

Introduction to Infectious Diseases in a Global Health Setting

UChicago Center in Paris

Paris, France

January 2025

Goals for this lecture

- To explain what we're doing here
- To introduce global health
- To introduce infectious disease
- To introduce methods for the study of infectious diseases

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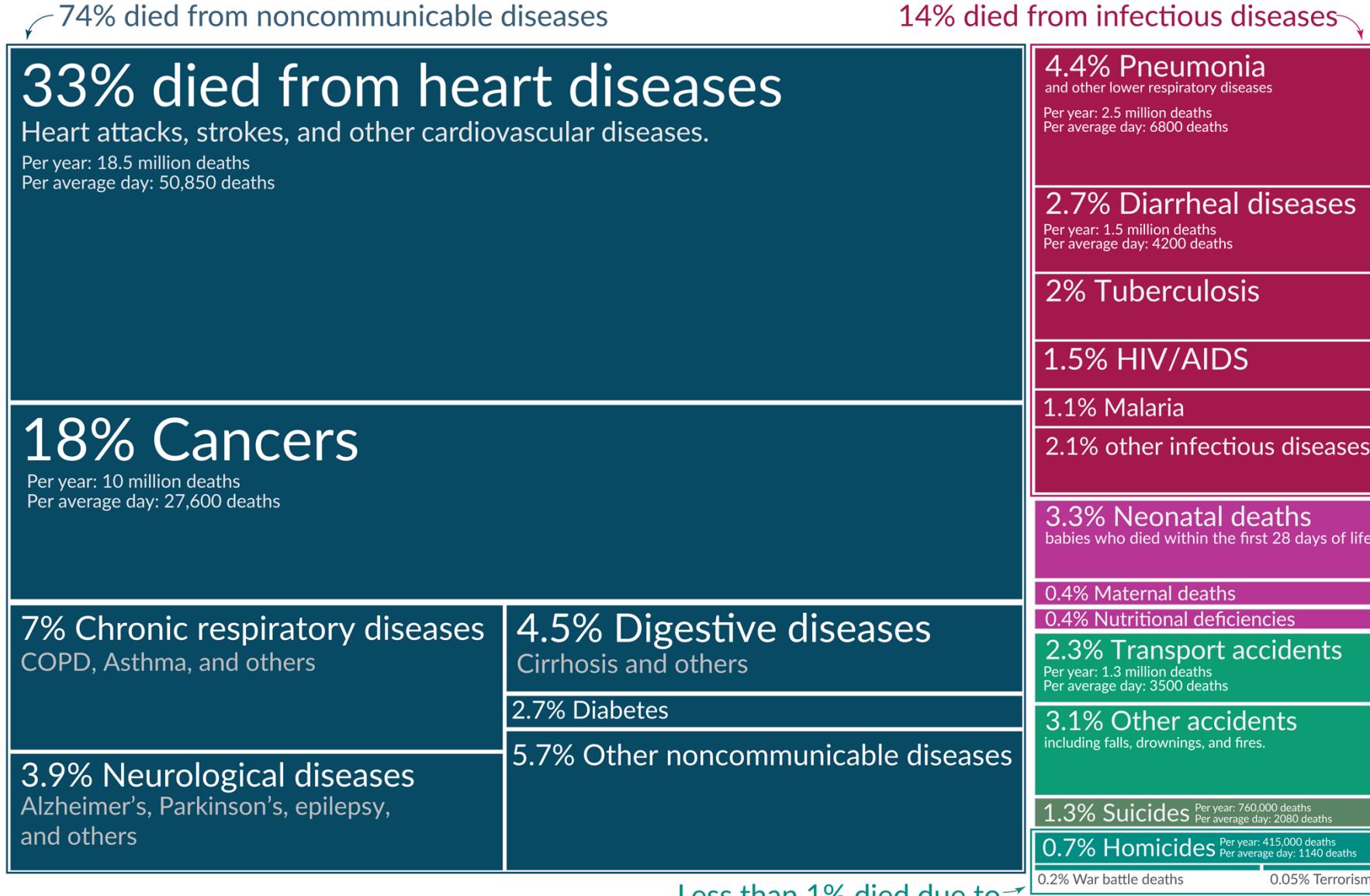
What is global health?

- the health of the populations in the worldwide context (WHO 2006)
- an area of study, research, and practice that places a priority on improving health and achieving equity in health for all people worldwide
- focus on problems that transcend national borders or have a global political and economic impact are often emphasized (reduction of disparities, protection against global threats)
 - e.g. COVID (vaccination), polio eradication
- Different from international health, the branch of public health focused on foreign aid efforts led by high income countries to improve health in low- and middle-income countries (LMICs)

What do people die from? Causes of death globally in 2019

The size of the entire visualization represents the total number of deaths in 2019: 55 million.
Each rectangle within it is proportional to the share of deaths due to a particular cause.

Our World
in Data



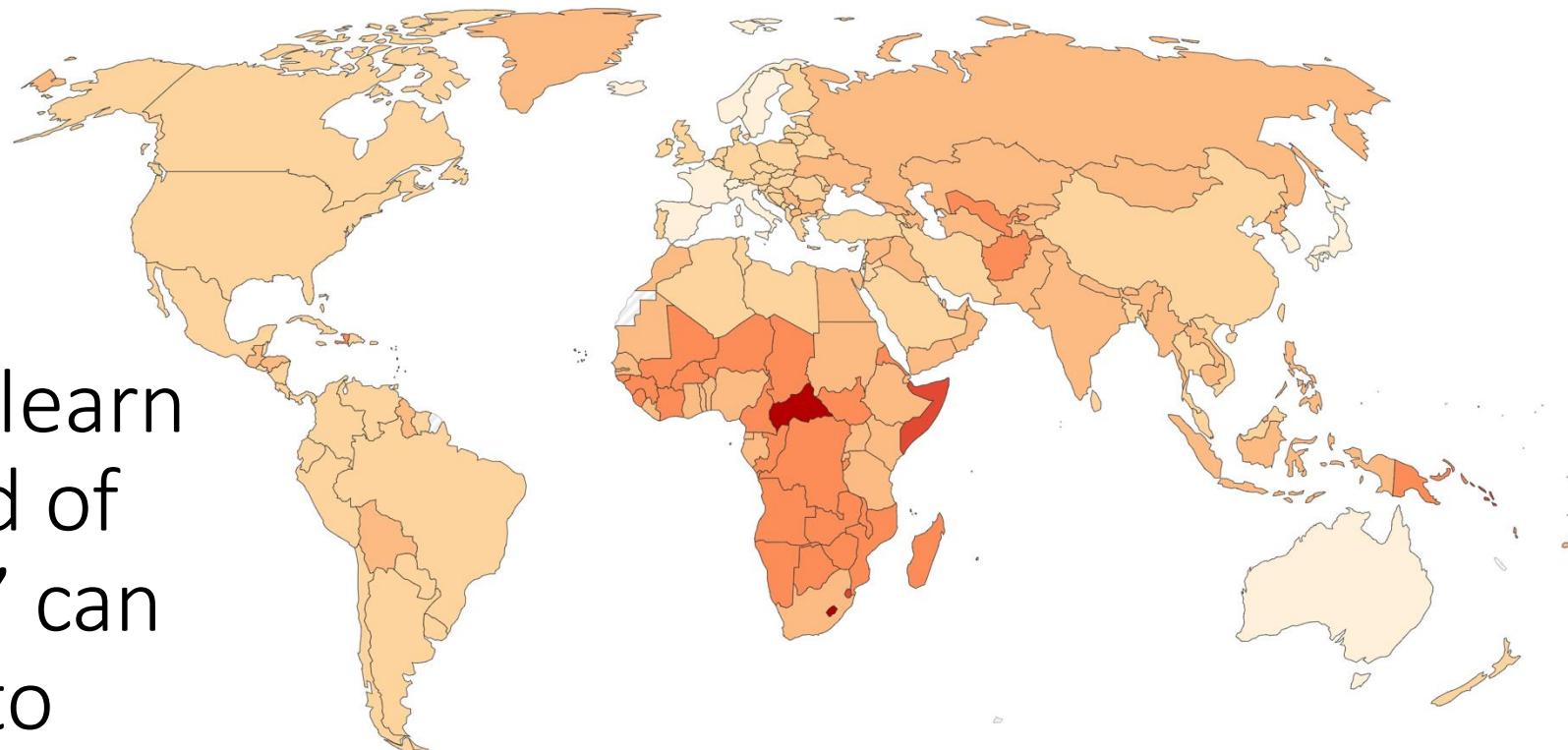
Global
death rates
are far from
equitable.

We're here to learn
how the field of
'global health' can
intervene to
reverse these
trends.

Annual death rate from all causes, 2019

The estimated annual death rate from all causes per 100,000 people.

Our World
in Data



Data source: IHME, Global Burden of Disease (2019)

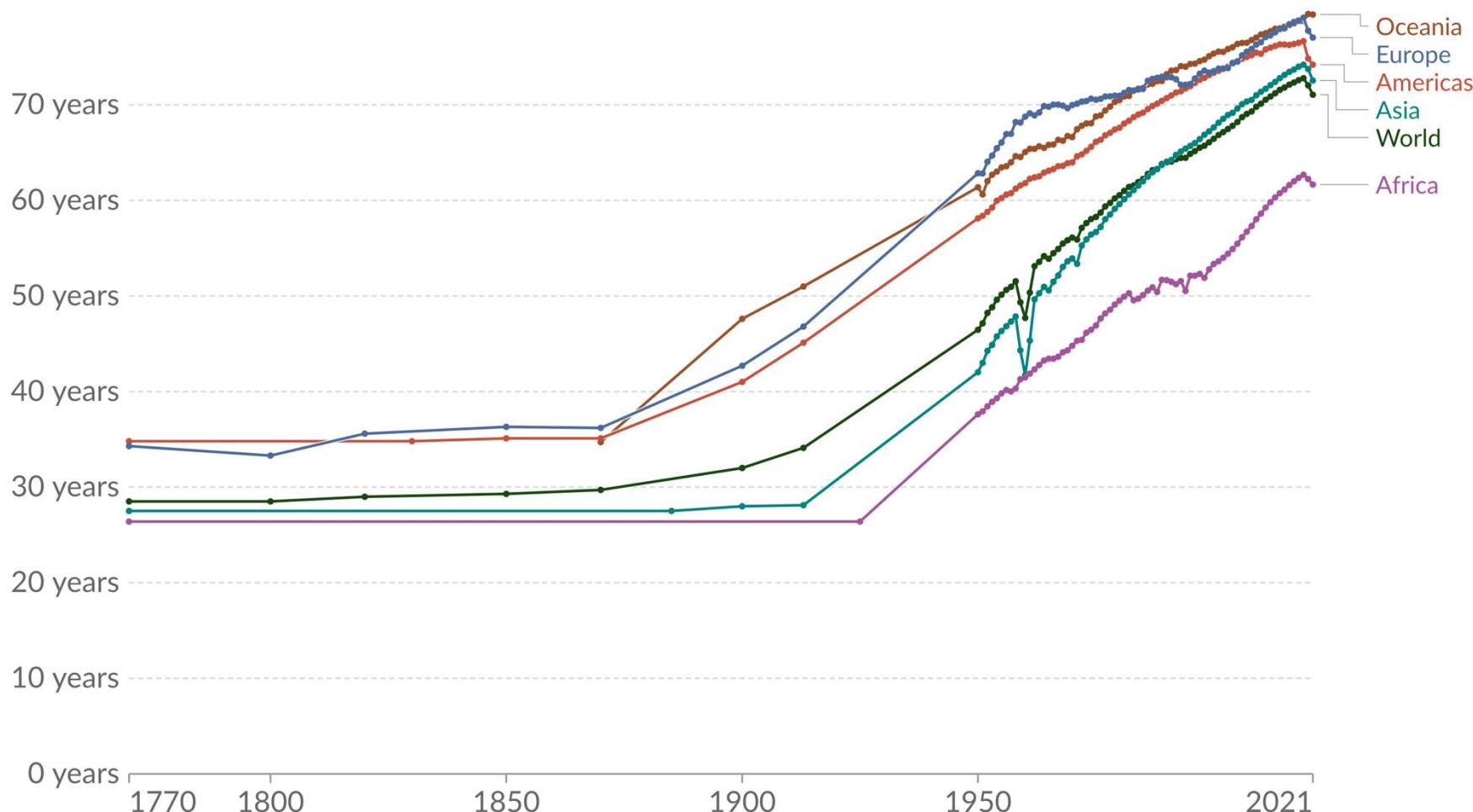
OurWorldInData.org/causes-of-death | CC BY

Note: To allow for comparisons between countries and over time, this metric is age-standardized¹.

1. Age standardization: Age standardization is an adjustment that makes it possible to compare populations with different age structures by standardizing them to a common reference population. [Read more: How does age standardization make health metrics comparable?](#)

Life expectancy

The period life expectancy¹ at birth, in a given year.



