Mortality and Other Measures of Disease Impact

HSC 4501

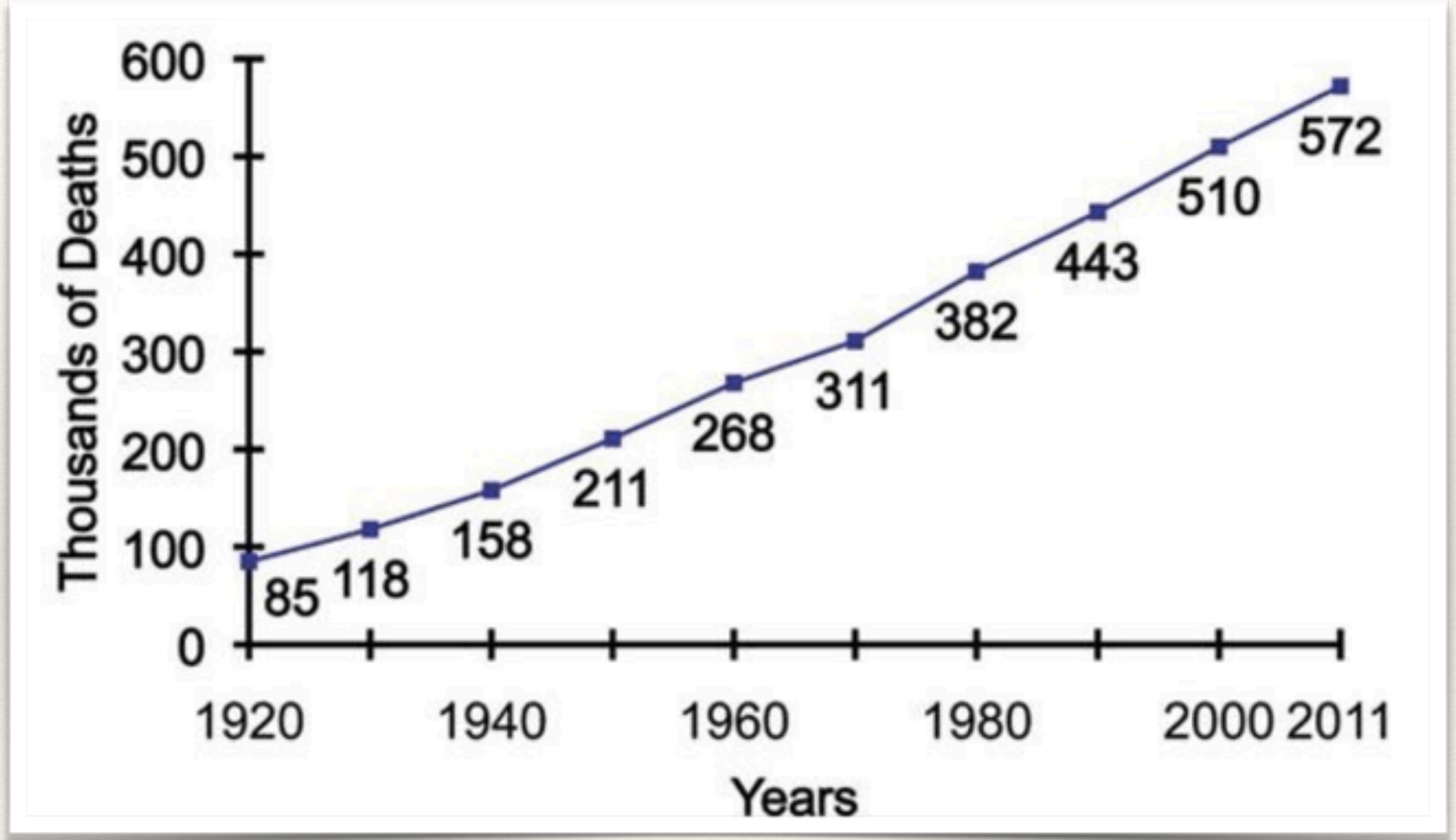
Learning Objectives 7.1

At the end of the lecture students will be able to:

- Compare different measures of mortality, including mortality rates, case-fatality, and proportionate mortality.
- Describe years of potential life lost as a measure of mortality.
- Show when mortality can approximate the risk of disease.

