Population health

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Summary

The study of population health is mostly rooted in classical epidemiology, which focuses on the distribution and determinants of disease in populations. Population health studies have a wide range of applications that include guiding public health policy and interventions, evaluating the importance and potential impact of PICO questions for clinical research, and informing clinical practice (e.g., using prevalence measures to estimate the pretest probability of a disease). The most common types of epidemiological studies used in population health are observational studies. These can be descriptive studies (e.g., ecological studies), analytical studies (e.g., cohort studies), and studies that can be both observational and analytical (e.g., cross-sectional studies). They typically seek to identify populations with particular outcomes and assess the association between potential exposures and these outcomes. This article focuses on basic concepts of population health (e.g., population pyramids, and endemic, epidemic, or pandemic diseases) and measures of disease frequency, e.g., incidence, prevalence, birth rates, mortality rates, case-fatality rates, morbidity, and disease burden.

The following concepts are discussed separately: causal relationships in research studies, other reasons for observed associations (e.g., random errors, systematic errors, confounding), measures of association commonly encountered in studies of clinical interventions (e.g., relative risk, absolute risk reduction), measures used in the evaluation of diagnostic research studies (e.g., sensitivity, specificity), precision and validity, and foundational statistical concepts (e.g., measures of central tendency, measures of dispersion, normal distribution, confidence intervals).

See also "Epidemiology," "Statistical analysis of data," and "Interpreting medical evidence."