Data source: UN WPP (2022); HMD (2023); Zijdeman et al. (2015); Riley (2005)

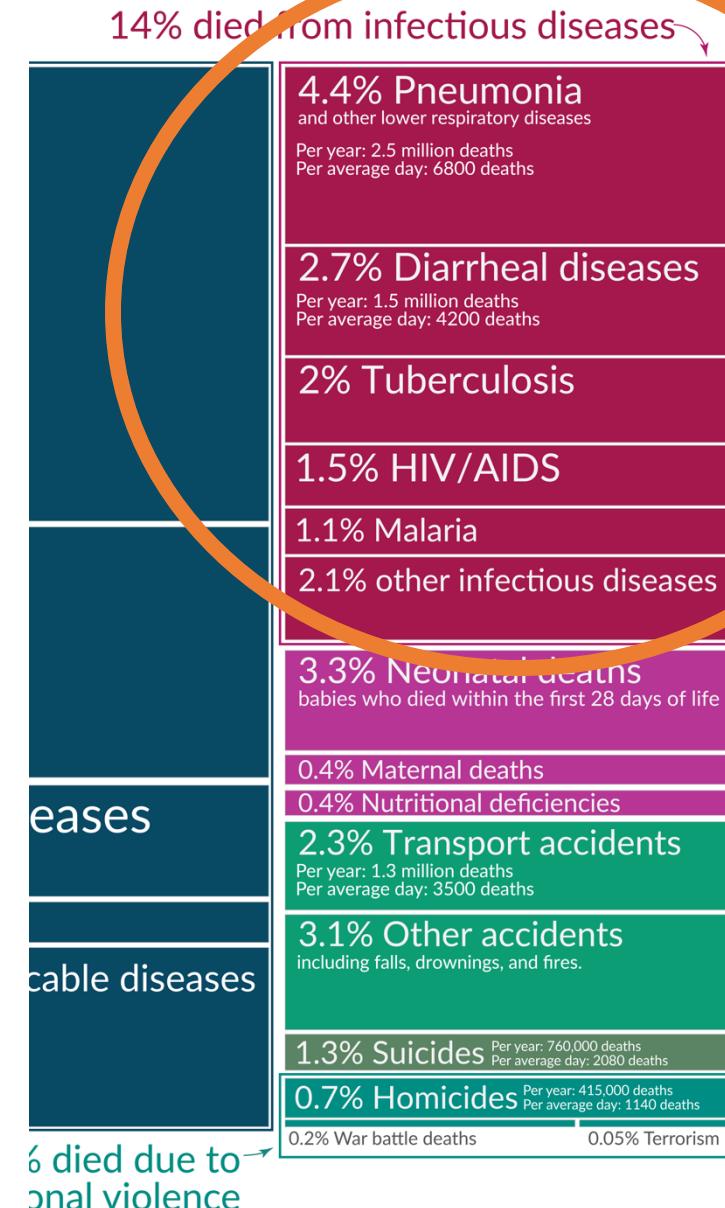
OurWorldInData.org/life-expectancy | CC BY

1. Period life expectancy: Period life expectancy is a metric that summarizes death rates across all age groups in one particular year. For a given year, it represents the average lifespan for a hypothetical group of people, if they experienced the same age-specific death rates throughout their whole lives as the age-specific death rates seen in that particular year. Learn more in our article: "Life expectancy" – What does this actually mean?

BIOS27815: Infectious Diseases

lth globally in 2019
55 million.
cause.

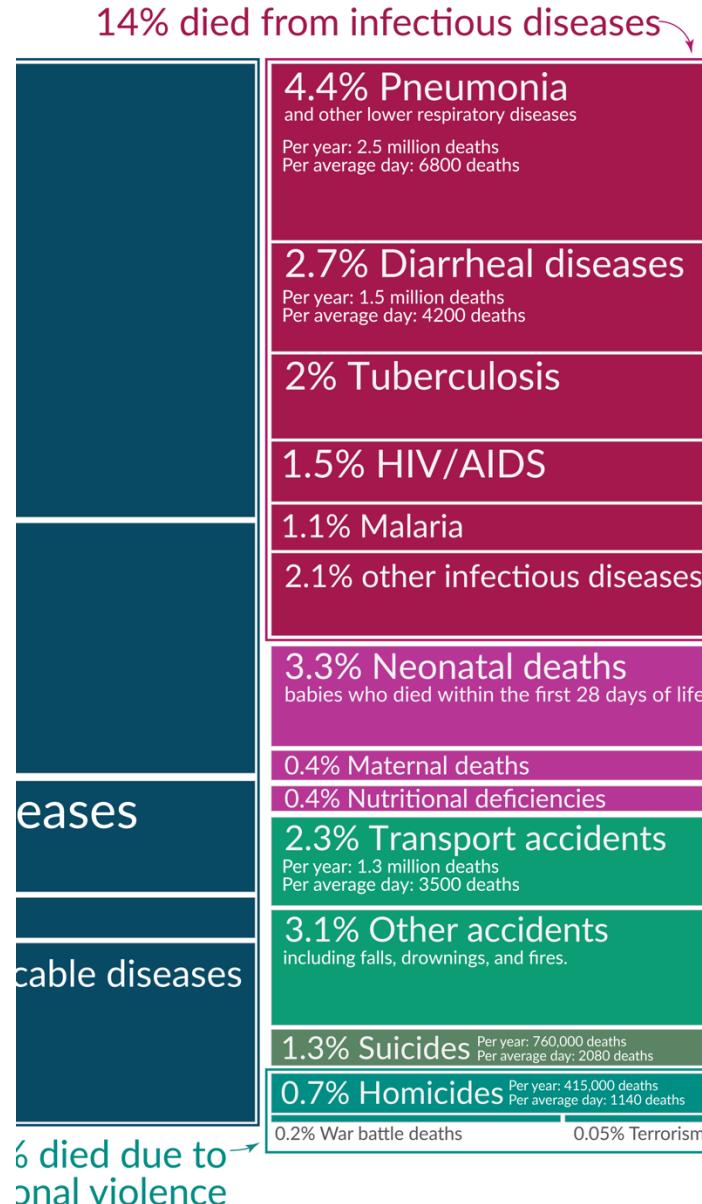
Our World
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- The ‘**Big Three**’ (**malaria, TB, and HIV**) are the three top single infectious disease killers globally, accounting for >2.7 million annual deaths.
- They disproportionately affect citizens of Low- and Middle-Income Countries (**LMICs**).
- They receive the bulk of US and international global health funding, including through **The Global Fund**, a Geneva-based non-profit to fight HIV, TB, and malaria, with a ~\$5 billion annual budget.

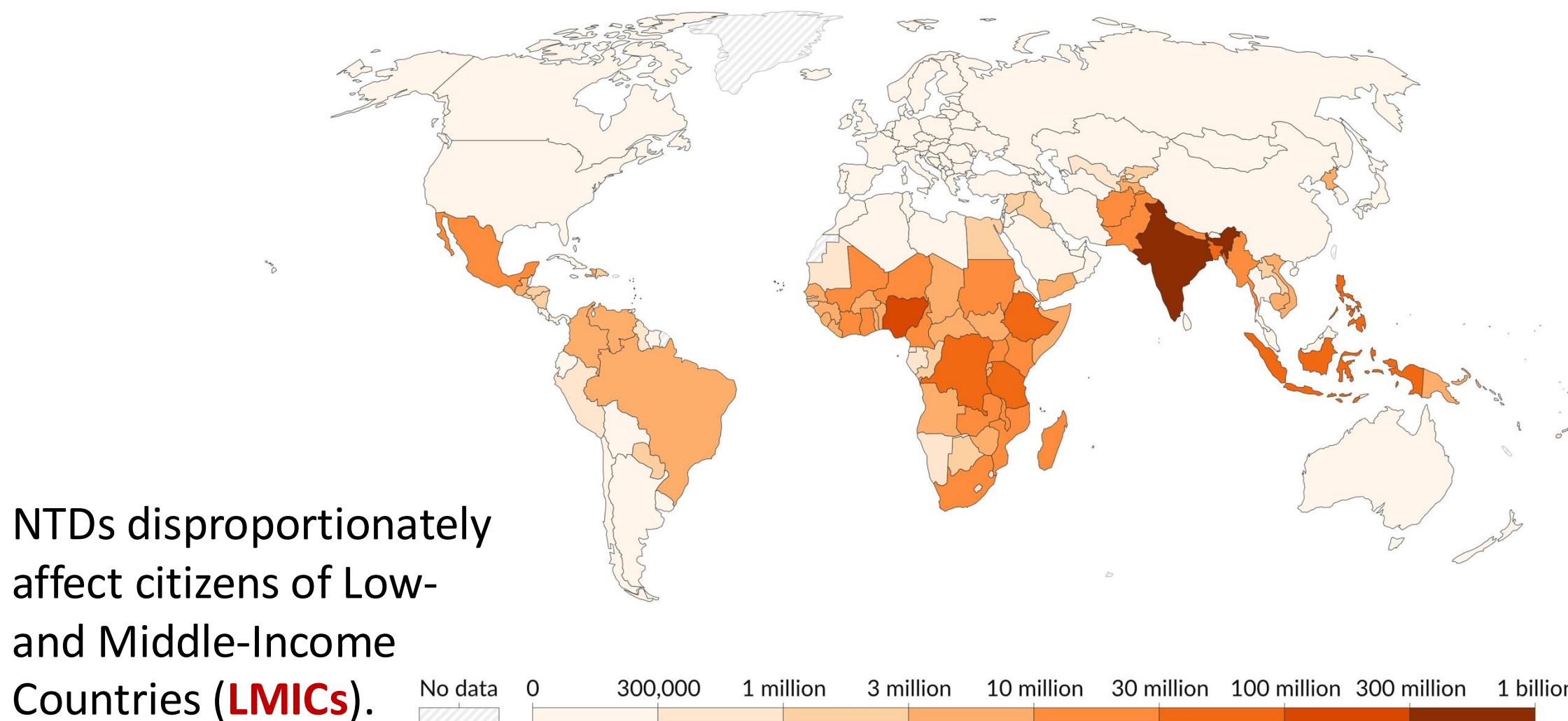
Neglected Tropical Diseases (NTDs).

- **NTDs** are diseases mainly prevalent among impoverished communities in tropical areas (though some have a larger geographical distribution) which are **under-resourced as compared to the Big Three.**
- NTDs affect more than 1 billion people globally
- **WHO recognizes 21 NTDs:**

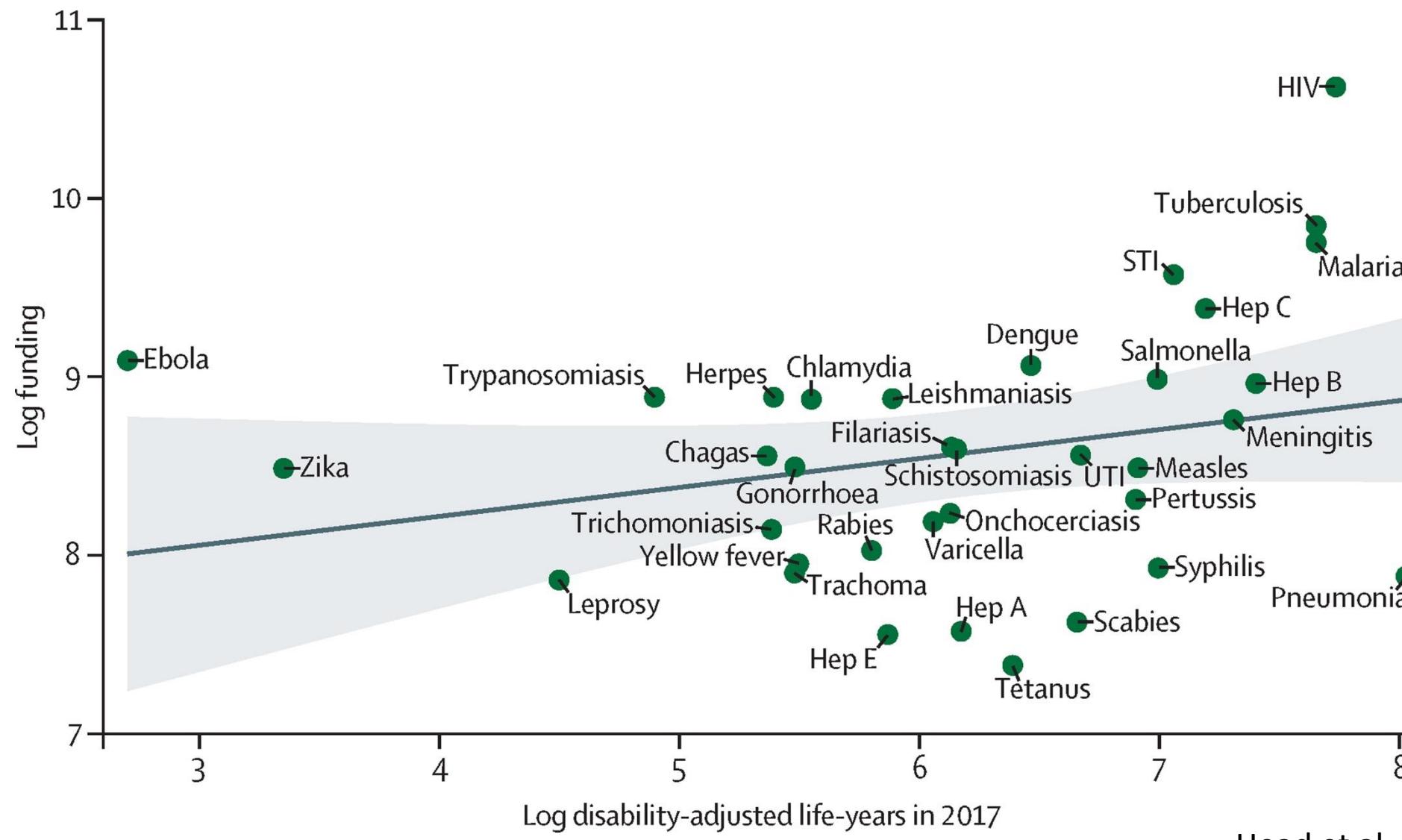
- | | | |
|-------------------------------|--------------------------------------|---------------------------------------|
| 1. Buruli ulcer | trypanosomiasis | 15. scabies, |
| 2. Chagas disease | 8. leishmaniasis | ectoparasitoses |
| 3. dengue and
chikungunya | 9. leprosy | 16. schistosomiasis |
| 4. Dracunculiasis | 10. lymphatic filariasis | 17. soil-transmitted
helminthiases |
| 5. echinococcosis | 11. mycetoma,
chromoblastomycosis | 18. snakebite envenoming |
| 6. foodborne
trematodiases | 12. noma | 19. taeniasis/cysticercosis |
| 7. human African | 13. onchocerciasis | 20. trachoma |
| | 14. rabies | 21. yaws |

Number of people requiring treatment against neglected tropical diseases, 2021

Estimated number of people requiring medical treatment for neglected tropical diseases (NTDs)¹.



The funding dominance of the ‘**Big Three**’ means that **many** high burden infectious diseases are **neglected** every year.



