CHAPTER SIX

MORTALITY
Causes and Consequences

Whereas birth is the very first human experience, death is the last. It is not ordinarily desired, but we are all aware that it is inevitable. Thus, attitudes toward death are ambivalent. The lack of preparation for death among people and their families is widespread. This can bring about an array of problems, depending upon such things as the age at which death occurs, its cause, and for how long it had been anticipated. In the United States, about 80 percent of the deaths every year occur in hospitals, hospices, or nursing homes. And among these, 70 percent occur after a decision is taken to forgo life-sustaining treatment. The practice of terminating life unnaturally through means such as suicide, assisted suicide, and voluntary or involuntary euthanasia is widely contested, even in the few countries where these procedures are legal. The grieving and bereavement processes that take place over the loss of a loved one are virtually universal, but the form they take is strongly influenced by cultural factors. It is possible to learn to accommodate the occurrence of death more effectively; and perhaps this is something that would benefit individuals and society at large. But ultimately there is nothing that can be done to avoid it.

For these reasons, a detailed discussion of death may not be the most pleasant subject to which one devotes a chapter in a textbook. However, it is of central importance to the material to be covered from this point on. In Chapter 2, we saw that the origins of demography in the seventeenth century coincided with the earliest attempts to account scientifically for the impact of death on the size and structure of populations. Similarly, many of the important innovations in the history of demographic research are associated with the study of death and mortality, including the invention of the life table, the use of parish records, and the quantification and computerization of population data. It is also in the study of death that our field overlaps most thoroughly with the disciplines of actuarial science and public health. Thus, it would not be redundant to say that mortality is an especially vital characteristic.

Mortality refers to the process of the depletion of a population through death. Death comes as the result of diseases, accidents, homicide, and, in about one of every 70 cases (in the United States), it is self-inflicted. And death comes at all ages, although some age groups are at greater risk than others. The term *general mortality* is used when referring to the occurrence of death regardless of cause or age, and cause-specific and **age-specific mortality** are used when such details are of interest.

The related concept of **morbidity** refers to an abnormal or pathological state. Its immediate root is in the Latin word *morbus*, meaning "diseased." In demographic

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applications, the term is nearly always used in combination with mortality, because of the linkage between certain kinds of pathologies and death. In this respect, its meaning is more akin to "*deadly* illness," and it is closer to the Greek root *marainien*, which means "to waste away." The connection between the two terms is reflected in the leading U.S. publication on the subject, *Morbidity and Mortality Weekly Report*, published by the CDC.[1] Like fertility and mortality, morbidity is measured in terms of rates, proportions, and ratios, as we shall see in a moment.

Our survey of mortality begins with the topic of measurement. This discussion focuses on the rates and ratios that allow us to quantify the occurrence and risks of illness and death. Next we take up the causes of mortality, both social and environmental. Here we get a direct introduction to the public-health perspective on demographic studies. The chapter concludes with two sections on the facts of mortality, past, present, and in various parts of the world. The first of these sections focuses specifically on mortality in the United States. The second, and the last of the chapter, looks at international trends. At the conclusion of this discussion we will have a chance to reflect for a moment on the place of mortality in the larger demographic scheme of things. There we will consider the mutual impact of mortality and fertility. It is this impact, known a **natural increase**, which combines with migration—the subject of Chapter 7, to determine the amount and rate of population growth.

MEASURING MORBIDITY AND MORTALITY

Dorland's Illustrated Medical Dictionary (25th edition) defines death as the irreversible cessation of (a) total cerebral function, (b) spontaneous function of the respiratory system, and (c) spontaneous function of the circulatory system. As we all know, medical science has made it possible to sustain a person artificially even when one or more of these functions has stopped. Thus, for demographic purposes, we operationally define a death as the event as verified in writing (in a document known as a "certificate of death") by a licensed physician or other competent authority. This means that a person being sustained by life-support systems is demographically alive until and unless a doctor certifies otherwise, and that someone whose whereabouts are unknown following an accident is considered to be alive until a formal declaration is made that the accident was fatal. Once a death is certified, it is recorded in a national, state, or local register of vital statistics and thus it becomes demographic data.[2]

Extending and preserving life has been one of the oldest concerns of humankind. In order to prevent death, it is essential to learn about all causes of death that are either diseases or events leading to death as recorded in death certificates. They provide valuable data that may be analyzed for discerning demographic correlates. Given the universal interest in the causes of death, the World Health Organization has developed a system of statistical classification of diseases along with a coding system known as the International Classification of Diseases (ICD).[3] The current version, ICD-10, came into being in 1994, with the next revision envisioned for 2017. The latest version of ICD-10-CM is now being used in the United States.[4]

ICD-10 classification groups similar diseases under a unique block. For example, diseases of the digestive system are assigned the block identifier k00-k93. Each of the identifiers such as k00 is constituted by subblocks, k00.1 to K00.9 and each subblock consists of a number of similar diseases. Assignment of accurate ICD codes will depend upon the presence of medical personnel at the time of death as well as cause of death.

