **Common-source epidemics** arise from a specific source, whereas **propagated epidemics** arise from infections transmitted from one infected person to another. Transmission can occur through direct or indirect routes. Common-source epidemics tend to result in cases occurring more rapidly during the initial phase than do host-to-host epidemics. Identifying the common source of exposure and removing it typically causes the epidemic to abate rapidly. On the other hand, host-to-host epidemics rise and fall more slowly. Some examples of common-source epidemic diseases are anthrax, traced to milk or meat from infected animals; botulism, traced to soil-contaminated food; and cholera, traced to fecal contamination of food and water. Some examples of propagated epidemic diseases are tuberculosis, whooping cough, influenza, and measles.

In some diseases, natural immunity or death can decrease the susceptible population. Resistance to the disease can also occur with treatment or immunization, both of which reduce susceptibility. Disease transmission is usually a result of direct person-to-person contact or of contact with fomites, vehicles, or vectors. Syphilis and other sexually transmitted diseases (STDs) are examples of direct transmission. Hepatitis B and HIV/AIDS in needle-sharing drug users are examples of **vehicle-borne transmission**. Malaria spread by mosquitoes is an example of **vector-borne transmission**.

Some disease outbreaks may have both common-source and propagated epidemic features. A **mixed epidemic** occurs when victims of a common-source epidemic have person-to-person contact with others and spread the disease, resulting in a propagated outbreak. In some cases, it is difficult to determine which came first. During the mid 1980s, at the beginning of the AIDS epidemic in San Francisco, HIV spread rapidly in bathhouses. Homosexual men had sexual contact before entering the bathhouses, yet the bathhouses would be considered the common source aspect of the epidemic, and the person-to-person spread through sexual intercourse would be the source of direct transmission. Direct disease transmission from person-to-person contact occurred in some individuals before and after entering a bathhouse. The bathhouses (the common source) were clearly a point for public health intervention and control, and thus, the bathhouses were closed in an attempt to slow the epidemic.

CASE CONCEPTS IN EPIDEMIOLOGY

When an epidemic is confirmed and the epidemiology investigation begins, one activity of the epidemiologist is to look for and examine cases of the disease. Any individual in a population group identified as having a particular disease, disorder, injury, or condition is considered a **case**. A clinical record of an individual, or someone identified in a screening process, or from a survey of the population or general data registry can also be an epidemiologic case. Thus, the epidemiologic definition of a case is broader than the clinical definition because a variety of criteria can be used to identify cases in epidemiology.

In an epidemic, the first disease case in the population is the **primary case**. The first disease case brought to the attention of the epidemiologist is the **index case**. The index case is not always the primary case. Those persons who become infected and ill after a disease has been introduced into a population and who become infected from contact with the primary case are **secondary cases**. A **suspect case** is an individual (or a group of individuals) who has all of the signs and symptoms of a disease or condition yet has not been diagnosed as having the disease, or has the cause of the symptoms connected to a suspected **pathogen** (i.e., any virus, bacteria, fungus, parasite).[1] For example, a cholera outbreak could be in progress, and a person could have vomiting and diarrhea, symptoms consistent with cholera. This is a suspect case as the presence of cholera bacteria in the person's body has not been confirmed, and the disease has not been definitely identified as cholera because it could be one of the other gastrointestinal diseases, such as salmonella food poisoning.

As indicated previously, since epidemics occur across time and in different places, each case must be described in exactly the same way each time in order to standardize disease investigations. As cases occur in each separate epidemic, they must be described and diagnosed consistently—and with the same diagnostic criteria—from case to case. When standard disease diagnosis criteria are used by all the people assisting in outbreak investigations, the epidemiologist can compare the numbers of cases of a disease that occur in one outbreak (numbers of new cases in a certain place and time) with those in different outbreaks of the same disease (cases from different epidemics in different places and times). Computerized laboratory analysis that is now available, even in remote communities, has enhanced the ability of those involved to arrive at a case-specific definition. With advanced computer-assisted support directly and quickly available from the CDC, case definitions of almost all diseases have become extremely accurate and specific.

Different levels of diagnosis (suspect, probable, or confirmed) are generally used by the physician who is assisting in epidemic investigations. As more information (such as laboratory results) becomes available to the physician, the physician generally upgrades the diagnosis. When all criteria are met for the case definition, the case is classified as a confirmed case. If the case definition is not matched, then the exposed person is labeled "not a case," and other possible diseases are considered until the case definition fits. Elaborate diagnoses are not always needed in those epidemics in which obvious symptoms can be quickly seen, such as measles and chicken pox.[3]

If people become ill enough to require hospitalization, the severity of the illness is of concern. **Case severity** is found by looking at several variables that are effective measures of it. One such measure is the average length of stay in a hospital. The longer the hospital stay the greater the severity of the illness. Subjectively, severity is also measured by how disabling or debilitating the illness is, the chances of recovery, how long the person is ill, and how much care the person (case) needs.[16–19]

THE EPIDEMIOLOGY TRIANGLE

When the colonists settled America, they introduced smallpox to the Native Americans. Epidemics became rampant, and entire tribes died as a result. In the 1500s, the entire native population of the island of Jamaica died when smallpox was introduced. Poor sanitation and basic knowledge of disease, the low levels of immunity, the various modes of transmission, and the environmental conditions all allowed such epidemics to run wild and wipe out entire populations. A multitude of epidemiologic circumstances allowed such epidemics to happen. The interrelatedness of four epidemiologic factors often contributed to an outbreak of a disease: (1) the role of the host; (2) the agent or disease-causing organism; (3) the environmental circumstances needed for a disease to thrive, survive, and spread; and (4) time-related issues.