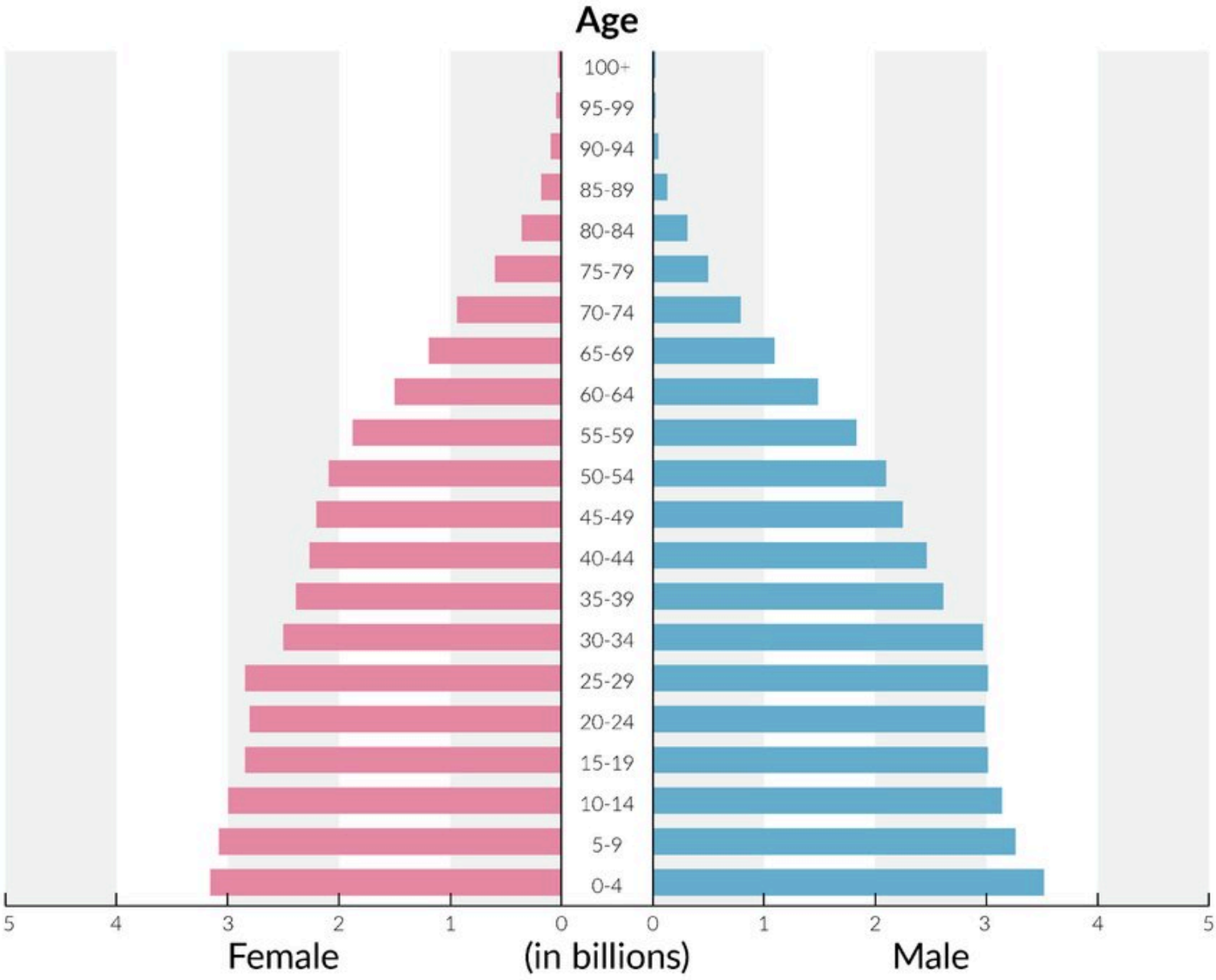
Elements describing population health

Population pyramid

Definition: a graphical representation of age and sex distribution in a population [1]