Measures of morbidity describe the occurrence of illness in a population. Such measures are important because an understanding of the conditions that lead to death is essential in describing and explaining mortality patterns. The two approaches to measuring how frequently a disease occurs are the **prevalence** and the **incidence** methods. Prevalence measures indicate the proportion of individuals in a population who have a specific disease at a particular point in time or during a specified interval. Incidence refers to the number cases of a disease *newly diagnosed* during a specified period of time, usually one year.

Morbidity Rates

The most straightforward demographic measure of illness is the simple proportion of those affected, symbolized by "pr," where pr = number of individuals with particular disease/total population size.

For example, in 2004, the number of persons with one of the two of the leading causes of death in the United States, heart diseases and hypertension (high blood pressure), was 26.84 million and 56.58 million, respectively (*Statistical Abstract of the United States, 2012*: Table 197). These numbers refer to all persons who were diagnosed with either or both of these diseases during the year of interest or before it, perhaps many years before. To find the prevalence proportions, the totals are divided by the midyear population size, which in 2009 was 307.44 million. Thus,

$pr_{\text{heart conditions}}$ = 26.84/307.44 = .087 or 8.7 percent; and

$pr_{\text{hypertension}}$ = 56.58/307.44 = .184 or 18.4 percent

With rates approaching 9 and 19 percent, respectively, you can see why these two conditions are of such serious concern in the medical community.

The incidence rate, symbolized by "I," is the number of new cases of a disease that occur per 100,000 persons in the population.[5] The duration is measured from the time the disease is positively diagnosed to the point at which the person either dies or is cured. One of the most closely followed sets of incidence rates is for cancer. The CDC lists 10 specific categories of the disease according to the site of onset: colon, rectum, pancreas, lung and bronchus, and so on. Table 6.1 lists the incidence rates for the two most common sites for men and women between 2006 and 2011. Lung and prostate cancer are by far the most common types among men, and breast and colon cancer lead among women. To illustrate the incidence rate, let us consider breast cancer among African American women during 2010. That year, 24,513 new cases of the disease were diagnosed among this group. With a Census 2010 total of 20,155,262 African American women in the U.S. population,

I = 24,513/20,155,262 = 0.00121,62 or 121.6 per 100,000

As Table 6.1 indicates, the breast cancer incidence rate for this group remained steady at the 125-per-100,000 level between 2006 and 2011. The rate for European American women was consistently higher during this period, but it did exhibit a general decline.

Table 6.1. Incidence Rates for Cancer, United States, 2006–2011

Group/Site	2006	2007	2008	2009	2010	2111
EA Males (all)	562.60	571.40	551.11	541.14	528.22	513.05
Lung	73.07	72.70	70.67	69.55	67.24	64.40
Prostate	167.84	169.23	152.40	149.29	141.03	133.39
AA Males (all)	641.14	663.54	658.40	632.26	606.67	577.75
Lung	100.60	100.07	102.69	96.63	85.06	85.29
Prostate	252.30	264.20	249.62	240.86	226.23	214.83
EA Females (all)	433.64	434.55	436.74	439.26	429.33	426.99
Breast	130.32	132.33	131.23	134.00	130.24	132.58
Colon	30.57	30.19	29.73	28.09	25.41	24.86
AA Females (all)	414.21	413.34	415.71	419.23	402.69	406.52
Breast	124.56	124.47	127.55	128.40	121.62	126.69
Colon	41.48	39.35	36.14	36.72	32.67	31.28

Note: "All" refers to all sites; *EA* is European American and *AA* is African American.

Source: National Institutes of Health, National Cancer Institute: *SEER Cancer Statistics Review* 1975–2011 Incidence Tables 2006–2011. Surveillance Epidemiology and End Results Program, National Institutes of Health, *www.cancer.gov.*

Crude Death Rates

As is true of birth and morbidity, the most important sources of data on death and mortality are vital registration systems. Various types of registration systems are used in the industrialized countries, but all are considered to be reliable. In the United States, states and local governmental units are assigned the primary responsibility for registering and recording deaths. Then, through a cooperative agreement, this information is conveyed to the Federal Government and to the National Center for Health Statistics (NCHS), where it is made available to researchers and the general public. The NCHS and the counterpart organizations (usually the national census bureaus) in Europe, Japan, Canada, Australia, and New Zealand also provide data on important correlates of mortality such as age, gender, cause, marital status, and occupation. In contrast, in most less-developed countries, the vital registration systems are incomplete. Deaths go unreported and the causes of death are often not clearly entered. These limitations constrain our ability to measure mortality accurately on a worldwide basis; and they should serve to caution us to treat such data from such areas as approximate.

