Emergence of Zoonotic Disease Due to Habitat Loss and Biodiversity

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ZOONOSIS IN GENERAL

Definition, prevalence, & reasons for concern

Zoonotic Disease

- Disease that can be transmitted from animals to humans
- 3 out of every 4 new or emerging infectious diseases (EIDs) in people come from animals (*Centers for Disease Control and Prevention, 2017*).
  - Examples:
    - COVID-19
    - Ebola
    - Salmonella
    - Zika Virus
    - Swine Flu

Chomel, B.B.,(2009). *Encyclopedia of Microbiology* 820-829

Zoonotic Disease

- A significant and growing threat to global health, global economy and global security
- Emergence involves dynamic interactions among populations of wildlife, livestock, and people within rapidly changing environment
- Complex mechanisms

Allen, T. et al (2017) *Nature Communications.* 8:1

CORRELATES

Contributors to emergence
and increasing prevalence

Factors Contributing to Increase of EID

- Rise of global temperatures
  - Greater vector distribution (mosquitos, ticks, sandflies, rodents)
- Travel and tourism on the rise to more exotic areas
- Agriculture and Farming
  - Disrupts natural ecosystems
  - Intermingling of species
  - Exploitive antibiotic use
- Urban Expansion & Deforestation
- Bushmeat and Hunting

Preneshni, N. (2020) *Archives of Clinical Microbiology*

Other Factors

- Also baseline dependent on:
  - Geographical distribution
  - Method of transmission
  - Biodiversity
  - Population density
  - Efficacy of control efforts

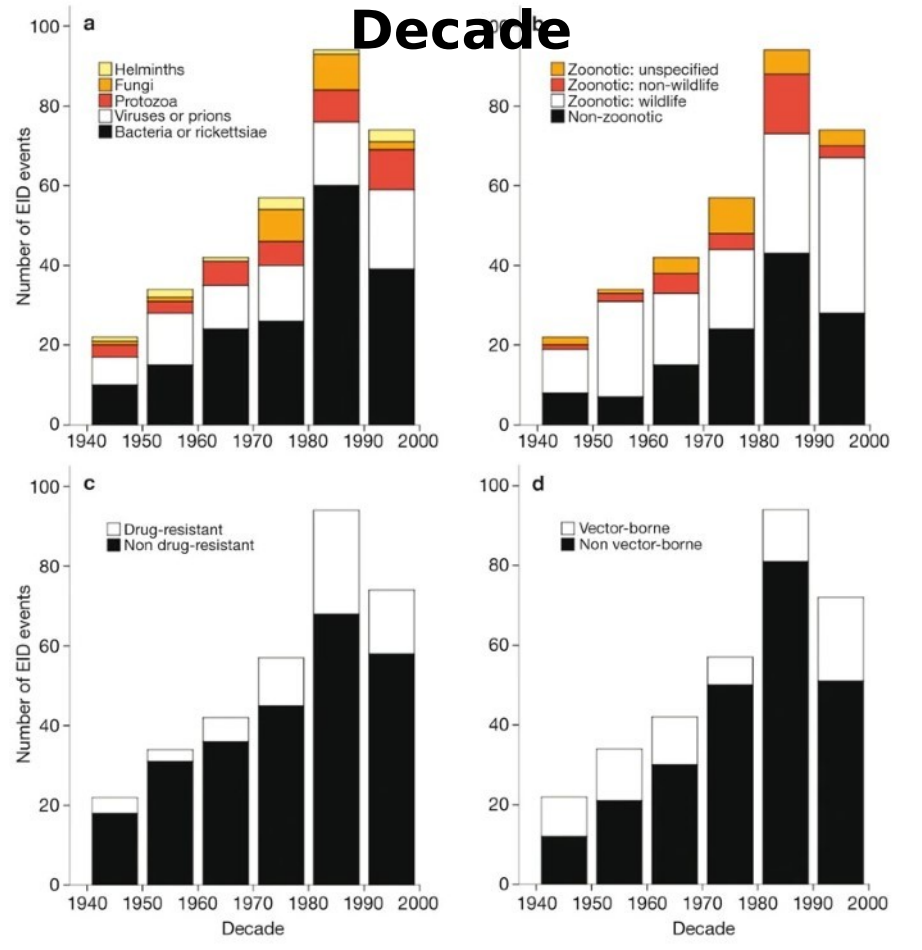
Preneshni, N. (2020) *Archives of Clinical Microbiology*