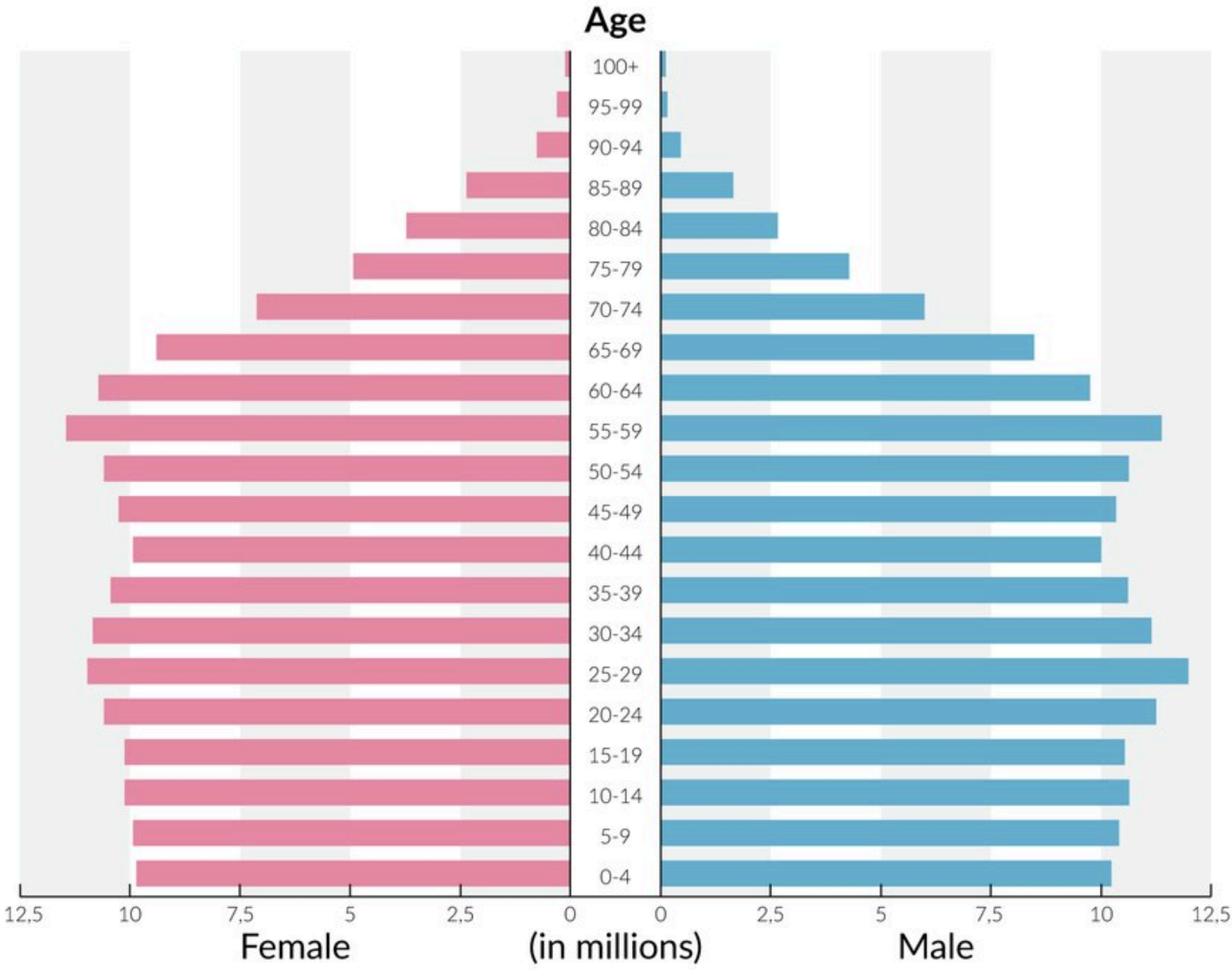
Overview of population pyramids

	Expansive pyramid	Stationary pyramid	Constrictive pyramid
Population	• Growing (e.g., rapid growth)	• Stable (e.g., slow population growth)	• Declining (e.g., zero population growth)
Age distribution	• Higher percentage of young people	• Remains constant over time	• Higher percentage of older people
Life expectancy	• Low	• Increasing	• High
Birth rate	• Very high	• Low	• Very low
Mortality rate	• High	• Low	• Low



