

Measuring Health and Disease in Populations

College of Health @ LEHIGH | Eric Delmelle February 9, 11, 23 2026

Table of Contents

Part 1: Comparing Health Events

- Introduction and Key Concepts
- Types of Comparisons (Time, Place, Group, Event)
- Policy Implications

Part 2: Measuring Health and Disease

- Incidence and Prevalence
 - Mortality Metrics
 - Life Tables and Life Expectancy
 - Demographic Transitions and Aging Populations
 - Fertility Rates
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Part 1: Comparing Health Events

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.

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

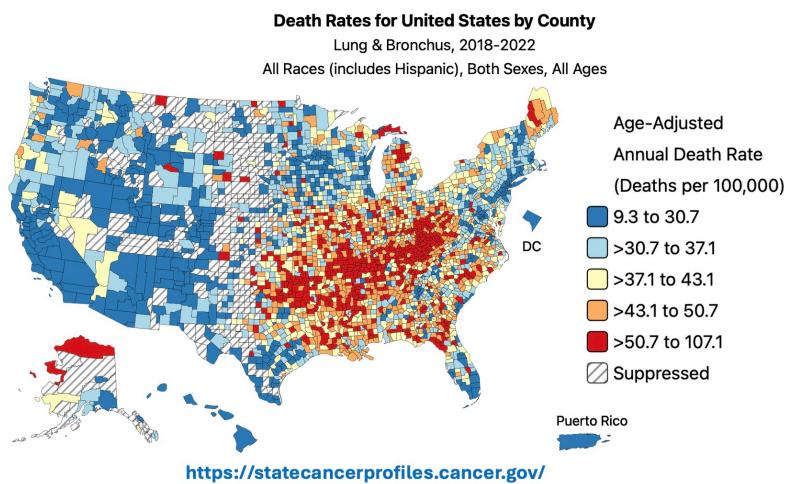
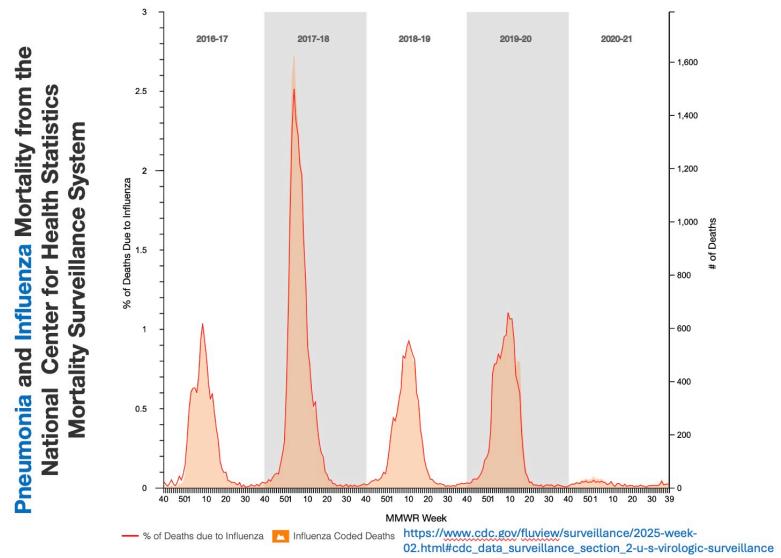
- **John Snow:** Cholera outbreak mapping.
 - **Ignaz Semmelweis:** Importance of handwashing.
 - **Joseph Goldberger:** Nutritional causes of pellagra.
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Types of Comparisons

Time-Based

Key Metrics:

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

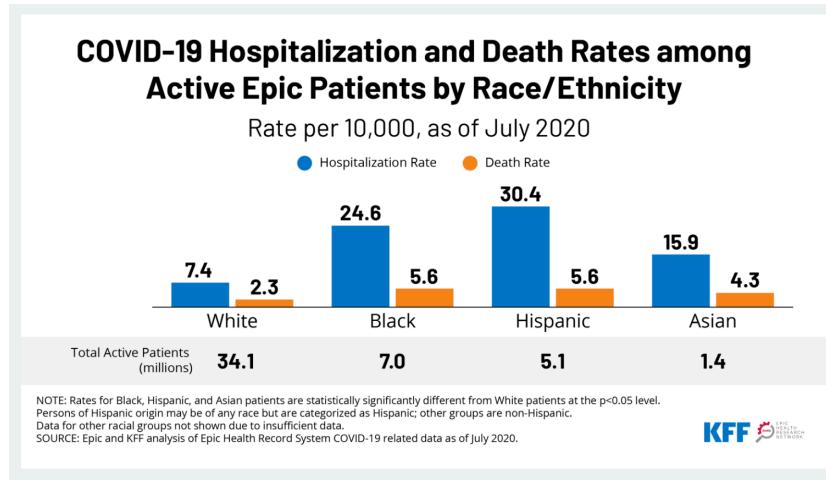
Example:

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

Example:

