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EXTREME PANDEMIC SCENARIOS

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International Mortality and Longevity Symposium
Royal Holloway, University of London, 6 September 2016

Natural Hazards

PANDEMIC

Man-made Hazards

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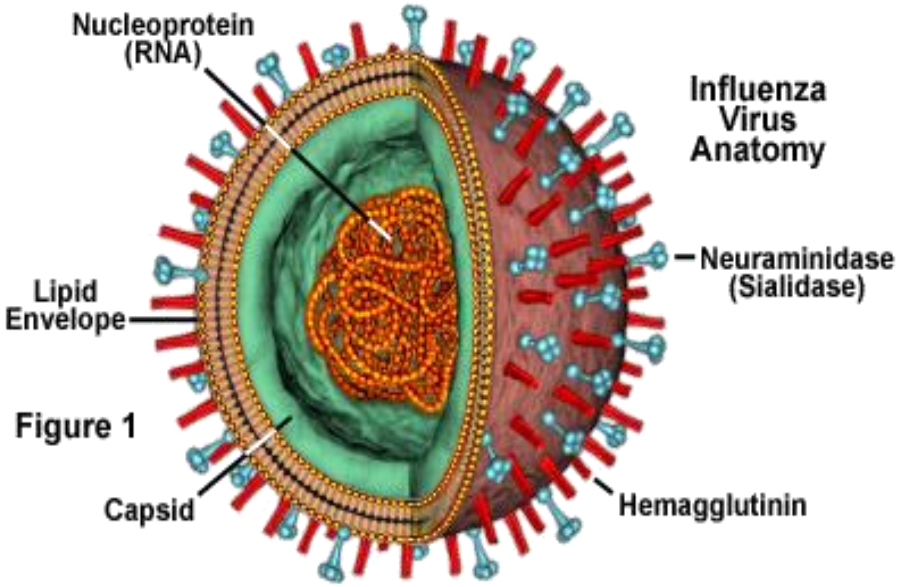
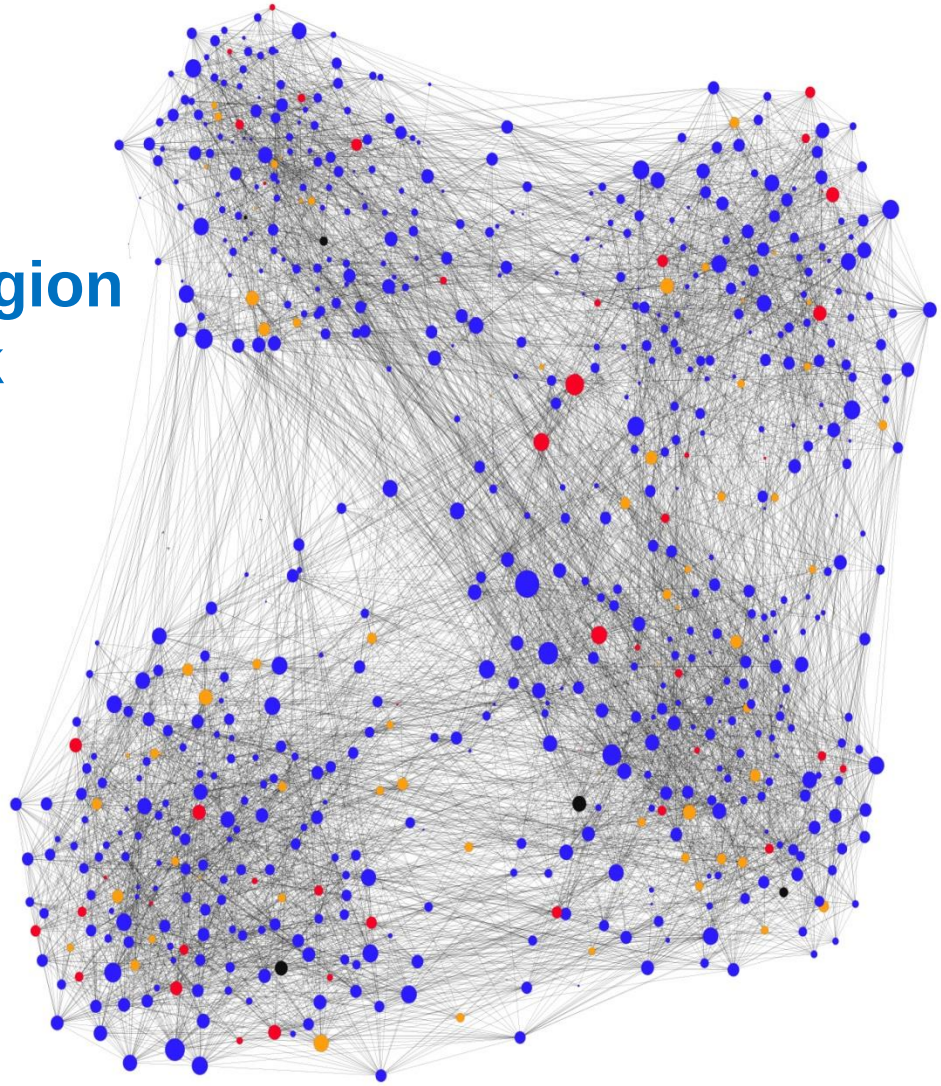
Influenza: not just a natural hazard

The term *influenza* used by Domenico Gagliarde in 1733 is derived from the Italian word *'influence',* its original meaning implying a disaster sent from the heaven.

We now know that the past was not inevitable, and that there could have been alternative realizations of what happened.

Flu contagion network



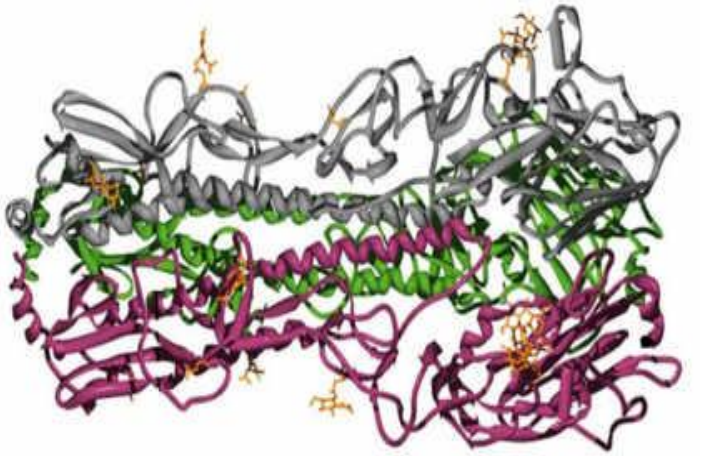


students
teachers
non-instructional staff
other

fewer contact partners
more contact partners

The hemagglutinin molecule

The hemagglutinin (HA) molecule is actually a combination of three identical parts (shown here as grey, green, and purple) that are bound together to form an elongated cylindrical shape.



A mutation that changes just one of hundreds of amino acids in the protein structure can alter the viral properties significantly. There are many millions of possible combinations of genetic changes that might potentially lead to dangerous characteristics.

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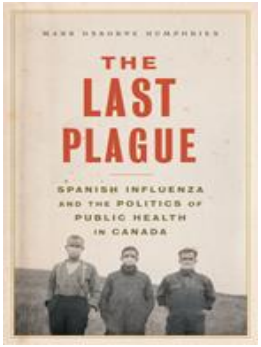
Trans-continental population flux driver of pandemic catastrophe

- The Plague of Justinian in the 6th century was transmitted by shipments of grain from North Africa.
- The Black Death was transmitted through Italian traders moving across the Black Sea.
- The Aztec and Inca empires were devastated by Spanish invasion.
- Cholera was exported from India by a British expedition to Oman in 1821.
- But for the transport of 100,000 Chinese labourers to the Western Front, the 1918 pandemic would not have been so severe.

Pandemic: a coupled natural and man-made peril

'Viral threats may emerge anywhere, and can develop over relatively long periods of time, erupting when long entrenched patterns of socio-economic activity begin to change.'



Mark Humphries (2013)
Paths of Infection: The First World War
and the Origins of the 1918 Influenza pandemic

'Laws and regulations may govern the conduct of war, but disease and infections recognise no such laws and refuse to signal out the combatant only.'

Guy Carleton Jones, future Canadian Surgeon-General, August 1914

Virulence: Case fatality rate

Year(s)	Virus Type	Case Fatality Rate
1729-1730; 1732-1733		High
1761-1762		
1780-1782		Very Low
1788-1790		Low
1830-1831;1832-1833 1836-1837		Low
1889-1893	H2N2 or H3N8	0.1 – 0.28%
1918-1919	H1N1 [Spanish?]	2.5%
1957-1958	H2N2 [Asian]	0.13%
1968	H3N2 [Hong Kong]	< 0.1%
1977-1978	H1N1	
2009	H1N1 [Mexico]	0.05%

H1N1 Pandemic 2009

During the spring of 2009, a novel H1N1 virus of swine origin caused human infection and acute respiratory illness in Mexico.