Global Trends in Emerging Infectious Diseases (*Nature*, 2008)

- Methods:
  - Biological, temporal and spatial data from 335 infectious diseases between 1940 and 2004.
  - Accounted for biases
  - Compared the location of EID events to five socio-economic, environmental, and ecological variables matched onto a one degree grid of the globe
- Categories:
  - Pathogen Name, Year, Pathogen Type, Transmission Type, Transmission Mode, Driver, Economic Development and Land Use, & Location

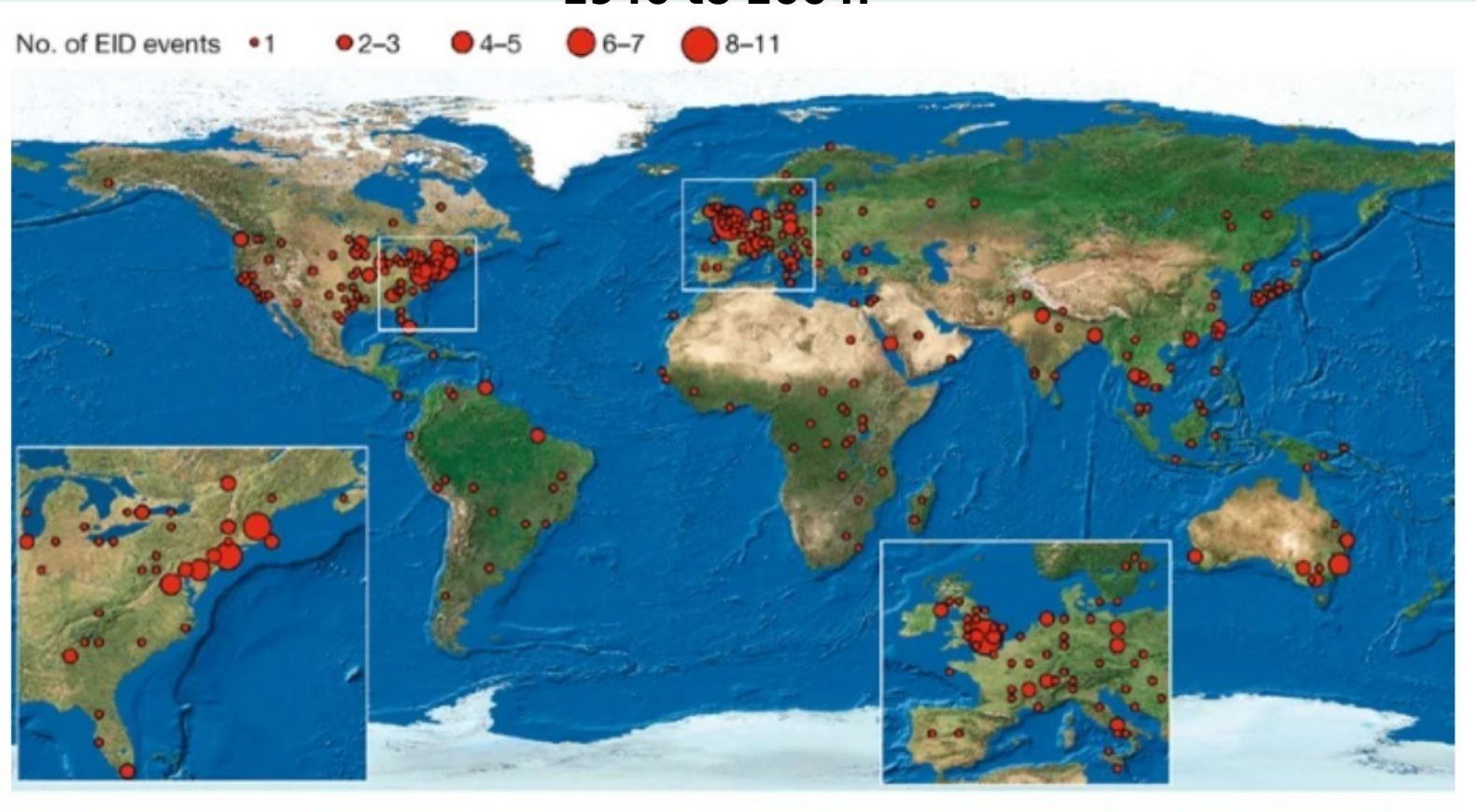
Jones, K.. et al (2008) *Nature Communications.* 451: 990-993

Number of EID Events Per Decade



Jones, K.. et al (2008)
Nature Communications.
451: 990-993

Global richness map of the geographic origins of EID events from 1940 to 2004.