We speak of the *force of mortality* when referring to the probability that member of a population will die at some specific moment (compare this with the force of *natality* introduced in Chapter 5). This force, or likelihood, varies with time and from person to person depending on variables such as gender, age, and socioeconomic status (SES). The most common measure is the *annual crude death rate* (CDR). It is defined as the number of deaths that occur in a population during the course of one year for every 1,000 persons alive at midyear. The formula is:

$$\text{CDR} = (\text{D/P}) \times 1{,}000$$

where D is the number of deaths and P is the total population size (see Table 6.2). To illustrate, in the year 2009 Canada's midyear population size was approximately

33.7 million, and about 210,700 deaths were reported for the period. Thus, we find its CDR:

$$\text{CDR} = (239{,}461/33{,}726{,}915) \times 1{,}000 = .007 \times 1{,}000 = 7 \text{ (per thousand).}$$

For the sake of comparison, for the same year, the total population size of the United States was 306.7 million, and about 2,576,881 deaths were recorded. This yields a CDR of 2576/306,771 × 1000 = 8.4 (per thousand) By this criterion, then, we can say that the *overall* probability of dying was lower in Canada than in the United States (at least for the year 2009). But does it mean that Canada's mortality level (the rate at which its population is being depleted by death) is lower than that of the United States? Unfortunately, the answer is "maybe yes and maybe no."

Because the CDR is not a "pure" measure, it alone cannot determine the actual force of mortality or other important aspects of the incidence of death. So we would be misled if we were to compare the CDRs in Table 6.2 to determine (for instance) the quality of medical care in the countries shown—that is, on the assumption that high CDRs go with poor medical care and low CDRs are associated with good care. If this were true, then we would conclude that Sweden and Gambia were about equal in health care access, or that Albania surpassed Japan in this respect. Obviously, the CDR is measuring something else.

Like all demographic indicators, the CDR incorporates certain assumptions in the absence of facts. Some of these are relatively trivial, and some have significant consequences. One fairly inconsequential (and commonly made) assumption is that the size of the midyear population is the same as the yearly average size: the number one would get by summing the sizes of the population on each and every day of the year and then dividing by 365. Of course, we do not know that this is the case, but it seems to be a reasonable guess. It is a much more serious matter to assume, as the CDR does, that each member of a population has the same chance as every other member to die during the course of the year. That is, by taking total deaths divided

Table 6.2. Crude Death Rates for Selected Countries, 2009

Country	Deaths	Population Size	CDR
Albania	20,376.0	3.0	6.0
Australia	139,384.0	22.0	6.0
Bolivia	73,631.0	10.0	7.0
China	9,425,321.0	1331.0	7.0
Cuba	83,266.0	11.0	7.0
Gambia, The	16,746.0	2.0	10.0
Israel	38,925.0	7.0	5.0
Japan	116,0777.0	128.0	9.0
Portugal	104,198.0	11.0	10.0
Rwanda	87,828.0	11.0	8.0
Saudi Arabia	89,125.0	27.0	3.0
South Africa	703,157.0	49.0	14.0
Sweden	90,196.0	9.0	10.0
Yemen, Rep.	168,923.0	22.0	8.0

Population size in millions, crude death rate per 1,000 persons.

Source: World Bank, Crude death rates, http://data.worldbank.org/indicator/SP.DYN.CDRT.IN.

by total population, the rate "averages out" the risk of dying. But we know that this is not true: some cohorts are at greater risk than others are, the risks for men differ from those of women, and so on.

The practical consequence is that a population may have a high CDR in comparison to another (say the United States and Canada) for any of several reasons. It might be because the risk of dying in the first population is truly greater *or* it might be because the first population has proportionately more members in high-risk categories—say, many very elderly people.

Because of this "averaging out" characteristic, we refer to the rate as *crude*. Here, "crude" means unrefined or unspecific. To avoid this crudity, several adjustments are made that provide us with a set of other, more specialized measures of mortality. The first of these is a simple procedure that accounts for the instability of the CDR. The value of this rate depends on the level of mortality, the age structure, the sex, structure, and several cause-specific factors (incidence of morbidity, etc.). Each of these elements varies somewhat each year, and in combination they cause the CDR to fluctuate. To account for this, we can calculate a stable or **central crude death rate** for a specific year, y, by taking the average of the CDR for Y and for the preceding and the following year, y – 1 and y + 1, respectively (Shryock and Siegel 1976:225). The formula for this rate is:

$$[(D_{y-1}/P_{y-1} + D_y/P_y + D_{y+1}/P_{y+1})/3] \times 1{,}000 = (CD_{y-1} + CDR_y + CDR_{y+1})/3$$

Although the CDR for the United States has, in fact, been very stable for many years at less than 9 per 1,000 (between 7.94 and 8.54), during 2005 there was sufficient fluctuation to justify calculating this kind of rate. In 2008, the total (midyear) population size was 304,798,000 and 2,471,984 deaths were reported, which yields a CDR of 8.11 per 1,000. For the preceding year, 2007, the CDR was 8.02, and for the following year, 2009, the rate was 7.43. Adding these three rates together and dividing by 3, we get 8.02: not very different from the observed rates, but more likely to be accurate.

An alternative measure of the central CDR is to add the deaths for the three years (the target year, the one preceding, and the one following) and multiply by one-third. This gives the average number of deaths. Then, divide by the population size of the target year, on the assumption that it is the average population—and multiply by 1,000. With a total of 2,471,984 deaths in 2008 and 2,437,163 in 2010, we calculate the CDR for the United States as follows:

1. Average number of deaths = (1/3) × (2,471,984 + 2,423,712 + 2,437,163) × 1000

1/3 × (7,332,859) = 2, 444, 286

2. CDR = (2,444,286/304,798,000) × 1,000 = 8.01

which is probably the best estimate (and the lowest).

