

# Measuring Health and Disease in Populations

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## Part 1: Comparing Health Events

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### Introduction

- **Definition of Health Events:** Disease outbreaks, chronic conditions, injuries, and health behaviors.
- **Importance of Comparisons:** Understanding disparities, identifying risk factors, guiding public health interventions.
- **Key Concepts:** Population health, epidemiology, and biostatistics.

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## Objectives of Population Health

### Four Key Objectives:

1. **Describe:** Understand population-level health outcomes.
  2. **Explain:** Identify determinants and drivers of health outcomes.
  3. **Predict:** Anticipate future health trends and patterns.
  4. **Control:** Implement interventions to improve outcomes.
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## Historical Context

### Key Figures

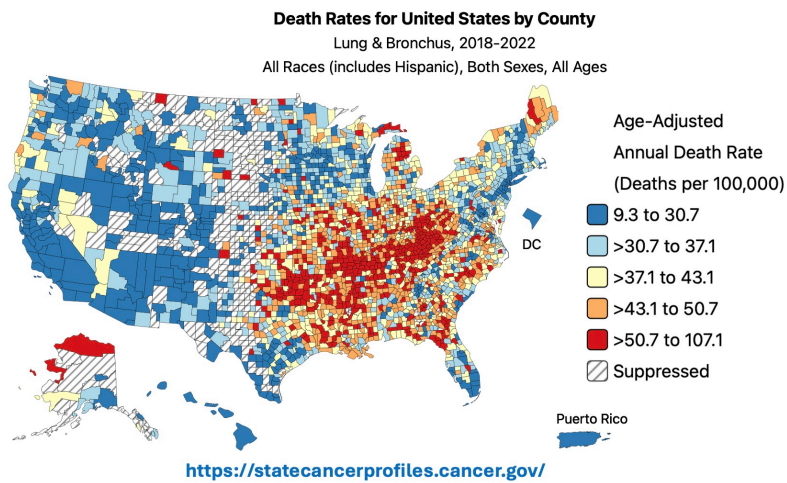
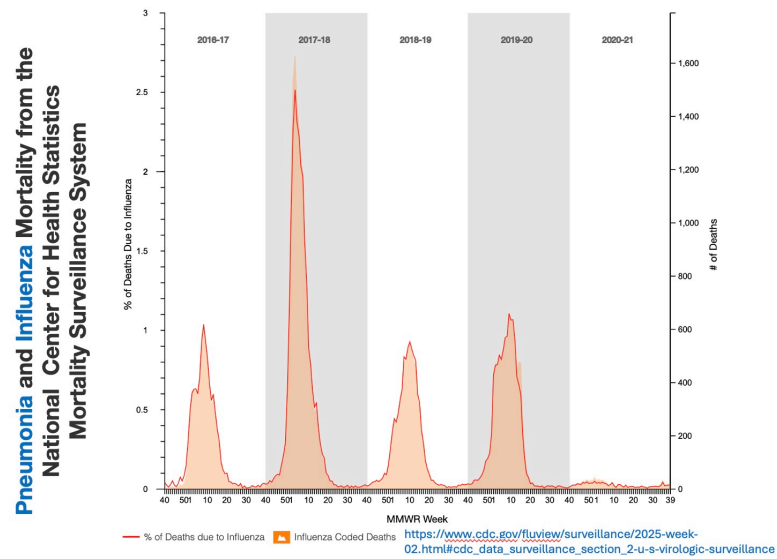
- **John Snow:** Cholera outbreak mapping.
  - **Ignaz Semmelweis:** Importance of handwashing.
  - **Joseph Goldberger:** Nutritional causes of pellagra.
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## Types of Comparisons

### Time-Based

#### Key Metrics:

- **Incidence:** New cases over time.
  - **Prevalence:** Existing cases at a given time.
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## Place-Based

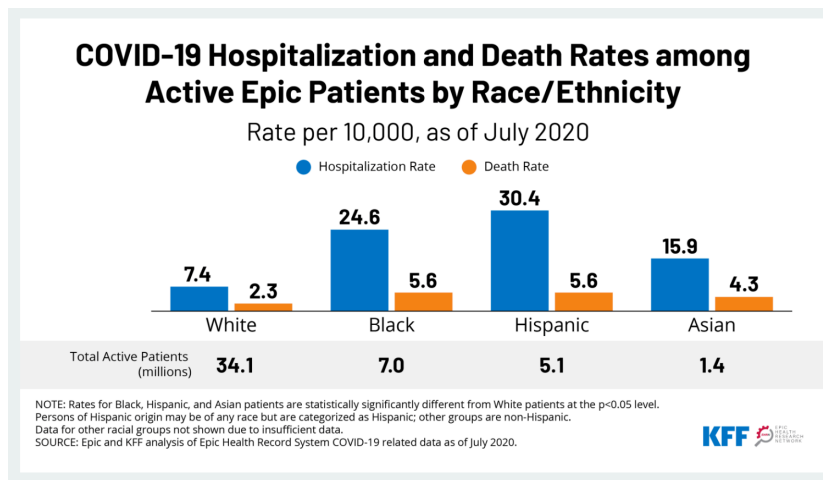
### Example:

- **Urban vs. Rural Heart Disease Mortality:**
    - Urban: 50 per 100,000.
    - Rural: 75 per 100,000.
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## Group-Based

### Example:

- Health disparities by race, age, and income.



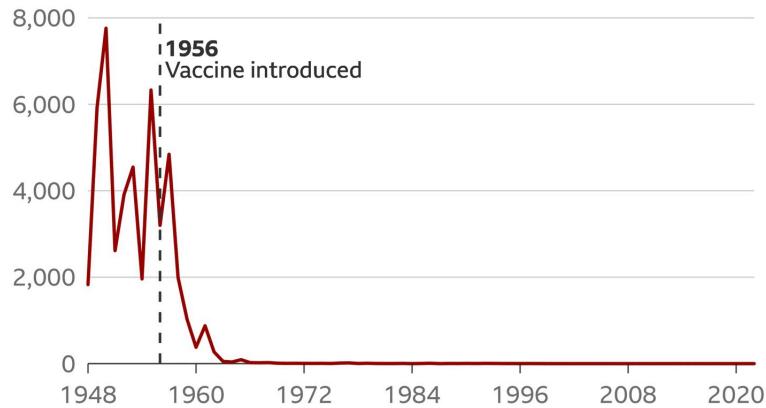
## Event-Based

### Key Concept:

- Natural experiments: Before vs. after policy changes or interventions.
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## How polio was eradicated

Number of polio cases in England and Wales (1948-2022)



Source: Public Health England

BBC

### Additional Event-Based Example

## Part 2: Measuring Health and Disease

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### Introduction to Measurement

#### Key Concepts in Measuring Health and Disease

- Definitions of incidence and prevalence.
  - Importance of population health metrics.
  - Ageing in the population
  - Demographic transition
  - Life expectancy
  - The importance to standardize
- 

### Incidence and Prevalence

#### Definitions

- **Incidence:** Number of new cases in a specified time period.



