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Zoonotic infectious diseases: a “One Health” approach

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Questions? sli.do #Q689

BBSRC bioscience for the future

LIDo London Interdisciplinary Doctoral Programme
@ UCL, KCL, QMUL, Birkbeck, LSHTM, RVC

Infectious diseases in resource poor settings

Objectives

- Introduce the concept of “One Health”
- Define zoonotic infectious diseases
- Introduce the biological and ecological processes driving disease spillover events
- Highlight the role of “One Health” in reducing the risk of and response to spillovers of zoonotic infectious diseases

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Global Health, One Health and Planetary Health

- Global health has no true consensus definition.
- One health is a collaborative, multisectorial approach working across different geographic scales to optimize health outcomes. Recognising the interconnection between people, animals, plants and their shared environment
- Planetary health is the health of human civilization and the state of the natural systems on which it depends

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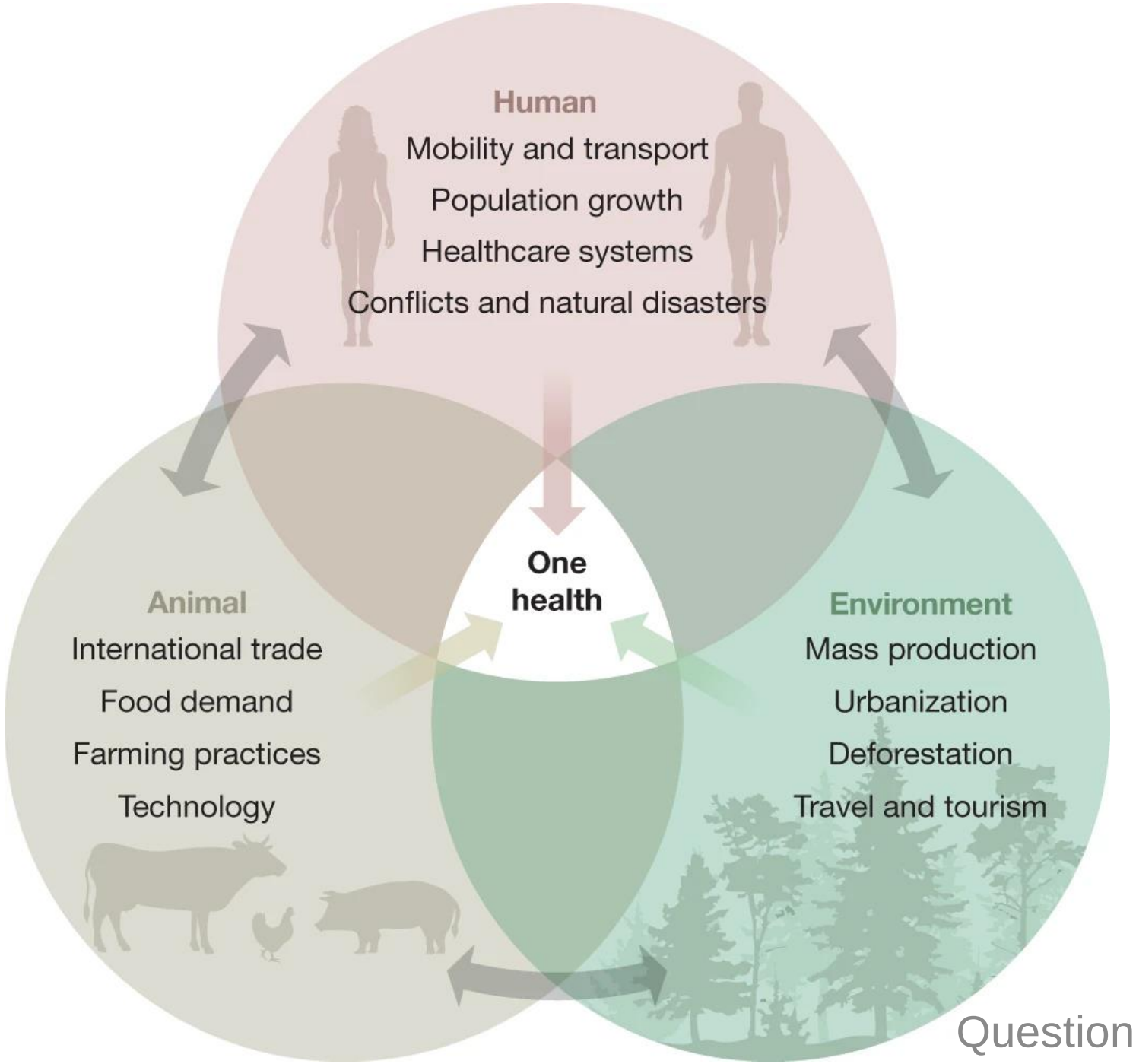

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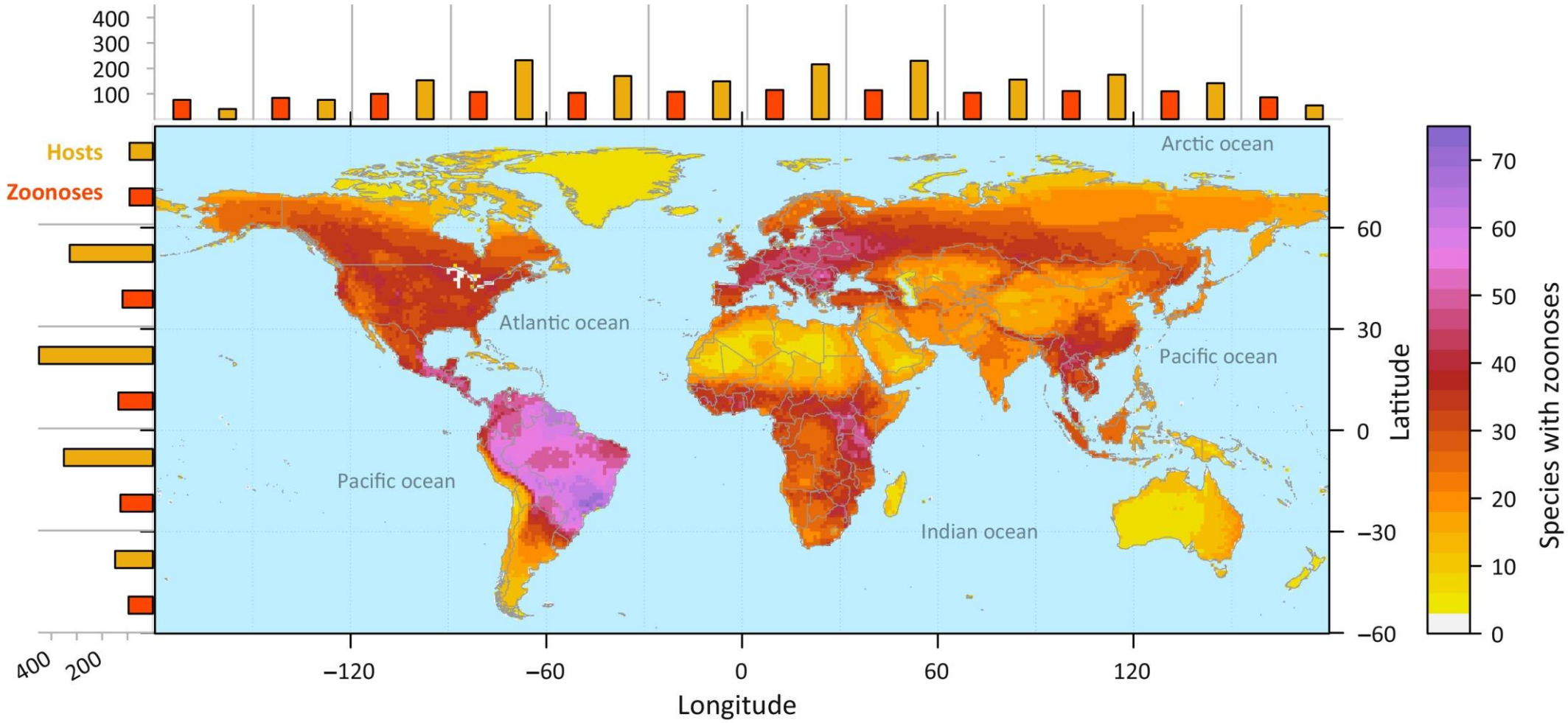
Where are the zoonoses?

