
# Measures of Disease Occurrence

- Ratios, Proportions, and Rates
- Prevalence and incidence
- Standardized rates

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# Descriptive Epidemiology: *who*, *where*, and *when*

**Person**, **place**, and **time**, are the key components of descriptive observational epidemiology

Since epidemiology is mainly concerned with the **occurrence of disease** in **groups** of people rather than in individuals, **populations** are at the heart of epidemiologists' measurements.

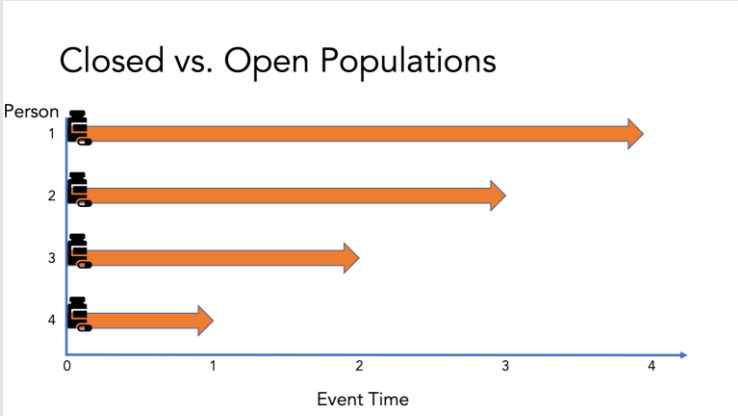
Population: group of people with a **common** characteristic; place of residence, religion, gender, age, use of hospital services, or life event (such as giving birth)…

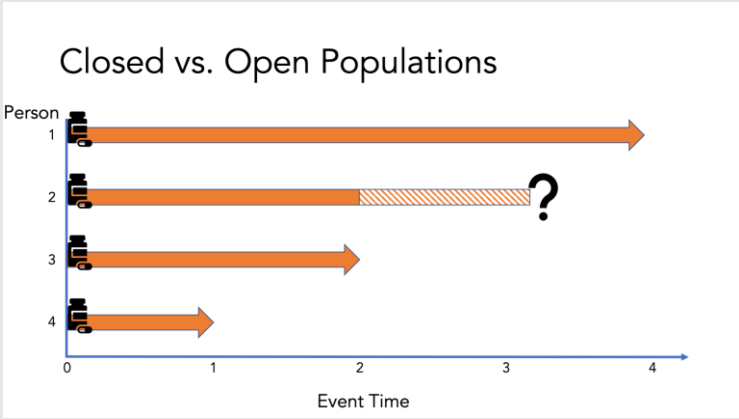
| Type of population | Key element | Example |
|---|---|---|
| **Fixed/Closed** | Membership is based on an event and is **permanent** | Japanese atomic bomb survivors |
| **Dynamic/Open** | Membership is based on a condition and is **transitory** | Residents of a city, hospital patients |

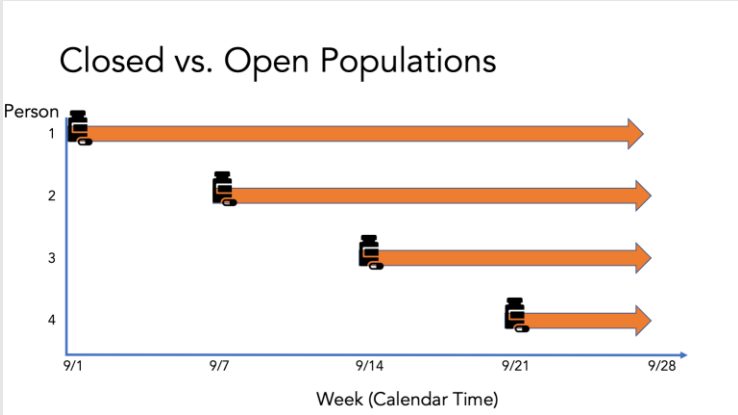
A **fixed/closed** population adds no new members over time and loses members ***only at death***

A **dynamic/open** population may gain members over time, [immigration…birth], or lose members who are still alive […emigration], or both.

The key distinction depends on **how membership** is defined. A more *subtle* concept relates to the time:




**Time axis**: follow up
All people who *ever used* a aspirin would constitute a **closed** population if time is measured from ***start of their use*** of the drug (observed thereafter for a **fixed** time period, i.e. the successive month).

**Time axis**: calendar time
For 4 weeks we observe **new users** of aspirin. This is an **open** population in *calendar time*, because **new users** might accumulate during observation.

