Module 6:
Introduction to Stochastic Epidemic Models with Inference
(Virtually again)

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Stockholm University

QUOTE FROM ME IN JUNE 2020 (PARAPHRASED)

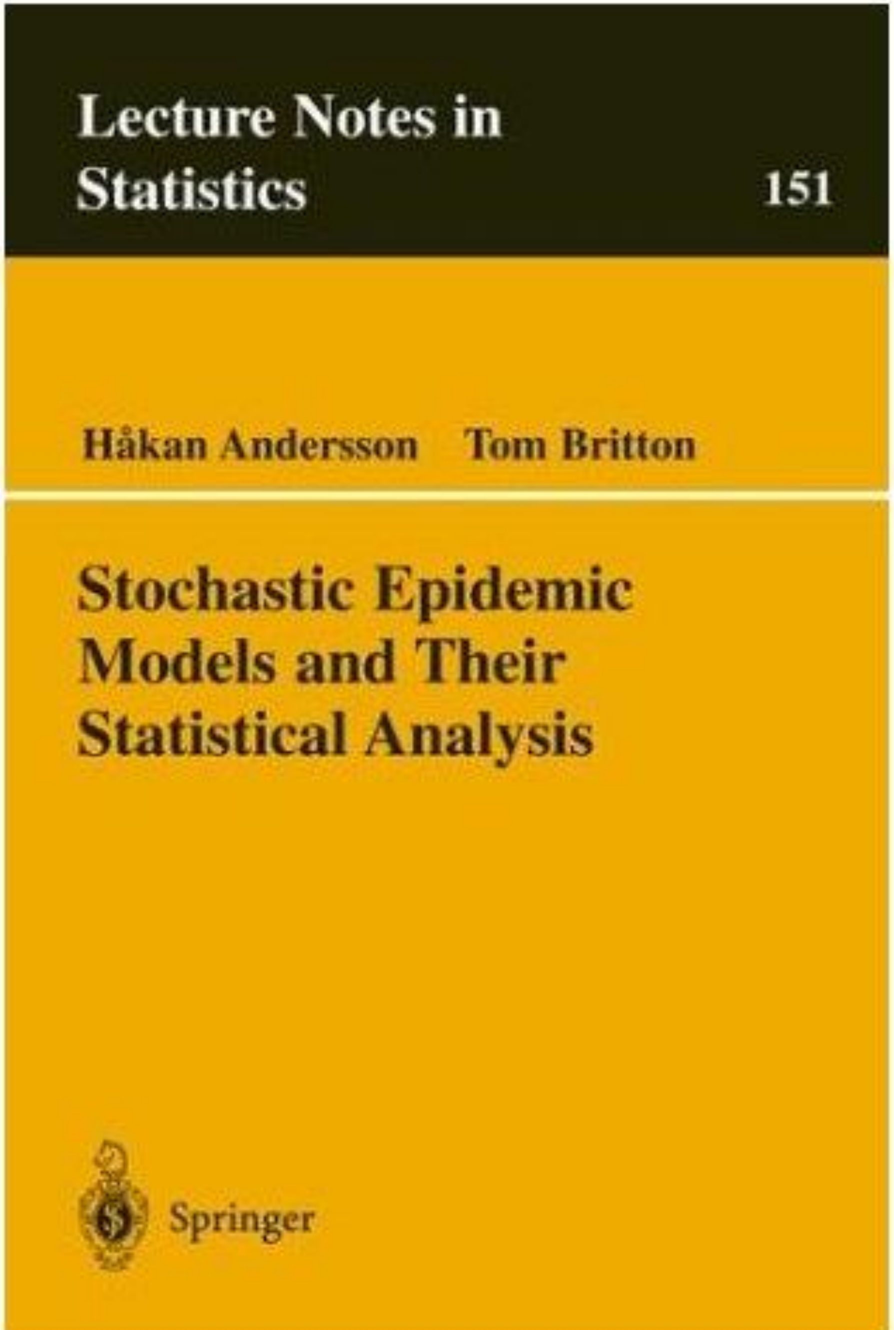
"We will have COVID vaccines for sure in early 2021, and we should have SISMID in person next year," i.e., July 2021