– Formula:  $(\text{New cases during time period} / \text{Population at risk}) \times \text{multiplier}.$

- **Prevalence:** Total number of existing cases at a given time.

– Formula:  $(\text{Existing cases} / \text{Total population}) \times \text{multiplier}.$

## Differences

- Incidence: Measures risk; useful for studying causation.
- Prevalence: Measures disease burden; important for planning healthcare services.

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## Impact of New and Existing Cases

- **Prevalence Formula Relation:**

– Prevalence = Incidence  $\times$  Duration of Disease  
 – check this [youTube](#) video

- **Factors affecting prevalence:**

- **Increase:** Longer disease duration, improved survival without a cure.
  - **Decrease:** Shorter duration, high mortality rates, or prevention.
- 

## Rates, Ratios, and Proportions

- **Rate:** A measure of change per unit time (e.g., incidence density).
    - *pay attention to **rate instability***
  - **Ratio:** Comparison of two numbers, unrelated (e.g., sex ratio).
  - **Proportion:** A part of a whole (e.g., percentage of women in a study group).
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## Cumulative Incidence

- **Proportion** of an initially disease-free group of individuals who develop the disease within a specified period of observation.
  - *pay attention to **censoring*** (when individuals drop out or are lost to follow-up)

$$CI = \frac{\text{new cases}}{\text{number of individuals at start of the period}}$$

- Example: Start with **100 disease-free individuals**. After **one year**, **10 develop the disease**.

$$CI = \frac{10}{100} = 0.10$$

- After **one year**, **10% of the population developed the disease**.
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## Incidence Density

- **Rate** that measures how often new cases of a disease occur while accounting for different lengths of time that people are at risk

$$ID = \frac{\text{new cases}}{\text{total person-time at risk}}$$

- Study follows **5 individuals**:
  - **Person A**: 2 years at risk
  - **Person B**: 3 years at risk
  - **Person C**: 1 year at risk
  - **Person D**: 4 years at risk
  - **Person E**: 2 years at risk
- **Total person-time at risk = 12 person-years**

## Why different times?

- Developed disease
  - Died (other causes)
  - Lost to follow-up
  - Study ended
- 

## Incidence Density

- **Total person-time at risk = 2 + 3 + 1 + 4 + 2 = 12 person-years**
- **New cases = 3**

$$ID = \frac{3}{12} = 0.25 \text{ cases per person-year}$$

- **0.25 cases per person-year** means that, on average, for every 4 people followed for a year, 1 will develop the disease.
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## Measures of Comparison

### Key Metrics:

- **Age-Standardized Rates:** Adjusted to eliminate age structure differences.
  - **Attributable Risk:** Measures the impact of specific risk factors on outcomes.
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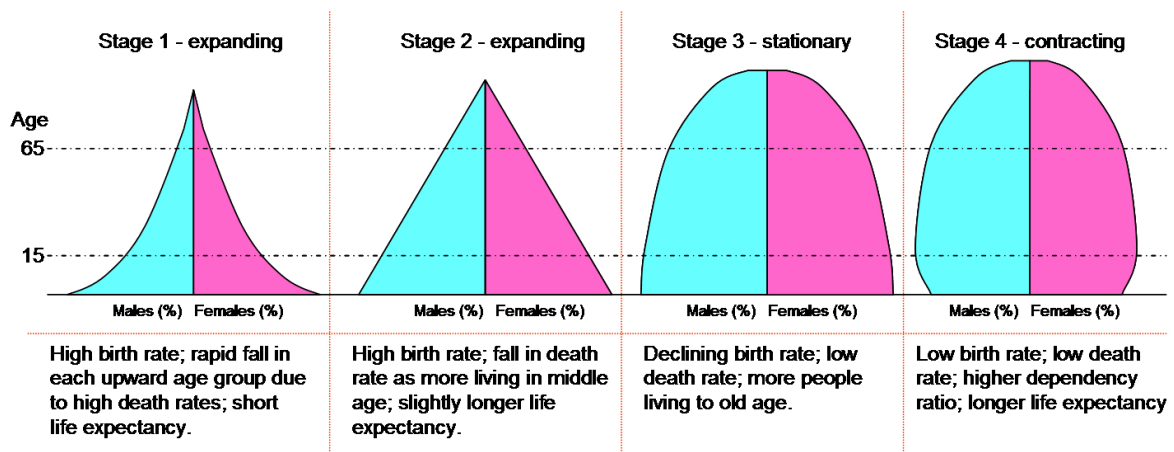
## Demographic Changes and Health Metrics