Specific Death Rates

Demographers adjust for the manner in which the CDR treats all members of the population alike with respect to the risk of dying with the use of *specific* rates. As the name suggests, these rates refer to the deaths that occur among a specific subpopulation or subaggregate whose members are known to have a common level of exposure to disease and other causes of death. For any subpopulation, "S," the specific (annual) death rate for that group, DR_s is:

$$DR_s = D_s/P_s \times 1{,}000$$

where D_s is the number of deaths that occur to members of that subpopulation, and P_s is the size of the group at midyear. Note that the group of interest, not the general population, is represented in both the numerator and denominator of this fraction.

Tables 6.3 and 6.4 contain information about four major subpopulations in the United States: African Americans, both male and female, and European Americans, male and female. During the year for which the data in Table 6.3 were collected (2009), the CDR for the nation was 8.12 per 1,000. But that figure conceals the fact that the gender-specific rate for men was well above the average and that for women well below it. The CDR also doesn't indicate that European American males had the highest death rates and African American females the lowest. The African American male death rate experienced significant declines between 1995 and 2010. Table 6.4 shows that in general, death rates for all groups declined during the last quarter of the twentieth century, although European American women saw a fairly steady increase during the period.

Table 6.3. Group-Specific Death Rates, United States, 2009

Group	Persons	Deaths	Death Rate
Males	151,777	1,232	8.12
European American	121,408	1,051	8.66
African American	20,044	145	7.25
Females	157,027	1,236	7.87
European American	124,021, 027	1,036	8.58
African American	21,963	141	6.42

Source: Sherry L. Murphy, Jiaquan Xu, and Kenneth D. Kochanek, Division of Vital Statistics. "Deaths: Final Data for 2010," *National Vital Statistics Reports* 61, no. 4 (May 8, 2013).

Table 6.4. Group-Specific Death Rates (per 1,000 Persons), 1995–2010

Group	1995	2000	2005	2010
Males	9.01	8.53	8.32	8.12
European Americans	9.21	8.73	8.73	8.66
African Americans	9.60	7.96	7.96	7.25
Females	8.37	8.25	8.25	7.87
European Americans	8.43	8.81	8.81	8.57
African Americans	7.43	6.99	6.99	6.42

Source: Sherry L. Murphy, Jiaquan Xu, and Kenneth D. Kochanek, Division of Vital Statistics. "Deaths: Final Data for 2010," *National Vital Statistics Reports* 61, no. 4 (May 8, 2013): Table 1, p. 18.

Age-Specific Rates

Age-specific death rates (**ASDR**s) measure the incidence of death among members of the same cohorts. They are the most widely used specific rates, and the ones most sensitive to the force of mortality. The ASDRs allow us to speak of deaths among persons who are 40 years old, or those age 20, and so on. Data that refer to single years in this manner, single-year cohorts, are collected as "unabridged" data—as we discuss in Chapter 9. However, it is more common to use larger intervals of five or 10 years, such as 24 to 29, or 20 to 29. An exception is made in the case of the very youngest cohorts, ages 5 and below, because death rates at these ages are high and because the variation between single years, say between ages 1 and 2, is significant. In addition, the oldest cohort is usually treated as an open-ended interval: 65 and above or 85+. Table 6.5 compares ASDRs for the United States, Canada, and Mexico.

The formula for the ASDR is:

$$ASDR_x = (D_x/P_x) \times 1{,}000$$

where x is a specific age or age interval. As you can see, this is quite similar to the formula for CDR, except that we specify the age to which we are referring. We will illustrate with data from the state of California. Suppose, for example, we are interested in the death rate for persons between ages 25 and 29, for a specific year—2010. Then the rate we wish to find is symbolized as $ASDR_{25-29}$. To calculate it, we first need to know the number of persons in the state alive at midyear in that cohort, which was estimated to be 2,668,604. This is expressed as $P_{25-29} = 2{,}668{,}604$, indicating the size of the cohort. Next, we need to know the number of deaths at that age that occurred in the state during the year. This total is 1,836, symbolized as $D_{25-29} = 1{,}836$. Therefore,

$$ASDR_{25-29} = (D_{25-29}/ P_{25-29}) \times 1{,}000 = (1{,}836/2{,}668{,}604) \times 1{,}000 = 0.68 \text{ (per 1,000)}$$

Table 6.5. Age-Specific Deaths and Death Rates for Mexico, the United States, and Canada

	Mexico (2010)			United States (2009)			Canada (2008)		
Age	Persons	Deaths	ASDR	Persons	Deaths	ASDR	Persons	Deaths	ASDR
1–4	8.06	5.64	0.7	14.83	4.45	0.3	1.33	0.27	0.2
5–9	9.56	2.87	0.3	25.23	2.52	0.1	2.01	0.2	0.1
10–14	11.97	3.59	0.3	15.64	3.13	0.2	2.46	0.25	0.1
15–24	21.08	23.01	1.09	44.04	30.42	0.69	4.34	2.16	0.5
25–34	17.31	30.21	1.74	40.51	42.5	1.05	4.43	2.66	0.6
35–44	15.38	38.1	2.48	41.60	74.67	1.79	4.9	5.46	1.11
45–54	11.05	54.46	4.93	44.95	187.57	4.17	5.3	14.44	2.72
55–64	7.01	77.21	11.01	34.64	303.31	8.76	3.94	25.94	6.58
65–74	4.19	102.16	24.36	20.76	401.03	19.31	2.41	39.48	16.37
75–84	2.04	120.63	59.04	13.15	627.73	47.72	1.57	69.21	44.06
85–94	0.62	82.52	133.29	5.64	733.18	129.97	0.54	64.45	118.92

Source: United Nations Department of Economic and Social Affairs, *Demographic Yearbook 2013*, Table 19.

