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INTRODUCTION TO EPIDEMIOLOGY

Recently, a news story described an inner-city neighborhood's concern about the rise in the number of children with asthma. Another story reported the revised recommendations for who should receive influenza vaccine this year. A third story discussed the extensive disease-monitoring strategies being implemented in a city recently affected by a massive hurricane. A fourth story described a finding published in a leading medical journal of an association in workers exposed to a particular chemical and an increased risk of cancer. Each of these news stories included interviews with public health officials or researchers who called themselves epidemiologists. Well, who are these epidemiologists, and what do they do? What is epidemiology? This lesson is intended to answer those questions by describing what epidemiology is, how it has evolved and how it is used today, and what some of the key methods and concepts are. The focus is on epidemiology in public health practice, that is, the kind of epidemiology that is done at health departments.

Objectives

After studying this lesson and answering the questions in the exercises, you will be able to:

- *Define epidemiology*
- *Summarize the historical evolution of epidemiology*
- *Name some of the key uses of epidemiology*
- *Identify the core epidemiology functions*
- *Describe primary applications of epidemiology in public health practice*
- *Specify the elements of a case definition and state the effect of changing the value of any of the elements*
- *List the key features and uses of descriptive epidemiology*
- *List the key features and uses of analytic epidemiology*
- *List the three components of the epidemiologic triad*
- *Describe the different modes of transmission of communicable disease in a population*

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Definition of Epidemiology

Students of journalism are taught that a good news story, whether it be about a bank robbery, dramatic rescue, or presidential candidate's speech, must include the 5 W's: what, who, where, when and why (sometimes cited as why/how). The 5 W's are the essential components of a news story because if any of the five are missing, the story is incomplete.

The same is true in characterizing epidemiologic events, whether it be an outbreak of norovirus among cruise ship passengers or the use of mammograms to detect early breast cancer. The difference is that epidemiologists tend to use synonyms for the 5 W's: diagnosis or health event (what), person (who), place (where), time (when), and causes, risk factors, and modes of transmission (why/how).

The word epidemiology comes from the Greek words *epi*, meaning on or upon, *demos*, meaning people, and *logos*, meaning the study of. In other words, the word epidemiology has its roots in the study of what befalls a population. Many definitions have been proposed, but the following definition captures the underlying principles and public health spirit of epidemiology:

> *Epidemiology is the* ***study*** *of the* ***distribution*** *and* ***determinants*** *of* ***health-related states or events*** *in* ***specified populations****, and the* ***application*** *of this study to the control of health problems.*[1]

Key terms in this definition reflect some of the important principles of epidemiology.

Study

Epidemiology is a scientific discipline with sound methods of scientific inquiry at its foundation. Epidemiology is data-driven and relies on a systematic and unbiased approach to the collection, analysis, and interpretation of data. Basic epidemiologic methods tend to rely on careful observation and use of valid comparison groups to assess whether what was observed, such as the number of cases of disease in a particular area during a particular time period or the frequency of an exposure among persons with disease, differs from what might be expected. However, epidemiology also draws on methods from other scientific fields, including biostatistics and informatics, with biologic, economic, social, and behavioral sciences.

In fact, epidemiology is often described as the basic science of public health, and for good reason. First, epidemiology is a quantitative discipline that relies on a working knowledge of probability, statistics, and sound research methods. Second, epidemiology is a method of causal reasoning based on developing and testing hypotheses grounded in such scientific fields as biology, behavioral sciences, physics, and ergonomics to explain health-related behaviors, states, and events. However, epidemiology is not just a research activity but an integral component of public health, providing the foundation for directing practical and appropriate public health action based on this science and causal reasoning.[2]

Distribution

Epidemiology is concerned with the **frequency** and **pattern** of health events in a population:

> **Frequency** refers not only to the number of health events such as the number of cases of meningitis or diabetes in a population, but also to the relationship of that number to the size of the population. The resulting rate allows epidemiologists to compare disease occurrence across different populations.
>
> **Pattern** refers to the occurrence of health-related events by time, place, and person. Time patterns may be annual, seasonal, weekly, daily, hourly, weekday versus weekend, or any other breakdown of time that may influence disease or injury occurrence. Place patterns include geographic variation, urban/rural differences, and location of work sites or schools. Personal characteristics include demographic factors which may be related to risk of illness, injury, or disability such as age, sex, marital status, and socioeconomic status, as well as behaviors and environmental exposures.

