Human impact on (emerging) infectious diseases – part 1

Lecturer: Prof. Melanie Blokesch

Outline of today's lecture

How do humans impact (emerging) infectious diseases [IDs].

1. **Theorectical aspects.**
2. **Examples.**

(Emerging) IDs and planetary health

1. Population growth and urbanization.
2. Deforestation and habitat encroachment.
3. Climate change.
4. Globalization and travel.
5. Behavioral factors.
6. Healthcare infrastructure and access.
7. Technology and biomedical research.

1. Population Growth and Urbanization

- Increased human-animal interaction.
- Dense population centres and transmission dynamics.
- Poor sanitation and water quality.
- Nutrition and health disparities.
- Global connectivity and rapid spread.

The ID cholera

- Disease of **<u>severe, watery diarrhea</u>**

Cholera rapidly leads to
severe dehydration =>
can be fatal if left untreated.

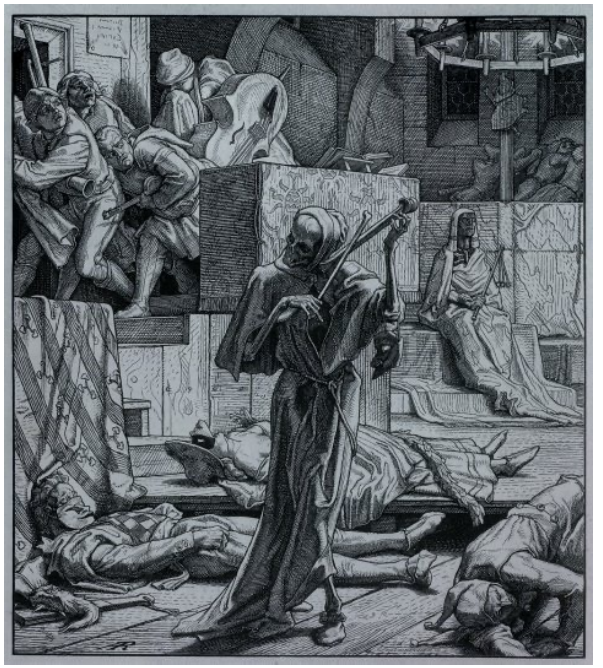
- Water- or food-borne disease.
- Causative agent: bacterium *Vibrio cholerae*.

Seven cholera pandemics in recent history

Historical data on cholera pandemics:

- 1st 1816-1826 Bengal, India, China, Caspian Sea
- 2nd 1829-1851 Europe, Russia, North America
- 3rd 1852-1860 mainly affected Russia
- 4th 1863-1875 Europe, Africa, North America
- 5th 1881-1896 last serious European outbreak
- 6th 1899-1923 Russia was badly affected
- 7th 1961- Indonesia, India, Bangladesh
  USSR, North Africa, South America

Ongoing for > 60 years



Cholera and its treatment

Cholera treatment unit (CTU)

Image credit: M. Blokesch (*Haiti, 2011*)

Sack *et al*. (2004)

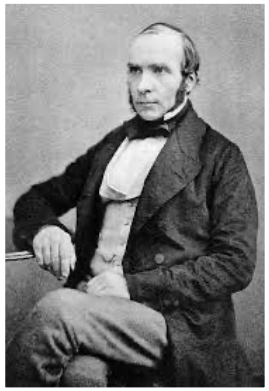
Rice-water stool:

10^8 *Vibrio cholerae* per ml

Cholera is not extinct

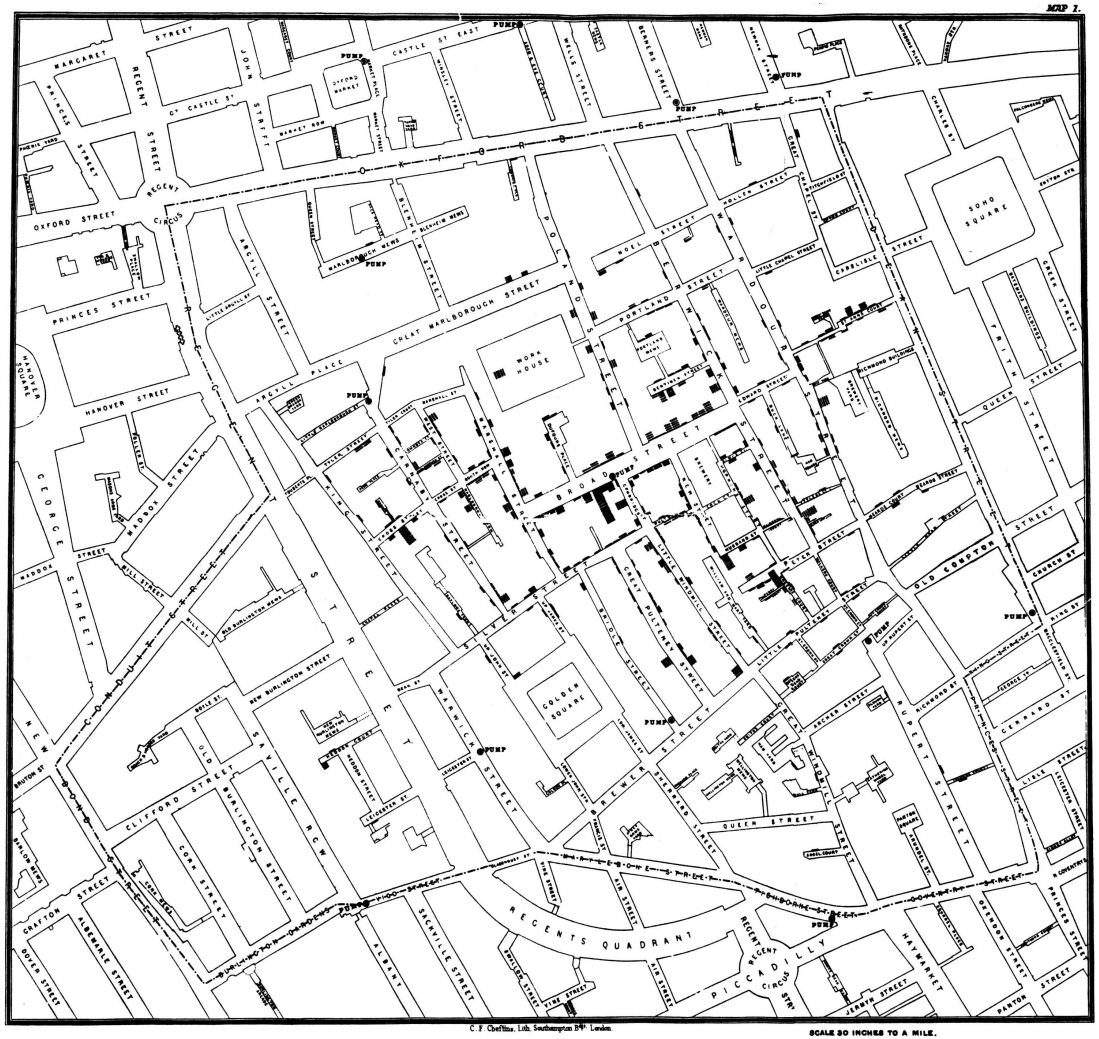
How did we learn that cholera is linked to poor water quality?

The birth of modern epidemiology



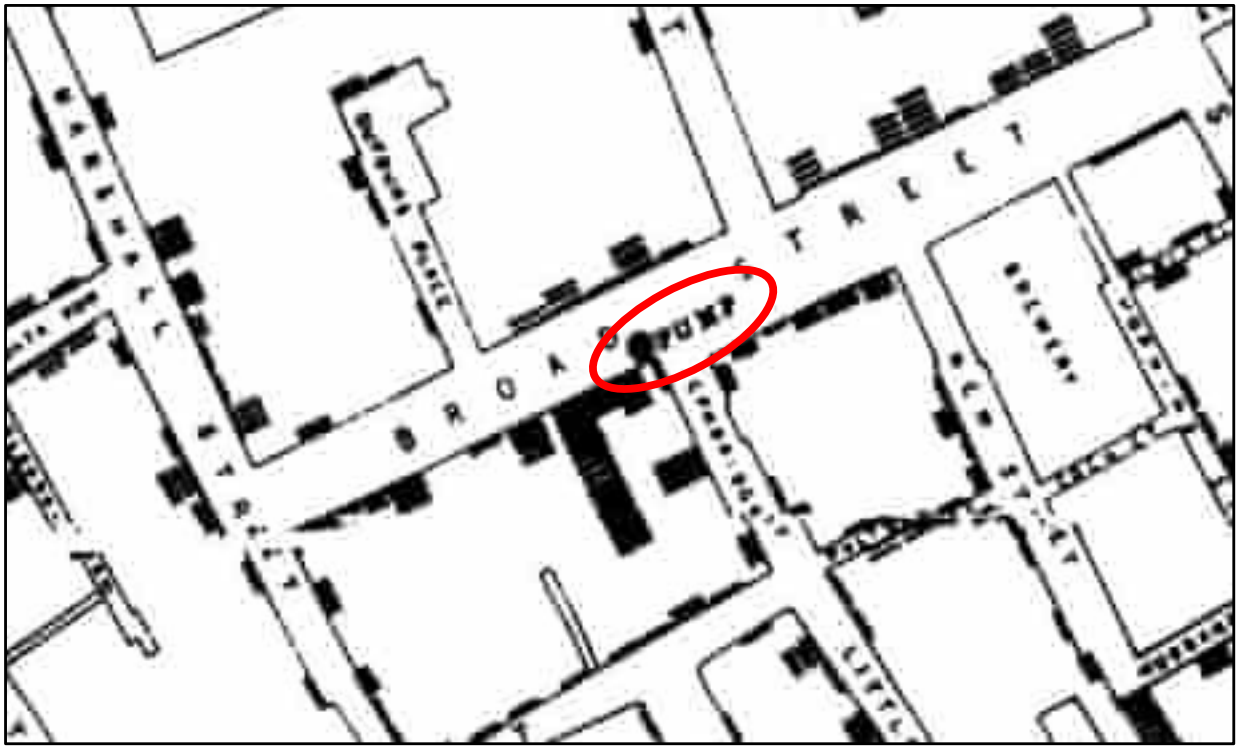
John Snow

London (1854)