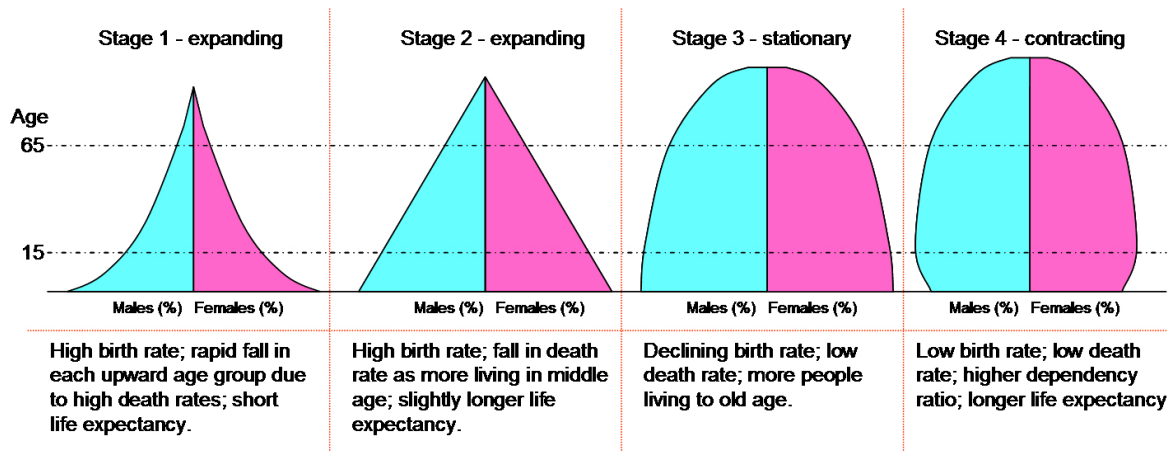
- **Fertility Rate:** Key measure of reproductive behavior.
  - **Mortality:** Affects life expectancy and health metrics.
  - **Migration:** Alters population composition, health service demands.
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## Population Structure

### Age Pyramids

- Graphical representation of age and sex distribution.
- Shows aging trends, and reveals impact of demographic events like wars, migrations.





## Age Pyramids

- **Developed Countries:** Narrow base, wider top (aging population).
- **Developing Countries:** Broad base, narrow top (younger population).
- [Interactive](#) pyramid.