But, we can ***partially observe*** someone…

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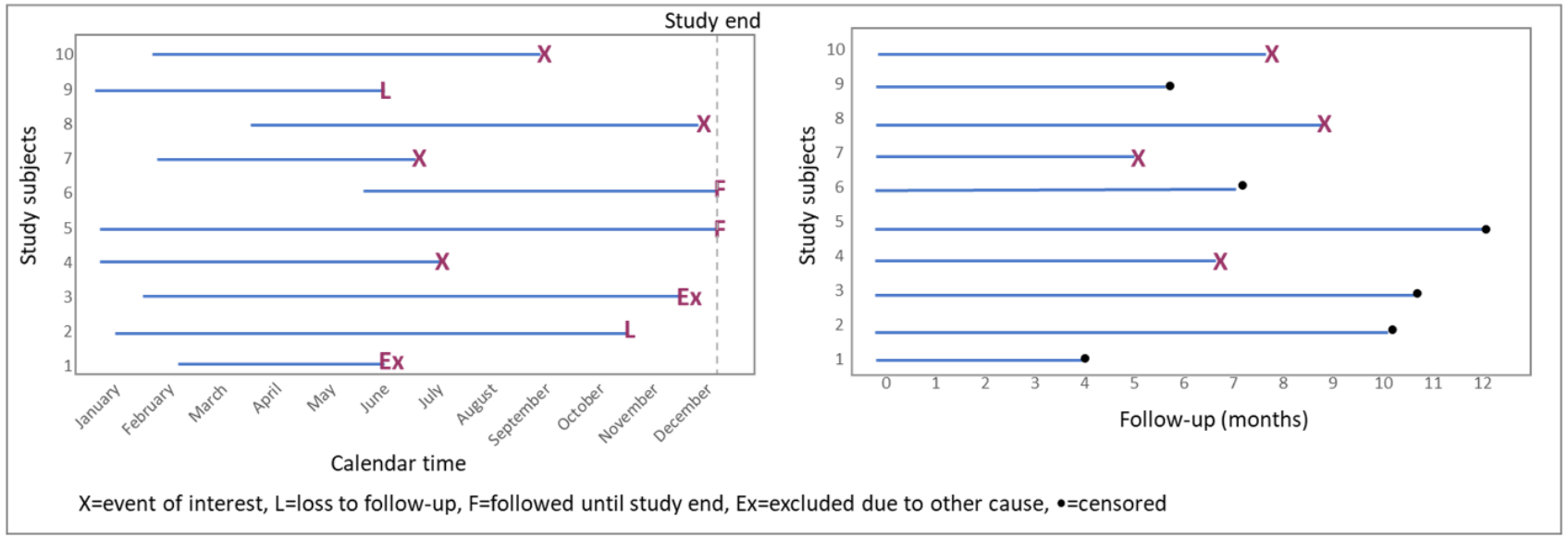
The term **cohort** is also often used: a group of people for whom **membership** is defined in a *permanent fashion*, or a population in which membership is determined by a ***single defining event*** and so becomes permanent.

- ✓ members of the graduating class of a school in a given year
- ✓ A **birth cohort** is the cohort defined by being born at a particular time/place, e.g., all people born in Ethiopia in 1990 constitute the Ethiopian birth cohort for 1990.




The study population may begin with **all the cohort members** but may gradually dwindle to a **small subset** of that cohort as those initially recruited are ***lost to follow-up (censored)***/dead.

In this context, members of any cohort can constitute a "***closed***" **population** along the time axis in which the **defining event** (e.g., birth with Down syndrome, or study recruitment) is taken as **zero time** (**baseline**).

Once the **population** is defined, then:

Epidemiologists must always consider (at least) **3** factors when they quantitatively measure how commonly a disease occurs in a group of people:

(1) the **number** of people who are affected by the disease
(2) the **size** of the population from which the cases of disease arise
(3) the **length of time** that the population is followed

County A:
population=50,000
100 new cases of breast cancer occurred over a 1-year period.

County B:
Population=5,000
75 new cases occurred over a 3-year period.

To compare, convert data into the **same** population size and time period:

County A:
200 cases/100,000 population/ 1 year.

County B:
75 cases/5,000 population/ 3 year=
25 cases/5,000 population/ 1 year=
500 cases/100,000 population / 1 year

# Ratios, Proportions & Rates

**Ratio** : one number divided by another. The entities represented by the two numbers do not have to be related to one another. The individuals in the numerator can be **different** from those in the denominator.

***Gender ratio*** is a ratio of two unrelated numbers: the number of males divided by the number of females, usually expressed as the number of males per 100 females.

Ex: according to 2016 U.S. Census estimates, the gender ratio among U.S. residents in Florida was 95.5 males per 100 females.

A **proportion** : one number divided by another, but the entities represented by these numbers are related to one another. The numerator of a proportion is always a **subset** of the denominator.

Ex: according to 2016 U.S. Census estimates, the proportion of Black U.S. residents was 0.141, or 14.1%.

**Rate** : one number divided by another, but **time** is an integral part of the denominator.

We are familiar with rates in our daily travels because a rate is a measure of how fast we travel.

The maximum speed or rate at which cars are permitted to travel is 90 kilometres per hour.

[This rate can also be written as 55 miles / 1 hour (≈ 90 km / h)].

The measure of **time** in the denominator is what makes this number a rate.

The measures of disease occurrence calculated previously for Counties A and B are also rates.



County A:
200 cases/100,000 population/ 1 year

County B:
500 cases/100,000 population / 1 year

# Measures of Disease Occurrence

The **two** basic measures of disease frequency in epidemiology are **incidence** and **prevalence**.

**Incidence** measures the occurrence of **new** disease
**Prevalence** measures the existence of **current** disease

Incidence: the occurrence of **new** cases that develop in a **candidate population** over a specified **time** period.

New disease events: for diseases that can occur more than once, it usually measures the **first occurrence** of the disease *(→ more on this in the survival analysis block)*.

Candidate population: a population of people who are "**at risk**" of getting the disease.

**Time** period : two different measures, ***cumulative*** *incidence* and *incidence* ***rate***.

**Cumulative incidence**: proportion of a candidate population that becomes diseased *over a specified period of time*.

$$\frac{\#\ New\ Cases}{\#\ At\ Risk}$$

[observed over a *certain period of time*]

Time is not an integral part of this proportion but rather is *expressed by the words* that accompany the numbers of the cumulative incidence measure.

Cumulative incidence can be thought of as the **average risk** of getting a disease over a certain period of time.

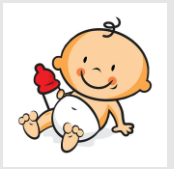
Example: lifetime risk of breast cancer among women

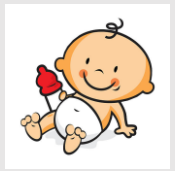
1 in 8 among U.S. women (about 12%) will develop breast cancer sometime during the course of their lives.