Table 6.6. Age-Specific Death Rates for the State of California, 2010

Age Cohort	Persons	Deaths	ASDR
below 1	568,771	2419	4.25
1–4	2,201,909	436	0.20
5–9	2,745,233	239	0.09
10–14	2,691,330	307	0.11
15–19	3,054,118	1,127	0.37
20–24	2,915,575	1,869	0.64
25–29	2,668,256	1,836	0.69
30–34	2,487,744	2,040	0.82
35–39	2,658,460	2,600	0.98
40–44	2,830,879	4,102	1.45
45–49	2,904,236	6,893	2.37
50–54	2,724,228	10,152	3.73
55–59	2,330,002	13,433	5.77
60–64	1,948,855	15,994	8.21
65–69	1,375,945	16,689	12.13
70–74	1,012,104	19,236	19.01
75–79	784,016	24,562	31.33
80–84	611,691	32,789	53.6
85–89	401,966	37,900	94.29
90–100	226,306	38,492	170.09
Total	39137,325	233,143	5.96

ASR per 1,000 persons except for below 1 category.

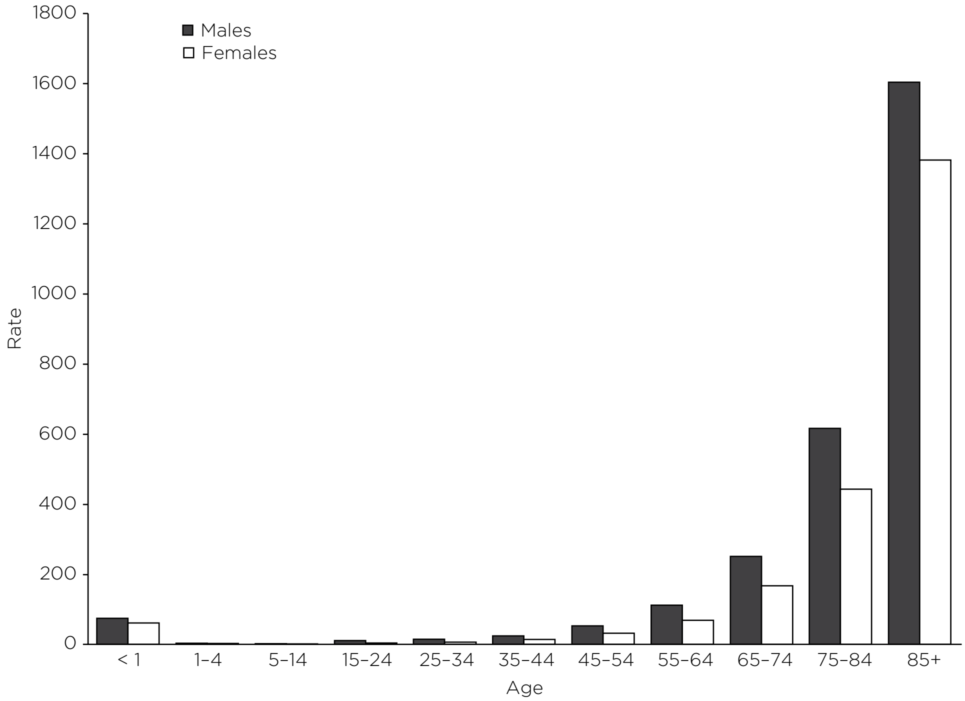
Source: State of California, Department of Public Health, Death Records, Table 5-4, "Deaths and five-year age-specific death rates by sex, California, 2010."

Table 6.6, which contains the entire set of ASDRs for California, 2010, indicates that the state's CDR for that year was 5.9 per 1,000. Although this is well below the CDR for the nation during 2009 (that is, 8.1), it certainly is much higher—more than 12 times higher—than the age-specific rate for persons between ages 25 and 29. The reason for this discrepancy can be seen in the table. The CDR is based on the deaths to persons in every cohort, not only the 25–29 year olds but also the very elderly groups, with ASDRs as high as 170, and the infants who have a rate of 4.2. When deaths are distributed by age, as in Figure 6.1, the highly variable nature of the force of mortality becomes very clear. The ASDRs represent the probability that a person who has reached exact age x will die before reaching exact age x+1; and these rates are used for constructing life tables.[6]

The risk of dying among persons age 5 and below is very high. In virtually every population, the only death rates that are higher are those of the very oldest cohorts. Moreover, because the very young are the most vulnerable to infectious disease, malnutrition, and other illnesses that can prove fatal, the rate at which deaths occur among them is an especially sensitive indicator of socioeconomic conditions. To account for these conditions, several special rates have been devised, including:

1. **Neonatal mortality rate** (**NMR**), which focuses on the first 28 days of life.
2. **Infant mortality rate** (**IMR**), covering the first year of life.
3. **Child mortality rate** (**CMR**), which measures death among persons one to five years old.