The traditional triangle of epidemiology is shown in Figure 1-1. This triangle is based on the communicable disease model and is useful in showing the interaction and interdependence of agent, host, environment, and time as used in the investigation of diseases and epidemics. The **agent** is the cause of the disease; the **host** is an organism, usually a human or an animal, that harbors the disease; the **environment** includes those surroundings and conditions external to the human or animal that cause or allow disease transmission; and **time** accounts for incubation periods, life expectancy of the host or the pathogen, and duration of the course of the illness or condition.

Agents of infectious disease include bacteria, viruses, parasites, fungi, and molds. With regard to noninfectious disease, disability, injury, or death, agents can include chemicals from

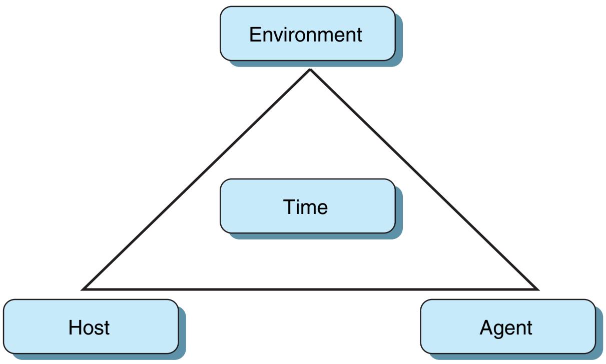

FIGURE 1-1 The triangle of epidemiology.

dietary foods, tobacco smoke, solvents, radiation or heat, nutritional deficiencies, or other substances, such as rattlesnake poison. One or several agents may contribute to an illness.

A host offers subsistence and lodging for a pathogen and may or may not develop the disease. The level of immunity, genetic makeup, level of exposure, state of health, and overall fitness of the host can determine the effect a disease organism will have on it. The makeup of the host and the ability of the pathogen to accept the new environment can also be a determining factor because some pathogens only thrive under limited ideal conditions. For example, many infectious disease agents can exist only in a limited temperature range.

Environmental factors can include biological aspects as well as physical stresses (excessive heat, cold, and noise; radiation and vehicular collisions; workplace injuries; and so on), chemicals (drugs, acids, alkali, heavy metals, poisons, and some enzymes), and psychosocial milieu (families and households, socioeconomic status, social networks and social support, neighborhoods and communities, formal institutions, and public health policy). The surroundings in which a pathogen lives and the effect the surroundings have on it are a part of the environment. The environment can be within a host or external to it in the community. Finally, time includes severity of illness in relation to how long a person is infected or until the condition causes death or passes the threshold of danger toward recovery. Delays in time from infection to when symptoms develop, duration of illness, and threshold of an epidemic in a population are time elements with which the epidemiologist is concerned.

The primary mission of epidemiology is to provide information that results in breaking one of the legs of the triangle, thereby disrupting the connection among environment, host, and agent and stopping the outbreak. On the basis of epidemiologic information, public health efforts are able to prevent and control health-related states and events (**Figure 1-2**). An epidemic can be stopped when one of the elements of the triangle is interfered with, altered, changed, or removed from existence so that the disease no longer continues along its mode of transmission.

FIGURE 1-2 Airplanes are often used to spray the watery breeding places (environment) of mosquitoes in an effort to kill this *vector* of malaria, St. Louis encephalitis, and yellow fever. Picture courtesy of Centers for Disease Control and Prevention, Atlanta, Georgia.

SOME DISEASE TRANSMISSION CONCEPTS

Several disease transmission concepts that relate to or influence the epidemiology triangle are fomites, vectors, reservoirs, and carriers.

Fomites (fomes = singular) are objects such as clothing, towels, and utensils that can harbor a disease agent and are capable of transmitting it.[1] An example of transmission of cutaneous anthrax from drums to a woman is shown in **Figure 1-3**.

A **vector** is an invertebrate animal (e.g., tick, mite, mosquito, bloodsucking fly) that is capable of transmitting an infectious agent among vertebrates.[1] A vector can spread an infectious agent from an infected animal or human to other susceptible animals or humans through its waste products, bite or body fluids, or indirectly through food contamination. Transmission may be either mechanical (i.e., the agent does not multiply or undergo physiologic changes in the vector) or biological (i.e., the agent undergoes part of its life cycle inside the vector before being transmitted to a new host).