Cumulative Incidence: probability related to a *time interval*

Cumulative incidence (CI) is influenced by the **length of time** to which it applies.

CI is mainly used in **fixed/closed populations** when there are no or *small* losses to follow-up (and *possibly* all subjects are potentially observed *for the same amount* of time).





Cumulative incidence of pre-term birth (< 37 weeks) is the number of pre-term births divided by the number of births over a follow up of 9 months.

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**Incidence rate** : the occurrence of **new** cases of disease that arise during **person-time** of observation.

$$\frac{\#\ New\ Cases}{\#\ Person-Time}$$

The incidence rate's denominator integrates time and therefore is a true rate.

Person-time is only accrued ***among candidates*** for the disease. Could be applied to open/dynamic populations.

A person **contributes time to the denominator** of an incidence rate only up until he/she is diagnosed with the disease of interest.

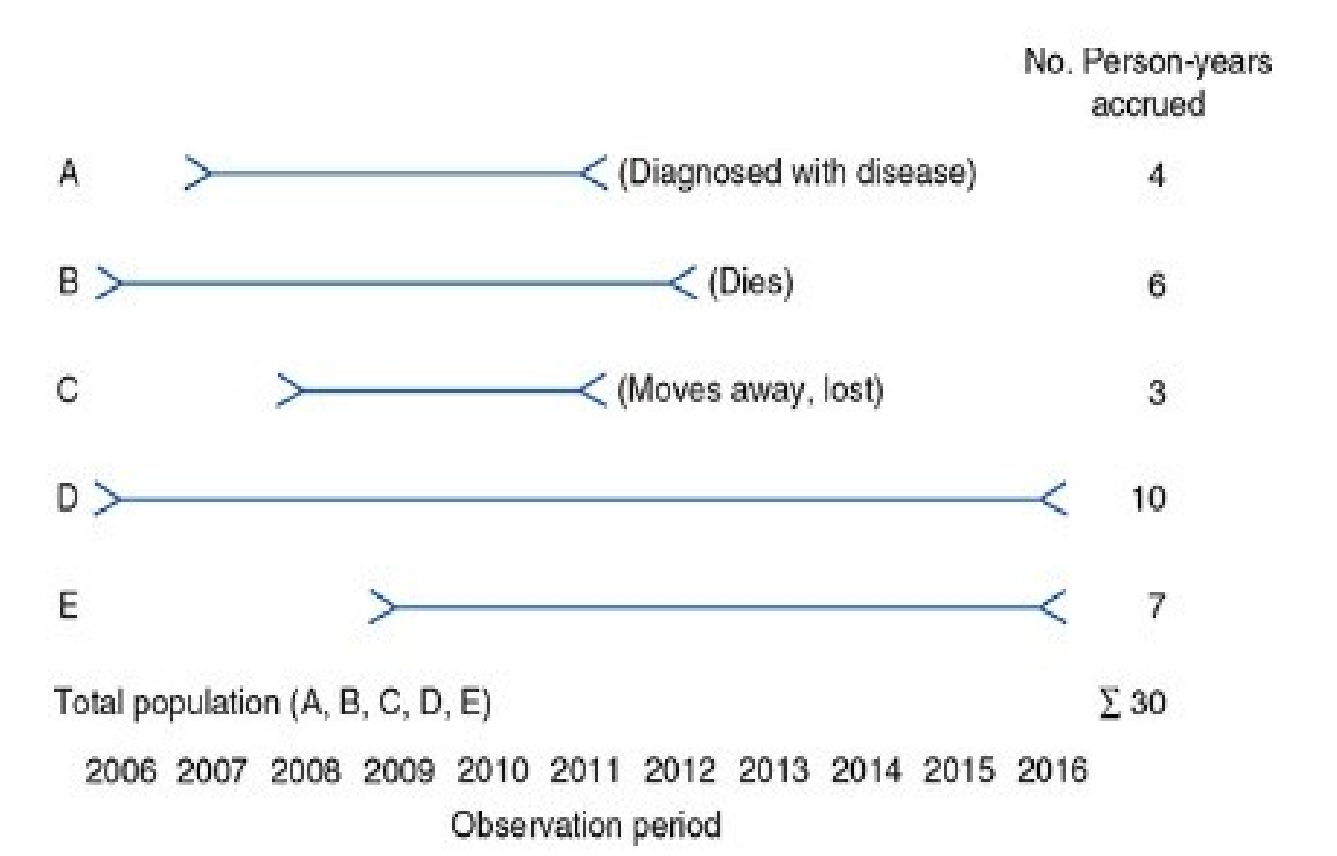
[*Person-time is the epidemiological «version» of the survival analysis approach, more on block 4*]

Incidence rate (IR) is not based upon the assumption (as CI) that everyone in the candidate population has been followed for a *fixed pre-specified* time period.

Person-time is accrued only while the candidate ***is being followed***.

Accrual of person-time stops when the person dies or is lost to follow-up.

The incidence rate can be calculated for either a fixed or dynamic population.




IR : 1/30 person-years.

Regardless of how the person-time is accrued (e.g., from 5 x 6 years or 3 x 10 years), the **person-time units** are assumed to be *equivalent*.