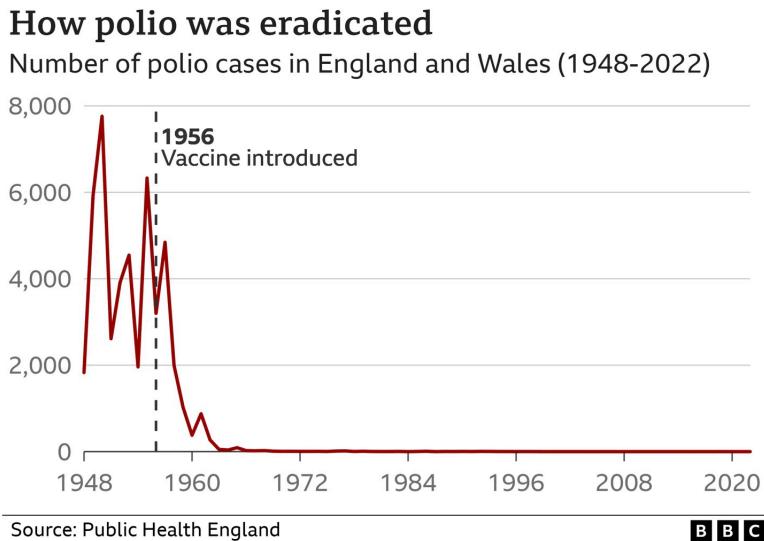
- Health disparities by race, age, and income.



Event-Based

Key Concept:

- Natural experiments: Before vs. after policy changes or interventions.
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Additional Event-Based Example

Part 2: Measuring Health and Disease

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
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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.
-

Impact of New and Existing Cases

- **Prevalence Formula Relation:**
 - $\text{Prevalence} = \text{Incidence} \times \text{Duration of Disease}$
 - check this [YouTube](#) video
- **Factors affecting prevalence:**

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

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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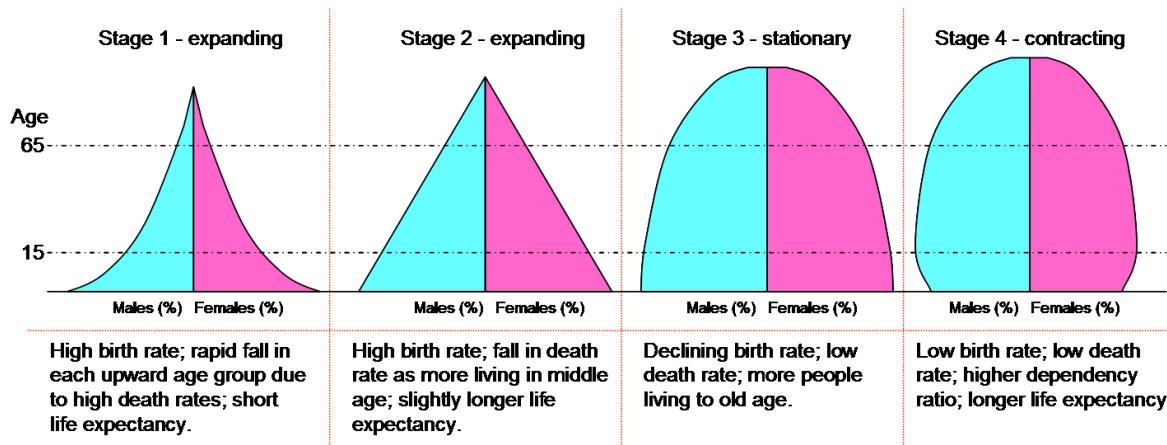
Demographic Changes and Health Metrics

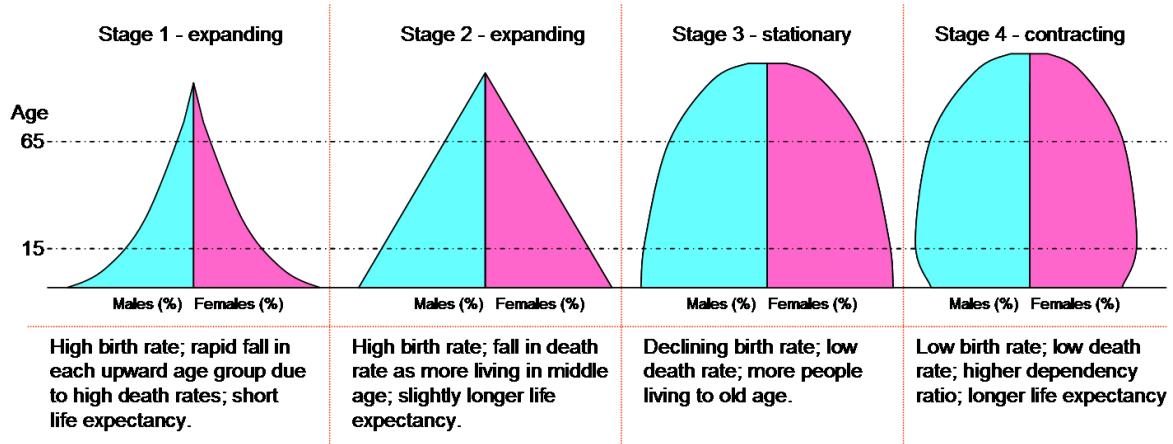
- **Fertility Rate:** Key measure of reproductive behavior.
 - **Mortality:** Affects life expectancy and health metrics.
 - **Migration:** Alters population composition, health service demands.
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Population Structure