Characterizing health events by time, place, and person are activities of **descriptive epidemiology**, discussed in more detail later in this lesson.

Determinants

Determinant: any factor, whether event, characteristic, or other definable entity, that brings about a change in a health condition or other defined characteristic.[1]

Epidemiology is also used to search for **determinants**, which are the causes and other factors that influence the occurrence of disease and other health-related events. Epidemiologists assume that illness does not occur randomly in a population, but happens only when the right accumulation of risk factors or determinants exists in an individual. To search for these determinants, epidemiologists use analytic epidemiology or epidemiologic studies to provide the "Why" and "How" of such events. They assess whether groups with different rates of disease differ in their demographic characteristics, genetic or immunologic make-up, behaviors, environmental exposures, or other so-called potential risk factors. Ideally, the findings provide sufficient evidence to direct prompt and effective public health control and prevention measures.

Health-related states or events

Epidemiology was originally focused exclusively on epidemics of communicable diseases[3] but was subsequently expanded to address endemic communicable diseases and non-communicable infectious diseases. By the middle of the 20th Century, additional epidemiologic methods had been developed and applied to chronic diseases, injuries, birth defects, maternal-child health, occupational health, and environmental health. Then epidemiologists began to look at behaviors related to health and well-being, such as amount of exercise and seat belt use. Now, with the recent explosion in molecular methods, epidemiologists can make important strides in examining genetic markers of disease risk. Indeed, the term health-related states or events may be seen as anything that affects the well-being of a population. Nonetheless, many epidemiologists still use the term "disease" as shorthand for the wide range of health-related states and events that are studied.

Specified populations

Although epidemiologists and direct health-care providers (clinicians) are both concerned with occurrence and control of disease, they differ greatly in how they view "the patient." The clinician is concerned about the health of an individual; the epidemiologist is concerned about the collective health of the people in a community or population. In other words, the clinician's "patient" is the individual; the epidemiologist's "patient" is the community. Therefore, the clinician and the epidemiologist have different responsibilities when faced with a person with illness. For example, when a patient with diarrheal disease presents, both are interested in establishing the correct diagnosis. However, while the clinician usually focuses on treating and caring for the individual, the epidemiologist focuses on identifying the exposure or source that caused the illness; the number of other persons who may have been similarly exposed; the potential for further spread in the community; and interventions to prevent additional cases or recurrences.

Application

Epidemiology is not just "the study of" health in a population; it also involves applying the knowledge gained by the studies to community-based practice. Like the practice of medicine, the practice of epidemiology is both a science and an art. To make the proper diagnosis and prescribe appropriate treatment for a patient, the clinician combines medical (scientific) knowledge with experience, clinical judgment, and understanding of the patient. Similarly, the epidemiologist uses the scientific methods of descriptive and analytic epidemiology as well as experience, epidemiologic judgment, and understanding of local conditions in “diagnosing” the health of a community and proposing appropriate, practical, and acceptable public health interventions to control and prevent disease in the community.

Summary

Epidemiology is the study (scientific, systematic, data-driven) of the distribution (frequency, pattern) and determinants (causes, risk factors) of health-related states and events (not just diseases) in specified populations (patient is community, individuals viewed collectively), and the application of (since epidemiology is a discipline within public health) this study to the control of health problems.

Exercise 1.1

Below are four key terms taken from the definition of epidemiology, followed by a list of activities that an epidemiologist might perform. Match the term to the activity that best describes it. You should match only one term per activity.