Han, B. et al. 2016. *Trends in Parasitology*



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Zoonotic infectious diseases

- What human pathogens come to mind as zoonotic diseases?

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Some zoonotic pathogens

- Viral
  - Influenza A
  - Hantavirus
  - Orf
  - Rabies
  - CCHF
  - Ebola
  - Lassa
  - MERS
  - Monkeypox
  - Nipah
  - SARS
  - COVID-19
  - WNV
- Bacterial
  - Anthrax
  - Campylobacter
  - Bartenellosis
  - HUS
  - Leptospirosis
  - Borellia burgdorferi (Lyme)
  - Q fever
  - Brucellosis
  - Plague
- Parasitic
  - Cysticercosis
  - Cryptosporiosis
  - Giardia
  - Hydatid disease
  - Ringworm
  - Toxoplasmosis
  - Plasmodium knowlesi
  - Trypanosomiasis
  - Schistosomiasis

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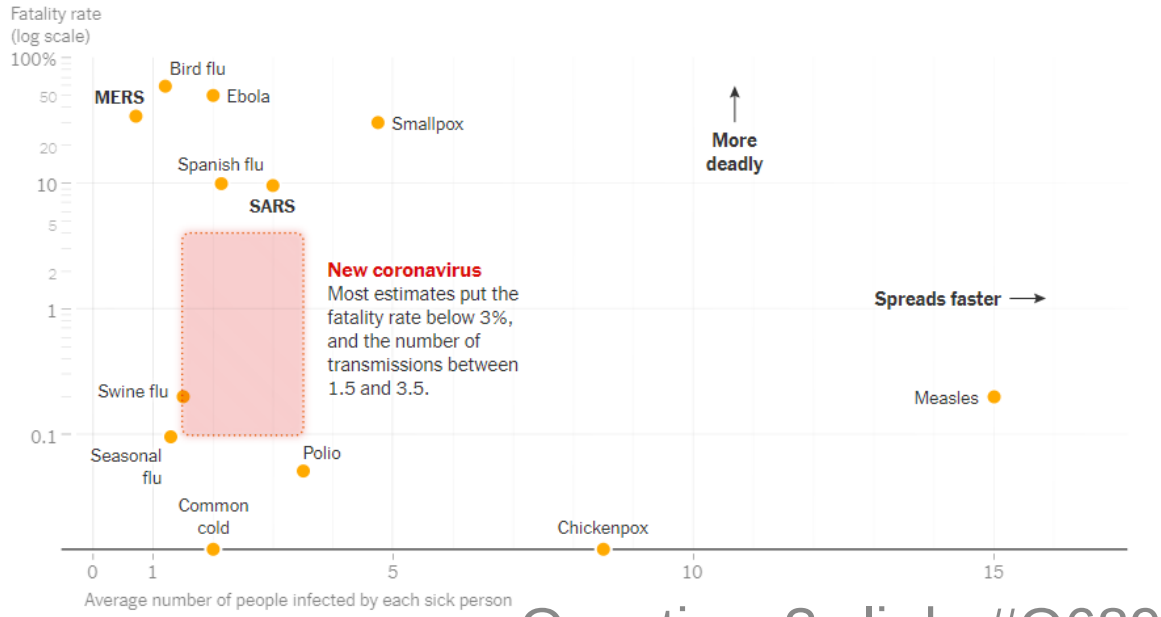
Infectious disease dynamics primer

- R_0 - The number of secondary infections after introduction to a fully susceptible population
- β – The force of infection, or the rate at which susceptible individuals become infectious



New York Times, 2020.

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Spillover events

- What are they?
- Why are they important?
- How do they happen?
- Can we avert them?

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Spillover – What is it?

- A spillover event is the transmission of a pathogen from its reservoir host into a non-reservoir host
- Spillover into non-human hosts can be seen in Nipah & WNV leading to amplification
- Spillover into humans can lead to infection and disease e.g. Lassa, P. knowlesi which does not spread much further
- Spillover into humans can lead to sustained human-to-human infection e.g. HIV, Ebola, COVID-19

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Spillover – Why is it important?

- Trypanosomiasis – large parts of Eastern and Southern Africa were historically uninhabited despite being incredibly fertile.

- Three specific case studies
  - HIV
  - Ebola virus disease
  - SARS-CoV-2

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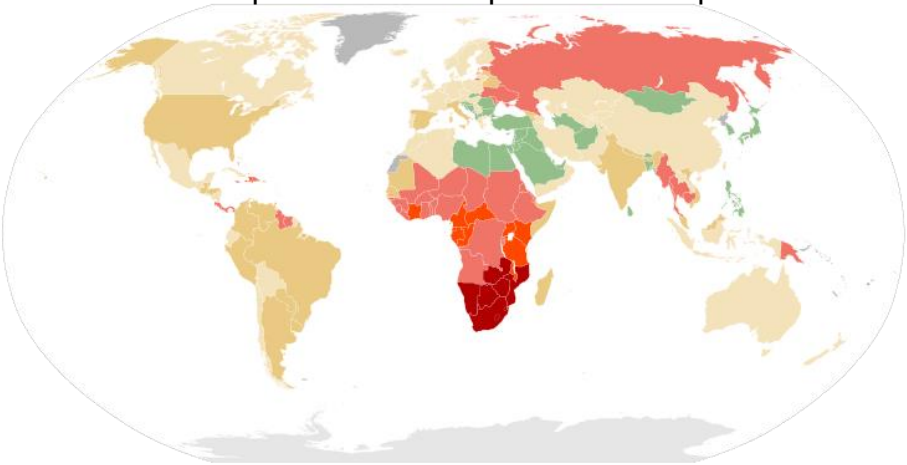
HIV

Wikipedia 2020. HIV prevalence map



- Closely related to SIV – likely origin
- Evidence of local infection and transmission in DRC prior to the 1960's
- Infection was already widespread before patients in the US and high-income countries were diagnosed with AIDS
- Has become a disease of humans, no further spillovers from reservoir populations
- What are the factors of this disease that enabled this?

