Chapter 6: Mortality
The Epidemiological Transition: Historical Stages

- The age of pestilence and famine
  - Precedes the mortality transition; LE = <40yrs
- The age of receding pandemics
  - Less variation in mortality with steady decline
- The age of degenerative or human-made diseases
  - Life expectancy reaches 70 years and above

(Source: Omran, 1971)
The Epidemiological Transition: The Future?

- The age of delayed degenerative diseases?
  - With health advancements, chronic diseases are postponed to much later in life

- The age of emerging/re-emerging infectious and parasitic diseases?
  - New infectious diseases (such as HIV/AIDS) may continue to appear and old diseases return because of antibiotic resistance and compromised immune systems among the elderly
Health Transition

Demographic Transition
- Urbanization
- Industrialization
- Expansion of education
- Improved medical and public health technology

Infectious disease mortality declines

Fertility declines

Population ages

Chronic and noncommunicable diseases emerge

Economic recession and increasing inequality

Persistence or re-emergence of communicable diseases

Protracted-polarized Epidemiologic Transition

Relations Among the Demographic, Epidemiologic and Health Transitions
Life Expectancy Gains in Major World Regions, 1950-55 to 1995-00
The Structure of Mortality

High Mortality

Young Age Structure \[\text{Infectious Diseases}\]

Low Mortality

Older Age Structure \[\text{Chronic Diseases}\]
Matlab, Bangladesh

Percent distribution of population and deaths, 1987

Source: ICDDR,B
Sweden

Percent distribution of population and deaths, 1985

Source: Keyfitz and Flieger, 1990
Determinants of Variations in Morbidity and Mortality

- **Proximate determinants**: Factors that directly influence the risk of disease and the outcomes of disease processes in individuals.

- **Distal (underlying) determinants**: Social, economic, and cultural factors that influence the health status of a population by operating through one or more of the proximate causes.
Proximate Determinants Of Morbidity and Mortality

- **Personal behaviors**: Diet, hygiene, alcohol and tobacco use, sexual behavior, etc.

- **Environmental exposures**: Exposure to infectious or chemical or physical agents, occupational hazards, etc.

- **Nutrition**: Under nutrition, micronutrient deficiency, over nutrition/obesity etc.

- **Injuries**: Intentional or accidental injuries.

- **Personal illness control**: Specific preventive and sickness care actions.
Underlying Determinants Of Morbidity and Mortality

- **Socio-economic factors**: Household wealth, community development, women’s education and employment, etc.

- **Institutional factors**: Health systems, health regulations, technological developments, information programs, environmental interventions, etc.

- **Cultural factors**: Traditional beliefs about health and disease, religious values, role and status of women etc.

- **Broader context**: Ecological setting, political economy, transportation and communication systems, agricultural development, markets, urbanization, etc.
A Determinants of Morbidity and Mortality Framework

Socio-economic, cultural and institutional factors

- Health behaviors
- Environmental exposure
- Nutrition
- Injury

Healthy → Sick → Death

Personal illness control

Prevention → Treatment

(Adapted from Mosley and Chen, 1983)
Definitions and Indicators
Mortality and Morbidity as Indicators of Health Status of a Population

- Death is a unique and universal event, and as a final event, clearly defined
- Age at death and cause provide an instant depiction of health status
- In high mortality settings, information on trends of death (by causes) substantiate the progress of health programs
Mortality and Morbidity as Indicators of Health Status of a Population

- As survival improves with modernization and populations age, mortality measures do not give an adequate picture of a population’s health status.
- Indicators of morbidity such as the prevalence of chronic diseases and disabilities become more important.
Major Sources of Mortality Information

- National vital registration systems - a major source in developed countries
- Sample registration systems (e.g., in China and India)
- Household surveys - to estimate infant and child mortality
- Special longitudinal investigations (e.g., maternal mortality studies)
De Jure vs. De Facto

- De jure
  - Death is registered at place of residence

- De facto
  - Death is registered at place of occurrence
Death Registration: Counting the Events

- Definition: official notification that a death has occurred
- Usually a legal requirement before burial/cremation
- Counts (rates) by age, sex, location and time provide invaluable health data
- Concurrent registration essential for good cause of death determination
Data Collection for Vital Registration

- Events are collected by a local registration office, usually a government agency.
- Who reports to registration office?
  - Individual citizens, local officials, physicians, hospital employees, etc.
- Main advantage is universal coverage.
- Disadvantages are late or never reporting.
Measures of Mortality