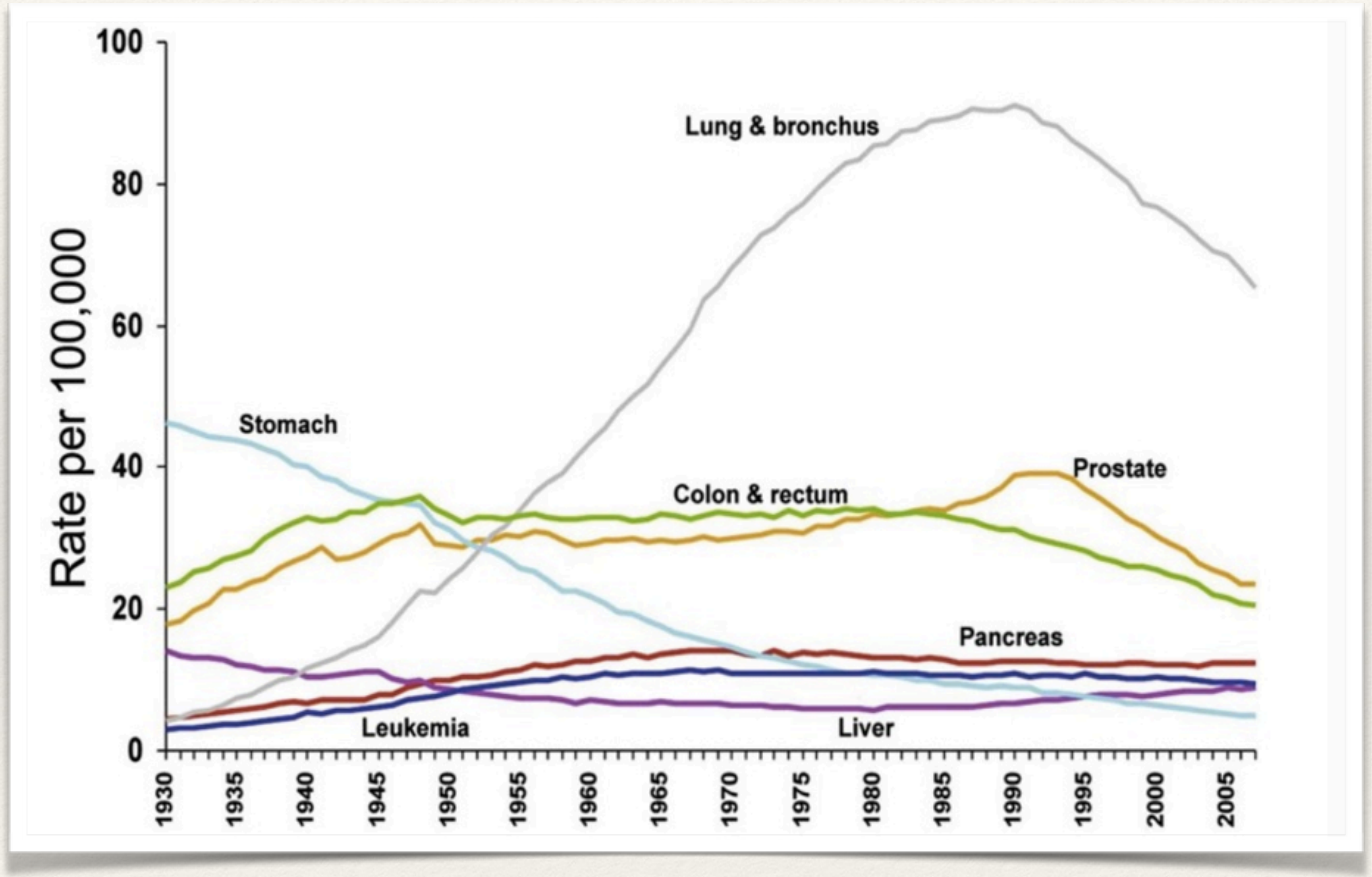
Measures of Mortality cont.

- Clearly, the absolute number of people dying from cancer is seen increasing significantly through the year 2011, but from this graph, **we cannot say that the risk of dying from cancer is increasing, because the only data that we have in this graph are numbers of deaths (numerators); we do not have denominators (populations at risk).**
- If, for example, the size of the U.S. population is also increasing at the same rate, the risk of dying from cancer does not change