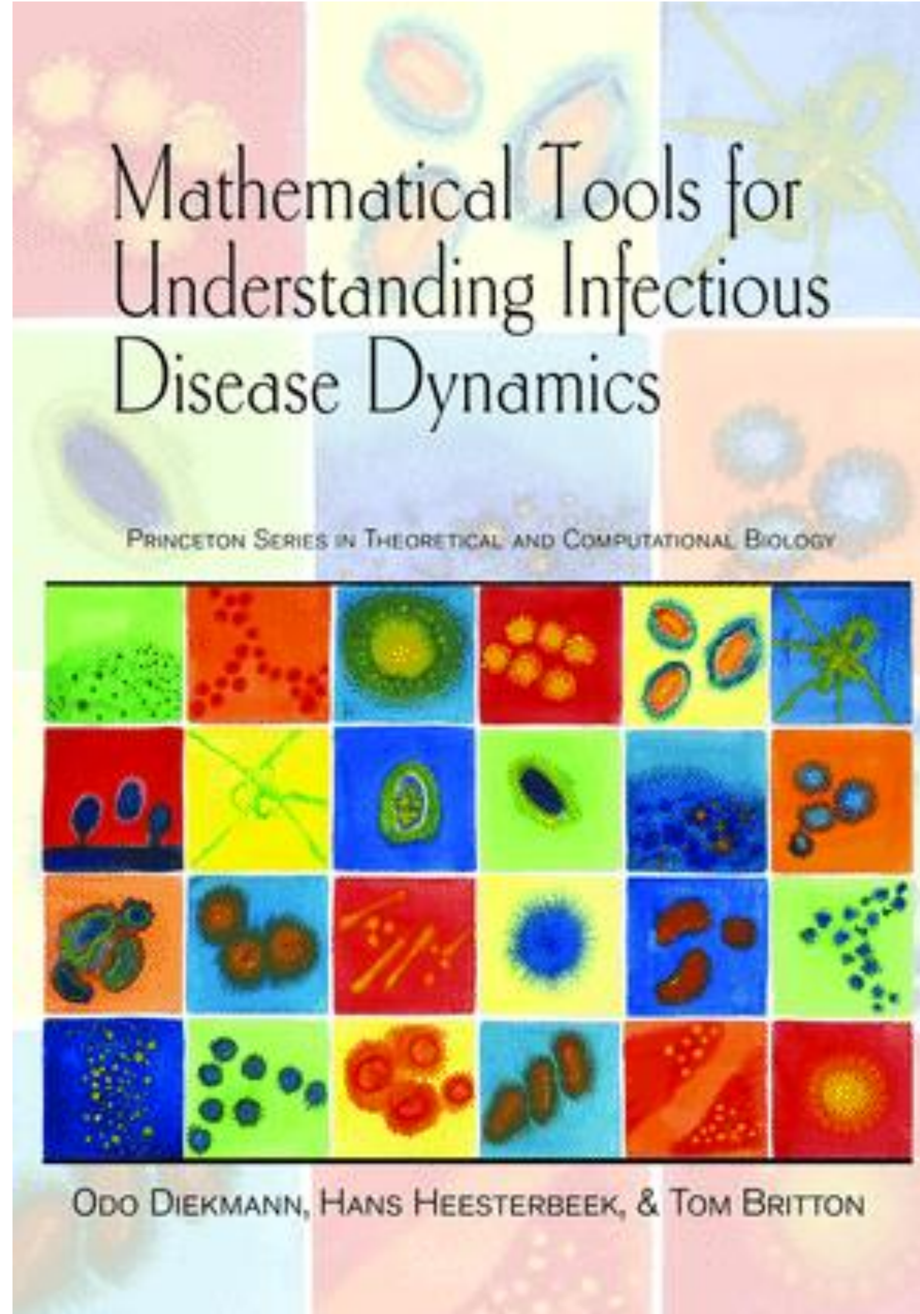
Well, at least the first part is true!