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.
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Qatar and Japan Age Pyramids

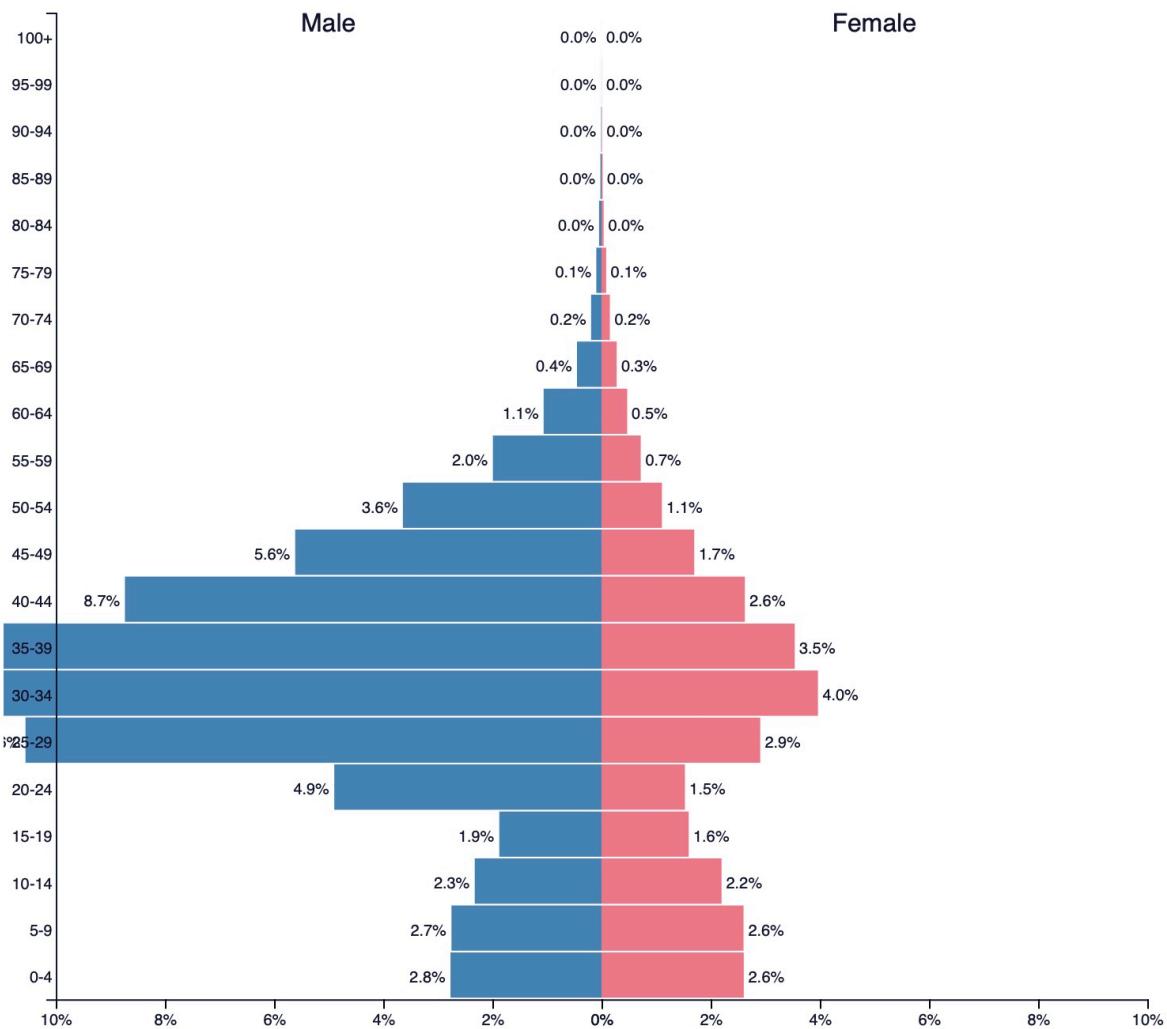
[Qatar](#)