Wikipedia & National Geographic

Birth of modern epidemiology



The Guardian

Broad Street Pump in London

Handle removed

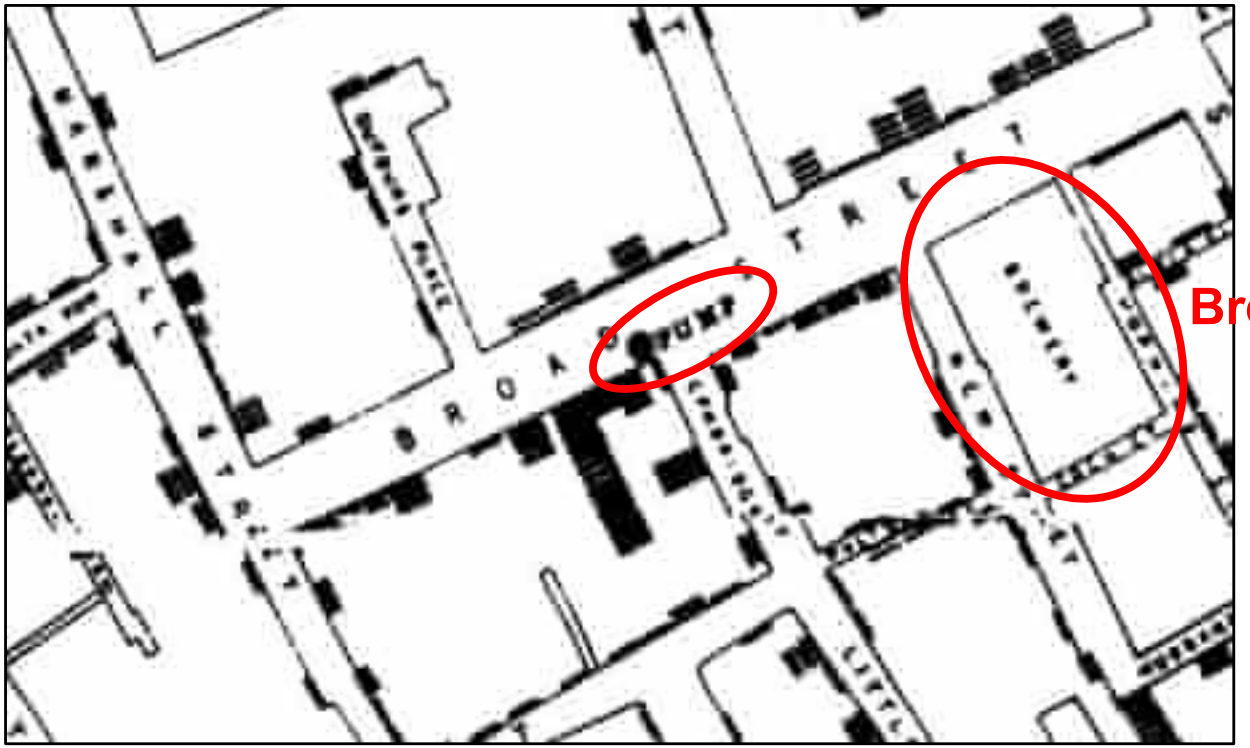
Fun fact

HISTORY COLLECTION ANCIENT HISTORY PEOPLE AMERICAN HISTORY MIDDLE AGES HOLLYWOOD ARCHAEOLOGY A11 WATCH HOMAGE

John Snow Stopped Cholera in London with the Help of 500 Beer Drinkers

Patrick Lynch - October 1, 2017

Fun fact



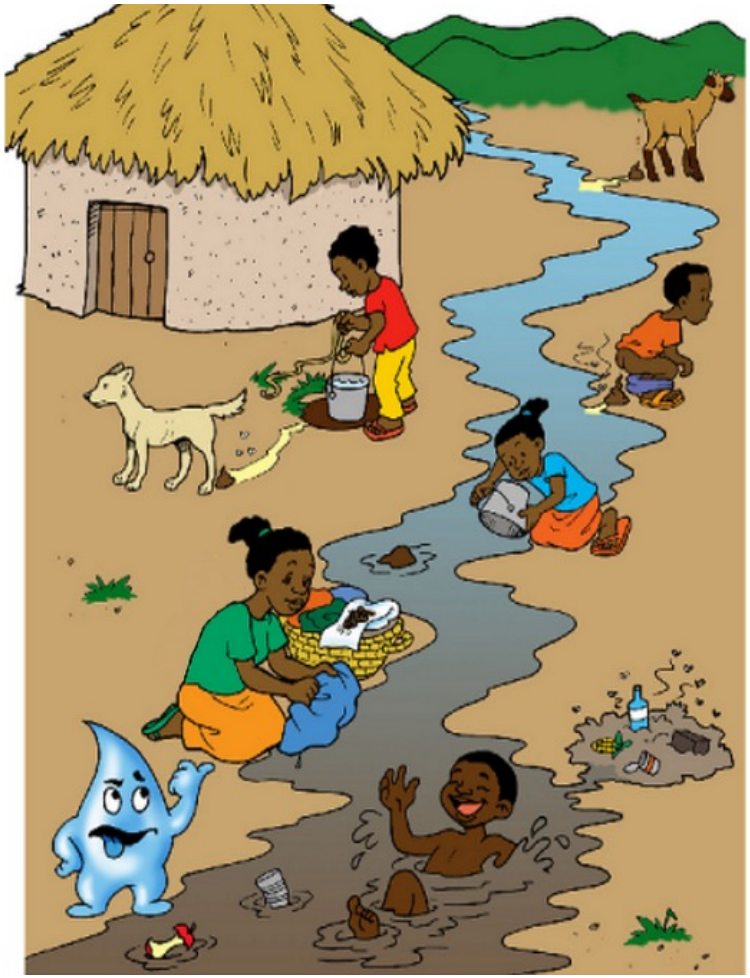
1. Population Growth and Urbanization

Mitigation strategies:

- Improved Sanitation and Hygiene Practices.
- Health Education and Awareness Campaigns.
- Urban Planning and Infrastructure Development.
- Strengthening Healthcare Systems.
- Community Engagement and Participation.
- Regulation and Enforcement of Health Standards.
- Integration of a One Health Approach.

Example for Health Education and Awareness Campaigns.

Haiti 2011



Terre des hommes
aide à l'enfance | Kinderhilfe
aiuto all'infanzia | child relief | www.tdh.ch

Example for Health Education and Awareness Campaigns.

Haiti 2011

Kisa kolera ye?

Se yon maladi ki bay moun anpil dyare ak vomisman,e kika trete.

Terre des hommes
aide à l'enfance | Kinderhilfe
aiuto all'infanzia | child relief | www.tdh.ch

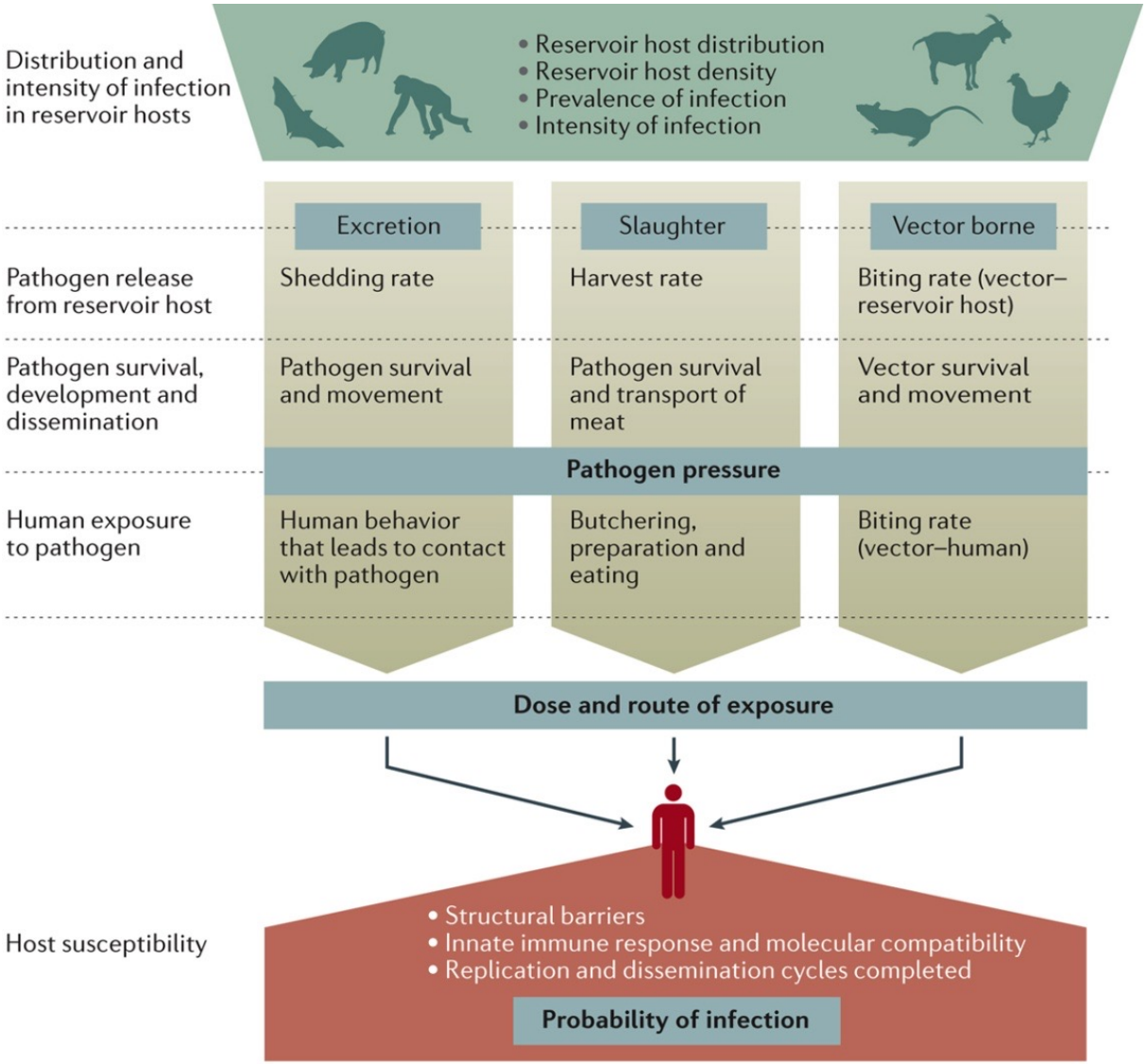
2. Deforestation and Habitat Encroachment

- Increased contact between humans and wildlife.
- Expansion of agricultural activities.
- Biodiversity loss and altered ecological balance.
- Changes in vector dynamics.
- Habitat fragmentation and human exposure.

=> can lead to spillover

What is spillover?