A. Distribution
B. Determinants
C. Application

_____ 1. Compare food histories between persons with *Staphylococcus* food poisoning and those without

_____ 2. Compare frequency of brain cancer among anatomists with frequency in general population

_____ 3. Mark on a map the residences of all children born with birth defects within 2 miles of a hazardous waste site

_____ 4. Graph the number of cases of congenital syphilis by year for the country

_____ 5. Recommend that close contacts of a child recently reported with meningococcal meningitis receive Rifampin

_____ 6. Tabulate the frequency of clinical signs, symptoms, and laboratory findings among children with chickenpox in Cincinnati, Ohio

✔ **Check your answers on page 1-81**

Historical Evolution of Epidemiology

Although epidemiology as a discipline has blossomed since World War II, epidemiologic thinking has been traced from Hippocrates through John Graunt, William Farr, John Snow, and others. The contributions of some of these early and more recent thinkers are described below.[5]

Circa 400 B.C.

Epidemiology's roots are nearly 2500 years old.

Hippocrates attempted to explain disease occurrence from a rational rather than a supernatural viewpoint. In his essay entitled "On Airs, Waters, and Places," Hippocrates suggested that environmental and host factors such as behaviors might influence the development of disease.

1662

Another early contributor to epidemiology was John Graunt**,** a London haberdasher and councilman who published a landmark analysis of mortality data in 1662. This publication was the first to quantify patterns of birth, death, and disease occurrence, noting disparities between males and females, high infant mortality, urban/rural differences, and seasonal variations.[5]

1800

William Farr built upon Graunt's work by systematically collecting and analyzing Britain's mortality statistics. Farr, considered the father of modern vital statistics and surveillance, developed many of the basic practices used today in vital statistics and disease classification. He concentrated his efforts on collecting vital statistics, assembling and evaluating those data, and reporting to responsible health authorities and the general public.[4]

1854

In the mid-1800s, an anesthesiologist named John Snow was conducting a series of investigations in London that warrant his being considered the "father of field epidemiology." Twenty years before the development of the microscope, Snow conducted studies of cholera outbreaks both to discover the cause of disease and to prevent its recurrence. Because his work illustrates the classic sequence from descriptive epidemiology to hypothesis generation to hypothesis testing (analytic epidemiology) to application, two of his investigations will be described in detail.

Snow conducted one of his now famous studies in 1854 when an epidemic of cholera erupted in the Golden Square of London.[5] He began his investigation by determining where in this area persons with cholera lived and worked. He marked each residence on a map of the area, as shown in Figure 1.1. Today, this type of map, showing the geographic distribution of cases, is called a spot map.

Figure 1.1 Spot map of deaths from cholera in Golden Square area, London, 1854 (redrawn from original)

Source: Snow J. Snow on cholera. London: Humphrey Milford: Oxford University Press; 1936.

Because Snow believed that water was a source of infection for cholera, he marked the location of water pumps on his spot map, then looked for a relationship between the distribution of households with cases of cholera and the location of pumps. He noticed that more case households clustered around Pump A, the Broad Street pump, than around Pump B or C. When he questioned residents who lived in the Golden Square area, he was told that they avoided Pump B because it was grossly contaminated, and that Pump C was located too inconveniently for most of them. From this information, Snow concluded that the Broad Street pump (Pump A) was the primary source of water and the most likely source of infection for most persons with cholera in the Golden Square area. He noted with curiosity, however, that no cases of cholera had occurred in a two-block area just to the east of the Broad Street pump. Upon investigating, Snow found a brewery located there with a deep well on the premises. Brewery workers got their water from this well, and also received a daily portion of malt liquor. Access to these uncontaminated rations could explain why none of the brewery's employees contracted cholera.

To confirm that the Broad Street pump was the source of the epidemic, Snow gathered information on where persons with cholera had obtained their water. Consumption of water from the Broad Street pump was the one common factor among the cholera patients. After Snow presented his findings to municipal officials, the handle of the pump was removed and the outbreak ended. The site of the pump is now marked by a plaque mounted on the wall outside of the appropriately named John Snow Pub.