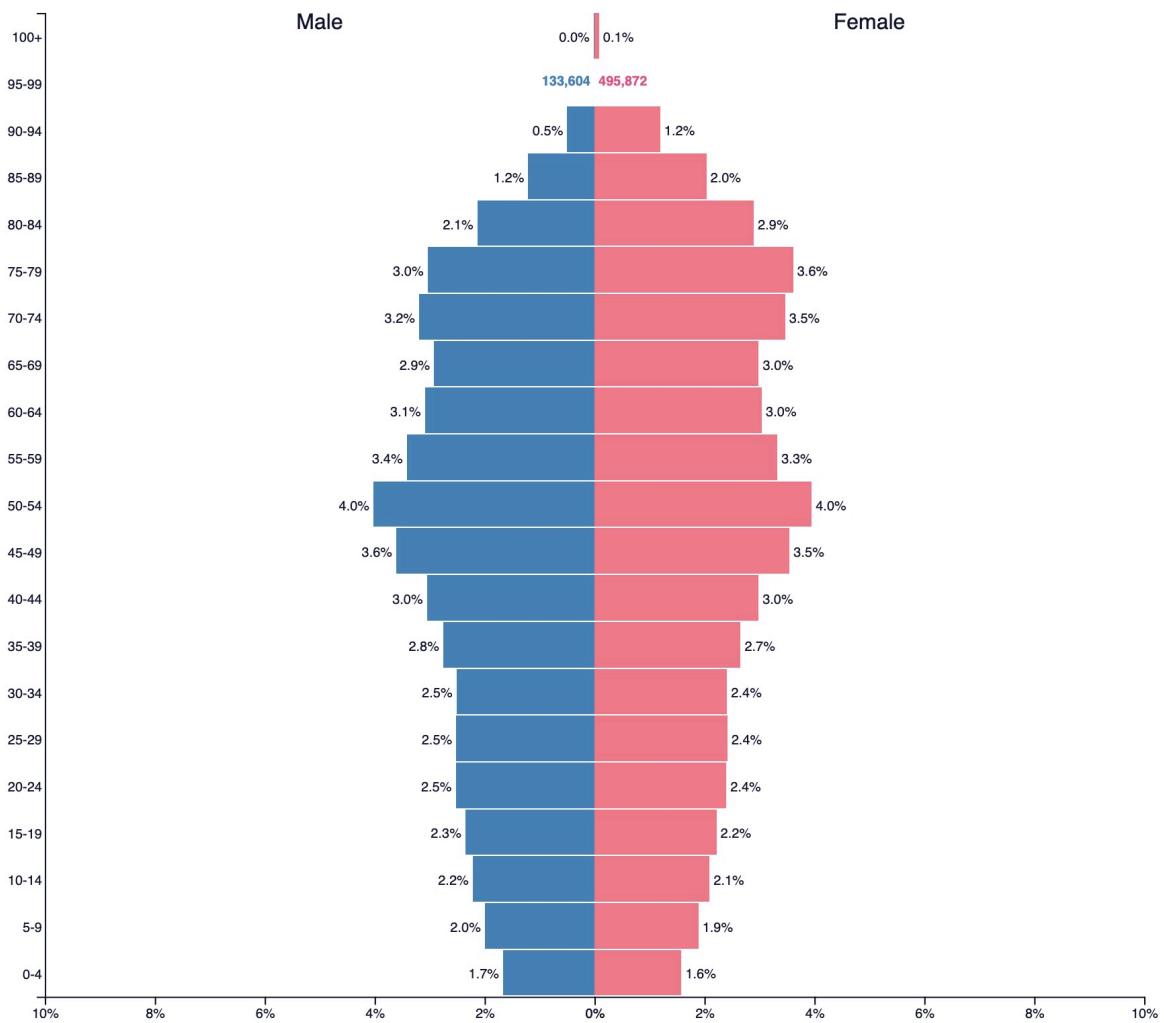
[Japan](#)

Interactive Activity

Analysis Instructions

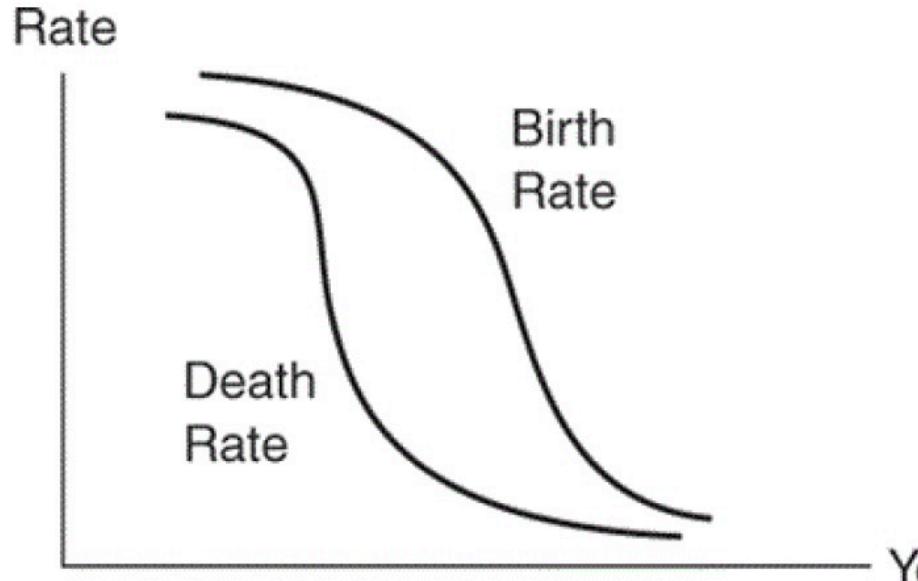
- Choose an age pyramid.
 - [international](#) pyramid.
 - [local level](#) pyramid.
 - Explain to class what you see and what you expect the population to look like in 15, 30 and 50 years.
-