Figure 6.1. Age-Specific Mortality Rates for the United States, 2012



Source: Centers for Disease Control and Prevention, National Center for Health Statistics. Compressed Mortality File 1999–2012 on CDC WONDER Online Database, released October 2014. Data are from the Compressed Mortality File 1999–2012 Series 20 No. 2R, 2014, as compiled from data provided by the 57 vital statistics jurisdictions through the Vital Statistics Cooperative Program.

Unlike most other age-specific death rates, the annual neonatal mortality rate is calculated by dividing the number of deaths to persons age 1 to 28 days that occur during a year by the number of live births, not by the size of the cohort. The formula for this rate (NMR) is

$$NMR = (D_{1-28} \text{ days}/B) \times 1{,}000,$$

where B is the number of births. The source from which the age-specific data on California were derived also provided information on neonatal mortality. According to the Department, in 2008, 2,015 infants died before reaching their 29th day of life and a total of 544,594 children were born. Thus, the NMR = (2,015/544,594) × 1,000 = 3.7. Table 6.7 lists neonatal mortality rates for the U.S. population between 1995 and 2009. These rates are given for the general population and for European Americans and minority groups (combined). The fact that these rates have steadily declined among the general population, from 4.91 to 4.18 deaths per 1,000 live births, is evidence of steadily improving health conditions. The fact that rates among the ethnic minority groups have been consistently twice as high as rates among the majority is a clear indication of the level of social and economic inequality that persists in the United States (as discussed in Chapter 3).

Table 6.7. Neonatal Mortality Rates, United States, 1995–2009

Year	Total	European American	All Minorities
1995	4.91	4.08	8.13
1998	4.80	3.98	7.91
1999	4.73	3.88	7.94
2000	4.63	3.82	7.60
2001	4.54	3.78	7.37
2002	4.66	3.89	7.55
2003	4.62	3.87	7.40
2004	4.52	3.78	7.19
2005	4.54	3.79	7.18
2006	4.45	3.72	7.00
2007	4.42	3.70	8.86
2008	4.29	3.62	6.54
2009	4.18	3.48	6.48

Source: *National Vital Statistics Reports* 60, no. 3 (December 29, 2011): Table 20.

The practice of using births instead of cohort size in the denominator is based on the fact that the 1 to 28 day cohort at midyear is only one small part of the population base in which neonatal deaths occur. Every month there is a different set of babies who are in their first month of life; yet neonatal mortality refers to deaths throughout the year. Because births are counted from January 1 to December 31—and not just on July 1 as in the case of cohort size, they provide the correct subpopulation to which neonatal mortality is referred.

This same convention applies to measures of infant mortality, for a similar but slightly different reason. In this case, the numerator, D_{0-1}, or the number of infant deaths, is not confined to the number of infants born during the year for which infant mortality rate (IMR) is computed. In any year, a number of infants born during the preceding calendar year may die. Therefore, using cohort size to measure infant mortality does not produce an accurate indication of the actual probabilities of dying. This is especially true if the number of births changes significantly from one calendar year to another. The widely used IMR is thus defined as:

$$(D_{0-1}/B) \times 1{,}000$$

the number of deaths that occur annually to members of a population during their first year of life, divided by the number of live births during the year (times 1,000). As we saw in the case of California, there were 2,419 infant deaths during 2010 and 568,771 births. Thus, the IMR was:

$$(2{,}419/568{,}771) \times 1{,}000 = 4.2$$

You have probably noticed that neonatal deaths are a component of infant deaths. That is, in the latter case, the first 28 days of life are considered to be part of the first year. Consequently, the neonatal mortality rate for a population is always lower than its IMR. The other component of infant mortality, deaths that occur between the 29th and the 365th day of life, is referred to as "postneonatal mortality." The associated rate is, of course, calculated by subtracting the neonatal mortality rate from the IMR. Thus, for Colorado, 1996, the postneonatal mortality rate is equal to (6.6 − 4.4), or 2.2 deaths per 1,000 live births.

Table 6.8 gives the percentage distribution of infant deaths in the United States for selected years between 1980 and 2005. Here, neonatal mortality is divided between the categories "early" (less than 7 days) and "late" (7 to 27 days), and these are compared with postneonatal mortality. As you can see, the period of highest risk is by far the first week of life. Although only one-third the length of the late neonatal period, and less than one-tenth the length of the postneonatal period, more than one-half of all infant deaths occur before the age of 7 days. This proportion remained steady during the years shown, whereas there was a decline in the percentage of postneonatal deaths.