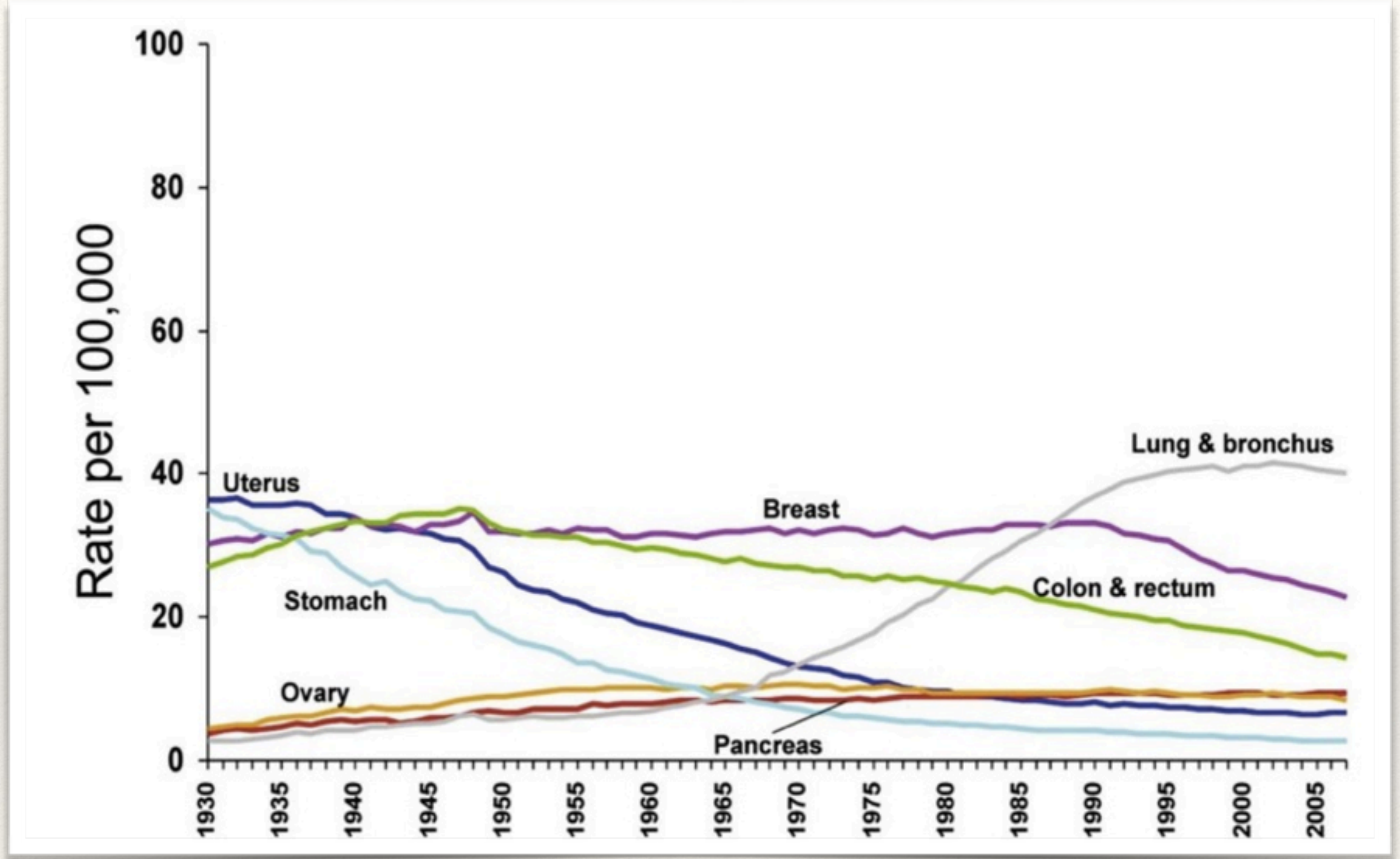


Measures of Mortality

- If we wish to address the risk of dying, we must deal with rates.



Measures of Morbidity



- Uterine cancer mortality has declined, perhaps because of earlier detection and diagnosis. Lung cancer mortality in women has increased, and lung cancer has exceeded breast cancer as a cause of death in women. Lung cancer is now the leading cause of cancer death in women. **It is a tragedy that an almost completely preventable cause of cancer that is precipitated by a lifestyle habit, cigarette smoking, which has been voluntarily adopted by many women, is the main cause of cancer death in women in the United States.**

Mortality Rate

Annual Mortality Rate (Crude Rate):

Annual mortality rate for all causes

$$\text{(per 1,000 population)} = \frac{\text{Total no. of deaths from all causes in 1 year}}{\text{No. of persons in the population at midyear}} \times 1,000$$

- Note that because the population changes over time, the number of persons in the **population at midyear is generally used as an approximation**.
- **The same principles mentioned in the discussion of morbidity applies to mortality: for a mortality rate to make sense, anyone in the group represented by the denominator must have the potential to enter the group represented by the numerator**.

Crude Mortality Rate

- The crude mortality rate is the mortality rate from all causes of death for a population. In the United States in 2003, a total of 2,419,921 deaths occurred. The estimated population was 290,809,777.

The crude mortality rate in 2003 was, therefore, (2,419,921/290,809,777) × 100,000, or 832.1 deaths per 100,000 population.

Mortality Rate cont.

Specified Mortality Rate

- We may not always be interested in a rate for the entire population; perhaps we are interested only in a certain age group, in men or in women, or in one ethnic group. Thus, if we are interested in mortality in children younger than 10 years, we can calculate a rate specifically for that group:

$$\text{Annual mortality rate from all causes for children younger than 10 years of age (per 1,000 population)} = \frac{\text{No. of deaths from all causes in one year in children younger than 10 years of age}}{\text{No. of children in the population younger than 10 years of age at midyear}} \times 1,000$$

Note: that in putting a restriction, on age, for example, the same restriction must apply to both the numerator and the denominator, so that every person in the denominator group will be at risk for entering the numerator group. When such a restriction is placed on a rate, it is called a specific rate. The above rate, then, is an age-specific mortality rate.

Mortality Rate cont.

- Disease-specific or a cause-specific rate:
  - We could also place a restriction on a rate by specifying a diagnosis, and thus limit the rate to deaths from a certain disease. For example, if we are interested in mortality from lung cancer, we would calculate it in the following manner:

$$\text{Annual mortality rate from lung cancer (per 1,000 population)} = \frac{\text{No. of deaths from lung cancer in one year}}{\text{No. of persons in the population at midyear}} \times 1{,}000$$

- Age-specified mortality rate:
  - We can also place restrictions on more than one characteristic simultaneously, for example, age and cause of death, as follows:

$$\text{Annual mortality rate from leukemia in children younger than 10 years of age (per 1,000 population)} = \frac{\text{No. of deaths from leukemia in one year in children younger than 10 years of age}}{\text{No. of children in the population younger than 10 years of age at midyear}} \times 1{,}000$$

  - Time must also be specified in any mortality rate. Mortality can be calculated over 1 year, 5 years, or longer. The period selected is arbitrary, but it must be specified precisely.