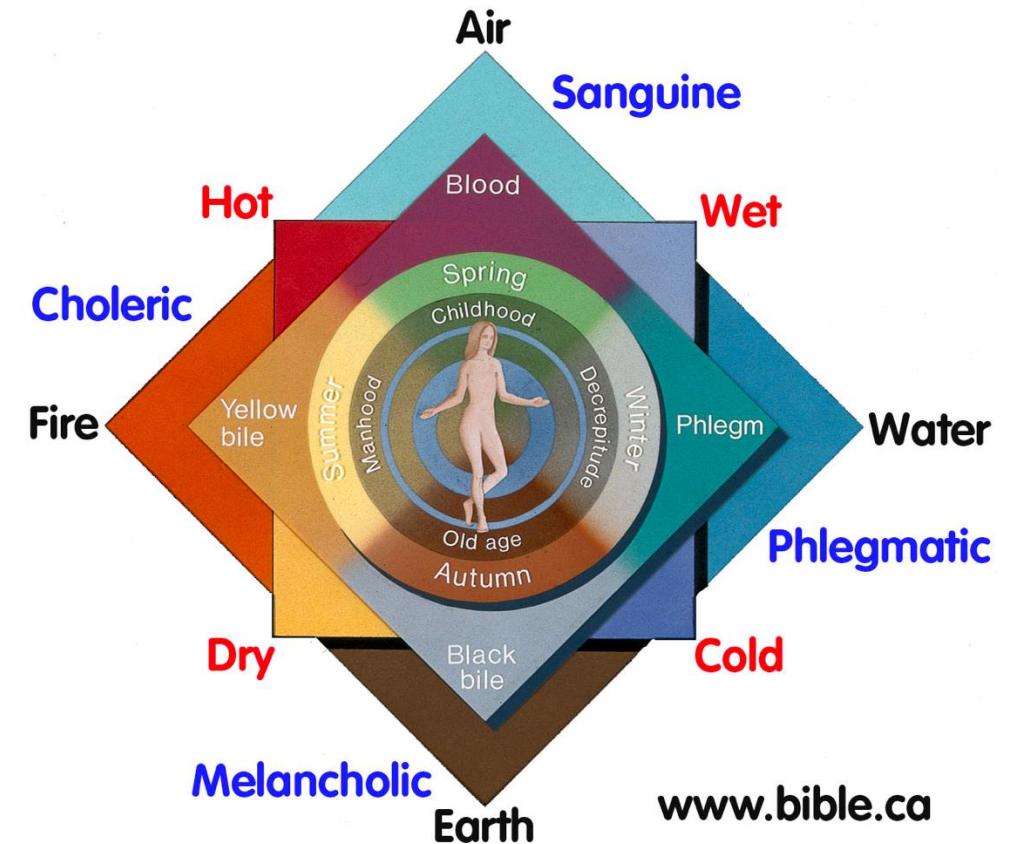
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What causes disease? *Perspectives through the ages*

1. **Four Humors:** Hippocrates (c. 400 BC) wrote that disease results from an imbalance of the four humors

**The Four Humors of Hippocratic Medicine
450 BC - 1858 AD**
Melancholy Blood (depression)



What causes disease?

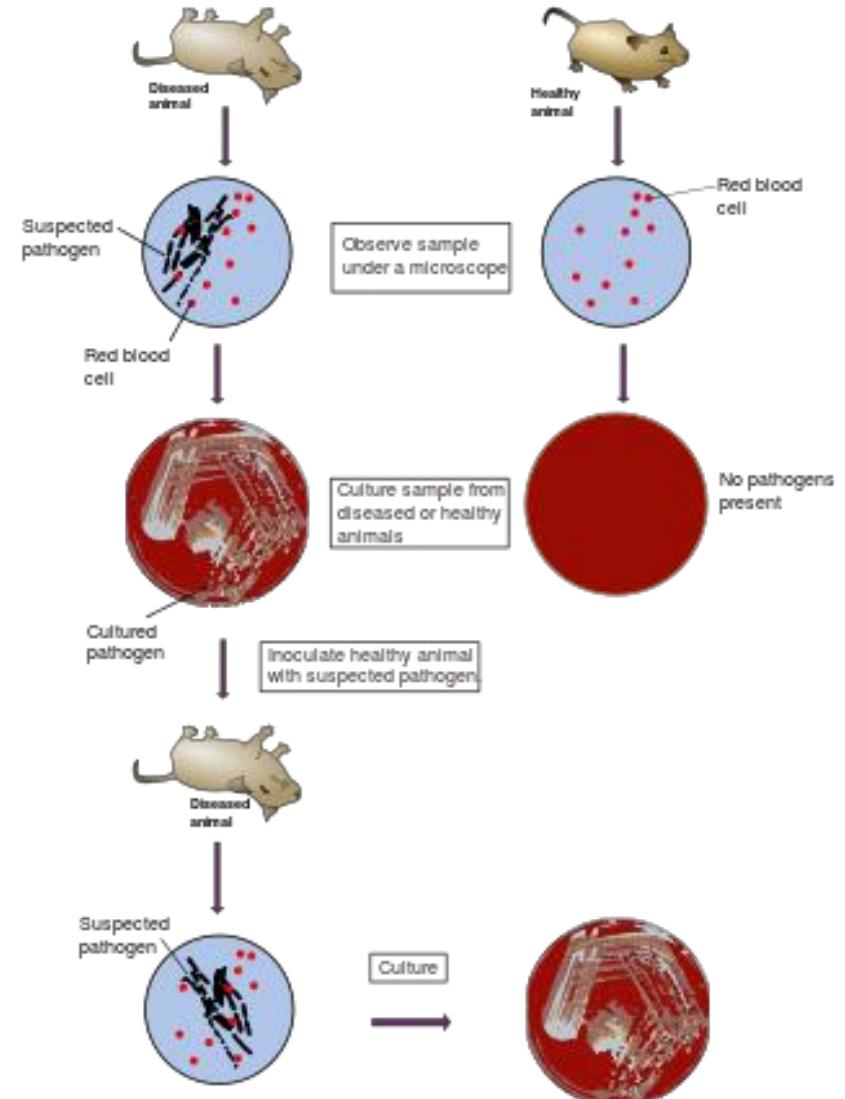
Perspectives through the ages

1. **Four Humors:** Hippocrates (c. 400 BC) wrote that disease results from an imbalance of the four humors
2. **Miasmatic Theory:** Extension of Hippocrates that lasted through the 1800s – idea that disease was caused by bad air. Popularized by Florence Nightengale



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 - Popularized by Florence Nightengale
3. **Germ Theory of Disease:** Idea that disease results from germs
 - Leuwenhoek's microscope (1675)
 - Koch's postulates (1890)



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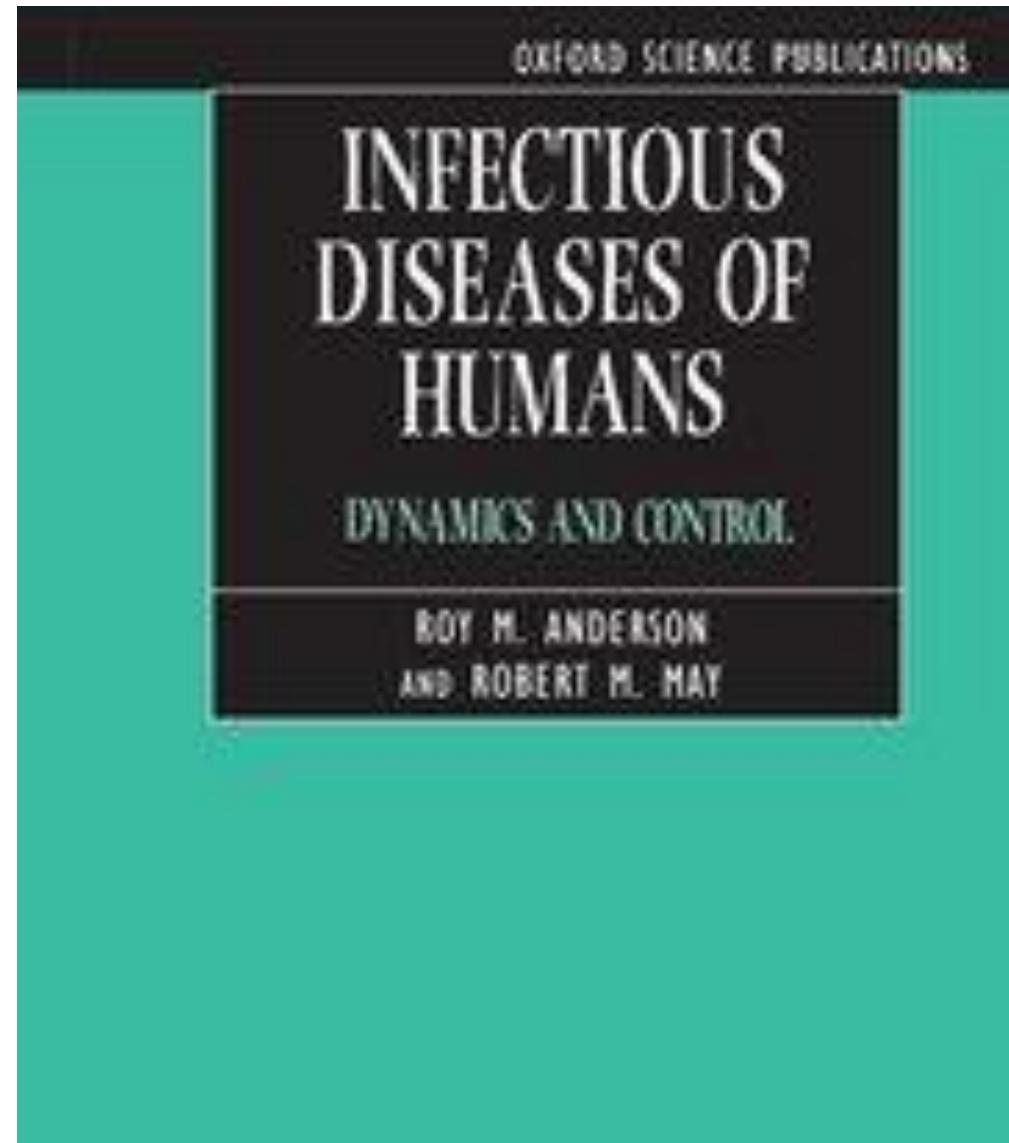
4. Classic epidemiology

- Risk factors for disease = John Snow (1854)

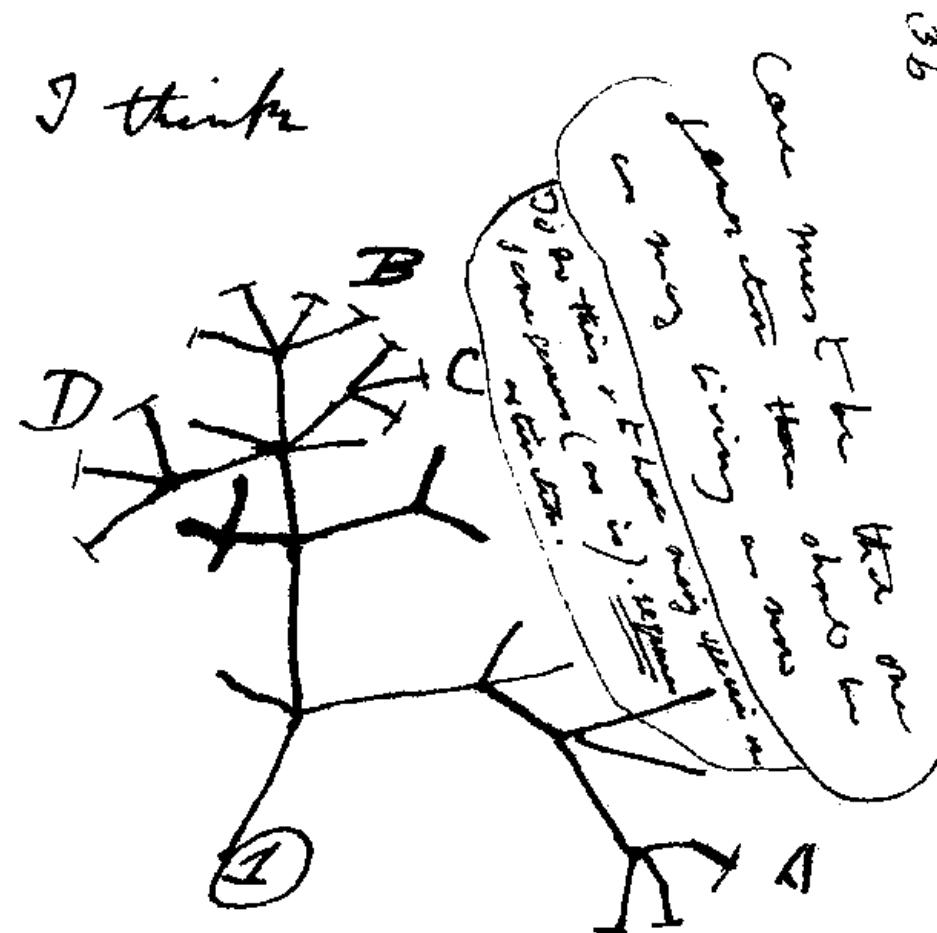


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4. **Classic epidemiology**
 - Risk factors for disease = John Snow (1854)
5. **Population biology of infectious disease**
 - Understanding the *process* of infectious disease *transmission.* = Kermack and McKendrick (1927); Anderson and May (1991).