- Crude Death Rates
- Age-Specific Death Rates
- Life Table Estimates
  - Life expectancy
  - Survivorship (by age)
- Cause-Specific Death Rates
- Special Indicators
  - Infant and maternal mortality rates
Indicators

- Basic indicator
  - *Crude death rate*—Number of deaths per 1,000 population

\[
\text{Number of deaths} / \text{Midyear population} \times 1000
\]
Indicators

- Midyear population is an approximation of the average population exposed to risk
- Total person-years lived is a better denominator if available
Indicators

- Typically computed for calendar year so as to eliminate the effect of seasonal or monthly variations on the comparability of the rates
- There is a problem if the mid-point of the time reference for the numerator does not correspond to the time of the midpoint population
Crude Death Rate: Example

- Uganda’s crude death rate in 1999 is

\[
\frac{\text{# of deaths}}{\text{Total mid-year population}} \times k = \frac{420,296}{22,804,973} \times 1000 = 18.4
\]

which indicates that there were about 18 deaths per 1000 inhabitants in the year 1999.
Crude Death Rates in Africa, 1999

Data Source: World Population Data Sheet, 1999, PRB

Deaths per 1000

- 19 to 24 (11)*
- 18 (12)
- 14 to 17 (7)
- 11 to 13 (13)
- 3 to 10 (11)

* Figures in brackets indicate # of countries
Crude Death Rates Around the World

Data Source: World Population data sheet, 1999, PRB
Crude Death Rates
Points to Note

- Risks of death change by age, so CDR is affected by population age structure
- Aging populations can have rising CDRs, even as the health conditions are improving
- LDCs with very young populations will often have lower CDRs than MDCs even though their overall health conditions are poorer
- Therefore mortality comparisons across countries should always use mortality indicators that are adjusted for differences in age composition
Age Specific Death Rate:

- *Age Specific Death Rate*—Number of deaths per 1,000 persons of a specific age (group)

\[
\frac{D_a}{P_a} \times 1000
\]

- Where
  - \(D_a\) = Number of deaths in age (group) \(a\)
  - \(P_a\) = Midyear population in age (group) \(a\)
Death Rates by Age, Sweden, 1945 and 1996

Data Source: UN Demographic Yearbooks, 1948, and 1997
Egypt ASDR Graph 1990

Source: UN, Demographic year book 1990
Why Age Specific Death Rates?

- Can compare mortality at different ages
- Can compare mortality in the same age groups over time and/or between countries and areas
- Can be used to calculate life tables to create an age-independent measure of mortality (life-expectancy)
Events Occurring During Pregnancy or Around the Time of Birth
Infant Mortality “Rate”

- *Infant Mortality Rate*—Number of infant deaths per 1000 births

\[
\text{IMR} = \frac{D_0}{B} \times 1000
\]

- Where \(D_0\) = Number of infant (< 1 year) deaths
  
  \(B\) = Number of births

*Continued*
Infant Mortality “Rate”

IMR is a Period Measure
## Exercise

**Infant Mortality "Rate"**

- Calculate the conventional infant mortality rate for the U.S. (1990), based on the following data

<table>
<thead>
<tr>
<th>Year</th>
<th>Birth Cohort</th>
<th>Births</th>
<th>Deaths</th>
<th>Infant Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>1989</td>
<td>4,040,958</td>
<td>39,655</td>
<td>33,645</td>
</tr>
<tr>
<td>1990</td>
<td>1989</td>
<td>--</td>
<td>--</td>
<td>5,861</td>
</tr>
<tr>
<td>1990</td>
<td>1990</td>
<td>4,158,212</td>
<td>38,351</td>
<td>32,490</td>
</tr>
<tr>
<td>1991</td>
<td>1990</td>
<td>--</td>
<td>--</td>
<td>5,657</td>
</tr>
</tbody>
</table>

*You have 15 seconds to calculate the answer. You may pause the presentation if you need more time.*

The correct IMR for 1990 is as follows:
- 9.22 infant deaths per 1,000 births

<table>
<thead>
<tr>
<th>Year</th>
<th>Birth Cohort</th>
<th>Births</th>
<th>Deaths</th>
<th>Infant Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
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<td>4,040,958</td>
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</tr>
<tr>
<td>1991</td>
<td>1990</td>
<td>--</td>
<td>--</td>
<td>5,657</td>
</tr>
</tbody>
</table>
Infant Mortality “Rate”

