LEARNING OBJECTIVES

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

- Define three mathematical terms applied to epidemiology and provide examples of each.
- Compare incidence and prevalence and explain how they are interrelated.
- State one epidemiologic measure of mortality, giving its formula.
- Distinguish between a fertility rate and a birth rate.
- Name the limitations of crude rates and define alternative measures.

CHAPTER OUTLINE

I. Introduction
II. Mathematical Terms Used in Epidemiology
III. General Information Regarding Epidemiologic Measures
IV. Types of Epidemiologic Measures
V. Epidemiologic Measures Related to Mortality
VI. Specific Rates
VII. Adjusted Rates
VIII. Measures of Natality and Mortality Linked to Natality
IX. Conclusion
X. Study Questions and Exercises

INTRODUCTION

Epidemiologic measurements aid in describing the occurrence of morbidity and mortality in populations. The chapter begins by covering four key mathematical terms that involve the use of fractions and that appear in epidemiologic constructs. You will learn how these terms are applied to fundamental epidemiologic measures of the frequency of diseases in populations and risks associated with exposures to disease agents. This chapter also reveals the different conclusions that can be drawn by examining existing and new cases of disease. Additional topics include basic measures of morbidity and mortality as well as alternative calculations for improving estimates of morbidity and mortality. Finally, you will learn about miscellaneous statistics related to natality and mortality linked to natality. Refer to Table 3-1 for a list of the major terms and concepts covered in this chapter.

MATHEMATICAL TERMS USED IN EPIDEMIOLOGY

Some important mathematical terms applied to epidemiologic measures are rate, proportion, and percentage; these measures are types of ratios. (Refer to Figure 3-1.) The following section defines these terms and gives calculation examples of ratios, proportions, and percentages for mortality from AIDS. The topic of rates will be covered later in the chapter. Data for use in calculating the examples of rates,
proportions, and percentages are given in Table 3-2. Following are some data that will be used for the calculations.

**Ratio**

A ratio is defined as “[t]he value obtained by dividing one quantity by another. Rates and proportions (including risk) are ratios…. Ratios are sometimes expressed as percentages.” Although a ratio consists of a numerator and a denominator, its most general form does not necessarily have any specified relationship between the numerator and denominator.

A ratio is expressed as follows: \( \frac{X}{Y} \).

Calculation example of a ratio:

**Example 1:** With respect to AIDS mortality, the sex ratio of deaths (male to female deaths) = \( \frac{X}{Y} \), where: \( X = 450,451 \) and \( Y = 89,895 \). The sex ratio = 450,451/89,895 = 5 to 1 (approximately).
more women and girls than men and boys. At the same time, there were considerable variations by state; Alaska and Nevada had the highest sex ratios. In 2010, the U.S. sex ratio increased to 96.7. At birth the sex ratio is approximately 105 males to 100 females. Due to higher mortality among males, the sex ratio decreases with age, a trend shown in Figure 3-2. However, from 2000 to 2010, the population of males 60 years and older increased in comparison with the population of females in the same age group. According to the U.S. Census Bureau, this change can be attributed to a narrowing of male-female mortality differences.

**Proportion**

A proportion is a type of ratio in which the numerator is part of the denominator. Proportions may be expressed as percentages.

A proportion is expressed as follows: proportion = A/A + B

Calculation example of a proportion:

**Example 1:** Proportion of AIDS deaths

Suppose that A = the number of male deaths from AIDS

\[ A = 450,451 \]

**Example 2:** Referring to the data in Table 3-2, you can observe that the ratio of users of intravenous drugs to nonusers is 19 to 1.

**Example 3:** In demography, the sex ratio refers to the number of males per 100 females. In the United States, the sex ratio in 2005 was 96.5, meaning that there were

### Table 3-2 Data for Calculations of Rates, Proportions, and Percentages

<table>
<thead>
<tr>
<th>Description</th>
<th>Values</th>
</tr>
</thead>
</table>
| Cumulative U.S. AIDS mortality, 2002–2006; deaths among adults and adolescents | Males = 450,541
|                                                                             | Females = 89,895         |
| Author’s hypothetical survey of clinic patients (n = 20) regarding intravenous drug use (IDU) in a clinic | Number of IDU users = 19
|                                                                             | Number of persons who did not use = 1

**FIGURE 3-2** Sex ratio, by age—2000 and 2010.

![Graph showing sex ratio by age from 2000 to 2010](Reprinted from U.S. Census Bureau. Age and Sex Composition: 2010. 2010 Census Brief. May 2011/S.)
by pain in the shoulder (9%), finger (7%), and hip (7%). Joint pain can be caused by osteoarthritis, injury, prolonged abnormal posture, or repetitive motion.5(p467)

Let’s consider how a proportion (as well as a percentage) can be helpful in describing health conditions. A proportion indicates how important a health outcome is relative to the size of a group. Refer to the following example: suppose there were 10 college dorm residents who had infectious mononucleosis (a virus-caused disease that produces fever, sore throat, and tiredness). How large a problem did these 10 cases represent? To answer this question, one would need to know whether the dormitory housed 20 students or 500 students. If there were only 20 students, then 50% (or 0.50) were ill. Conversely, if there were 500 students in the dormitory, then only 2% (or 0.02) were ill. Clearly, these two scenarios paint a completely different picture of the magnitude of the problem. In this situation, expressing the count as a proportion is indeed helpful. In most situations, it will be informative to have some idea about the size of the denominator. Although the construction of a proportion is straightforward, one of the central concerns of epidemiology is to find and enumerate appropriate denominators to describe and compare groups in a meaningful and useful way.