Jones, K.. et al (2008) *Nature Communications.* 451: 990

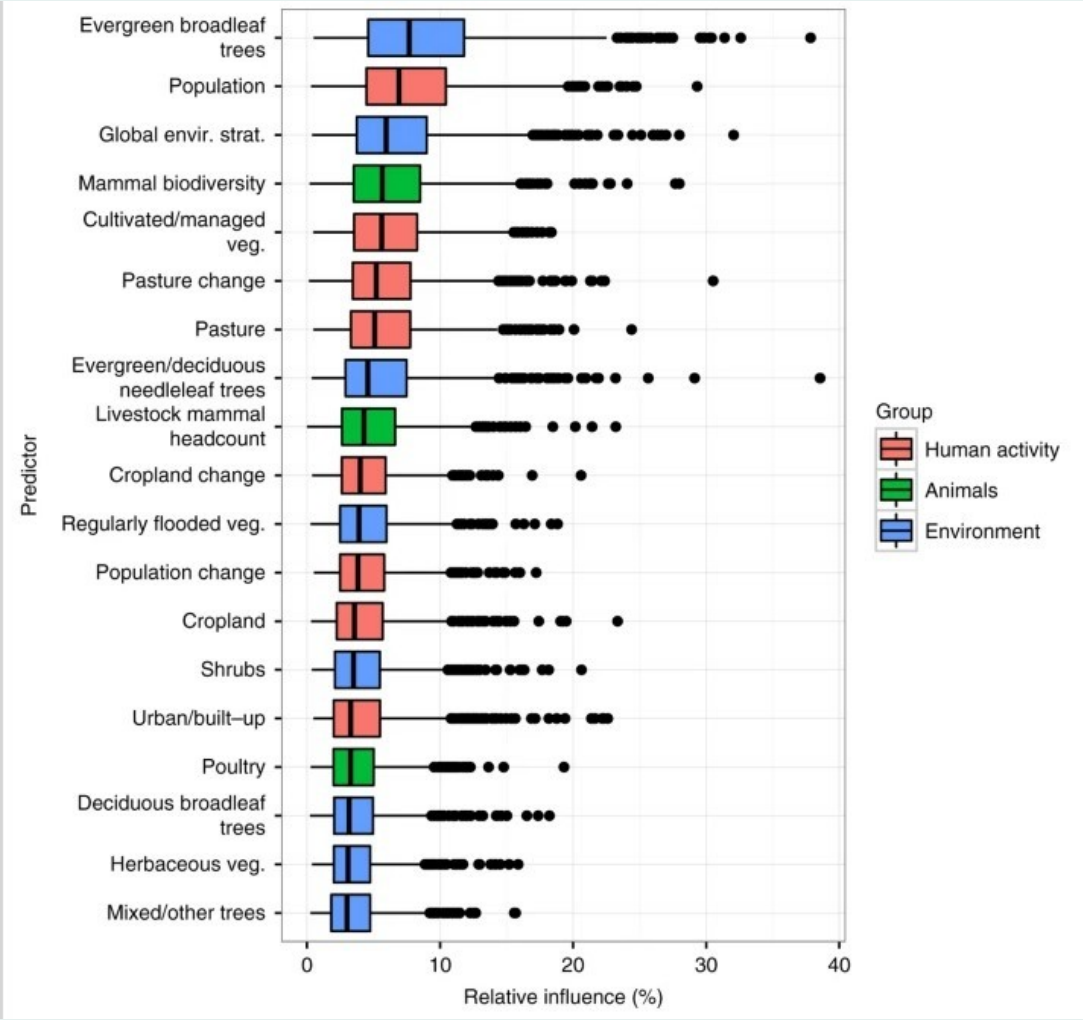
Global Hotspots and Correlates of Emerging Infectious Disease (Nature 2017)

- Built on 2008 study:
  - Claim it is limited in its' mechanistic inference due to lack of specificity in predictors and reporting bias
  - Updated database and employed a new modeling framework
    - Regression tree models
    - Spacial Model