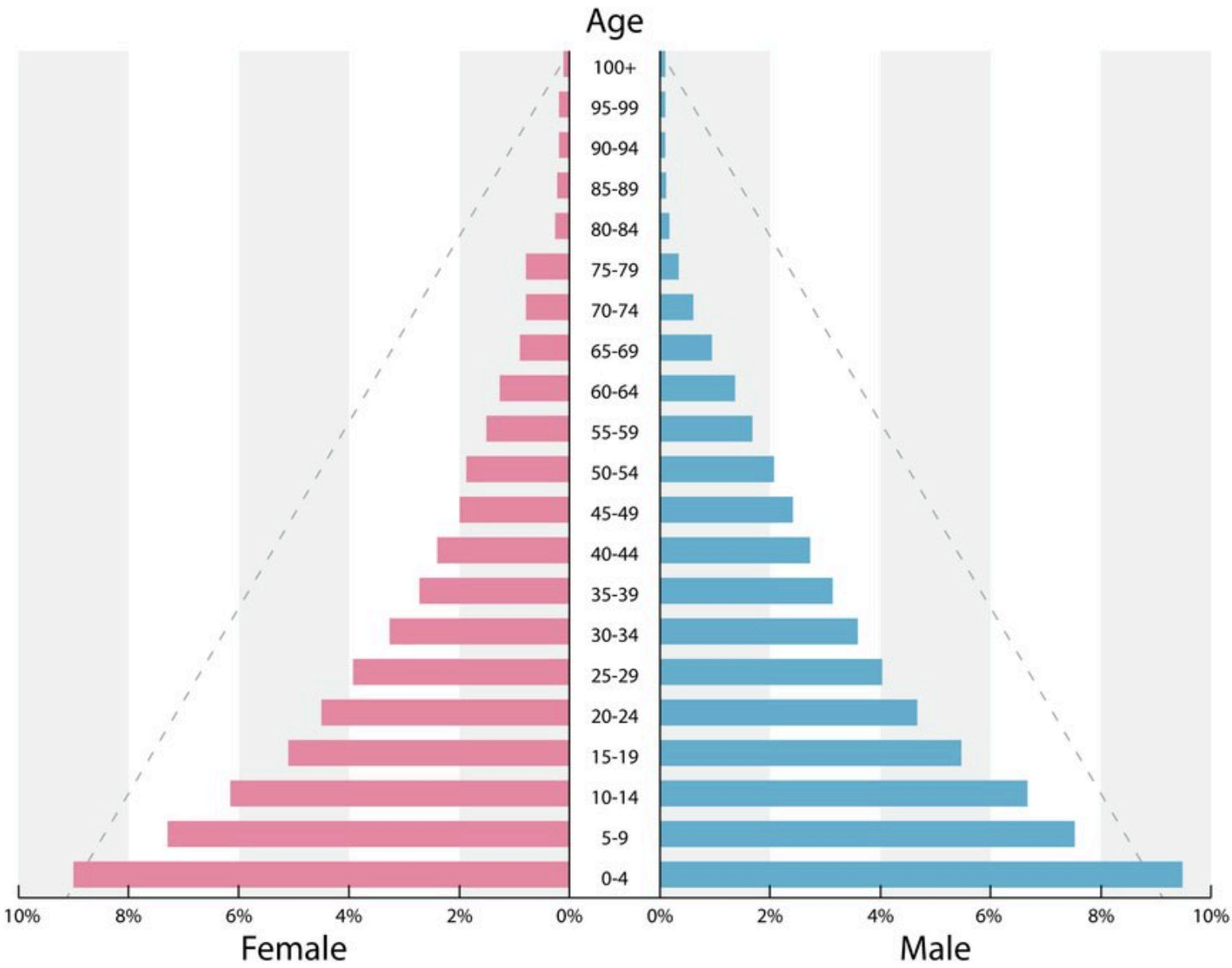
World 2018

Population: 7,597,175,534

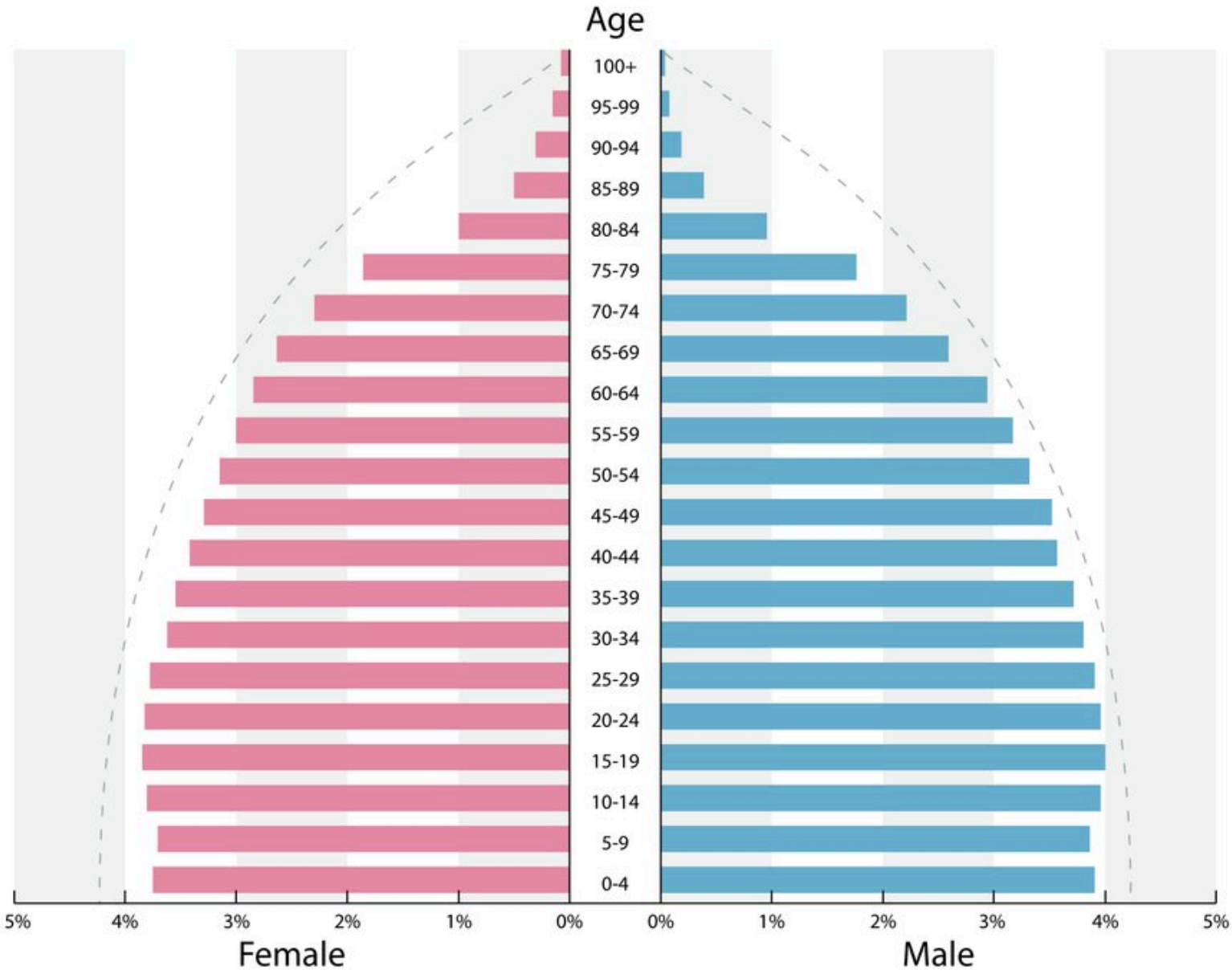


United States of America 2018

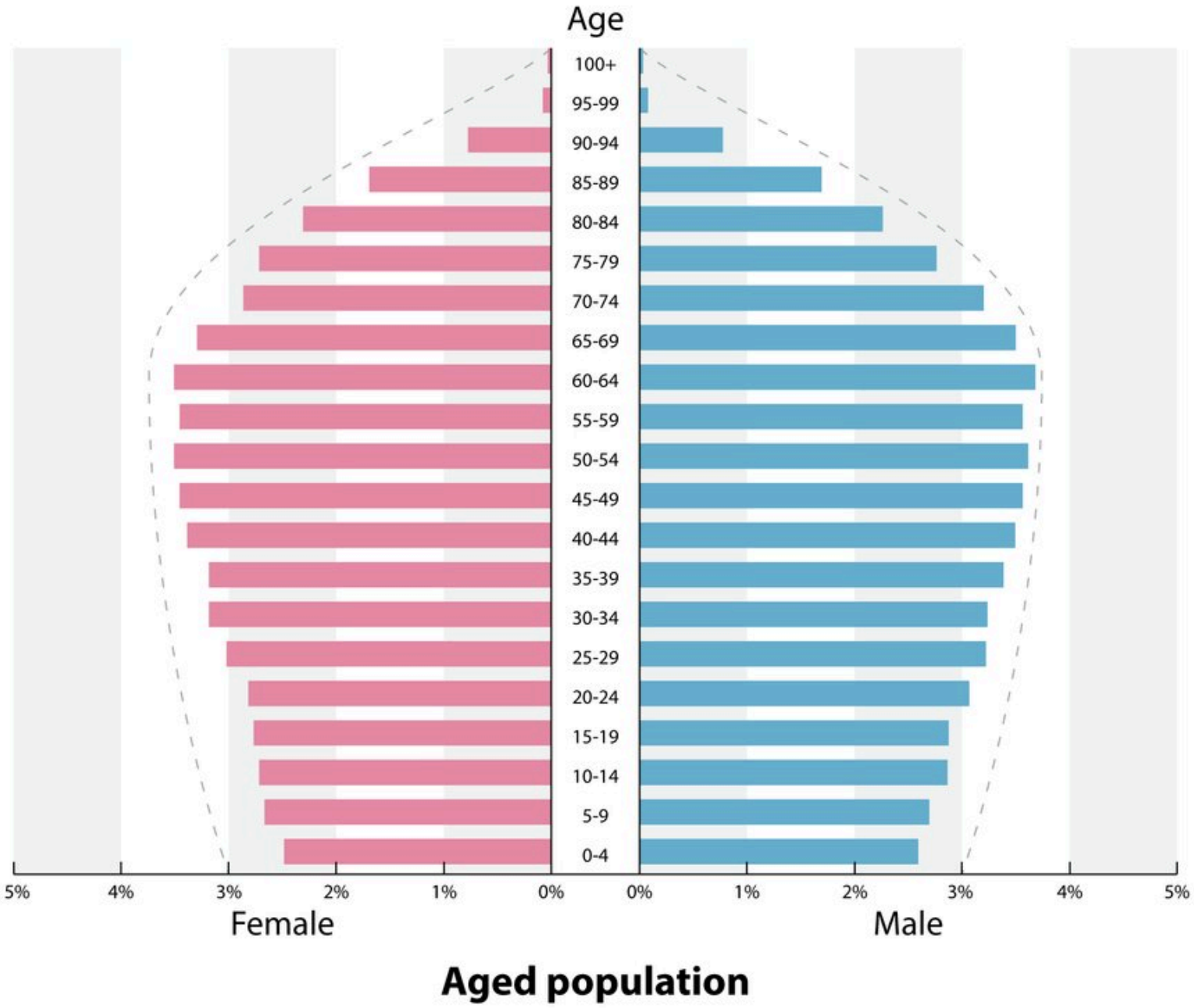
Population: 328.835.763



Youthful population



Aging population



Demographic transition

- **Definition**: changes that occur in a population that goes from having high birth rates and high death rates to having low birth rates and low death rates [1]
- **Demographic Transition Model**: describes, in stages, the evolving relationship between birth and death rates in a population over time [1]
  - Stage I: high birth rates and high death rates (low or no population growth)

- Stage II: high birth rates and decreasing death rates (high population growth)
- Stage III: decreasing birth rates and low death rates (slowed population growth)
- Stage IV: low birth rates and low death rates (low or no population growth)

The goal of healthy demographic transitions is to lower death rates, lower birth rates, and ensure a healthy aging population.

Endemic, epidemic, and pandemic diseases

Diseases can be classified according to their pattern of occurrence across time and geographic area.

Types of diseases			
	Endemic	**Epidemic**	**Pandemic**
Definition [2]	• A disease that affects individuals at a relatively constant rate within a specific population in a given region	• A disease that affects individuals at a rapid rate within a specific population in a given region	• A disease that affects a wide geographic area, e.g., multiple countries or continents