- Good index of child mortality in low mortality populations; less good in high mortality populations
- Because of the very high level of mortality in the first hours, days, and weeks of life, IMR is broken down into even more specific rates
- Not a true rate
Summary

- Mortality is one of the demographic phenomena most commonly studied.
- It is important to take into consideration the definitions in the data collection systems when interpreting and comparing different rates.
- There are several ways of calculating infant mortality rates; the results can be somewhat different.
Neonatal Mortality Rate

- Neonatal Mortality Rate—Number of deaths of newborns in the first month of life per 1,000 births

\[
= \frac{D_{0-3\,\text{weeks}}}{B} \times 1000 \quad \text{or}
\]

\[
= \frac{D_{<1\,\text{month}}}{B} \times 1000
\]
Post-Neonatal Mortality Rate

- *Post-Neonatal Mortality Rate*—Number of deaths of babies between the 1st and 12th month of life per 1,000 births

\[
= \frac{D_{4-51\,\text{weeks}}}{B} \times 1000 \quad \text{or} \quad \\
= \frac{D_{1-11\,\text{months}}}{B} \times 1000
\]
Infant Mortality Rate (IMR)

- Note:
  - IMR = Neonatal mortality rate + Post-neonatal mortality rate
Fetal Death

- Early fetal loss: < 20 weeks
- Intermediate: 20–27 weeks
- Late: 28+ weeks
Fetal Death

- Let $D_f = \text{Number of fetal deaths}$
  $B = \text{Number of births}$

1) Fetal death ratio

$$= \frac{D_f}{B}$$

2) Fetal death rate

$$= \frac{D_f}{B + D_f}$$
Perinatal Mortality Rate

- *Perinatal Mortality Rate*—Number of stillbirths and deaths of babies up to one week old per 1,000 births

\[
\frac{(\text{late fetal deaths} + \text{early neonatal deaths})}{\text{Live births}} \times 1000
\]
Maternal Mortality

- Maternal Mortality—Death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration or site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental causes (WHO)
Maternal Mortality

- Let $D_{mc} = \text{Number of deaths due to maternal causes}$
- $W_{15-49} = \text{Number of women of reproductive age}$
- $B = \text{Total live births}$
Maternal Mortality Ratio

- Maternal Mortality Ratio—Number of deaths due to maternal causes per 100,000 births

\[
D_{mc} = \frac{D}{B} \times 100000
\]
Maternal Mortality Rate

- *Maternal Mortality Rate*—Number of deaths due to maternal causes per 1,000 women of reproductive ages

\[
D_{mc} = \frac{1}{W_{15-49}} \times 1000
\]

- Note: Maternal mortality ratio is more widely used
Exercise

Maternal Mortality Ratio and Rate

- Calculate the maternal mortality ratio and rate for the U.S. (1990), based on the following data

<table>
<thead>
<tr>
<th>United States, 1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>Births</td>
</tr>
<tr>
<td>Maternal deaths</td>
</tr>
<tr>
<td>(W_{15-49} )</td>
</tr>
</tbody>
</table>

You have 15 seconds to calculate the answer. You may pause the presentation if you need more time.

Exercise Answer
Maternal Mortality Ratio and Rate

- The correct answer for the maternal mortality indicator is as follows:

**Ratio:**
8.25 per 100,000

**Rate:**
5.23 per 1,000

United States, 1990

<table>
<thead>
<tr>
<th>Births</th>
<th>Maternal deaths</th>
<th>(W_{15-49} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>4,158,212</td>
<td>343</td>
<td>656,244</td>
</tr>
</tbody>
</table>
Cause-Specific Morbidity and Mortality

- Let $D_c = \text{Number of deaths from cause (disease) } c$
- $C_c = \text{Number of cases of cause } c$
- $N_c = \text{Number of new cases of cause (disease) } c$
- $D = \text{Total number of deaths}$
- $P = \text{Mid-point population}$
Cause-Specific Death Ratio

• *Cause-Specific Death Ratio*—Proportion of all deaths attributable to cause c

\[
\frac{D_c}{D} \times 100
\]
Cause-Specific Death Rate

- *Cause-Specific Death Rate*—Number of deaths attributable to cause c per 100,000 population

\[
\text{Rate} = \frac{D_c}{P} \times 100000
\]
# Table: Selected CSDR in Egypt and U.S. 1987