Philosophy of this course (i.e., Reductionist statements)

- Analytic work on the transmission and control of infectious diseases depends on an understanding of epidemic theory
- A technical understanding of the underlying non-linear, stochastic dynamics of infectious disease transmission is the basis for this understanding
  - This almost always involves non-linear functions for the interaction of ***x*** susceptible and ***y*** infected people at time *t*.
- This technical understanding leads to sound inferential structures for estimation of governing parameters and functions

Some Books of Interest for This Course





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Statistics for Biology and Health

M. Elizabeth Halloran • Ira M. Longini, Jr. • Claudio J. Struchiner

Design and Analysis of Vaccine Studies

Widespread immunization has many different kinds of effects in individuals and populations, including in the unvaccinated individuals. The challenge is in understanding and estimating all of these effects. This book presents a unified conceptual framework of the different effects of vaccination at the individual and at the population level. The book covers many different vaccine effects, including vaccine efficacy for susceptibility, for disease, for post-infection outcomes, and for infectiousness. The book includes methods for evaluating indirect, total and overall effects of vaccination programs in populations. Topics include household studies, evaluating correlates of immune protection, and applications of casual inference. Material on concepts of infectious disease epidemiology, transmission models, casual inference, and vaccines provides background for the reader. This is the first book to present vaccine evaluation in this comprehensive conceptual framework.

This book is intended for colleagues and students in statistics, biostatistics, epidemiology, and infectious diseases. Most essential concepts are described in simple language accessible to epidemiologists, followed by technical material accessible to statisticians.

Elizabeth Halloran and Ira Longini are professors of biostatistics at the University of Washington and the Fred Hutchinson Cancer Research Center in Seattle. Claudio Struchiner is professor of epidemiology and biostatistics at the Brazilian School of Public Health of the Oswaldo Cruz Foundation in Rio de Janeiro. The authors are prominent researchers in the area. Halloran and Struchiner developed the study designs for dependent happenings to delineate indirect, total, and overall effects. Halloran has made contributions at the interface of epidemiological methods, causal inference, and transmission dynamics. Longini works in the area of stochastic processes applied to epidemiological infectious disease problems, specializing in the mathematical and statistical theory of epidemics. Struchiner has contributed to understanding the role of transmission in interpreting vaccine effects.