## Qatar and Japan Age Pyramids

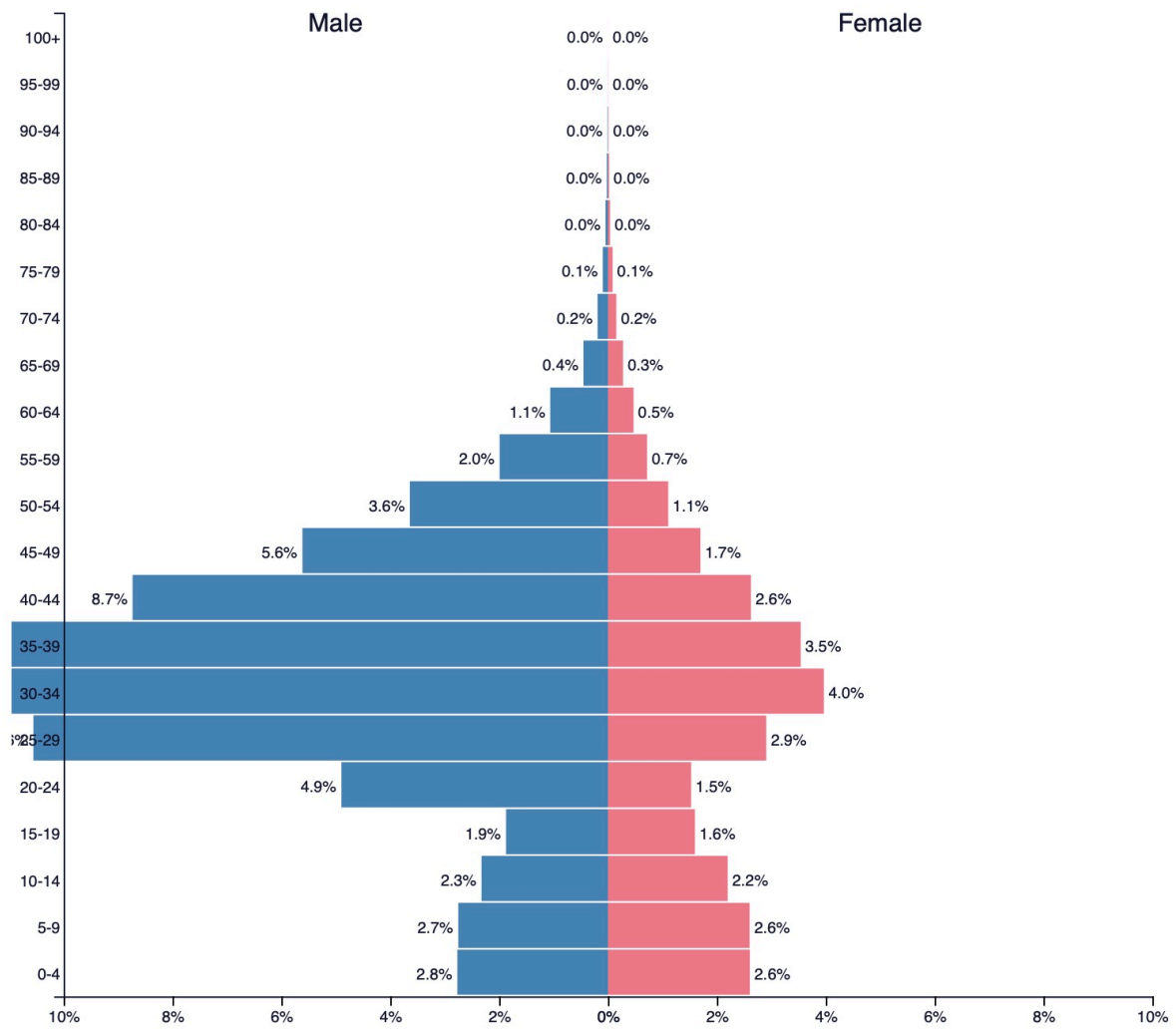
Qatar

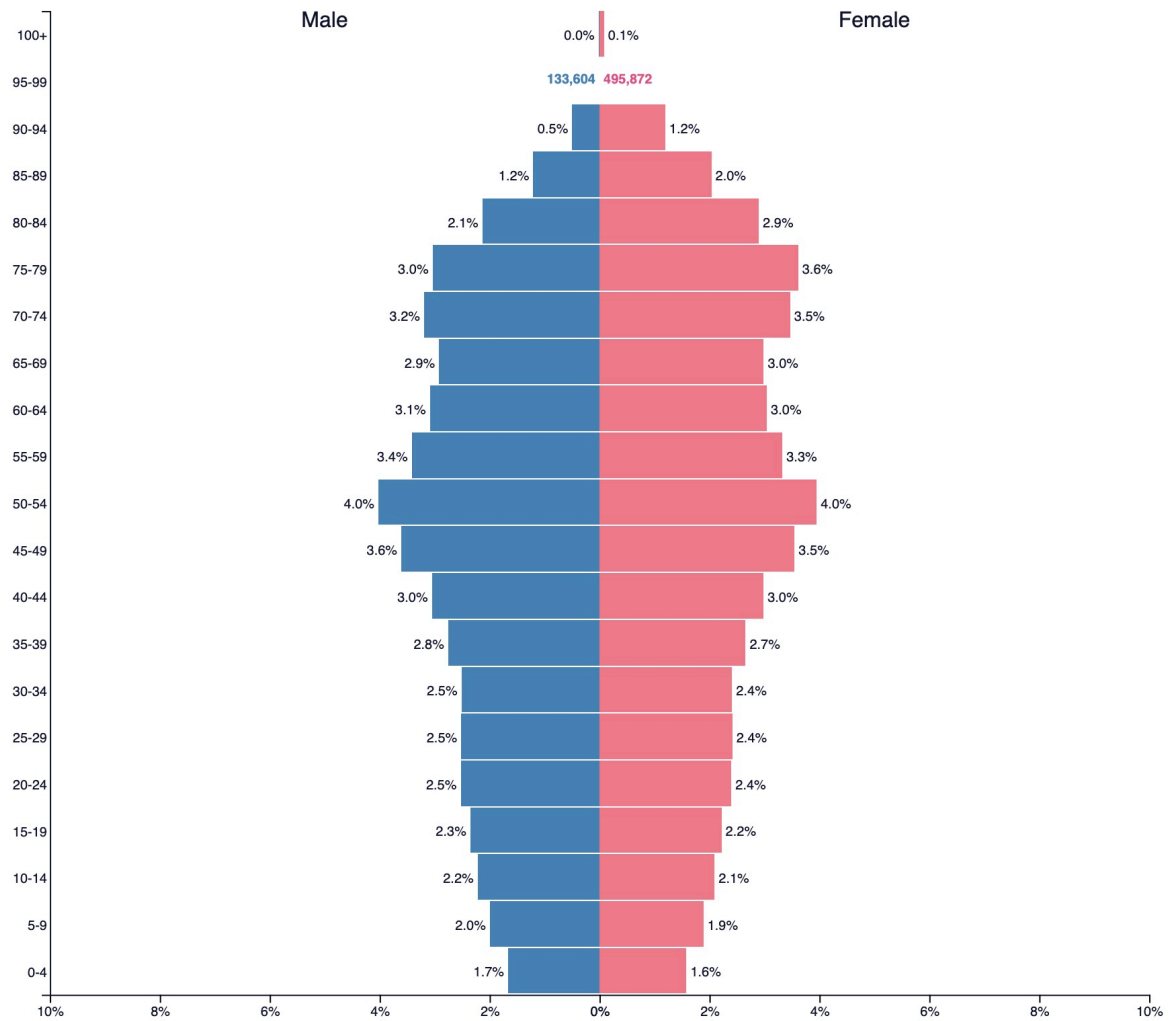
Japan

## Interactive Activity

### Analysis Instructions

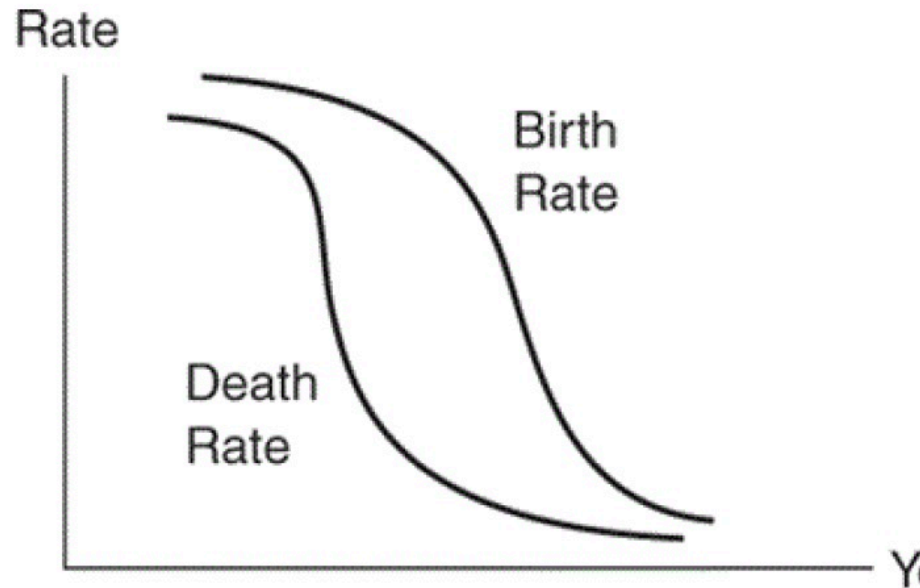
- Choose an age pyramid.
  - [international](#) pyramid.
  - [local level](#) pyramid.
- Explain to class what you see and what you expect the population to look like in 15, 30 and 50 years.





## Demographic Transition

- 4 stages of transitions
- There is actually a fifth stage!