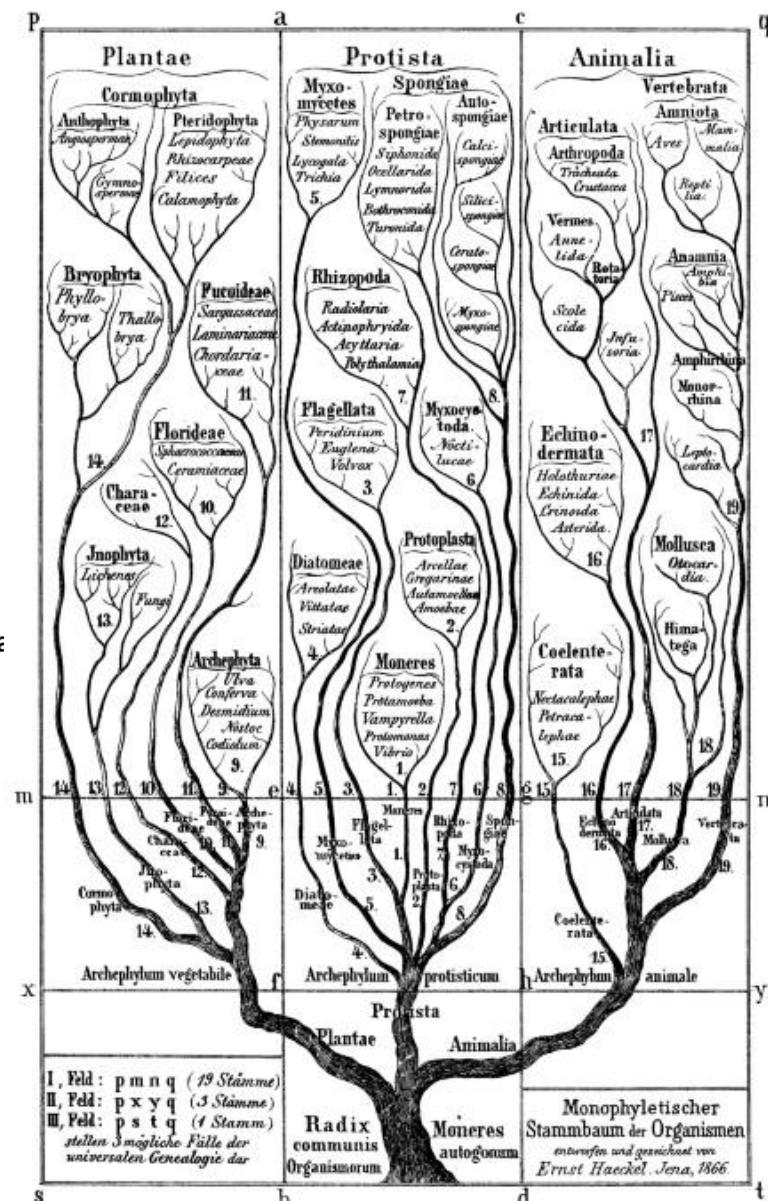
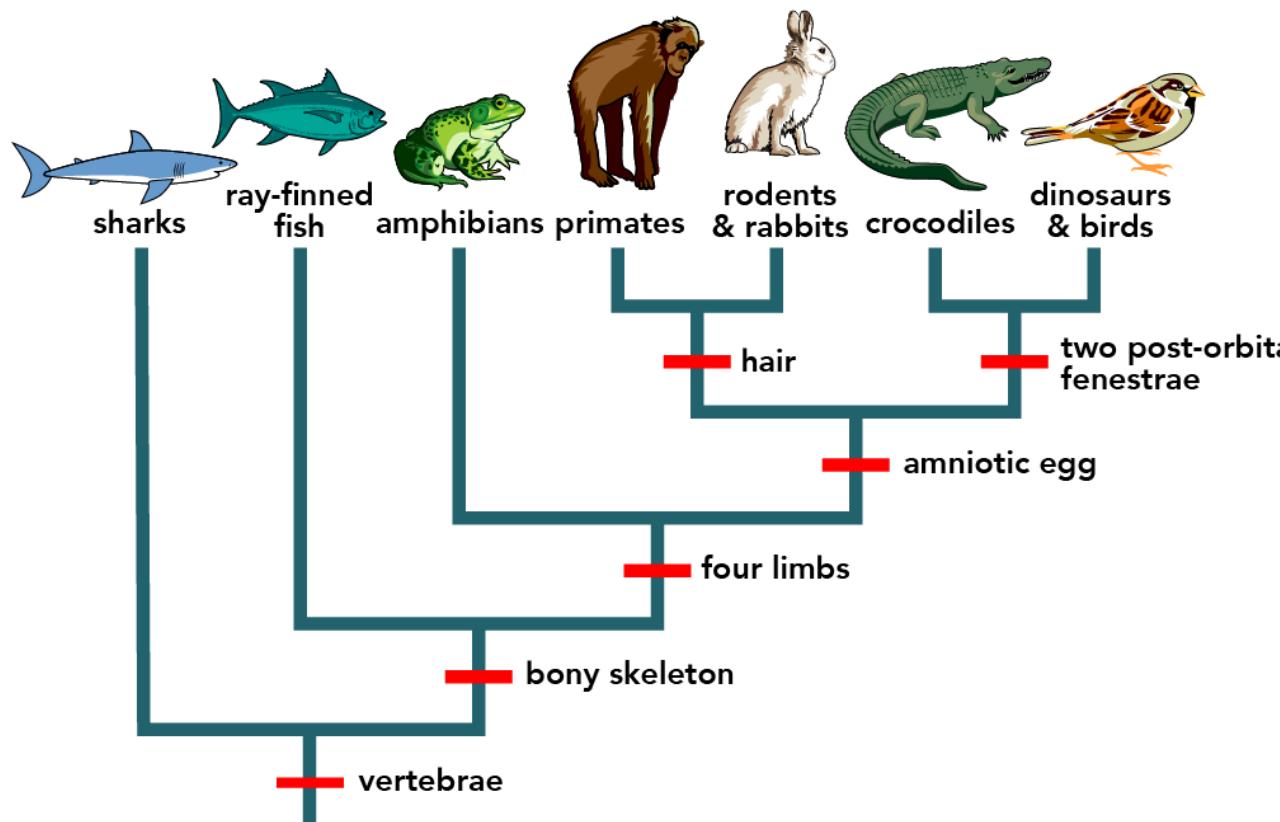


What is this?

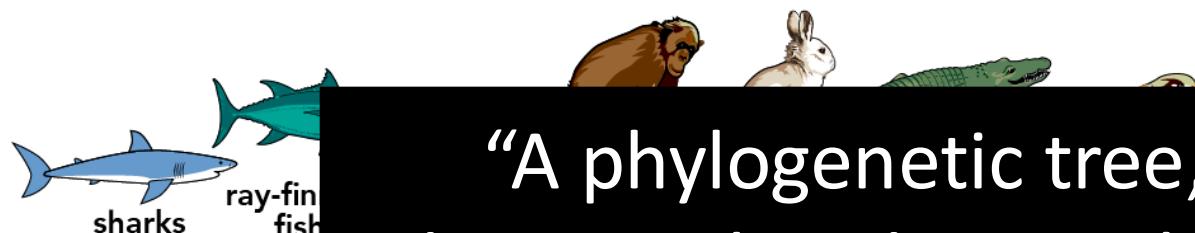


Charles Darwin's
notes –
world's first
phylogenetic tree !

What is a phylogeny?

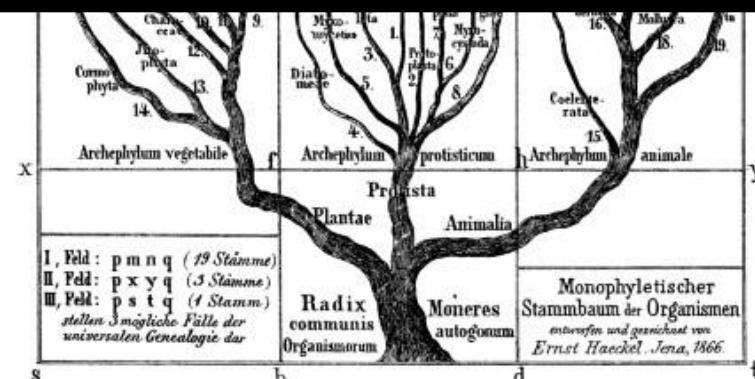
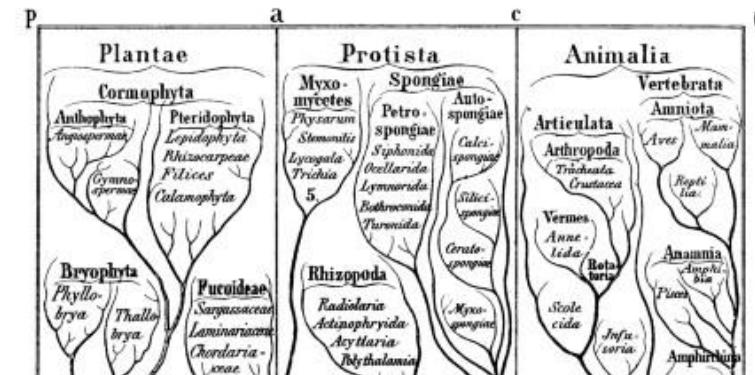
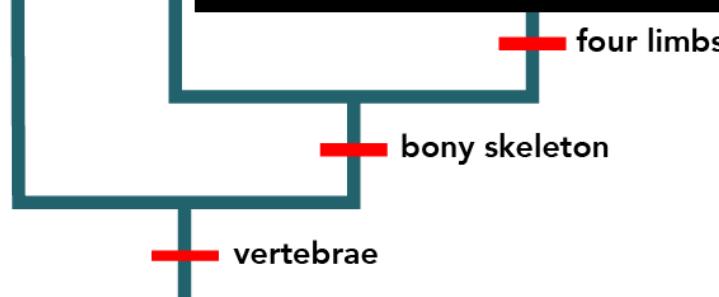


What is a phylogeny?

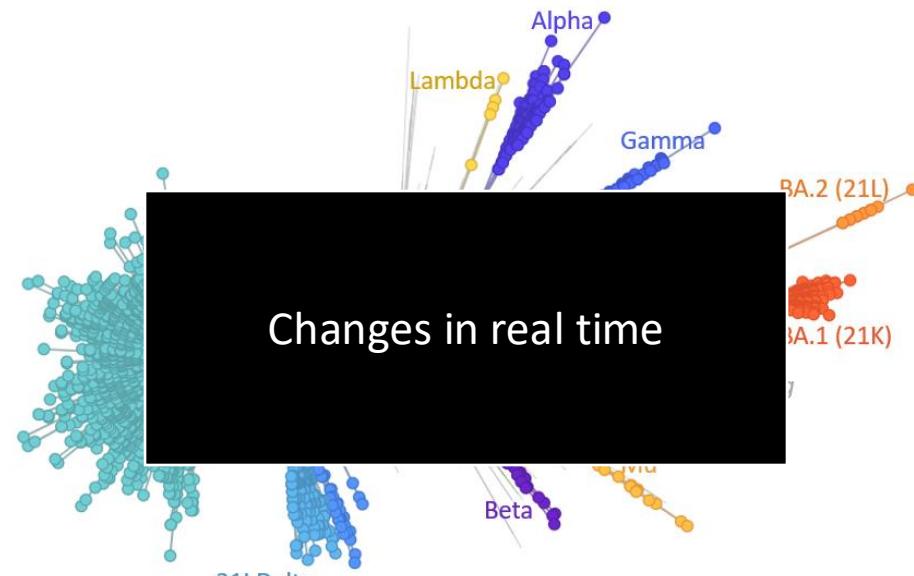
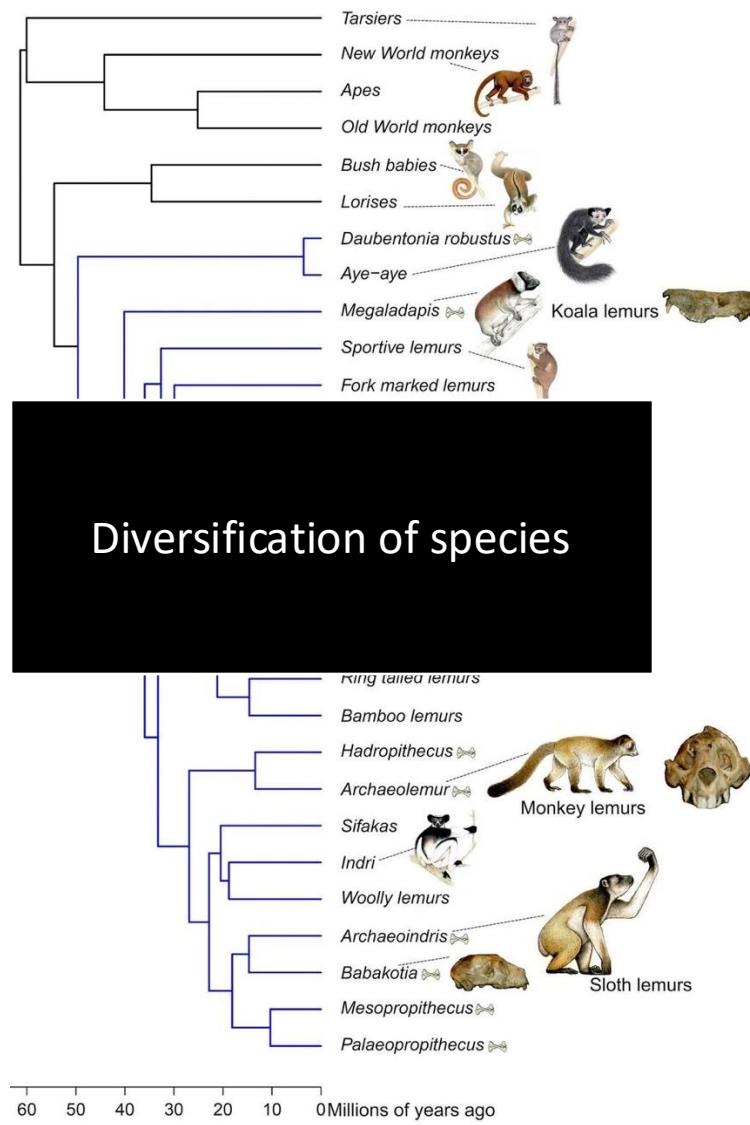
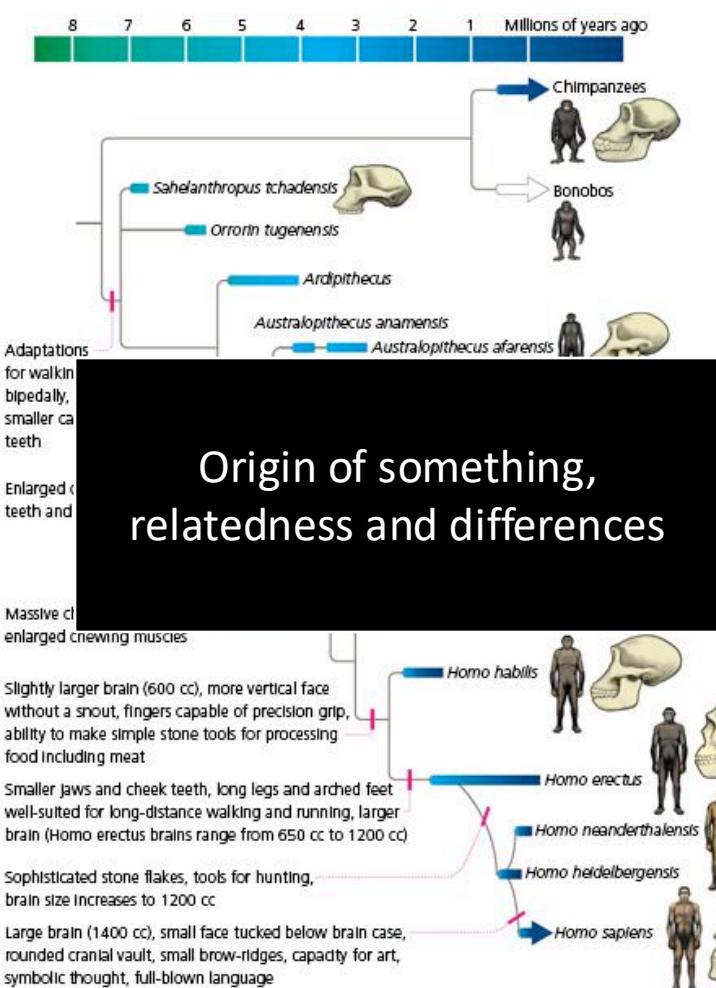