Mortality Rate

- **Cause-specific mortality rate ~ USA population = 290,809,777**
- The cause-specific mortality rate is the mortality rate from a specified cause for a population. The numerator is the number of deaths attributed to a specific cause. The denominator remains the size of the population at the midpoint of the time period. The fraction is usually expressed per 100,000 population. In the United States in 2003, a total of 108,256 deaths were attributed to accidents (unintentional injuries).
- What is the cause-specific mortality rate?
  - 37.2 per 100,000 population
- **Age-specific mortality rate ~ USA population** = 290,809,777
- An age-specific mortality rate is a mortality rate limited to a particular age group. The numerator is the number of deaths in that age group; the denominator is the number of persons in that age group in the population. In the United States in 2003, a total of 130,761 deaths occurred among persons aged 25–44 years.
- What is the age-specific mortality rate?
  - 153.0 per 100,000 25–44 year olds.

Case Fatality

- We must distinguish between a **mortality rate and case-fatality.** Case-fatality is calculated as follows:

$$\text{Case-fatality (percent)} = \frac{\begin{array}{c}\text{No. of individuals dying during a}\\ \text{specified period of time after disease}\\ \text{onset or diagnosis}\end{array}}{\text{No. of individuals with the specified disease}} \times 100$$

- In other words, what percentage of people who have a certain disease die within a certain time after their disease was diagnosed?
- (If the information is to be obtained from respondents, it is worth noting that if the disease in question is a serious one, the date on which the diagnosis was given may well have been a life-changing date for the patient and not easily forgotten.

Case Fatality Vs Mortality Rate

- What is the difference between case-fatality and a mortality rate? In a mortality rate, the denominator represents the entire population at risk of dying from the disease, including both those who have the disease and those who do not have the disease (but who are at risk of developing the disease).
- In case-fatality, however, the denominator is limited to those who already have the disease. Thus, case-fatality is a measure of the severity of the disease. It can also be used to measure any benefits of a new therapy: as therapy improves, case-fatality would be expected to decline. **You will note that case-fatality is not a rate but a percentage (of those with the disease)**

Case Fatality vs Mortality Rate

Assume that in a population of 100,000 persons, 20 have disease X. In one year, 18 people die from that disease. The mortality is very low (0.018%) because the disease is rare; however, once a person has the disease, the chances of his or her dying are great (90%

Assume a population of 100,000 people of whom 20 are sick with disease X, and in 1 year, 18 of the 20 die from disease X.

Mortality rate from disease X = $\frac{18}{100{,}000}$ = 0.00018, or 0.018%.

Case-fatality from disease X = $\frac{18}{20}$ = 0.9, or 90%.

Percentages and Rates

Percentages:

- Numerator and denominator are the same unit of measure
- Both the numerator and denominator are positive whole numbers
- The numerator is never greater than the denominator

$$\text{Case-fatality (percent)} = \frac{\begin{array}{c}\text{No. of individuals dying during a}\\ \text{specified period of time after disease}\\ \text{onset or diagnosis}\end{array}}{\text{No. of individuals with the specified disease}} \times 100$$

Rates:

- Numerator and denominator do not use the same unit of measure
- There can be more than one countable outcome for a unit in the denominator

$$\begin{array}{l}\text{Annual mortality rate for all causes}\\ \text{(per 1,000 population)} = \end{array}$$
$$\frac{\text{Total no. of deaths from all causes in 1 year}}{\text{No. of persons in the population at midyear}} \times 1,000$$

Ratios

- Method for calculating a ratio:

$$\frac{\textit{Number or rate of events, items, persons, etc. in one group}}{\textit{Number or rate of events, items, persons, etc. in another group}}$$

- After the numerator is divided by the denominator, the result is often expressed as the result “to one” or written as the result “:1.”
- Note that in certain ratios, the numerator and denominator are different categories of the same variable, such as males and females, or persons 20–29 years and 30–39 years of age. In other ratios, the numerator and denominator are completely different variables, such as the number of hospitals in a city and the size of the population living in that city.

Calculating Ratios

EXAMPLE: Calculating a Ratio — Different Categories of Same Variable

Between 1971 and 1975, as part of the National Health and Nutrition Examination Survey (NHANES), 7,381 persons ages 40–77 years were enrolled in a follow-up study.(1) At the time of enrollment, each study participant was classified as having or not having diabetes. During 1982–1984, enrollees were documented either to have died or were still alive. The results are summarized as follows.

Of the men enrolled in the NHANES follow-up study, 3,151 were nondiabetic and 189 were diabetic. Calculate the ratio of non-diabetic to diabetic men.

Participant	Original Enrollment (1971–1975)	Dead at Follow-Up (1982–1984)
Diabetic men	189	100
Nondiabetic men	3,151	811
Diabetic women	218	72
Nondiabetic women	3,823	511