Figure 1.2 John Snow Pub, London

Source: The John Snow Society [Internet]. London: [updated 2005 Oct 14; cited 2006 Feb 6]. Available from: http://www.johnsnowsociety.org/.

Snow's second investigation reexamined data from the 1854 cholera outbreak in London. During a cholera epidemic a few years earlier, Snow had noted that districts with the highest death rates were serviced by two water companies: the Lambeth Company and the Southwark and Vauxhall Company. At that time, both companies obtained water from the Thames River at intake points that were downstream from London and thus susceptible to contamination from London sewage, which was discharged directly into the Thames. To avoid contamination by London sewage, in 1852 the Lambeth Company moved its intake water works to a site on the Thames well upstream from London. Over a 7-week period during the summer of 1854, Snow compared cholera mortality among districts that received water from one or the other or both water companies. The results are shown in Table 1.1.

Table 1.1 Mortality from Cholera in the Districts of London Supplied by the Southwark and Vauxhall and the Lambeth Companies, July 9–August 26, 1854

Districts with Water Supplied By:	Population (1851 Census)	Number of Deaths from Cholera	Cholera Death Rate per 1,000 Population
Southwark and Vauxhall Only	167,654	844	5.0
Lambeth Only	19,133	18	0.9
Both Companies	300,149	652	2.2

Source: Snow J. Snow on cholera. London: Humphrey Milford: Oxford University Press; 1936.

The data in Table 1.1 show that the cholera death rate was more than 5 times higher in districts served only by the Southwark and Vauxhall Company (intake downstream from London) than in those served only by the Lambeth Company (intake upstream from London). Interestingly, the mortality rate in districts supplied by both companies fell between the rates for districts served exclusively by either company. These data were consistent with the hypothesis that water obtained from the Thames below London was a source of cholera. Alternatively, the populations supplied by the two companies may have differed on other factors that affected their risk of cholera.

To test his water supply hypothesis, Snow focused on the districts served by both companies, because the households within a district were generally comparable except for the water supply company. In these districts, Snow identified the water supply company for every house in which a death from cholera had occurred during the 7-week period. Table 1.2 shows his findings.

Table 1.2 Mortality from Cholera in London Related to the Water Supply of Individual Houses in Districts Served by Both the Southwark and Vauxhall Company and the Lambeth Company, July 9–August 26, 1854

Water Supply of Individual House	Population (1851 Census)	Number of Deaths from Cholera	Cholera Death Rate per 1,000 Population
Southwark and Vauxhall Only	98,862	419	4.2
Lambeth Only	154,615	80	0.5

Source: Snow J. Snow on cholera. London: Humphrey Milford: Oxford University Press; 1936.

This study, demonstrating a higher death rate from cholera among households served by the Southwark and Vauxhall Company in the mixed districts, added support to Snow's hypothesis. It also established the sequence of steps used by current-day epidemiologists to investigate outbreaks of disease. Based on a characterization of the cases and population at risk by time, place, and person, Snow developed a testable hypothesis. He then tested his hypothesis with a more rigorously designed study, ensuring that the groups to be compared were comparable. After this study, efforts to control the epidemic were directed at changing the location of the water intake of the Southwark and Vauxhall Company to avoid sources of contamination. Thus, with no knowledge of the existence of microorganisms, Snow demonstrated through epidemiologic studies that water could serve as a vehicle for transmitting cholera and that epidemiologic information could be used to direct prompt and appropriate public health action.

19th and 20th centuries

In the mid- and late-1800s, epidemiological methods began to be applied in the investigation of disease occurrence. At that time, most investigators focused on acute infectious diseases. In the 1930s and 1940s, epidemiologists extended their methods to noninfectious diseases. The period since World War II has seen an explosion in the development of research methods and the theoretical underpinnings of epidemiology. Epidemiology has been applied to the entire range of health-related outcomes, behaviors, and even knowledge and attitudes. The studies by Doll and Hill linking lung cancer to smoking[6] and the study of cardiovascular disease among residents of Framingham, Massachusetts[7] are two examples of how pioneering researchers have applied epidemiologic methods to chronic disease since World War II. During the 1960s and early 1970s health workers applied epidemiologic methods to eradicate naturally occurring smallpox worldwide.[8] This was an achievement in applied epidemiology of unprecedented proportions.

