Lecture 2: Measuring the Occurrence of Disease

Lecture prepared by Dr. Hailey Banack, PhD

Surveillance

- Fundamental role of public health- provides data on occurrence (new cases) of disease and monitoring the health of the population.

"ongoing systematic collection, analysis, and interpretation of health data essential to the planning, implementation, and evaluation of public health practice"

-Includes infectious diseases and other conditions (chronic, congenital, injuries), vaccination rates, specific organisms (TB, measles)

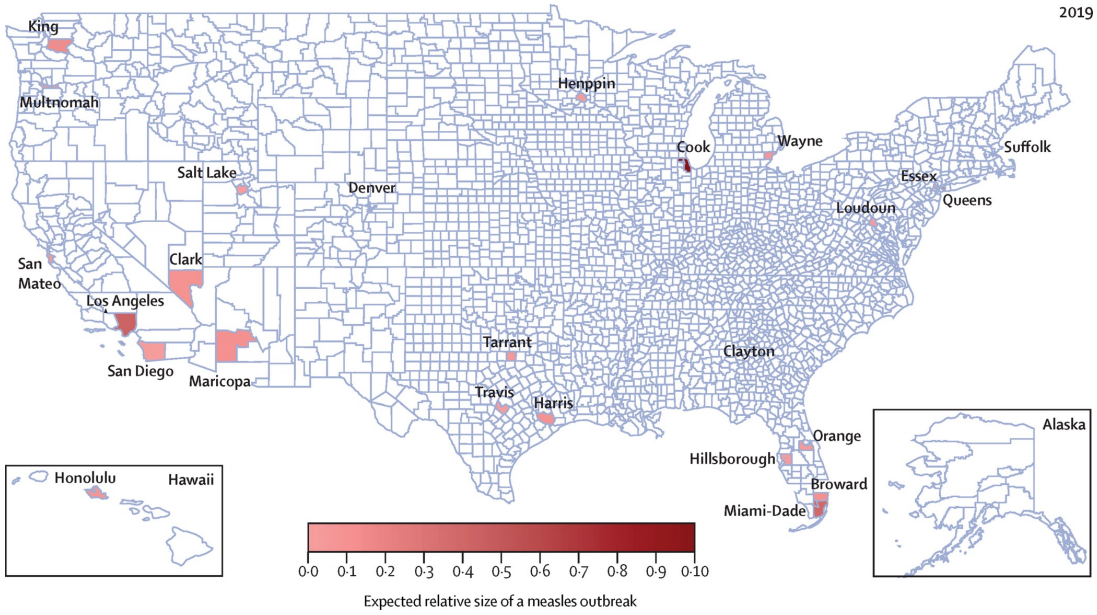
Measles in United States

- Measles vaccine first available in 1963
  - Prior to that ~3-4 million children got measles /year
  - 400-500 deaths per year,
  - ~50,000 hospitalizations
  - 1000 cases of encephalitis

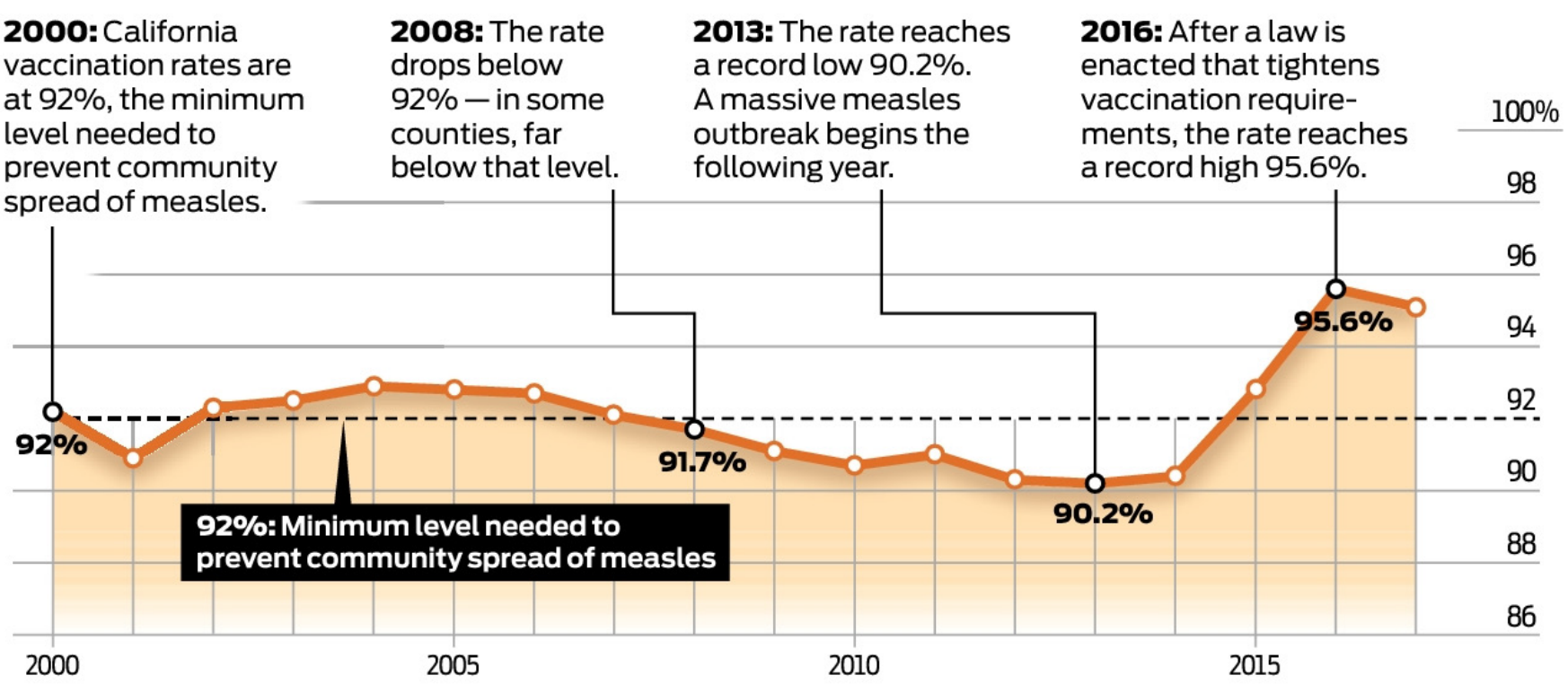
- Measles was declared eliminated in the U.S. in 2000
  - Absence of disease transmission for more than 12 mo
  - Disease no longer constantly present in the U.S.
  - **Historic public health accomplishment, driven by vaccination rates**

Measles vaccines & surveillance

- In 1999, Andrew Wakefield published a paper claiming that MMR vaccines are a cause of autism in children
- Caused widespread panic, global decline in vaccination rates
  - Increased number of measles cases
  - Increased number of hospitalizations
  - Deaths