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

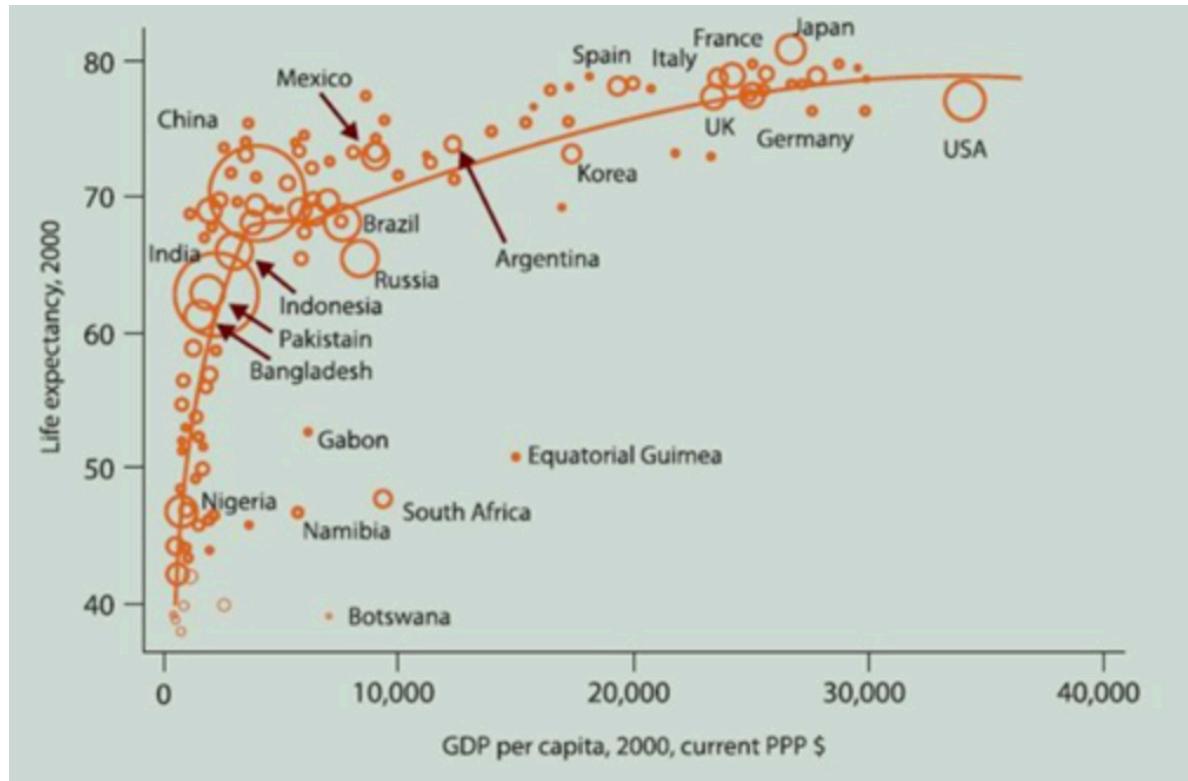
Demographic Transition

- 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
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Preston Curve