sharks
ray-finned
fish

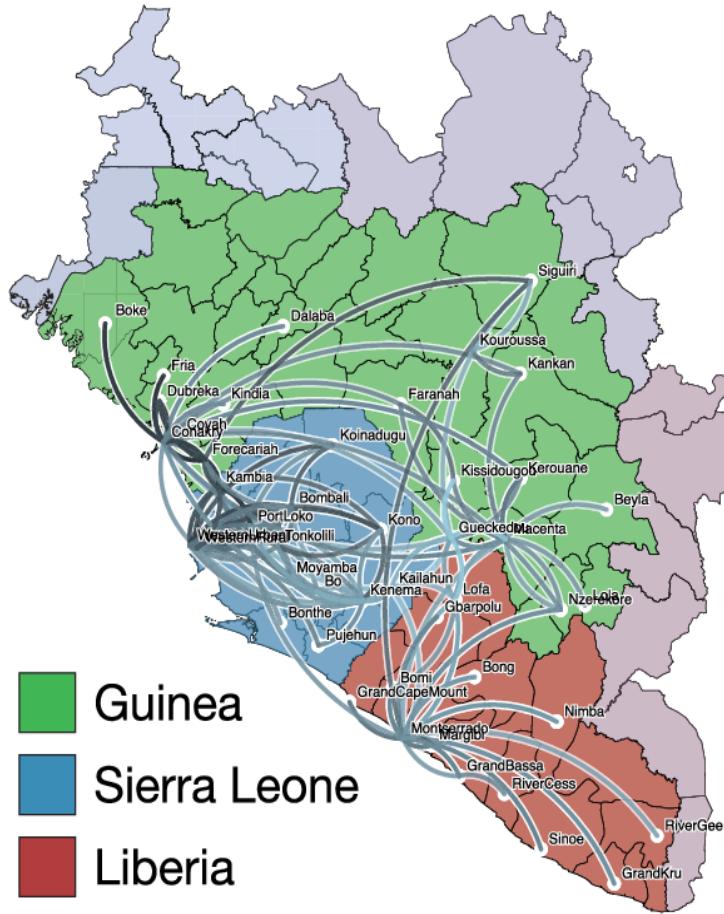
"A phylogenetic tree, or a phylogeny, is a diagram that depicts the lines of evolutionary descent of different species, organisms, or genes from a common ancestor."



What can you do with phylogenies?



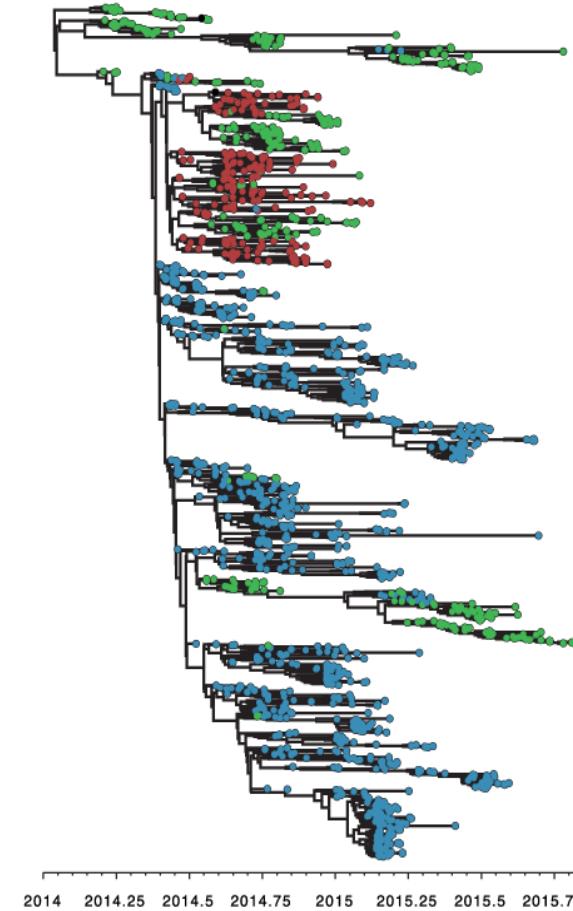
Phyldynamics



WHERE does it go?

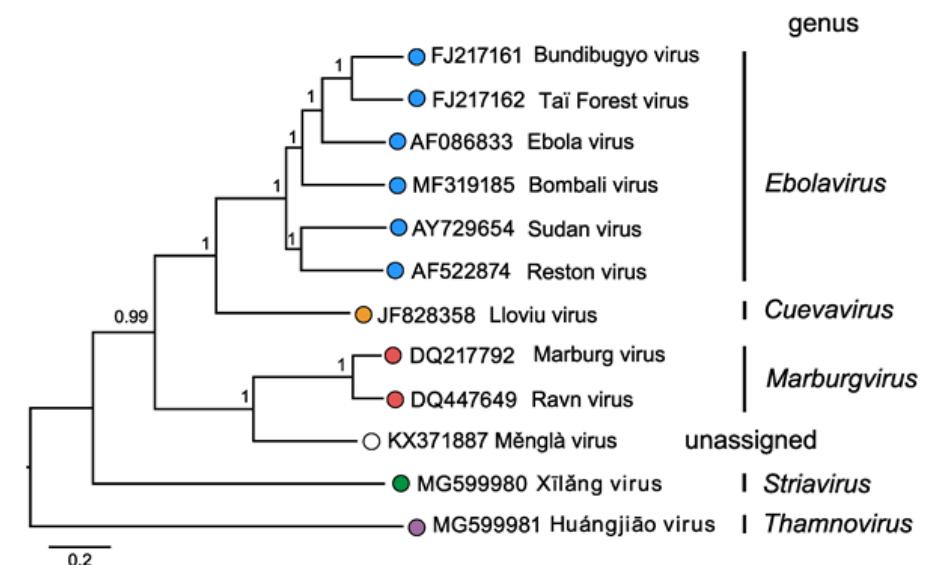
Changes in real time

Bayesian trees



WHEN is the most recent common ancestor?

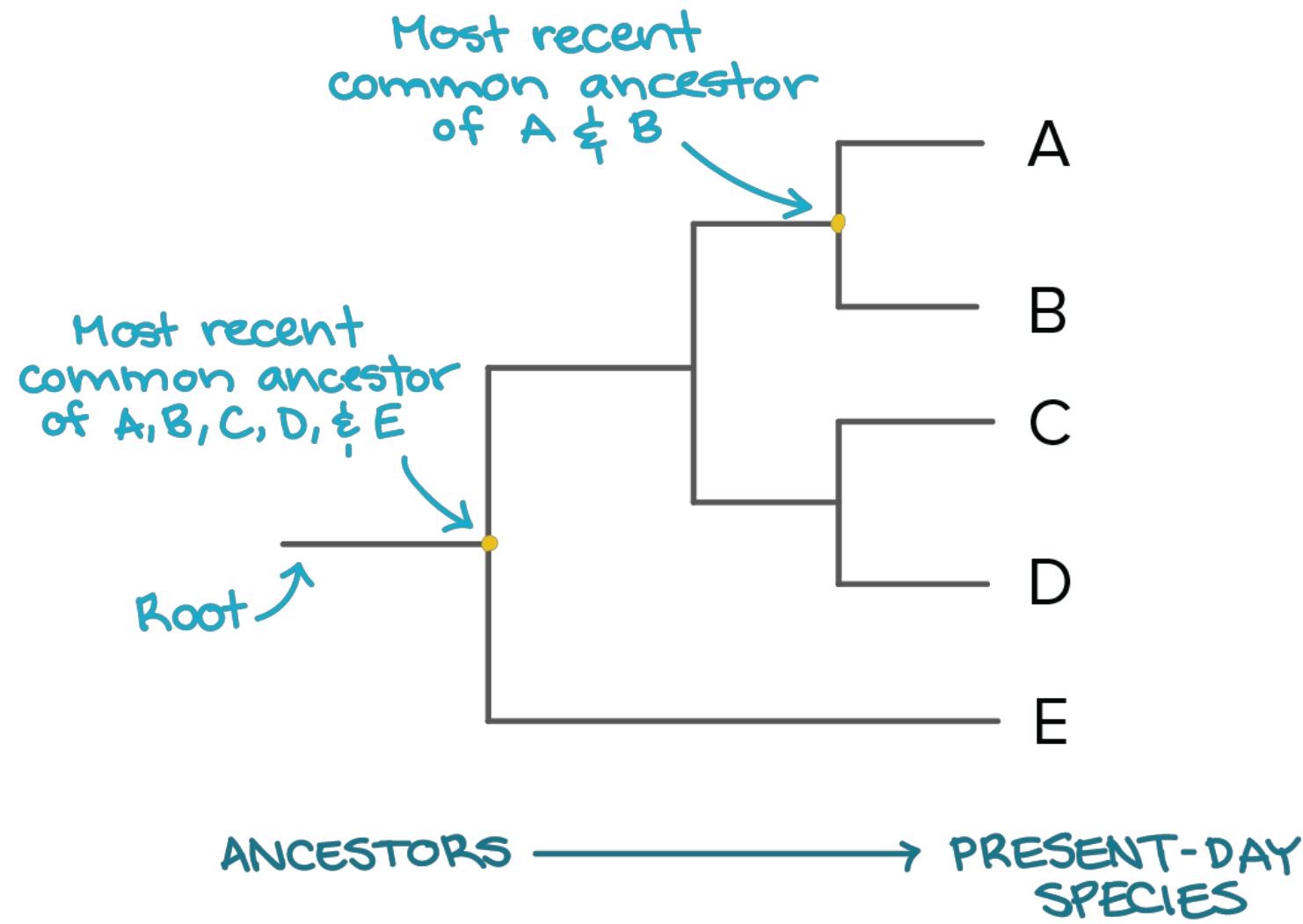
Maximum likelihood



HOW different is it to what's known?