After initially spreading among persons in North America, the virus spread globally, resulting in the first influenza pandemic since 1968.

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Great War demobilization

- Demobilization cannot account for the diffusion of the fatal pandemic wave which began in late August and peaked in late October and early November 1918.
- None of the belligerents demobilized until well after the crisis passed.

Veterans Parade in St. Louis, Missouri

1918 pandemic case fatality rate geographical variation

- Compared with average mortality rates among the infected in other parts of the world, in China they were much lower:
  0.13% in Shanghai.
- This is likely because of population immunity gained from earlier exposure.
- As a comparative illustration, in San Francisco where 22,639 were infected and 2122 died, the case fatality rate was 9%.

Rationale for the Chinese Labour Corps

China wanted to regain possession of Shandong province which was occupied by Japan, after the German colonial garrison had left.

In support of the allies on the Western Front, the Chinese Labour Corps was formed. Most came from Shandong province.

In late 1917, a virulent respiratory disease of unknown origins erupted in the interior of northern China.

The mobilization of the Chinese Labour Corps moved 100,000 from the region where the outbreak occurred, across Canada from Vancouver to Europe.

In the summer of 1918, a more virulent mutation of the disease diffused from the Channel coast.

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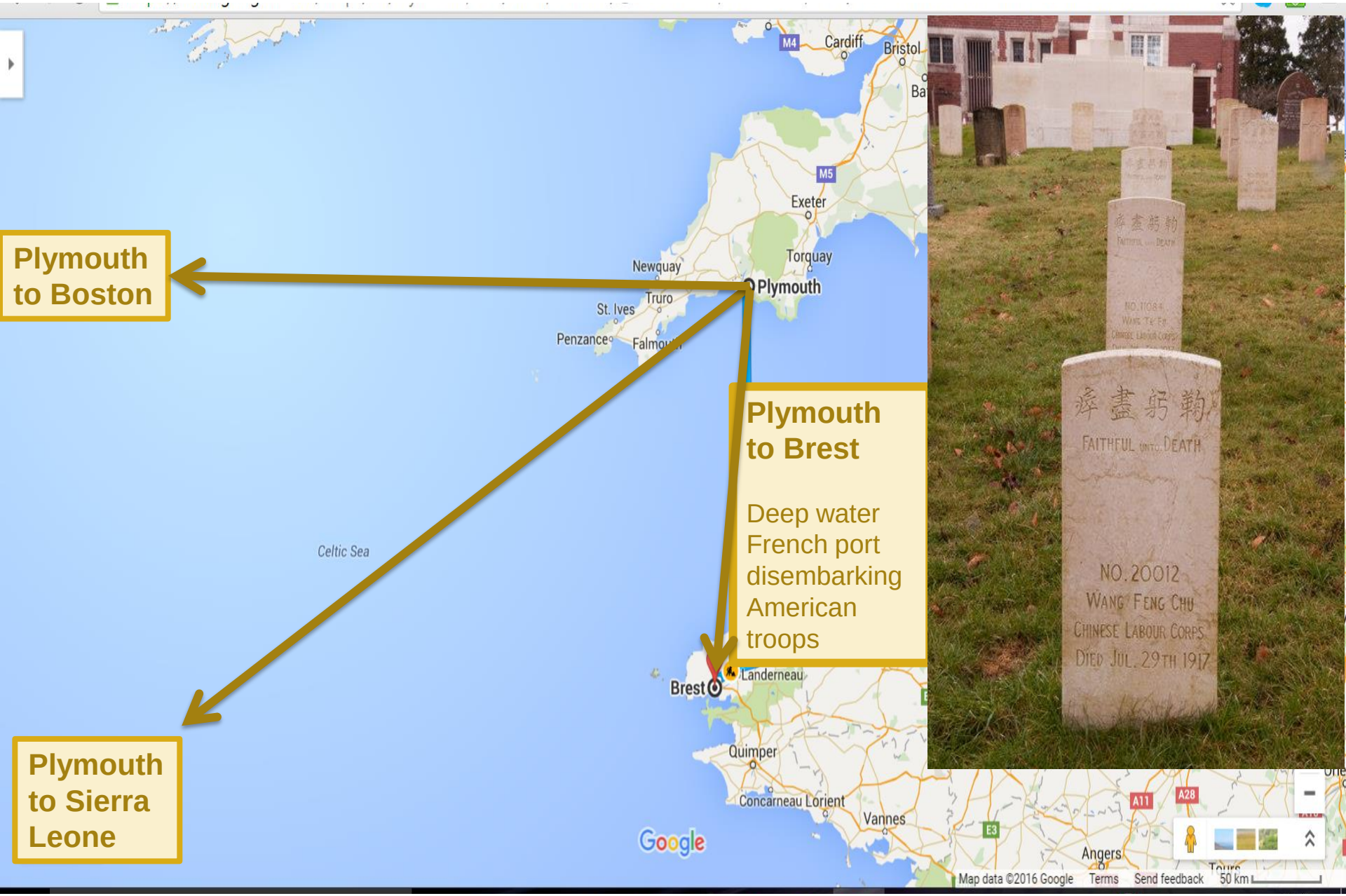
Pandemic spread outwards from Brest, Sierra Leone and Boston



Chinese labourers were frequently offloaded at Plymouth and transported by rail to Kent.

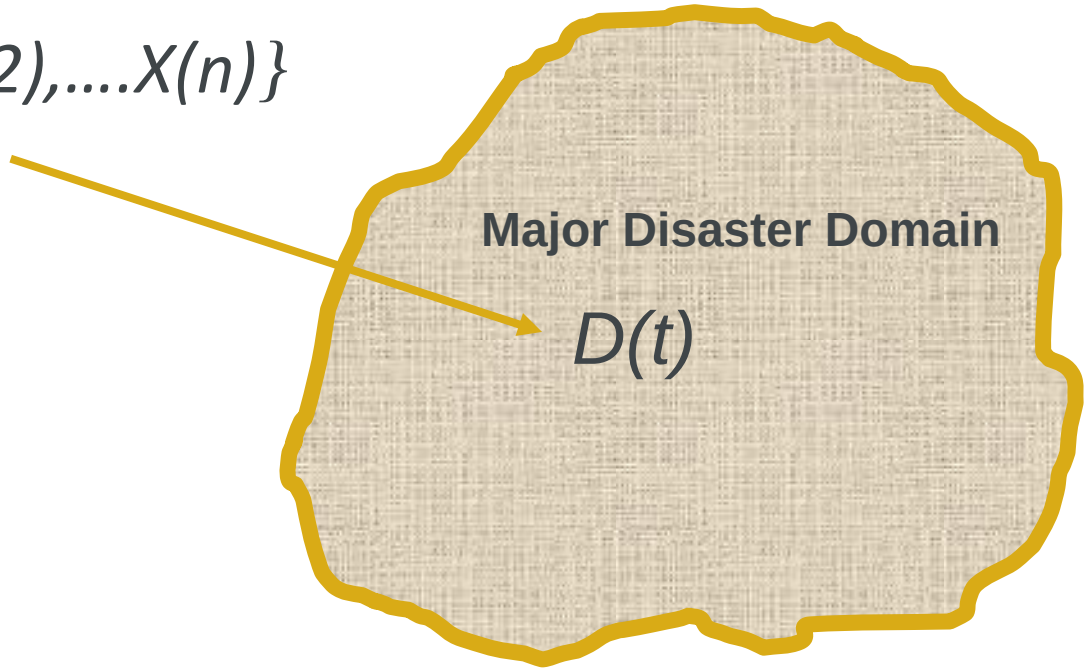
Super-spreaders of pandemic disease

- Extreme pandemics may be triggered by a large population flux introducing an emerging disease into new territory. This flux may be a consequence of military operations or refugee migration in a regional political conflict.
- If the influx of people has some community immunity to the emerging disease, they may appear only mildly sick.
- However, they may act as ‘super-spreaders’ in a new territory, causing severe illness and high mortality in the host community.