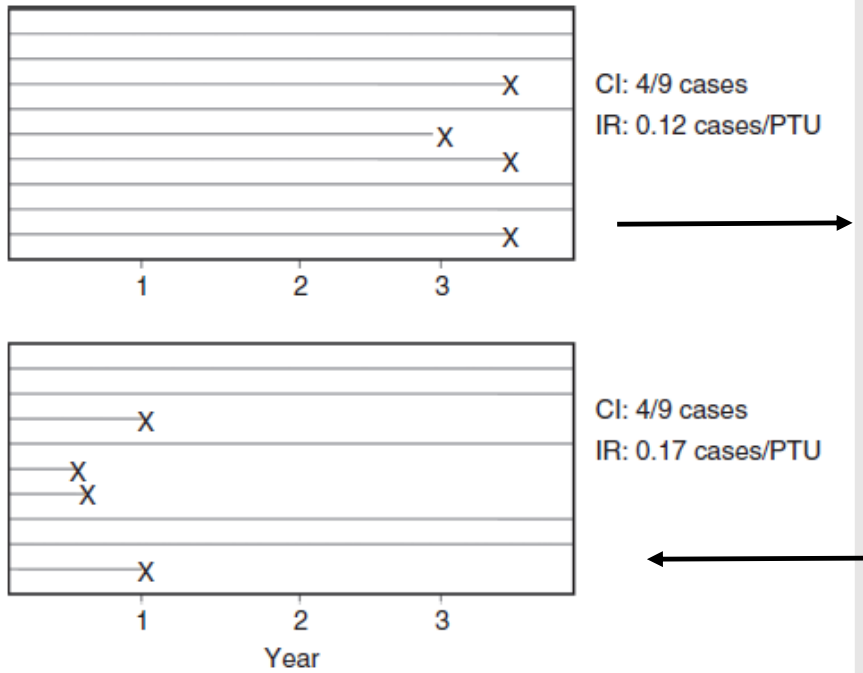
Because person-time is calculated for each subject, it can accommodate people coming into and leaving the study

CI and IR focus on measuring the ***transition*** from health to disease.

CI is easy to calculate and explain to the general audience

IR has greater accuracy, but its ***person-time*** denominator is more difficult to calculate and understand
*[statisticians "prefer" survival analysis tools, block 4]*

IR is more useful for **open/dynamic** populations, and CI is usually reserved for **fixed/closed** populations




$$PTU_1 = 4 + 4 + 3.5 + 4 + 3 + 3.5 + 4 + 4 + 3.5 = 33.5$$

$$IR_1 = \frac{4}{33.5} = 0.12$$

patients developed the disease *more slowly* than in the second example

$$PTU_2 = 4 + 4 + 1 + 4 + 0.5 + 0.5 + 4 + 4 + 1 = 23$$

$$IR_2 = \frac{4}{23} = 0.17$$

## Prevalence:

Whereas incidence measures the frequency with which new disease develops, prevalence measures the frequency of ***existing*** disease.

It is simply defined as the **proportion** of the total population that is diseased.

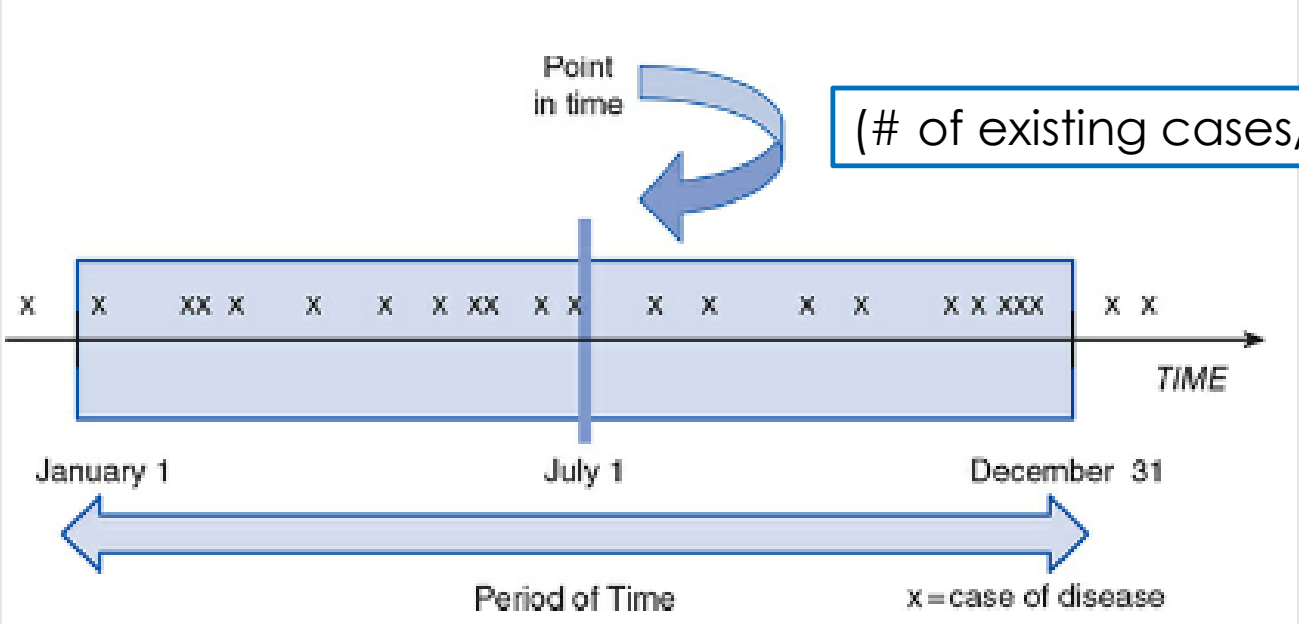
$$\frac{\#\ Cases}{\#\ People}$$

There are **two** types of prevalence measures - ***point*** prevalence and ***period*** prevalence - that relate prevalence to different amounts of time.