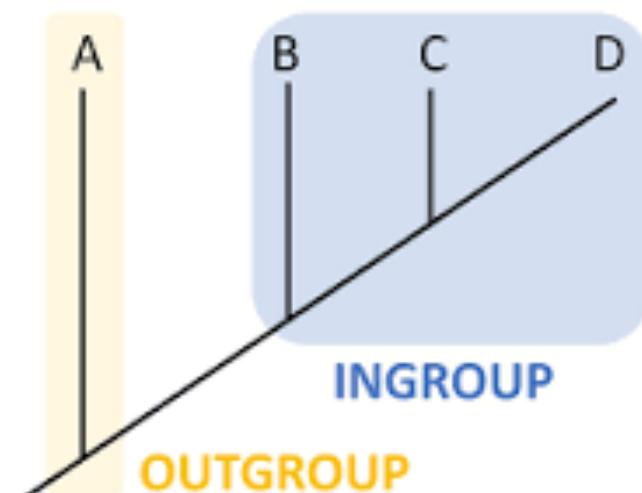
Suchard et al. 2018
Kuhn et al. 2019

CONFIDENCE

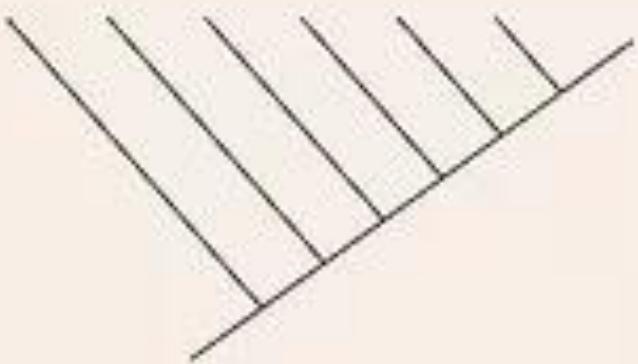


BOOTSTRAP VALUE

STRONGLY SUPPORTED	>90%
WELL SUPPORTED	70%-90%
WEAKLY SUPPORTED	50%-70%
NOT SUPPORTED	<50%



CLADOGRAM

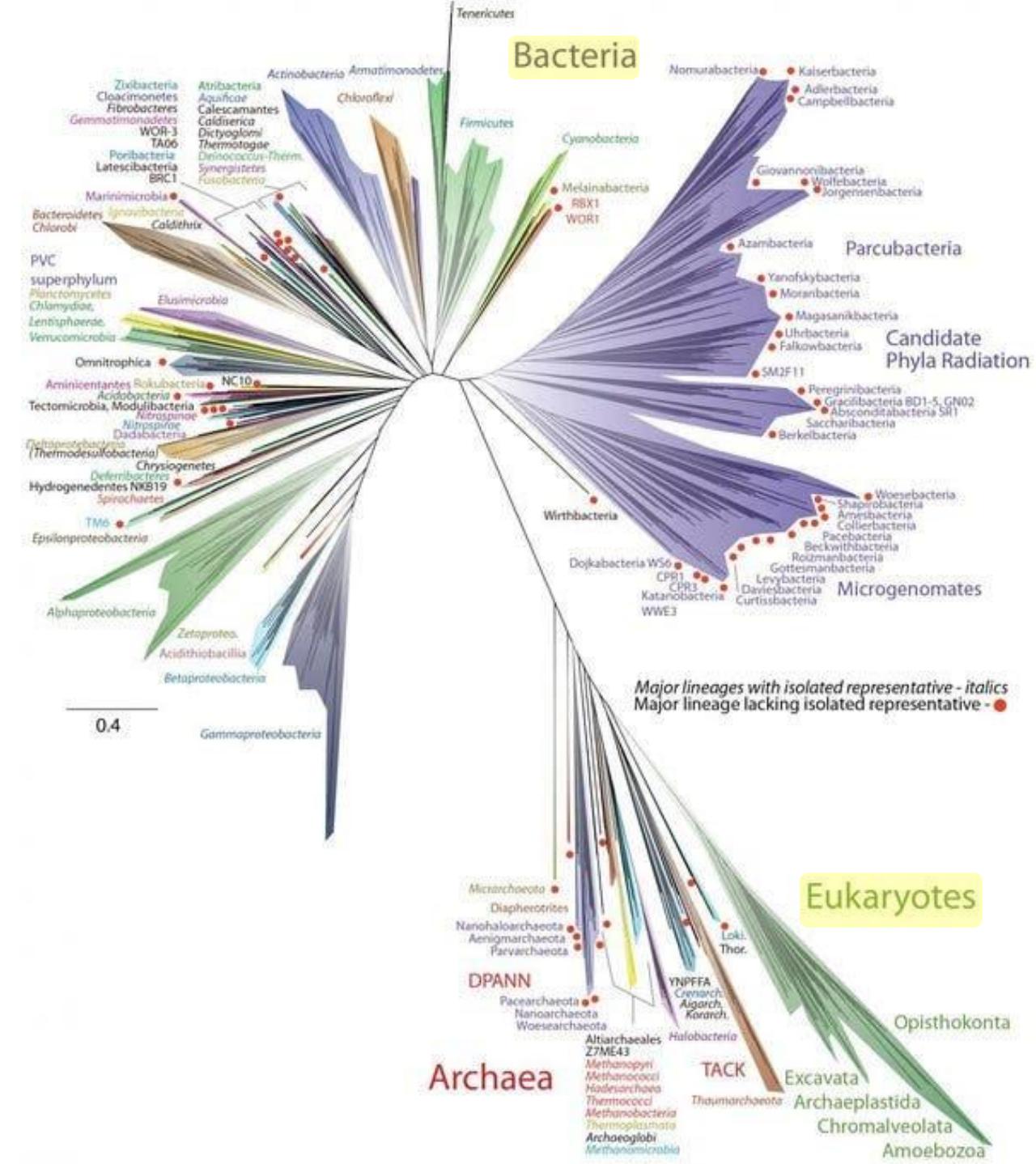


- the relationships are *hypothetical*
- you can easily make on your own

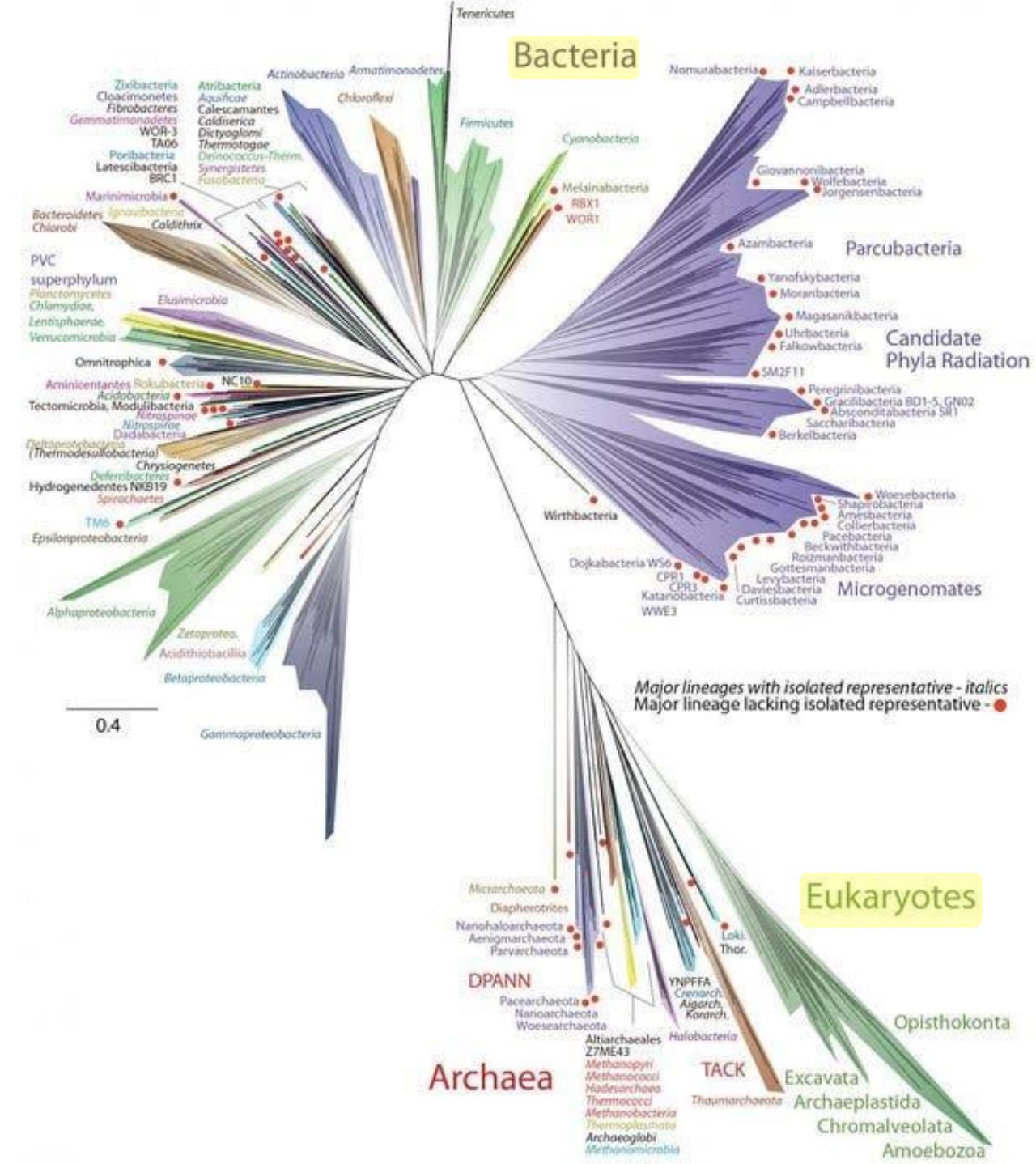
PHYLOGENETIC TREE



- the relationships are *backed by molecular evidence*
- should have access to DNA or other molecular data



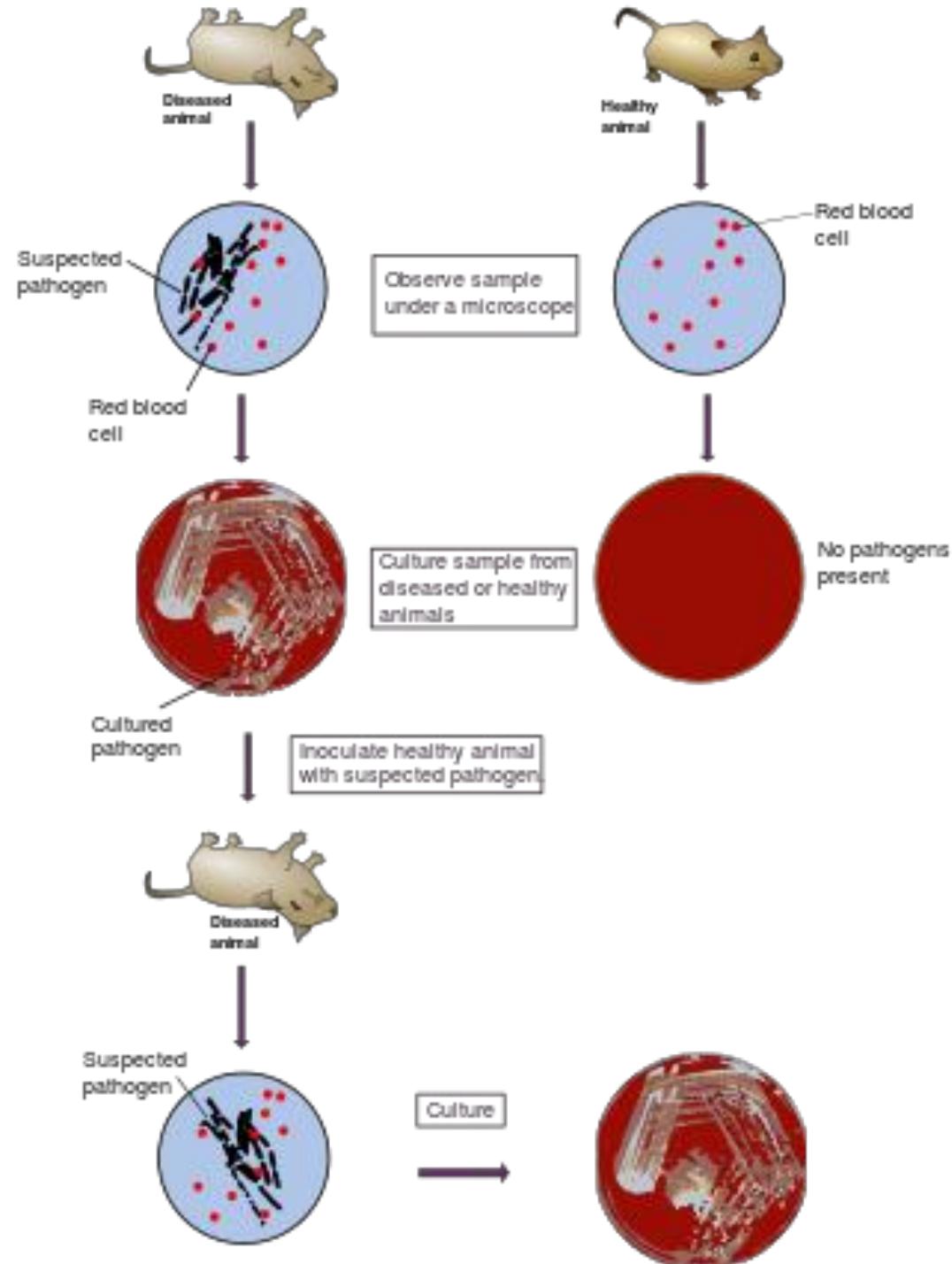
The parasite and pathogen tree of life



The parasite and pathogen tree of life

viruses???

Infectious diseases manifest from infection with a parasite or pathogen



The parasite and pathogen tree of life

- Parasite: an organism that lives in or on another organism and benefits at the expense of others (***these are eukaryotes***).
 - Ex: helminths (parasitic worms: tapeworms, roundworms, hookworms), ectoparasites (ticks, fleas)



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- Pathogen: a microorganism that can cause disease.
 - Ex: bacterium (***prokaryote***), ***virus***, protozoan (***eukaryote***)

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Pathogen: *Yersinia pestis*

Disease: Plague



The parasite and pathogen tree of life

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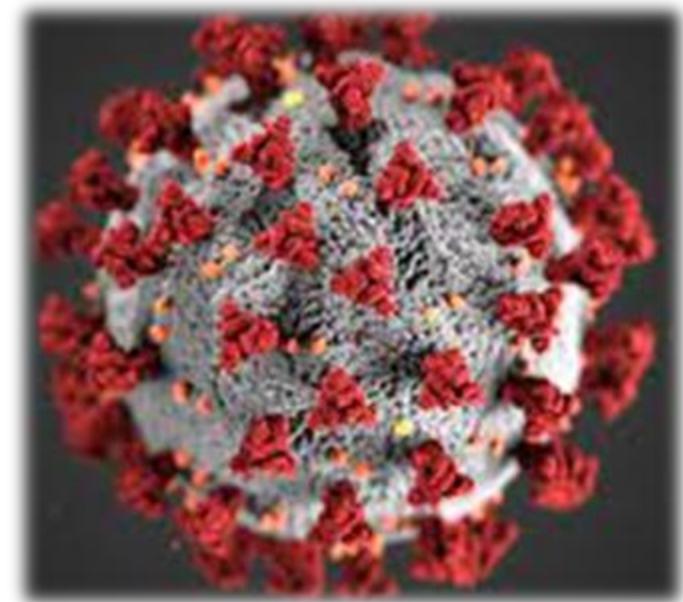
Pathogen: *Yersinia pestis*

Disease: Plague



Pathogen: SARS-CoV-2

Disease: COVID-19



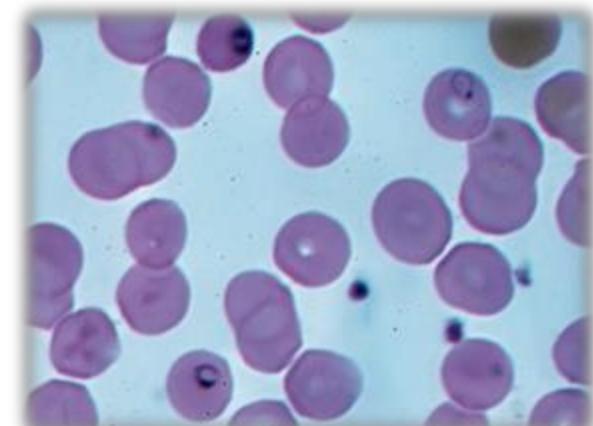
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Pathogen: *Yersinia pestis*
Disease: Plague

Pathogen: SARS-CoV-2
Disease: COVID-19

Pathogen:
Plasmodium falciparum, *P. vivax*, *P. malariae*, *P. ovale*, *P. knowlesi*
Disease: malaria



Parasites and pathogens have shaped human history.