<table>
<thead>
<tr>
<th>Causes</th>
<th>Egypt 1987</th>
<th>U.S. 1987</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>950.4</td>
<td>874.4</td>
</tr>
<tr>
<td>Cholera</td>
<td>-</td>
<td>0.0</td>
</tr>
<tr>
<td>Typhoid fever</td>
<td>0.2</td>
<td>0.0</td>
</tr>
<tr>
<td>Other intestinal infectious diseases</td>
<td>82.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>2.6</td>
<td>0.7</td>
</tr>
<tr>
<td>Tetanus</td>
<td>7.2</td>
<td>0.0</td>
</tr>
<tr>
<td>Septicemia</td>
<td>0.7</td>
<td>8.2</td>
</tr>
<tr>
<td>Malignant neoplasm of stomach</td>
<td>0.9</td>
<td>5.7</td>
</tr>
<tr>
<td>Malignant neoplasm of colon</td>
<td>0.2</td>
<td>19.9</td>
</tr>
<tr>
<td>Malignant neoplasm of rectum, rectosigmoid junction and anus</td>
<td>0.6</td>
<td>3.3</td>
</tr>
<tr>
<td>Malignant neoplasm of trachea, bronchus and lung</td>
<td>1.7</td>
<td>53.5</td>
</tr>
<tr>
<td>Malignant neoplasm of female breast</td>
<td>-</td>
<td>41.2</td>
</tr>
<tr>
<td>Malignant neoplasm of cervix uteri</td>
<td>-</td>
<td>4.5</td>
</tr>
<tr>
<td>All other malignant neoplasms</td>
<td>14.6</td>
<td>88.2</td>
</tr>
<tr>
<td>Acute myocardial infarction</td>
<td>0.2</td>
<td>104.4</td>
</tr>
</tbody>
</table>

*Source: UN, Demographic Year book 1996*
<table>
<thead>
<tr>
<th>Causes</th>
<th>Egypt 1987</th>
<th>U.S. 1987</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other ischaemic heart diseases</td>
<td>16.0</td>
<td>106.5</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>18.9</td>
<td>61.7</td>
</tr>
<tr>
<td>Other diseases of circulatory system</td>
<td>243.9</td>
<td>101.4</td>
</tr>
<tr>
<td>Bronchitis, emphysema and asthma</td>
<td>29.5</td>
<td>9.2</td>
</tr>
<tr>
<td>Abortion</td>
<td>12.5</td>
<td>1.2</td>
</tr>
<tr>
<td>Direct obstetric causes</td>
<td>46.8</td>
<td>5.0</td>
</tr>
<tr>
<td>Indirect obstetric causes</td>
<td>5.9</td>
<td>0.4</td>
</tr>
<tr>
<td>Congenital anomalies</td>
<td>9.0</td>
<td>5.1</td>
</tr>
<tr>
<td>Birth trauma</td>
<td>0.5</td>
<td>6.8</td>
</tr>
<tr>
<td>Other conditions originating in the perinatal period</td>
<td>639.5</td>
<td>471.5</td>
</tr>
<tr>
<td>Motor vehicle traffic accidents</td>
<td>6.6</td>
<td>19.5</td>
</tr>
<tr>
<td>Suicide and self-inflicted injury</td>
<td>0.0</td>
<td>12.7</td>
</tr>
<tr>
<td>Homicide and injury purposely inflicted by other persons</td>
<td>0.5</td>
<td>8.6</td>
</tr>
<tr>
<td>Other violence</td>
<td>20.4</td>
<td>1.4</td>
</tr>
</tbody>
</table>

*Source: UN, Demographic Year book 1996*
Morbidity - Indicators

Incidence Rate

- Number of persons contracting a disease during a given time period per 1000 population at risk
- Refers only to new cases during a defined period
Incidence Rate - Example

Incidence for malaria will be given by:

\[
\frac{\text{# of persons developing malaria during a given time period}}{\text{Population at risk}} \times k
\]
Morbidity - Indicators

Prevalence Rate

- Number of persons who have a particular disease/condition at a given point in time per 1,000 population
- A snapshot of an existing health situation
- Includes all known cases of a disease that have not resulted in death, cure or remission
Prevalence Rate - Example

Prevalence of HIV/AIDS among adults at a given point in time will be

\[
\frac{\text{# of persons ages 15 - 49 with HIV/AIDS}}{\text{Total population ages 15 - 49}} \times k
\]
Adult HIV/AIDS Prevalence by Region, 1998