Time	• Unlimited	• Limited	• Limited
Area	• Limited	• Limited	• Unlimited
Examples	• Malaria in parts of Africa • Yellow fever in parts of South America and Africa	• Ebola fever in West Africa (2014) • Seasonal influenza	• Spanish flu (1918/19) • COVID-19
Possible contributing factors	• Spread of disease vectors and pathogen reservoirs • Geographical conditions • Climate • Living conditions (e.g., sewage systems, housing, work)	• Infectivity of a pathogen: increased ability to multiply in a host • Living conditions (e.g., living in crowded areas) • Spread/introduction of the pathogen to a new geographical area	• Global trade and travel • Increased infectivity of a pathogen (e.g., antigenic shift)

Measures of disease frequency

Overview

- Measures of disease frequency can be used to: [3]
  - Quantify mortality and/or morbidity (i.e., incidence and prevalence of disease)
  - Describe population characteristics (e.g., at-risk populations, life expectancy)
  - Determine the association between two factors (e.g., exposure and disease)
- Data is systematically collected and analyzed and then used for planning, implementing, and evaluating public health practices (i.e., public health surveillance), in order to:
  - Detect changes in health behavior, health issues, and identify potential outbreaks and epidemics
  - Estimate the magnitude of a health issue (e.g., disease or risk factor), measure trends, and characterize a disease

- Identify individuals with infectious diseases or exposures to environmental agents and their contacts
- Determine the effectiveness of control measures and public health programs
- Develop future research hypotheses

Incidence and prevalence

Incidence

- **Description**: number of new cases [4]
- **Population at risk**: the group of people that are at risk of developing the condition being studied (individuals at risk cannot have the condition at the time the study period starts)
- **Incidence study**
  - Used to determine the incidence of a particular event in a population during a certain time period (usually a year). If the event in consideration is death, the study is called a mortality study.
  - Usually performed as a cohort study to compare the incidence of an event (e.g., disease) between two groups

Measures of incidence		
	Incidence rate	**Cumulative incidence**
Description	• The number of new cases of a disease per unit of person-time • Incidence rate is a useful measurement if the population at risk changes over time (e.g., because of study dropouts) or when comparing groups with different follow-up periods.	• The proportion of new cases of disease in a previously disease-free population over a defined period of time • Measures risk of disease (using the same calculation as absolute risk) • In the setting of disease outbreaks, cumulative incidence is referred to as attack rate: the proportion of people who become ill in relation to the total number of people exposed.