EPIDEMIOLOGY

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› springer.com

Halloran • Longini
Struchiner

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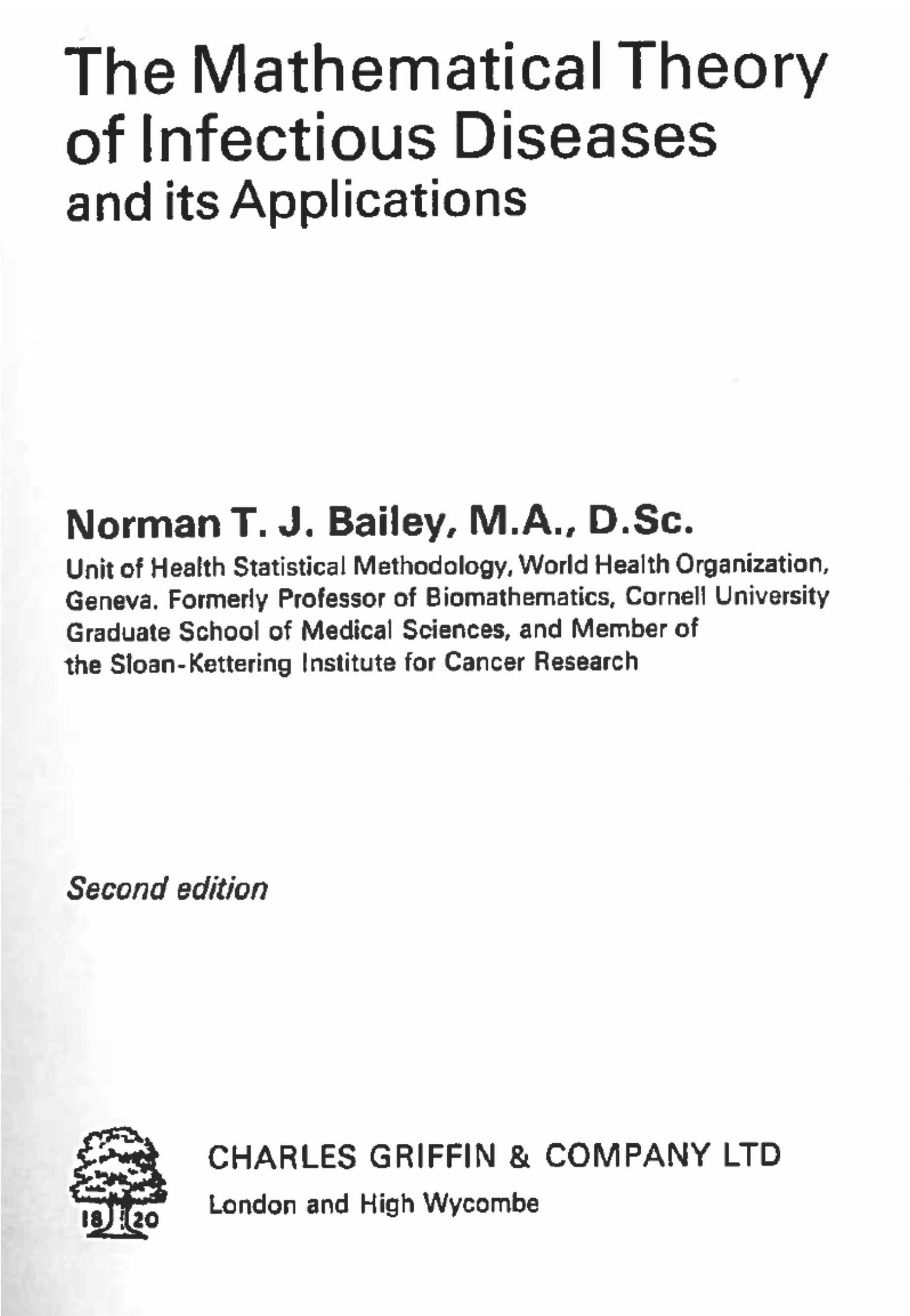
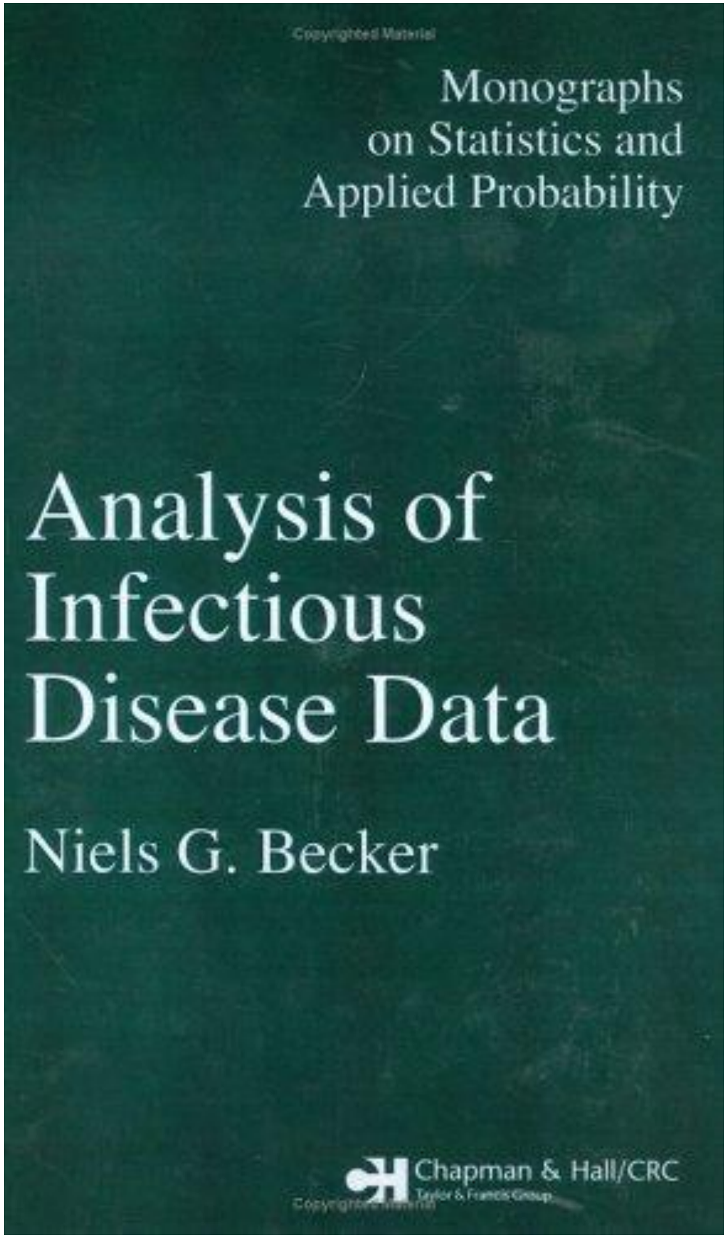