- E. Europe: 0.1
- W. Europe: 0.3
- North Am.: 0.6
- Latin Am.: 0.6
- S/SE Asia: 0.7
- SSA: 8

Percent of adults ages 15-49 with HIV/AIDS

### Estimated Worldwide Incidence, Prevalence and Deaths For Selected Infectious Diseases, 1990

<table>
<thead>
<tr>
<th>Disease</th>
<th>Incidence</th>
<th></th>
<th>Prevalence</th>
<th></th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>New cases (1000s)</td>
<td>Rate per 100,000</td>
<td>Cases (1000s)</td>
<td>Rate per 100,000</td>
<td>Deaths (1000s)</td>
</tr>
<tr>
<td>Malaria</td>
<td>213,743</td>
<td>4,058</td>
<td>2,777</td>
<td>53</td>
<td>856</td>
</tr>
<tr>
<td>Measles</td>
<td>44,334</td>
<td>842</td>
<td>1,739</td>
<td>33</td>
<td>1,058</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>6,346</td>
<td>121</td>
<td>12,739</td>
<td>242</td>
<td>2,040</td>
</tr>
<tr>
<td>HIV and AIDS</td>
<td>2,153</td>
<td>41</td>
<td>8,823</td>
<td>167</td>
<td>312</td>
</tr>
<tr>
<td>Poliomyelitis</td>
<td>215</td>
<td>4</td>
<td>10,648</td>
<td>203</td>
<td>27</td>
</tr>
</tbody>
</table>

*Source: C. Murray and A. Lopez, Global Health Statistics: Epidemiologic Tables (1996)*
Incidence of Cause (Disease) c

- $I(c)$—Proportion of new cases of cause (disease) c in a population

Number of new cases of cause (disease) c in time $(t, t+1)$

\[ I(c) = \frac{N_c}{P} \]

Mid-point population
Case Fatality Rate Due to Cause (Disease) $c$

- Case Fatality Rate Due to Cause (Disease) $c$—Proportion of persons with cause (disease) $c$ who die from it

\[ \frac{D_c}{C_c} = \]
Acute Causes (Diseases)

- Note: For acute causes (diseases), case fatality = \[
\frac{D_c}{N_c}
\]

- So

\[
\frac{D_c}{P} = \frac{N_c}{P} \times \frac{D_c}{N_c}
\]
Cause-Specific Death Rate

- Therefore:

  \[
  \text{cause specific death rate} = \text{incidence} \times \text{case fatality}
  \]

- This relationship works well for acute diseases but not for chronic ones
Person Years of Life Lost From Cause c (PYLL\(_c\))

\[
PYLL_{(c)} = \sum_{a=0}^{70} (70 - a) m_{ac} \times 1000
\]

- Where \( c \) = Cause of death
- \( a \) = Age at death
- \( m_{ac} \) = Age-cause specific death rate
Calculation of potential years of life lost between ages 1 and 70 (PYLL), Rate and Age-Adjusted Rate, Ontario, Ischemic Heart Disease, Males 1974 (Source: Hetzel BS. In: New Developments in the Analysis of Mortality and Cause of Death. 1986)