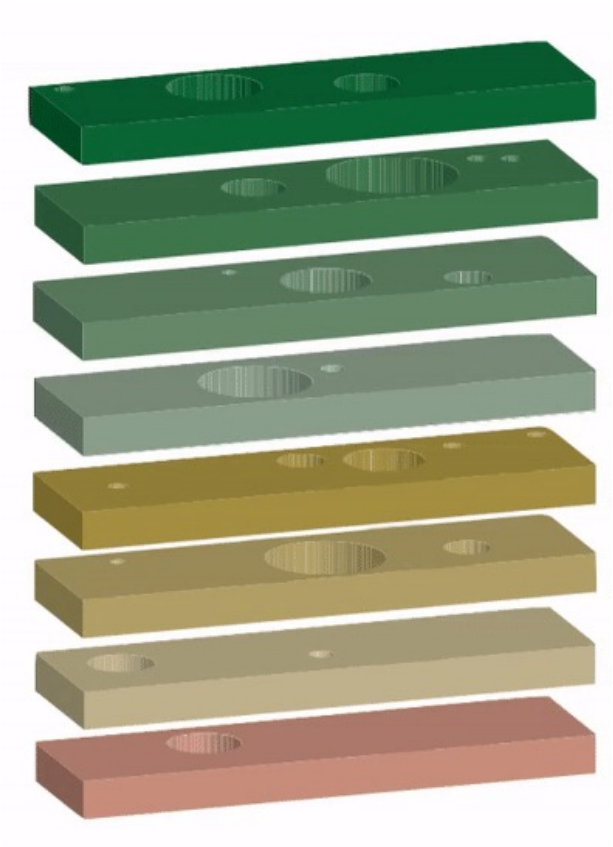
Pathways to spillover

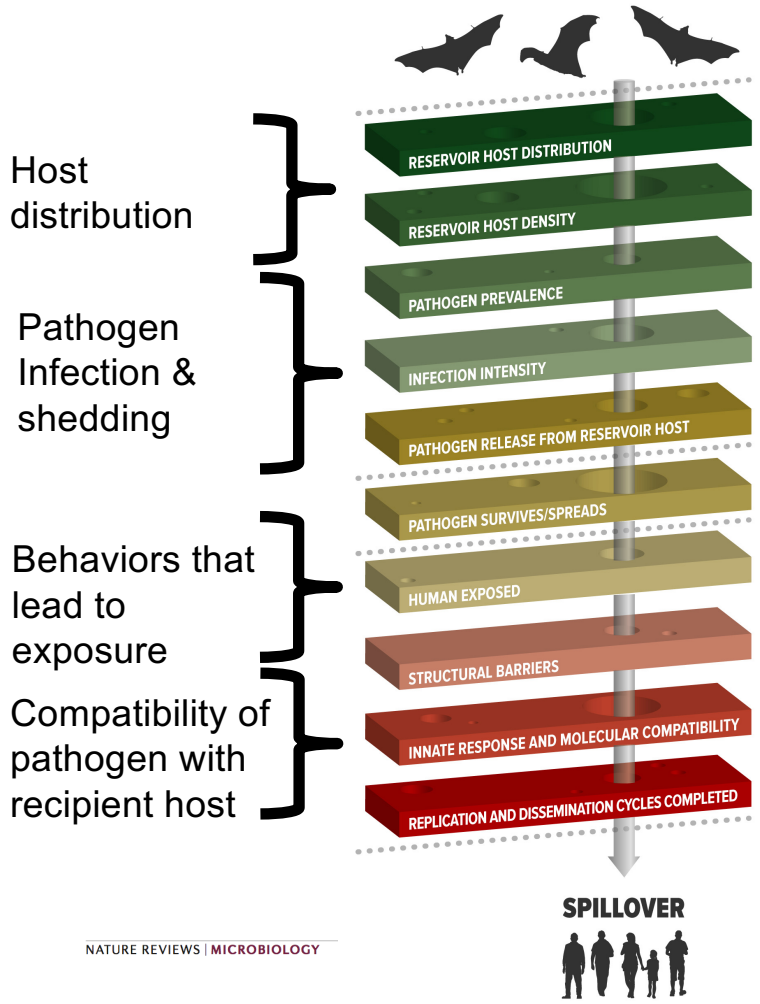


Plowright *et al.* (2017) *Nat. Rev. Microbiol.*

Barriers to spillover are dynamic in space and time

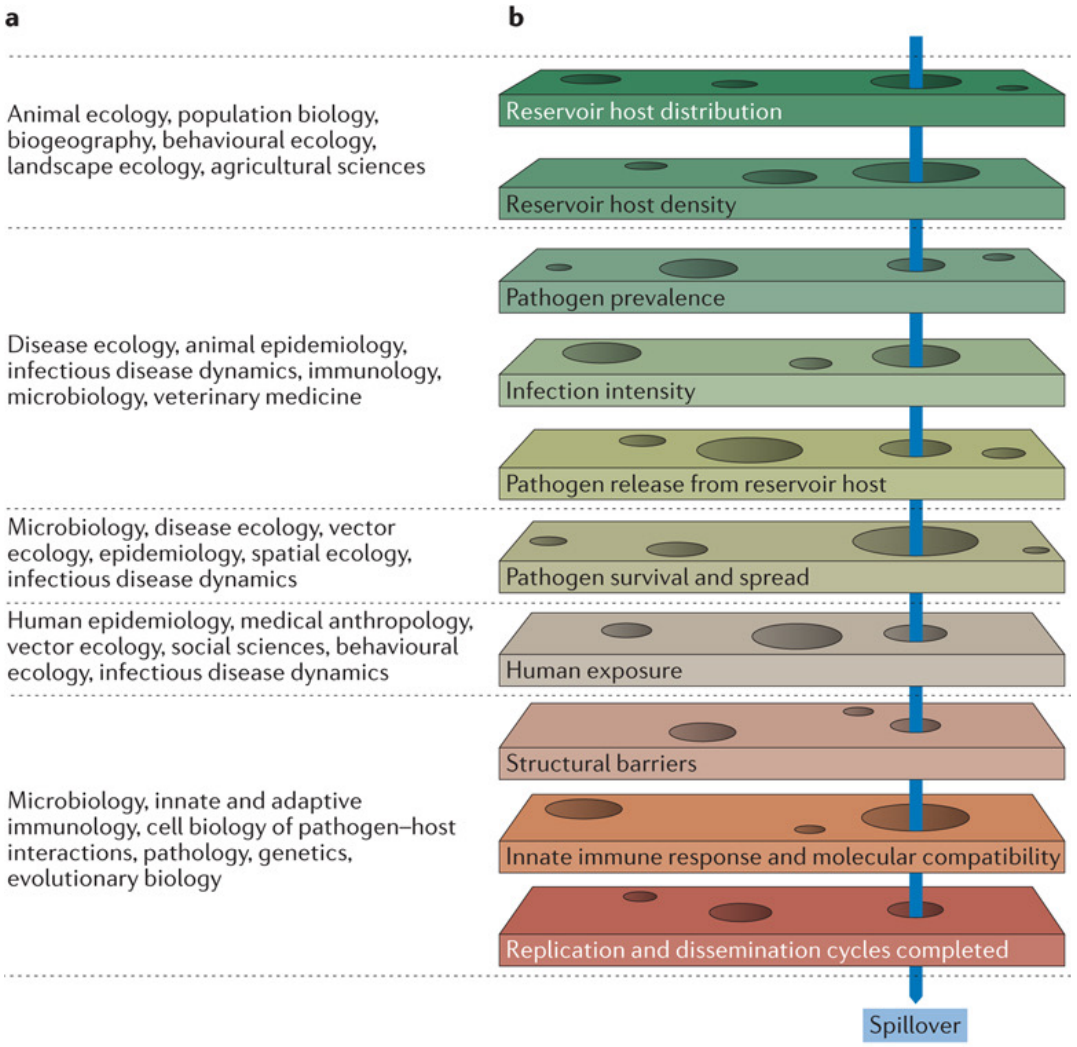
Pathways to zoonotic spillover





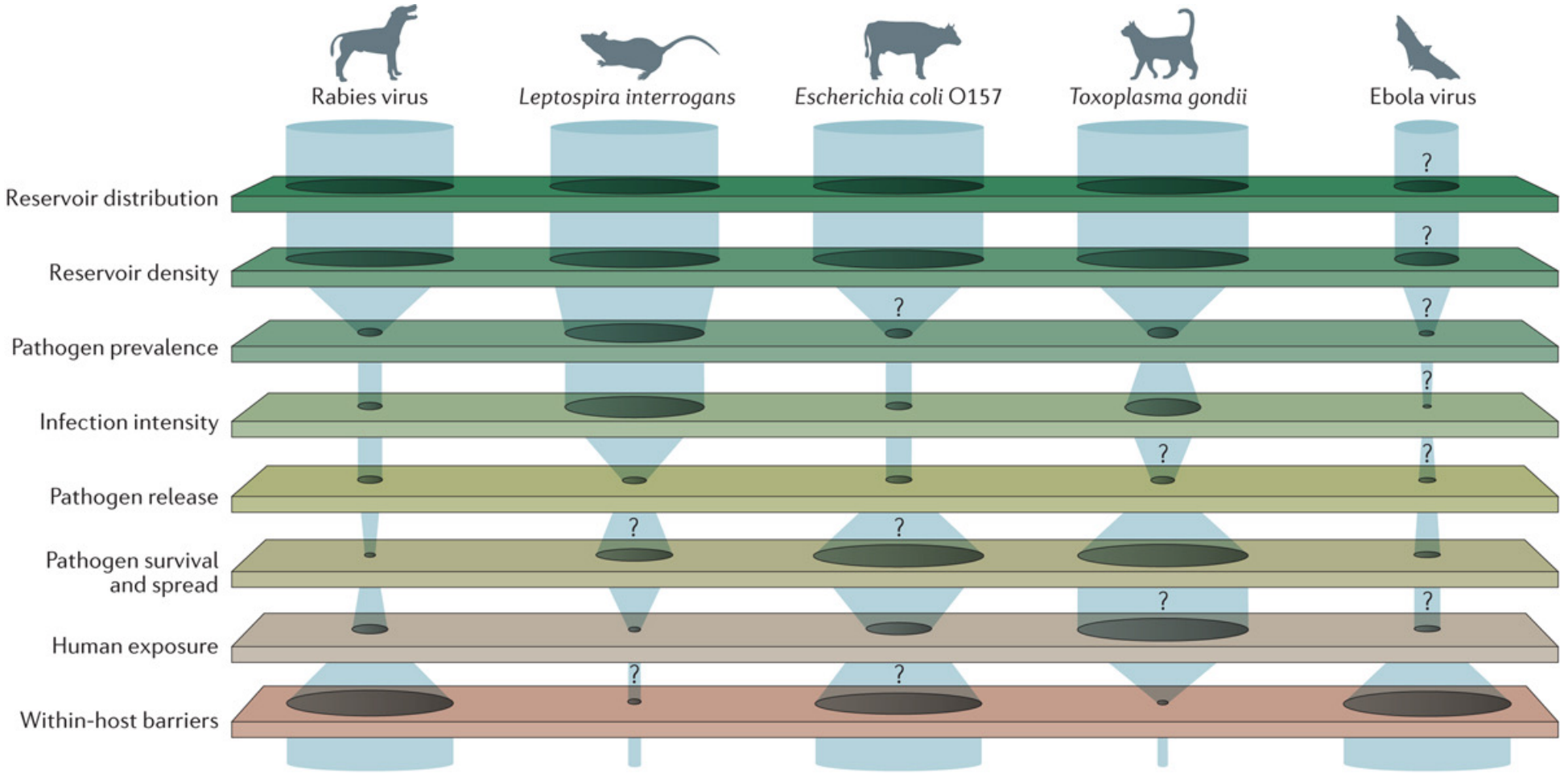
Plowright *et al.* (2017) *Nat. Rev. Microbiol.*

Barriers to spillover and dose–response relationships



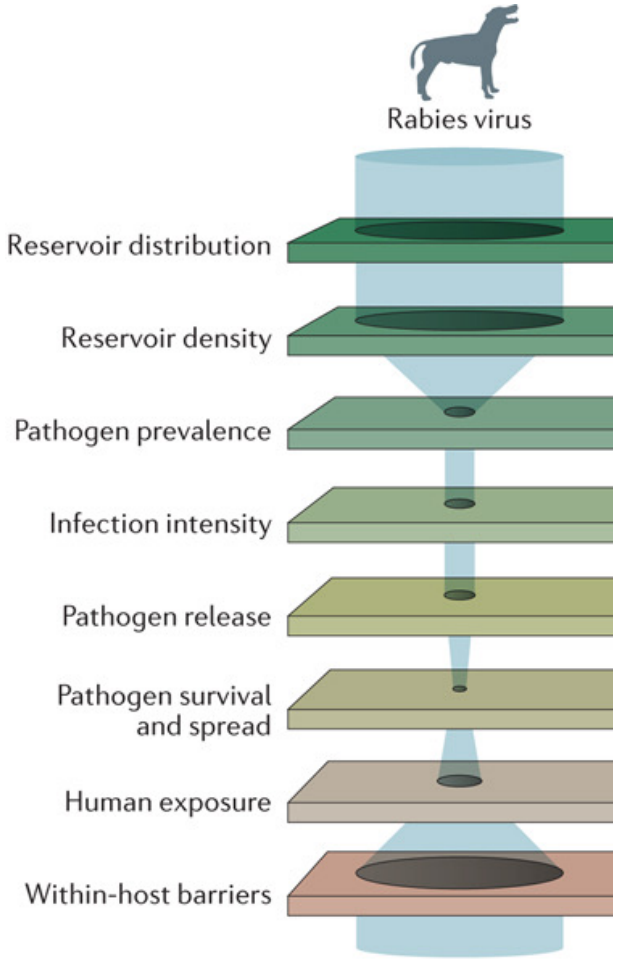
Plowright *et al.* (2017) *Nat. Rev. Microbiol.*