Stage	1	2	3	4
Birth Rate	High	High	↓	Low
Death Rate	High	↓	Low	Low

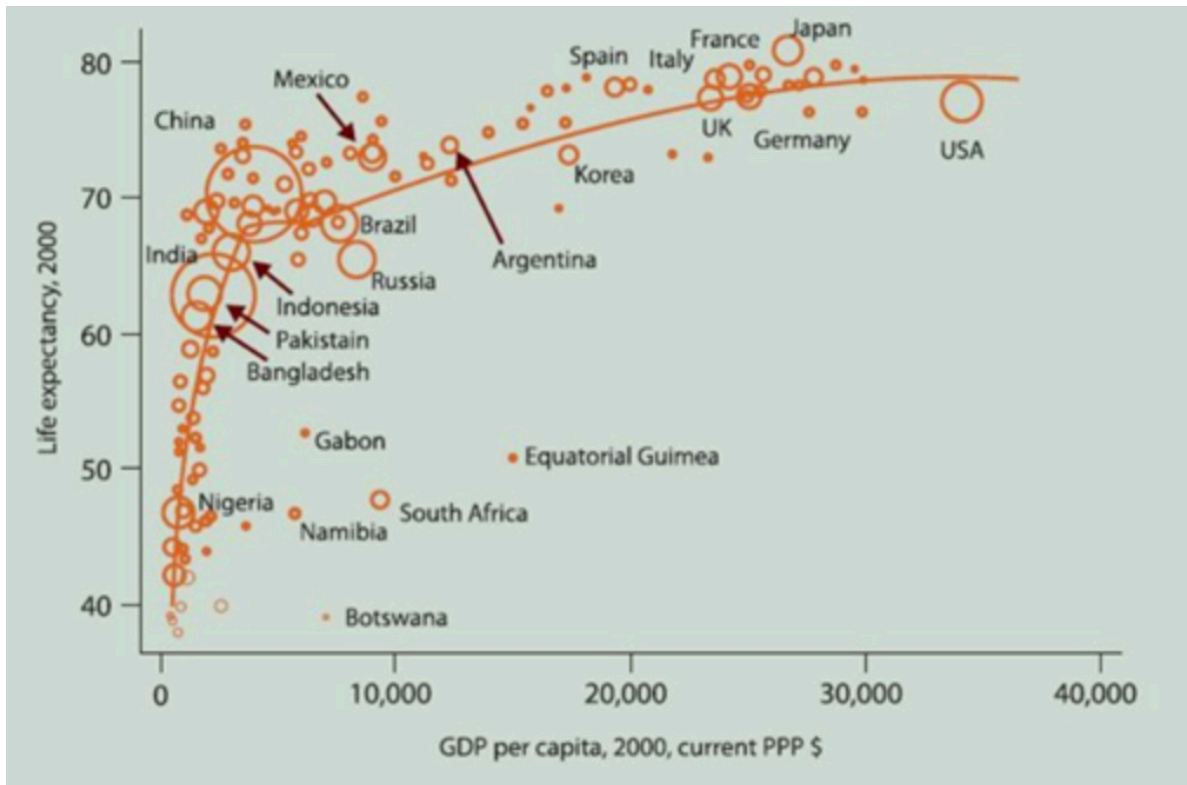
## Demographic Transition

- **Stage 1:** high burden of infectious diseases, high maternal/child mortality
- **Stages 2 & 3:** transition to chronic diseases; improved health infrastructure
- **Stages 4 and 5:** dominance of Non-Communicable Diseases (NCDs), and ageing related conditions

## Preston Curve

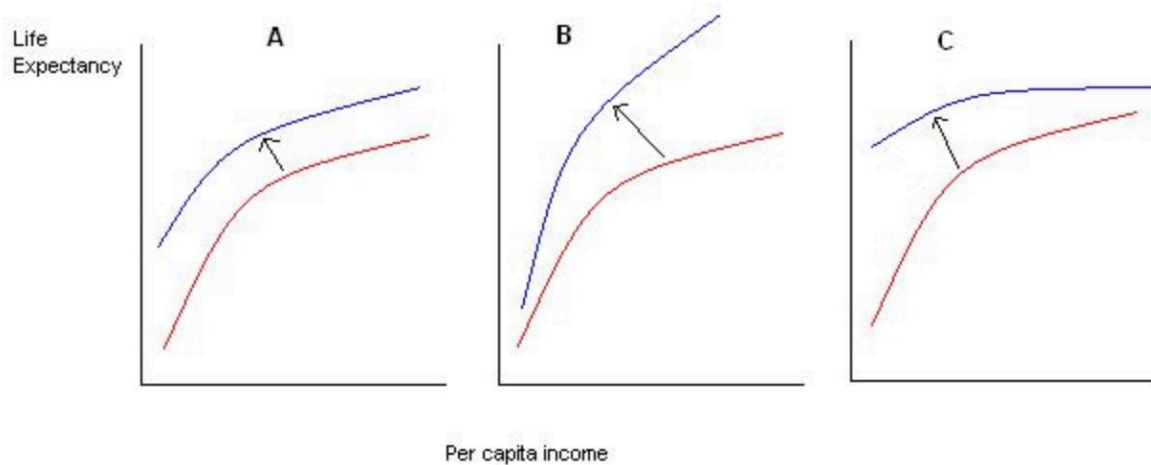
## GDP vs. Life Expectancy

- How do country's economic status and life expectancy relate?
  - Higher GDP often correlates with longer life expectancy.
  - Plateau effect beyond a certain GDP.



## Preston Curve

- **A:** the new technology is equally applicable in all countries regardless of their level of income.
- **B:** the new technology has a disproportionately larger effect in rich countries.
- **C:** poorer countries benefit more.



## Aging Populations

- Trends:

- Increasing proportion of elderly.
- Dependency ratios rise, impacting economic and health systems.

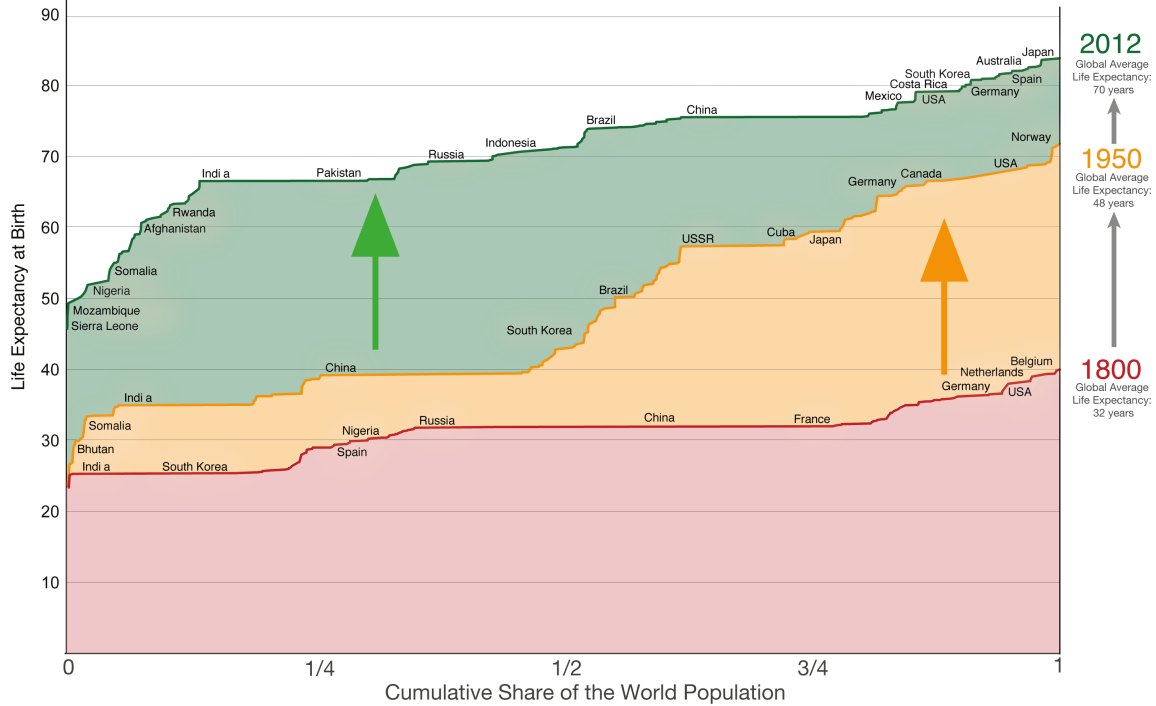
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## Aging Populations