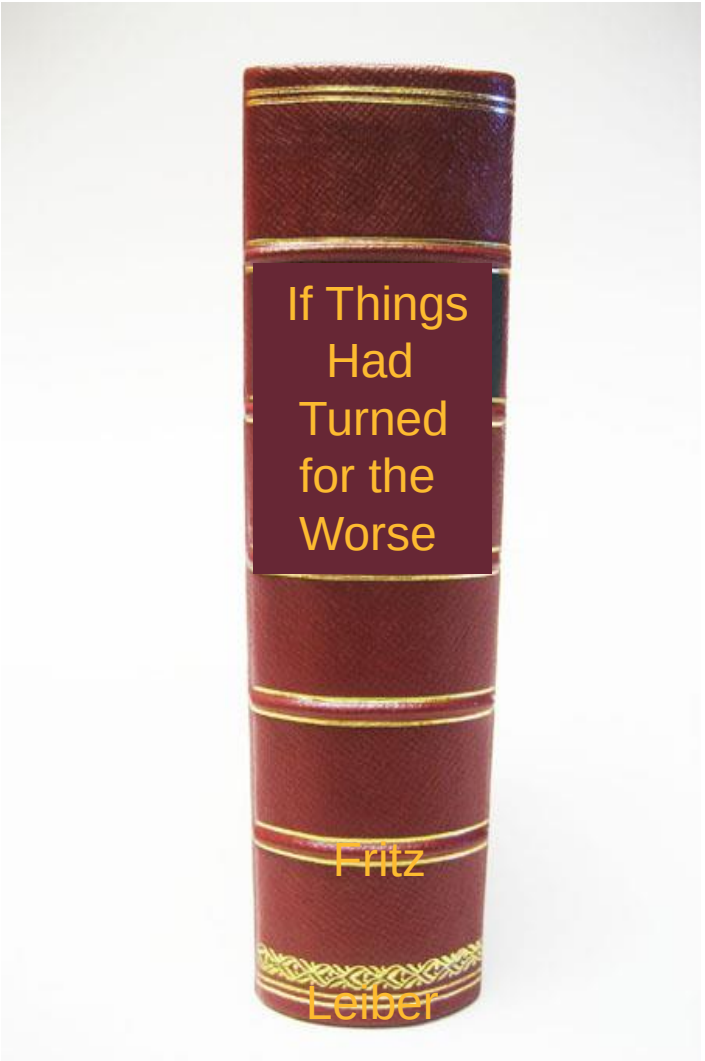
What perturbation to the historical context might have caused a disaster to get much worse?

System State

{ X(1), X(2),....X(n)}



Could the 1918 pandemic have been worse?



Not long after a request from the Canadian Surgeon-General, the British government decided to cancel the Chinese Labour Corps programme because of the danger posed by ‘plague’ in China.

Continuation of the CLC programme for a few more months would have accelerated and expanded the pandemic spread.

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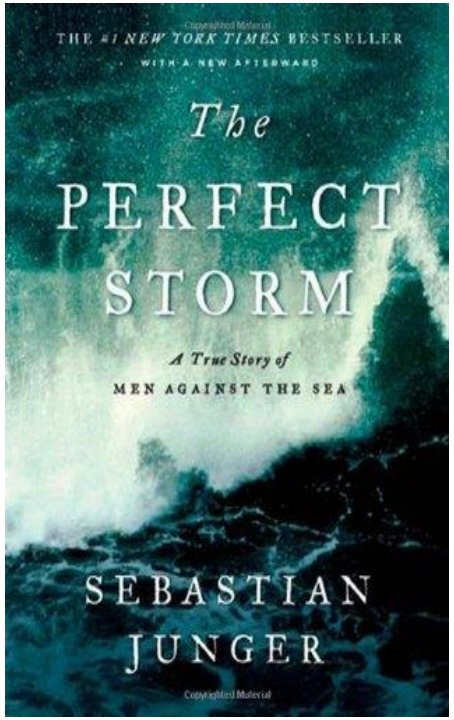
Excess deaths from a combination of perils



The **Great Kanto** Tokyo earthquake in Japan occurred on 1 September 1923, and coincided with a typhoon.

A large firestorm was generated, and produced a gigantic fire whirl that killed 38,000 people in fifteen minutes. The overall death toll was about 100,000.

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Political conflict impact on public health

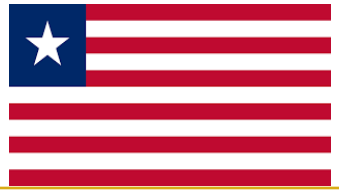
- Without security, there can be no effective public health system.
- Immunization systems can collapse rapidly.
- Vaccination coverage can drop by 50%, in particular for the new-born.
- Water-borne diseases like cholera can proliferate.
- Overcrowding and unsanitary conditions contribute to the spread of infectious diseases.

Political instability in West Africa

1989 First Liberian Civil War **1997**

1991 The Sierra Leone Civil War **2002**

1999 Second Liberian Civil War **2003**



2016 Land dispute could trigger another conflict in Liberia

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Failed health infrastructure in Sierra Leone

The medical care infrastructure of Sierra Leone in 2014 was very primitive. There were only two doctors for every 100,000 people. (Cuba has more than 500). There were just 40 hospital beds per 100,000.

Sierra Leone has the highest maternal mortality rate in the world ~ 1%.

Maternity hospital funded by the Italian Committee for UNICEF

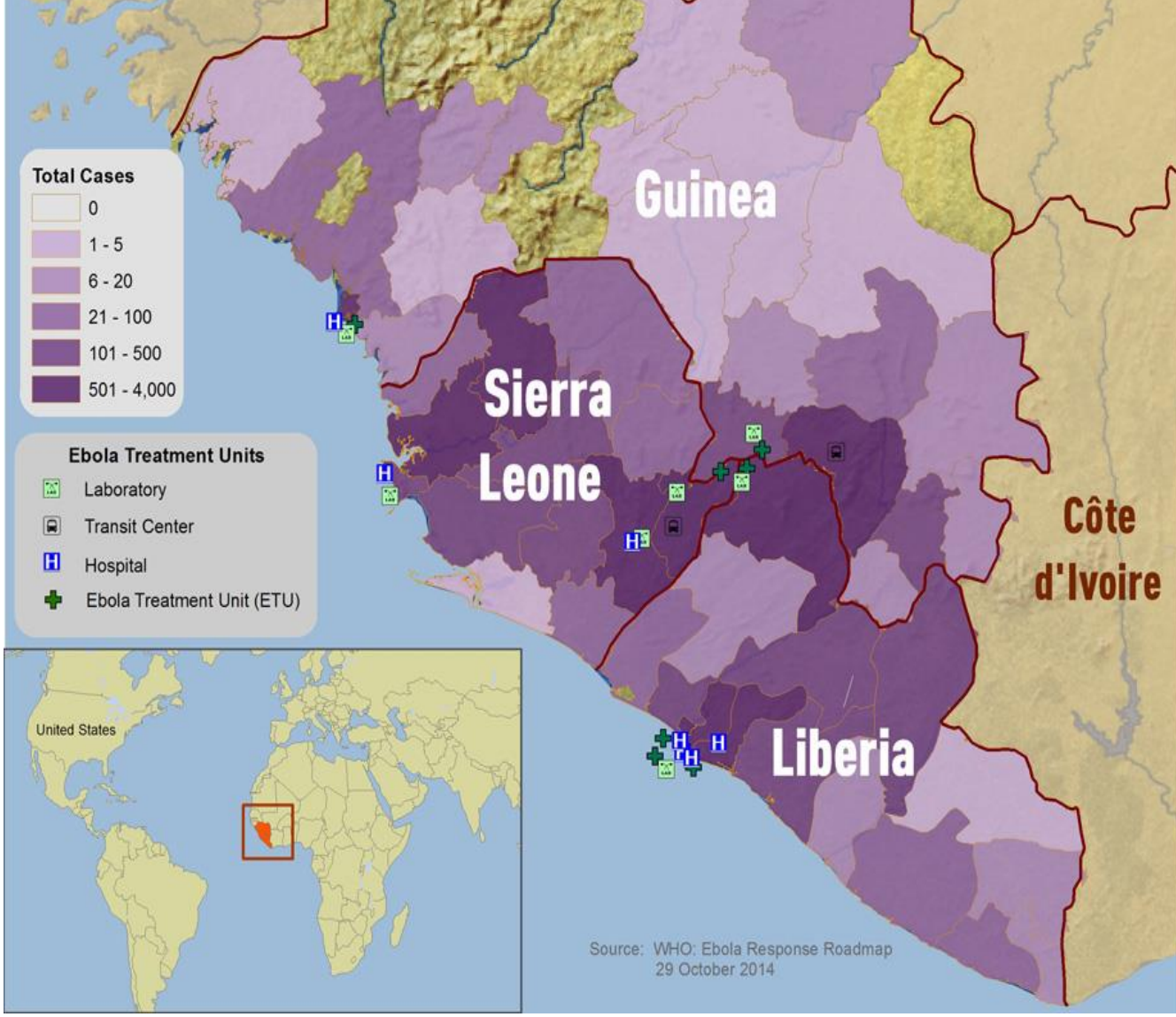
Lessons from the Ebola crisis 2014

- The control of an emerging infectious disease is very country-specific, being dependent on the national standard of medicine, health care and public hygiene, veterinary surveillance etc..
- The spread of an epidemic depends on national societal factors such as public education, the preservation of public order, reporting and isolation of cases, compliance with quarantine and movement restrictions and funeral ordinances.