Rate

Also a type of ratio, a rate differs from a proportion because the denominator involves a measure of time. (Refer back to Figure 3-1). The rate measure shown in the figure is the mathematical formula in which elapsed time is denoted in the denominator by the symbol Δt.

Epidemiologic rates are composed of a numerator (the number of events such as health outcomes), a denominator (a population in which the events occur), and a measure of time.¹ This measure of time is the time period during which events in the numerator occur. The denominator consists of the average population in which the events occurred during this same time period.

In epidemiology, rates are used to measure risks associated with exposures and provide information about the speed of development of a disease. Also, rates can be used to make comparisons among populations. More detailed information on rates is provided in the section on crude rates. Medical publications may use the terms ratio, proportion, and rate without strict adherence to the mathematical definitions for these terms. Hence, you must be alert regarding how a measure is defined and calculated.⁶

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**Percentage**

A percentage is a proportion that has been multiplied by 100. The formula for a percentage is as follows:

\[ \text{percentage} = \left( \frac{A}{A + B} \right) \times 100 \]

**Example 1**: The percentage of male deaths from AIDS was (0.83 × 100) = 83%.

**Example 2**: The percentage of IDU users was (0.95 × 100) = 95%.

**Example 3**: Refer to Figure 3-3, which is a graph of the percentage of adults who reported joint pain or stiffness in the United States in 2006. The figure demonstrates that slightly less than one-third of adults had symptoms of joint pain within the preceding 30-day period. The most frequently reported form of pain was knee pain. "During 2006, approximately 30% of adults reported experiencing some type of joint pain during the preceding 30 days. Knee pain was reported by 18% of respondents, followed by pain in the shoulder (9%), finger (7%), and hip (7%). Joint pain can be caused by osteoarthritis, injury, prolonged abnormal posture, or repetitive motion."5(p467)

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**FIGURE 3-3 Percentage of adults reporting joint pain or stiffness, National Health Interview Survey—United States, 2006.**

who are capable of developing a disease, for example, people who are not immune to an infectious disease.

- Existing (all cases) versus new cases.

The following sections will define the foregoing terms and concepts.

**Types of Epidemiologic Measures**

A number of quantitative terms, useful in epidemiology, have been developed to characterize the occurrence of disease, morbidity, and mortality in populations. Particularly noteworthy are the terms **incidence** and **prevalence**, which can be stated as frequencies or raw numbers of cases. (These terms are defined later.) In order to make comparisons among populations that differ in size, statisticians divide the number of cases by the population size.

**Counts**

The simplest and most frequently performed quantitative measure in epidemiology is a count. As the term implies, a **count** refers merely to the number of cases of a disease or other health phenomenon being studied. As shown in Table 3-3, an example of a count is the number of cases of infrequently reported notifiable diseases per year.

The previous discussion may leave the reader with the impression that counts, because they are simple measures, are of little value in epidemiology; this is not true, however. In fact, case reports of patients with particularly unusual presentations or combinations of symptoms often spur epidemiologic investigations. In addition, for some diseases even a single case is sufficient to be of public health importance. For example, if a case of smallpox (now eradicated) or Ebola virus disease were reported, the size of the denominator would be irrelevant. That is, in these instances a single case, regardless of the size of the population at risk, would stimulate an investigation.

**Measures of Incidence**

Measures of incidence are measures of risk of acquiring a disease or measures of the rate at which new cases of disease develop in a population. They may also be used to assess other health outcomes in addition to diseases. The terms covered in this section are incidence, incidence rate, cumulative incidence, incidence density, and attack rate. Incidence measures are central to the study of causal mechanisms with regard to how exposures affect health outcomes. Incidence measures such as cumulative incidence are used to describe the risks associated with certain exposures; they can be used to estimate in a

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**Figure 3-4**

Epidemiologic measures—measures of occurrence.

influences on the composition of populations. To overcome this challenge, the population at the midpoint of the year is used as the denominator and is considered to be the average population at risk. The formula for the incidence rate shown in the text box is the formula used commonly in public health.

**Incidence**

The term incidence refers to “[t]he number of instances of illness commencing, or of persons falling ill, during a given period in a specified population. More generally, the number of new health-related events in a defined population within a specified period of time.” Ways to express incidence include: incidence rate, cumulative incidence, incidence density, and attack rate.

**Incidence Rate**

The incidence rate is defined as “[t]he RATE at which new events occur in a population.” The new events are usually new cases of disease but can be other health outcomes. The incidence rate is a rate because a time period during which the new cases occur is specified and the population at risk is observed. Figure 3-5 presents the incidence rates for tuberculosis by state in the United States.