In the 1980s, epidemiology was extended to the studies of injuries and violence. In the 1990s, the related fields of molecular and genetic epidemiology (expansion of epidemiology to look at specific pathways, molecules and genes that influence risk of developing disease) took root. Meanwhile, infectious diseases continued to challenge epidemiologists as new infectious agents emerged (Ebola virus, Human Immunodeficiency virus (HIV)/ Acquired Immunodeficiency Syndrome (AIDS)), were identified (Legionella, Severe Acute Respiratory Syndrome (SARS)), or changed (drug-resistant Mycobacterium tuberculosis, Avian influenza). Beginning in the 1990s and accelerating after the terrorist attacks of September 11, 2001, epidemiologists have had to consider not only natural transmission of infectious organisms but also deliberate spread through biologic warfare and bioterrorism.

Today, public health workers throughout the world accept and use epidemiology regularly to characterize the health of their communities and to solve day-to-day problems, large and small.

Uses

Epidemiology and the information generated by epidemiologic methods have been used in many ways.[9] Some common uses are described below.

Assessing the community's health

Public health officials responsible for policy development, implementation, and evaluation use epidemiologic information as a factual framework for decision making. To assess the health of a population or community, relevant sources of data must be identified and analyzed by person, place, and time (descriptive epidemiology).

- What are the actual and potential health problems in the community?
- Where are they occurring?
- Which populations are at increased risk?
- Which problems have declined over time?
- Which ones are increasing or have the potential to increase?
- How do these patterns relate to the level and distribution of public health services available?

More detailed data may need to be collected and analyzed to determine whether health services are available, accessible, effective, and efficient. For example, public health officials used epidemiologic data and methods to identify baselines, to set health goals for the nation in 2000 and 2010, and to monitor progress toward these goals.[10-12]

Making individual decisions

Many individuals may not realize that they use epidemiologic information to make daily decisions affecting their health. When persons decide to quit smoking, climb the stairs rather than wait for an elevator, eat a salad rather than a cheeseburger with fries for lunch, or use a condom, they may be influenced, consciously or unconsciously, by epidemiologists' assessment of risk. Since World War II, epidemiologists have provided information related to all those decisions. In the 1950s, epidemiologists reported the increased risk of lung cancer among smokers. In the 1970s, epidemiologists documented the role of exercise and proper diet in reducing the risk of heart disease. In the mid-1980s, epidemiologists identified the increased risk of HIV infection associated with certain sexual and drug-related behaviors. These and hundreds of other epidemiologic findings are directly relevant to the choices people make every day, choices that affect their health over a lifetime.

Completing the clinical picture

When investigating a disease outbreak, epidemiologists rely on health-care providers and laboratorians to establish the proper diagnosis of individual patients. But epidemiologists also contribute to physicians' understanding of the clinical picture and natural history of disease. For example, in late 1989, a physician saw three patients with unexplained eosinophilia (an increase in the number of a specific type of white blood cell called an eosinophil) and myalgias (severe muscle pains). Although the physician could not make a definitive diagnosis, he notified public health authorities. Within weeks, epidemiologists had identified enough other cases to characterize the spectrum and course of the illness that came to be known as eosinophilia-myalgia syndrome.[13] More recently, epidemiologists, clinicians, and researchers around the world have collaborated to characterize SARS, a disease caused by a new type of coronavirus that emerged in China in late 2002.[14] Epidemiology has also been instrumental in characterizing many non-acute diseases, such as the numerous conditions associated with cigarette smoking — from pulmonary and heart disease to lip, throat, and lung cancer.