During the Sierra Leone Civil War of the 1990s, more than 2 million (well over one-third of the population) were displaced internally and externally. The conflict began on 23 March 1991 and ended on 11 January 2002.

The containment of Ebola in Sierra Leone was challenging, and would have been far more difficult had there been a state of civil war in 2014 as in the 1990s.

Medical aid workers, such as MSF, would have found it too dangerous to work effectively.



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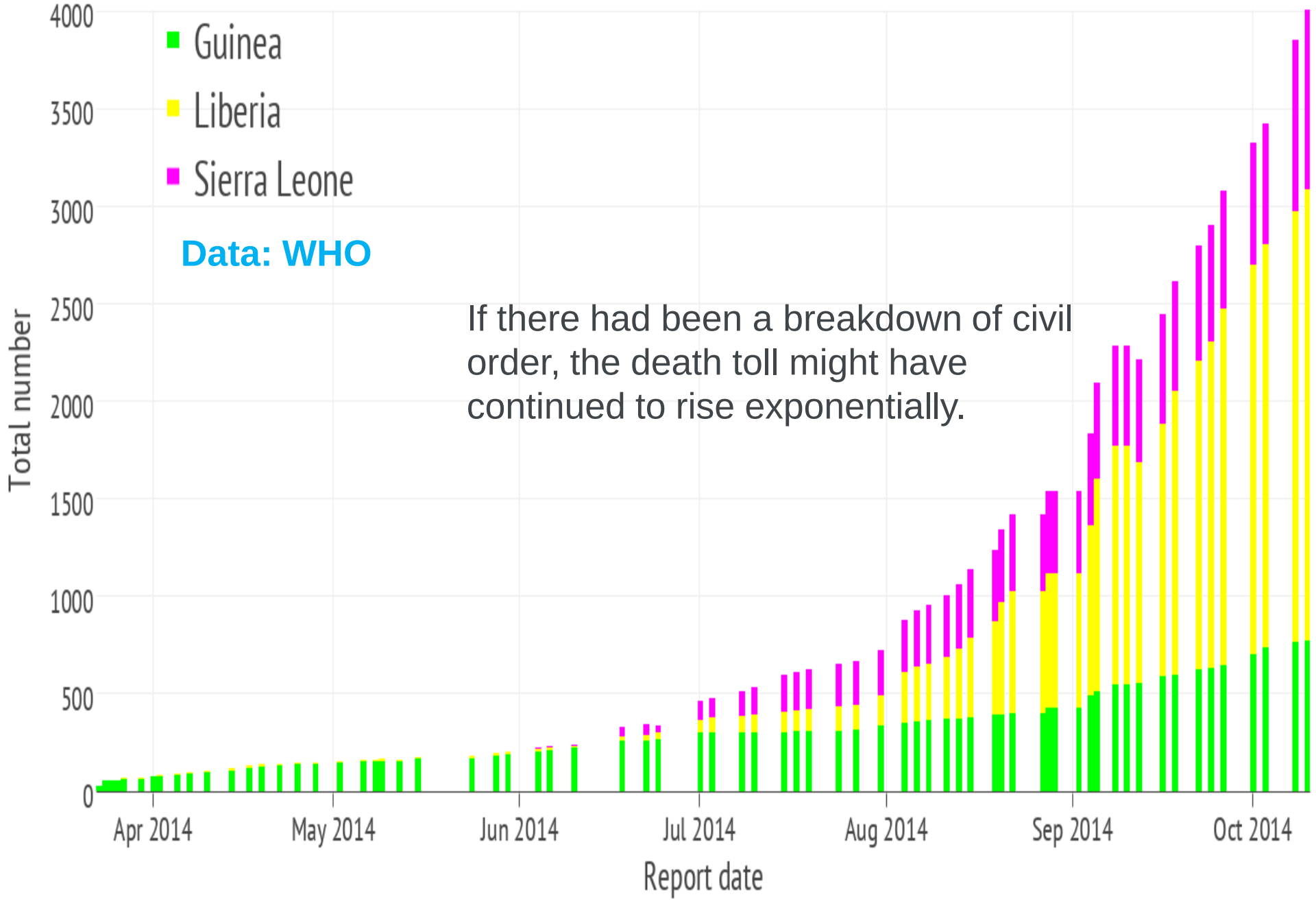
Dynamic reproduction ratio: R_0

- R_0 depends on:
  - [a] the number of people that an infected person comes into contact with
  - [b] the likelihood of infecting another person

- The first factor is a function of the social network of an individual.
- The second factor is a function of the transmissivity characteristics of the pandemic virus, and protective measures taken to avoid contagion.

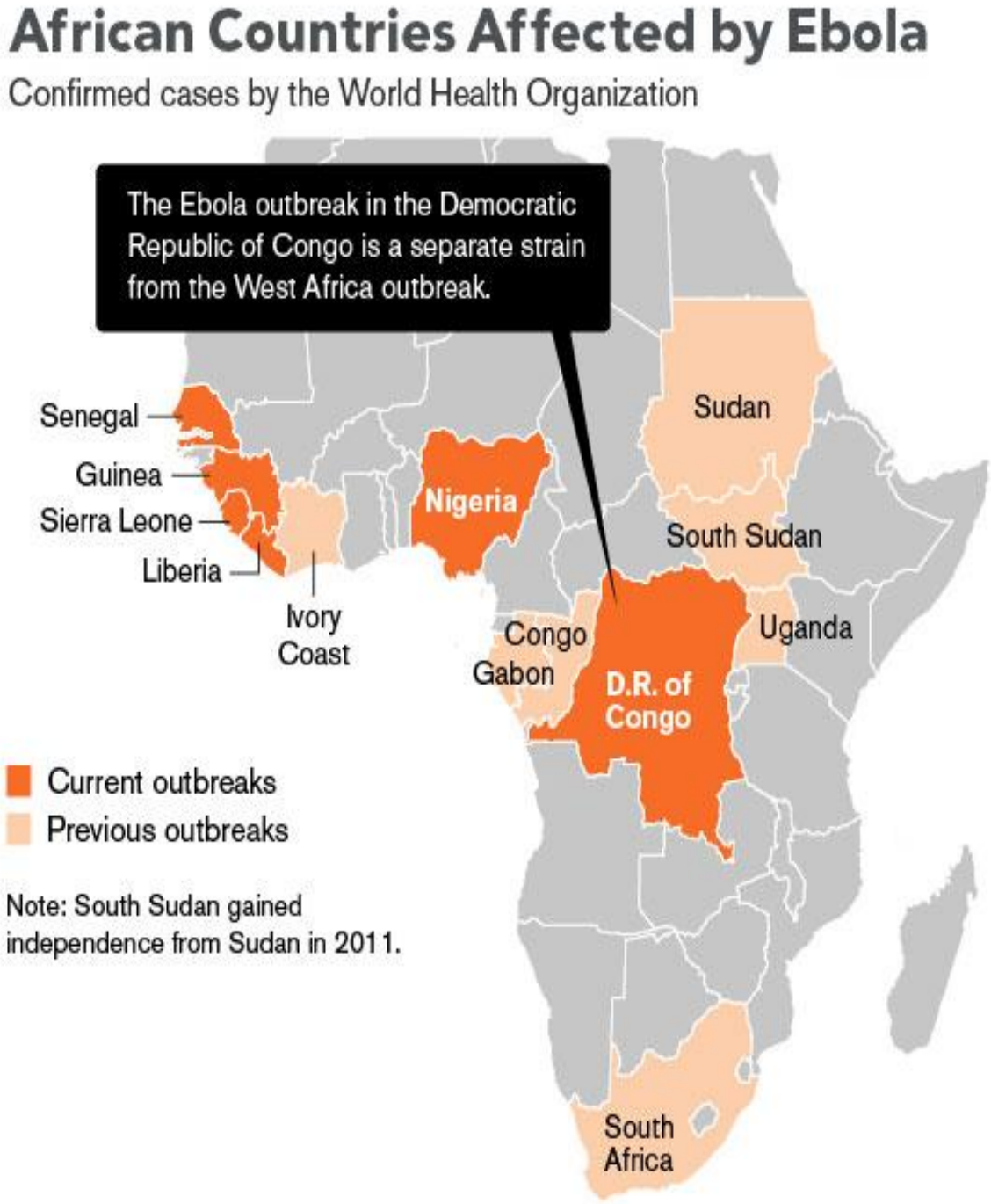
Escalation in the Ebola death count in West Africa



The first known outbreak of Ebola virus disease (EVD) occurred in 1976 in South Sudan.