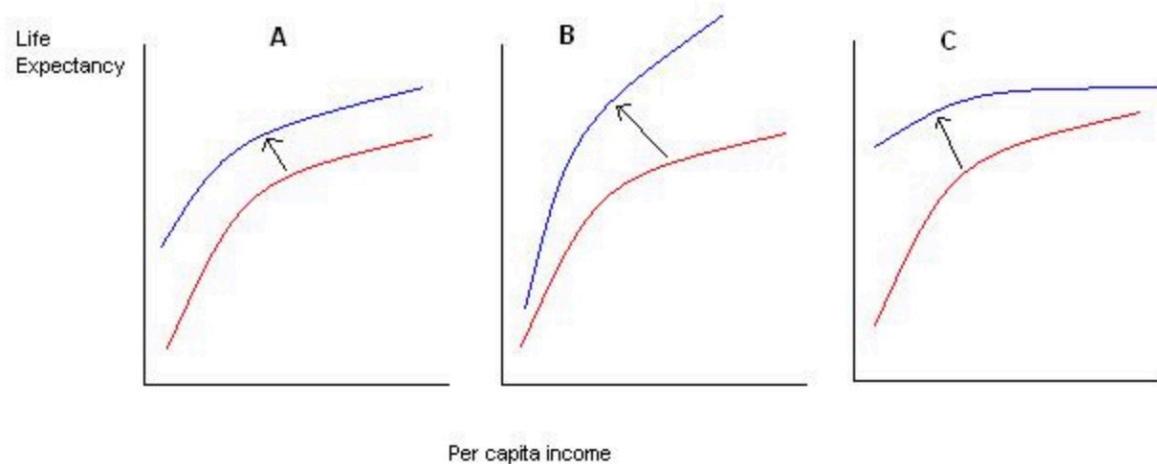
GDP vs. Life Expectancy

- 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

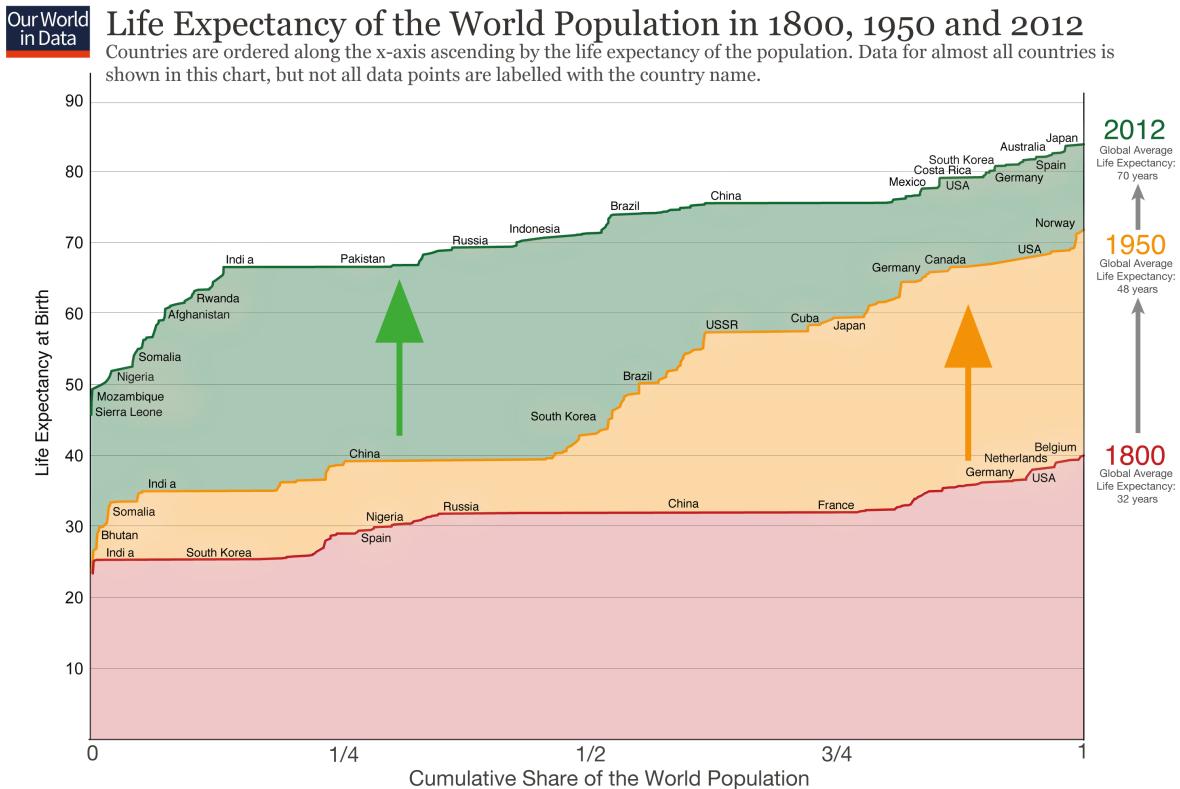
- A: the new technology is equally applicable in all countries regardless of their level of income.
- B: the new technology has a disproportionately larger effect in rich countries.
- C: poorer countries benefit more.



Aging Populations

- Trends:
 - Increasing proportion of elderly.
 - Dependency ratios rise, impacting economic and health systems.
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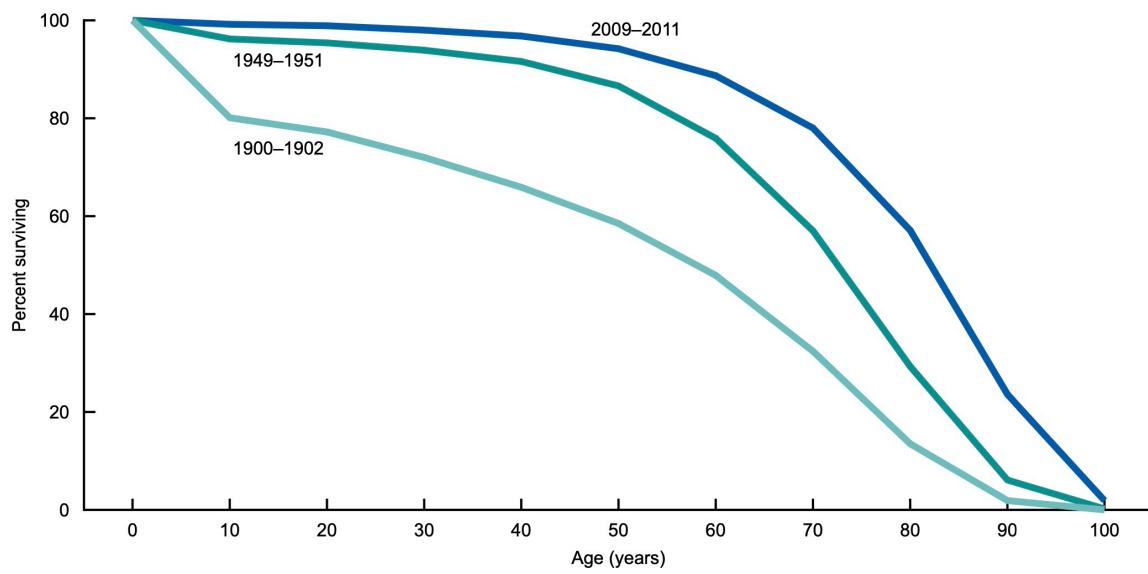
Aging Populations