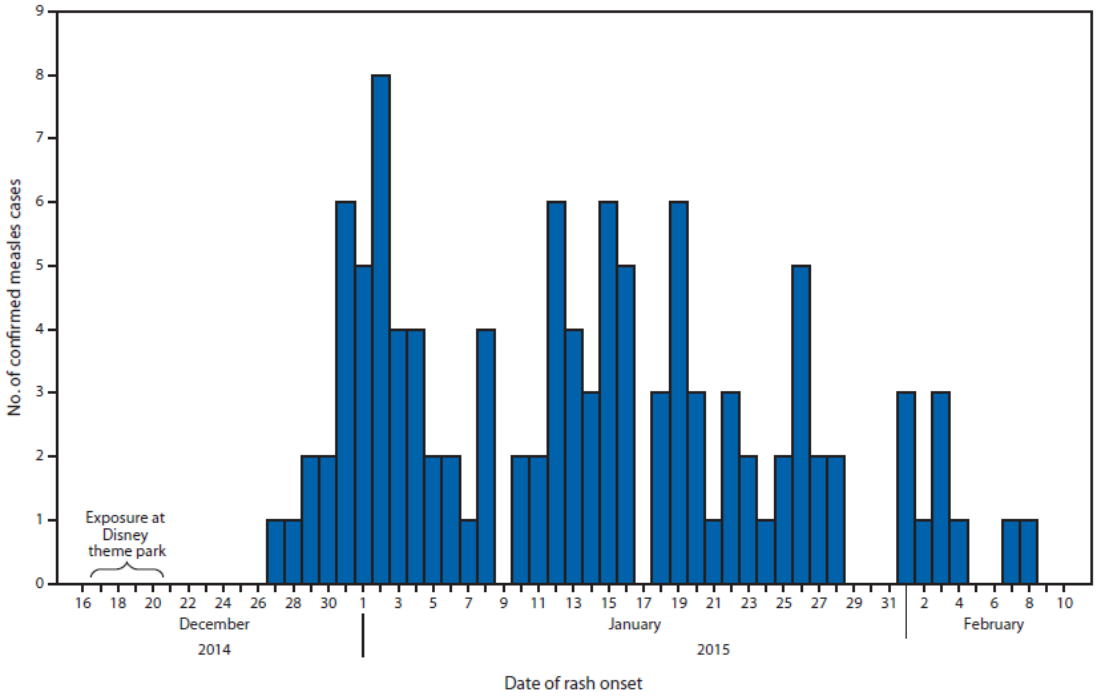
California Measles Outbreak



Note: Vaccination rates are calculated for incoming kindergarten students.

Source: California Department of Public Health

Disney Measles Outbreak



As of February 11, a total of 125 measles cases with rash occurring during December 28, 2014–February 8, 2015, had been confirmed in U.S. residents connected with this outbreak

"45% were unvaccinated… 12 of the unvaccinated patients were infants too young to be vaccinated. Among the 37 remaining vaccine-eligible patients, 28 (67%) were intentionally unvaccinated because of personal beliefs…Among the 84 patients with known hospitalization status, 17 (20%) were hospitalized."

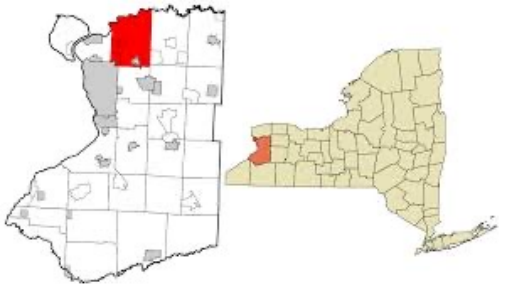
Defining the Population

- A population is a group of people, defined by at least one organizing characteristic
- The definition **you** choose has implications for analysis, interpretation of study results, and generalizability of results
- Can be observed at a single point in time (cross-sectionally) or over time (longitudinally)

Characteristics of Persons, Events or Exposures

There are three main categories that are useful for defining eligibility for a study population:

- Geographic space and time
- Defining characteristic, event, or exposure
- Criteria that promote the likelihood of a successful study



Identifying a Population

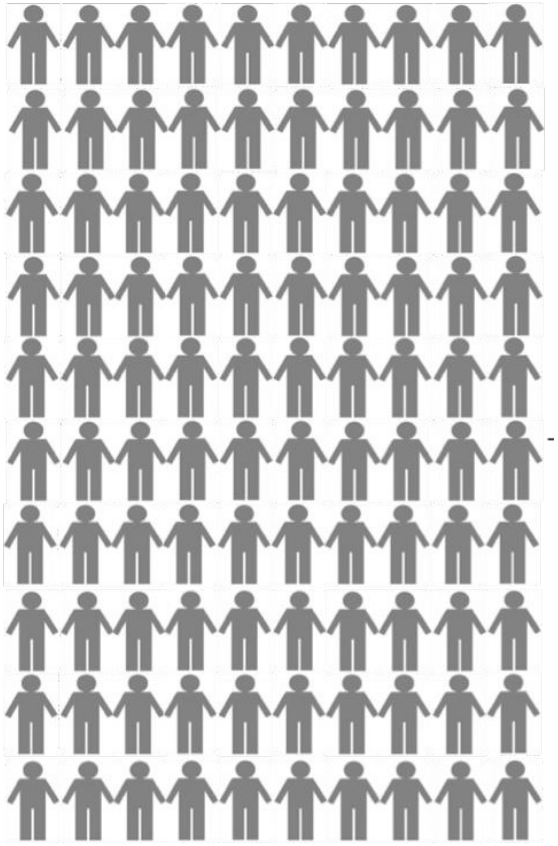
1. **Eligibility criteria**
   - Geographic and temporal period of interest
   - Characteristics of persons, events or exposures
   - Factors that promote successful study completion
2. **Whether individuals can move in or out of the population**
   - Closed population
   - Open population

Closed and Open Populations

- Closed population: adds no new members over time, loses members only to death
  - Index time/entry time is the point at which an individual joins a population
- Open population: gains members over time through immigration or birth, and loses members over time through emigration and death

Sometimes called stationary (”not changing”) and dynamic (“changing over time”) but this is confusing so I don’t use this terminology