Searching for causes

Much epidemiologic research is devoted to searching for causal factors that influence one's risk of disease. Ideally, the goal is to identify a cause so that appropriate public health action might be taken. One can argue that epidemiology can never prove a causal relationship between an exposure and a disease, since much of epidemiology is based on ecologic reasoning. Nevertheless, epidemiology often provides enough information to support effective action. Examples date from the removal of the handle from the Broad St. pump following John Snow's investigation of cholera in the Golden Square area of London in 1854,[5] to the withdrawal of a vaccine against rotavirus in 1999 after epidemiologists found that it increased the risk of intussusception, a potentially life-threatening condition.[15] Just as often, epidemiology and laboratory science converge to provide the evidence needed to establish causation. For example, epidemiologists were able to identify a variety of risk factors during an outbreak of pneumonia among persons attending the American Legion Convention in Philadelphia in 1976, even though the Legionnaires' bacillus was not identified in the laboratory from lung tissue of a person who had died from Legionnaires' disease until almost 6 months later.[16]

Exercise 1.2

In August 1999, epidemiologists learned of a cluster of cases of encephalitis caused by West Nile virus infection among residents of Queens, New York. West Nile virus infection, transmitted by mosquitoes, had never before been identified in North America.

Describe how this information might be used for each of the following:

1. Assessing the community's health

2. Making decisions about individual patients

3. Documenting the clinical picture of the illness

4. Searching for causes to prevent future outbreaks

✓ **Check your answers on page 1-81**

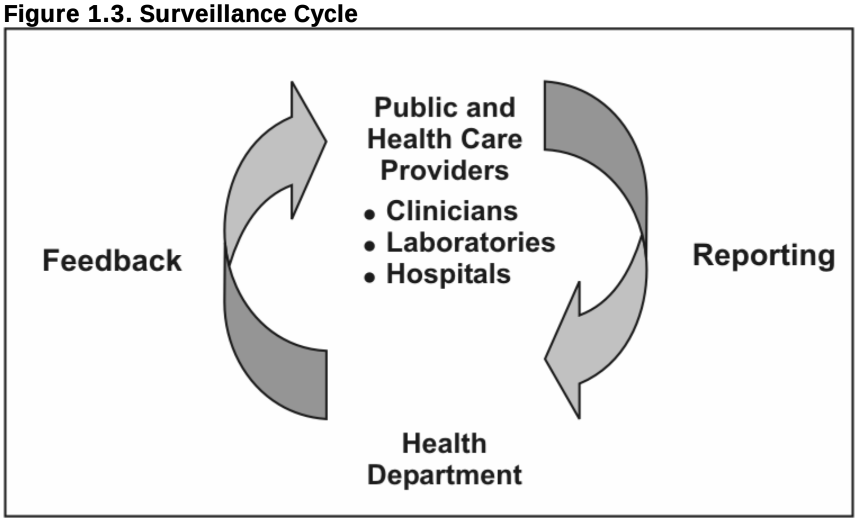
Core Epidemiologic Functions

In the mid-1980s, five major tasks of epidemiology in public health practice were identified: **public health surveillance, field investigation, analytic studies, evaluation, and linkages.**[17] A sixth task, **policy development**, was recently added. These tasks are described below.

Public health surveillance

Public health surveillance is the ongoing, systematic collection, analysis, interpretation, and dissemination of health data to help guide public health decision making and action. Surveillance is equivalent to monitoring the pulse of the community. The purpose of public health surveillance, which is sometimes called "information for action,"[18] is to portray the ongoing patterns of disease occurrence and disease potential so that investigation, control, and prevention measures can be applied efficiently and effectively. This is accomplished through the systematic collection and evaluation of morbidity and mortality reports and other relevant health information, and the dissemination of these data and their interpretation to those involved in disease control and public health decision making.