**Point** prevalence refers to the proportion of the population that is diseased at a **single point** in time and can be thought of as a **single snapshot** of the population.

The point can be either a particular calendar date such as July 1, 2017, or a point in someone's life, such as college graduation.

The **period** prevalence includes the number of cases that were present ***at any time*** over the course of a time-interval.




(# of existing cases/# in total population) *at point in time*

Ex: on July 1, 2017, there were 5 cases of pneumonia among the 500 nursing home residents.

The **point prevalence** of pneumonia was 5/500, or 1%.

(# of existing cases/# in total population) *during a period of time*

During the period January 1 through December 31, 2017, there were 45 cases of pneumonia among the 500 nursing home residents; the **period prevalence** was 45/500, or 9%, during the year.

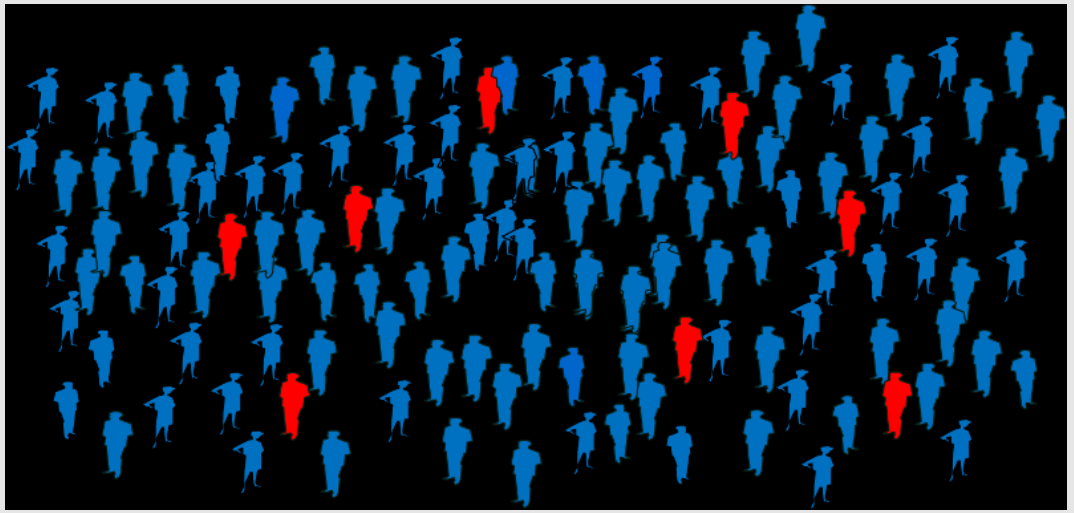
Of note: if the nursing home population had gained or lost members during the year, the ***average size*** of the nursing home population during 2017 would have been the appropriate denominator for the period prevalence measure (average or mid-interval population).

Note also that the numerator (existing cases) is a **subset** of the denominator (total population).

Unlike the numerator for the two incidence measures, the prevalence numerator includes **all currently living cases** regardless of when they first developed.

The denominator includes everyone in the population - sick, healthy, at risk, and not at risk.

Prevalence is a proportion, it is dimensionless, and its possible values range from 0 to 1, or 0% to 100%.



Just to fix :

Prevalence and incidence are sometimes **confused**.

Prevalence refers to proportion of people ***who have*** a condition at or during a particular time period, whereas incidence refers to the proportion or rate of people ***who develop*** a condition during a particular time period.

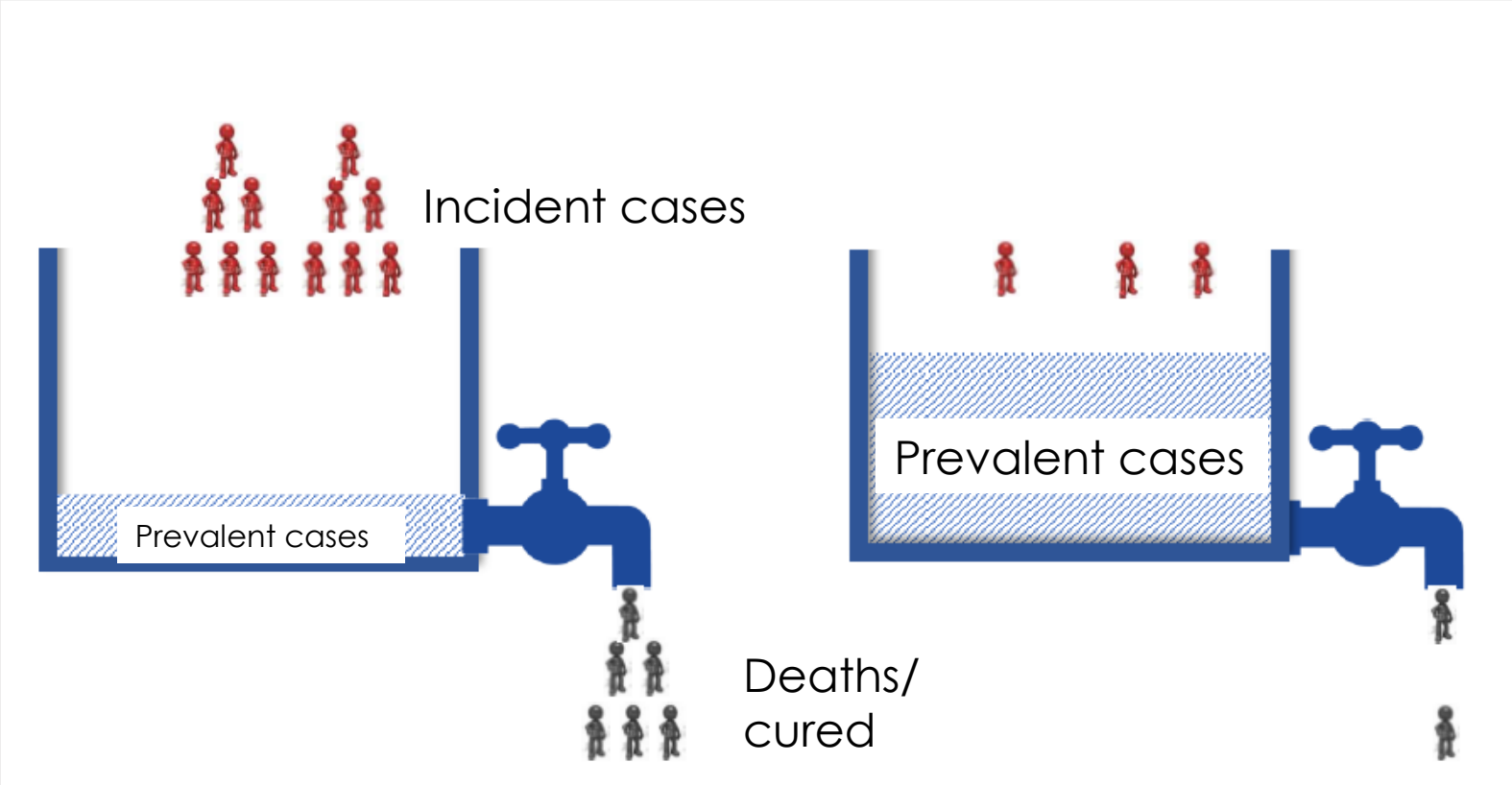
So prevalence and incidence are *similar*, but prevalence includes new and pre-existing cases whereas incidence includes new cases only.