Outbreaks in D.R. Congo occurred sporadically in 1976, 1994, 2003, 2007 and 2012.

Aum Shinrikyo sent a team to Congo in the early 1990s to assess how Ebola might be weaponized.



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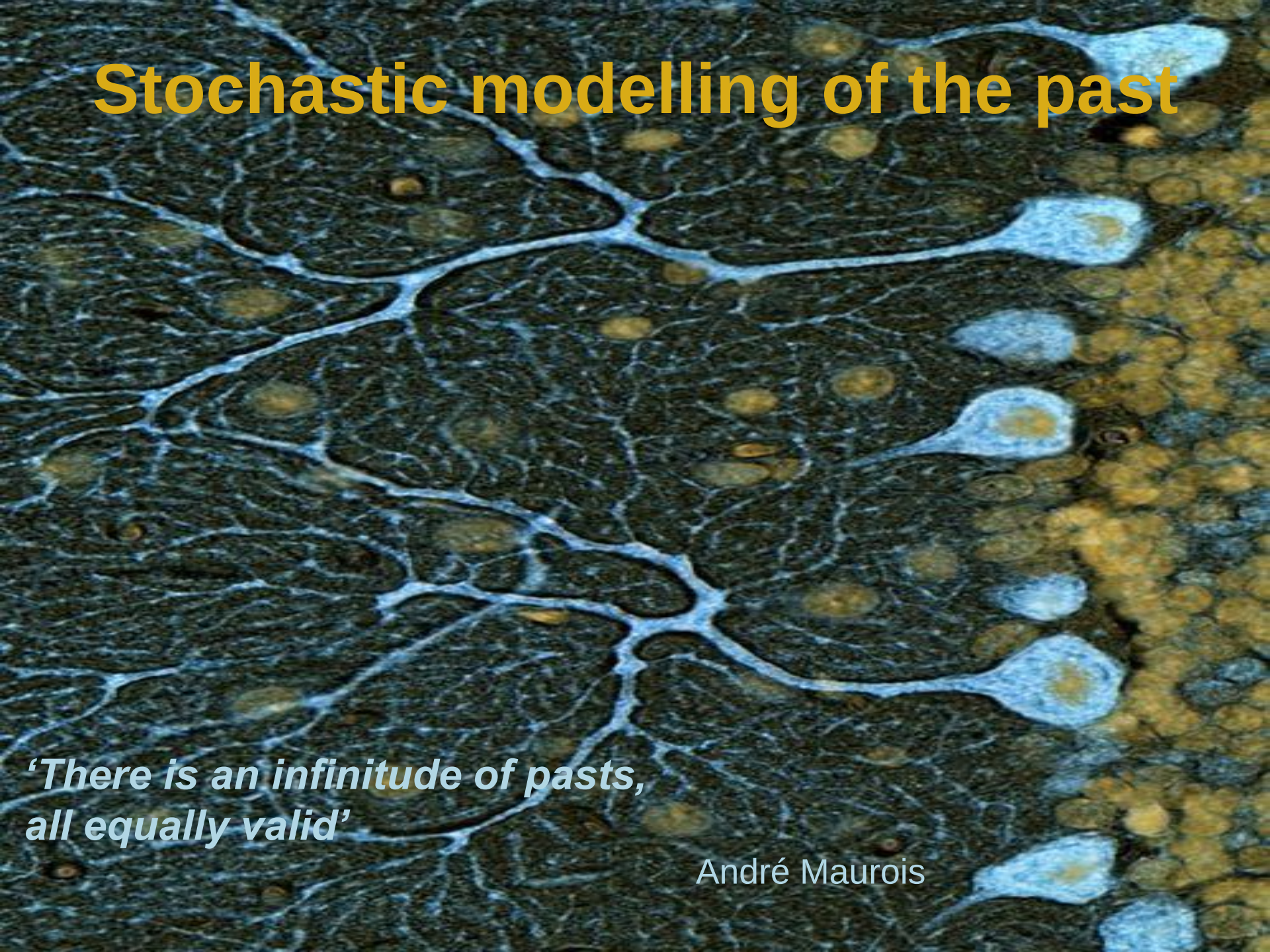
COUNTERFACTUAL PANDEMIC SCENARIO: MERS +

16 August 2016

Stochastic modelling of the past



'There is an infinitude of pasts, all equally valid'

André Maurois

Middle East Respiratory Syndrome (MERS)

World Health Organization

The strain of coronavirus that causes MERS was first identified in 2012 in Saudi Arabia. All reported MERS cases originated in the Arabian Peninsula, or can be linked to an infected traveller from the region.

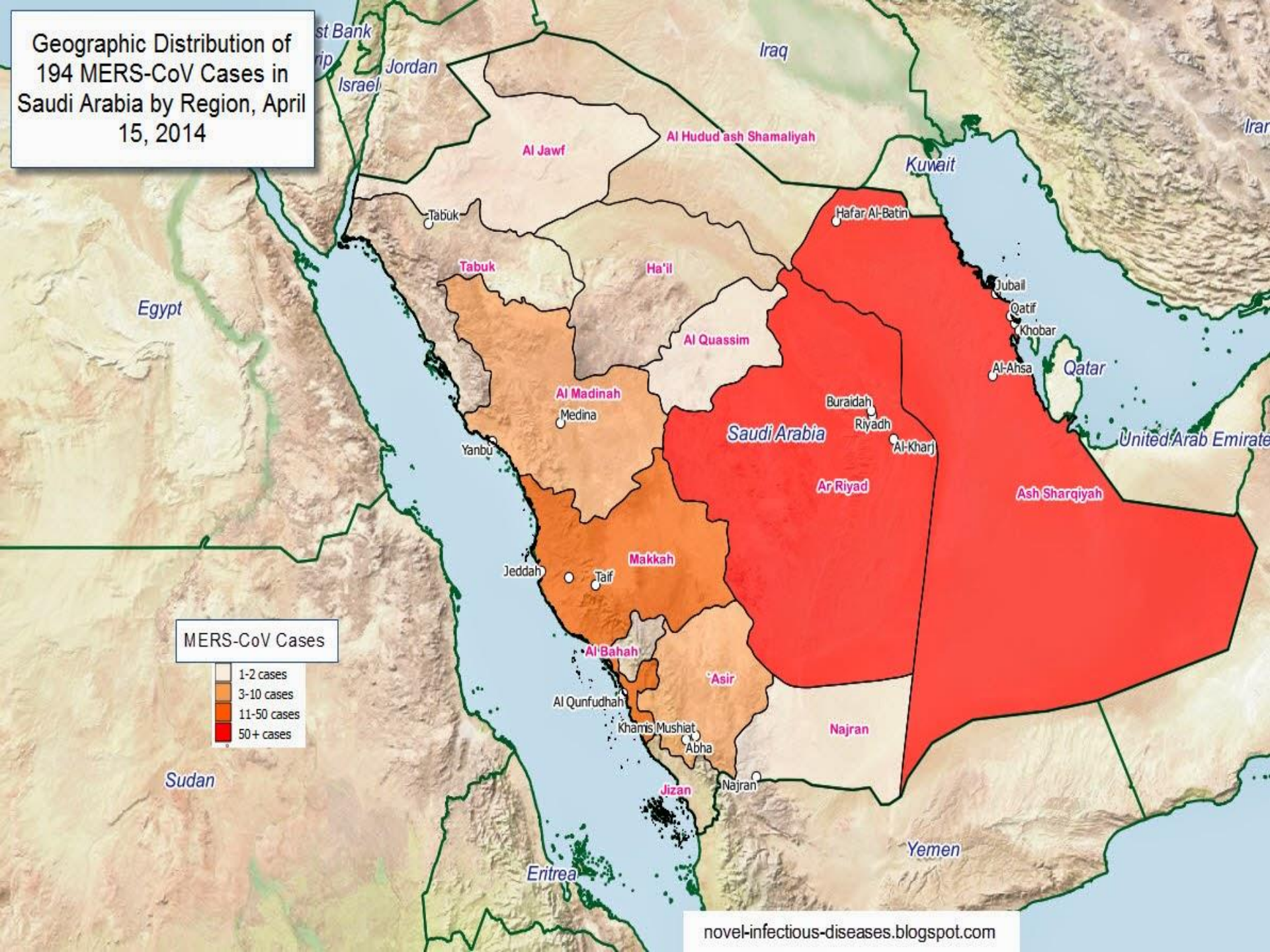
Among 1,791 laboratory confirmed cases of MERS infection, the case fatality rate has been about 35%. 27 countries have reported cases.

Camel host for MERS

Camels serve as hosts for MERS.

The strongest evidence of camel-to-human transmission of MERS comes from a study in Saudi Arabia in which MERS was isolated from a man with fatal infection, and from one of his camels.

Full-genome sequencing demonstrated that the viruses isolated from the man and his camel were identical.