A **reservoir** is the habitat (living or nonliving) in or on which an infectious agent lives, grows, and multiplies and on which it depends for its survival in nature.[1,3] As infectious organisms reproduce in the reservoir, they do so in a manner that allows disease to be transmitted to a susceptible host. Humans often serve as both reservoir and host. A disease transmitted to a human from an animal is referred to as a zoonosis. The World Health Organization states that **zoonoses** are those diseases and infections that are transmitted between vertebrate animals and humans.[20]

A **vehicle** is a nonliving intermediary such as a fomite, food or water that conveys the infectious agent from its reservoir to a susceptible host.

A **carrier** contains, spreads, or harbors an infectious organism (**Figure 1-4**). The infected person (or animal) harboring the disease-producing organism often lacks discernible clinical manifestation of the disease; nevertheless, the person or animal serves as a potential source of infection and disease transmission to other humans (or animals). The carrier condition can exist throughout the entire course of a disease if it is not treated, and its presence can be unapparent because the carrier may not be sick (healthy carriers). Some people can even be carriers for their entire lives. An example of this was Typhoid Mary (see Chapter 2, "Historic Developments in Epidemiology"). Some carriers can be cured of this condition. Typhoid Mary may have been cured by surgery (removal of the gallbladder

FIGURE 1-3 These drums, purchased in Haiti, served as a *fomite* and were responsible for transmitting cutaneous anthrax to the 22-year-old female who purchased them. Picture courtesy of Centers for Disease Control and Prevention, Atlanta, Georgia.

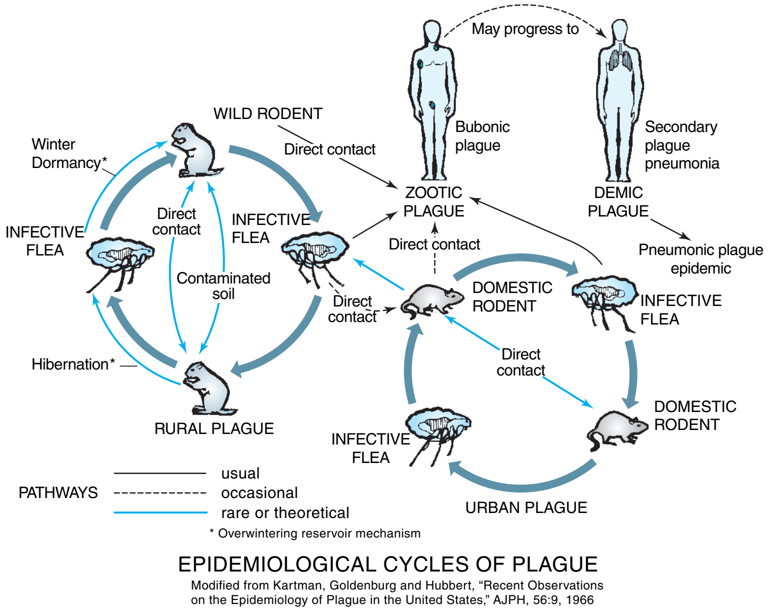

FIGURE 1-4 Rodents and coyotes are often *carriers* of bubonic plague. Fleas serve as *vectors* in transmitting this disease to humans as shown in these epidemiological cycles of the bubonic plague. Courtesy of Centers for Disease Control and Prevention, Atlanta, Georgia.

provides a cure in 60% of all typhoid carriers), and if she had lived in modern times, antibiotics would have been effective.[16–18] Tuberculosis is another example of a disease that is commonly known to have carriers.

Carriers have been found to have several different conditions or states. Traditionally, five types of carriers have been identified by the public health and medical fields.

1. **Active carriers**. Individuals who have been exposed to and harbor a disease-causing organism (pathogen) and who have done so for some time, even though they may have recovered from the disease.
2. **Convalescent carriers**. Individuals who harbor a pathogen and who, although in the recovery phase of the course of the disease, are still infectious.
3. **Healthy carriers** (also called passive carriers). Individuals who have been exposed to and harbor a pathogen but have not become ill or shown any of the symptoms of the disease. This could be referred to as a subclinical case.
4. **Incubatory carriers**. Individuals who have been exposed to and harbor a pathogen, are in the beginning stages of the disease, are showing symptoms, and have the ability to transmit the disease.
5. **Intermittent carriers**. Individuals who have been exposed to and harbor a pathogen and who can spread the disease in different places or intervals.[21,22]

MODES OF DISEASE TRANSMISSION

There are two general **modes of disease transmission**: direct transmission and indirect transmission.

Direct transmission is the direct and immediate transfer of an agent from a host/reservoir to a susceptible host. Direct transmission can occur through direct physical contact (see News File [later in this chapter]), such as exposure to a person or animal or its waste products. Examples of direct transmission include mucous membrane to mucous membrane (STDs), skin-to-skin (herpes type 1, anthrax from direct contact with an infected animal), across placenta (toxoplasmosis), fecal-oral, and ingestion of infected food (trichinosis).