Analyzing Infant Mortality

Table 6.9 and Figure 6.2 feature comparative IMRs. The table, which is modeled after Table 6.7, contains trends in the IMR for the U.S. population, for European Americans, and for all minority groups combined, between 1993 and 2010. IMR declined steadily during the period, from 8.4 to 6.1 per 1,000 births for the population as a whole. Nevertheless, the rates for minorities remained consistently almost twice as high as the rates of European Americans.

The data on which Figure 6.2 is based came from the sample of 66 nations introduced in Chapters 3 and 4. The mean IMR for the entire sample is 23.35 per 1,000 live births, and there is a substantial amount of variation between countries. The values range between 3.8 for Japan and 50 per 1,000 for Gambia. As these values and Figure 6.2 indicate, a very close, inverse relationship exists between level of socioeconomic development and infant mortality: the higher the per-capita gross national product (GNP), the lower the IMR. The CIA World Fact Book indicated that the average IMR for the world was 49.4 per 1,000. For the more-developed countries, the rate was 9; and for the less-developed countries it was more than *seven* times higher, at 64 per 1,000. Africa, the continent with the lowest per-capita GNP and the highest IMR had a rate of 89 per 1,000—10 times the average of the more-developed nations. The highest IMRs in the world today are in the range of 100 to 150 deaths per 1,000 live births.

Table 6.8. Infant Deaths by Age of Infant, United States, 1980–2005 (in Percentages)

Year	Early Neonatal	Late Neonatal	Postneonatal
1980	56.35	11.11	32.54
1990	52.17	10.87	36.96
1995	52.63	11.84	35.53
2000	53.62	13.04	33.33
2001	52.94	13.24	33.82
2002	52.86	14.29	32.86
2003	53.62	13.04	31.88
2004	52.94	13.24	33.82
2005	52.17	13.04	33.33

Source: U.S. Census Bureau, Statistical Abstract of the United States: 2012, Table 112; U.S. National Center for Health Statistics, *Health, United States, 2008*. See also http://cdc.gov/nchs/hus.htm.

Table 6.9. Infant Mortality Rates, United States, 1993–2010 (Rates per 1,000 Births)

Year	Total, All Groups	European American	African American
2010	6.15	5.20	9.28
2007	6.75	5.64	10.55
2006	6.69	5.56	10.60
2005	6.87	5.73	10.92
2004	6.79	5.66	10.92
2003	6.85	5.72	11.09
2002	6.97	5.79	11.41
2001	6.85	5.65	11.33
2000	6.91	5.68	11.44
1999	7.06	5.77	11.94
1998	7.20	5.95	11.92
1997	7.23	6.03	11.76
1996	7.32	6.07	12.18
1993	8.37	6.82	14.07

Source: Sherry L. Murphy, Jiaquan Xu, and Kenneth D. Kochanek, Division of Vital Statistics. "Deaths: Final Data for 2010," *National Vital Statistics Reports* 61, no. 4 (May 8, 2013): Table 20, p. 91.

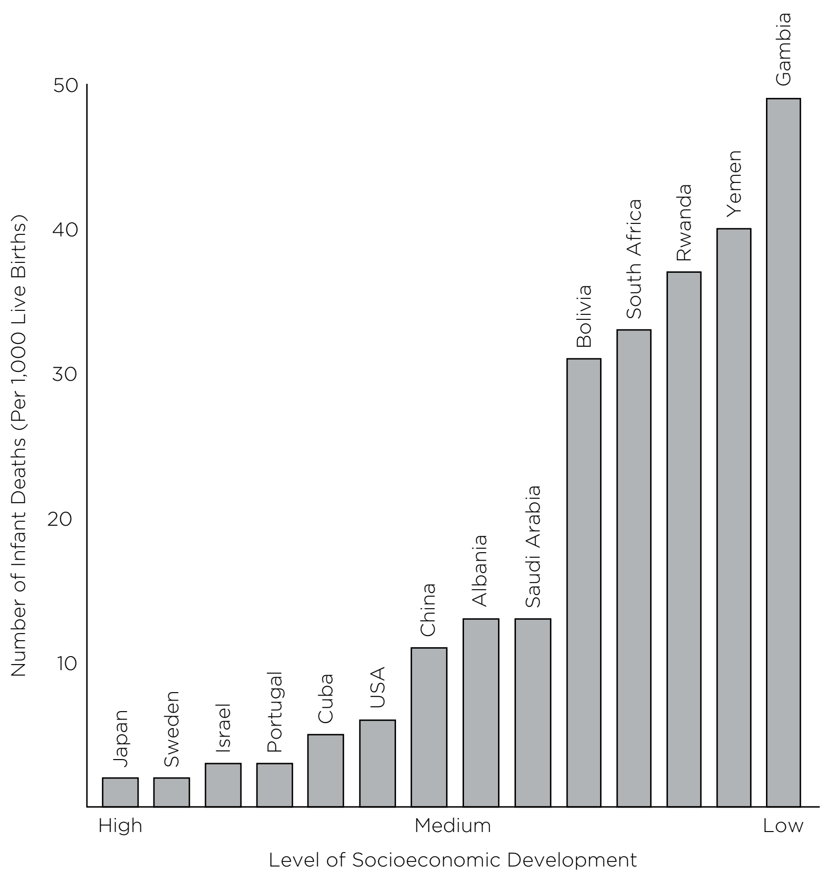


Figure 6.2. Infant Mortality Rates for 14 Countries, 2013
Source: World Bank Online Data, http://data.worldbank.org/indicator/SP.DYN.IMRT.IN.