The incidence rate denotes a rate formed by dividing the number of new cases that occur during a time period by the average number of individuals in the population at risk during the same time period times a multiplier. (Refer to the box, Incidence rate.) The denominator is the average number of persons at risk for the following reason: In most situations, populations are not static because of migration and other influences on the composition of populations. To overcome this challenge, the population at the midpoint of the year is used as the denominator and is considered to be the average population at risk. The formula for the incidence rate shown in the text box is the formula used commonly in public health.

**TABLE 3-3** Cases of Selected Infrequently Reported Notifiable Diseases (< 1,000 Cases Reported)—United States, 2011–2015

<table>
<thead>
<tr>
<th>Disease</th>
<th>2015*</th>
<th>2014</th>
<th>2013</th>
<th>2012</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Botulism, foodborne</td>
<td>37</td>
<td>15</td>
<td>4</td>
<td>27</td>
<td>24</td>
</tr>
<tr>
<td>Cholera</td>
<td>2</td>
<td>5</td>
<td>14</td>
<td>17</td>
<td>40</td>
</tr>
<tr>
<td>Hansen’s disease (leprosy)†</td>
<td>89</td>
<td>88</td>
<td>81</td>
<td>82</td>
<td>82</td>
</tr>
<tr>
<td>Rabies, human</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>6</td>
</tr>
</tbody>
</table>

*Not reportable in all states.
†Case counts for 2015 are provisional.
An incidence rate is called **cumulative incidence (incidence proportion)** when all individuals in the population are at risk throughout the time period during which they were observed. (Refer to the box, Cumulative incidence.) An example of a population in which all members of the population are at risk is a fixed or closed population (such as the participants in a cohort study) in which no new members are allowed to enter the study after it begins.

Here is a hypothetical calculation example for cumulative incidence: An epidemiologist studies cardiovascular disease among 23,502 male middle-aged alumni of an Ivy League university. Initial medical examinations certify that the alumni have never had a heart attack in the past. During the first year of the research, 111 alums have heart attacks.

\[
\text{Cumulative incidence (incidence proportion)} = \frac{\text{Number of new cases over a time period}}{\text{Total population at risk during the same time period}}
\]

\[
\text{Cumulative incidence} = \frac{111}{23,502} = .005 \text{ (0.5\%)}
\]

In this example the cumulative incidence (incidence proportion) is .005, or 0.5% when expressed as a percentage.

**Incidence Density**

**Incidence density** is a variation of an incidence rate that is used when the time periods of observation of the members of a population vary from person to person. During a study that takes place over an extended period of time (for example, a cohort study, which is described later in the text), participants may be observed for varying periods of time because some drop out before the study is completed. In order to make use of all participants’ data, we calculate incidence density according to the formula shown in the box. The numerator is the number of new cases during the time period and the
denominator is the total person-time of observation. Person-time is the total period of time that each individual at risk has been observed. For example, one person-year means that one subject has been observed for one year. For a further discussion of person-time of observation and incidence density, refer to Friis and Sellers.  

\[
\text{Incidence density} = \frac{\text{Number of new cases during the time period}}{\text{Total person-time of observation}}
\]

Note: Person-years of observation are often used as the denominator.

**Attack Rate**

An **attack rate** is a type of incidence rate used when the occurrence of disease among a population at risk increases greatly over a short period of time; attack rate is often related to a specific exposure. The attack rate is frequently used to describe the occurrence of foodborne illness, infectious diseases, and other acute epidemics. An attack rate is not a true rate because the time dimension is often uncertain. The formula for an attack rate is:

\[
\text{Attack rate} = \frac{\text{Ill}/(\text{Ill} + \text{Well}) \times 100}{\text{during a time period}}
\]

**Calculation example:** Fifty-nine people ate roast beef suspected of causing a *Salmonella* outbreak. Thirty-four people fell ill; 25 remained well.

- Number ill = 34
- Number well = 25
- Attack rate = \(\frac{34}{(34 + 25)} \times 100 = 57.6\%\)

**Prevalence**

The term **prevalence** (expressed as a proportion) refers to the number of existing cases of a disease or health condition, or deaths in a population at some designated time divided by the number of persons in that population. The two forms of prevalence are point prevalence and period prevalence. **Point prevalence** refers to all cases of a disease, health condition, or deaths that exist at a particular point in time relative to a specific population from which the cases are derived. For example, if we are referring to illness (morbidity) in a group of people, the formula for point prevalence is shown in the following box.

**Point prevalence** = \(\frac{\text{Number of persons ill}}{\text{Total number in the group}}\) at a point in time

Point prevalence may be expressed as a proportion formed by dividing the number of cases that occur in a population by the size of the population in which the cases occurred times a multiplier. Note that point prevalence is a proportion and not a rate. If the value of 100 is used as the multiplier, prevalence becomes a percentage.

**Figure 3-6** presents information on asthma period prevalence (defined below) and current (point) asthma prevalence in the United States. Data are from the National Health Interview Survey. Current asthma prevalence was based on the questions “Has a doctor or other health professional ever told you that (you/your child) had asthma? AND (Do you/do your child) still have asthma?” The second question corresponds to point prevalence because the point of assessment refers to having asthma at the time when the question was asked. See Figure 3-6.