- Plague of Justinian (541-549 AD)
 - First historically recorded pandemic of *Yersinia pestis*
 - Launched the ‘first plague pandemic’ resulting in the deaths of 15-100 million people, 25-60% of Europe’s population at the time



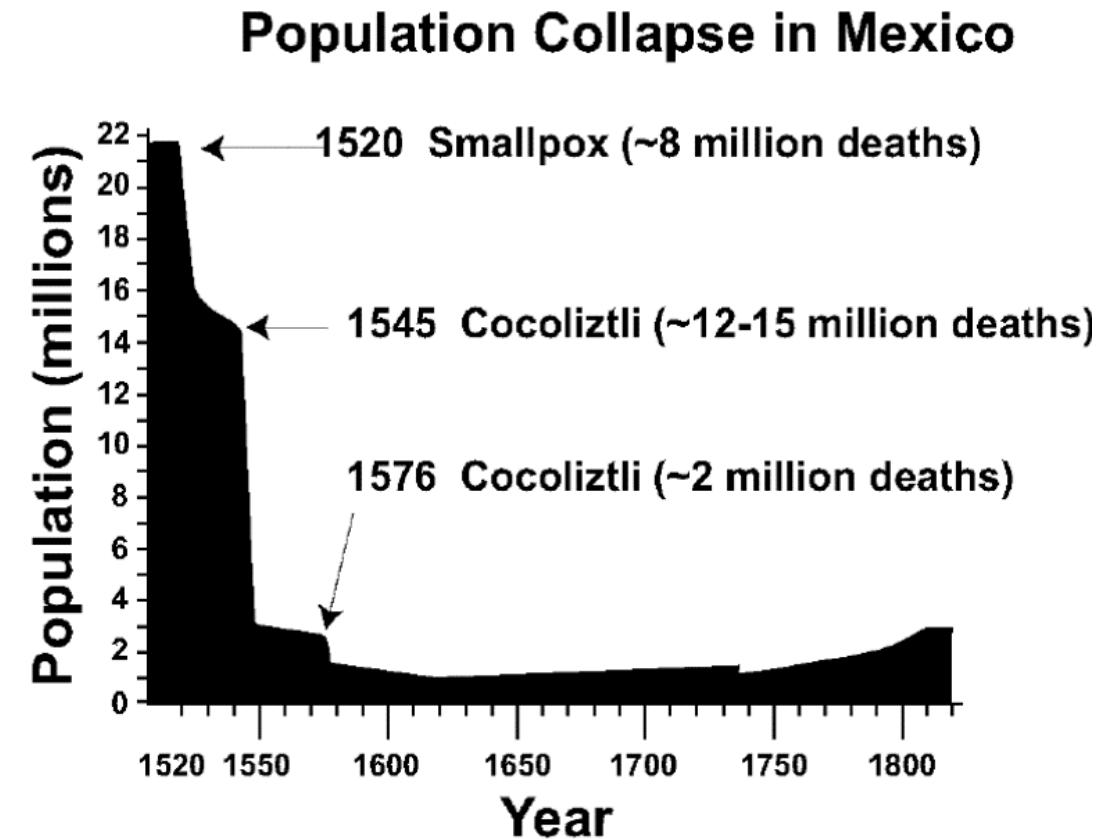
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- Plague of Justinian (541-549 AD)
- Black Death (1346-1353 AD)
 - Most fatal pandemic in human history, resulting in deaths of 75-200 million people
 - Killed 30-60% of Europe's population at the time; 17-54% of global population



Parasites and pathogens have shaped human history.

- Plague of Justinian (541-549 AD)
- Black Death (1346-1353 AD)
- Cocoliztli (1545-1548)
 - Pathogen still unknown! Maybe viral hemorrhagic fever, maybe bacterium
 - Killed 80% of the population of Mexico



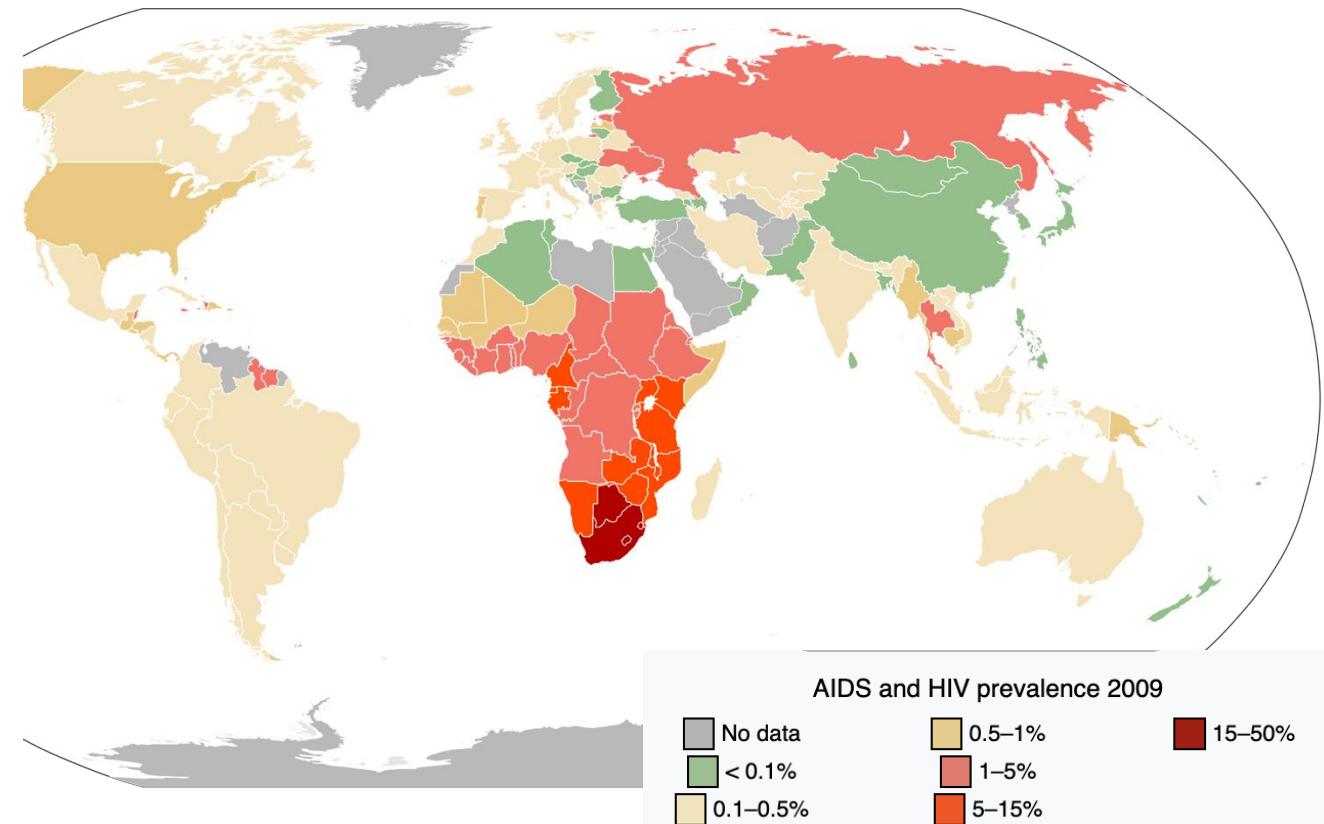
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- Plague of Justinian (541-549 AD)
- Black Death (1346-1353 AD)
- Cocoliztli (1545-1548)
- Spanish Influenza (1918-1920)
 - 17-100 million deaths worldwide.
 - 1-5% of global population
 - 2nd-most devastating pandemic in history (after Black Death)



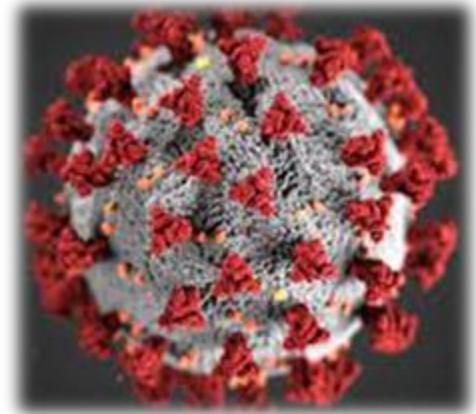
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- Spanish Influenza (1918-1920)
- HIV (~1960-now)
 - >40 million deaths and counting
 - Prevalence still >20% in some countries in southern Africa



Parasites and pathogens have shaped human history.

- Plague of Justinian (541-549 AD)
- Black Death (1346-1353 AD)
- Cocoliztli (1545-1548)
- Spanish Influenza (1918-1920)
- HIV (~1960-now)
- COVID-19 (2019-now)
 - ~7-30 million deaths worldwide and counting
 - ~0.1-0.4% of population



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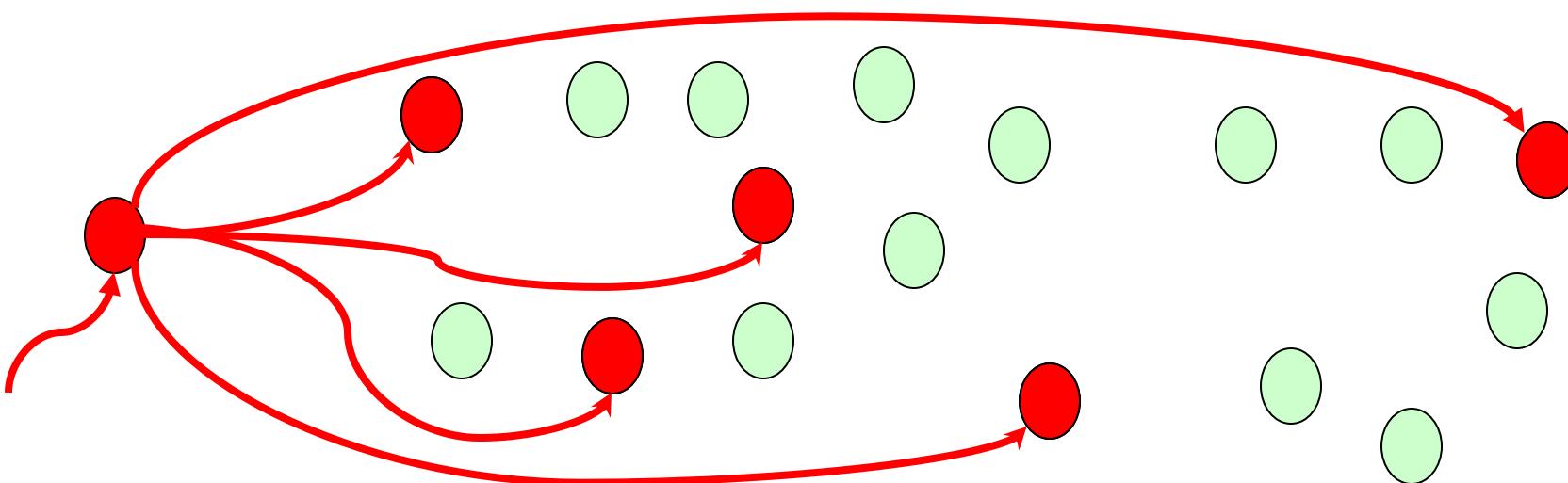
Epidemiology vs. Population Biology (Disease Dynamics)

- Epidemiology = “the study of **what** is on the people”
 - Coined by Spanish physician Villalba in 1802
- Emphasis on the study and analysis of the **distribution and determinants** of health and disease (“risk factors”)
 - Including chronic diseases!
- Often uses **cross-sectional** data to demonstrate associations of variables with outcome (disease)
- More statistical ($y=mx+b$)
 - **Pattern**

- Population biology = the study of **how** a disease spreads
 - Emphasis on the **interactions** of organisms with each other and the environment...when interactions result in disease
- Emphasis on understanding the **transmission dynamics** of infectious disease
- Typically involves fitting dynamical (population) models to **time series** data
- More mathematical (dN/dt)
 - **Process**

R_o

- The **basic reproduction number** for a pathogen
- Defined as: the number of new cases caused by one infectious case in a **completely susceptible** population



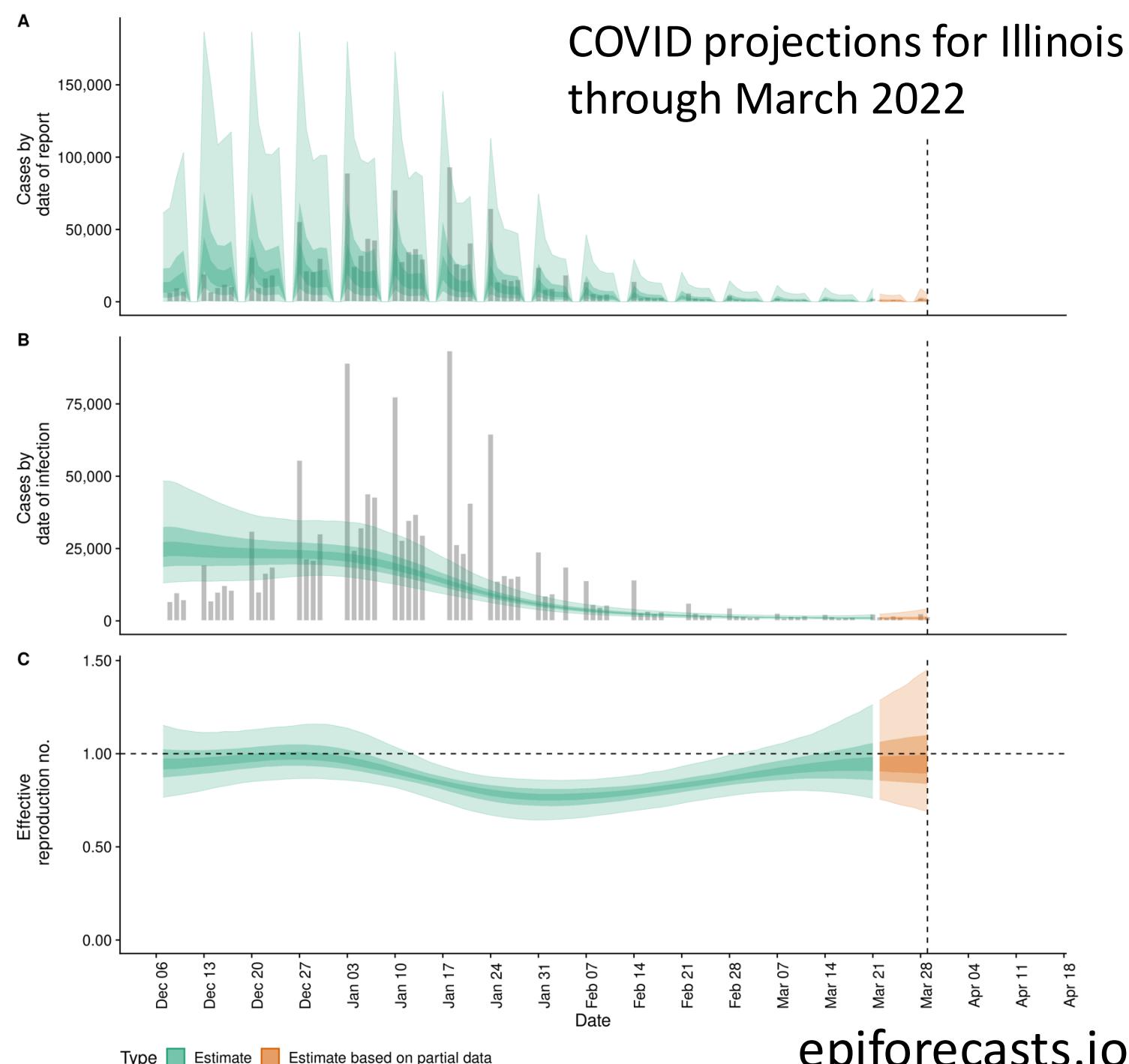
What is R_o ?