Closed Population



N= 100

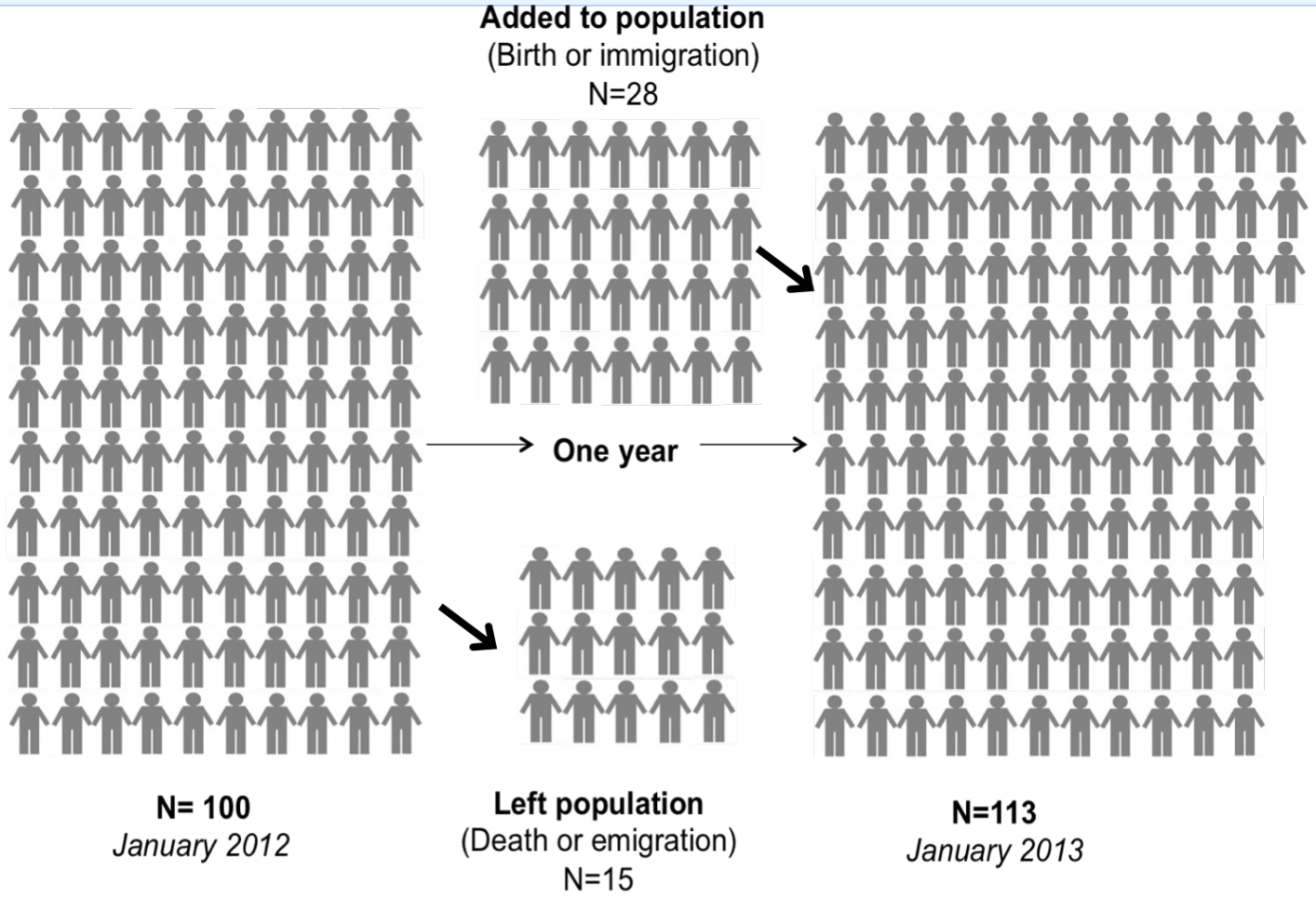
Closed

e.g., 100 People living in Delhi with TB in January 2012

-Adds no new members, loses members only to death

-Recruit a population and follow them for some period of time and **no new subjects** are enrolled

Open Population

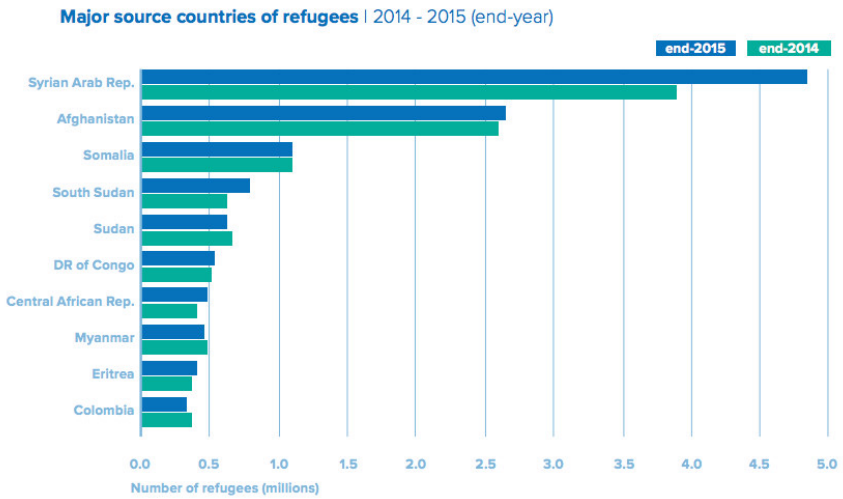


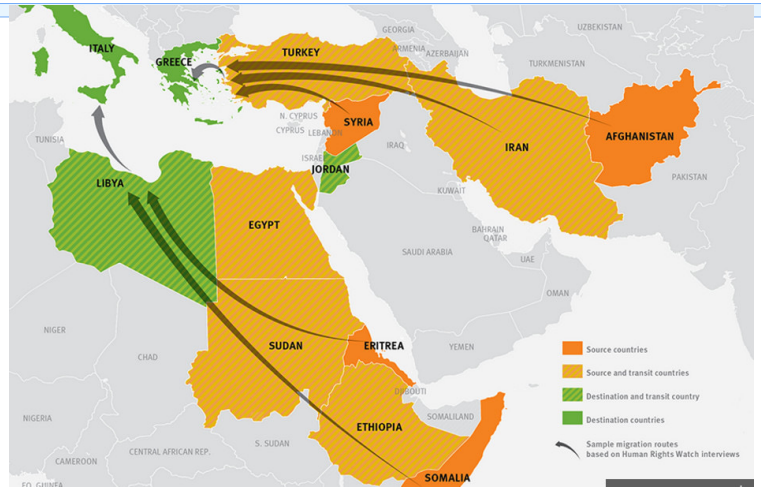
Closed populations: Natural Disasters

- Provide a clear demonstration of the concept of a closed population
- Example: Superstorm Sandy

Closed population: Nurses Health Study

Open populations: Global refugee crisis





-Number of displaced persons is at the highest levels since WWII

-Multifactorial, country-specific drivers of this crisis (e.g, civil war in Syria, Taliban rule, oppression of specific ethnic groups)

-End result is people fleeing their homes/countries for safer lives in Europe

-In 2015, 1 million refugees fled to Europe

Steady State Population

- Specific type of open population
- Number of people entering = number of people exiting
- Births balance deaths, immigration balances emigration
- Very uncommon in practice, more of a theoretical concept to understand

Study Populations

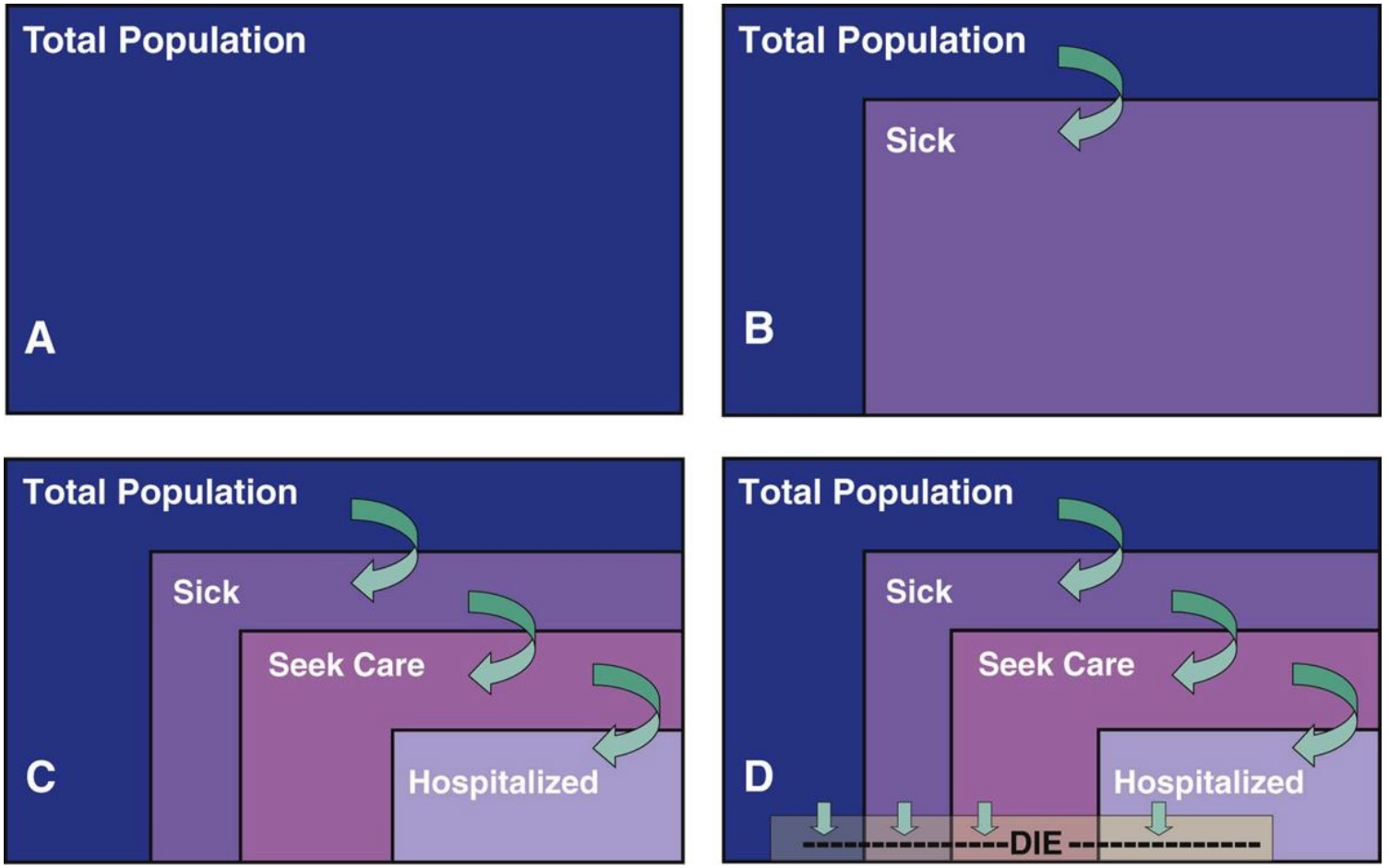
Three common terms used to describe populations in epidemiology