The second variety of prevalence is **period prevalence**, which denotes the total number of cases of a disease that
Prevalence measures are used to describe the scope and distribution of health outcomes in the population. The scope or amount of disease is called the burden of disease in the population. By offering a snapshot of disease occurrence, prevalence data contribute to the accomplishment of two of the primary functions of descriptive epidemiology: to assess variations in the occurrence of disease and to aid in the development of hypotheses that can be followed up by analytic studies.

Populations that differ in size cannot be compared directly by using frequency data, i.e., just the numbers of cases. In order to make such comparisons, prevalence proportions need to be calculated. Then it is possible to compare the proportions of health outcomes among different geographic areas. For example, Figure 3-7 shows how asthma lifetime prevalence (%) varies from state to state.

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Mortality rates (death rates) have trended downward over time in this country. Increasing life expectancy has accompanied this decline in mortality rates. The term life expectancy refers to the number of years that a person is expected to live, at any particular year. Life expectancy at birth represents the average number of years that a group of infants would live if the group was to experience throughout life the age-specific death rates present in the year of birth. In 2013, life expectancy for the population of the United States was 78.8 years overall, 81.2 years for females, and 76.4 years for males.

Crude Rates/Crude Death Rate

The basic concept of a rate can be broken down into three general categories: crude rates, specific rates, and adjusted rates. A crude rate is a type of rate that has not been modified to take into account any of the factors, such as the demographic makeup of the population, that may affect the observed rate. Remember that rates include a time period during which an event occurred. Crude rates are summary rates based on the actual number of events in a population over a given time period. The numerator consists of the frequency of a disease (or other health-related outcome) over a specified period of time, and the denominator is a unit size of population (Exhibit 3-1). An example is the crude death rate, which approximates the portion of a population that dies during a time period of interest.

In the formula shown in Exhibit 3-1, the denominator is also termed the reference population, which is defined as the population from which cases of a disease have been taken. For example, in calculating the annual crude death rate (crude mortality rate) in the United States, one would count all the deaths that occurred in the country during a certain year and assign this value to the numerator. The value for the denominator would be the size of the population of the country during that year. The best estimate of the size of a population is often taken as the size of the population around the midpoint of the year, if such information can be obtained. Referring to Exhibit 3-1, one calculates the U.S. crude mortality rate as 821.5 per 100,000 persons for 2013 (the most recently available data as of this writing).

Rates improve our ability to make comparisons, although they also have limitations. For example, rates of mortality for a specific disease (see the section on cause-specific mortality rates later in this chapter) reduce the standard of comparison to a common denominator, the unit size of population. To illustrate, the U.S. crude death rate for diseases of the heart in 2013 was 193.3 per 100,000. One also might calculate the
Case Fatality Rate

An additional measure covered in this section is the case fatality rate (CFR). The case fatality rate refers to the number of deaths due to a disease that occur among people who are afflicted with that disease. The CFR(%) provides a measure of the lethality of a disease, is defined as the number of deaths due to a specific disease within a specified time period divided by the number of cases of that disease during the same time period multiplied by 100. The formula is expressed as follows:

\[
\text{CFR(\%)} = \frac{\text{Number of deaths due to disease } X}{\text{Number of cases of disease } X} \times 100
\]

The numerator and denominator refer to the same time period. For example, suppose that 45 cases of hantavirus infection occurred in a western U.S. state during a year of interest. Of these cases, 22 were fatal. The CFR would be:

\[
\text{CFR(\%)} = \frac{22}{45} \times 100 = 48.9\%
\]

An example of an infectious disease that has a high case fatality rate is primary amebic meningoencephalitis, which is extremely rare and nearly always fatal. The causative organism is a type of amoeba (Naegleria fowleri) found in bodies of fresh water such as hot springs. This uncommon infection occurs when amoeba-contaminated water enters the nose and the parasites migrate to the brain via the optic nerve.
Proportional Mortality Ratio

The National Vital Statistics Reports (for example, Deaths: Final Data for 2013) provide data on the mortality experience of the United States. From these data, one can compute the crude death rate for the U.S. population as demonstrated previously. In comparison with the crude rate, the proportional mortality ratio (PMR) is used to express the proportion of all deaths that can be attributed to a given cause, for example, diseases of the heart. In 2013, the three leading causes of death were heart disease, cancer, and chronic lower respiratory diseases.

The proportional mortality ratio PMR(%) is the number of deaths within a population due to a specific disease or cause divided by the total number of deaths in the population (and multiplied by 100).