Formula	• Number of new cases/**person-time units**
	• Person-time units (denominator)
	  ◦ Describes the total time that the population was at risk
	  ◦ Person-time = time each person was observed, totaled for all persons = number of people observed × mean duration of observation
	  ◦ The time units can be in days, months, years, etc.
		• Number of new cases in a specific time period/**number of people in a given population at risk**

Example	• Individuals in a community are followed for 130,000 person-years of observation. 12 people develop lung cancer during that time. The incidence rate of lung cancer in that community would be 12 per 130,000 person-years (or 9 per 100,000 person-years)	• Individuals in a community with a population of 150,000 are followed for 10 years. 12 people develop lung cancer during that time. The cumulative incidence of lung cancer in that community would be 12 per 150,000 individuals (or 8 per 100,000 individuals) over 10 years.

Prevalence

- **Description**: number of current (i.e., new and preexisting) cases
  - The proportion of all **people with a disease** to the **total** number of people in a **population** at a particular point in time or time period

- Corresponds to **disease frequency** (how common a disease is)
- Reflects the pretest probability of a disease
- Correlates directly with the positive predictive value and inversely with the negative predictive value (see "Evaluation of diagnostic tests" below)

- **Formula**: total number of cases/total population during a specific time
  - The time period can be:
    - A specific point in time (point prevalence), e.g., a day
    - A specific period of observation (period prevalence), e.g., during puberty
  - For example, if a survey conducted in 2020 in a town with a population of 120,000 reveals that 451 people have lung cancer, the prevalence of lung cancer in that town would be 451 per 120,000, which would be expressed as 375.8 per 100,000.

Relationship between prevalence and incidence

- **Formulas**
  - Prevalence = (incidence) × (average duration of disease)
  - If the population is in a **steady state**, the relationship between incidence rate (IR), prevalence (P), and the average duration of the disease (T) can be described mathematically as follows:
    - $P/(1 - P) = IR \times T$
      OR
    - $IR = (P/(1 - P))/T$
  - If the disease is extremely rare, $P \approx IR \times T$
  - Number of new cases per unit time = IR × (population at risk)
- **Distribution**
  - Chronic disease: prevalence is usually greater than incidence
  - Acute disease: prevalence and incidence are usually similar
- **Reasons for changes in prevalence and incidence**
  - **Increased prevalence** with stable incidence
    - Increased survival (e.g., improved quality of health care)
    - Prolonged duration of the disease
  - **Decreased prevalence** with stable incidence
    - Increased mortality
    - Decreased recovery time
    - Introduction of new effective treatment
  - **Increased prevalence and incidence**: higher diagnostic sensitivity
  - **Decreased prevalence and incidence**
    - Extensive vaccine administration
    - Removal of risk factors
    - Mitigation of infectious disease spread (e.g., social distancing, contact tracing, masks, quarantine)

Mortality

- **Definition**: the number of deaths in a population within a specific time interval