$R_o = 5$

R_E OR R_t

- The **effective reproduction number** for a pathogen
- Defined as: the number of new cases caused by one infectious case in a **partially susceptible** population
- Calculated as $R_0 * \text{proportion susceptible}$

$$R_E = R_0 \frac{S}{N}$$



Public health interventions can be employed to reduce both R_0 and R_E

R_0 interventions

- Social distancing
- Masking
- Limits to gathering sizes
- Drugs that shorten the infectious period



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R_E interventions

- Vaccination



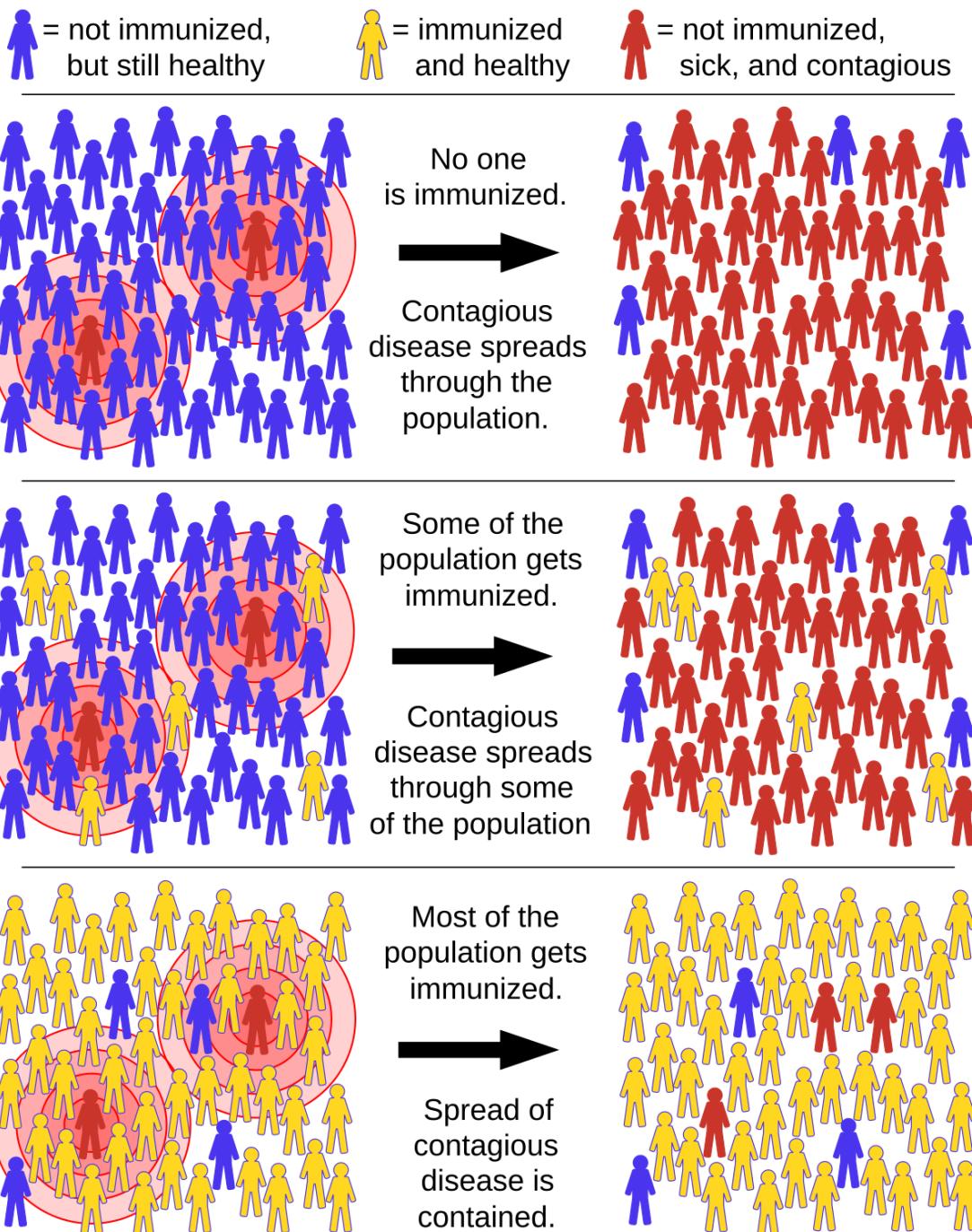
Vaccination and Herd Immunity

herd immunity threshold:

$$P_V > 1 - \frac{1}{R_0}$$

P_V = proportion
needed to vaccinate

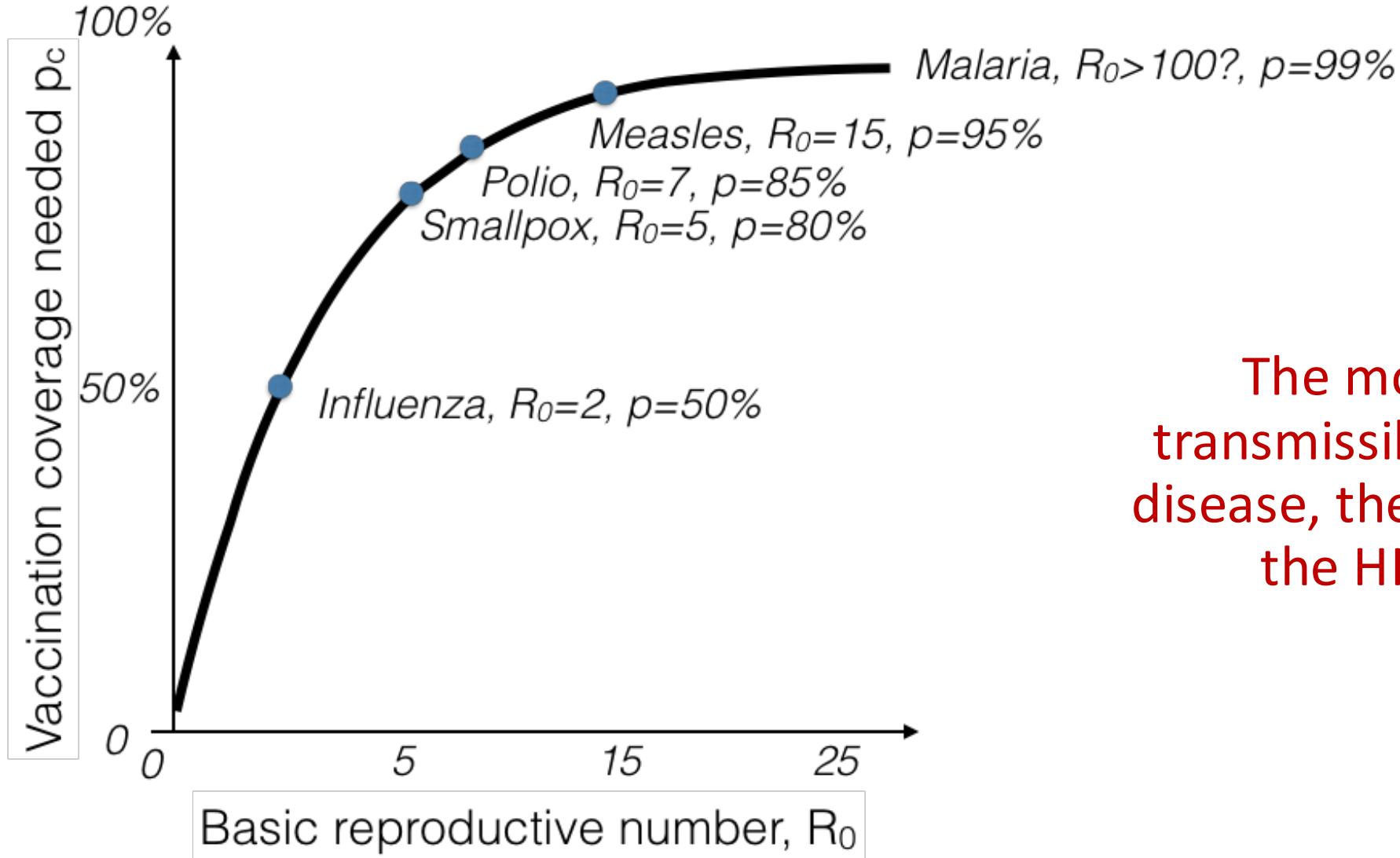
- Vaccination aims to reduce the host population below **critical community size (CCS)** for the pathogen of interest.
- CCS, the **minimum number of hosts needed to maintain endemic transmission of a pathogen indefinitely into the future**, varies based on the transmissibility of the pathogen.



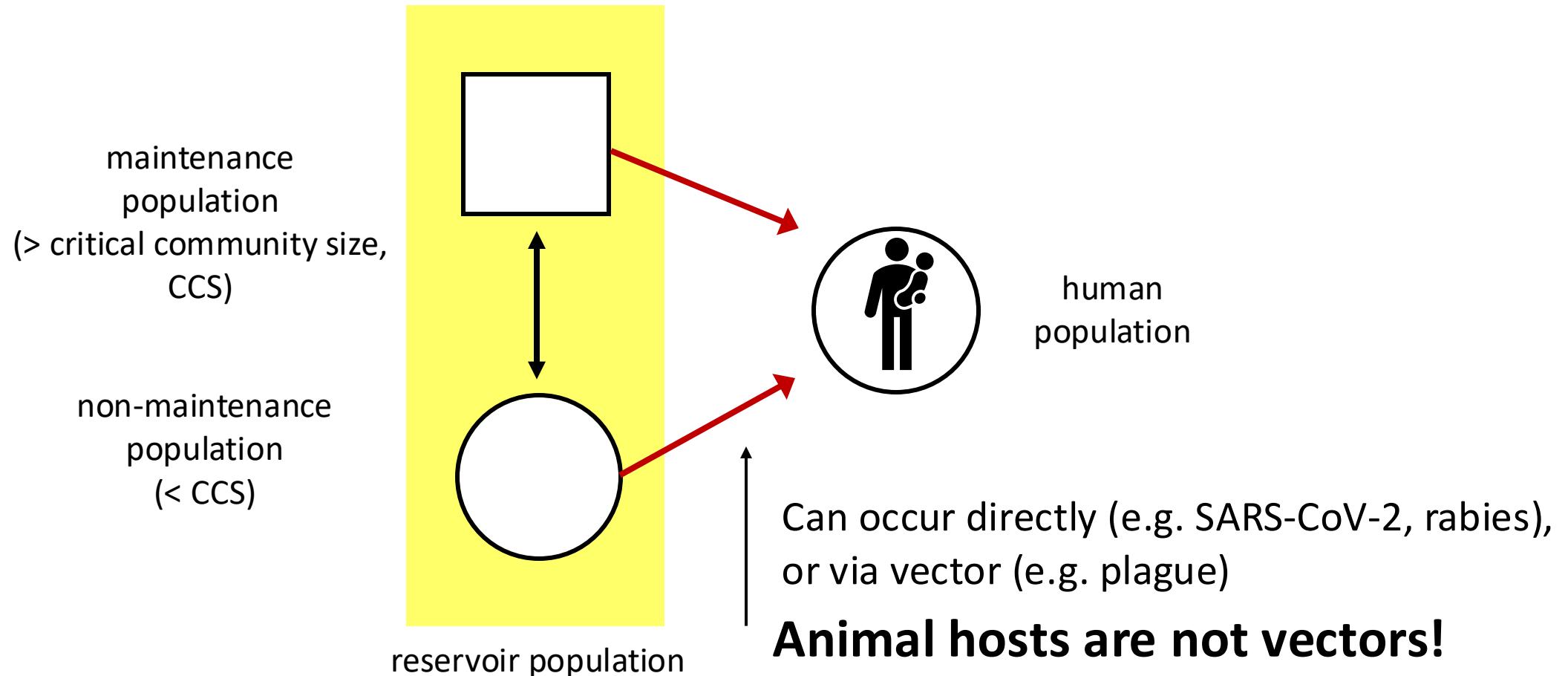
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Zoonosis is the transmission of a pathogen from a **wildlife reservoir host** to a **human target host** population.



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