The Mathematical Theory of Infectious Diseases and its Applications

Norman T. J. Bailey, M.A., D.Sc.
Unit of Health Statistical Methodology, World Health Organization, Geneva. Formerly Professor of Biomathematics, Cornell University Graduate School of Medical Sciences, and Member of the Sloan-Kettering Institute for Cancer Research

Second edition

CHARLES GRIFFIN & COMPANY LTD
London and High Wycombe



1975, 1st addition 1957

Inference on infectious diseases modules in addition to this one

- **Module 5**: Spatial Statistics in Epidemiology and Public Health, July 12 – 14
- **Module 7**: Simulation-based Inference for Epidemiological Dynamics, July 12 – 14
- **Module 8**: MCMC I for Infectious Diseases, July 14 – 16
- **Module 11**: MCMC II for Infectious Diseases, July 19 – 21
- **Module 12**: Statistics and Modeling with Novel Data Streams, July 19 – 21

Lectures

Monday, July 12:

1. Introduction to stochastic epidemic models; notation, properties, examples, IL, TB
2. Important properties of epidemics and endemic situations, TB
3. Inference on stochastic epidemic models, TB
4. Modeling using networks and other heterogeneities, Computer simulations, TB, DZ

Tuesday, July 13:

5. Different models for vaccine mechanisms, IL
6. Stochastic models for small groups such as households, IL

Lectures

Tuesday, July 13

7. Continuation, Heterogeneities, inference from big outbreaks, TB
8. COVID-19 analysis, TB, DZ

Wednesday, July 14

9. Study designs for evaluating vaccine efficacy, IL
10. Design and analysis of randomized vaccine trials for emerging infectious disease epidemics: The case of Ebola and COVID-19, IL

Schedule for Zoom lectures

Date	Time (PDT)	Topic	Instructor
Monday, July 12	8:30 – 8:45	Introduction	IL, TB
	9:00 – 9:45	Lecture 1 + exercises	TB
	10:00 – 10:45	Lecture 2 + exercises	TB
	11:00 – 11:45	Lecture 3 + exercises	TB
	12:00 – 12:45	Lecture 4 + exercises + computer simulations	TB, DZ
Tuesday, July 13	9:00 – 9:45	Lecture 5	IL
	10:00 – 10:45	Lecture 6	IL
	11:00 – 11:45	Lecture 7	TB
	12:00 – 12:45	Lecture 8 + exercises +computer inference	TB, DZ
Wednesday, July 14	9:00 – 9:45	Lecture 9	IL
	10:00 – 10:45	Lecture 10	IL