Jones, K.. et al (2008) *Nature Communications.* 451: 990-993

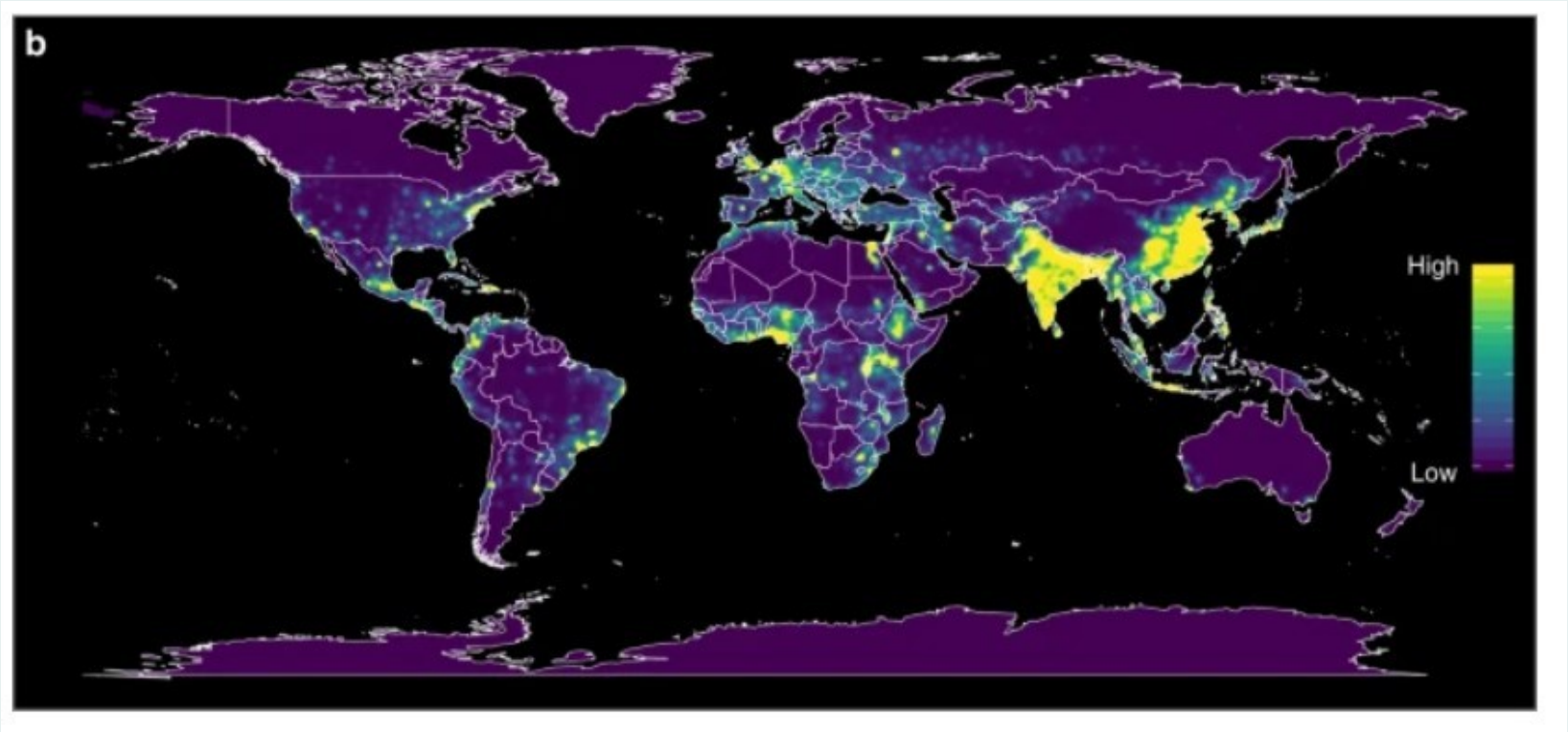
Relative influence of predictors on EID event occurrence probability (2017)

- Tropical forest climate, large population, & high mammalian biodiversity had highest relative influence
- Could be due to increased “depth” of the pathogen pool



Allen, T. et al (2017) *Nature Communications.* 8:1124

Heat map of predicted relative risk distribution of zoonotic EID events



Allen, T. et al (2017) *Nature Communications.* 8:1124

ETIOLOGY

Mechanisms of action for zoonotic disease in the human body

Causes

- Zoonotic diseases can be caused by:
  - Bacteria
  - **Viruses**
  - Fungi
  - Parasites
  - Prions
- Mostly transmitted through mammals
  - Due to close evolutionary relation