Table 3-4 presents mortality data for 2013 for the 10 leading causes of death in the United States. In Figure 3-9 a pie chart illustrates the percentage of total deaths for each of the 10 leading causes of death listed in Table 3-4.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Cause of Death</th>
<th>Number</th>
<th>Percentage of Total Deaths</th>
<th>2013 Crude Death Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All causes</td>
<td>2,596,993</td>
<td>100.0</td>
<td>821.5</td>
</tr>
<tr>
<td>1</td>
<td>Diseases of heart</td>
<td>611,105</td>
<td>23.5</td>
<td>193.3</td>
</tr>
<tr>
<td>2</td>
<td>Malignant neoplasms</td>
<td>548,881</td>
<td>22.5</td>
<td>185.0</td>
</tr>
<tr>
<td>3</td>
<td>Chronic lower respiratory diseases</td>
<td>149,205</td>
<td>5.7</td>
<td>47.2</td>
</tr>
<tr>
<td>4</td>
<td>Accidents (unintentional injuries)</td>
<td>130,557</td>
<td>5.0</td>
<td>41.3</td>
</tr>
<tr>
<td>5</td>
<td>Cerebrovascular diseases</td>
<td>128,978</td>
<td>5.0</td>
<td>40.8</td>
</tr>
<tr>
<td>6</td>
<td>Alzheimer’s disease</td>
<td>84,767</td>
<td>3.3</td>
<td>26.8</td>
</tr>
<tr>
<td>7</td>
<td>Diabetes mellitus</td>
<td>75,578</td>
<td>2.9</td>
<td>23.9</td>
</tr>
<tr>
<td>8</td>
<td>Influenza and pneumonia</td>
<td>56,979</td>
<td>2.2</td>
<td>18.0</td>
</tr>
<tr>
<td>9</td>
<td>Nephritis, nephrotic syndrome, and nephrosis</td>
<td>47,112</td>
<td>1.8</td>
<td>14.9</td>
</tr>
<tr>
<td>10</td>
<td>Intentional self-harm (suicide)</td>
<td>41,149</td>
<td>1.6</td>
<td>13.0</td>
</tr>
</tbody>
</table>

A specific rate is a statistic referring to a particular subgroup of the population defined in terms of race, age, or sex. A specific rate also may refer to the entire population but is specific for some single cause of death or illness. The three examples of specific rates discussed in this chapter are cause-specific rates, age-specific rates, and sex-specific rates. You will learn how they can be applied in various situations.

**Cause-Specific Rate**

The cause-specific rate is a measure that refers to mortality (or frequency of a given disease) divided by the population size at the midpoint of a time period times a multiplier. An example of a cause-specific rate is the cause-specific mortality rate, which, as the name implies, is the rate associated with a specific cause of death. The formula for a cause-specific rate (cause-specific mortality rate) is shown in the text box.

\[
\text{Specific rate (e.g., cause-specific mortality rate)} = \frac{\text{Mortality (or frequency of a given disease)} \times 100,000}{\text{Population size at midpoint of time period}}
\]

Refer back to Table 3-4 for data used in the following sample calculation of the cause-specific mortality rate for accidents (unintentional injuries) for 2013. In the United States, the number of deaths for accidents (unintentional injuries) was 130,557, whereas the population total on July 1, 2013 was estimated to be 316,128,839. The crude cause-specific mortality rate due to accidents (unintentional injuries) per 100,000 was 130,557/316,128,839 \times 100,000 or 41.3 per 100,000.

**Age-Specific Rates**

An age-specific rate refers to the number of cases of disease per age group of the population during a specified time period. Age-specific rates help in making comparisons regarding a cause of morbidity or mortality across age groups. A more precise definition of an age-specific rate is the frequency of a disease (or health condition) in a particular age stratum divided by the total number of persons within that age stratum during a time period. The formula for an age-specific rate is shown in the text box.

\[
\text{Age-specific rate (R)} = \frac{\text{Number of deaths among those age 15 to 24 years}}{\text{Number of persons who are age 15 to 24 years}} \times 100,000
\]

Sample calculation (deaths from malignant neoplasms): In the United States during 2013, there were 1,496 deaths due to malignant neoplasms among the group age 15 to 24 years, and there were 43,954,402 persons in that age group. The age-specific malignant neoplasm death rate in this age group is 1,496/43,954,402 \times 100,000 = 3.4 per 100,000.
Figure 3-10 illustrates data for age-specific rates of hospitalization for kidney disease. For people 45 years of age and older, the age-specific hospitalization rates have shown an increasing trend. The highest rates of hospitalization and the sharpest increase in rates occurred among people age 75 years and older.

**Sex-Specific Rates**

A sex-specific rate refers to the frequency of a disease in a sex group divided by the total number of persons within that sex group during a time period times a multiplier. The formula for a sex-specific rate is shown in the following text box.

Sex-specific rate (e.g., sex-specific death rate) =

\[
\frac{\text{Number of deaths in a sex group}}{\text{Total number of persons in the sex group}} \times 100,000
\]

**Sample calculation:** In 2013, the following information was recorded about mortality and the population size:

- Number of deaths among males: 1,306,034
- Number of deaths among females: 1,290,959

- Estimated number of males in the population as of July 1, 2013: 155,651,602
- Estimated number of females in the population as of July 1, 2013: 160,477,237

The sex-specific crude death rate for males in 2013 per 100,000 was 1,306,034/155,651,602 \( \times \) 100,000 = 839.1 per 100,000.

The sex-specific crude death rate for females in 2013 per 100,000 was 1,290,959/160,477,237 \( \times \) 100,000 = 804.4 per 100,000.