Target population: group for whom info is relevant or applicable

Source population: Subset of target eligible from which persons will be sampled

Study population: subset of source pop'n included in measures of disease frequency

Morbidity and Mortality in Populations



Health and Disease

- World Health Organization (WHO): “Health is a state of complete physical, mental and social well-being, not merely the absence of disease or infirmity”
- Diseases are catalogued by the WHO in the International Classification of Disease (ICD-10)
- Defining disease is more challenging
  - Simple definition “illness or sickness characterised by specific signs or symptoms”
- Definition of disease changes over time
  - Changes in diagnostic ability or social/economic reasons
  - E.g. osteoporosis- normal part of aging → disease

Definition of diseases

-**Infectious disease:** caused by germs (such as bacteria, viruses, and fungi) that enter the body, multiply, and can cause an infection. Some infectious diseases are contagious (or communicable), that is, spread from one person to another.

-**Chronic disease:** conditions that last 1 year or more and require ongoing medical attention or limit activities of daily living or both.

Infectious	Chronic
• Foodborne and waterborne illnesses • Infections that spread in hospitals • Infections that are resistant to antibiotics • Deadly diseases like Ebola and anthrax • Illnesses that affect immigrants, migrants, refugees, and travelers • Diseases caused by contact with animals • Diseases spread by mosquitoes, ticks, and fleas	• Heart disease • Cancer • Chronic lung disease • Stroke • Alzheimer's disease • Diabetes • Chronic kidney disease

Social construction of disease

- A notable example of how social influences shape our definition of what a disease is
- 1968: Homosexuality classified as a mental disorder, caused by endocrine disruption requiring hormone therapy or electroshock therapy
- 1974: APA votes removes homosexuality from DSM
- Sexual orientation, preferences and gender identity are all recognized now as multi-faceted characteristics of individuals, not pathological disease/disorders
- Raises an important question→ who gets to decide?!

Example: Osteopenia

- Loss of bone mass, weaker bones than normal but no clinical increase in risk of fracture

I'd encourage you to read this, because it's a fascinating story:

https://www.npr.org/2009/12/21/121609815/how-a-bone-disease-grew-to-fit-the-prescription

Natural History of Disease

- In most instances, diseases don't get diagnosed until they present clinically (symptoms have developed)
- Sub-clinical and asymptomatic disease are also important, especially for infectious disease transmission

Types of Non-Clinical Disease

Pre-Clinical Disease: Not clinically apparent but is destined to progress to clinical disease (e.g., HPV-> cervical cancer)

Sub-clinical Disease: Not clinically apparent and is not destined to become clinically apparent (e.g., asymptomatic COVID)

Persistent Disease: Clinical infection that results in subsequent symptoms that are different than original symptoms (e.g., post-polio syndrome)

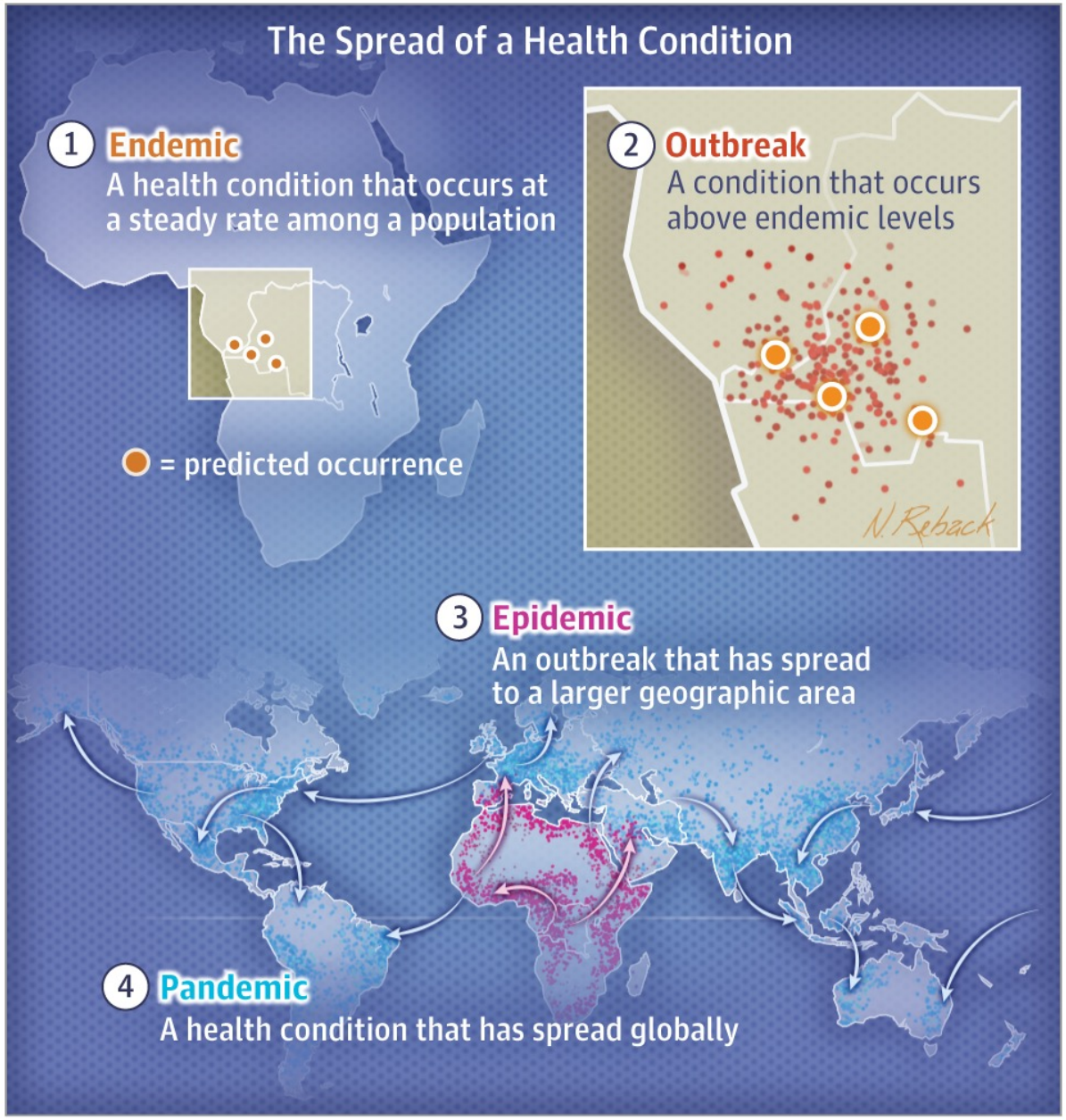
Latent Disease: An infection with no active multiplication of the agent (e.g., herpes virus)

Sub-clinical disease: COVID & the Diamond Princess cruise

- 3063 COVID tests were administered on the cruise
- Of those, 634 were positive cases
- 306 were symptomatic and 328 were asymptomatic
- Realization that ~50% of individuals infected with COVID do not have symptoms