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Factors supporting HIV spread

- Indolent virus – following seroconversion may be asymptomatic for many years despite significant viral load
- Seroconversion is relatively short, patients may not present during this time or investigations may not be conducted
- Long infectious period – individuals may spread the disease for many years
- Mode of transmission – relatively high frequency event (sexual) and low frequency but important effective events (blood-borne, childbirth)
- RNA virus – high mutation rate
- Globalisation
- Marginalised populations

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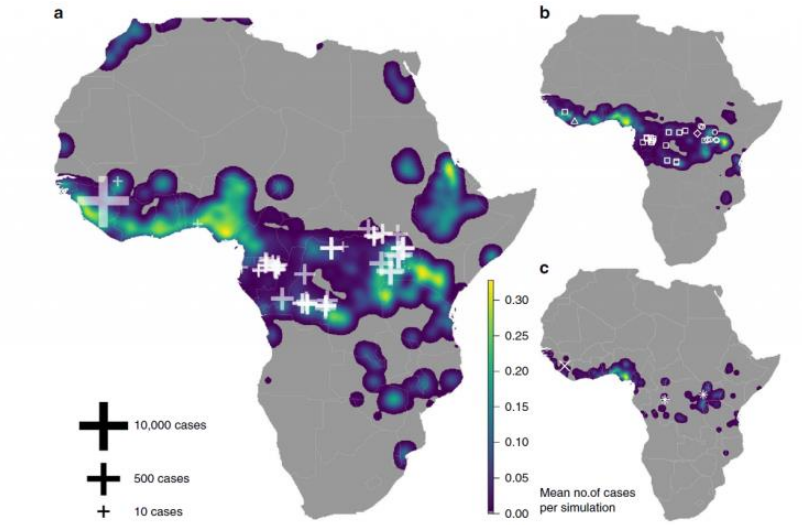
Ebola virus disease

Redding et al. 2019. *Nature communications*



- Several similar flaviviruses incl. Marburg
- Reservoir is believed to be bat spp.
- Events lead to high mortality epidemics, historically low numbers of infected individuals
- Epidemics are localised to Western and Central Africa
- High burden on healthcare infrastructure
- Important human-to-human transmission
- What are the factors that support Ebola transmission?

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Factors supporting Ebola spread

- Human-to-human transmission is in bodily fluids
- Burial practices increased risk of disease transmission
- Poor healthcare infrastructure increased nosocomial spread
  - Poor IPC strategies
- Conflict and community resistance to outside actors
- Limited information dissemination

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Johns Hopkins University, Coronavirus map. 2020

SARS-CoV-2

- Coronavirus's cause 20% of human colds (not all are zoonotic, ?historical spillover)
- SARS & MERS are further zoonotic examples
- This disease likely emerged from a "Wet Market"
- Similar to SARS likely bat spp. reservoir
- Expected that there is an amplifying species, current viral sequences suggest Pangolins
- What we are seeing now is human-to-human transmission

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Factors supporting SARS-CoV-2 spread

- Aerosol or droplet spread in respiratory secretions
- High proportion of asymptomatic or sub-clinical cases
- Increased globalisation and transport infrastructure
- High density population centres
- Long incubation periods

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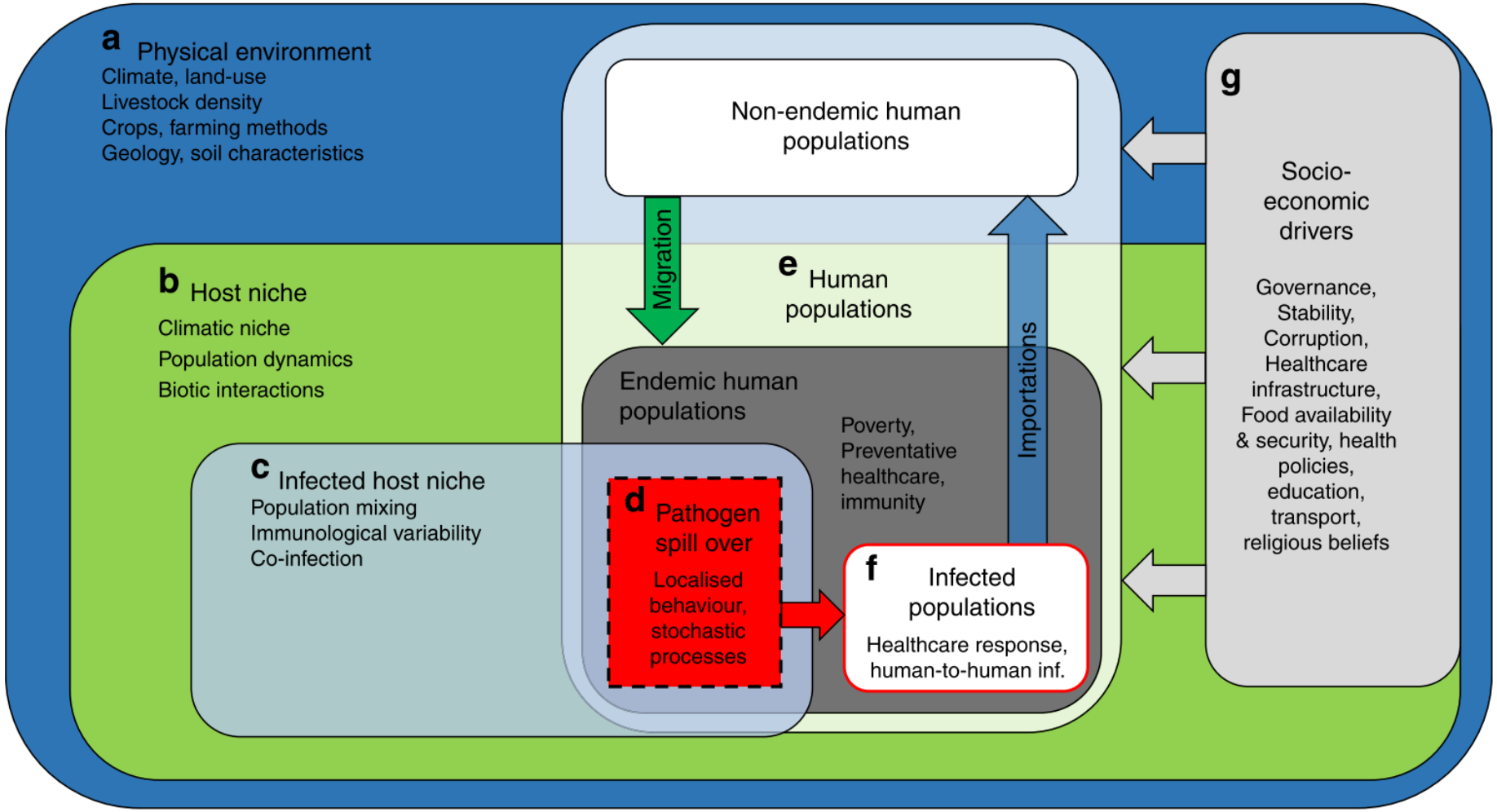
Spillover – How do they happen?