Indirect transmission occurs when an agent is transferred or carried by some intermediate item, organism, means, or process to a susceptible host, resulting in disease. Fomites, vectors, air currents, dust particles, water, food, oral–fecal contact, and other mechanisms that effectively transfer disease-causing organisms are means of indirect disease transmission. **Airborne transmission** occurs when droplets or dust particles carry the pathogen to the host and cause infection. This may result when a person sneezes, coughs, or talks, spraying microscopic pathogen-carrying droplets into the air that can be breathed in by nearby susceptible hosts. It also occurs when droplets are carried through a building's heating or air conditioning ducts or are spread by fans throughout a building or complex of buildings. **Vector-borne transmission** is when an arthropod (such as a mosquito, flea, or tick), conveys the infections agent. **Vehicle-borne transmission** is related to fomites, food or water that acts as conveyance. For example, this occurs when a pathogen such as cholera or shigellosis is carried in drinking water or swimming pools, streams, or lakes used for swimming.

Some epidemiologists classify droplet spread as direct transmission because it usually takes place within a few feet of the susceptible host. Logically, however, the droplets from a sneeze or cough use the intermediary mechanism of the droplet to carry the pathogen; thus, it is an indirect transmission. This is also a form of person-to-person transmission, and influenza and the common cold are commonly spread this way. Droplets can also be spread by air-moving equipment and air-circulation processes (heating and air conditioning) within buildings, which carry droplet-borne disease great distances, often to remote locations, causing illness. Such equipment has been implicated in cases of tuberculosis and Legionnaire's disease.

Some vector-borne disease transmission processes are simple mechanical processes, such as when the pathogen, in order to spread, uses a host (e.g., a fly, flea, louse, or rat) as a mechanism for a ride, for nourishment, or as part of a physical transfer process. This is called **mechanical transmission**. When the pathogen undergoes changes as part of its life cycle while within the host/vector and before being transmitted to the new host, it is called **biological transmission**. Biological transmission is easily seen in malaria, in which the female Anopheles mosquito's blood meal is required for the Plasmodium protozoan parasite to complete its sexual development cycle. This can only occur with the ingested blood nutrients found in the intestine of the Anopheles mosquito.

CHAIN OF INFECTION

There is a close association between the triangle of epidemiology and the chain of infection (**Figure 1-5**). Disease transmission occurs when the pathogen leaves the reservoir through a **portal of exit** and is spread by one of several modes of transmission. The pathogen or disease-causing agent enters the body through a **portal of entry** and infects the host if the host is susceptible.

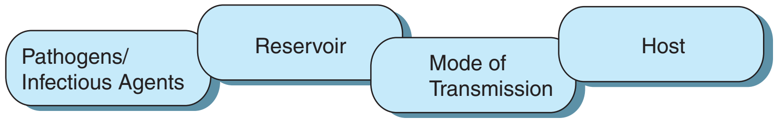

FIGURE 1-5 The chain of infection.

The reservoir is the medium or habitat in which pathogens or infectious agents thrive, propagate, and multiply. Reservoirs are humans, animals, or certain environmental conditions or substances, such as food, feces, or decaying organic matter, that are conducive to the growth of pathogens. Two types of human or animal reservoirs are generally recognized: symptomatic (ill) persons who have a disease and carriers who are asymptomatic and can still transmit the disease.

Once a pathogen leaves its reservoir, it follows its mode of transmission to a susceptible host, either by direct transmission (person-to-person contact) or by indirect transmission (airborne droplets or dust particles, vectors, fomites, food). The final link in the chain of infection is thus the susceptible individual or host, usually a human or an animal. The host is generally protected from invasion of pathogens by the skin, mucous membranes, and the body's physiological responses (weeping of mucous membranes to cleanse themselves, acidity in the stomach, cilia in the respiratory tract, coughing, and the natural response of the immune system). If the pathogen is able to enter the host, the result will most likely be illness if the host has no immunity to the pathogen.

Susceptibility is based on level of immunity. Natural immunity can come from genetic makeup; that is, some people seem better able to resist disease than others. Active immunity occurs when the body develops antibodies and antigens in response to a pathogen invading the body. Passive immunity comes from antibodies entering a baby through the placenta or from antitoxin or immune globulin injections.[3]

OTHER MODES OF CAUSATION

The epidemiology triangle as used in a discussion of communicable disease is basic and foundational to all epidemiology; however, infectious diseases are no longer the leading cause of death in industrialized nations, so a more advanced model of the triangle of epidemiology has been proposed. This new model includes all facets of the communicable disease model, and to make it more relevant and useful with regard to today's diseases, conditions, disorders, defects, injuries, and deaths, it also reflects the causes of current illnesses and conditions. Behavior, lifestyle factors, environmental causes, ecologic elements, physical factors, and chronic diseases must be taken into account. **Figure 1-6** presents an adapted and advanced model of the triangle of epidemiology, better reflecting the behavior, lifestyle, and chronic disease issues found in modern times.