The key difference is in their **numerators**.

Numerator of incidence = **new** cases that occurred during a given time period

Numerator of prevalence = **all** cases present during a given time period (regardless of when the illness began).

Prevalence (P) depends on the **rate** at which new cases of disease develop (IR) as well as the **duration** [average] or length of time that individuals have the disease (D).




$$P = IR * D$$

This equation assumes that the population is in *steady state* (i.e., inflow equals outflow) and that the incidence rate and duration do not change over time.

Prevalence *obscures* causal relationships because it combines incidence and survival…

But, prevalence is useful for estimating the needs of medical facilities and allocating resources.

Moreover, for **chronic conditions** (whose beginnings are difficult to pinpoint) there is often no choice but to use prevalence.

Between 1973 and 1977 the incidence of lung cancer was 45.9 per 100,000, the *average* annual prevalence of 23 per 100,000. What was the *average duration* of the disease?

Duration = Prevalence/Incidence = 23/45,9 = 0.5 years = 6 months

**High-incidence** diseases can have a **low prevalence** if the average duration is **short**.

| Example 2 : | |
|---|---|
| U.S. population at 1/7/1972 | 208.232.000 |
| TBC cases at 1/1/1972 | 44.000 |
| TBC cases «re-activated» during 1972 | 3500 |
| New TBC cases in 1972 | 32882 |

$$CI_{72} = \frac{32882}{208232000 - 44000} = 0.000158$$

15.8 cases/100.000

$$Prev_{1-1-72} = \frac{44000}{208232000} = 0.00021$$

21 cases /100.000

39 cases /100.000

$$Period\_Prev_{1972} = \frac{44000 + 3500 + 32882}{208232000} = 0.00039$$

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# Distinguishing Characteristics of Incidence and Prevalence

| Measure | Type | Units | Range | Num | Den | Major Use |
|---|---|---|---|---|---|---|
| Cumulative Incidence (CI) | Proportion | None | 0 to 1 | New cases | Population at risk | Causes, prevention, treatment |
| Incidence Rate (IR) | *True* rate | 1/t or $t^{-1}$ | 0 to infinity | New cases | Person-time at risk | Causes, prevention, treatment |
| Prevalence (P) | Proportion | None | 0 to 1 | Existing cases | Total population | Resource planning |