Disease Carriers

- Harbor virus or bacteria but is not deemed infected by serology and has no antibody response
- Can still infect others in short or long term
- ”Typhoid Mary” carried *Salmonella typhi* and caused several outbreaks of Typhoid fever but never got sick herself


The Spread of a Health Condition
1 Endemic
A health condition that occurs at a steady rate among a population
= predicted occurrence
2 Outbreak
A condition that occurs above endemic levels
N. Reback
3 Epidemic
An outbreak that has spread to a larger geographic area
4 Pandemic
A health condition that has spread globally

Endemic, Epidemic, Pandemic

Endemic: usual presence of a disease within a given geographic area	**Malaria in Africa**
Outbreak: Sudden increase in cases beyond what is expected	**E.Coli from romaine lettuce**
Epidemic: Outbreak that spreads to a wider area	**Zika virus in Latin America**
Pandemic: Worldwide epidemic	**1918 Spanish Influenza**

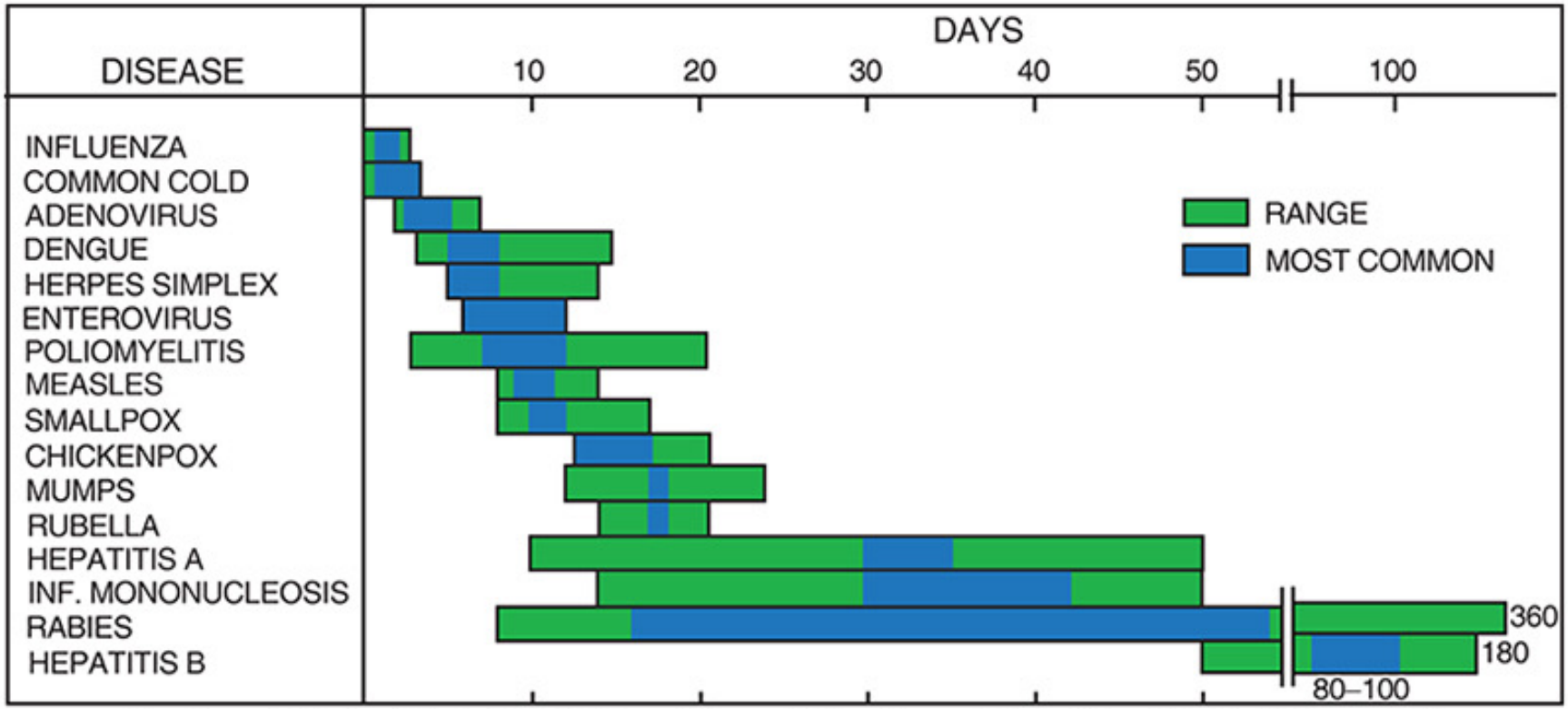
1918 Spanish Influenza

Incubation Period

- Time from exposure to infection to the onset of clinical illness
- You may feel completely healthy as the virus/bacteria replicates to a level that it can cause clinical disease
- If someone is known to have been exposed to an infected individual/agent, they may be required to **quarantine** for a certain period of time to determine if they develop symptoms
- If they do develop symptoms, they should be **isolated**

Note distinction between quarantine of a pre-symptomatic person and isolation of a symptomatic person

Differences in incubation periods



From Evans AS, Kaslow RA, eds. *Viral Infections of Humans: Epidemiology and Control*. 4th ed. New York: Plenum; 1997.

Measurement in Epidemiology

1. Measures of occurrence and frequency

- Counts, prevalence, incidence

2. Measures of association

- Risk ratio, risk difference, odds ratio …

3. Measures of effect: burden

- Attributable fraction, exposed attributable fraction, population attributable fraction

Terminology

- **Counts**: An integer (whole number)
- **Ratio:** One number divided by another (A/B)
- **Proportion:** A ratio in which the numerator is included in the denominator [A/(A+B)]
  - It is bounded by the range [0,1]
  - Dimensionless because the units in the numerator and denominator cancel out

Terminology

Rate: A ratio in which the numerator is the number of new events (N) and the denominator is the sum of "person-time" (T) contributed by people at risk for the event

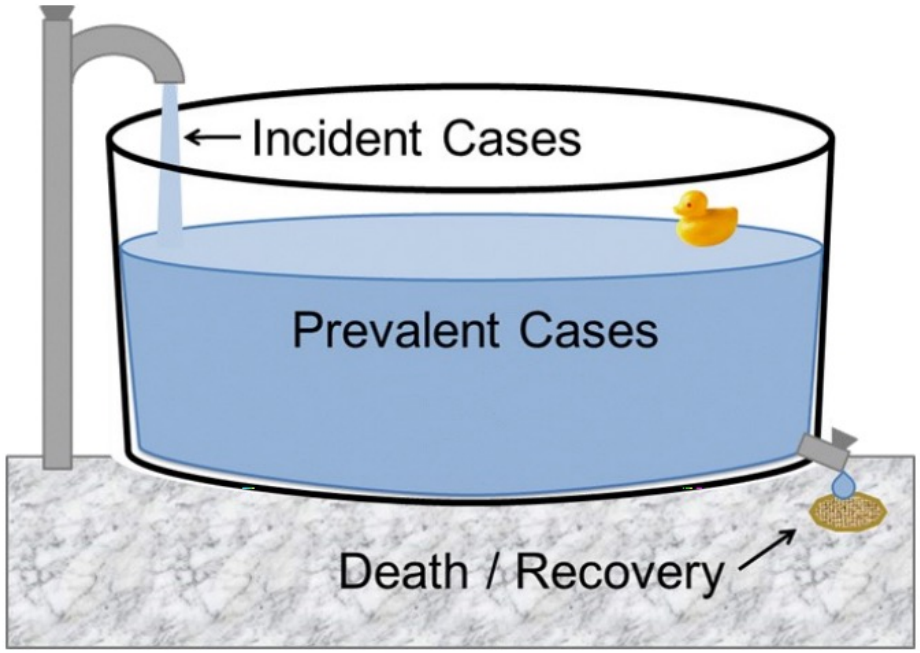
- Not bounded like a proportion, range [0,∞]
- Unit of a rate is TIME

$$\text{Rate} = \frac{\mathbf{N}}{\mathbf{T}}$$

Incidence vs. Prevalence

- Measures of **incidence** tell us about **new cases** of disease in the population over a specific time period