The advanced model of the triangle of epidemiology, like the traditional epidemiology triangle, is not comprehensive or complete; however, the advanced model recognizes that disease states and conditions affecting a population are complex and that there are many causative factors. The term agent is replaced with causative factors, which implies the need to identify multiple causes or etiologic factors of disease, disability, injury, and death.

Another model that has been developed to capture the multifactorial nature of causation for many health-related states or events is Rothman's causal pies.[23] Assume the factors that

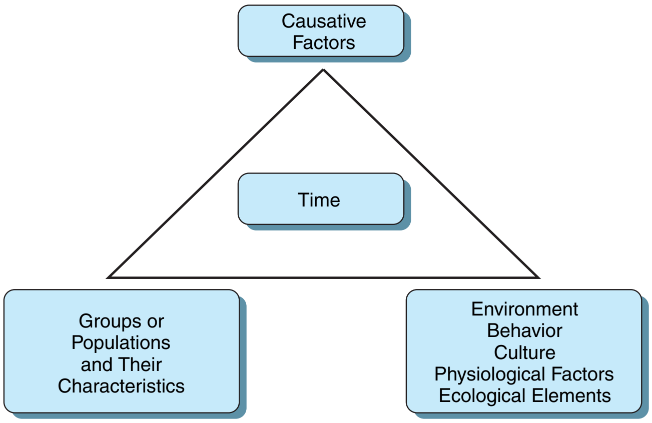

FIGURE 1-6 Advanced model of the triangle of epidemiology.

cause the adverse health outcome are pieces of a pie, with the whole pie being required to cause the health problem (**Figure 1-7**). The health-related state or event may have more than one sufficient cause, as illustrated in the figure, with each sufficient cause consisting of multiple contributing factors that are called component causes. The different component causes include the agent, host factors, and environmental factors. Where a given component cause is required in each of the different sufficient causes, it is referred to as a necessary cause. In Figure 1-7, the letter "A" represents a necessary cause because it is included in each of the three sufficient causes for the adverse health outcome. Exposure to the rubivirus is necessary for rubella-related birth defects to occur but not sufficient to cause birth defects. Component causes that may be required to make a sufficient cause may include a susceptible host who is not immune and illness during the first few months of pregnancy.

Prevention and control measures do not require identifying every component of a sufficient cause because the health problem can be prevented by blocking any single component of a sufficient cause.

In Chapter 9, "Statistical and Causal Associations," the web of causation is presented as an effective method of investigation into chronic disease and behaviorally founded causes of disease, disability, injury, and death. The web of causation shows the importance of looking for many causes or an array of contributing factors to various maladies.

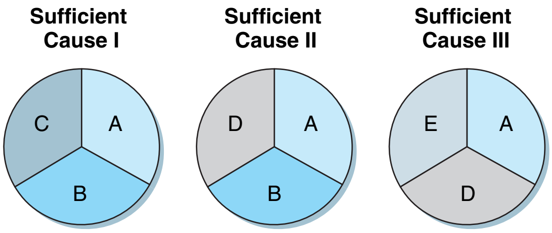

FIGURE 1-7 Three sufficient causes of an adverse health outcome.

LEVELS OF PREVENTION

Three types of prevention have been established in public health: primary prevention, secondary prevention, and tertiary prevention.

Primary Prevention

Primary prevention is preventing a disease or disorder before it happens. Health promotion, health education, and health protection are three main facets of primary prevention. Lifestyle changes, community health education, school health education, good prenatal care, good behavioral choices, proper nutrition, and safe and healthy conditions at home, school, and the workplace are all primary prevention activities. Fundamental public health measures and activities such as sanitation; infection control; immunizations; protection of food, milk, and water supplies; environmental protection; and protection against occupational hazards and accidents are all basic to primary prevention. Basic personal hygiene and public health measures have had a major impact on halting communicable disease epidemics. Immunizations, infection control (e.g., hand washing), refrigeration of foods, garbage collection, solid and liquid waste management, water supply protection and treatment, and general sanitation have reduced infectious disease threats to populations.