# Standardized Rates

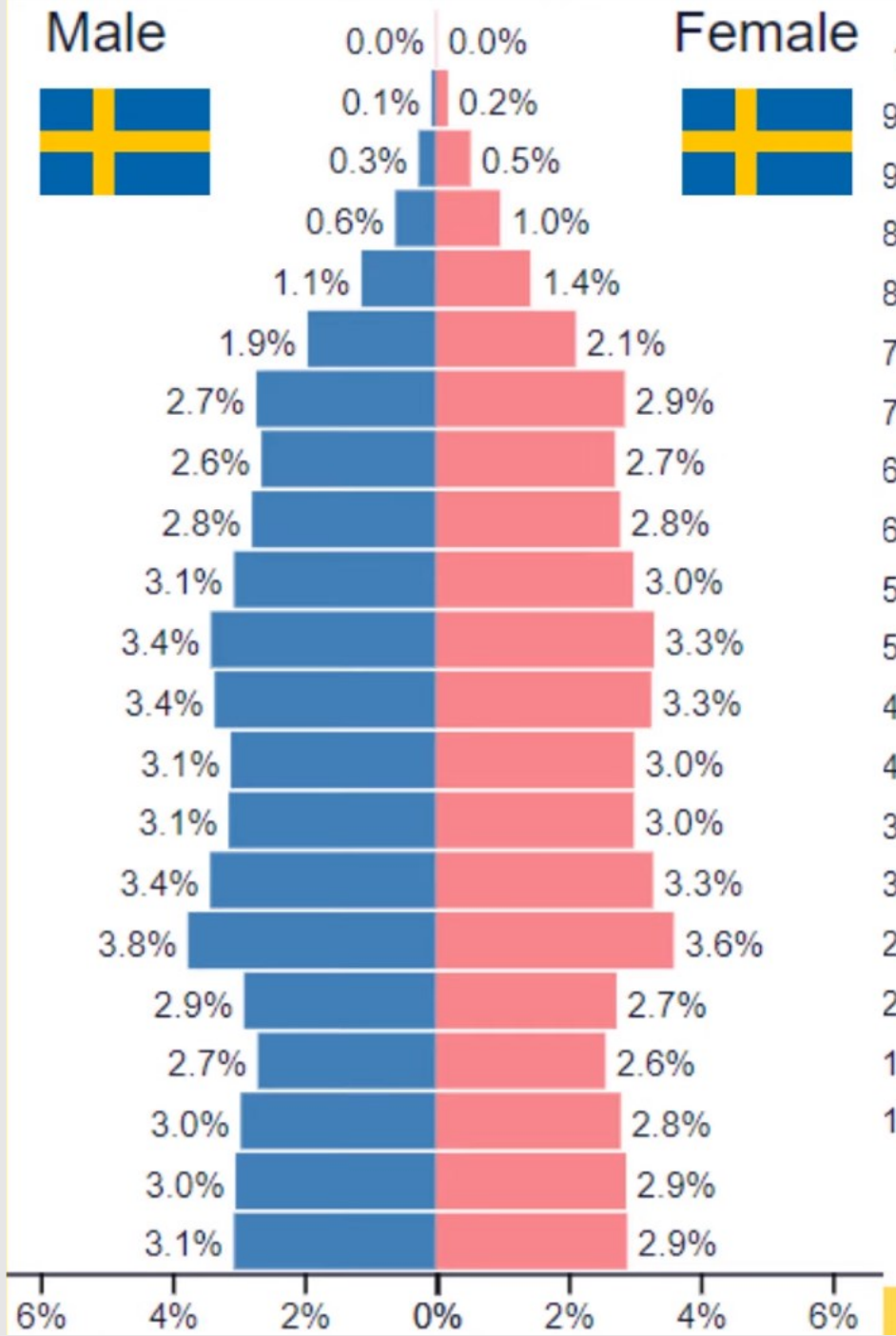
A principal role in **descriptive epidemiology** is to **compare** the incidence of disease or mortality between two or more populations.

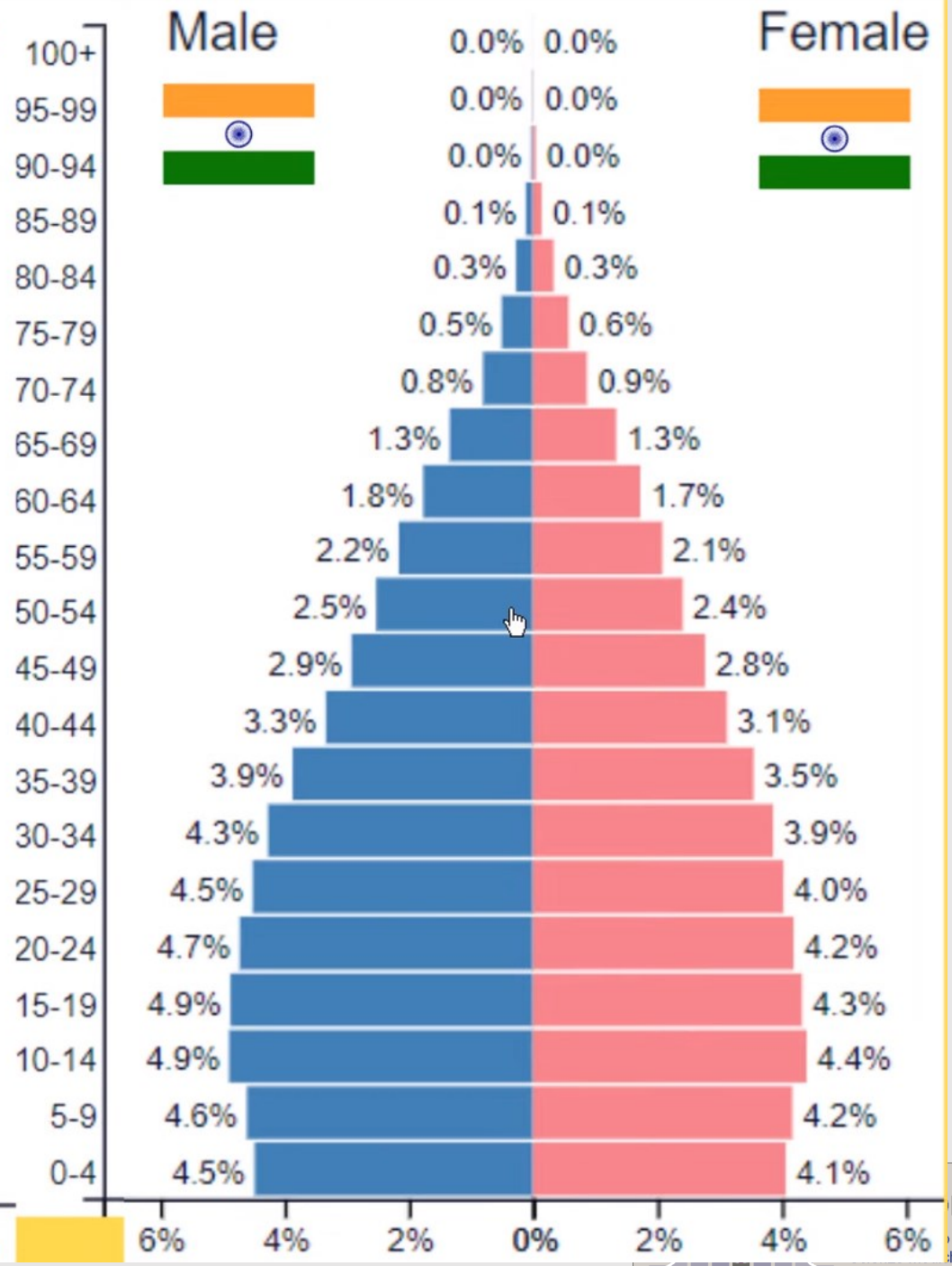
However, the comparison of **crude** mortality or morbidity rates is often **misleading** because the populations being compared ***may differ significantly*** with respect to certain underlying characteristics, such as age or sex, that will affect the overall rate of morbidity or mortality.