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

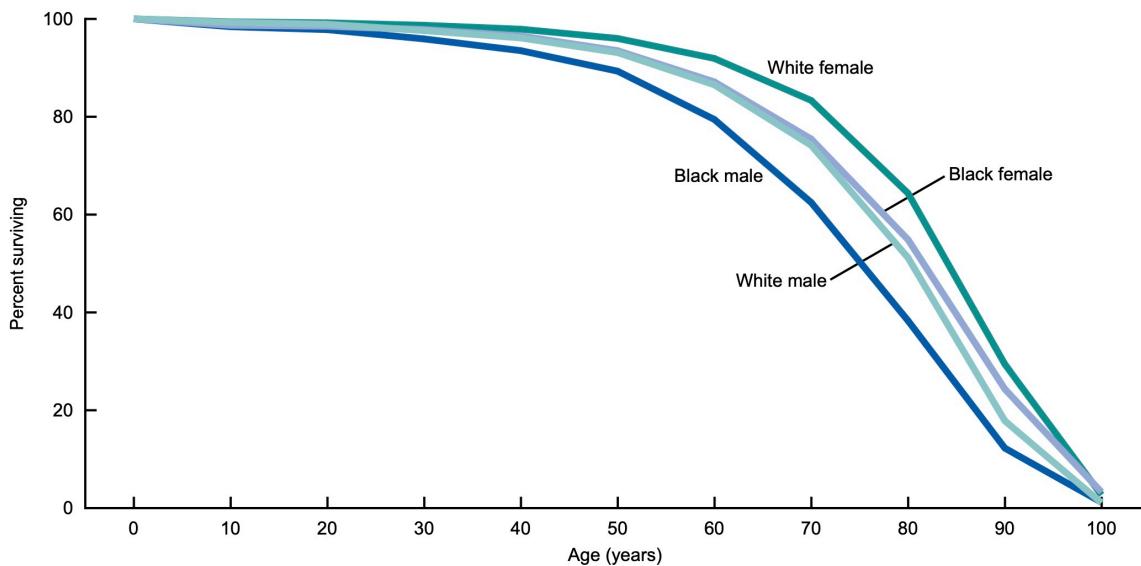
The interactive data visualisation is available at [OurWorldinData.org](#). There you find the raw data and more visualisations on this topic.

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



SOURCE: NCHS, National Vital Statistics System, Mortality.

Aging Populations



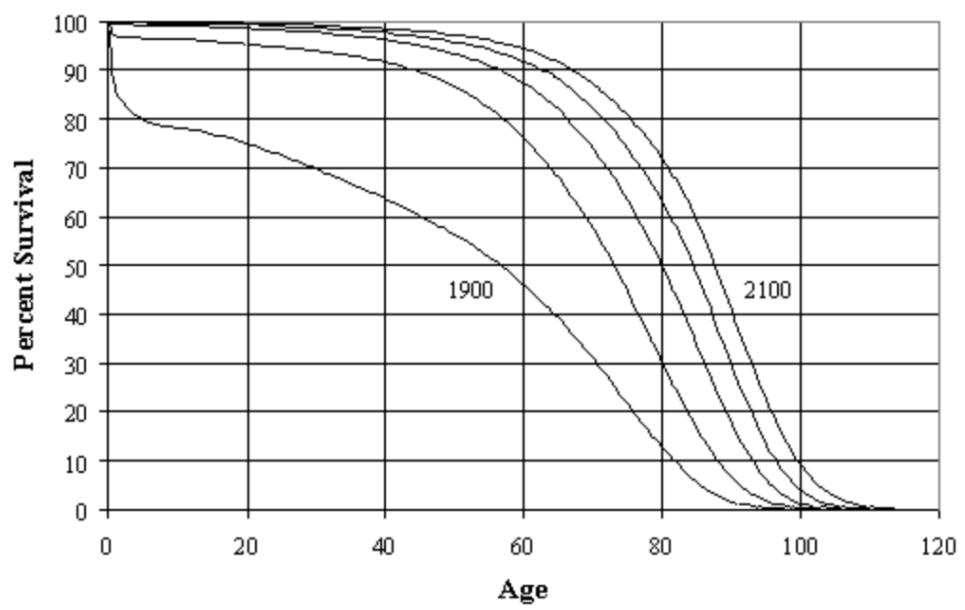
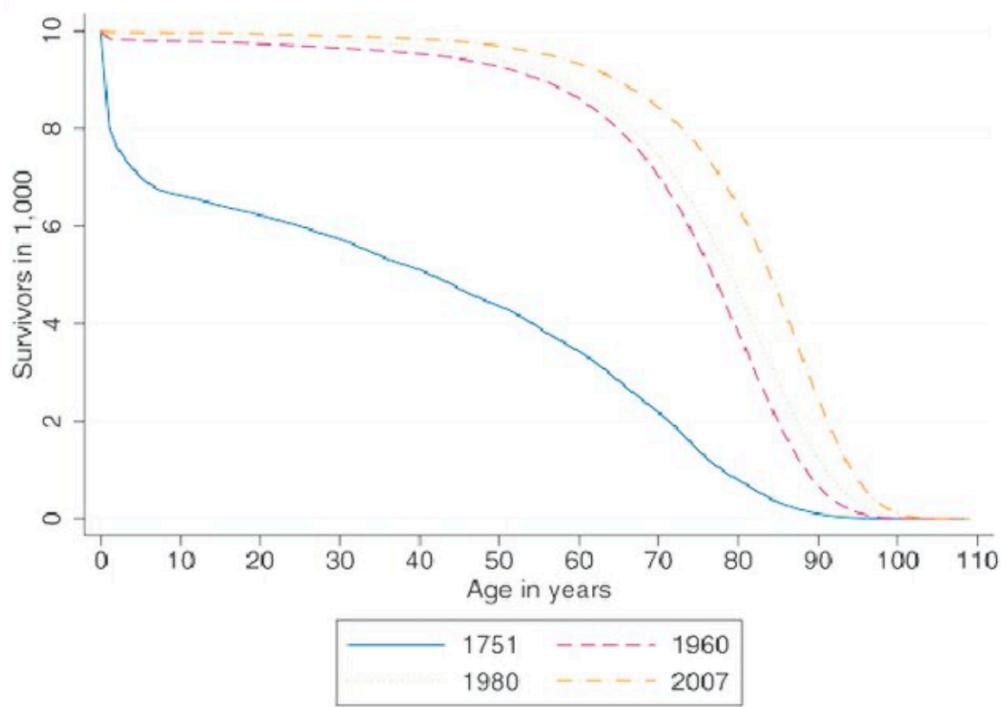
SOURCE: NCHS, National Vital Statistics System, Mortality.