- Proximal and distal factors
- Proximal include:
  - Airborne – Nipah & SARS-CoV-2
  - Contamination – Lassa
  - Vector borne – P. knowlesi
  - Consumption (livestock) – Cysticercosis
  - Consumption (opportunistic) – HIV & Ebola
  - Wound/Saliva – Rabies
- Distal will be discussed further

A systems dynamic approach

Redding et al. 2019. *Nature communications*



The physical environment

- Climate
- Land use
- Livestock density
- Crops and farming methods
- Geology and soil characteristics

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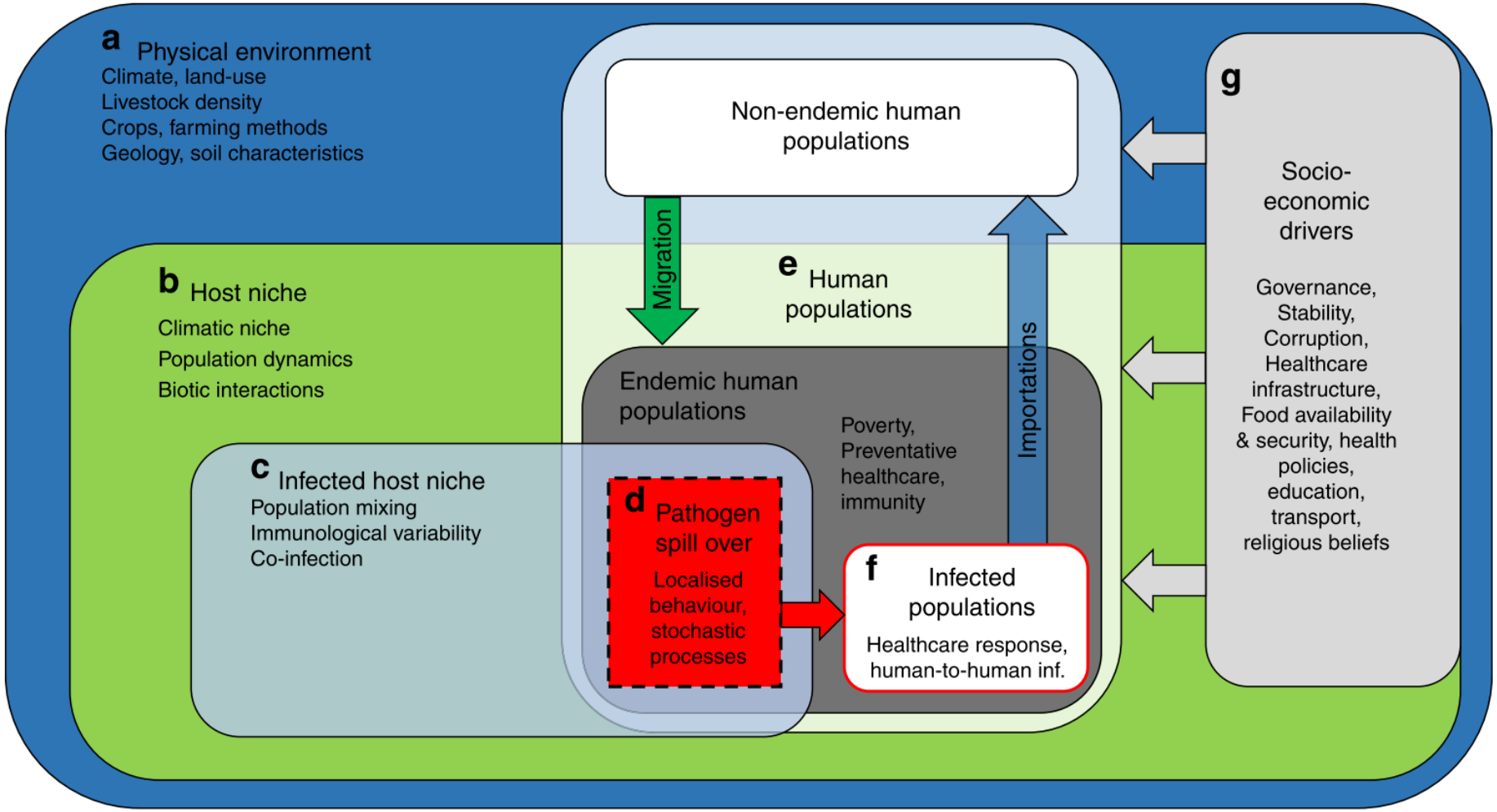
A systems dynamic approach



Host niche

- Climatic niche
- Population dynamics
- Biotic interactions

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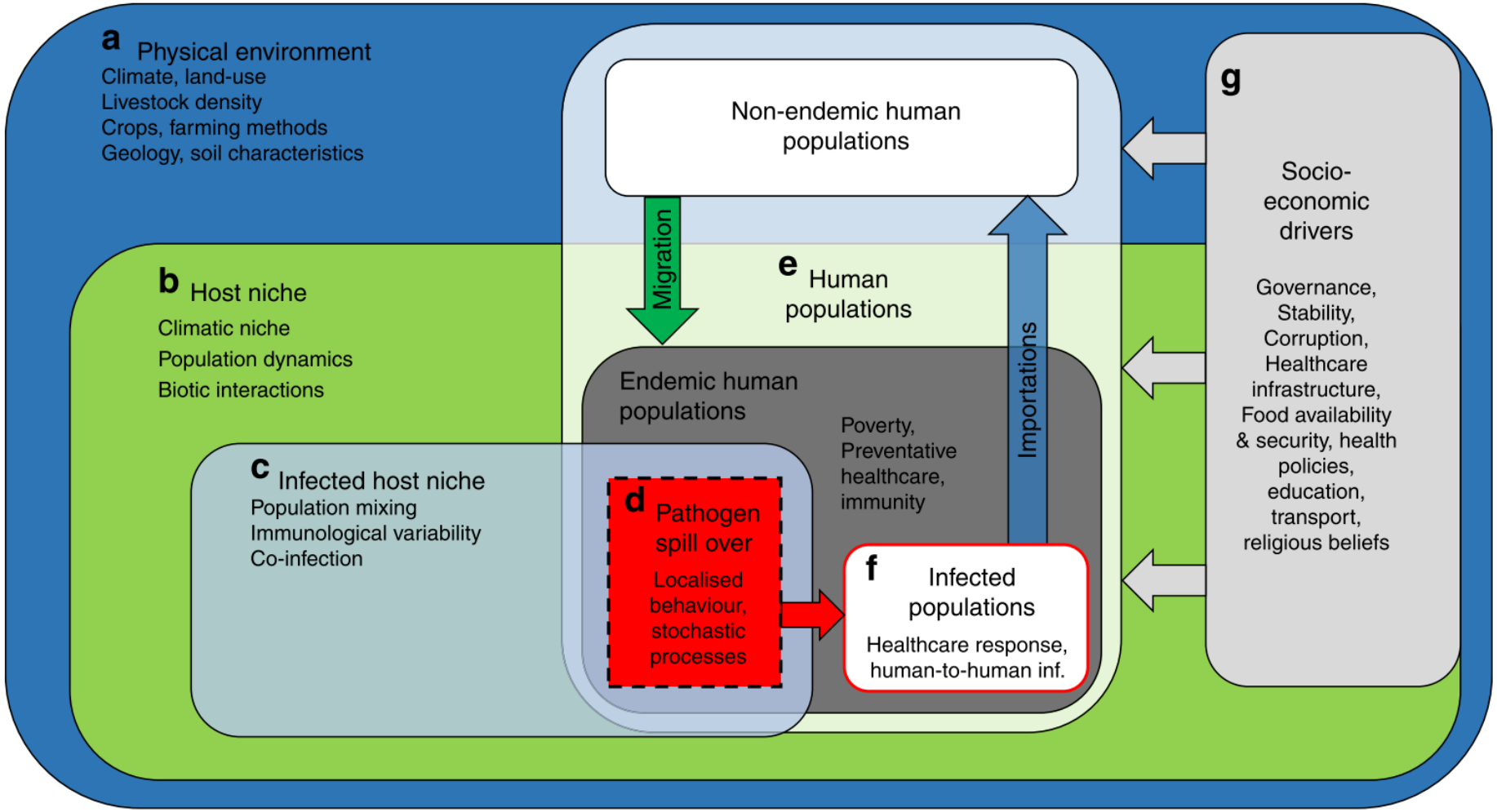
A systems dynamic approach