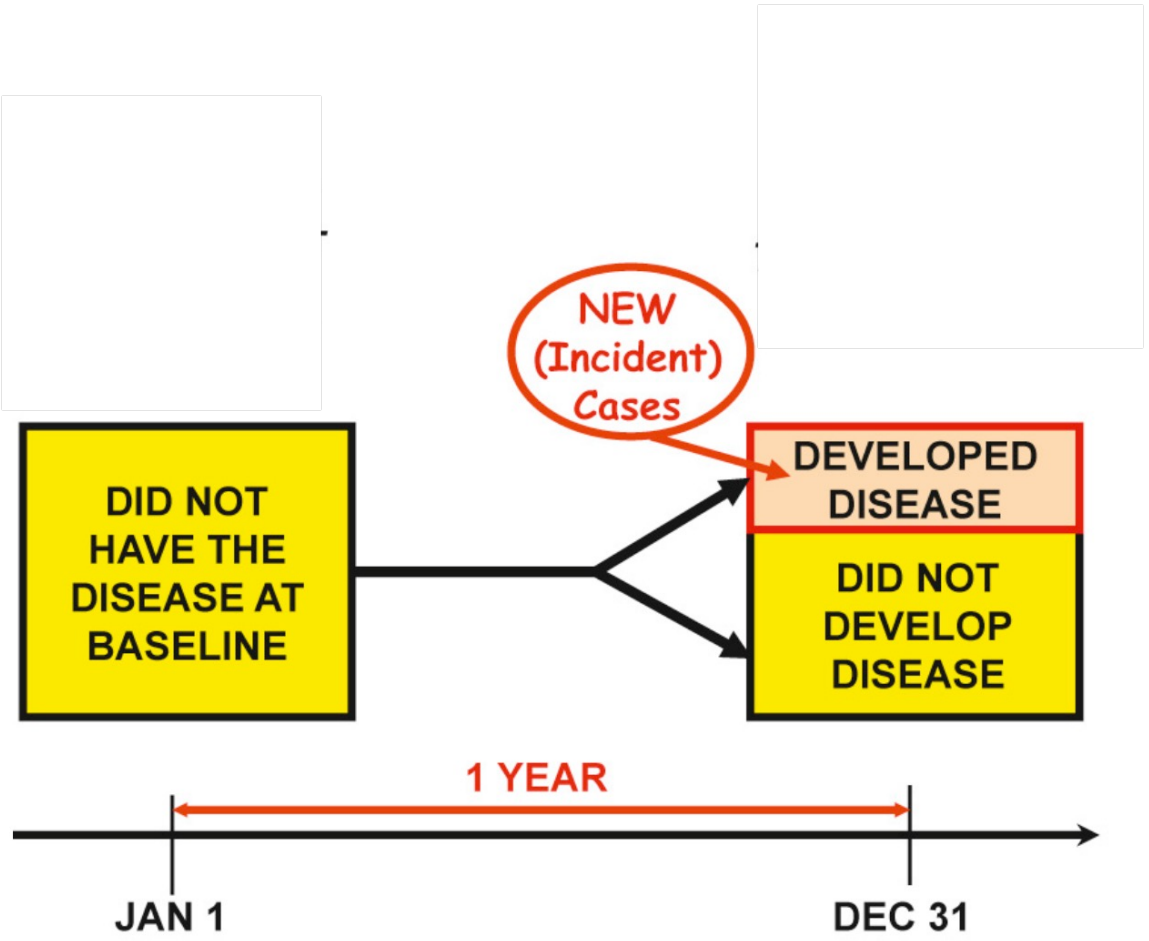
- Measures of **prevalence** tell us about **existing cases** of disease in a population over a specific time period



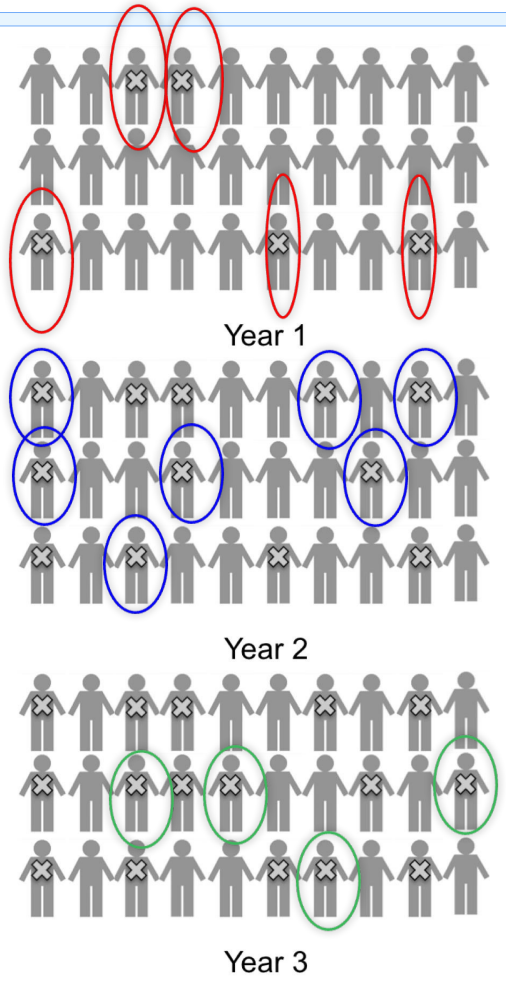
Incidence Proportion

$$\text{Incidence Proportion} = \frac{\text{Number of new cases of disease}}{\text{Number of people in population}}$$

- Also known as cumulative incidence or **RISK**
- Tells us the fraction of the population affected by disease/death
- Denominator composed of people who have been followed for the entire time period
- Must specify time component (1-year incidence, 10-year incidence)


NEW
(Incident)
Cases
DID NOT
HAVE THE
DISEASE AT
BASELINE
DEVELOPED
DISEASE
DID NOT
DEVELOP
DISEASE
1 YEAR
JAN 1
DEC 31

Incidence Proportion



Year 1 : 5 incident cases of disease
Incidence proportion Year 1= 5/30

Year 2 : 7 incident cases of disease
Incidence proportion Year 2= 7/30

Year 3 : 4 incident cases of disease
Incidence proportion Year 3= 4/30

Attack Rate

$$\text{Attack Rate} = \frac{\text{Number of susceptible individuals who develop disease}}{\text{Total number of susceptible people in the epidemic period}}$$

Proximity of Residence to Bodies of Water and Risk for West Nile Virus Infection: A Case-Control Study in Houston, Texas

Melissa S. Nolan,[1] Ana Zangeneh,[1] Salma A. Khuwaja,[2] Diana Martinez,[3] Susan N. Rossmann,[4] Victor Cardenas,[1] and Kristy O. Murray[1]

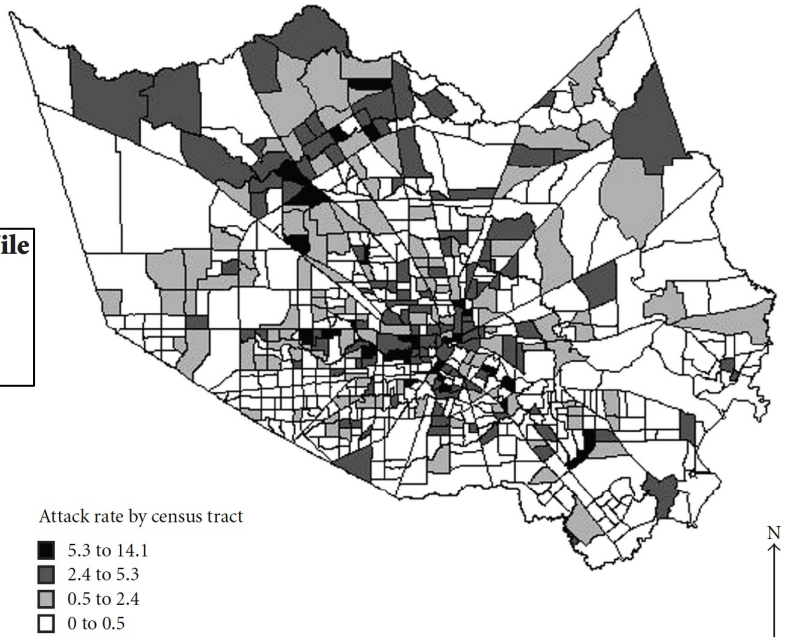


FIGURE 1: Attack rate: number of reported West Nile virus cases per 10,000 population using 2000 US census tract data in the Houston metropolitan area, Texas.