Ratio = $3{,}151 / 189 \times 1 = 16.7:1$

Proportionate mortality

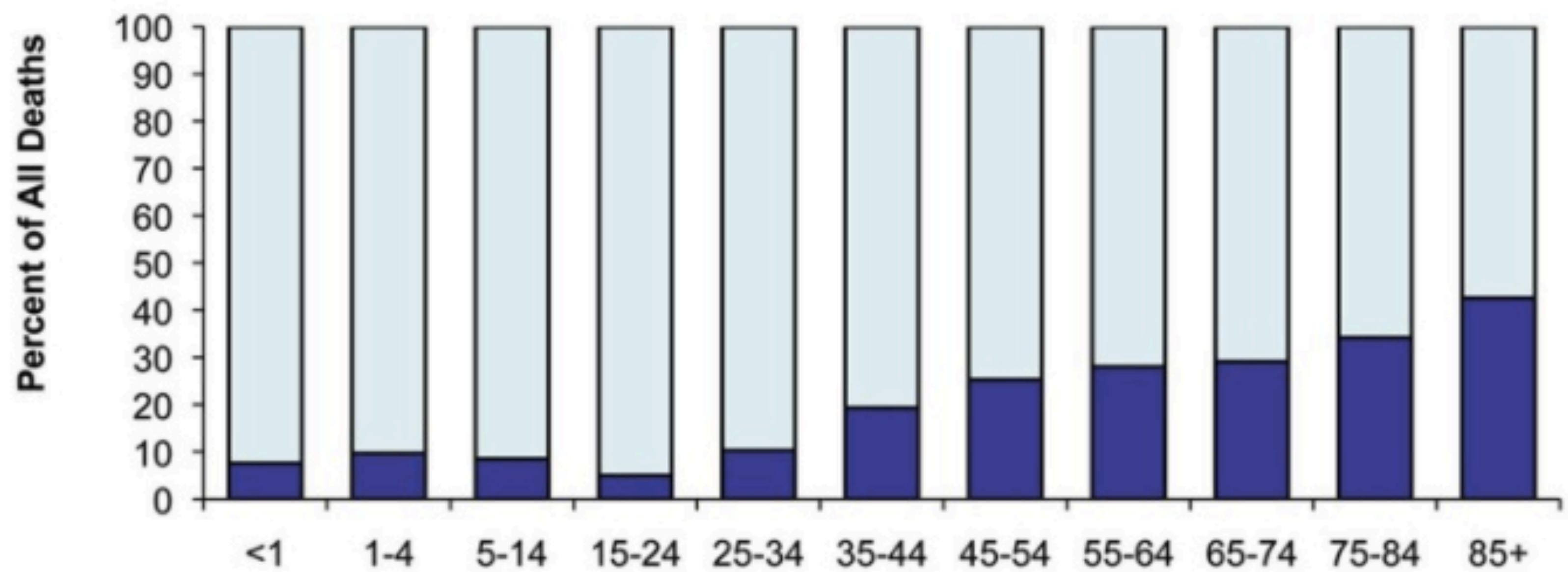
Proportionate mortality

Proportionate Mortality:

$$\text{Proportionate mortality from cardiovascular diseases in the U.S. in 2010 (percent)} = \frac{\text{No. of deaths from cardiovascular diseases in the U.S. in 2010}}{\text{Total deaths in the U.S. in 2010}} \times 100$$

- We see that the *proportion* of deaths from heart disease increases with age. **However, this does not tell us that the *risk* of death from heart disease is also increasing.**

Figure 4-6 Deaths from heart disease as a percentage of deaths from all causes, by age group, United States, 2008.



Proportionate Mortality cont.

- The table below shows all deaths and deaths from heart disease in two communities, A and B. All-cause mortality in community A is twice that in community B. When we look at proportionate mortality, we find that 10% of the deaths in community A and 20% of the deaths in community B are due to heart disease. Does this tell us that the risk of dying from heart disease is twice as high in community B as it is in A?

TABLE 4-2 Comparison of Mortality Rate and Proportionate Mortality: I. Deaths from Heart Disease in Two Communities