Geographic Distribution of 194 MERS-CoV Cases in Saudi Arabia by Region, April 15, 2014
st Bank
Jordan
Israel
Iraq
Al Jawf
Al Hudud ash Shamaliyah
Kuwait
Tabuk
Hafar Al-Batin
Tabuk
Ha'il
Egypt
Jubail
Qatif
Khobar
Al Quassim
Al-Ahsa
Qatar
Al Madinah
Medina
Buraidah
Riyadh
Saudi Arabia
Al-Kharj
United Arab Emirate
Yanbu
Ar Riyad
Ash Sharqiyah
Makkah
Jeddah
Taif
MERS-CoV Cases
1-2 cases
3-10 cases
11-50 cases
50+ cases
Al Bahah
Asir
Al Qunfudhah
Khamis Mushiat
Abha
Najran
Sudan
Jizan
Najran
Yemen
Eritrea
novel-infectious-diseases.blogspot.com

Low transmission of MERS

- Sustained human-to-human transmission of MERS has not been observed, and R_0 is estimated to be less than 1.
- As evidence of very low human-to-human transmission, there were no MERS cases reported in either the 2012 or 2013 Hajj, although an Indonesian couple may have caught MERS in the 2014 Hajj.

Occasional spread between people

The MERS virus can occasionally spread between people, as happened in South Korea in May 2015, but only in hospital settings, or to a much lesser extent in households where people caring for an infected person have had close contact.

In hospital settings, medical procedures on an undiagnosed patient, for example to aid breathing, can generate aerosols from the lungs that contaminate the area and infect people nearby with the virus. Otherwise, MERS which infects the deeper areas of the lung, is not coughed out.

There is no vaccine for MERS nor specific medication.
Progress has been made with a DNA-based vaccine for camels.

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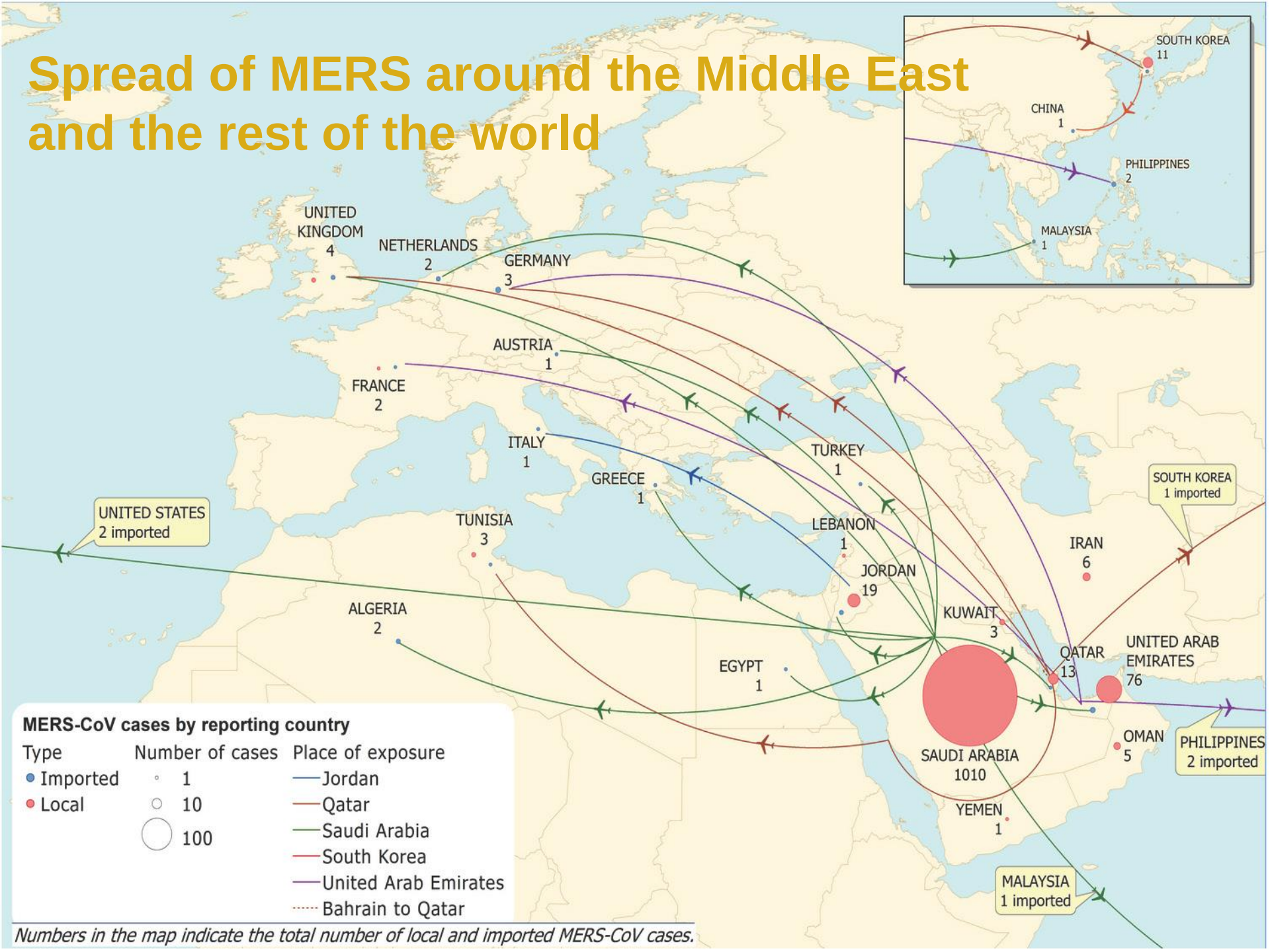
Spread of MERS around the Middle East and the rest of the world



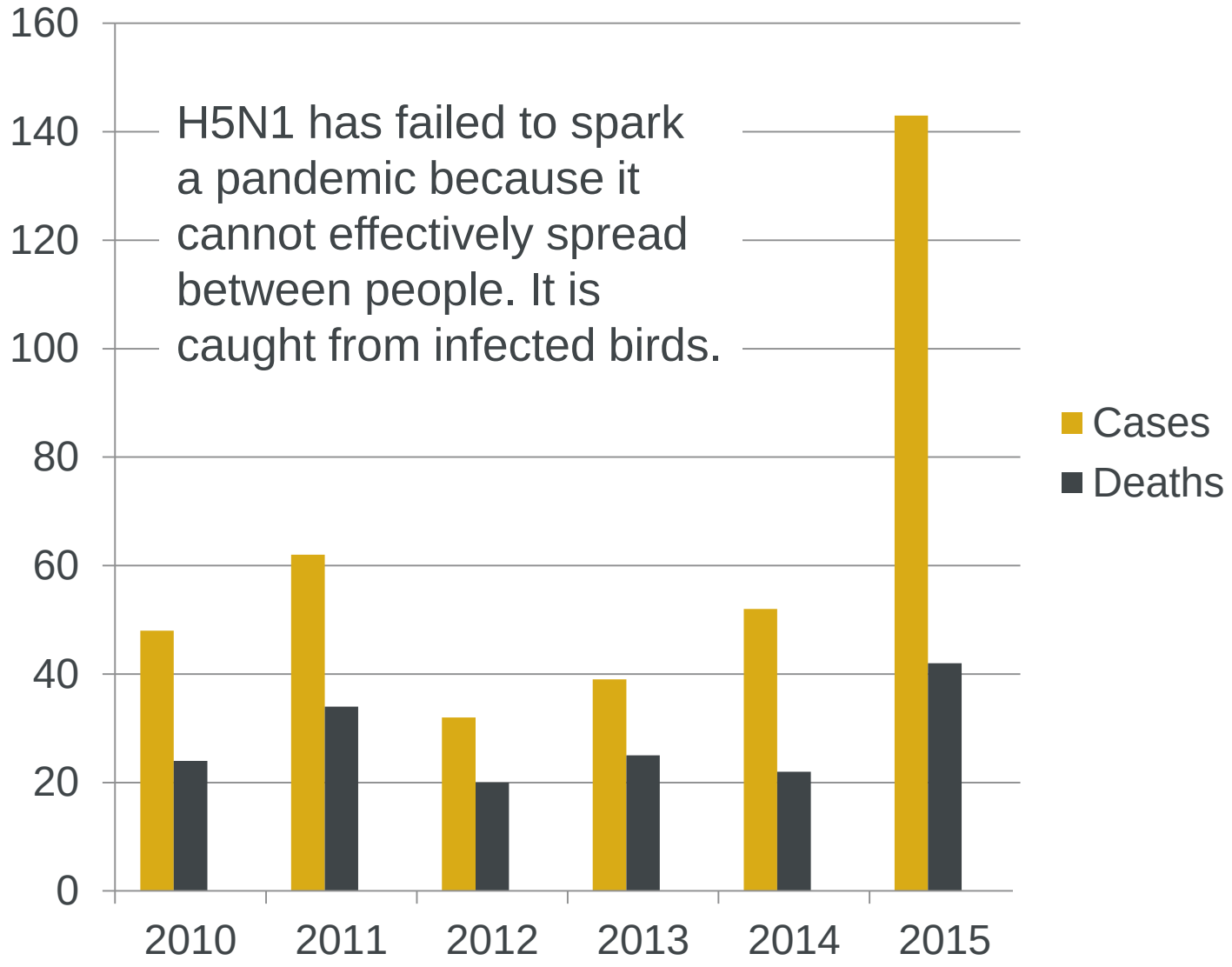
Numbers in the map indicate the total number of local and imported MERS-CoV cases.