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## Life Expectancy of the World Population in 1800, 1950 and 2012

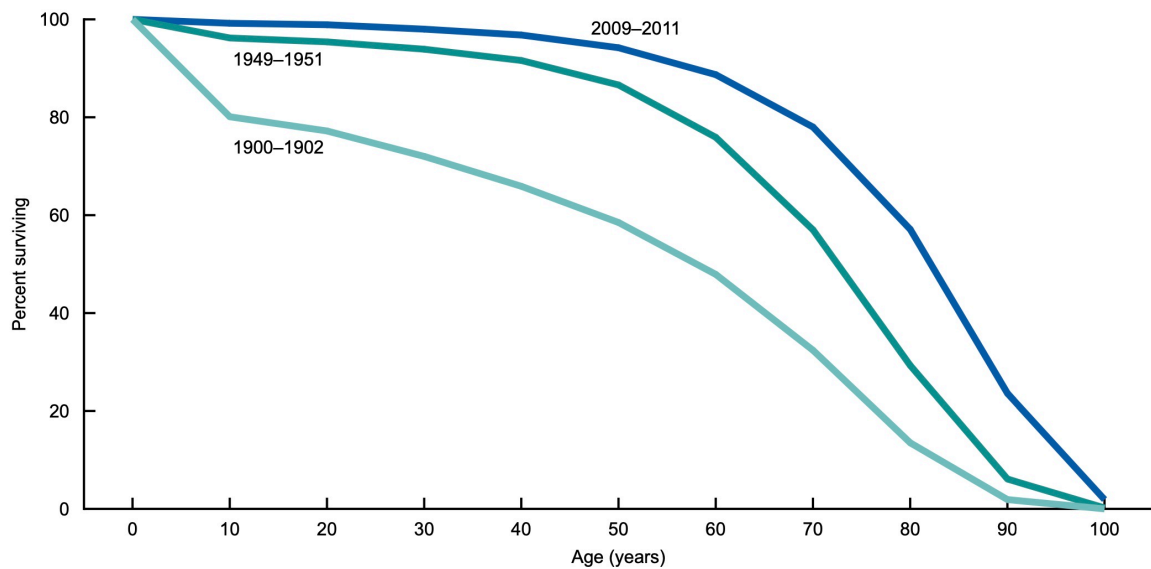
Countries are ordered along the x-axis ascending by the life expectancy of the population. Data for almost all countries is shown in this chart, but not all data points are labelled with the country name.



Data source: The data on life expectancy by country and population by country are taken from [Gapminder.org](https://gapminder.org).

The interactive data visualisation is available at [OurWorldinData.org](https://OurWorldinData.org). There you find the raw data and more visualisations on this topic.

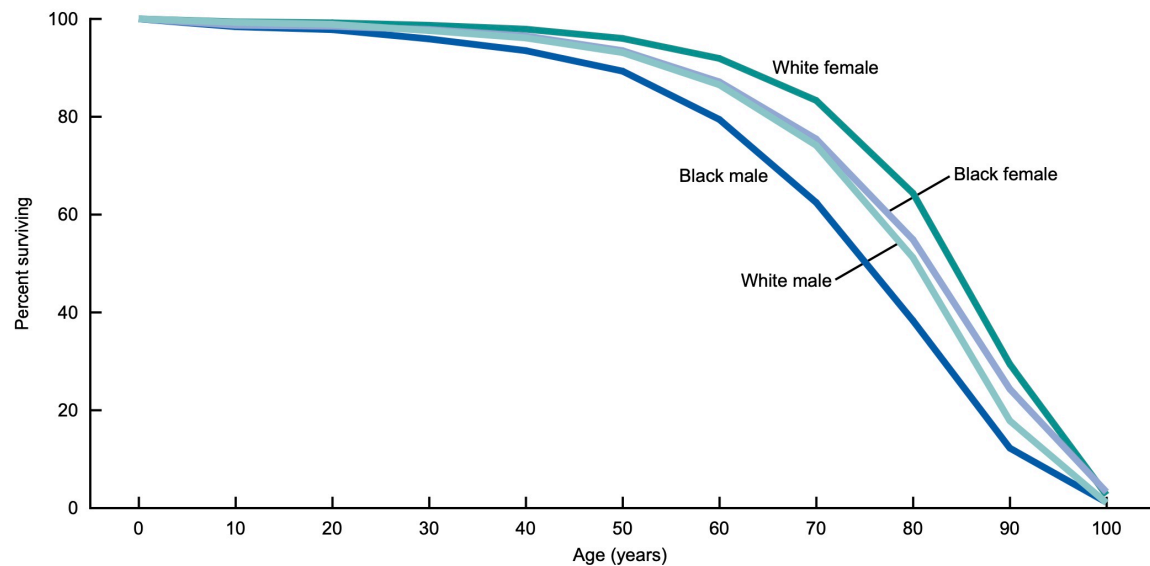
Licensed under CC-BY-SA by the author Max Roser.



SOURCE: NCHS, National Vital Statistics System, Mortality.