The NCHS and similar agencies in Europe and Canada also report two additional measures related to infant and neonatal mortality. These are (1) maternal mortality rates and (2) fetal death rates (see U.S. Department of Commerce: Tables 123 and 124). The former rates account for the deaths that occur among women who are carrying, delivering, or who have just given birth ("puerperal" causes). The annual rate is calculated by dividing the total number of deaths among this group by the number of live births during the year, and it is expressed per 100,000. In 2007, the maternal mortality rate was 12.9 deaths per 100,000 live births.

Fetal mortality, also called "involuntary abortion" or "miscarriage," is death that occurs to a viable fetus whose period of gestation is understood to be twenty weeks or more. The annual rate is based upon the number of deaths of this type, per year, for every 1,000 live births. The U.S. fetal death rate declined steadily from 7.0 to 6.2 between 1995 and 2006. By way of comparison, rates of *voluntary* abortion also declined steadily between 1990 and 2005, as shown in Table 6.10.

Cause-Specific Rates

The decomposition of death rates by cause has important, and perhaps obvious, medical applications. Of course, we are always interested in knowing the rate at which members of a population are dying, and the ages at which death is more and less likely to occur. But, if we are also able to identify the major factors that put people at fatal risk, preventative measures can be attempted. For this reason, the study of **cause-specific mortality** is closely related to research on morbidity. In fact, the way in which both prevalence and incidence data are collected is, in part, based on the assumption that certain conditions are likely to become significant causes of death.

As with other specific death rates, cause-specific rates are calculated by dividing the number of deaths in a category by a population base. In most cases, cause-specific rates are stated annually and given per 100,000 members of the reference

Table 6.10. Number of Voluntary Abortions per 1,000 Pregnancies

Year	All Groups	European American	Others
1990	27.4	19.7	50.30
1991	26.2	18.1	50.85
1992	25.7	16.7	51.90
1993	25.0	16.1	48.75
1994	23.7	14.8	48.25
1995	22.5	14.2	44.45
1996	22.4	13.6	45.25
1997	21.9	13.2	44.10
1998	21.5	12.5	44.05
1999	21.4	11.9	44.30
2000	21.3	11.7	44.00
2001	20.9	11.3	42.65
2002	20.5	10.9	41.75
2003	20.2	10.8	40.90
2004	19.7	10.5	39.95
2005	19.4	10.5	39.10

Source: Stephanie J. Ventura, Joyce C. Abma, William D. Mosher, Division of Vital Statistics; and Stanley K. Henshaw, The Guttmacher Institute. "Estimated Pregnancy Rates for the United States, 1990–2005: An Update." *National Vital Statistics Reports* 58, no. 4 (October 14, 2009).

population.[7] For example, according to the NCHS, in 2010, 12,859 persons in the United States died from accidents (of all types, not just auto accidents). We will symbolize this as $D_{accidents}$. With a midyear population size, P, of 309 million, we can calculate $DR_{accidents,}$ the annual accident-specific death rate.

$$DR_{accidents} = (D_{accidents} / P) \times 100{,}000 =$$
$$(120{,}859/309{,}000{,}000) \times 100{,}000 = 39.1$$

All known causes of death vary significantly with age, gender, and socioeconomic characteristics. Thus, reports on the subject produced by the CDC and other organizations typically include information on such variables along with lists of diseases, other causes, and death rates. So, for example, the rate for the leading cause of death in the United States, heart disease, was 193.6 deaths per 100,000 persons. This is about five times the death-by-accident rate. Box 6.1 and Table 6.11 contain further information about the leading causes of death in the United States by gender and age.

SOCIAL AND ENVIRONMENTAL FACTORS

In Chapters 8 and 12, we discuss the current widespread fear of population explosion, and how it has been fueled by dramatic declines in mortality rates globally. The

Box 6.1 The 15 Leading Causes of Death in the United States

		(ABBREVIATION)
1	Diseases of heart*	(heart)
2	Malignant neoplasms*	(neoplasm)
3	Chronic lower respiratory diseases*	(pulmonary)
4	Cerebrovascular diseases*	(cerebrovascular)
5	Accidents (unintentional injuries)*	(accidents)
6	Alzheimer's disease*	(Alzheimer's)
7	Diabetes mellitus (diabetes)	(diabetes)
8	Nephritis, nephrotic syndrome, and nephrosis	(kidney)
9	Influenza and pneumonia	(flu and pneumonia)
10	Intentional self-harm	(suicide)
11	Septicemia	(septicemia)
12	Chronic liver disease and cirrhosis	(liver)
13	Essential hypertension and hypertensive renal disease	(hypertension)
14	Parkinson's disease	(Parkinson's)
15	Pneumonitis due to solids and liquids	(pneumonitis)

*See Table 6.11 for further data on causes of death 1–6.