Spickler, A. (2015) *Merck Veterinary Ma*

Transmission

Food-borne

Direct Contact with Animals

Close Proximity to Animals

Vectors

Airborne Transfer

Spickler, A. (2015) *Merck Veterinary M*

Zoonotic Viruses

- Invade normal, living cells and use those cells to multiply and produce other viral-cells like themselves
- Virus must:
  - Shed enough from the original animal host
  - Be equipped with the molecular machinery to enter human cells
    - needs the right protein to bind to a receptor on a human cell
  - Be able to replicate & infect other cells
  - Evade the human immune system

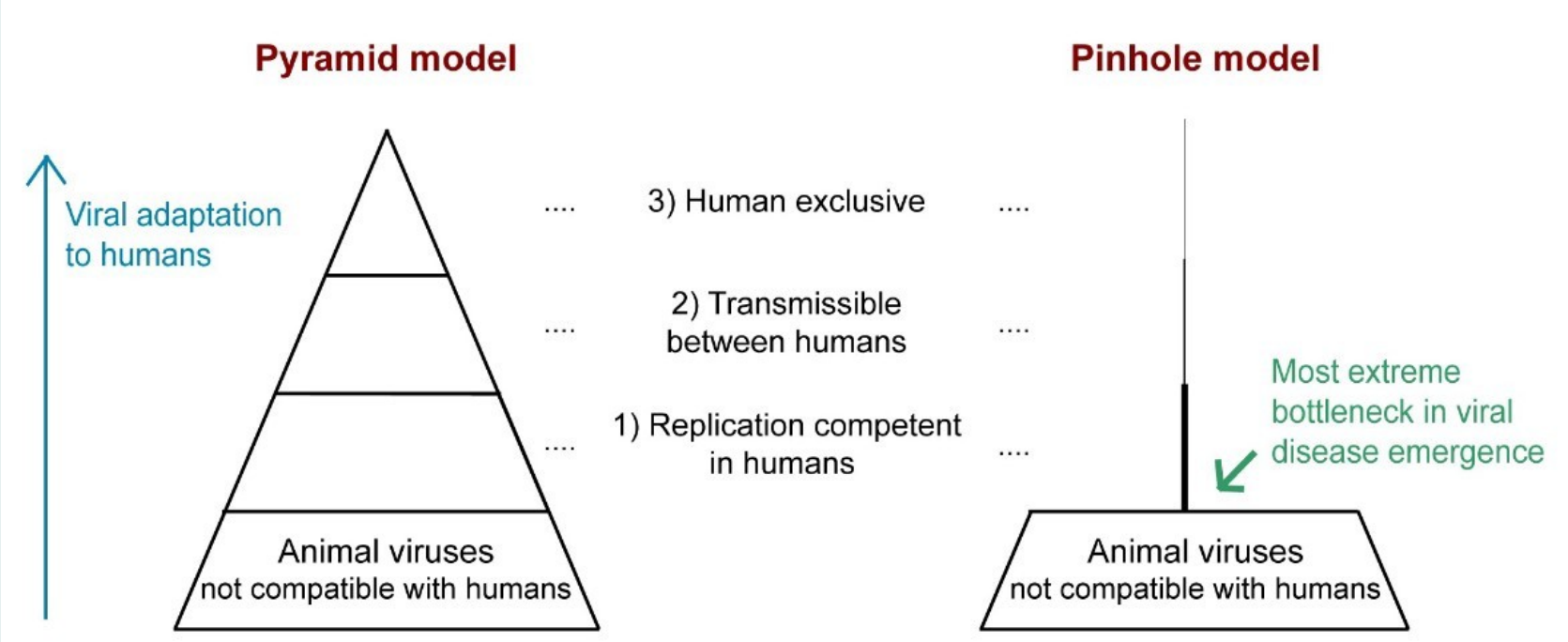
Rahman, M. et al. (2020). *Microbiology*

Study: Viral Zoonosis & Host Genetics (2019)

- Host genetics define success for which animal viruses will achieve replication
  - Must correctly execute tens to hundreds of protein-to-protein interactions within the host cell
- Extreme bottleneck effect: viruses with greatest risk to humans have fewer genetic barriers to integrate into host cell machinery

Warren CJ, Sawyer SL (2019) *PLOS Biology* 17(4): e3000

Extreme bottleneck in viral disease emergence: The replication of animal viruses in early human host.