Infected host niche

- Population mixing
- Immunological variability
- Co-infection

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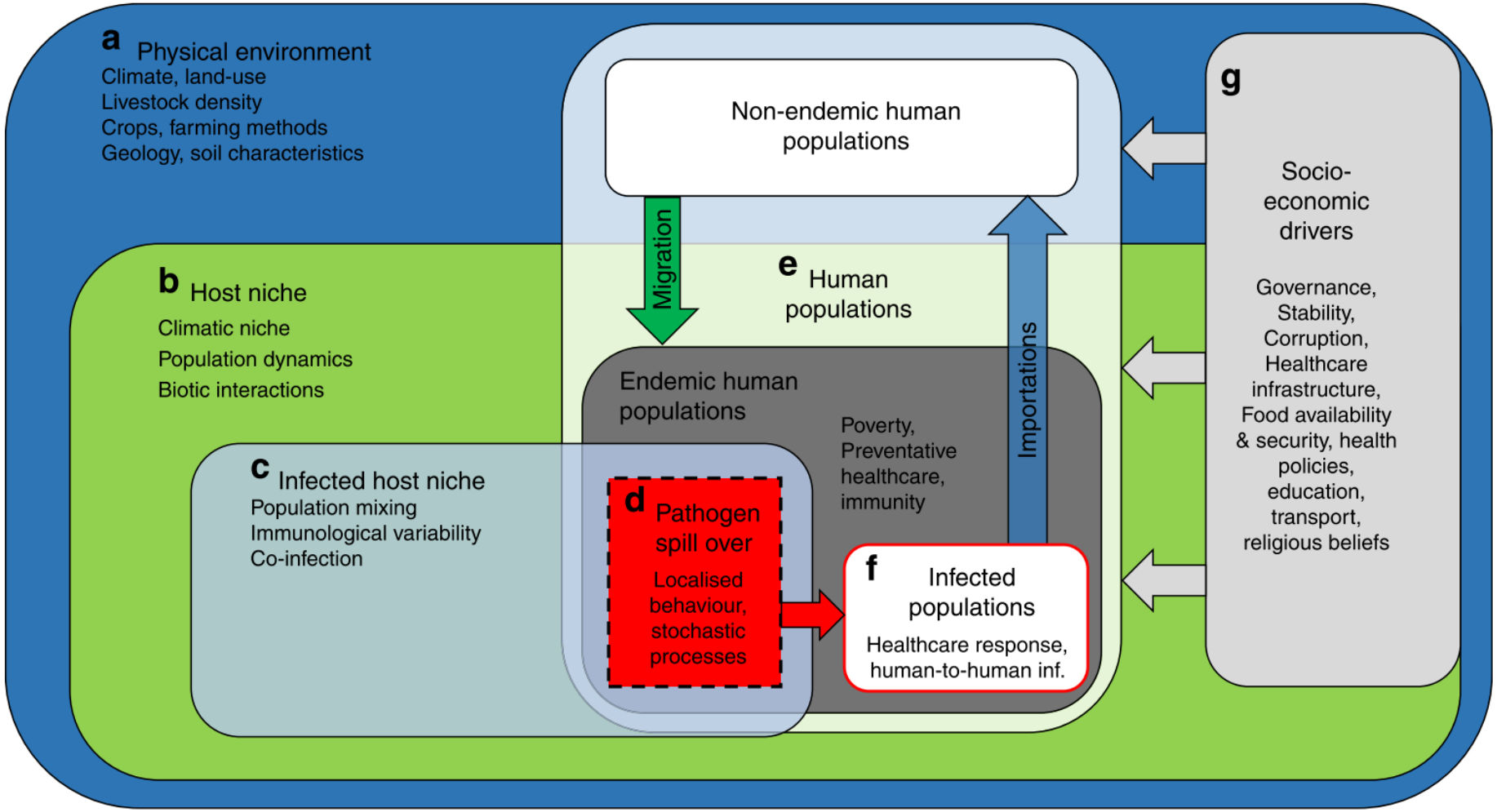

Pathogen Spillover

- Localised behaviour
- Stochastic processes

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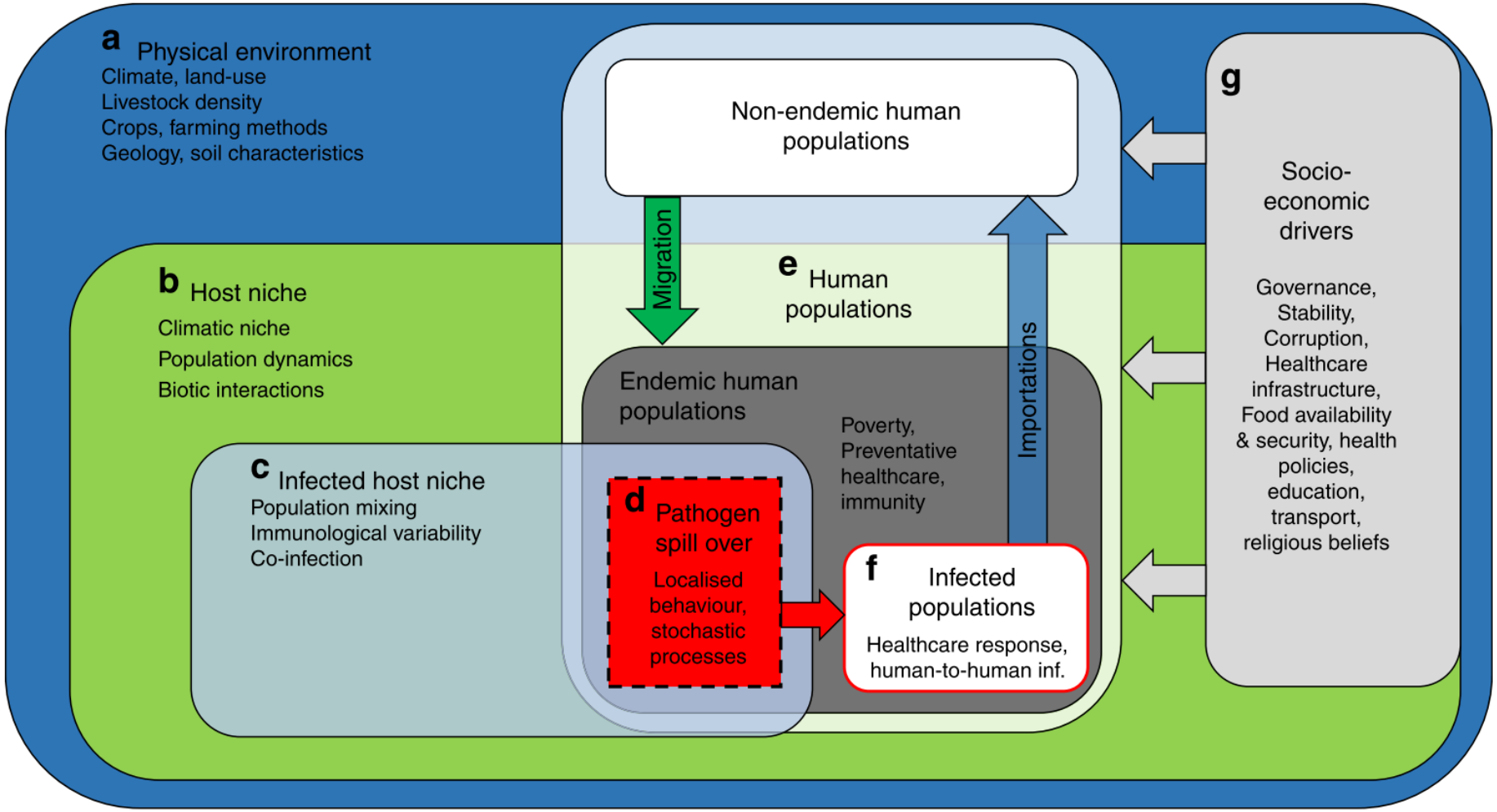