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.
-

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.

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:** $\text{CFR} = (\text{Disease deaths} / \text{Total diagnosed cases}) \times 100$
-

Standardized Mortality Ratio (SMR)

- Adjusts mortality rates for different population age structures.
 - **Formula:** $\text{SMR} = (\text{Observed Deaths} / \text{Expected Deaths}) \times 100$
 - **Example Calculation:**
 - Observed deaths: 93
 - Expected deaths: 70.5
 - $\text{SMR} = (93 / 70.5) \times 100 = 132$ (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: $\text{YLL} = T - a_i$ where:
 - T is the threshold age,
 - a_i is the individual's age at death.

Summation of YLL

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

Example Calculation

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

- **Individual 1:**

- Age at death: 25
 - $\text{YLL} = 75 - 25 = \mathbf{50 \text{ years}}$

- **Individual 2:**

- Age at death: 35
 - $\text{YLL} = 75 - 35 = \mathbf{40 \text{ years}}$

- **Individual 3:**

- Age at death: 60
 - $\text{YLL} = 75 - 60 = \mathbf{15 \text{ years}}$

- **Total YLL:** $50 + 40 + 15 = 105 \text{ years}$

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)
-

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.

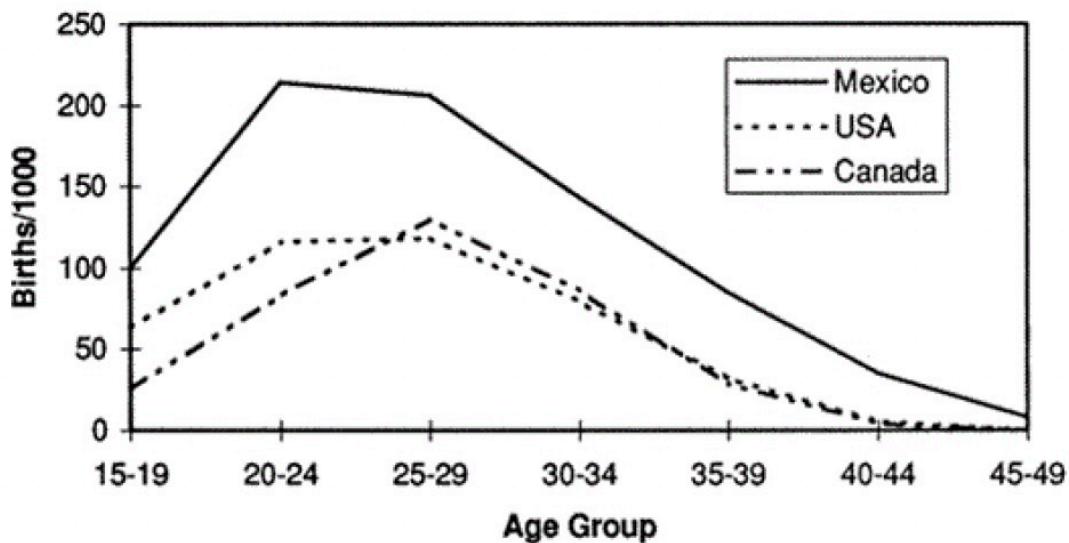
- YLL helps prioritize public health interventions by identifying the most significant sources of early death.
-

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.
-

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.
-

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
Total	138,055,000	143,368,000	281,423,000

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)
-

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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