Thus, in 2013, the sex-specific crude death rate for males was 839.1 per 100,000 population versus 804.4 per 100,000 population for females.

**ADJUSTED RATES**

An adjusted rate is a rate of morbidity or mortality in a population in which statistical procedures have been applied to permit fair comparisons across populations by removing the effect of differences in the composition of various populations. A factor in rate adjustment is age adjustment. Calculation of age-adjusted rates is a much more involved procedure than that required for crude
According to the National Center for Health Statistics, the age-adjusted death rate in the United States in 2013 was 731.9 deaths per 100,000 U.S. standard population. This figure compares with a crude rate of 821.5 per 100,000 population. In most years since 1980 (with the exception of 1983, 1985, 1988, 1993, 1999, 2005, 2008, and 2013), the age-adjusted death rate in the United States has declined. Refer to Figure 3-11 for information on trends in age-adjusted and crude mortality rates over time.

Returning to the example in which we compared mortality in New York and Texas, the crude mortality rate for diseases of the heart in 2013 was 224.1 per 100,000 in New York; in Texas, the rate was 152.0 per 100,000. The corresponding age-adjusted rates were 184.8 per 100,000 and 170.7 per 100,000, respectively. The higher crude mortality rate observed in New York in comparison with Texas was due largely to differences in the age structures of the two states. You can see that when the rates were age adjusted, the differences in mortality for diseases of the heart diminished substantially. Consequently, age-adjusted rates permitted a more realistic comparison between the two states than crude rates.

MEASURES OF NATALITY AND MORTALITY LINKED TO NATALITY

Data about natality pertain to birth-related phenomena. Measures of natality include the crude birth rate and the fertility rate. Additionally, statisticians compute measures that describe mortality linked to natality. These indices are the maternal mortality rate, fetal mortality rate, and infant mortality rate. This section covers several measures that pertain to the number of births in a population (birth rate) and the fertility of women of childbearing age (fertility rate). Note that by statistical convention, one definition of the childbearing age is 15 to 44 years of age. Related to giving birth is maternal mortality, which occurs during a small number of births in this country. Another fatal outcome is death of the fetus during gestation; such deaths are called fetal mortality. Still another measure tracks death of the newborn during the first year of life. Consult Table 3-5 for measures presented in this section as well as some of their applications.

Maternal Mortality

Maternal mortality encompasses maternal deaths that result from causes associated with pregnancy. Among the factors related to maternal mortality are race, insufficient healthcare...
access, and social disadvantage. The maternal mortality rate is the number of maternal deaths ascribed to childbirth divided by the number of live births times 100,000 live births during a year. In 2005, the maternal mortality rate was 15.1 deaths per 100,000 live births (623 total deaths in 2005). The respective maternal mortality rates per 100,000 live births for black and white women were 36.5 and 11.1; the rate for black women was about 3.3 times that for white women.

Maternal mortality rate =

\[
\frac{\text{Number of deaths assigned to causes related to childbirth}}{\text{Number of live births}} \times \frac{100,000 \text{ live births (during a year)}}{1,000 \text{ live births}}
\]

Note: Live births include multiple births.

**Infant Mortality Rate**

The infant mortality rate is defined as the number of infant deaths among infants age 0 to 365 days during a year divided by the number of live births during the same year (expressed as the rate per 1,000 live births). Refer to the text box, Infant mortality rate.

The terms neonatal mortality and postneonatal mortality also are used to describe mortality during the first year of life. The neonatal mortality rate is the number of infant deaths under 28 days of age divided by the number of live births during a year. The postneonatal mortality rate refers to the number of infant deaths from 28 days to 365 days after birth divided by the number of live births minus neonatal deaths during a year (expressed as rate per 1,000 live births).

**Infant mortality (IM) rate =**

\[
\frac{\text{Number of infant deaths among infants age 0 - 365 days during the year}}{\text{Number of live births during the year}} \times \frac{1,000 \text{ live births}}{1,000 \text{ live births}}
\]

Sample calculation: In the United States during 2013, there were 23,440 deaths among infants under 1 year of age and 3,932,181 live births. The infant mortality rate was 

\[
\frac{23,440}{3,932,181} \times 1,000 = 5.96 \text{ per 1,000 live births}.
\]

From 2005 to 2013, the infant mortality rate in the United States declined by 13% (6.86 versus 5.96). Infant mortality is related to inadequate health care and poor environmental conditions. There are substantial racial/ethnic variations. (See Figure 3-12.)

**Fetal Mortality**

Fetal mortality is defined as the death of the fetus when it is in the uterus and before it has been delivered. Two measures of fetal mortality are the fetal death rate and the late fetal death rate. The formulas for these terms are shown in the text box.
**FIGURE 3-12** Infant mortality rates, by race and Hispanic origin of mother—United States, 2005 and 2013.