Socioeconomic drivers

- Governance
- Stability
- Corruption
- Healthcare infrastructure
- Food availability and security
- Health policies
- Education
- Transport
- Religious beliefs

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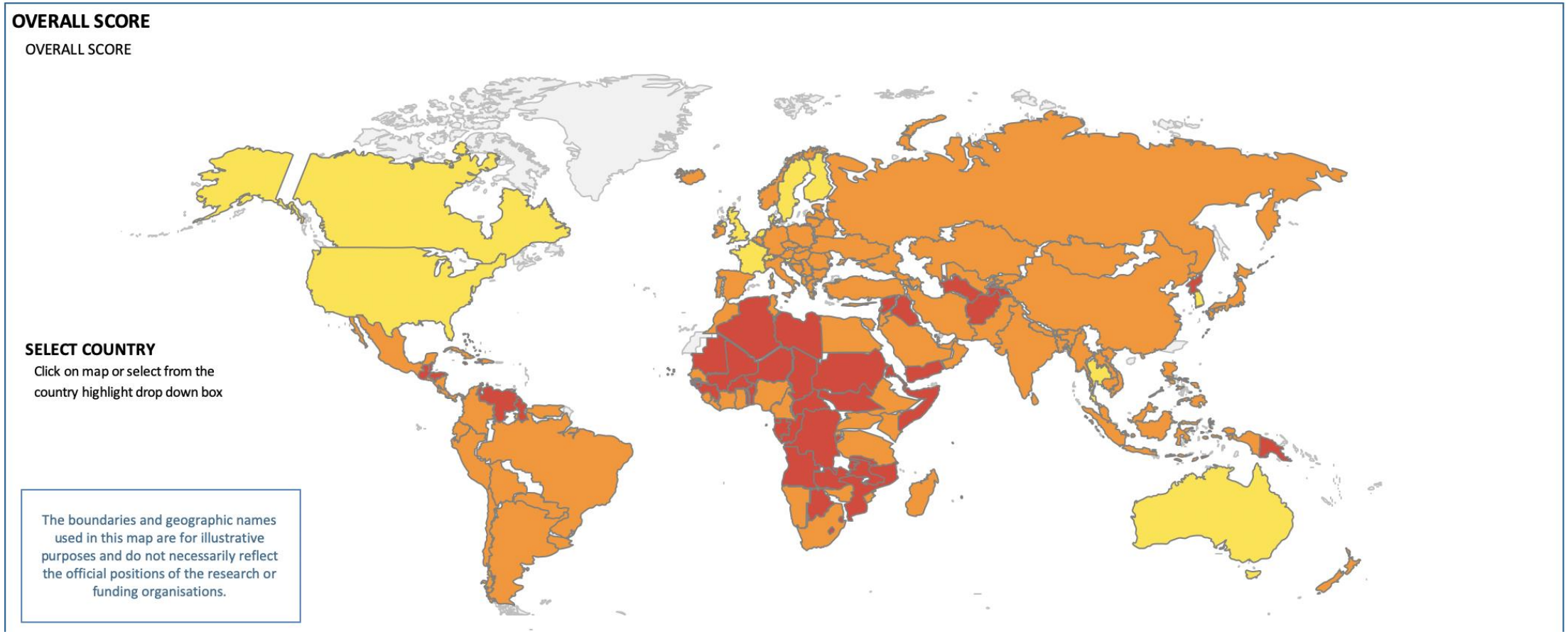
Global Health Security Index: 2019



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X - SELECT INDICATOR

2.2) Real time surveillance and reporting

Y - SELECT INDICATOR

1.2) Zoonotic disease

Show filter options

2) EARLY DETECTION & REPORTING EPIDEMICS OF POTENTIAL INTERNATIONAL CONCERN

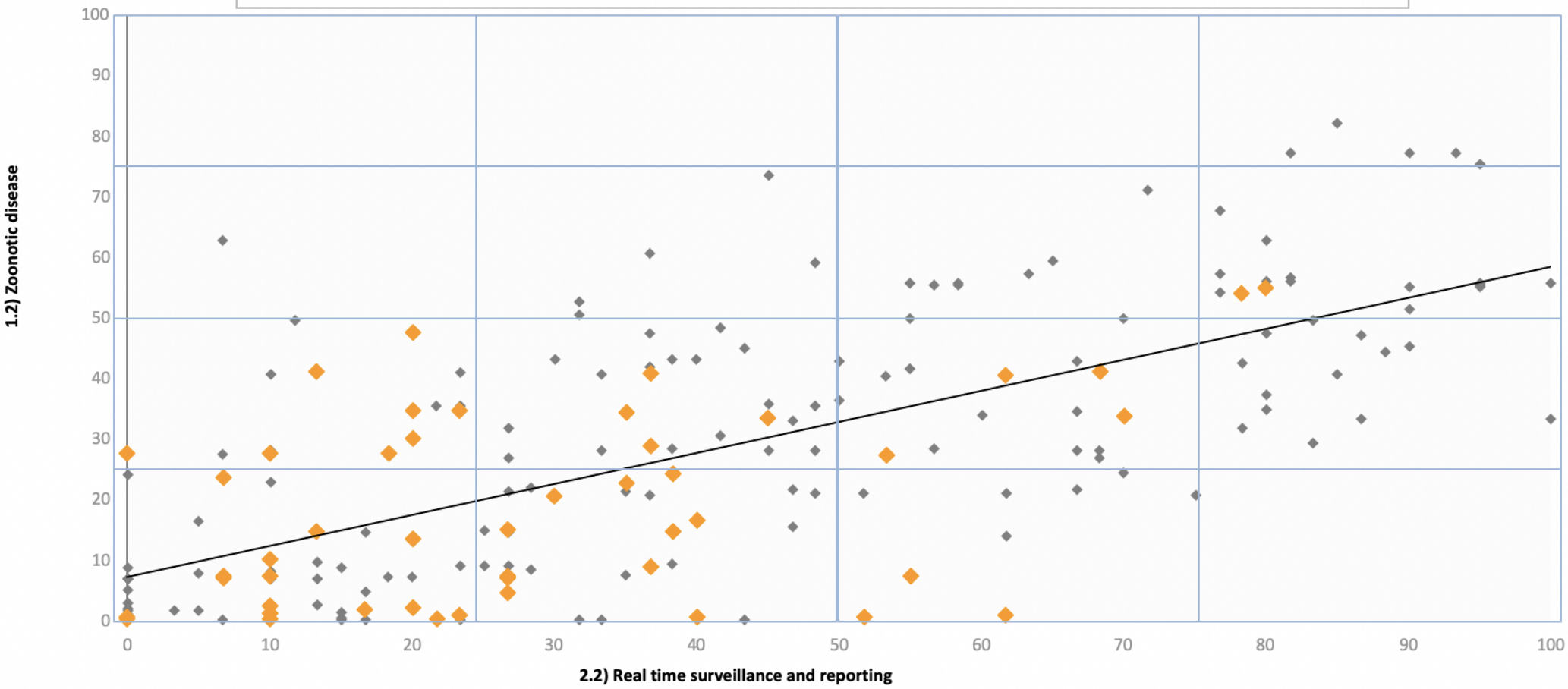
2.2) Real time surveillance and reporting