Bottlenecks to spillover



Plowright *et al.* (2017) *Nat. Rev. Microbiol.*

Bottlenecks to spillover



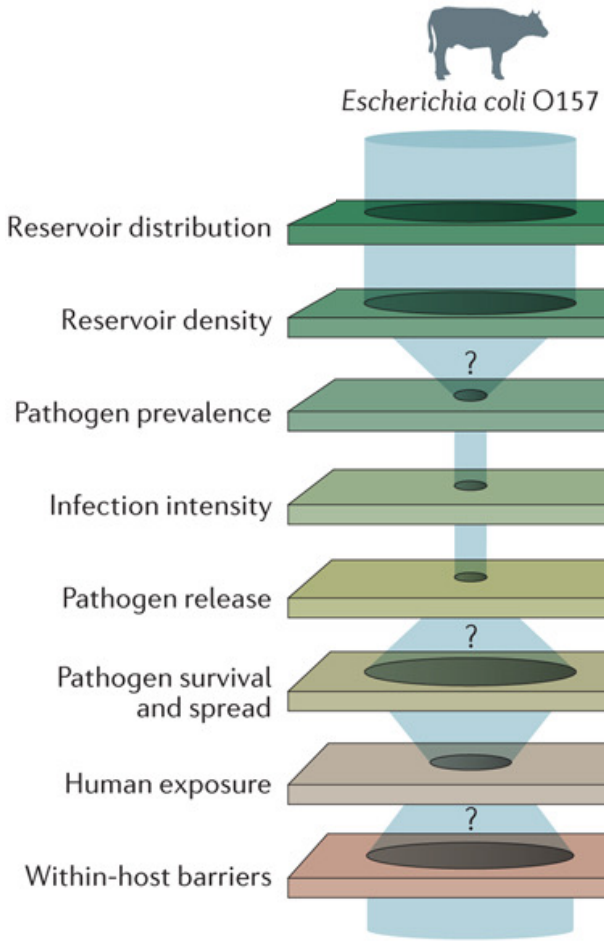
- Reservoirs = domestic dogs; widely distributed.
- Prevalence of rabies virus = low.
- Incidence of spillover closely tracks the prevalence of infection in the reservoir host

Rabies virus is almost always fatal to spillover hosts

- Interventions: reducing the prevalence in reservoir hosts through vaccination

Plowright *et al.* (2017) *Nat. Rev. Microbiol.*

Bottlenecks to spillover



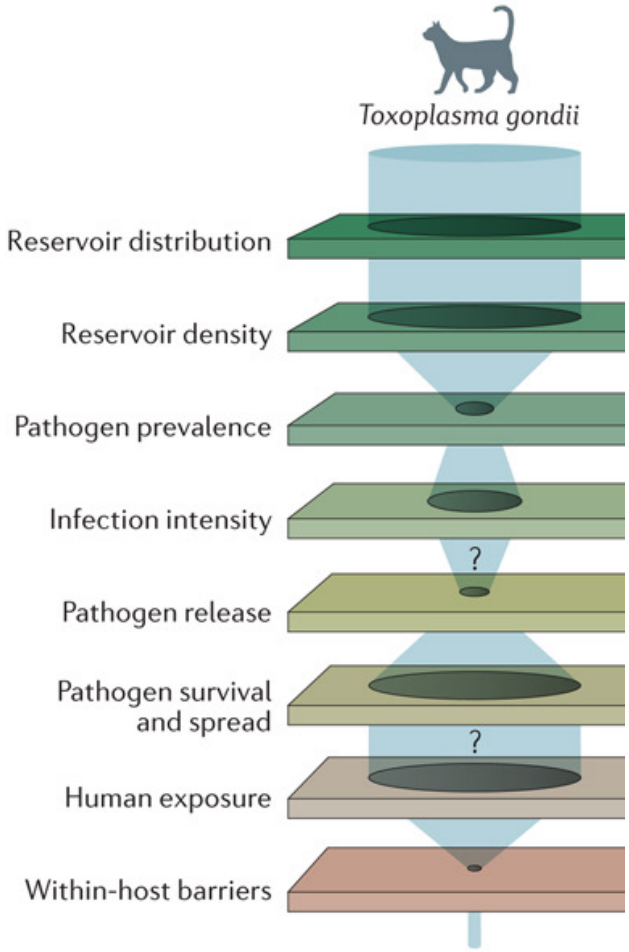
- Reservoirs = cattle.
- Heterogeneous shedding.
- Exposure is an important bottleneck.
- Widespread dispersal => uncertainties about source of outbreaks.
- Weak within-human barriers

Low doses of *E. coli* can cause infection!

- Interventions: pathogen eliminated from food (*e.g.,* through cooking).

Plowright *et al.* (2017) *Nat. Rev. Microbiol.*

Bottlenecks to spillover



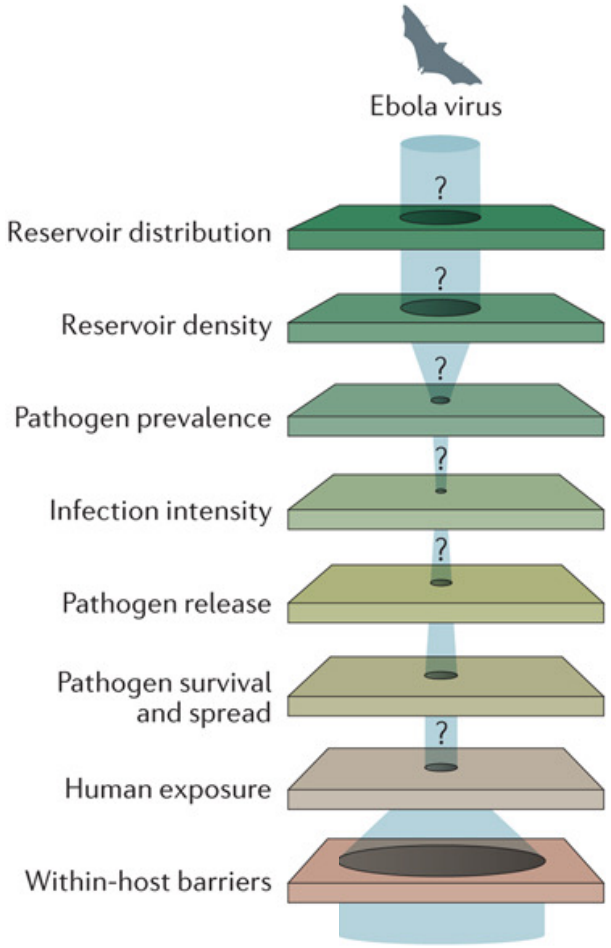
- Reservoirs = domestic cats; widely and densely distributed.
- Prevalence of *T. gondii* low in cats.
- Shedding of parasite oocysts only once in cat's lifetime.

Long survival of sporulated oocysts in environment!

- Interventions: limiting exposure (but unclear whether cats or environment are major source of infection for humans).

Plowright *et al.* (2017) *Nat. Rev. Microbiol.*

Bottlenecks to spillover



In next week's lecture

Plowright *et al.* (2017) *Nat. Rev. Microbiol.*

Epidemic/Pandemic viruses with known host jumps

virus	host combinations
Influenza A virus	avian to human, swine, horse, seal, dog. Swine to human, horse to dog
Human immunodeficiency virus	non-human primate to human, two major events
Ebola virus	bat to human, outbreaks, some extended epidemics
	bat to gorilla (to human)
	bat to duiker (to human)
MERS coronavirus	camel to human, mostly spillover, some outbreaks
SARS coronavirus	bat to palm civet to human, global spread but controlled
Nipah virus	bat to swine epidemic, spillover to humans
Canine parvovirus (CPV)	carnivore to dog pandemic
Zika virus	primate to human, adaptation to mosquito vector and humans resulted in epidemic

In next week's lecture

Wasik *et al.* (2019) *Phil. Trans. R. Soc. B*

2. Deforestation and Habitat Encroachment

Mitigation needs:

- Implemention of sustainable land-use practices.
- Promotion of reforestation efforts.
- Conservation of natural habitats.
- Protection of biodiversity.
- Wildlife management.
- Monitoring of disease reservoirs.

3. Climate Change

- Expanded geographic range of vectors.
- Altered transmission cycles.
- Increased incidence of vector-borne diseases.
- Food and water insecurity.
- Extreme weather events and disease outbreaks.
- Ecological imbalance and zoonotic diseases.

3. Climate Change

What is needed?

- Implementation of climate adaptation and mitigation strategies.
- Strengthening public health infrastructure.
- Improvement of disease surveillance.
- Establishment of early warning systems.
- Support of sustainable environmental practices.

4. Globalization and Travel

- Rapid and extensive movement of people.
- Global trade and commerce.
- Tourism and mass gatherings.
- Economic interconnectedness and disease spread.
- Challenges in surveillance and response.

Cholera today

A disease of poor countries mainly due to lack of …

... education

… sanitation

… and clean drinking water.

Cholera outbreak in Haiti *(pictures taken on a fact-finding mission to Haiti in July 2011)*

Cholera epidemic in Haiti:

819’000 **reported** cumulative cases with 9’789 deaths (WHO, Jan 2019)

How did cholera get to Haiti?