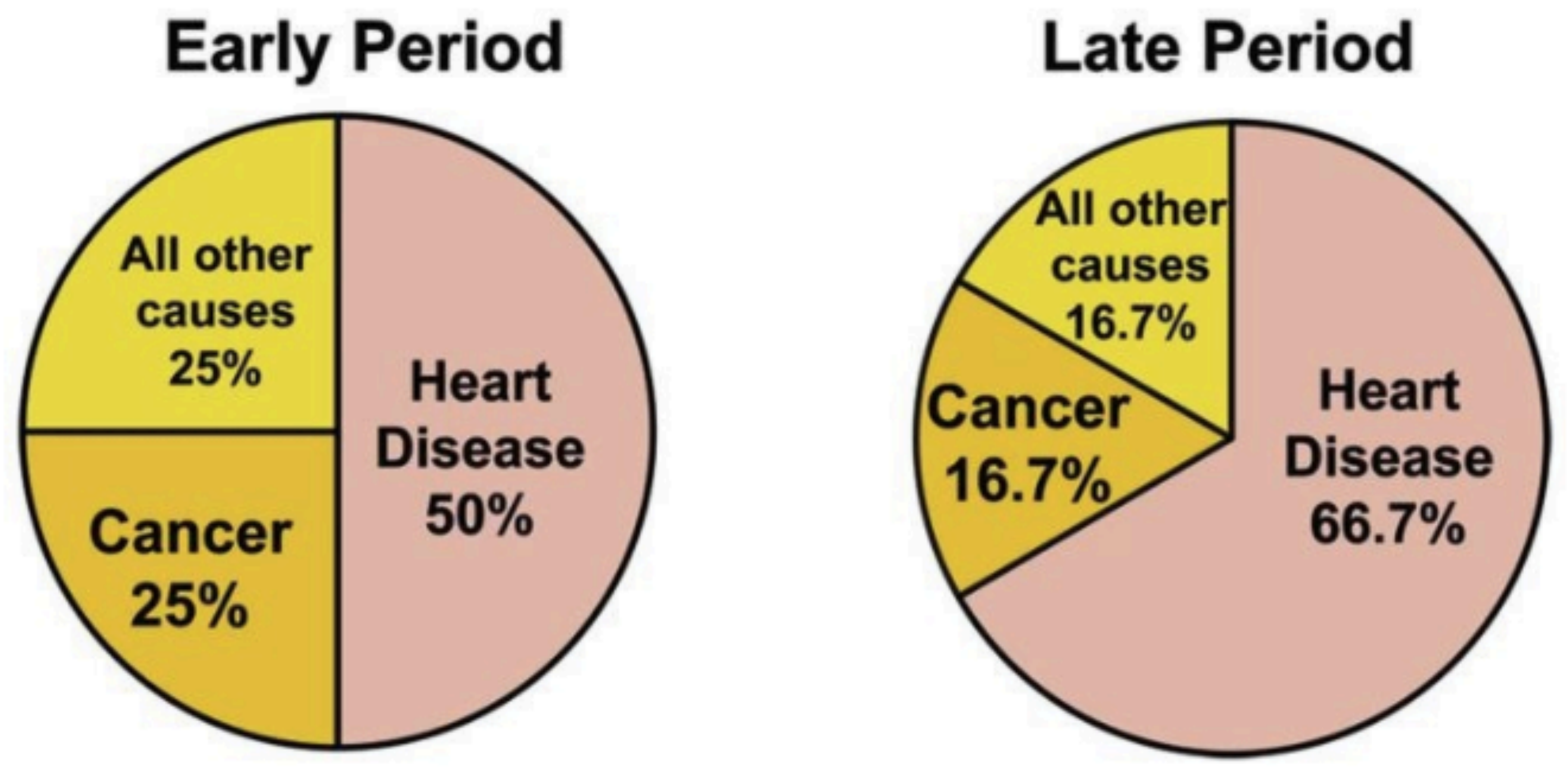
	Community A	Community B
Mortality rate from all causes	30/1,000	15/1,000
Proportionate mortality from heart disease	10%	20%
Mortality rate from heart disease	3/1,000	3/1,000

- The answer is no. For when the mortality rates from heart disease are calculated (10% of 30/1,000 and 20% of 15/1,000), we find that the mortality rates are identical

Proportionate mortality cont.

If we observe a change in proportionate mortality from a certain disease over time, the change may be due not to changes in mortality from that disease, but to changes in the mortality of some other disease.

Figure 4-7 Hypothetical example of proportionate mortality: Changes in proportionate mortality from heart disease, cancer, and other causes from the early period to the late period.



Years of Potential Life Lost

- In recent years, another mortality index, years of potential life lost (YPLL), has been increasingly used for setting health priorities. YPLL is a measure of premature mortality, or early death. YPLL recognizes that death occurring in the same person at a younger age clearly involves a greater loss of future productive years than death occurring at an older age.
- Two steps are involved in this calculation:
  - In the first step, for each cause, each deceased person's age at death is subtracted from a predetermined age at death. In the United States, this predetermined "standard" age is usually 75 years. Thus, an infant dying at 1 year of age has lost 74 years of life (75 – 1), but a person dying at 50 years of age has lost 25 years of life (75 – 50). Thus, the younger the age at which death occurs, the more years of potential life are lost.
  - In the second step, the "years of potential life lost" for each individual are then added together to yield the total YPLL for the specific cause of death. **When looking at reports that use YPLL, it is important to note what assumptions the author has made, including what predetermined standard age has been selected.**

Figure 4-9 Years of potential life lost (YPLL) before age 75, all races, both sexes, all deaths, United States, 2008.

Cause of Death	YPLL	Percent
All Causes	20,417,162	100.0%
Malignant Neoplasms	4,353,353	21.3%
Heart Disease	3,107,088	15.2%
Unintentional Injury	3,073,287	15.1%
Perinatal Period	1,042,793	5.1%
Suicide	1,042,845	5.1%
Homicide	756,233	3.7%
Congenital Anomalies	573,958	2.8%
Chronic Lower Respiratory Disease	533,984	2.6%
Cerebrovascular	525,979	2.6%
Diabetes Mellitus	496,159	2.4%
All Others	4,911,483	24.0%

YPLL cont.

YPLL can assist in three important public health functions:

1.) Establishing research and resource priorities

2.) Surveillance of temporal trends in premature mortality

3.) Evaluating the effectiveness of program interventions

Why Look at Mortality

- Mortality is clearly an index of the severity of a disease from both clinical and public health standpoints, but mortality can also be used as an index of the risk of disease.
- In general, mortality data are easier to obtain than incidence data for a given disease, and it therefore may be more feasible to use mortality data as an index of incidence.
- However, when a disease is mild and not fatal, mortality is not a good index of incidence.
- A mortality rate is a good reflection of the incidence rate under two conditions:
  - First, when the case-fatality rate is high (as in untreated rabies)
  - Second, when the duration of disease (survival) is short.
- Under these conditions, mortality is a good measure of incidence, and thus a measure of the risk of disease. For example, cancer of the pancreas is a highly lethal disease: death generally occurs within a few months of diagnosis, and long-term survival is rare. Thus, unfortunately, mortality from pancreatic cancer is a good surrogate for incidence of the disease.