Secondary Attack Rate

- Spread of disease in a family, household, dwelling unit, dormitory, or similar population group
- Close contacts of primary cases of disease

Example: Chicken pox outbreak

- 18 children from one kindergarten class all developed chicken pox
- There were 29 children in the classroom who were susceptible and 1 teacher
  - Attack rate= 18/30= 0.6 = 60%
- Two weeks later (the incubation period), 5 siblings of the primary cases had developed chicken pox
- The 18 households included 86 susceptible persons (parents, siblings)
  - Secondary attack rate= 5/(86-18)= 0.07=7%

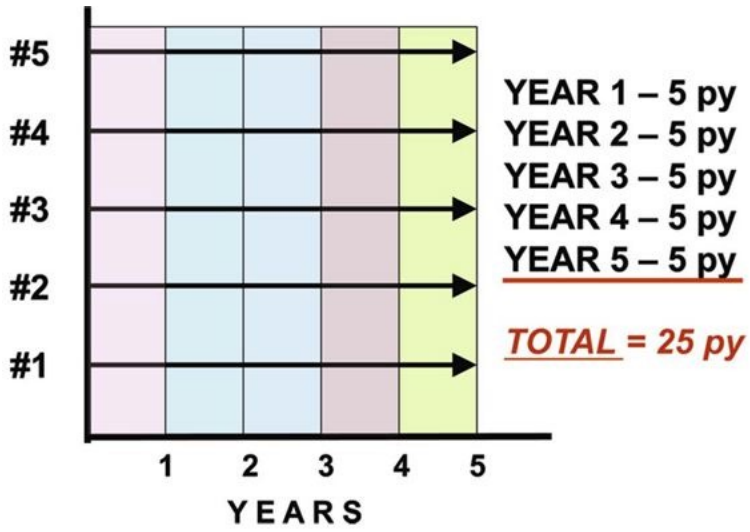
Incidence Rate

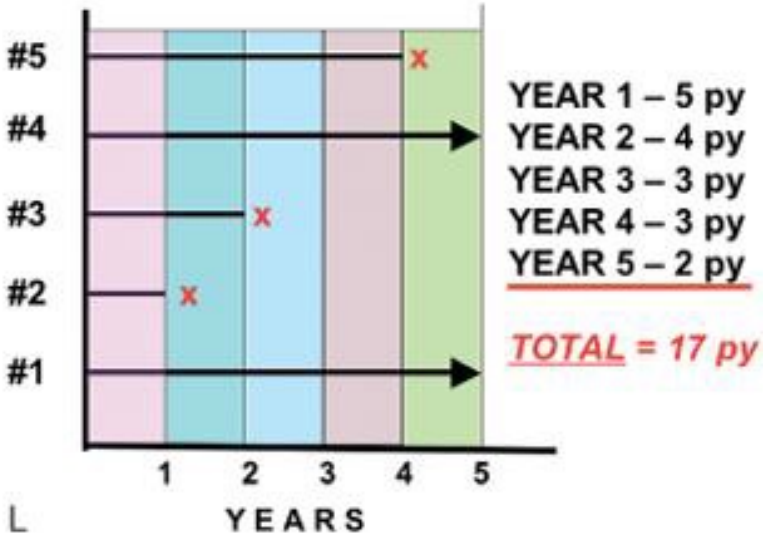
$$\text{Incidence Rate} = \frac{\text{Number of new cases of disease}}{\text{Total person-time at risk for disease}}$$

- Also known as incidence density
- Tells us how fast the disease is occurring in the population
- Denominator consists of 'person-time' or the sum of the total amount of time that each person was observed
- Denominator accounts for people who have not been followed for the entire time period (i.e., loss to follow-up, drop out)

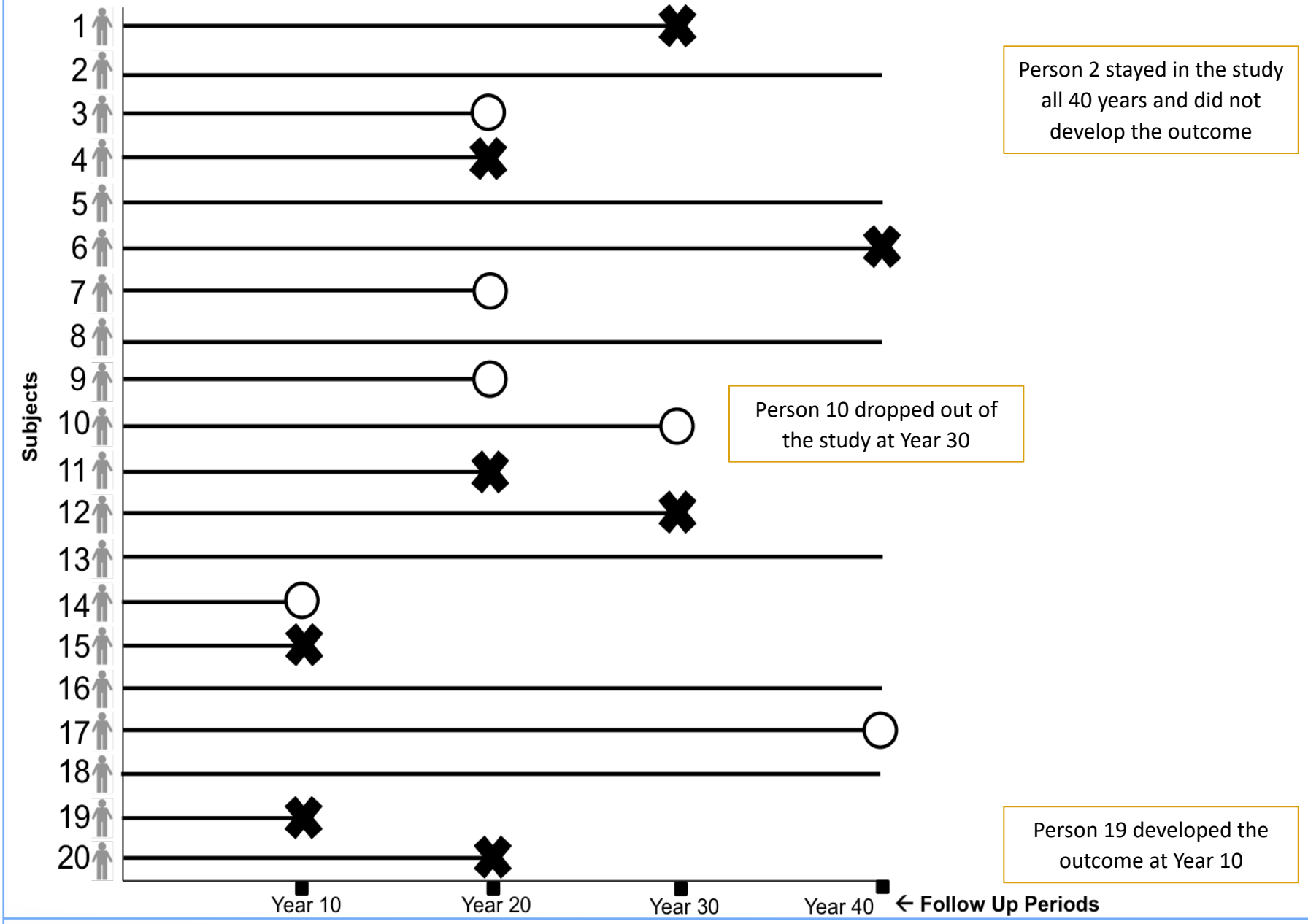
What does Person-Time mean?