Figure 1.3. Surveillance Cycle



Morbidity and mortality reports are common sources of surveillance data for local and state health departments. These reports generally are submitted by health-care providers, infection control practitioners, or laboratories that are required to notify the health department of any patient with a reportable disease such as pertussis, meningococcal meningitis, or AIDS. Other sources of health-related data that are used for surveillance include reports from investigations of individual cases and disease clusters, public health program data such as immunization coverage in a community, disease registries, and health surveys.

Most often, surveillance relies on simple systems to collect a limited amount of information about each case. Although not every case of disease is reported, health officials regularly review the case reports they do receive and look for patterns among them. These practices have proven invaluable in detecting problems, evaluating programs, and guiding public health action.

While public health surveillance traditionally has focused on communicable diseases, surveillance systems now exist that target injuries, chronic diseases, genetic and birth defects, occupational and potentially environmentally-related diseases, and health behaviors. Since September 11, 2001, a variety of systems that rely on electronic reporting have been developed, including those that report daily emergency department visits, sales of over-the-counter medicines, and worker absenteeism.[19,20] Because epidemiologists are likely to be called upon to design and use these and other new surveillance systems, an epidemiologist's core competencies must include design of data collection instruments, data management, descriptive methods and graphing, interpretation of data, and scientific writing and presentation.

Field investigation

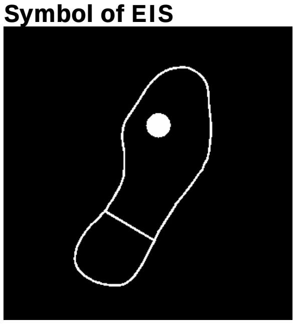
As noted above, surveillance provides information for action. One of the first actions that results from a surveillance case report or report of a cluster is investigation by the public health department. The investigation may be as limited as a phone call to the health-care provider to confirm or clarify the circumstances of the reported case, or it may involve a field investigation requiring the coordinated efforts of dozens of people to characterize the extent of an epidemic and to identify its cause.

The objectives of such investigations also vary. Investigations often lead to the identification of additional unreported or unrecognized ill persons who might otherwise continue to spread infection to others. For example, one of the hallmarks of investigations of persons with sexually transmitted disease is the identification of sexual partners or contacts of patients. When interviewed, many of these contacts are found to be infected without knowing it, and are given treatment they did not realize they needed. Identification and treatment of these contacts prevents further spread.

For some diseases, investigations may identify a source or vehicle of infection that can be controlled or eliminated. For example, the investigation of a case of *Escherichia coli* O157:H7 infection usually focuses on trying to identify the vehicle, often ground beef but sometimes something more unusual such as fruit juice. By identifying the vehicle, investigators may be able to determine how many other persons might have already been exposed and how many continue to be at risk. When a commercial product turns out to be the culprit, public announcements and recalling the product may prevent many additional cases.

Occasionally, the objective of an investigation may simply be to learn more about the natural history, clinical spectrum, descriptive epidemiology, and risk factors of the disease before determining what disease intervention methods might be appropriate. Early investigations of the epidemic of SARS in 2003 were needed to establish a case definition based on the clinical presentation, and to characterize the populations at risk by time, place, and person. As more was learned about the epidemiology of the disease and communicability of the virus, appropriate recommendations regarding isolation and quarantine were issued.[21]

Symbol of EIS



Field investigations of the type described above are sometimes referred to as "shoe leather epidemiology," conjuring up images of dedicated, if haggard, epidemiologists beating the pavement in search of additional cases and clues regarding source and mode of transmission. This approach is commemorated in the symbol of the Epidemic Intelligence Service (EIS), CDC's training program for disease detectives — a shoe with a hole in the sole.

Analytic studies

Surveillance and field investigations are usually sufficient to identify causes, modes of transmission, and appropriate control and prevention measures. But sometimes analytic studies employing more rigorous methods are needed. Often the methods are used in combination — with surveillance and field investigations providing clues or hypotheses about causes and modes of transmission, and analytic studies evaluating the credibility of those hypotheses.