Because of successes in primary prevention efforts directed at infectious diseases, noninfectious diseases are now the main causes of death in the United States and industrialized nations (**Table 1-2** and **Figure 1-8**).[24,25] The leading causes of death today are presented in

TABLE 1-2 Leading Causes of Death in the United States in 1900[23] and in 2000[24]

1900		**2000**	
Pneumonia and influenza	11.8%	Heart diseases	29.6%
Tuberculosis	11.3%	Cancer	23.0%
Diarrhea, enteritis, ulcerations of the intestines	8.3%	Cerebrovascular diseases	7.0%
Heart diseases	8.0%	Chronic obstructive pulmonary diseases	5.1%
Intracranial lesions of vascular origin	6.2%	Accidents	4.1%
Nephritis	5.2%	Diabetes mellitus	2.9%
Accidents	4.2%	Pneumonia and influenza	2.7%
Cancer	3.7%	Alzheimer's diseases	2.1%
Senility	2.9%	Nephritis	1.5%
Diphtheria	2.3%	Septicemia	1.3%
All other	36.1%	All other	20.7%
	100.0%		100.0%

Data are from the Center for Disease Control and Prevention. Leading causes of disease, 1900–1998. Retrieved May 10, 2005, from http://www.cdc.gov/nchs/data/statab/lead1900_98.pdf; and Centers for Disease Control and Prevention. US Mortality Public Use Data Tape, 2000. National Center for Health Statistics; 2002. US Mortality Public Use Data Tape, 2000. National Center for Health Statistics; 2000. Retrieved September 12, 2005, from http://webapp.cdc.gov/sasweb/ncipc/leadcaus10.html.

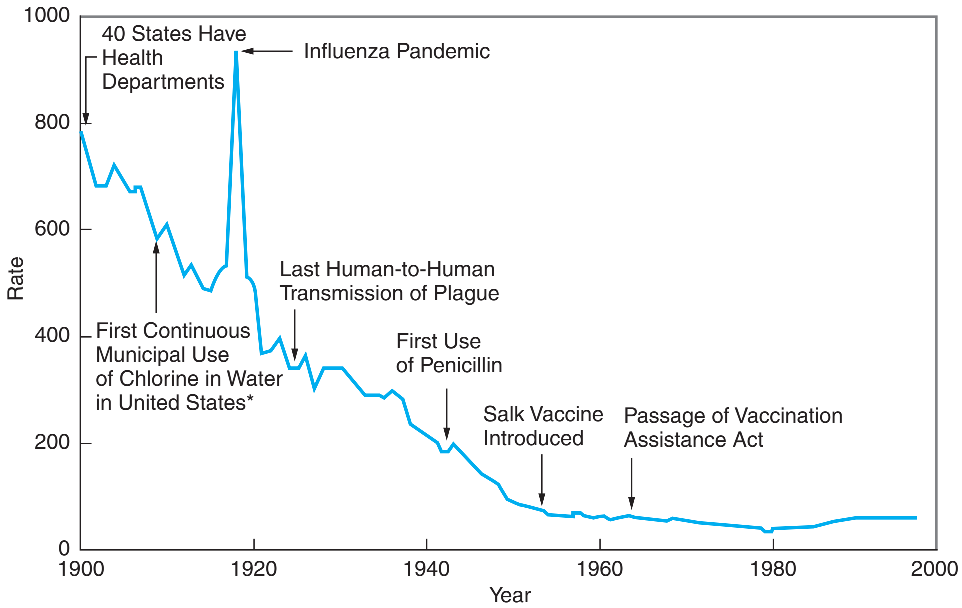

FIGURE 1-8 Crude death rates (per 100,000 person–years) for infectious diseases in the United States, 1900–1996. From Achievements in Public Health, 1900–1999: Control of infectious diseases. *MMWR* 1999;48(29):621–629; Adapted from Armstrong GL, Conn LA, Pinner RW. Trends in infectious disease mortality in the United States during the 20th century. *JAMA* 1999;281:61–66.

Figure 1-9. Common risk factors for these causes of death are environmental and behavior related (e.g., fine particulate matter in the air, smoking and tobacco use, alcohol and substance abuse, poor diet, and lack of physical fitness). Prevention at its basic levels now has to be behaviorally directed and lifestyle oriented. Efforts at the primary prevention level have to focus on influencing individual behavior and protecting the environment. In the future, the focus on treatment and health care by physicians should be lessened and replaced with a major effort in the area of primary prevention, including adequate economic support for prevention programs and activities.[16–19]

Two related terms are **active primary prevention** and **passive primary prevention**. Active primary prevention requires behavior change on the part of the individual (e.g., begin exercising, stop smoking, reduce dietary fat intake). Passive primary prevention does not require behavior change on the part of the individual (e.g., eating vitamin-enriched foods, drinking fluoridated water).

Secondary Prevention

Secondary prevention is aimed at the health screening and detection activities used to identify disease. If pathogenicity (the ability to cause disease) is discovered early, diagnosis and early treatment can prevent conditions from progressing and from spreading within the population and can stop or at least slow the progress of disease, disability, disorders, or