Readily transmissible MERS

Gain-of-function research by Ron Fouchier and others has shown how more transmissible mutations of lethal pandemic viruses can be developed in a laboratory. Repeated exposure of laboratory macaque monkeys might force a dangerous mutation of MERS.

Either in a laboratory or naturally, emergence of a readily transmissible form of MERS is a possibility: MERS+

H5N1 Avian Flu



H5N1 has failed to spark a pandemic because it cannot effectively spread between people. It is caught from infected birds.

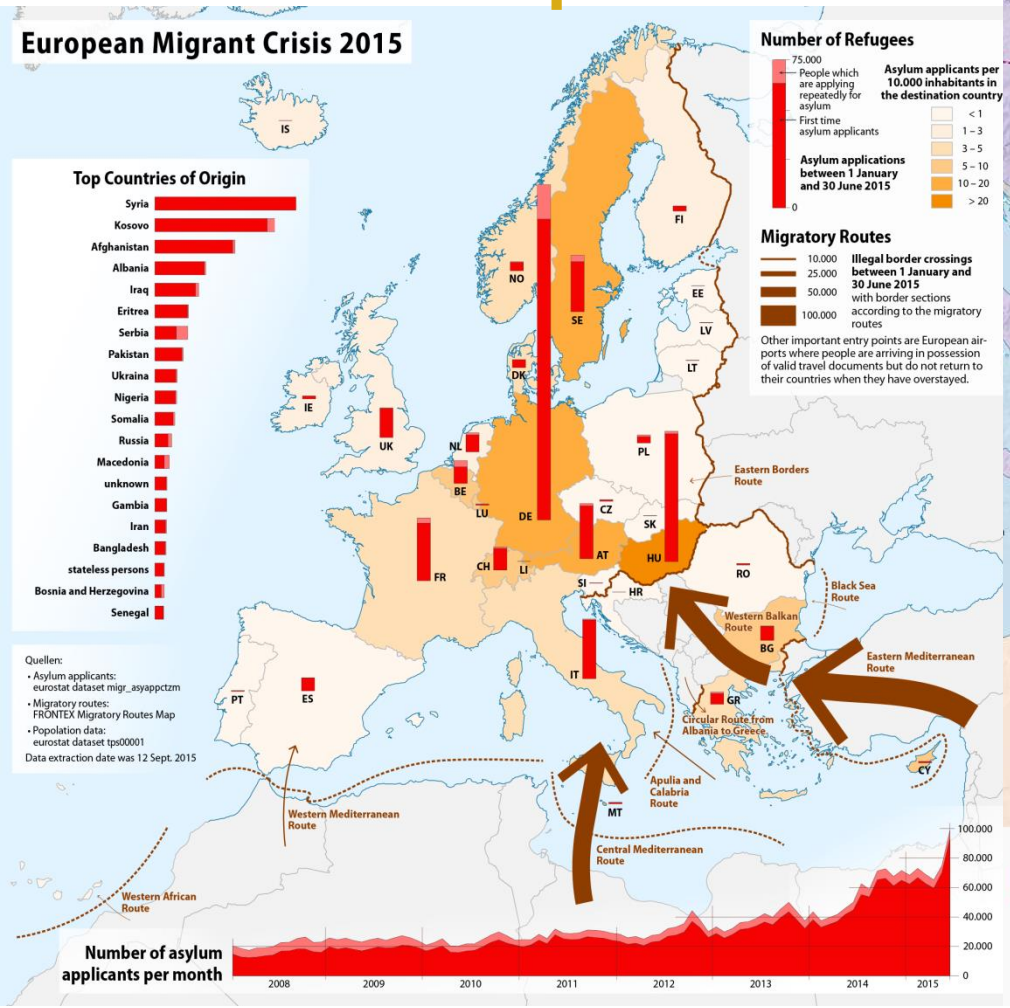
Mass migration disease spread

- The population spread of MERS+ would be increased involuntarily through the mass movement of refugees, escaping from political conflict.
- The Syrian civil war has introduced epidemics of infections that have spread through vulnerable populations in Syria and neighbouring countries. There may be a large number of cholera deaths in Syria.

Reported cases of communicable diseases per year between 2011 and 2013 in Lebanon

Disease	2011	2012	2013
Measles	9	9	1760
Leishmaniasis	5	2	1033
Hepatitis A	448	757	1551
Typhoid	362	426	407

Global population network expansion



Syrian Refugees: **4,087,139 people**

Syrian Internally Displaced People: **7,632,500 people**

12.2 million people in need of humanitarian assistance inside Syria

SOURCE: European Commision, Reuters, BBC

Vox

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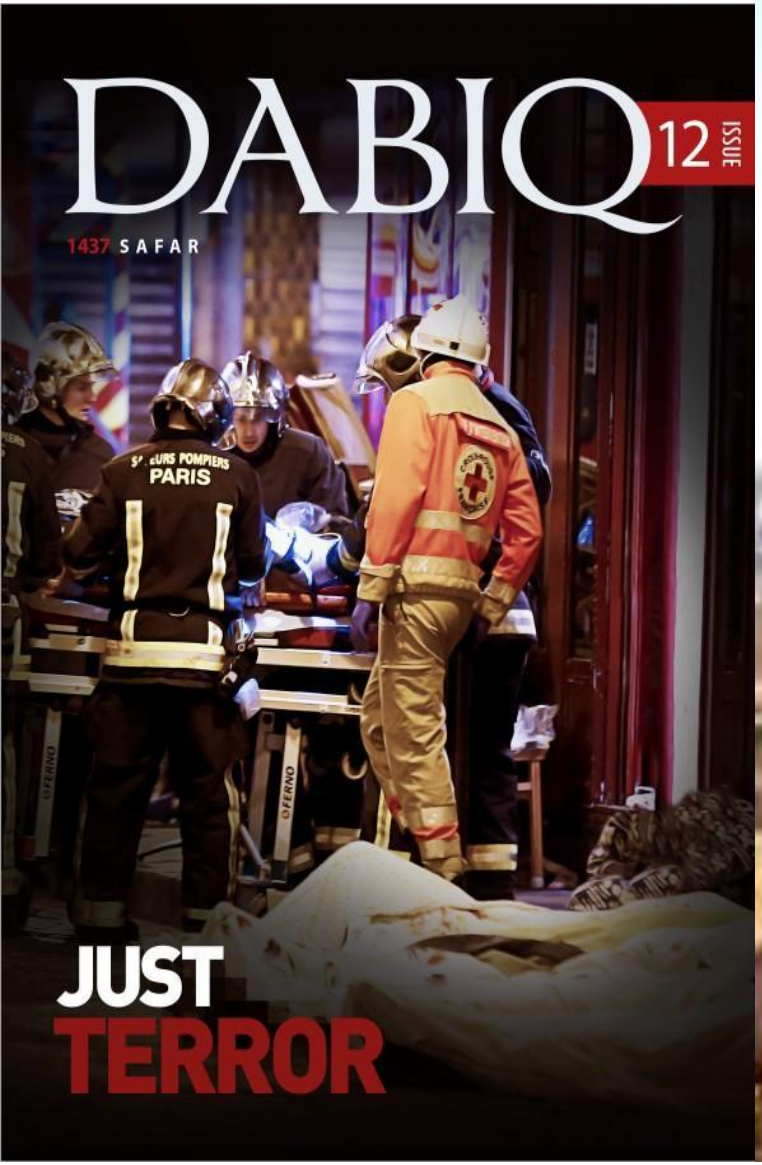
Spread of pandemic disease as a terrorist biological weapon