Clusters or outbreaks of disease frequently are investigated initially with descriptive epidemiology. The descriptive approach involves the study of disease incidence and distribution by time, place, and person. It includes the calculation of rates and identification of parts of the population at higher risk than others. Occasionally, when the association between exposure and disease is quite strong, the investigation may stop when descriptive epidemiology is complete and control measures may be implemented immediately. John Snow's 1854 investigation of cholera is an example. More frequently, descriptive studies, like case investigations, generate hypotheses that can be tested with analytic studies. While some field investigations are conducted in response to acute health problems such as outbreaks, many others are planned studies.

The hallmark of an analytic epidemiologic study is the use of a valid comparison group. Epidemiologists must be skilled in all aspects of such studies, including design, conduct, analysis, interpretation, and communication of findings.

- **Design** includes determining the appropriate research strategy and study design, writing justifications and protocols, calculating sample sizes, deciding on criteria for subject selection (e.g., developing case definitions), choosing an appropriate comparison group, and designing questionnaires.
- **Conduct** involves securing appropriate clearances and approvals, adhering to appropriate ethical principles, abstracting records, tracking down and interviewing subjects, collecting and handling specimens, and managing the data.
- **Analysis** begins with describing the characteristics of the subjects. It progresses to calculation of rates, creation of comparative tables (e.g., two-by-two tables), and computation of measures of association (e.g., risk ratios or odds ratios), tests of significance (e.g., chi-square test), confidence intervals, and the like. Many epidemiologic studies require more advanced analytic techniques such as stratified analysis, regression, and modeling.
- Finally, **interpretation** involves putting the study findings into perspective, identifying the key take-home messages, and making sound recommendations. Doing so requires that the epidemiologist be knowledgeable about the subject matter and the strengths and weaknesses of the study.

Evaluation

Epidemiologists, who are accustomed to using systematic and quantitative approaches, have come to play an important role in evaluation of public health services and other activities. Evaluation is the process of determining, as systematically and objectively as possible, the relevance, effectiveness, efficiency, and impact of activities with respect to established goals.[22]

- **Effectiveness** refers to the ability of a program to produce the intended or expected results in the field; effectiveness differs from **efficacy**, which is the ability to produce results under ideal conditions.
- **Efficiency** refers to the ability of the program to produce

the intended results with a minimum expenditure of time and resources.

The evaluation itself may focus on plans (formative evaluation), operations (process evaluation), impact (summative evaluation), or outcomes — or any combination of these. Evaluation of an immunization program, for example, might assess the efficiency of the operations, the proportion of the target population immunized, and the apparent impact of the program on the incidence of vaccine-preventable diseases. Similarly, evaluation of a surveillance system might address operations and attributes of the system, its ability to detect cases or outbreaks, and its usefulness.[23]

Linkages

Epidemiologists working in public health settings rarely act in isolation. In fact, field epidemiology is often said to be a "team sport." During an investigation an epidemiologist usually participates as either a member or the leader of a multidisciplinary team. Other team members may be laboratorians, sanitarians, infection control personnel, nurses or other clinical staff, and, increasingly, computer information specialists. Many outbreaks cross geographical and jurisdictional lines, so co-investigators may be from local, state, or federal levels of government, academic institutions, clinical facilities, or the private sector. To promote current and future collaboration, the epidemiologists need to maintain relationships with staff of other agencies and institutions. Mechanisms for sustaining such linkages include official memoranda of understanding, sharing of published or on-line information for public health audiences and outside partners, and informal networking that takes place at professional meetings.

Policy development

The definition of epidemiology ends with the following phrase: "...and the application of this study to the control of health problems." While some academically minded epidemiologists have stated that epidemiologists should stick to research and not get involved in policy development or even make recommendations,[24] public health epidemiologists do not have this luxury. Indeed, epidemiologists who understand a problem and the population in which it occurs are often in a uniquely qualified position to recommend appropriate interventions. As a result, epidemiologists working in public health regularly provide input, testimony, and recommendations regarding disease control strategies, reportable disease regulations, and health-care policy.