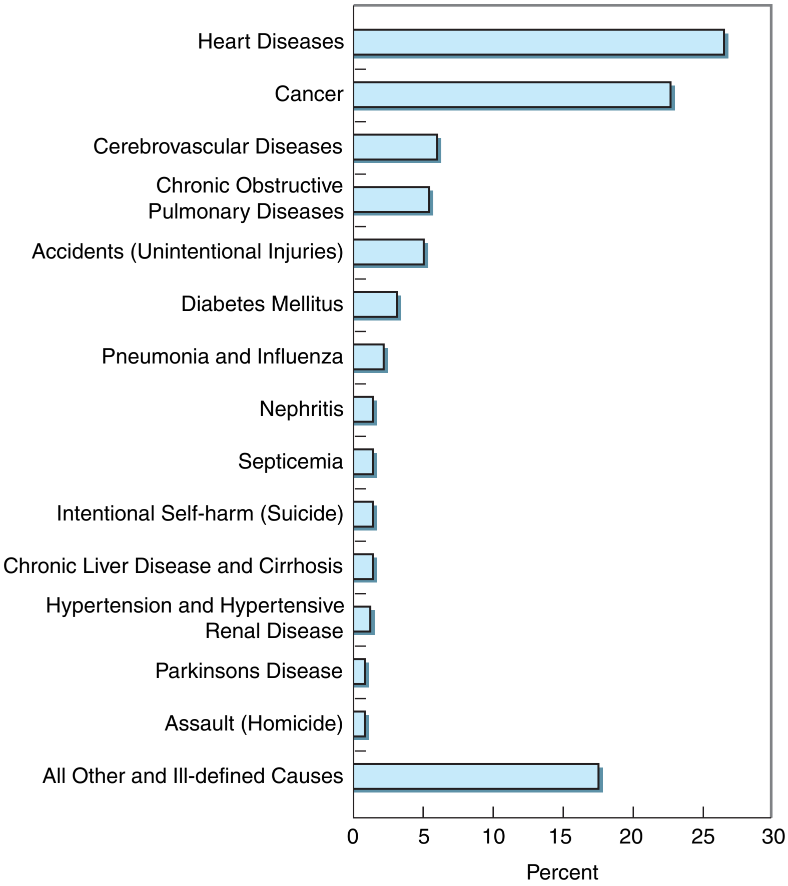

FIGURE 1-9 Leading causes of disease in the United States, 2005. From Kung HC, Hoyert DL, Xu J, Murphy SL. Deaths: Final data for 2005. National Vital Statistics Reports; vol. 56, no. 10. Hyattsville, MD: National Center for Health Statistics; 2008.

death.[1] Secondary prevention aims to block the progression of disease or prevent an injury from developing into an impairment or disability.[16,17,20]

Tertiary Prevention

The aim of the third level of prevention is to retard or block the progression of a disability, condition, or disorder in order to keep it from advancing and requiring excessive care. **Tertiary prevention** consists of limiting any disability by providing rehabilitation where a disease, injury, or disorder has already occurred and caused damage. At this level, the goal is to help those diseased, disabled, or injured individuals avoid wasteful use of healthcare services and not become dependent on healthcare practitioners and healthcare institutions. Prompt diagnosis and treatment, followed by proper rehabilitation and posttreatment recovery, proper patient education, behavior changes, and lifestyle changes are all necessary so that diseases or disorders will not recur. At the very minimum, the progression of the disease, disorder, or injury needs to be slowed and checked.[26,27]

Rehabilitation is any attempt to restore an afflicted person to a useful, productive, and satisfying lifestyle and to provide the highest quality of life possible, given the extent of the disease and disability. Rehabilitation is one component of tertiary prevention. Patient education, aftercare, health counseling, and some aspects of health promotion can be important components of tertiary prevention.

NEWS FILE

Pediculosis (Person-to-Person Transmission)

Head Lice: The Epidemic Continues

Some people think of head lice as a nuisance that bothers only the lower class and those with bad personal hygiene. Yet a nationwide epidemic of pediculosis continues to run rampant in both public and private schools.

The bloodsucking lice (Anoplura order) prefer mammal hosts and rarely infest even closely related species, including pets. Head lice limit themselves to the hair of the head near the nape of the neck and the ears. The life cycle of head lice is spent on the host, usually on the same person. The three-stage growth cycle of egg, nymph, and adult takes about 3 weeks. When head lice are not on the host, they die in a day or two. The head louse is very small, about 2 to 3 mm, and can be found grasping the hair shaft near the scalp with its special claws. The adult female louse lives about a month, laying 150 or more eggs called nits, about 10 a day. Nits are not to be confused with solidified globules of hair spray or dandruff. The yellowish-white, oval-shaped nit found glued to the bottom of the hair shaft takes about a week to hatch.

Little disease is transmitted through lice, but they themselves are a problem. They suck blood and inject saliva during the infestation, causing itching and secondary infections from excreta, bites, and scratching.

The louse cannot jump or fly, and thus transmission occurs either directly, from contact with an infested person, or indirectly, through fomites such as shared scarves, hats, coats, brushes, combs, sweaters, and bedding. Schools are particularly vulnerable because children may try on and wear each other's clothing. Because lice like a frequent blood meal and a warm and fuzzy environment, person-to-person transmission is most common. Control comes largely from not sharing combs, brushes, and head clothing or sleeping with infested persons.