## Aging Populations



SOURCE: NCHS, National Vital Statistics System, Mortality.

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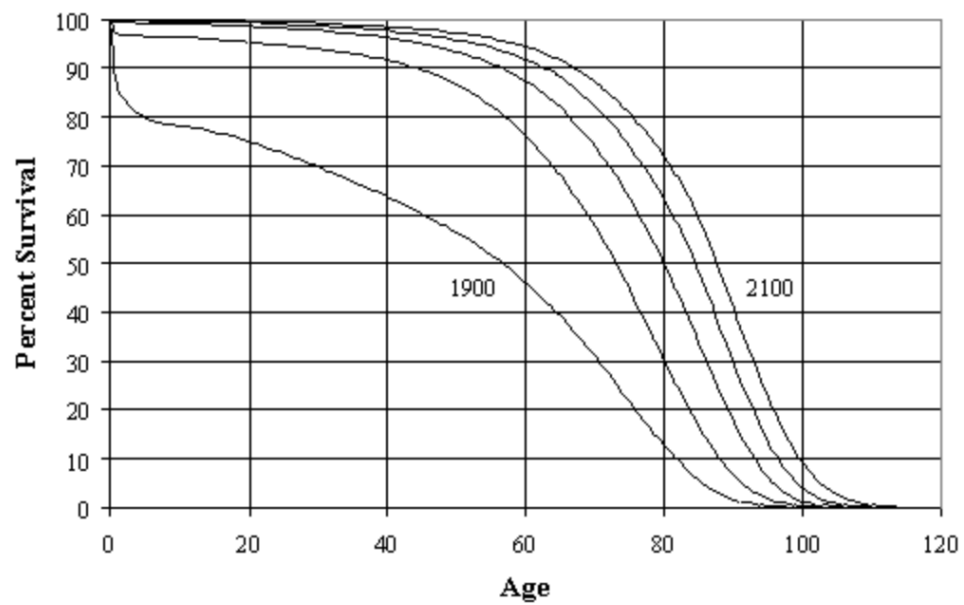
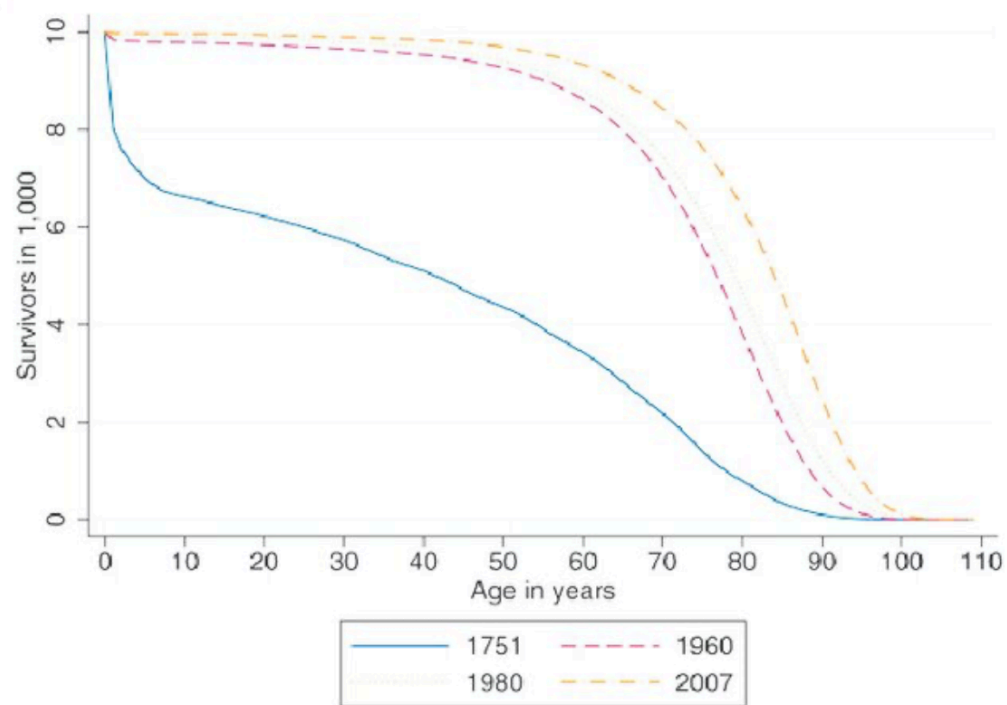
## Rectangularization of Life Expectancy

- Survival curves become more rectangular as mortality compresses toward older ages.
- **Implications:**
  - Shift to chronic diseases as leading health concerns.
  - Need for age-specific interventions.

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## Survival Curves in Sweden

Source: Schoder, J., & Zweifel, P. (2011). Flat-of-the-curve medicine: a new perspective on the production of health. Health Economics Review, 1, 1-10.



## Survival Curves in USA

Source: Bell, F. C., & Miller, M. L. (2005). Life tables for the United States social security area, 1900-2100 (No. 120). Social Security Administration, Office of the Chief Actuary.

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## Mortality Metrics

### Crude Death Rate (CDR)

- Number of deaths per 1,000 individuals per year.
- Can be refined by breaking it down by age, sex, and socioeconomic status.
- **Example:** CDR in Mexico < CDR in the USA, but age distribution must be considered.

### Case Fatality Rate (CFR)

- Proportion of individuals with a disease who die from it.
  - Indicates severity and lethality of a disease.
  - **Example Calculation:**  $CFR = (\text{Disease deaths} / \text{Total diagnosed cases}) \times 100$
- 

### Standardized Mortality Ratio (SMR)

- Adjusts mortality rates for different population age structures.
  - **Formula:**  $SMR = (\text{Observed Deaths} / \text{Expected Deaths}) \times 100$
  - **Example Calculation:**
    - Observed deaths: 93
    - Expected deaths: 70.5
    - $SMR = (93 / 70.5) \times 100 = \mathbf{132}$  (indicating 32% higher mortality than expected)
-

## Years of Life Lost

- Years of Life Lost (YLL) quantifies the impact of premature mortality in a population.
  - Used in public health to evaluate disease burden and prioritize interventions.
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## Methodology for Calculating YLL

### Definition of Premature Mortality Age

- Premature mortality is defined relative to a threshold age, typically the average life expectancy.
- For this example, we use **75 years**.