Warren CJ, Sawyer SL (2019) *PLOS Biology* 17(4): e3000

Study: Viral Zoonosis & Host Genetics (2019)

- To replicate:
  - Interact with useful human proteins
    - Receptors, restriction factors, etc.
  - Simultaneously avoid interaction with immunity proteins that will destroy them
    - B and T lymphocytes
- For most animal viruses in nature, this too many interactions to master by chance in a random encounter with humans
- Thin genetic barriers between animal and human cells are very dangerous

Warren CJ, Sawyer SL (2019) *PLOS Biology* 17(4): e3000

BATS & COVID19

A look into causes of the current global crisis

Coronaviruses (CoVs)

- Prone to cross-species transmission, able to rapidly adapt to new host
  - RNA virus
  - Large genome size
  - Frequent recombination
  - High genomic plasticity
- Recent emergence of a number of CoVs affecting livestock and human health

Latinne, A et al. (2020) *Nature Communications* 11

Bats are Sources of Viral Zoonotic Disease Worldwide

- Human exploitation & deterioration of habitat quality
  - Increased likelihood of human contact
- Bat viruses are not pathogenic in reservoir hosts
- Flight:
  - Causes elevated metabolic rate & body temperature
    - Faster DNA damage repair & genome evolution
    - No inflammatory response

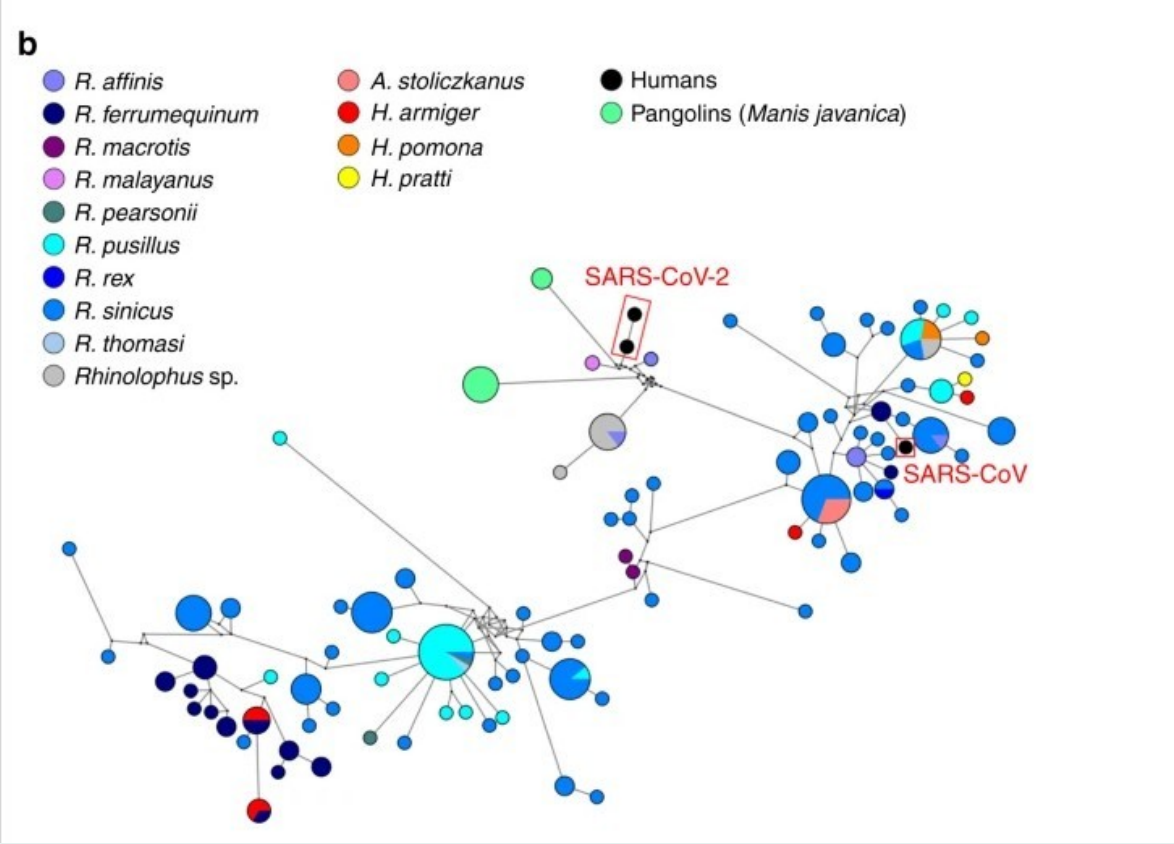
Platto, Sara et al. (2020) *Biochem. and Biophys. Research Co*