- Simply the amount of time each person is in your study population





- Person years (PY) is most common



(Keyes and Galea, 2013)

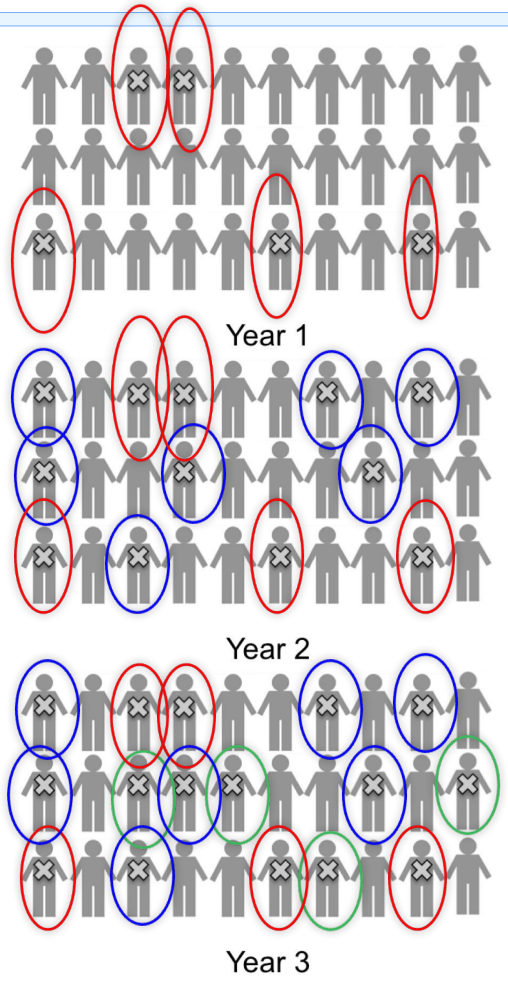
Calculating Prevalence

$$\text{Prevalence} = \frac{\text{(Number of new cases of disease + existing cases)}}{\text{Number of people in population}}$$

Point prevalence- proportion of people in a population with disease at a specific *point* in time

Period prevalence- proportion of people in a population with disease over a specified *time period.*

Measuring Prevalence



Year 1 : 5 incident cases of disease
Prevalence= 5/30= 0.16

Year 2 : 7 incident cases of disease
Prevalence= (5+7)/30= 0.40

Year 3 : 4 Incident cases of disease
Prevalence= (5+7+4)/30 =0.53

Increasing & Decreasing Prevalence

Factors that INCREASE prevalence	Factors that DECREASE prevalence
- Longer duration of disease - Prolonging of life without cure Increased incidence - In-migration of cases - Out-migration of healthy people - In-migration of susceptible people - Better diagnosis and detection	- Shorter duration of disease - High case fatality rate - Decreased incidence - In-migration of healthy people - Out-migration of cases - In-migration of immune people - Poorer cases detection

Relation between incidence and prevalence

- Prevalence of disease depends on both incidence and duration of disease after onset.
- Prevalence will increase as incidence of disease increases and will increase as the duration of disease increases
- In a steady state population with a constant incidence rate and duration of disease (D), the prevalence (P) and incidence (I) are related:

$$P = \frac{I\bar{D}}{1 + I\bar{D}}$$

Comparing Incidence and Prevalence

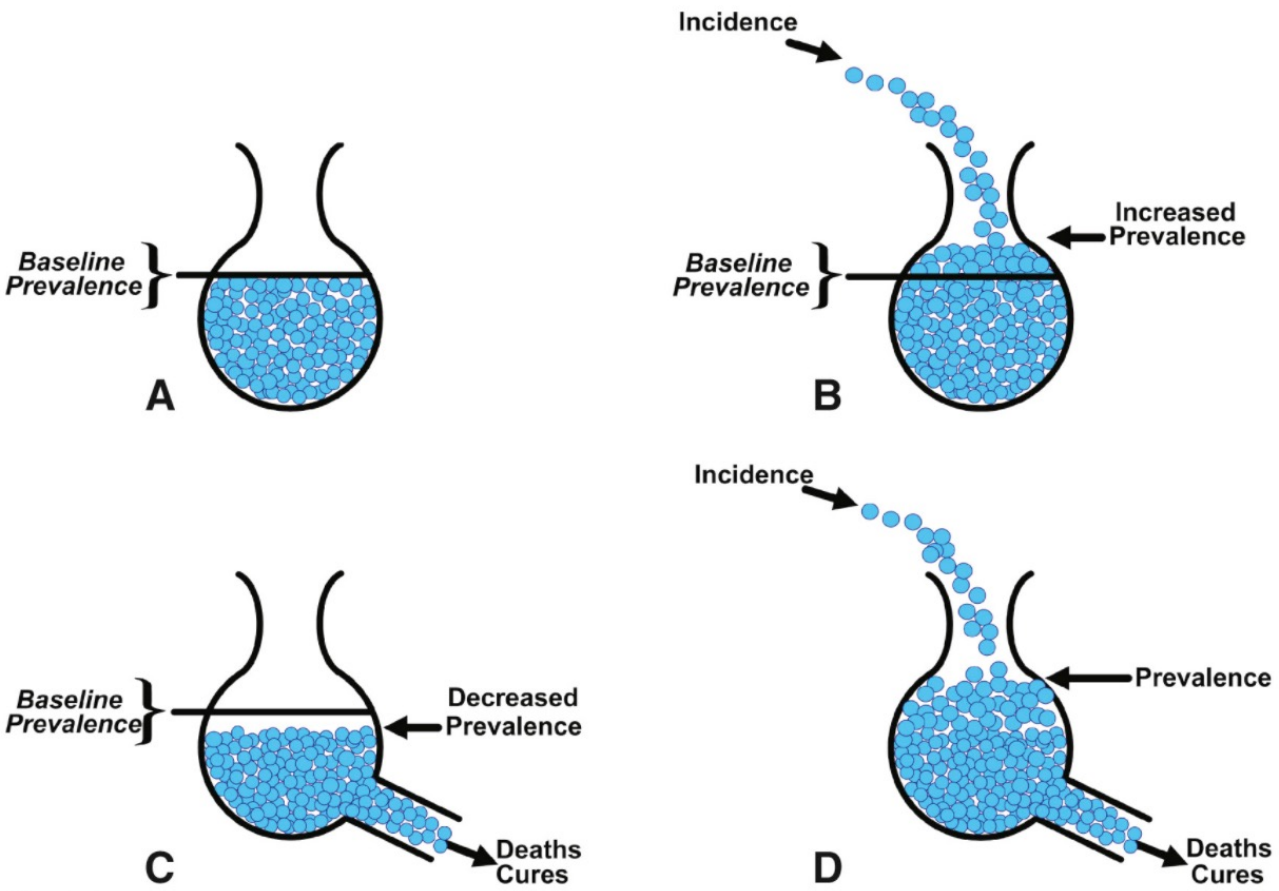


Fig. 3.12