1) PREVENTION OF THE EMERGENCE OR RELEASE OF PATHOGENS

1.2) Zoonotic disease

Zoom Reset

Click on a rectangle to zoom in, click again to zoom out or use reset button below. Works best when sheet is zoomed to 100%.



COUNTRY HIGHLIGHT

<none>

GROUP HIGHLIGHT

WB: Sub-Saharan Africa

LABELS

Show country labels

OUTLIERS

Show outliers (blue dots)

CORRELATION(X,Y)

0.69

CORRELATION(X,Y): Note, correlation does not prove causation.

The scatter chart above shows the extent of correlation, if any, between the two indicators selected. Correlation (X,Y) shows the linear correlation coefficient of the two indicators, where -1 = perfect negative correlation, 0 = no correlation and 1 = perfect positive correlation. This is calculated using a correlation equation (see right for the equation). If no correlation exists between the two indicators, data points appear randomly scattered across the chart. If a high correlation exists, data points are concentrated near a straight line. The scatter plot is a useful data visualization tool for illustrating a trend.

$$Correl(X,Y) = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2 \sum (y-\bar{y})^2}}$$

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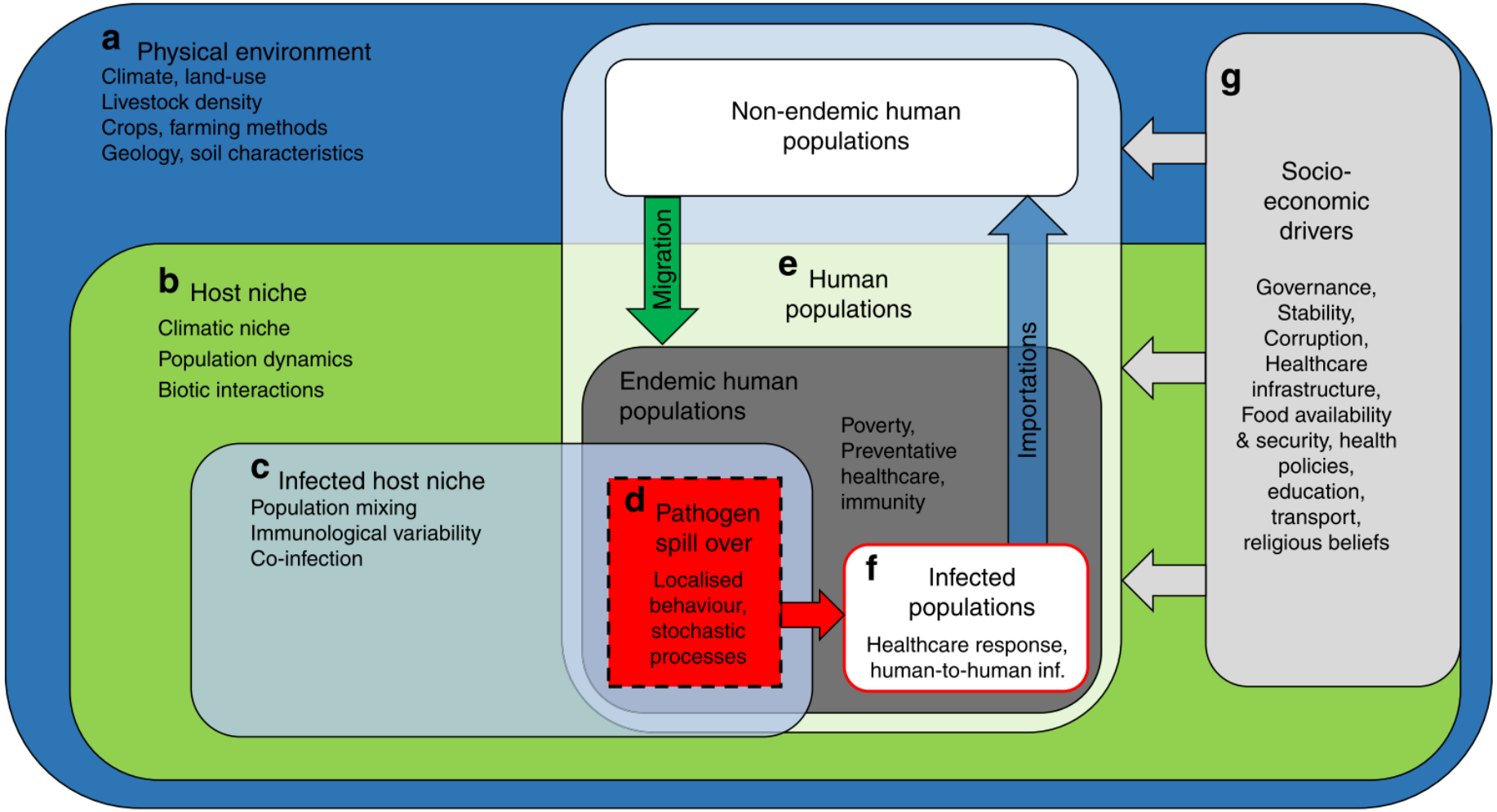
A systems dynamic approach