### Identification of Age at Death

- Essential for determining premature deaths.
  - Each death's impact varies depending on age at death.
- 

### Calculation of Individual YLL

- Formula:  $YLL = T - a_i$  where:
  - $T$  is the threshold age,
  - $a_i$  is the individual's age at death.

### Summation of YLL

- Total population impact calculated as:  $\text{Total YLL} = \sum YLL_i$
-

### Example Calculation

Consider three individuals dying at **ages 25, 35, and 60**, with a threshold of **75 years**:

- **Individual 1:**
    - Age at death: 25
    - $YLL = 75 - 25 = 50$  years
  - **Individual 2:**
    - Age at death: 35
    - $YLL = 75 - 35 = 40$  years
  - **Individual 3:**
    - Age at death: 60
    - $YLL = 75 - 60 = 15$  years
  - **Total YLL:**  $50 + 40 + 15 = 105$  years
- 

### Discussion

- The **105 years of YLL** highlight the burden of premature deaths.
  - Helps health authorities prioritize interventions.
  - Modifications include:
    - Discounting future years,
    - Weighting younger deaths more heavily,
    - Adjusting for epidemiological and demographic context.
  - Think about large campaigns to reduce road related deaths at young age (= preventable)
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### Summary

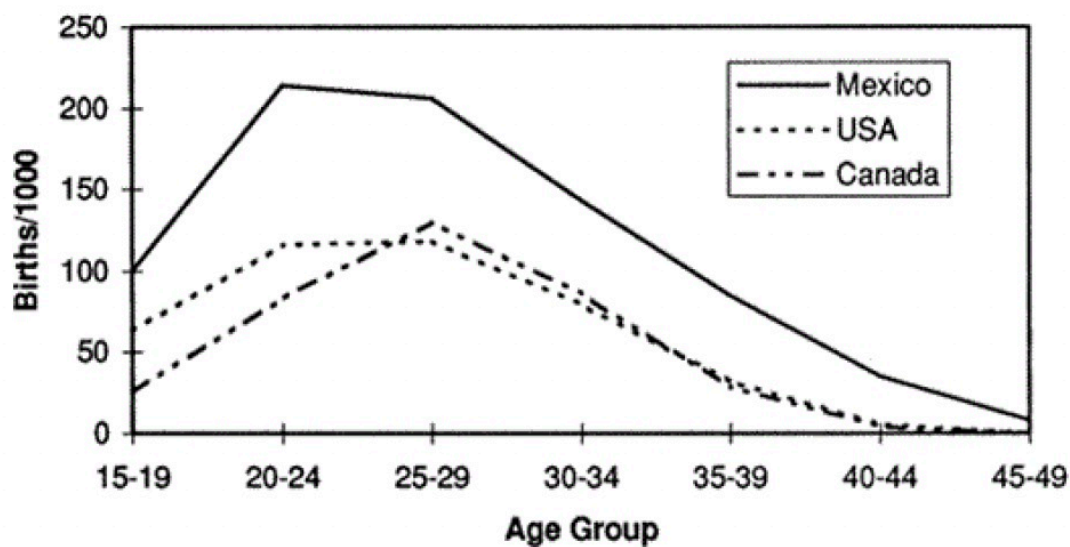
- Crude Death Rate (CDR) and Case Fatality Rate (CFR) provide baseline mortality measures.
- Standardized Mortality Ratio (SMR) adjusts for age distribution differences.
- **Years of Life Lost (YLL)** quantifies premature mortality and is crucial for measuring disease burden.

- YLL helps prioritize public health interventions by identifying the most significant sources of early death.
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## Fertility

- Some definitions
    - *crude birth rate (CBR)*: number of births per 1,000 population per year. The denominator, however, refers to the total population, including men and boys, young girls and old women!
    - *general fertility rate (GFR)*: restricts inclusion in its denominator only to women in the reproductive age range
    - *total fertility rate (TFR)*: summing all age-specific fertility rates for women in the childbearing ages.
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## Birth Rates in US, Canada, Mexico



## Deriving Total Fertility Rate

### Age-Specific Fertility Rates (ASFRs) for the U.S. (2000)

- 15–19: 48.5/1,000
- 20–24: 112.3/1,000
- 25–29: 121.4/1,000
- 30–34: 94.1/1,000
- 35–39: 40.4/1,000
- 40–44: 7.9/1,000
- 45–49: 0.5/1,000

**Total:** 425/1,000

### Explanation

- The ASFR represents the birth rate per 1,000 women in each age group.
  - Summing the ASFRs gives 425/1,000 for all age groups.
  - Since each ASFR represents a five-year average, multiplying by 5 gives 2,125/1,000. This means the TFR = 2.1 births per woman, the replacement-level fertility rate typical of developed countries.
  - Including ages 10–14 or 50–54 has little impact on the overall TFR.
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## Aging Populations

- **Policy Implications:**
    - Need for long-term care services.
    - Redesign of healthcare systems.
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## Book Exercise

### Exercise 2.1: State of the Population

In the 2000 census, the total population of the United States was 281,423,000, with the following age-sex distribution (rounded to the nearest thousand):

Age Group	Male Population	Female Population	Total Population
0–1	1,949,000	1,857,000	3,806,000
1–4	7,862,000	7,508,000	15,370,000
5–14	21,044,000	20,034,000	41,078,000
15–44	62,647,000	61,577,000	124,224,000
45–64	30,143,000	31,810,000	61,953,000
65+	14,410,000	20,582,000	34,992,000
<b>Total</b>	<b>138,055,000</b>	<b>143,368,000</b>	<b>281,423,000</b>

### Calculations

- (a) **Proportion of the Elderly (65+ years) in the Population**
  - (b) **Proportion of the Young (0–14 years) in the Population**
  - (c) **Sex Ratio in Age Group 0–14 (expressed as 100 males per females)**
  - (d) **Sex Ratio in Age Group 65+ (expressed as males per 100 females)**
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### Summary

#### Key Takeaways

- Differences between incidence and prevalence.
- Importance of understanding demographic changes.
- Using tools like age pyramids to predict health trends.

### Discussion Questions

- How do changes in prevalence reflect healthcare advances?
  - What policies can address the challenges of aging populations?
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