The NEW ENGLAND JOURNAL of MEDICINE

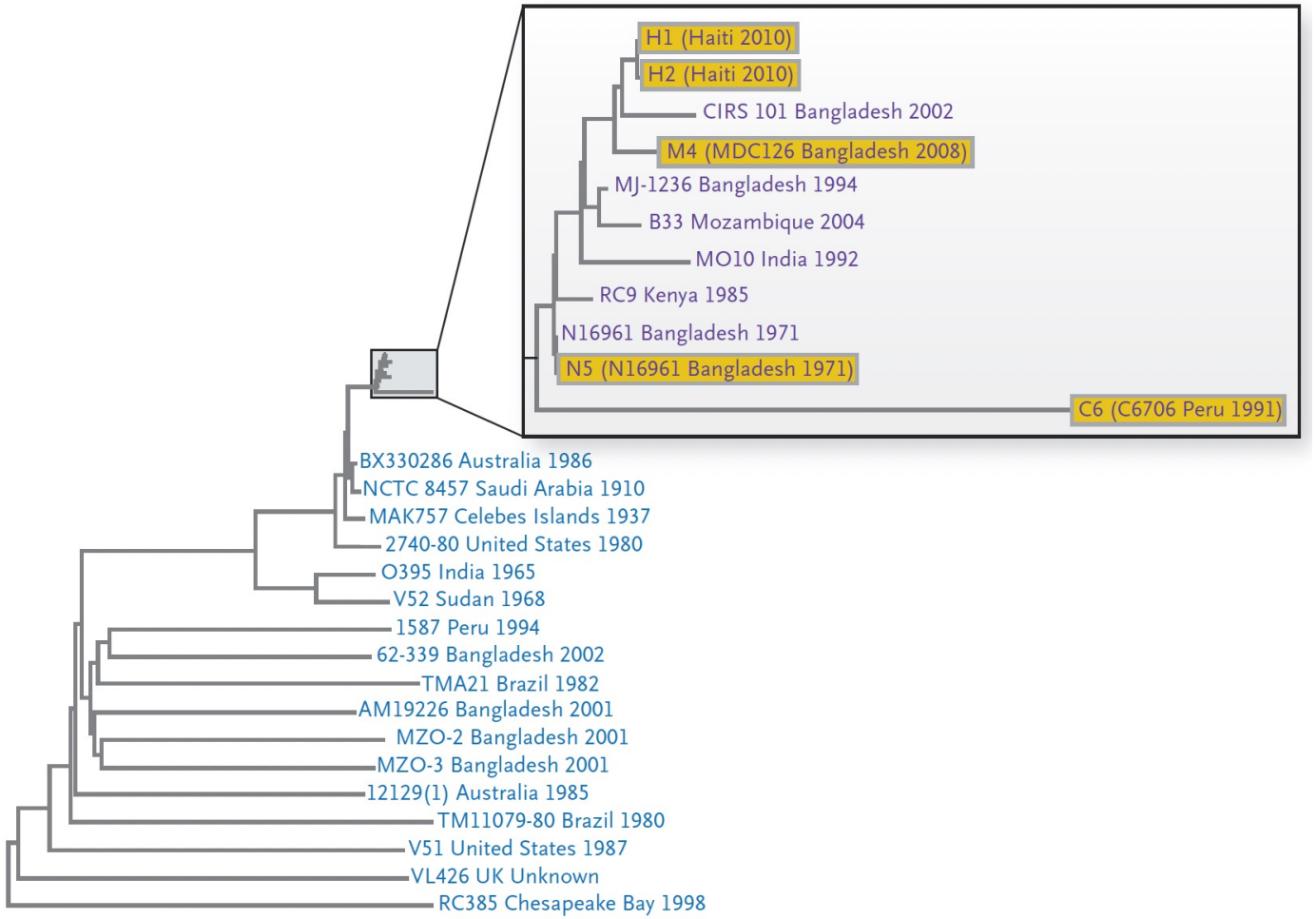
ORIGINAL ARTICLE

The Origin of the Haitian Cholera Outbreak Strain

Chen-Shan Chin, Ph.D., Jon Sorenson, Ph.D., Jason B. Harris, M.D., William P. Robins, Ph.D., Richelle C. Charles, M.D., Roger R. Jean-Charles, M.D., James Bullard, Ph.D., Dale R. Webster, Ph.D., Andrew Kasarskis, Ph.D., Paul Peluso, Ph.D., Ellen E. Paxinos, Ph.D., Yoshiharu Yamaichi, Ph.D., Stephen B. Calderwood, M.D., John J. Mekalanos, Ph.D., Eric E. Schadt, Ph.D., and Matthew K. Waldor, M.D., Ph.D.

Chin *et al.* (2011) *N. Engl. J. Med.*

How did cholera get to Haiti?



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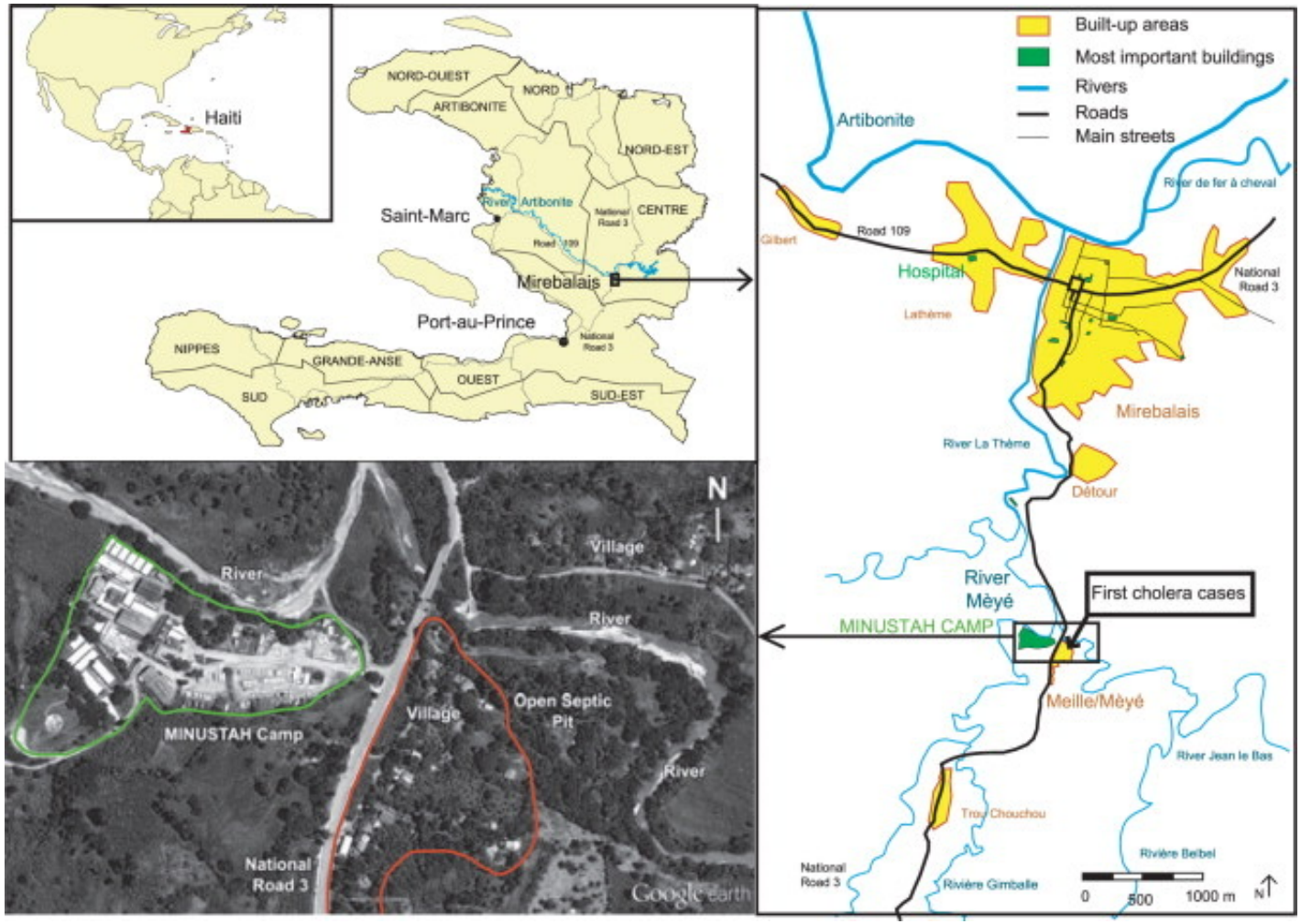
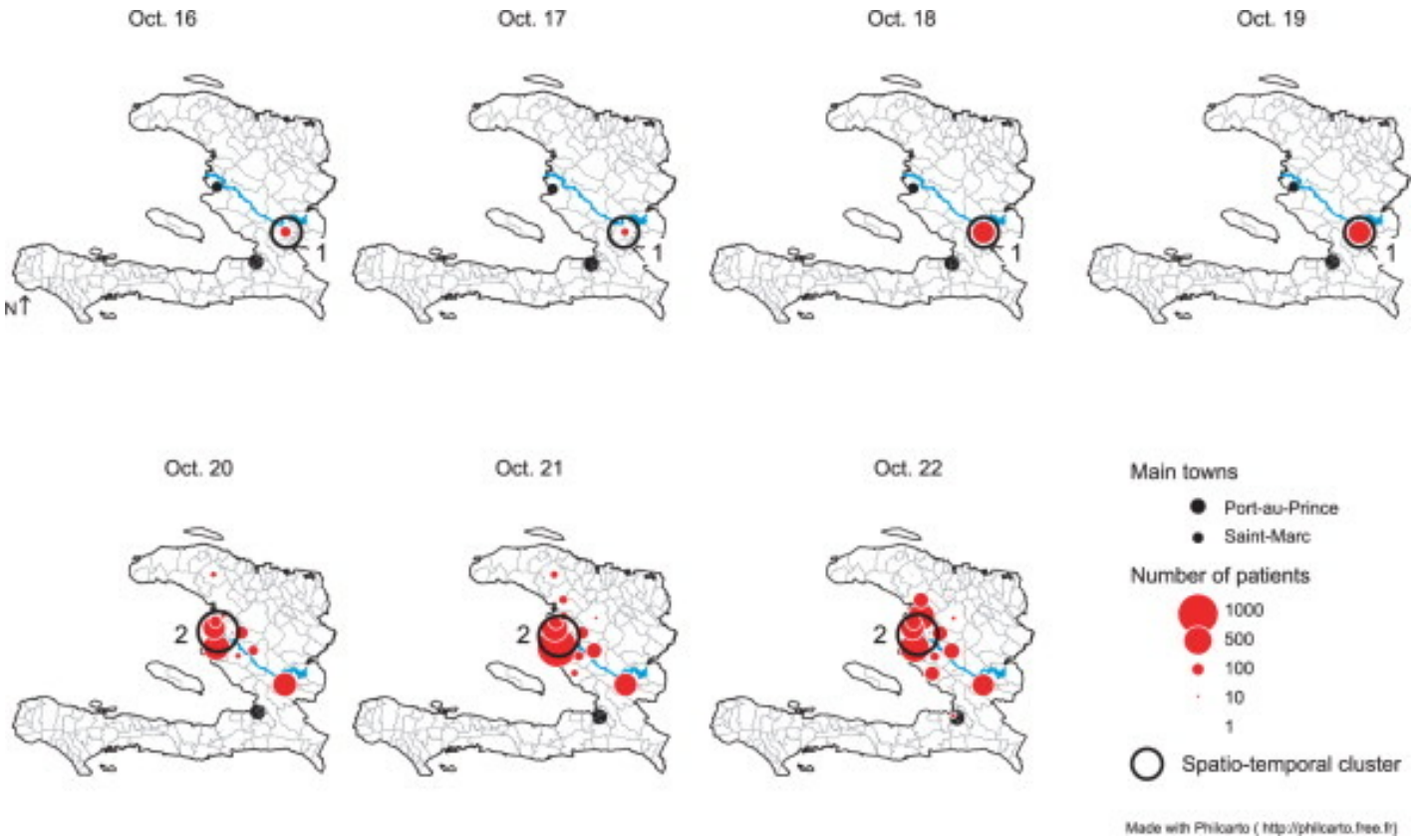


Frerichs *et al.* (2012) *Clin Microbiol Infect.*

How did cholera get to Haiti?



Frerichs *et al.* (2012) *Clin Microbiol Infect.*

4. Globalization and Travel

Addressing the impact of globalization and travel on IDs:

- Strengthening of public health infrastructure.
- Adhering to appropriate hygiene protocols (e.g., during travel).
- Information sharing.
- Raising public awareness about the importance of practicing preventive measures.
- Enhanced disease surveillance & early warning systems.
- Promotion of international collaboration in surveillance & response.
- Vaccination.

5. Behavioral Factors

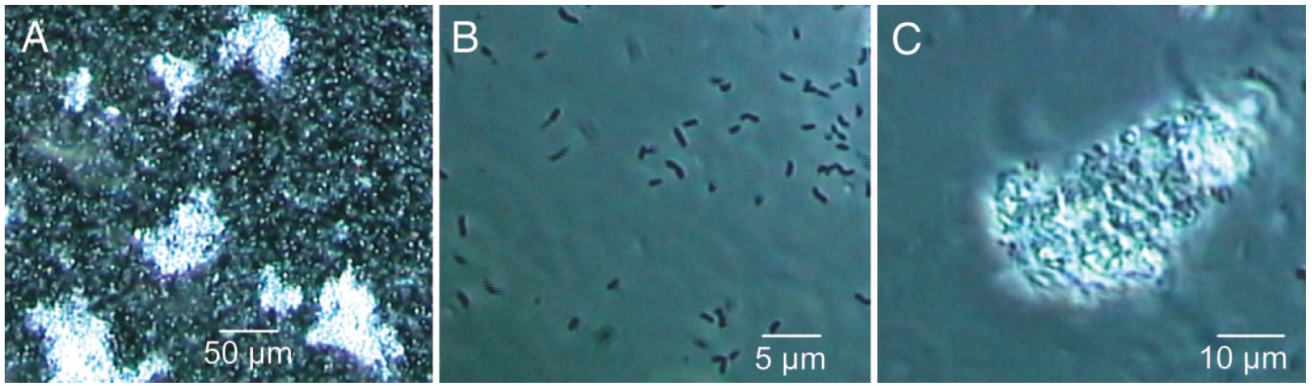
- Hygiene practices.
- Health-seeking behavior.
- Cultural practices and beliefs.
- Social interactions and mobility.
- Stigma and discrimination.
- Animal contact and exposure.
- Compliance with Public Health Measures.