Infected populations within endemic and non-endemic populations

- Healthcare response
- Human-to-human infection

- Poverty
- Preventative healthcare
- Immunity

- Pathogen transmission through importation and migration

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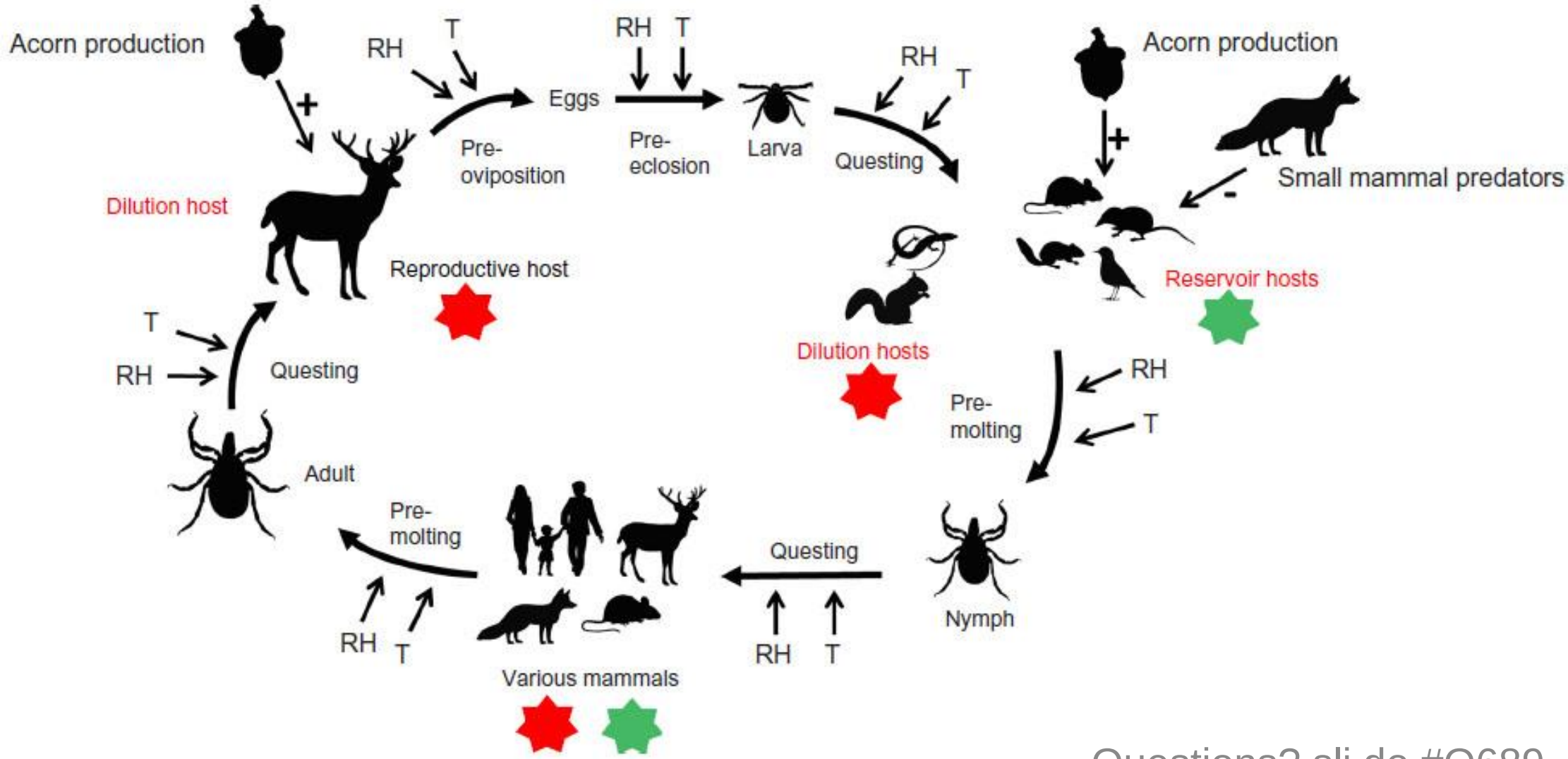
Biodiversity and zoonoses

Pfaffle, M. et al. 2015. *Research and Reports in Biodiversity Studies*



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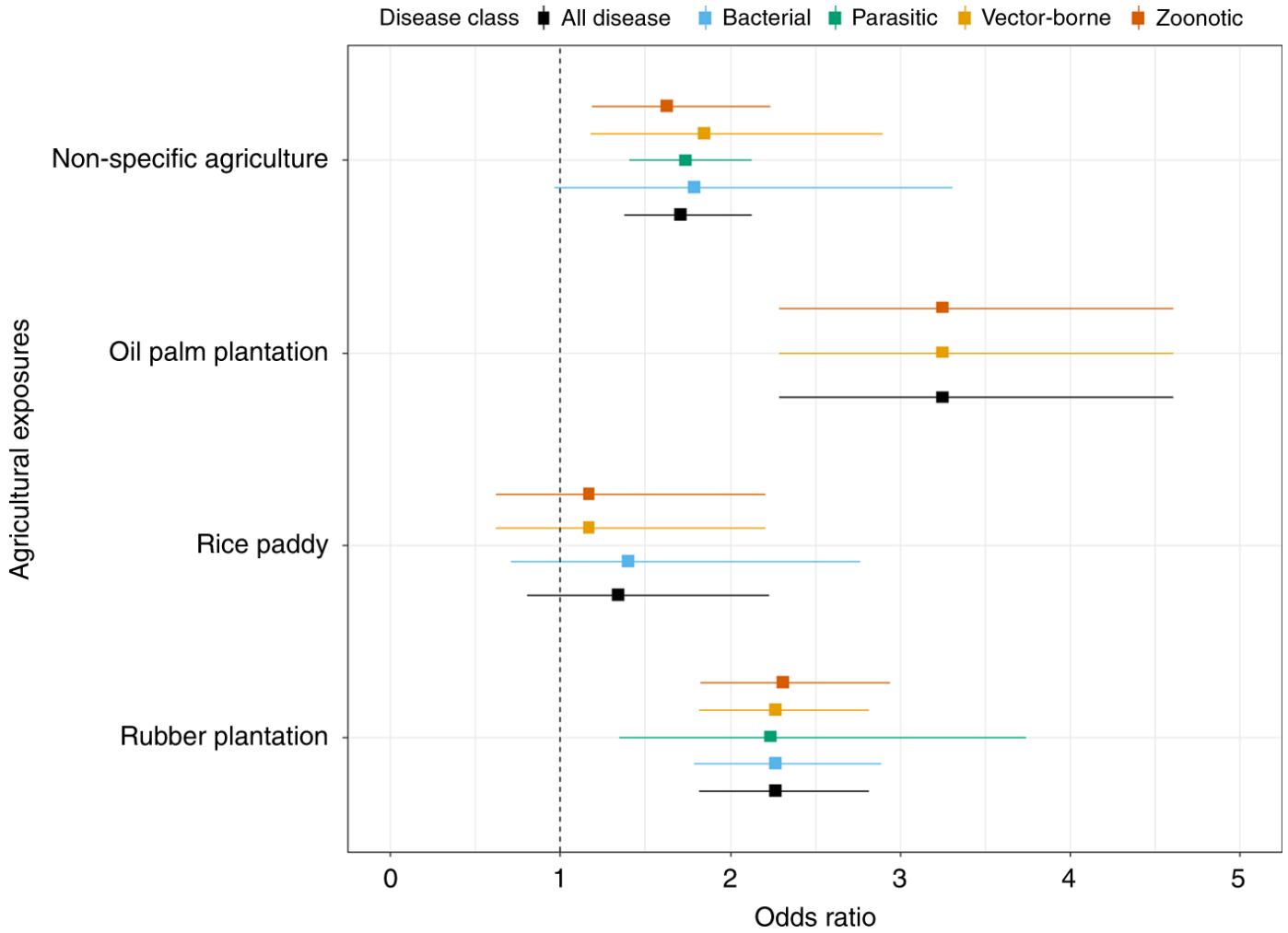
The role of land use change



Shah, H. A. et al. 2019. *Nature Communications*

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Conclusions and summary

- Zoonotic diseases are widespread.
- Spillover events into human populations are inevitable
- One health provides a framework to reduce this risk and develop strategies to prepare and prevent these events
- The systems in which these events occur are complex and act across vast scales
- Special attention has been payed to the role of anthropogenic changes to biodiversity and land use and the effect on zoonotic disease emergence

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