Artifactual vs Real difference in Mortality

TABLE 4-16 Possible Explanations of Trends or Differences in Mortality: I. Artifactual

1. Numerator	Errors in diagnosis Errors in age Changes in coding rules Changes in classification
2. Denominator	Errors in counting population Errors in classifying by demographic characteristics (e.g., age, race, sex) Differences in percentages of populations at risk

TABLE 4-17 Possible Explanations of Trends or Differences in Mortality: II. Real

Change in survivorship without change in incidence

Change in incidence

Change in age composition of the population(s)

A combination of the above factors

Problems with Mortality Data

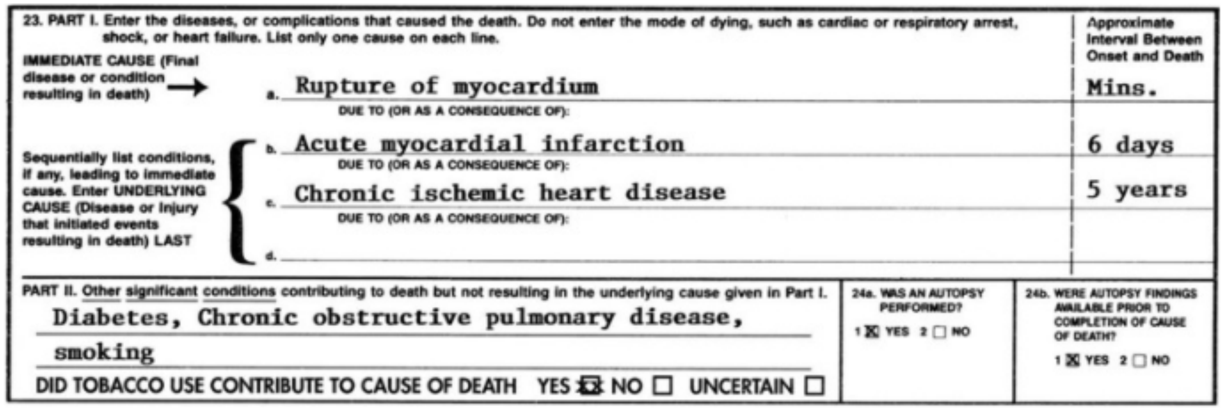
- Whenever we see a time trend of an increase or a decrease in mortality, the first question we must ask is, "Is it real?"

- By international agreement, deaths are coded according to the underlying cause. The underlying cause of death is defined as "the disease or injury which initiated the train of morbid events leading directly or indirectly to death or the circumstances of the accident or violence which produced the fatal injury."

- The underlying cause of death therefore"excludes information pertaining to the immediate cause of death, contributory causes and those causes that intervene between the underlying and immediate causes of death."

- The total contribution of a given cause of death may not be reflected in the mortality data as generally reported; this may apply to a greater extent in some diseases than in others.

- Changes in the definition of disease can also have a significant effect on the number of cases of he disease that are reported or that are reported and subsequently classified as meeting the diagnostic criteria for the disease


23. PART I. Enter the diseases, or complications that caused the death. Do not enter the mode of dying, such as cardiac or respiratory arrest, shock, or heart failure. List only one cause on each line.

Approximate Interval Between Onset and Death

IMMEDIATE CAUSE (Final disease or condition resulting in death) → a. Rupture of myocardium — Mins.

DUE TO (OR AS A CONSEQUENCE OF):

Sequentially list conditions, if any, leading to immediate cause. Enter UNDERLYING CAUSE (Disease or injury that initiated events resulting in death) LAST

b. Acute myocardial infarction — 6 days

DUE TO (OR AS A CONSEQUENCE OF):

c. Chronic ischemic heart disease — 5 years

DUE TO (OR AS A CONSEQUENCE OF):

d.

PART II. Other significant conditions contributing to death but not resulting in the underlying cause given in Part I.

Diabetes, Chronic obstructive pulmonary disease, smoking

DID TOBACCO USE CONTRIBUTE TO CAUSE OF DEATH YES ☒ NO ☐ UNCERTAIN ☐

24a. WAS AN AUTOPSY PERFORMED? 1 ☒ YES 2 ☐ NO

24b. WERE AUTOPSY FINDINGS AVAILABLE PRIOR TO COMPLETION OF CAUSE OF DEATH? 1 ☒ YES 2 ☐ NO

Figure 4-21 Example of a completed cause-of-death section on a death certificate, including immediate and underlying causes and other significant conditions.

Review 7.1

- Define and produce the formula for the different measures of mortality, including mortality rates, case-fatality, and proportionate mortality.
- What is the definition of years of potential life lost? Why is it used as a measure of mortality?
- When can mortality can approximate the risk of disease?

Objectives 7.2

At the end of the lecture student will be able to:

- Discuss issues that arise in comparing mortality across two or more population.
- Define, calculate, and interpret direct mortality rates.
- To introduce other measures of disease impact.

Comparing Mortality

- An important use of mortality data is to compare two or more populations, or one population in different time periods. Such populations may differ in regard to many characteristics that affect mortality, of which age distribution is the most important.
- In fact, age is the single most important predictor of mortality. Therefore, methods have been developed for comparing mortality in such populations while effectively holding constant characteristics such as age.