<table>
<thead>
<tr>
<th>Race and Hispanic Origin of Mother</th>
<th>Total</th>
<th>Non-Hispanic Black</th>
<th>American Indian or Alaskan Native</th>
<th>Puerto Rican</th>
<th>Non-Hispanic White</th>
<th>Mexican</th>
<th>Central and South American</th>
<th>Asian or Pacific Islander</th>
<th>Cuban</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>6.86</td>
<td>13.63</td>
<td>11.11</td>
<td>8.06</td>
<td>5.93</td>
<td>6.57</td>
<td>5.13</td>
<td>4.68</td>
<td>3.92</td>
</tr>
<tr>
<td>2013</td>
<td>5.96</td>
<td>11.11</td>
<td>8.06</td>
<td>5.93</td>
<td>5.76</td>
<td>5.30</td>
<td>4.89</td>
<td>4.30</td>
<td>3.02</td>
</tr>
</tbody>
</table>

**Fetal Death Rate and Late Fetal Death Rate**

Fetal death rate (per 1,000 live births plus fetal deaths) =

\[
\frac{\text{Number of fetal deaths after 20 weeks or more gestation}}{\text{Number of live births + number of fetal deaths after 20 weeks or more gestation}} \times 1,000
\]

Late fetal death rate (per 1,000 live births plus late fetal deaths) =

\[
\frac{\text{Number of fetal deaths after 28 weeks or more gestation}}{\text{Number of live births + number of fetal deaths after 28 weeks or more gestation}} \times 1,000
\]

**Birth Rates**

This section defines the terms *crude birth rate* and *general fertility rate*. The *crude birth rate* refers to the number of live births during a specified period such as a year per the resident population at the midpoint of the year. The birth rate affects the total size of the population.

**Sample calculation:** 3,932,181 babies were born in the United States during 2013, when the U.S. population was 316,128,839. The crude birth rate was \(\frac{3,932,181}{316,128,839} = 12.4\) per 1,000.

**General Fertility Rate (Fertility Rate)**

Related to birth rates is the *general fertility rate*, which refers to the number of live births reported in an area during a given time interval divided by the number of women age 15 to 44 years in the area (expressed as rate per 1,000).
Perinatal mortality (known as definition I from the National Center for Health Statistics) takes into account both late fetal deaths and deaths among newborns. The perinatal mortality rate is defined as the number of late fetal deaths (after 28 weeks or more gestation) plus infant deaths within 7 days of birth divided by the number of live births plus the number of late fetal deaths during a year (expressed as rate per 1,000 live births and fetal deaths).

**Perinatal Mortality**

Perinatal mortality (known as definition I from the National Center for Health Statistics) takes into account both late fetal deaths and deaths among newborns. The perinatal mortality rate is defined as the number of late fetal deaths (after 28 weeks or more gestation) plus infant deaths within 7 days of birth divided by the number of live births plus the number of late fetal deaths during a year (expressed as rate per 1,000 live births and fetal deaths).

**Sample calculation:** During 2013 there were 62,939,772 women age 15 to 44 years in the United States. There were 3,932,181 live births. The general fertility rate was $\frac{3,932,181}{62,939,772} = 62.5$ per 1,000 women age 15 to 44 years.

**Perinatal mortality rate**

$$\frac{\text{Number of late fetal deaths (after 28 weeks or more gestation) + infant deaths within 7 days of birth}}{\text{Number of live births + number of late fetal deaths}} \times 1,000$$

**Figure 3-13** compares perinatal mortality rates by race in the United States for 2013.
CONCLUSION

This chapter provided information on measures that are used in epidemiology; these were derived from ratios, such as rates, proportions, and percentages. Types of epidemiologic measures included counts and crude rates as well as case fatality rates, proportional mortality ratios, specific rates, and adjusted rates. These measures are helpful in making descriptive statements about the occurrence of morbidity and mortality and demonstrating risks of adverse health outcomes associated with particular exposures. Two important measures used in epidemiology are prevalence and incidence, which are interrelated terms. Rates are measures that specify a time period during which health events have occurred. A common epidemiologic rate is a crude rate, which allows comparisons of populations that differ in size but not in demographic composition. Specific rates and adjusted rates may be used to overcome some of the problems inherent in crude rates and thus can be used to make comparisons among populations.
6. Distinguish between period prevalence and incidence. What is the definition of lifetime prevalence? Explain the meaning of the formula, \( P \equiv \text{ID}. \)

7. Define the term **crude rate**, giving an example. What are the advantages of using crude rates instead of frequency data such as counts?

8. Define the term **adjusted rate**. What is one of the main purposes of adjusted rates? Compare the advantages and disadvantages of crude and adjusted rates. What is meant by age adjustment? Describe the applications of age-adjusted rates.

9. What types of information are found by using specific rates, such as cause-specific, age-specific, and sex-specific rates, instead of crude rates?

10. Many communities and jurisdictions throughout the United States have legalized recreational use of marijuana. Suppose you are asked to conduct a questionnaire study of the prevalence of marijuana use in a community where use of marijuana is legal. Propose interview questions to assess the following measures of prevalence: point prevalence, period prevalence (one-year time period), and lifetime prevalence.

11. Explain the following measures of incidence and compare their applications: incidence rate, cumulative incidence rate, incidence density, and attack rate.

12. In 2010, the sex ratio among the age group 70-79 years was 81.0. The sex ratio among the age group 100 years and older was 20.7. How might one account for this decline in the sex ratio?