Cholera and its causative agent

Sack *et al*. (2004)

Rice-water stool:

10^8 *Vibrio cholerae* per ml



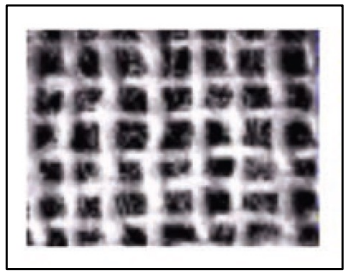
Micrographs of different fractions of human cholera stools. Both planktonic cells and biofilm-like clumps of *V. cholerae* cells are present in unfractionated stool

Faruque *et al.* (2006) *PNAS*

Health seeking behavior

Reduction of cholera in Bangladeshi villages by simple filtration

Rita R. Colwell*†‡, Anwar Huq*†, M. Sirajul Islam§, K. M. A. Aziz§, M. Yunus§, N. Huda Khan§, A. Mahmud§, R. Bradley Sack¶, G. B. Nair§, J. Chakraborty§, David A. Sack§, and E. Russek-Cohen‖

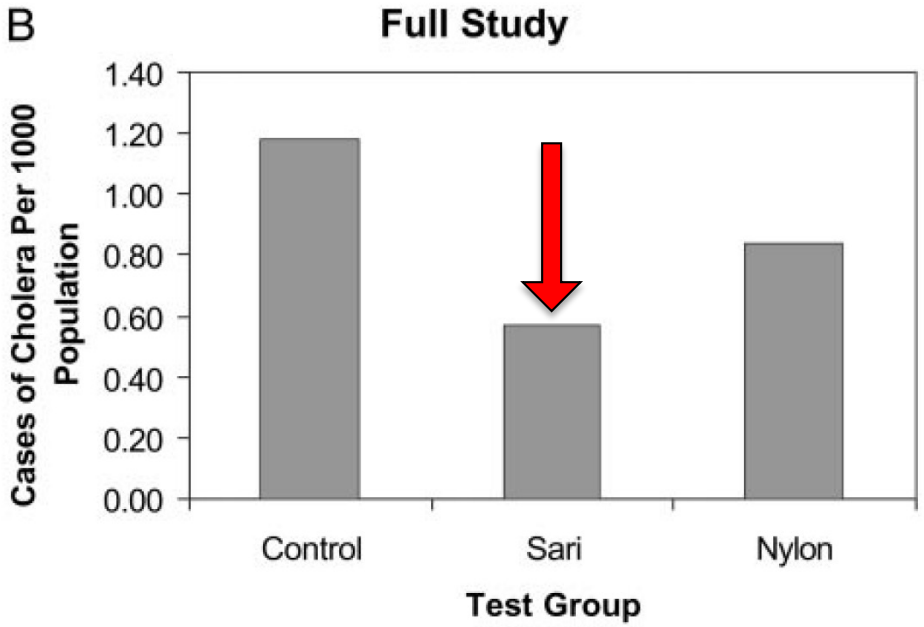


Sari cloth:
Pore size = 20 μm if folded 4-8 times.

Photo courtesy of Dr. Anwar Huq/University of Maryland
NIH Fogarty International Center webpage

Colwell *et al.* (2003) *PNAS*

Human intervention to limit cholera transmission



=> 48% reduction compared to control group

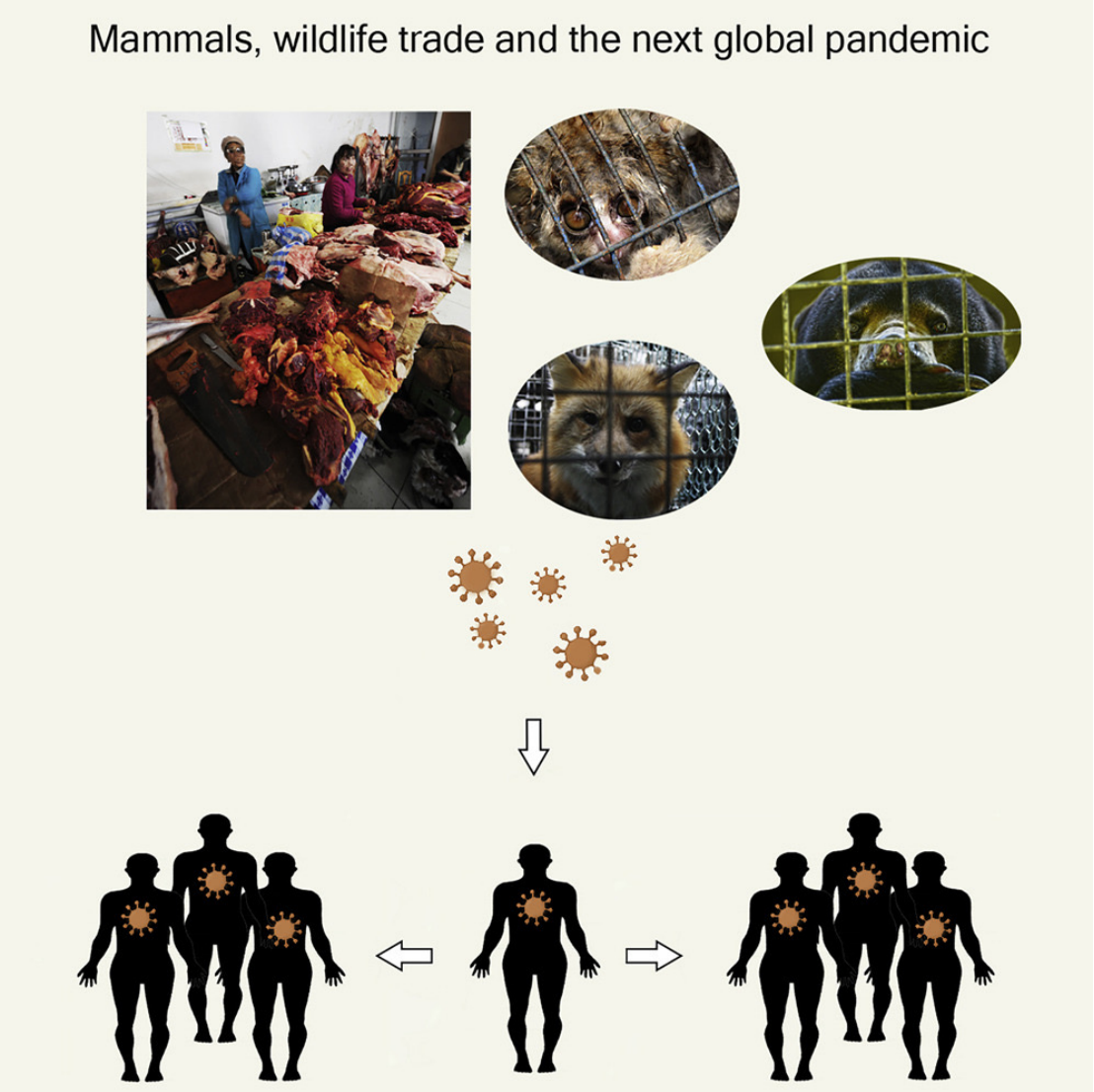
BUT: some communities stopped using the cloth due to social/religious aspects of sari cloth

Colwell *et al.* (2003) *PNAS*

5. Behavioral Factors

- Hygiene practices.
- Health-seeking behavior.
- Cultural practices and beliefs.
- Social interactions and mobility.
- Stigma and discrimination.
- Animal contact and exposure.
- Compliance with Public Health Measures.

Wildlife trade



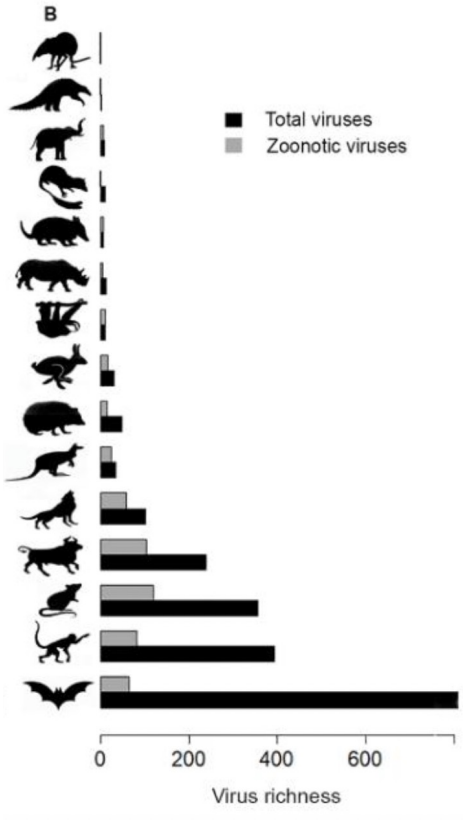
Shivaprakash *et al.* (2021) *Curr. Biol.*

Wildlife trade

- A quarter of mammals in wildlife trade host 75% of known zoonotic viruses.
- Ungulates, primates, and bats are major zoonotic reservoirs in wildlife trade.
- Not all mammals in wildlife trade host viruses harmful to humans.
- Mitigation measures should focus on reservoir species to prevent future pandemics.

Shivaprakash *et al.* (2021) *Curr. Biol.*

Virus richness across mammalian orders & wildlife trade



Shivaprakash *et al.* (2021) *Curr. Biol.*

5. Behavioral Factors

What is needed?

- Tailored public health interventions that consider cultural, social, and economic contexts.
- Engagement of communities.
- Promotion of health literacy.
- Partnerships between healthcare providers and local stakeholders.

Human impact on disease transmission & solution finding

Schistosomiasis (Bilharzia)

Parasite (blood fluke, trematode worm)

Schistosoma mansoni

CDC

Schistosomiasis (Bilharzia)

How can you get schistosomiasis?

- Infection occurs when skin comes in contact with contaminated freshwater in which specific snails that carry schistosomes are living.

CDC

Schistosomiasis (Bilharzia)

What are the signs and symptoms of schistosomiasis?

- Within days after infection: itchy skin.
- After 1-2 months of infection: fever, chills, cough, and muscle aches.
- Adult worms present => eggs travel to the intestine, liver or bladder, causing inflammation or scarring.
- After years of infection: parasite can damage the liver, intestine, lungs, and bladder.

=> Symptoms of schistosomiasis caused by the body's reaction to the eggs, not by the worms themselves.