Overview of other measures of mortality		
Measure	**Description**	**Formula** [5]
Mortality rate (crude death rate)	• Frequency of deaths in a population within a specific time interval	• MR = (number of deaths during a specific time period)/(population size) × 100 • Typically measured for one year and expressed as the number of deaths per 1000 individuals/year or 100,000 individuals/year
Case fatality rate (lethality)	• Percentage of cases (patients with a specific condition) that result in death within a specific time interval	• CFR = (number of deaths from a specific condition)/(number of cases with the same specific condition) × 100
Proportionate mortality rate	• Percentage of deaths due to a specific condition within a specific time interval	• PMR = (number of deaths from a specific cause in a specific time period)/(total deaths from all causes in that time period) × 100 or 1000
Fetal mortality rate	• Rate of fetal deaths within a specific time interval	• FMR = (number of fetal deaths of ≥ 20 weeks of gestation)/(total number of live births + fetal deaths) × 1,000
Neonatal mortality rate	• Rate of neonatal deaths within a specific time interval	• NMR = (number of infant deaths during the first 28 days of life)/(total number of live births) × 1,000 ◦ Late neonatal mortality rate = (number of infant deaths during postnatal days 7–28)/(total number of live births) × 1,000 ◦ Early neonatal mortality rate = (number of infant deaths during the first week after birth)/(total number of live births) × 1,000
Postneonatal mortality rate	• Rate of postneonatal deaths within a specific time interval (from 28 to 364 days of age)	• PNMR = (number of infant deaths between 28 and 364 days of age)/(total number of live births) × 1,000
Infant mortality rate	• Rate of total infant deaths within a specific time interval (from birth to 1 year of age) [5]	• IMR = (number of infant deaths during the first year after birth)/(total number of live births) × 1,000
Perinatal mortality rate	• The rate of fetal deaths (stillbirths) and early neonatal deaths within a specific time interval [6]	• PMR = (number of fetal + neonatal deaths)/(total number of live births + fetal deaths) × 1,000
Under-five mortality rate	• Rate of death of children younger than 5 years within a specific time interval [7]	• U5MR = (number of deaths of children younger than 5 years)/(total number of live births) x 1,000
Maternal mortality rate	• The rate of maternal deaths attributed to pregnancy within a specific time interval.	• MMR = (maternal deaths)/(live childbirths) × 100,000
Standardized mortality ratio	• The ratio of deaths observed in a specific population to deaths expected in the general population	• SMR = (number of deaths observed in population)/(number of deaths expected in population)
Years of potential life lost	• A measure of premature mortality; estimates the number of years a person in a given population would have lived if they hadn't died prematurely	• Individual YPLL = (standard year) - (age at individual's death) • Population YPLL = sum of individual YPLL across the population

Morbidity [8]

- **Definition**: the number of individuals in a population with a disease at a specific point in time or specific time interval (i.e., **disease frequency**)
- **Description**
  - Estimated using incidence and/or prevalence data
  - Data sources include: health surveys, registries (e.g., cancer registries), hospital or general practice statistics (e.g., electronic health records)

Disease burden

The "Global Burden of Disease (GBD) Study" provides estimates of the burden of diseases globally (see "Tips and Links").

- **Definitions**: estimated impact of a disease on a given population
- **Can be estimated using**, e.g.:
  - Disability-adjusted life years (DALYs): years of life lost due to disease, disability, and/or premature death
  - Quality-adjusted life years (QALYs): number of years a person is expected to live corrected for loss of quality of life caused by diseases and disabilities
  - Other indicators: financial cost, mortality, and/or morbidity

Other measures

- **Birth rate**: the number of live births divided by the number of people in a population within a specific time interval [5]
- **Fertility rate**: the number of live births among **women of childbearing age** (15–44 years) in a population within a specific time interval
- **Health-adjusted life expectancy**: average number of years a person is expected to live in full health

Leading causes of death in the US [9][10]

Leading causes of death by age in the US

	1st leading cause	2nd leading cause	3rd leading cause
< 1 year of age	Congenital anomalies	Preterm birth and/or low birth weight	Sudden infant death syndrome
1–4 years of age	Unintentional injuries	Congenital anomalies	Homicide
5–14 years of age		Cancer	Suicide
15–34 years of age		Suicide	Homicide
35–44 years of age		Cancer	Heart disease
45–64 years of age	Cancer	Heart disease	Unintentional injuries
> 65 years of age	Heart disease	Cancer	COVID-19

Leading causes of death by sex in the US

	Female individuals	Male individuals
1	Heart disease (21.8%)	Heart disease (24.2%)

Leading causes of death by sex in the US		
	Female individuals	**Male individuals**
2	Cancer (20.7%)	Cancer (21.9%)
3	Chronic lower respiratory disease (6.2%)	Unintentional injury (7.6%)
4	Cerebrovascular disease (6.2%)	Chronic lower respiratory disease (5.2%)
5	Alzheimer disease (6.1%)	Stroke (4.3%)
6	Unintentional injury (4.4%)	Diabetes mellitus (3.2%)
7	Diabetes mellitus (2.7%)	Suicide (2.6%)
8	Influenza/pneumonia (2.1%)	Alzheimer disease (2.6%)
9	Kidney disease (1.8%)	Influenza/pneumonia (1.8%)
10	Sepsis (1.6%)	Chronic liver disease (1.8%)