13. Refer back to Table 3-3. What quantitative measure is shown in the table? Describe the annual trends in the cases of infrequently reported notifiable diseases.

14. Calculate the incidence rate (per 100,000 population) of primary and secondary syphilis (combined) in 2013 from the following data:

   - Number of reported cases in 2013: 17,357
   - Estimated population of the United States as of July 1, 2013: 316,128,839

---

**Study Questions and Exercises**

1. Define the following terms and give an example of how each one is used in public health:
   a. Maternal mortality rate
   b. Infant mortality
   c. Fetal mortality
   d. Crude birth rate
   e. General fertility rate
   f. Perinatal mortality rate

2. Suppose that an immunization becomes available for an incurable highly fatal disease. A successful immunization campaign has resulted in the immunization of persons who are at risk of the disease. Which of the following measures is likely to be affected? The case-fatality rate, the mortality rate, or no change in either would occur.

3. Describe what is meant by the term **ratio**. Compare and contrast rates, proportions, and percentages. Give an example of each one.

4. An epidemiologist presented information regarding the annual prevalence (number of cases per 1,000) of adolescent pregnancy to a local health planning board. The epidemiologist compared data for the local county with data for the United States as a whole. One of the members of the planning board objected that this comparison was not valid because the county is much smaller than the entire country. Do you agree with the objection?

5. How does a prevalence proportion (expressed as number of cases per unit size of population) differ from an incidence rate?
15. Table 3-6 provides hypothetical data regarding the prevalence of diabetes in two counties in the United States.
   Based on 2020 prevalence (percentage), which of the two counties had a higher burden of disease from diabetes?

16. Refer to Exhibit 3-1. Calculate the crude death rate (per 100,000) from the following data:
   Number of deaths in the United States during 1990 = 2,148,463
   Population of the United States as of July 1, 1990 = 248,709,873
   How did the crude death rate in 2013 compare with the crude death rate in 1990?

17. Calculate the infant mortality rate (per 1,000 live births) from the following data:
   Number of infant deaths under 1 year in the United States during 1991 = 36,766
   Number of live births during 1991 = 4,111,000
   How did the infant mortality rate in 2013 compare with the infant mortality rate in 1991? (Note: refer to the text for 2013 data.)

18. Calculate the crude birth rate (per 1,000 population) from the following data:
   Number of live births during 1991 = 4,111,000
   Population of the United States as of July 1, 1991 = 252,688,000
   How did the crude birth rate in 2013 compare with the crude birth rate in 1991? (Note: refer to text for 2013 data.)

19. Calculate the general fertility rate (per 1,000 women aged 15-44) from the following data:
   Number of live births during 1991 = 4,111,000
   Number of women (15 to 44 years of age) in the United States as of July 1, 1991 = 59,139,000
   How did the general fertility rate in 2013 compare with the general fertility rate in 1991? (Note: refer to text for 2013 data.)

Questions 20 through 22 refer to Table 3-7.

20. What is the sex ratio for total injuries?
21. What is the crude mortality rate per 100,000 population?
22. What is (a) the cause-specific mortality rate for injuries, and (b) the case fatality rate (%) for injuries?

### TABLE 3-6 Hypothetical Data for Diabetes

<table>
<thead>
<tr>
<th></th>
<th>Estimated Total Population on July 1, 2020</th>
<th>Total Number of Cases of Diabetes in 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>County A</td>
<td>11,020,000</td>
<td>356,289</td>
</tr>
<tr>
<td>County B</td>
<td>3,900,000</td>
<td>253,612</td>
</tr>
</tbody>
</table>

### TABLE 3-7 Hypothetical Data for Unintentional Injuries

<table>
<thead>
<tr>
<th></th>
<th>Total Injuries</th>
<th>Fatal Injuries</th>
<th>Nonfatal Injuries</th>
<th>Number in Population</th>
<th>Total Deaths from All Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>73</td>
<td>3</td>
<td>70</td>
<td>2,856</td>
<td>9</td>
</tr>
<tr>
<td>Women</td>
<td>41</td>
<td>2</td>
<td>39</td>
<td>2,981</td>
<td>8</td>
</tr>
</tbody>
</table>
Answers to calculation problems

14. 5.5 per 100,000
15. County B (6.5% versus 3.2%)
16. The crude death rate declined from 863.8 per 100,000 to 821.5 per 100,000.
17. The infant mortality rate decreased from 8.95 to 5.86.
18. The crude birth rate declined from 16.3 per 1,000 to 12.4 per 1,000.
19. The general fertility rate declined from 69.5 per 1,000 to 62.5 per 1,000.
20. 1.78 to 1, male to female
21. 291.2 per 100,000
22. (a) 85.7 per 100,000; (b) 4.4%

Young Epidemiology Scholars (YES) Exercises

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

1. Bayona M, Olsen C. Measures in Epidemiology
2. Huang FI, Baumgarten M. Adolescent Suicide: The Role of Epidemiology in Public Health
3. McCrery F, St. George DMM. Mortality and the Trans-Atlantic Slave Trade
REFERENCES