The only way to get rid of nits and lice is to use pesticide treatment, which comes in the form of special shampoos, cream rinses, and topical lotions, with shampoos containing permethrin being most common and effective if used according to directions. Clothing and bedding must be washed in hot soapy water and dried in a hot dryer to destroy lice and nits. Nits must also be removed from the hair with fine-toothed combs. Children should be kept out of school until treatment is complete and successful.

From California Morbidity, Division of Communicable Disease Control, California Department of Health Services, 1996.

CONCLUSION

Epidemiology is the process of describing and understanding public health problems and the application of this knowledge to the promotion of physical, mental, and social well-being in the population. Epidemiology involves applying scientific models to the description of the frequency and pattern of health-related states or events, the identification of the causes of health-related states or events and modes of transmission, and the guidance of public health planning and decision making. Epidemiologic information is intended to guide health officials and assist individuals in making informed health behavior changes.

EXERCISES

Key Terms

Define the following terms.

Active carrier
Active primary prevention
Agent
Airborne transmission
Analytic epidemiology
Biological transmission
Carrier
Case
Case definition
Case severity
Chain of infection
Common-source epidemic
Convalescent carrier
Direct transmission
Effectiveness
Efficacy
Endemic
Environment
Epidemic
Epidemiologist
Epidemiology
Fomite
Healthy carrier
Host
Incubatory carrier
Index case
Indirect transmission
Intermittent carrier
Mechanical transmission
Mixed epidemic
Modes of disease transmission
Pandemic
Passive carrier
Passive primary prevention
Pathogen
Portal of entry
Portal of exit
Primary case
Propagated epidemic
Rehabilitation
Reservoir
Secondary case
Secondary prevention
Suspect case
Tertiary prevention
Time
Vector
Vector-borne transmission
Vehicle-borne transmission
Waterborne transmission
Zoonosis

STUDY QUESTIONS

1.1 The definition of epidemiology includes the terms “distribution” and “determinants.” Describe the meaning of these terms.

1.2 Epidemiology involves the study of more than just infectious diseases. Explain.

1.3 Describe the chain of infection.

1.4 List four types of epidemiologic information that are useful for influencing public health policy and planning and individual health decisions.

1.5 Define efficacy and effectiveness, and provide examples of both.

Use the following information to answer Questions 1.6 and 1.7.

Emergency Medical Services (EMS) responses were made to 1,551 nonindustrial injuries resulting from falls. Of total falls, 869 (56%) occurred at home, and 682 (44%) occurred elsewhere. The very young (< 4 years old) and the very old (80+ years) were the most vulnerable to falls. Persons over age 60 accounted for 44% of the total emergency calls for nonindustrial falls. On weekends, most injuries from falls occurred in the home. Time pattern analysis revealed that the greatest number of injuries from falls at home occurred in the late afternoon and evening, between 3:00 PM and midnight. Callers from three socioeconomic strata were identified from census tract information. Age and gender were tabulated for the three strata areas based on falls in the home. The greatest use of EMS was by those over 60 years of age in all three strata levels. Those aged 40–59 years in the low socioeconomic group and infants through 9 years of age in the low socioeconomic group were next highest users. The highest socioeconomic group had the lowest rates for each age group.[27] The percentages given are out of total emergency EMS responses. Table 1-3 represents percentages of falls per total population based on the rates per 100,000 people.

- Population for the high socioeconomic group was 143,798.
- Population for the medium socioeconomic group was 249,381.
- Population for the low socioeconomic group was 138,413.

1.6 With what you have learned from the scenario just described, what can you say about the role age plays in falls? Present statistics and provide a discussion of reasons for the age-related statistics and differences.

1.7 Explain the effect of socioeconomic status on falls as responded to by EMS, as shown in Table 1-3.

1.8 Explain the epidemiology triangle and compare and contrast it with the advanced epidemiology triangle.

1.9 Review Figure 1-8, and explain the implications of the 15 leading causes of death for public health. Include the three levels of prevention.

TABLE 1.3 Home Falls and Emergency Medical Service Response in the State of Washington

Age Group	High Socioeconomic Rate/100,000	Percentage of Total Population	Medium Socioeconomic Rate/100,000	Percentage of Total Population	Low Socioeconomic Rate/100,000	Percentage of Total Population
0–9	87.95	3.8	199.88	6.4	260.24	2.9
10–19	35.94	4.8	87.43	6.7	104.81	2.9
20–39	29.69	8.2	60.77	14.9	104.76	9.1
40–59	60.66	6.8	168.42	9.7	288.89	5.1
60+	444.05	3.4	355.18	9.3	420.66	5.9
TOTAL	—	**27.05**	—	**46.91**	—	**26.04**

1.10 HIV/AIDS can be transmitted from an infected person to another person through blood, semen, vaginal fluids, and breast milk. High-risk behaviors include homosexual practices; unprotected oral, vaginal, or anal sexual intercourse; and needle sharing. Discuss how this information can be used in public health action and individual decision making.

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