<table>
<thead>
<tr>
<th>Age</th>
<th>Remaining yrs</th>
<th>No. of deaths</th>
<th>PYLL</th>
<th>Correcting factor</th>
<th>Age-adjusted PYLL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 4</td>
<td>67</td>
<td>0</td>
<td>0</td>
<td>1.08</td>
<td>0</td>
</tr>
<tr>
<td>5 to 9</td>
<td>62.5</td>
<td>0</td>
<td>0</td>
<td>1.02</td>
<td>0</td>
</tr>
<tr>
<td>10 to 14</td>
<td>57.5</td>
<td>1</td>
<td>57.5</td>
<td>1.03</td>
<td>59.2</td>
</tr>
<tr>
<td>15 to 19</td>
<td>52.5</td>
<td>1</td>
<td>52.5</td>
<td>1.05</td>
<td>55.1</td>
</tr>
<tr>
<td>20 to 24</td>
<td>47.5</td>
<td>3</td>
<td>142.5</td>
<td>1.03</td>
<td>146.8</td>
</tr>
<tr>
<td>25 to 29</td>
<td>42.5</td>
<td>9</td>
<td>382.5</td>
<td>0.97</td>
<td>371</td>
</tr>
<tr>
<td>30 to 34</td>
<td>37.5</td>
<td>26</td>
<td>975</td>
<td>0.96</td>
<td>936</td>
</tr>
<tr>
<td>35 to 39</td>
<td>32.5</td>
<td>89</td>
<td>2,892.5</td>
<td>0.96</td>
<td>2,776.8</td>
</tr>
<tr>
<td>40 to 44</td>
<td>27.5</td>
<td>198</td>
<td>5,445</td>
<td>0.95</td>
<td>5,172.8</td>
</tr>
<tr>
<td>45 to 49</td>
<td>22.5</td>
<td>489</td>
<td>11,002.5</td>
<td>0.94</td>
<td>10,342.4</td>
</tr>
<tr>
<td>50 to 54</td>
<td>17.5</td>
<td>772</td>
<td>13,510</td>
<td>0.95</td>
<td>12,834.5</td>
</tr>
<tr>
<td>55 to 59</td>
<td>12.5</td>
<td>1,015</td>
<td>12,687.5</td>
<td>1</td>
<td>12,687.5</td>
</tr>
<tr>
<td>60 to 64</td>
<td>7.5</td>
<td>1,419</td>
<td>10,642.5</td>
<td>1</td>
<td>10,642.5</td>
</tr>
<tr>
<td>65 to 69</td>
<td>2.5</td>
<td>1,630</td>
<td>4,075</td>
<td>1.01</td>
<td>4,115.8</td>
</tr>
<tr>
<td>Total (1 to 70)</td>
<td>5,652</td>
<td></td>
<td>61,865</td>
<td></td>
<td>60,140.4</td>
</tr>
</tbody>
</table>

\[
\frac{61,865}{3,791,600} \times 1,000 = 16.3 \text{ per 1,000}
\]

\[
\frac{60,140.4}{3,791,600} \times 1,000 = 15.9 \text{ per 1,000}
\]
Summary

- Several indicators have been developed to measure fetal/newborn mortality
- Maternal mortality can be measured as a rate or as a ratio; the two indicators give different perspectives on the problem
- Cause-specific indicators are important in singling out the contribution of a particular disease or cause of death in a population
Relationships of Death Rates and Probability of Death, and Differential in Mortality Between Populations
Death Rate and Probability of Death

- Deriving probability of dying ($nq_x$) from observed mortality rate ($nM_x$), using the actuarial method

Let $nD^x_t = D =$ Deaths in age group $(x, x+n)$ in year $t$

$nP^x_t = P =$ Mid-point population in age group $(x, x+n)$ in year $t$

$nM^x_t = M =$ Mortality rate in age group $(x, x+n)$ in year $t$

$nM^x_t = nD^x_t / nP^x_t$
Death Rate and Probability of Death

- Also assume that
  - $nD^x_t$ are constant over the years
  - Deaths are linearly distributed throughout the year
Death Rate and Probability of Death

\[ n^P x^t \]

\[ \frac{n}{2} D \]

\[ \frac{n}{2} D \]

<table>
<thead>
<tr>
<th>t-4</th>
<th>t-3</th>
<th>t-2</th>
<th>t-1</th>
<th>t</th>
<th>t+1</th>
<th>t+2</th>
<th>t+3</th>
<th>t+4</th>
</tr>
</thead>
</table>
Death Rate and Probability of Death

\[ n q_x = \frac{n \times D}{P + \frac{n}{2}D} \]

and

\[ \frac{1}{nq_x} = \frac{P + \frac{n}{2}D}{n \times D} = \frac{1}{nM} + \frac{1}{2} = \frac{2 + nM}{2nM} = \frac{1 + \frac{n}{2}M}{nM} \]

so

\[ n q_x = \frac{n \times M}{1 + \frac{n}{2}M} \]
## Percentage of Error in a Ratio for Given Levels of Under and Overcount in Numerator and Denominator