An older population will have a higher overall mortality rate than a younger population. As a result, variations in age will complicate any comparison between two or more populations that have different age structures.

To understand how a comparison of **crude rates** can be affected by differing population distributions, it should be recognized that a crude overall rate is simply a ***weighted* average** of the individual category specific rates, with the ***weights*** being the proportion of the population in each category.

**SWEDEN**




**INDIA**

For overcoming the effects of ***confounding*** variables such as age we could compare the **age specific rates**. While this allows for a more comprehensive comparison of mortality or morbidity rates between two or more populations, as the number of stratum specific rates being compared increases, the volume of data being examined may become unmanageable.

It is, therefore, more useful **to combine** category specific rates into a **single summary rate** that has been *adjusted* to take into account its age structure or other confounding factor. This is achieved in descriptive epidemiology by using the **methods of standardisation**.

## DIRECT METHOD

the ***standard*** used is a *reference* population

1. Compute $w_i$ from observed data
2. Apply $w_i$ to standard $Pop_i$

$$\sum_{i=1}^{n} w_i * Pop_i$$

Both direct and indirect standardisation involves the calculation of numbers of ***expected*** events (e.g. deaths) which are compared to the number of ***observed*** events.

## INDIRECT METHOD

The **standard** used is a set of specific rates

1. Use $w_i$ from standard
2. Apply $w_i$ to observed $Pop_i$

# Direct method of standardisation

| | Country A | | | Country B | | |
|---|---|---|---|---|---|---|
| Age - group | No. of deaths | Population | Rate per 1,000 pyrs | No. of deaths | Population | Rate per 1,000 pyrs |
| 0-29 | 7,000 | 6,000,000 | 1.2 | 6,300 | 1,500,000 | 4.2 |
| 30-59 | 20,000 | 5,500,000 | 3.6 | 3,000 | 550,000 | 5.5 |
| 60+ | 120,000 | 2,500,000 | 48 | 6,000 | 120,000 | 50 |
| **Total** | **147,000** | **14,000,000** | **10.5** | **15,300** | **2,170,000** | **7** |

The overall **crude** mortality rate is higher for country A (10.5 deaths per 1,000 person years) compared with country B (7 deaths per 1,000 person years), despite the **age-specific** mortality rates being higher among all age-groups in country B.

# Direct method of standardisation

Age-structure of a "**standard**" population

| | |
|---|---|
| 0-29 | 100,000 |
| 30-59 | 65,000 |
| 60+ | 20,000 |
| Total | 185,000 |

Number of **expected** deaths for A and B **applied to the standard** population.

| | **Country A** | **Country B** |
|---|---|---|
| | Expected deaths | Expected deaths |
| 0-29 | 0.0012 x 100,000 = 120 | 0.0042 x 100,000 = 420 |
| 30-59 | 0.0036 x 65,000 = 234 | 0.0055 x 65,000 = 357.5 |
| 60+ | 0.048 x 20,000 = 960 | 0.05 x 20,000 = 1,000 |
| **Total expected deaths** | 1,314 | 1,777.5 |
| **Age adjusted rate** | **1,314/185,000 = 7.1 per 1,000 pyrs** | **1,777.5/185,000 =9.6 per 1,000 pyrs** |
| **Age standard rate ratio (B:A)= 9.6/7.1 = 1.35** | | |

**the rate is divided back by 1000 to give the basic rate

**Controlling for age**, mortality in B is **35% higher** than in A (CMR= *Comparative* Mortality Ratio).

The 'standard population' may be the distribution of one of the populations being compared or an outside standard population such as the 'European' or 'World' standard population.

# Indirect method of standardisation

Commonly used when age-specific rates are unavailable. For example if we did not know the age specific mortality rates for country B.

In this method, **a set of rates from a *standard population*** (country A) is applied to each of the populations being compared to calculate standardized morbidity/mortality ratios.

| | Country A | Country B |
|---|---|---|
| | Expected deaths | Expected deaths |
| 0-29 | 0.0012 x 6,000,000 = 7,200 | 0.0012 x 1,500,000 = 1,800 |
| 30-59 | 0.0036 x 5,500,000 = 19,800 | 0.0036 x 550,000 = 1,980 |
| 60+ | 0.048 x 2,500,000 = 120,000 | 0.048 x 120,000 = 5,760 |
| **Total expected deaths (E)** | 147,000 | 9,540 |
| **Total observed deaths (O)** | 147,000 | 15,300 |
| | | |
| **Standardised Mortality Ratio O/E x 100** | 100 | 160 |

# **expected deaths** if B had the same age-specific mortality rates as A.

# observed deaths in Country B is **60% higher** than the # we would expect if Country B had the same mortality experience as Country A

$$SMR = \frac{160}{100} = 1.6$$

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