Comparing Mortality cont.

- Mortality rates for white and black residents of Baltimore in 1965 are given. The data may seem surprising because we would expect rates to have been higher for blacks, given the problems associated with poorer living conditions and less access to medical care, particularly at that time.
- When we look at Table 4-8, we see the data from Table 4-7 on the left, but now we have added data for each age-specific stratum (layer) of the population. Interestingly, although in each age-specific group, mortality is higher in blacks than in whites, the overall mortality differs.

TABLE 4-7 Crude Mortality Rates by Race, Baltimore City, 1965

Race	Mortality per 1,000 Population
White	14.3
Black	10.2

TABLE 4-8 Death Rates by Age and Race, Baltimore City, 1965

	DEATH RATES BY AGE PER 1,000 POPULATION						
Race	All Ages	<1 yr	1–4 yrs	5–17 yrs	18–44 yrs	45–64 yrs	>65 yrs
White	14.3	23.9	0.7	0.4	2.5	15.2	69.3
Black	10.2	31.3	1.6	0.6	4.8	22.6	75.9

From Department of Biostatistics: Annual Vital Statistics Report for Maryland, 1965. Baltimore, Maryland State Department of Health, 1965.

Direct Age Adjustment

- When we calculate direct age adjustment values. We ask ourselves the question:
  - If the age composition of the populations were the same, would there be any differences in mortality between the populations being compared?
- In direct age adjustment, a standard population is used in order to eliminate the effects of any differences in age between two or more populations being compared. A hypothetical "standard" population is created to which we apply both the age-specific mortality rates from the groups being compared.

Direct Age Adjustment

- Let us look at an example of direct age adjustment using real data.When mortality in the United States and in Mexico was compared for 1995 to 1997, the crude mortality rate for all ages in the United States was 8.7 per 1,000 population and in Mexico only 4.7 per 1,000 population.
- But for each age group, the age-specific mortality rate was higher in Mexico than in the United States (aside from the over 65 group in which the rates were similar).
- Could the considerably higher crude mortality rate in the United States be due to the fact that there was a difference in the age distributions of the two populations, in that the U.S. population had a greater proportion of older individuals than did the population in Mexico?

TABLE 4-12 An Example of Direct Age Adjustment: Comparison of Age-adjusted Mortality Rates in Mexico and in the United States, 1995–1997

Age Group (yr)	Standard Population	Age-specific Mexico Mortality Rates per 100,000	Expected Numbers of Deaths Using Mexico Rates	Age-specific United States Mortality Rates per 100,000	Expected Numbers of Deaths Using United States Rates
All ages	100,000				
<1	2,400	1,693.2	41	737.8	18
1–4	9,600	112.5	11	38.5	4
5–14	19,000	36.2	7	21.7	4
15–24	17,000	102.9	17	90.3	15
25–44	26,000	209.6	55	176.4	46
45–64	19,000	841.1	160	702.3	133
65+	7,000	4,967.4	348	5,062.6	354
Total numbers of deaths expected in the standard population:			639		574

Age-adjusted rates:

$$\text{Mexico} = \frac{639}{100,000} = \frac{6.39}{1,000} \qquad \text{United States} = \frac{574}{100,000} = \frac{5.74}{1,000}$$

Indirect Age Adjustment (Standardized Mortality Ratios)

- **Indirect age adjustment is often used when numbers of deaths for each age-specific stratum are not available**. It is also used to study mortality in an occupationally exposed population: Do people who work in a certain industry, such as mining or construction, have a higher mortality than people of the same age in the general population? Is an additional risk associated with that occupation?
- To answer the question of whether a population of miners has a higher mortality than we would expect in a similar population that is not engaged in mining, the age-specific rates for a known population, such as all men of the same age, are applied to each age group in the population of interest.
- This will yield the number of deaths expected in each age group in the population of interest, if this population had had the mortality experience of the known population.
- Thus, for each age group, the number of deaths expected is calculated, and these numbers are totaled. The numbers of deaths that were actually observed in that population are also calculated and totaled.
- **The ratio of the total number of deaths actually observed to the total number of deaths expected, if the population of interest had had the mortality experience of the known population, is then calculated. This ratio is called the standardized mortality ratio (SMR)**

$$\text{SMR} = \frac{\text{Observed deaths for an occupation} - \text{cause} - \text{race group}}{\text{Expected deaths for an occupation} - \text{cause} - \text{race group}} \times 100$$

Other measures of disease impact

- Quality of Life & Disability Adjusted Life Years
- Most diseases have a major impact on the afflicted individuals above and beyond mortality. Diseases that may not be lethal may be associated with considerable physical and emotional suffering resulting from disability associated with the illness.
- It is therefore important to consider the total impact of a disease as measured by its effect on a person's quality of life, even though such measures are not, in fact, measures of disease occurrence.
- For example, it is possible to examine the extent to which patients with arthritis are compromised by the illness in carrying out activities of daily living.
- **Although considerable controversy exists about which quality-of-life measures are most appropriate and valid, there is general agreement that such measures can be reasonably used to plan short-term treatment programs for groups of patients.**

Review 7.2

- What are 2 issues that arise in comparing mortality across two or more populations?
- Define, calculate, and interpret direct age-adjusted mortality rates.
- What are some other measures of disease impact?