<table>
<thead>
<tr>
<th>Percent Undercount</th>
<th>Percent Overcount</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>0 - 7 -13 -18 -22 -26 -30 -33 36 -39 -42 -44 -46</td>
</tr>
<tr>
<td>25</td>
<td>7 0 - 6 -12 -17 -21 -25 -29 -32 -35 -38 -40 -42</td>
</tr>
<tr>
<td>20</td>
<td>14 7 0 - 6 -11 -16 -20 -24 -27 -30 -33 -36 -38</td>
</tr>
<tr>
<td>15</td>
<td>21 13 6 0 - 6 -11 -15 -19 -23 -26 -29 -32 -35</td>
</tr>
<tr>
<td>10</td>
<td>29 20 13 6 0 - 5 -10 -14 -18 -22 -25 -28 -31</td>
</tr>
<tr>
<td>5</td>
<td>36 27 19 12 6 0 - 5 -10 -14 -17 -21 -24 -27</td>
</tr>
<tr>
<td>0</td>
<td>43 33 25 18 11 5 0 - 5 - 9 -13 -17 -20 -23</td>
</tr>
<tr>
<td>5</td>
<td>50 40 31 24 17 11 5 0 - 5 - 9 -13 -16 -19</td>
</tr>
<tr>
<td>10</td>
<td>51 47 38 29 22 16 10 5 0 - 4 - 8 -12 -15</td>
</tr>
<tr>
<td>15</td>
<td>64 53 44 35 28 21 15 10 5 0 - 4 - 8 -12</td>
</tr>
<tr>
<td>20</td>
<td>71 60 50 41 33 26 20 14 9 4 0 - 4 - 8</td>
</tr>
<tr>
<td>25</td>
<td>79 67 56 47 39 32 25 19 14 9 4 0 - 4</td>
</tr>
<tr>
<td>30</td>
<td>86 73 63 53 44 37 30 24 18 13 8 4 0</td>
</tr>
</tbody>
</table>

*Source: Stan Becker, University of Dacca, August, 1978 (Not published)*
Differentials in Mortality

- Important variations in mortality are associated with a number of socio-economic characteristics:
  - Ethnicity / race
    - Blacks versus whites in the U.S.
  - Marital status
    - Single versus married
Differentials in Mortality

- Educational attainment
  - Higher education consistently associated with better health outcomes

- Occupation
  - Miner versus a white collar

- Income
  - Rich versus poor
Differentials in Mortality

- Important for understanding the physical and sociological factors in health and for program planning
Summary

- The life table probability of dying \((nq_x)\) can be calculated from the observed mortality rates \((nM_x)\).
- One of the most common methods used to derive \(nq_x\) from \(nM_x\) is the actuarial method which assumes that deaths are linearly distributed throughout the year.
- Important variations in mortality are associated with a number of socio-economic characteristics.
The Life Table

A powerful demographic tool used to simulate the lifetime mortality experience of a population, by taking that population’s age-specific death rates and applying them to a hypothetical population of 100,000 people born at the same time.
Measurement of Life Expectancy

Survivors at each age

Total years of life lived by 100,000 persons
Life Expectancy at Birth

- Average number of years lived among a cohort of births experiencing deaths at each year of age throughout their remaining life-time according to a specific schedule of age specific mortality rates

- Note: This measure of mortality is *independent* of the age structure of the population
Life Expectancy

- Estimate of the average number of additional years a person could expect to live if the age-specific death rates for a given year prevailed for the rest of his or her life.
Life Expectancy at Birth: Example

- If ASDRs for 1999 remain unchanged, males born in Uganda can expect to live 41 years on average; females can expect to live 42 years.
- The comparative figures for USA are 74 years and 79 years for males and females respectively.
Life Expectancy at Birth for Major World Regions

- North America: 77
- Europe: 73
- East Asia: 72
- SE Asia: 65
- West Asia: 68
- South America: 69
- South Africa: 56
- Middle Africa: 49
- West Africa: 52
- SSA: 49

Data Source: World Population Data Sheet, 1999, PRB
## Mortality Indicator Comparisons in Countries With Death Registration

<table>
<thead>
<tr>
<th>Country (1985)</th>
<th>CDR</th>
<th>Life Expectancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>8.74</td>
<td>71.3 Male, 78.4 Female</td>
</tr>
<tr>
<td>Sweden</td>
<td>11.26</td>
<td>73.8 Male, 79.8 Female</td>
</tr>
<tr>
<td>Japan</td>
<td>6.98</td>
<td>75.4 Male, 81.1 Female</td>
</tr>
<tr>
<td>Korea</td>
<td>6.17</td>
<td>66.2 Male, 72.5 Female</td>
</tr>
</tbody>
</table>

*Source: Keyfitz and Flieger, 1990*
Life Expectancy at Birth: Notes

- Most commonly cited life-expectancy measure
- Age independent, can be used to compare health conditions in different populations
- Good indicator of current health conditions