Bats & Coronavirus

- Bat origin: 64 millions of years
  - Coevolutionary process between Chiroptera and pathogens
  - Can infect a wide variety of hosts
- Bats are hosts for αCoV and βCoV
  - Combination of CoV virulence factors & bat morphology is dangerous

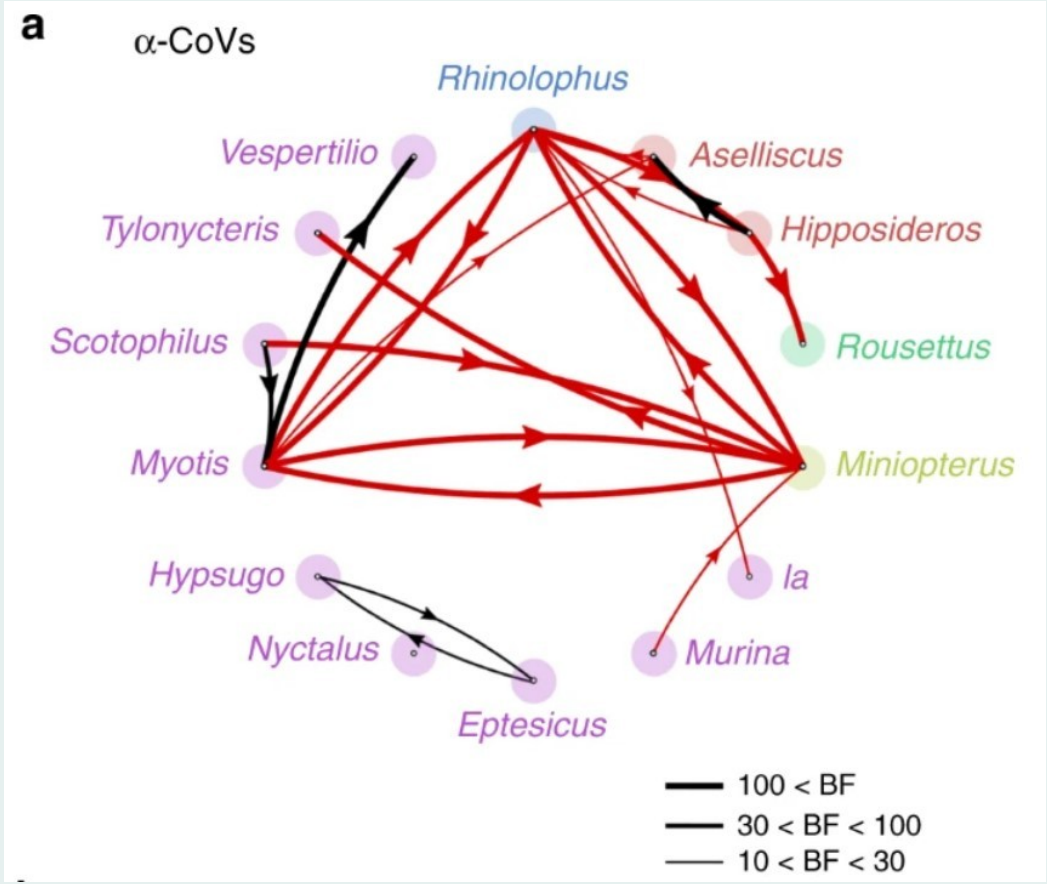
Latinne, A et al. (2020) *Nature Communications* 11