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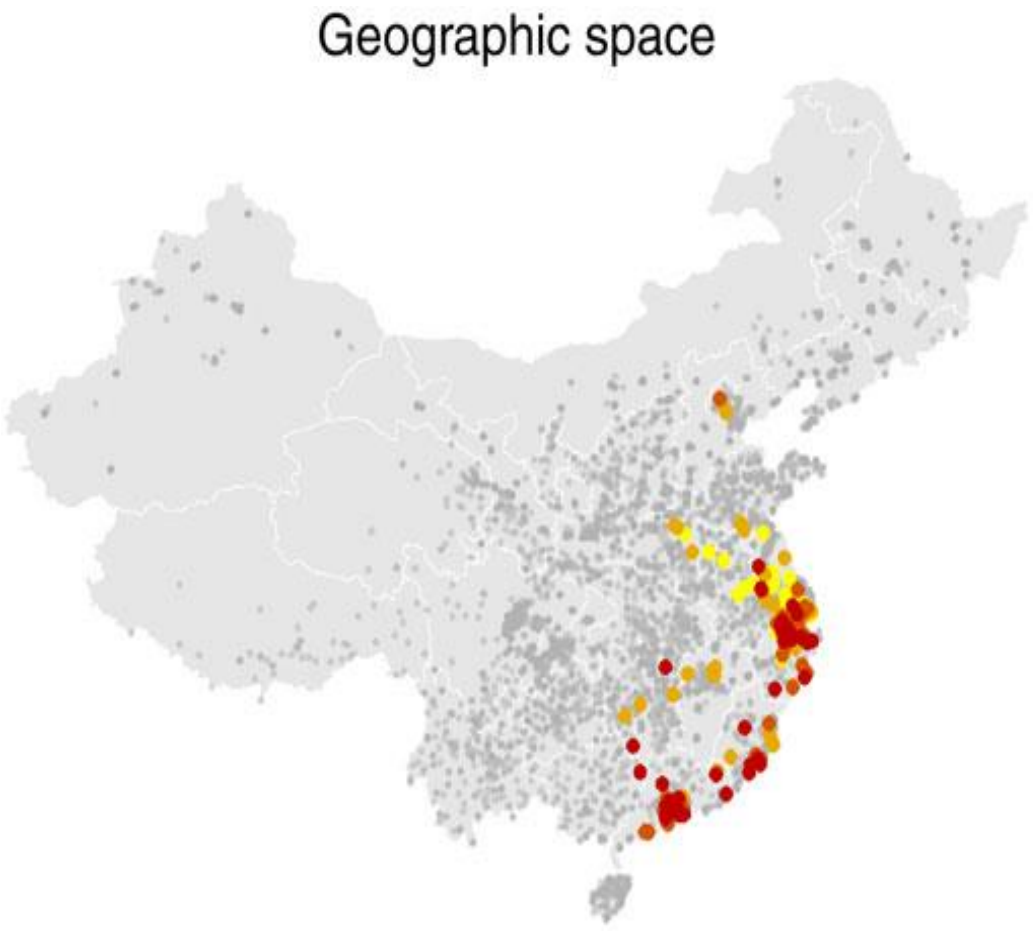
PANDEMIC RISK MITIGATION

16 August 2016

H7N9 avian flu

- H7N9 is a new strain of avian flu discovered in China in April 2013, that is transmissible from animals to humans.
- Similar to other avian influenza viruses, H7N9 attaches more strongly to tissues in the lower than the upper airway.
- Most patients had a history of recent exposure to poultry, generally at live bird markets.
- The H7N9 lethality rate is about 30%.

Predicting the risk of H7N9 in live-poultry markets



There are about 9,000 live-poultry markets in China.

The distribution of H7N9-negative markets is shown by grey points.

Potential H7N9-positive markets are shown by colour points:
the earliest are in yellow;
the most recent in red.

Gilbert M. et al., Nature Comm., 2014

Control of the H7N9 epidemic

- Local density of live-poultry markets is the most important predictor of H7N9 infection risk in markets, underscoring their key role in the spatial epidemiology of H7N9.
- Identification of areas in Asia with high suitability for H7N9 infection enhances capacity to target bio-surveillance and control, helping to restrict the spread of this important disease.

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Insurance for fire control

The Great Fire of London of 1666 raged for four days until it was finally extinguished, largely due to a change in wind direction. By then it had destroyed 373 acres of the city, including more than 13,000 houses and 84 churches as well as St Paul's Cathedral and much of London Bridge.

As a result, fire insurance brigades were developed as a way to deal with future fires. People paid a fee to an insurance company to insure their property against damage. The most common risk at this time was fire.

Insurance companies established their own fire brigades. These brigades were sent to insured properties if a fire occurred to minimize damage and cost.

Weak veterinary Capacity

↓

little or no surveillance in animals

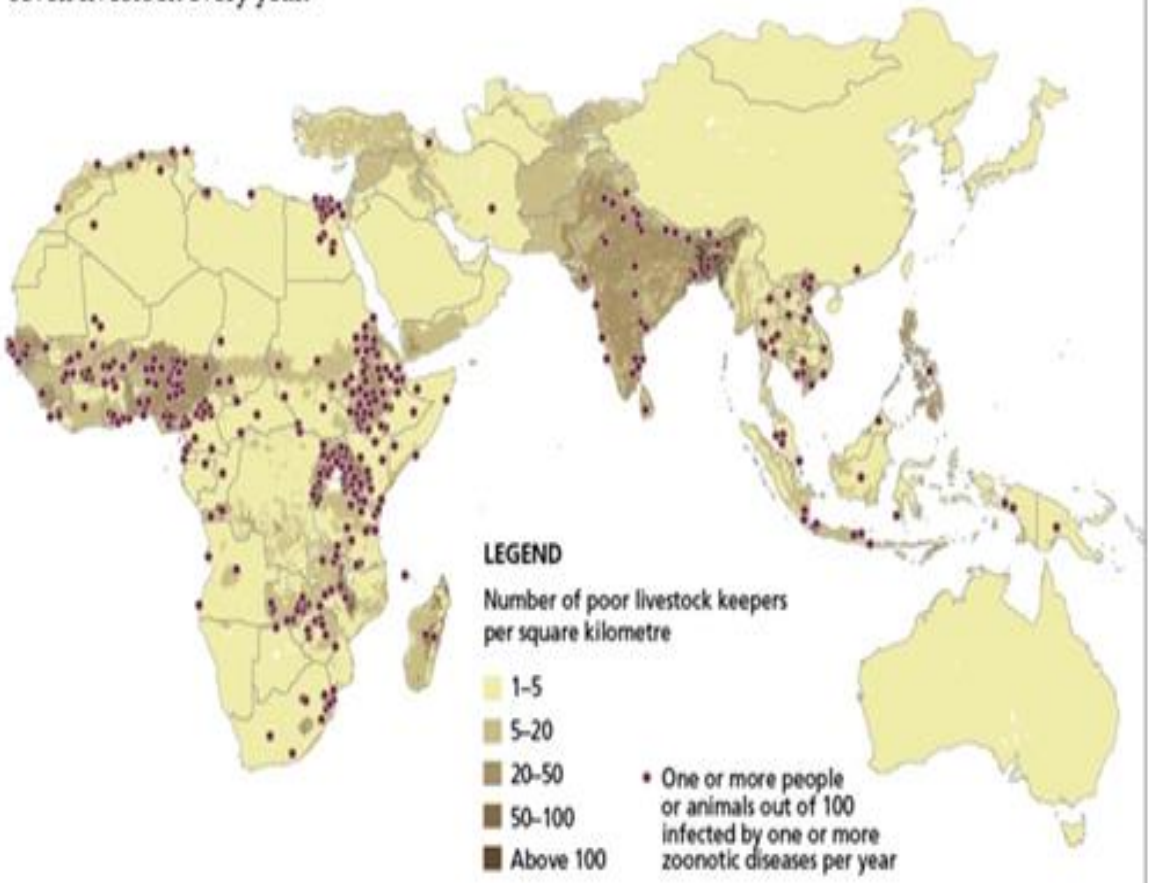
↓

no disease control at the animal source

Figure 4. The impact of animal-borne diseases

Greatest Burden of Zoonoses Falls on One Billion Poor Livestock Keepers

An ILRI study shows that zoonotic diseases are major obstacles in pathways out of poverty for one billion poor livestock keepers. The diseases mapped cause 2.3 billion human illnesses and 1.7 million human deaths a year. In poor countries, the diseases also infect more than one in seven livestock every year.



Map by ILRI, from original published in an ILRI report to DFID: *Mapping of Poverty and Likely Zoonoses Hotspots*, 2012.

Mitigating the risk of extreme pandemics

A primary source of pandemic disease is the weakness of veterinary and human public health systems in developing countries. Strengthening these would substantially mitigate the pandemic risk.

According to World Bank estimates, this would require an annual investment of about $3.4 billion. This is less than 0.1% of the global GDP loss from a pandemic of 1918 scale.

Life insurers might contribute towards global pandemic risk mitigation a sum commensurate with the reduction in capital needed to meet a pandemic catastrophe.

Global Health Threat

Can the life Insurance Industry move towards managing pandemic risk as one global industry?

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