CDC

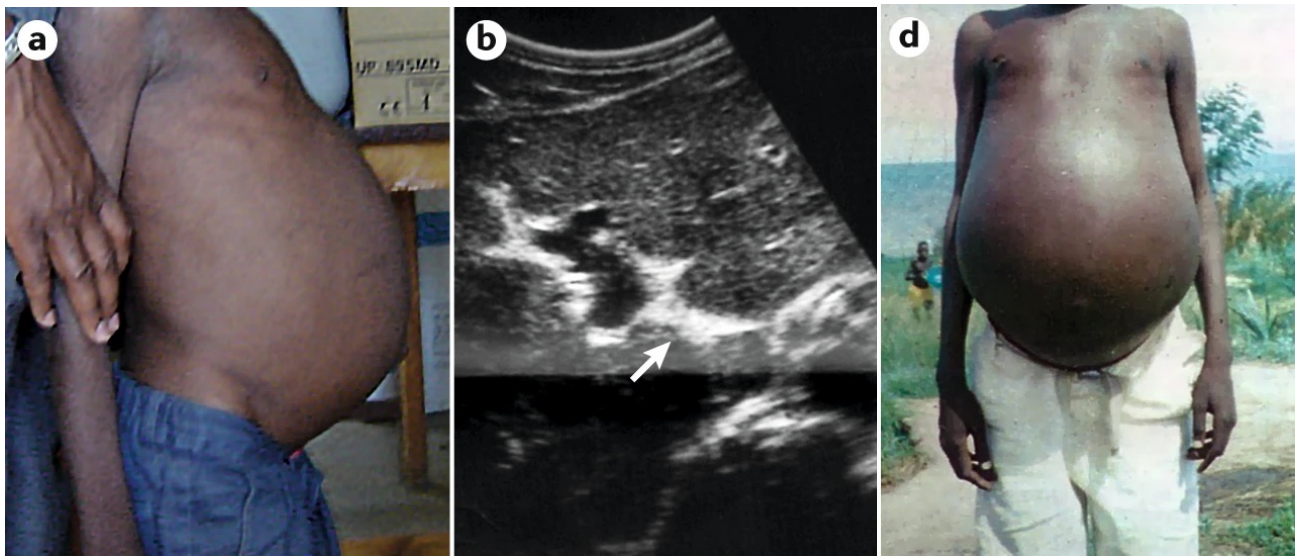
Schistosomiasis (Bilharzia)

- Acute and chronic parasitic disease.
- > 250 million people required preventive treatment in 2021.
- Schistosomiasis transmission reported from 78 countries.
- Deaths due to schistosomiasis ~ 12’000 year (likely underdiagnosed).
- Disease disables more than it kills => in children, schistosomiasis can cause anemia, stunting and reduced ability to learn.

=> mostly affects poor and rural communities, particularly agricultural and fishing populations

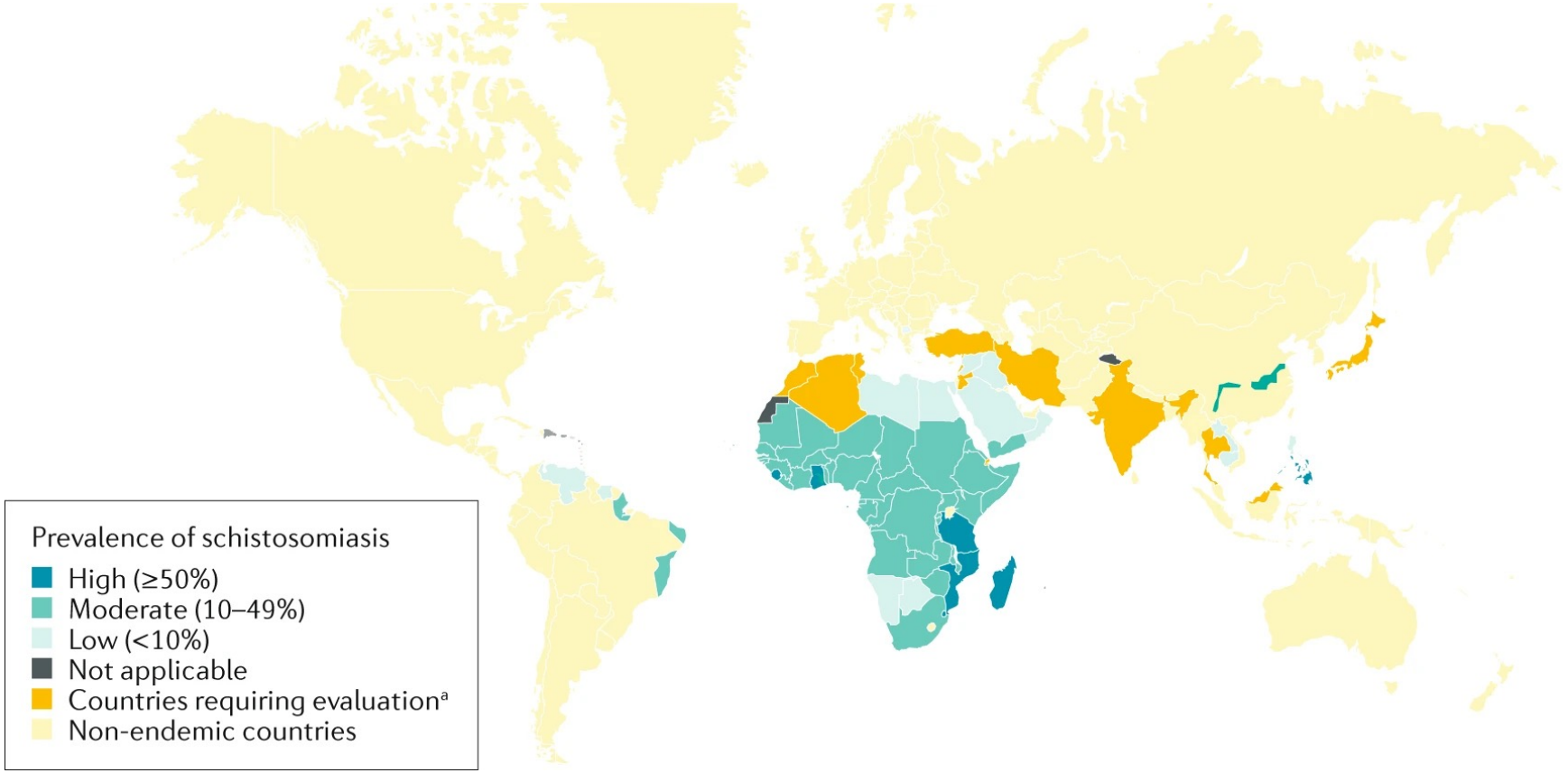
WHO

Active and late chronic schistosomiasis



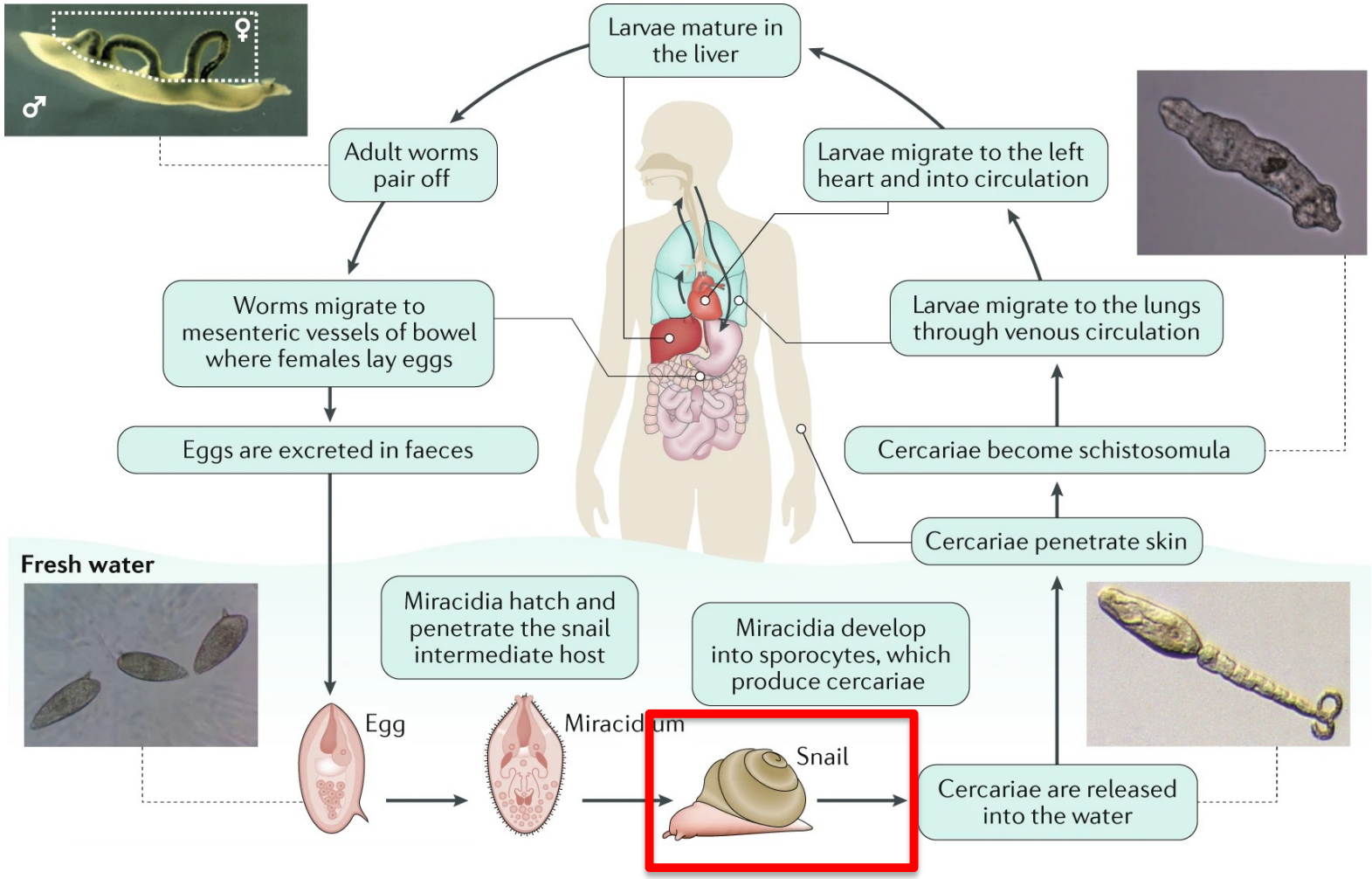
McManus *et al.* (2018) *Nat. Rev. Dis. Primers*

Prevalence of schistosomiasis



McManus *et al.* (2018) *Nat. Rev. Dis. Primers*

Schistosome life cycle



McManus *et al.* (2018) *Nat. Rev. Dis. Primers*

Biomphalaria pfeifferi

=> how could health intervention work?