Maximum clade credibility tree: Bat Species, Pangolins & Humans



Latinne, A et al. (2020) *Nature Communications* 11

Inter-genus host switches



Latinne, A et al. (2020) *Nature Communications* 11

SOLUTIONS

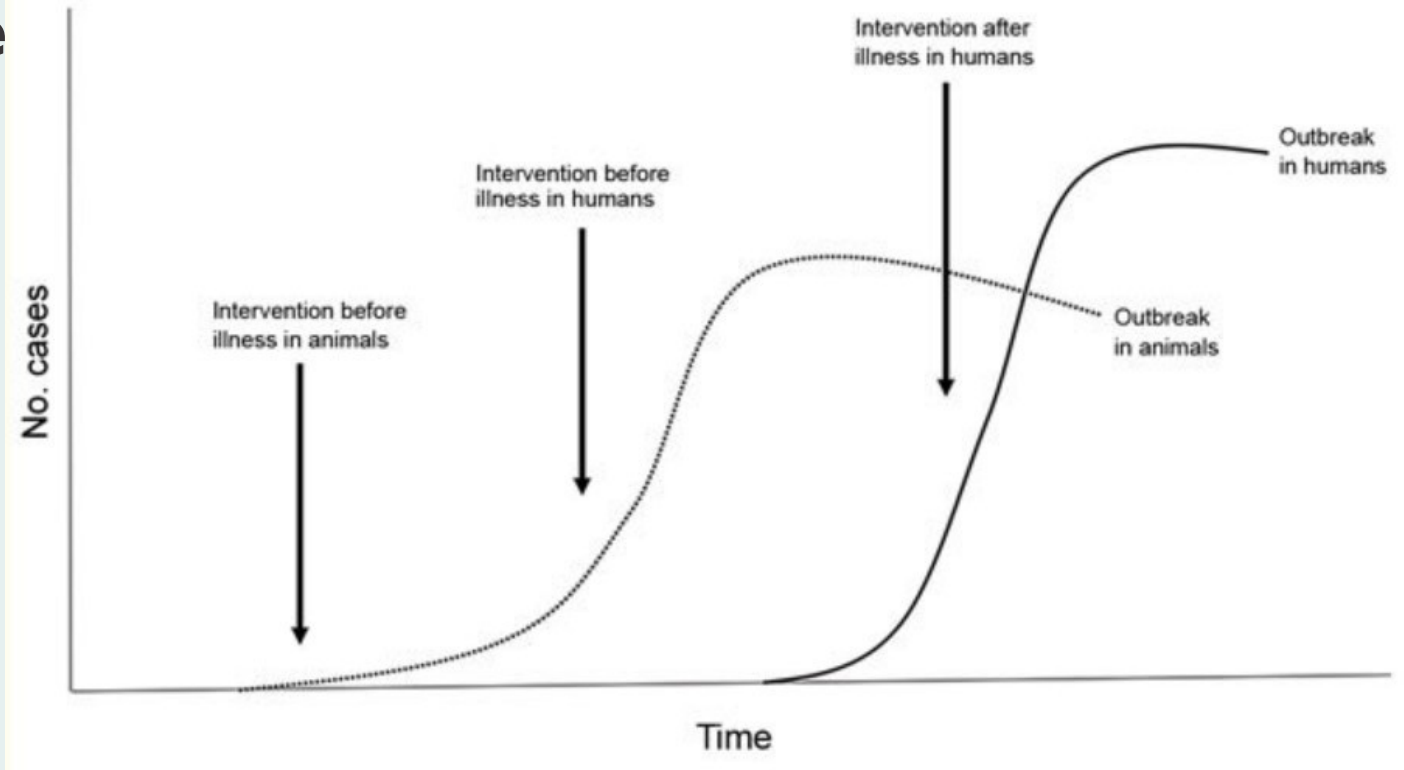
Preventative actions and future considerations

Need for Preventative Action

- Current efforts mostly post-emergence oriented:
  - Quarantine
  - Drug and vaccine development
- Delays in detection & response + increased global urbanization and connectivity cause extensive mortality across cultural, political, and national boundaries

Belay, Ermias D et al. (2017) *Emerging infectious diseases.*S6

Opportunities for intervention to prevent and control endemic and emerging zoonotic dise



Belay, Ermias D et al. (2017). *Emerging infectious diseases* S6

Preventative Steps

- Need to preemptively identify origins & causes
  - Focus on surveillance, prevention and control steps
  - Containing EIDs closer to source
- Close collaboration between global animal, human, and environment health sectors
- Main goal: reduce contact with high-risk wildlife
  - Wet markets, trade, bat caves, sensitive ecosystems

Belay, Ermias D et al. (2017) *Emerging infectious diseases.*S6

SUMMARY

Summary

- Experts believe that zoonotic diseases are the currently biggest threats to global public health.
- Climate change and habitat loss are pushing high-risk wildlife closer to humans, causing an increases in transmission & emergence rate.
- Bats are dangerous reservoir hosts for many EIDs
  - COVID19
- Action must be taken in order to predict EID capability to cause other epidemics

THANKS

Prof. Kenneth Kodama & EES097 professors

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