Lo and Arnold (2023) *Nature* - on Moodle

Article

A planetary health innovation for disease, food and water challenges in Africa

https://doi.org/10.1038/s41586-023-06313-z

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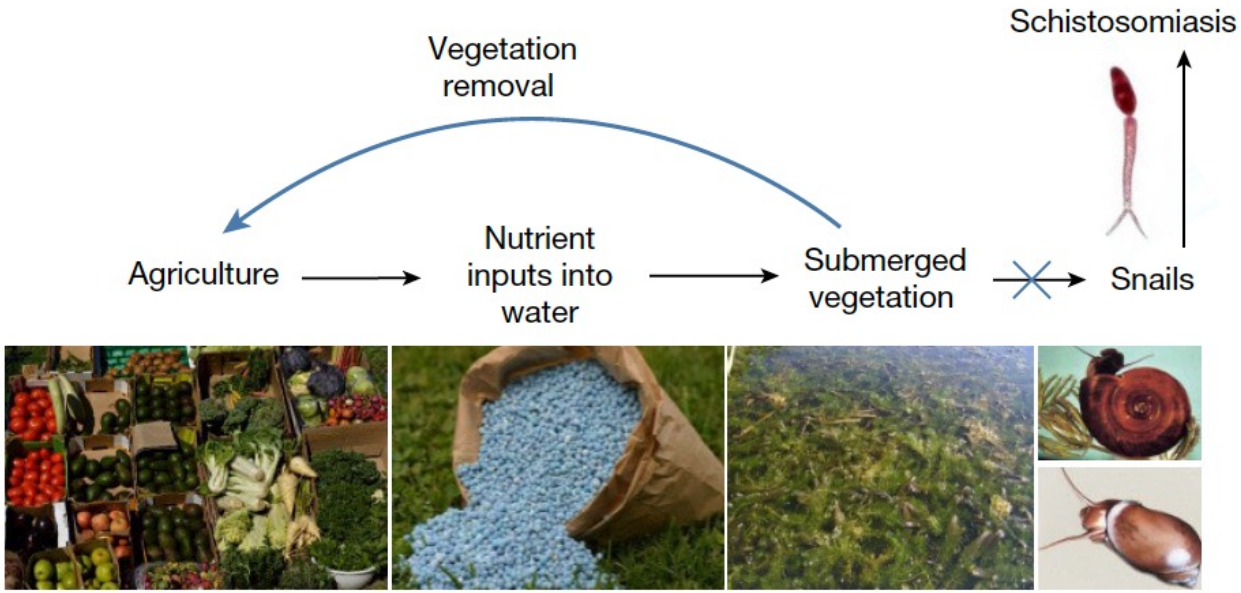
Published online: 12 July 2023

Jason R. Rohr[1]✉, Alexandra Sack[1], Sidy Bakhoum[2], Christopher B. Barrett[3], David Lopez-Carr[4], Andrew J. Chamberlin[5,6], David J. Civitello[7], Cledor Diatta[8], Molly J. Doruska[3], Giulio A. De Leo[5], Christopher J. E. Haggerty[1], Isabel J. Jones[5,6], Nicolas Jouanard[8,9], Andrea J. Lund[10,11], Amadou T. Ly[8], Raphael A. Ndione[8], Justin V. Remais[12], Gilles Riveau[8,13], Anne-Marie Schacht[8], Momy Seck[9], Simon Senghor[8], Susanne H. Sokolow[6] & Caitlin Wolfe[14]

Agricultural development and fertilizer use in West Africa have increased the burden of the parasitic disease schistosomiasis

Rohr *et al.* (2021) *Nature* – on Moodle

Agriculture and human schistosomiasis in Senegal



- Collaborative research with 23 communities in Senegal.
- Estimates: each 0.1 km^2 of agricultural cover associated with a 1.37 odds increase of *Schistosoma* cases.

Rohr *et al.* (2023) *Nature*

Aquatic vegetation removal trial

- Implemented a three-year cluster randomized controlled trial in 16 communities.
- Removed an estimated 433 metric tons (wet mass) of submerged aquatic vegetation (within water access points; not river & lakes).

=> 8-fold reduction of snails; 23.5% new infection rate in schoolchildren from treated areas compared to 31.5% in untreated control group.

Removing invasive vegetation likely shifted these systems towards an earlier, pre-disturbance state

- Key novelty: farmers could use this removed aquatic vegetation to increase crop and livestock yields => boosting economic well-being + incentivizing uptake of the intervention.
- Composted vegetation used as a fertilizer => onion & pepper production went up
- Vegetation replaced conventional livestock feed => 179-time cheaper.

Rohr *et al.* (2023) *Nature*

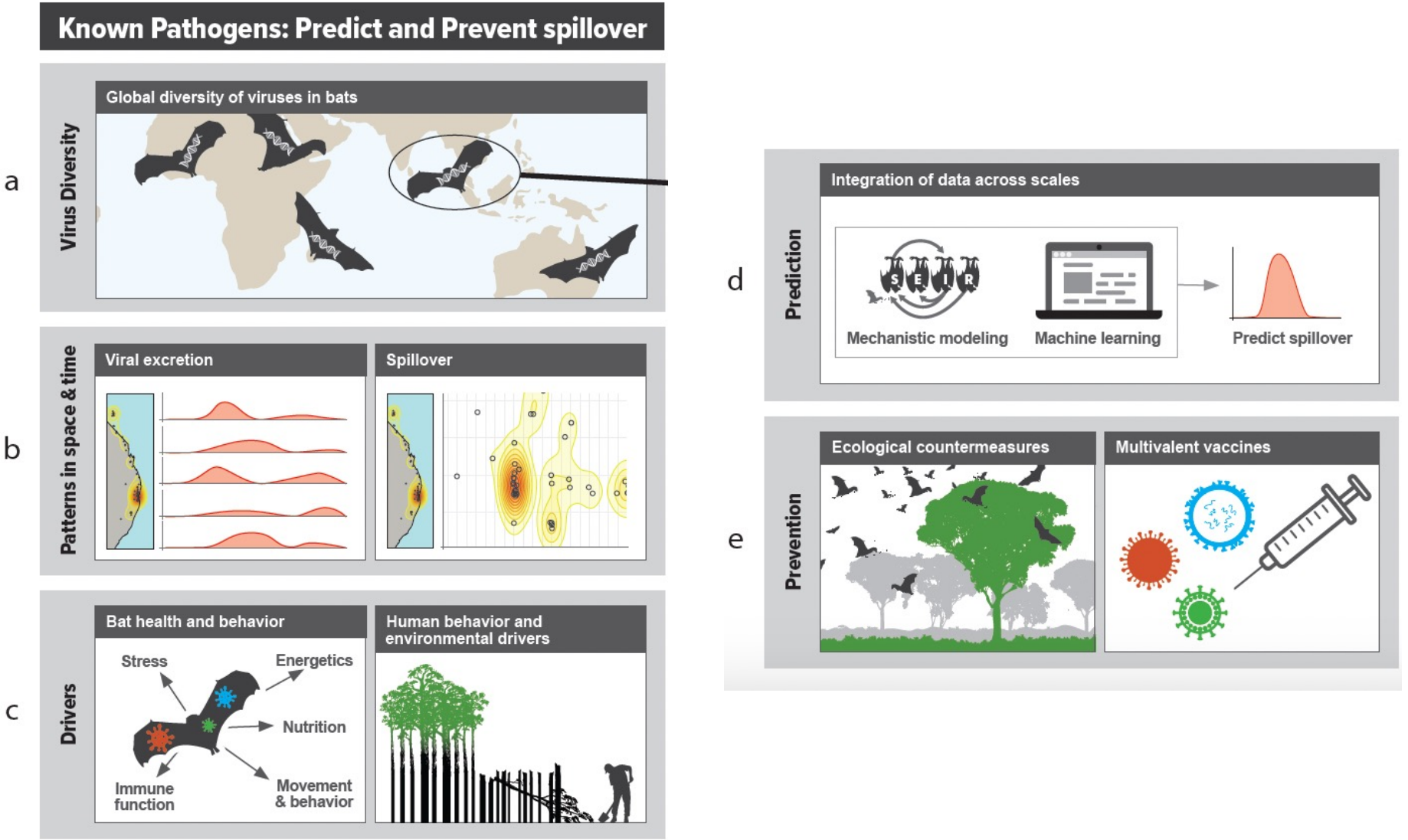
6. Healthcare Infrastructure and Access

- Timely detection and diagnosis.
- Effective surveillance and reporting systems.
- Access to vaccination and preventive care.
- Treatment and healthcare capacity.
- Equitable access and health disparities.

7. Technology and Biomedical Research

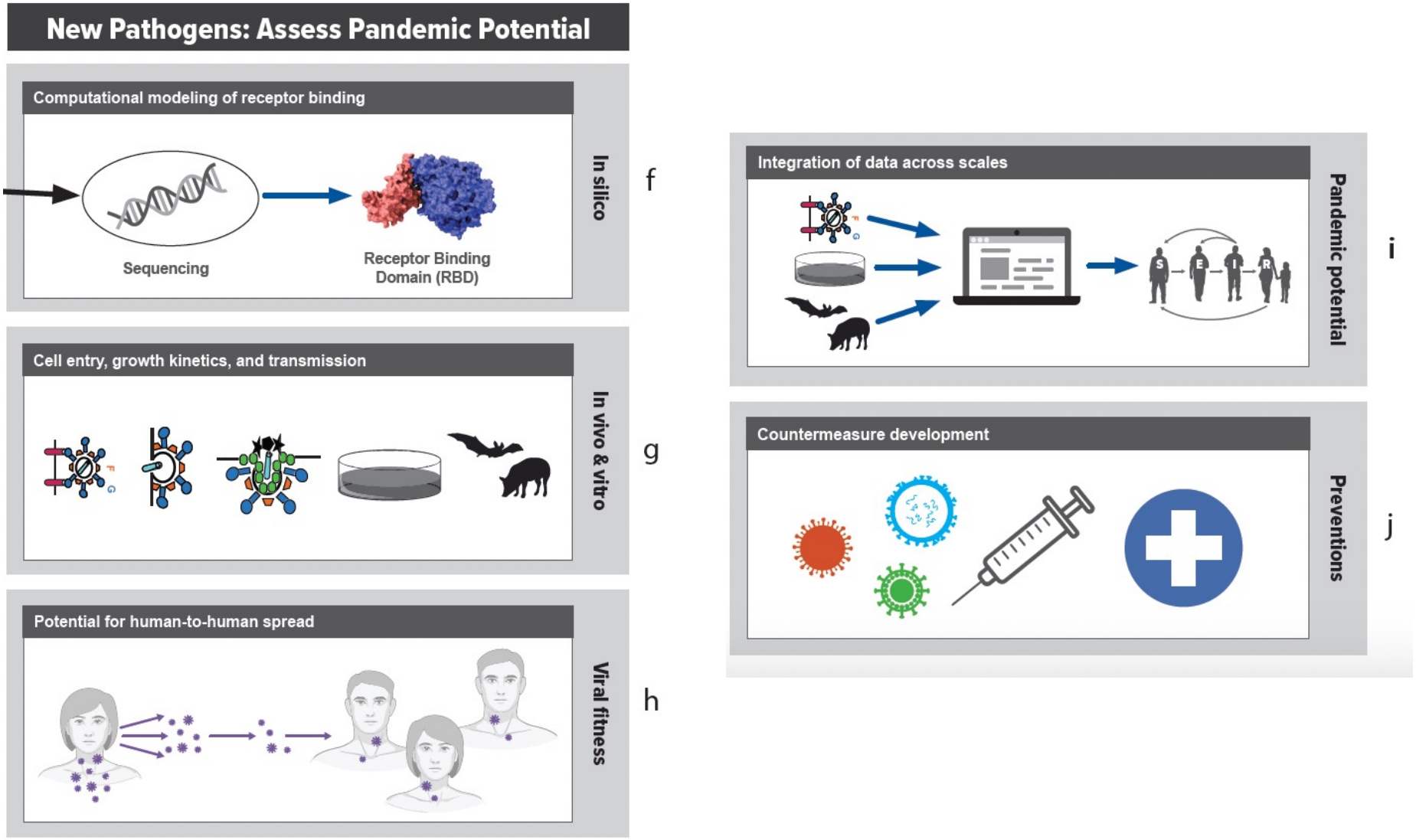
- Early Detection and surveillance.
- Vaccine development and immunization programs.
- Pathogen characterization.
- Genomic surveillance.
- Drug discovery and antimicrobial development.
- Data sharing and collaboration.
- Public health interventions.
- Digital health solutions.

Studying pathogen spillover



Plowright and Hudson (2021) *Viruses*

Studying pathogen spillover



Plowright and Hudson (2021) *Viruses*

7. Technology and Biomedical Research

Maximizing the impact of technology and biomedical research on IDs:

- Invest in research and development initiatives
- Promote interdisciplinary collaborations.
- Foster the adoption of innovative technologies in public health systems.
- Ensure equitable access to technology-driven healthcare solutions.
- Promote data privacy and security measures.

Next week's program

- **09:15-11:00 => 2nd lecture**
- **11:15-13:00 => journal club => read paper posted on Moodle ahead of time.**