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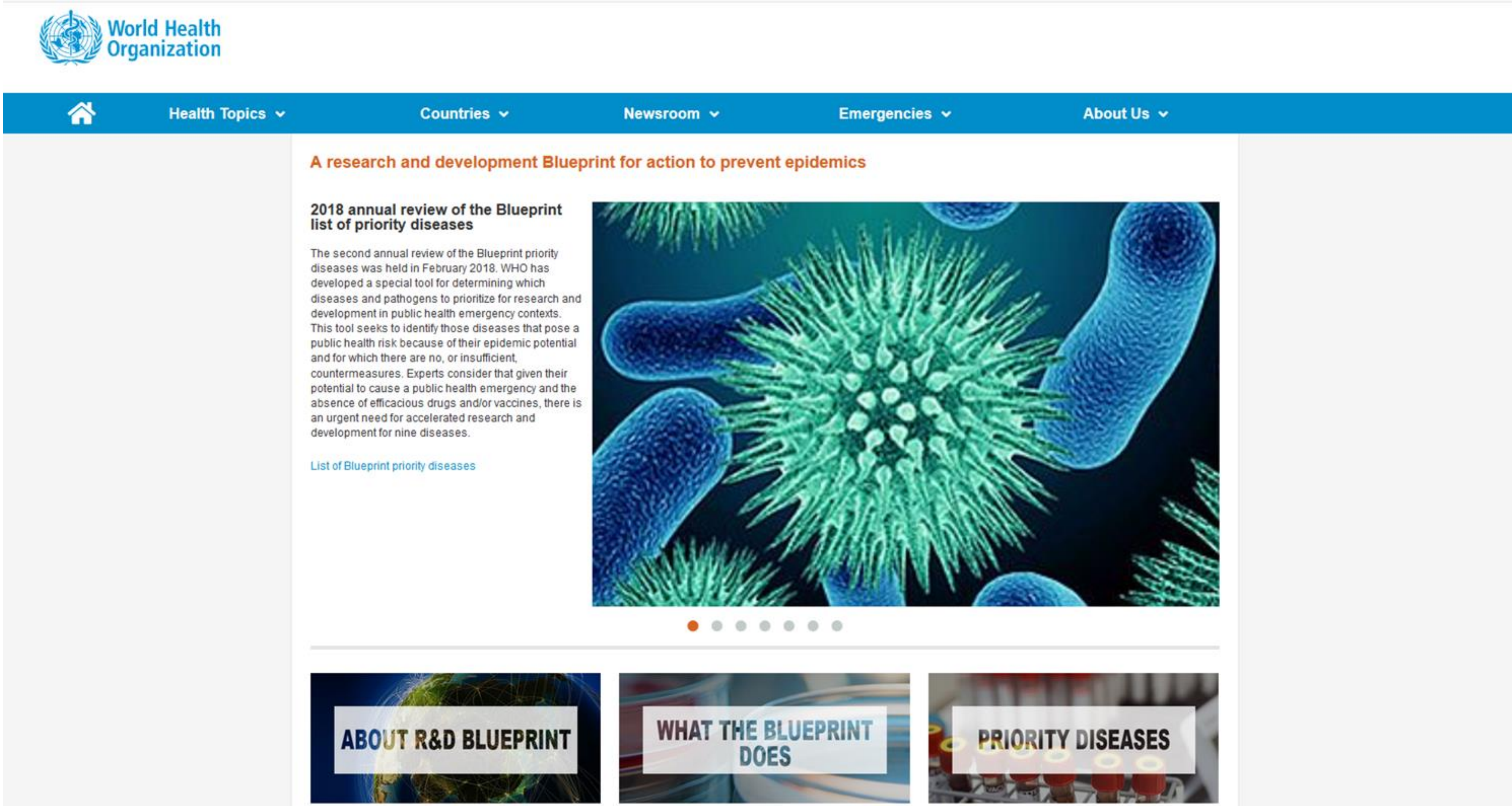
Some Infectious Diseases Under Study

- Influenza
- Novel Coronavirus: COVID-19, SARS-CoV, MERS-CoV
- Ebola and other filoviruses
- Cholera, Typhoid, Rotavirus
- Dengue, Zika, Chikungunya
- Lassa, Nipah, plague
- HIV
- Others, polio, pertussis, hand-foot-and-mouth (EV71)
- Agent X

WHO Blueprint to prevent epidemics



https://www.who.int/blueprint/en/

WHO Blueprint priority diseases

- Crimean-Congo haemorrhagic fever (CCHF)
- Ebola virus disease and Marburg virus disease
- Lassa fever
- Middle East respiratory syndrome coronavirus (MERS-CoV) and Severe Acute Respiratory Syndrome (SARS)
- Nipah and henipaviral diseases
- Rift Valley fever (RVF)
- Zika
- Disease X

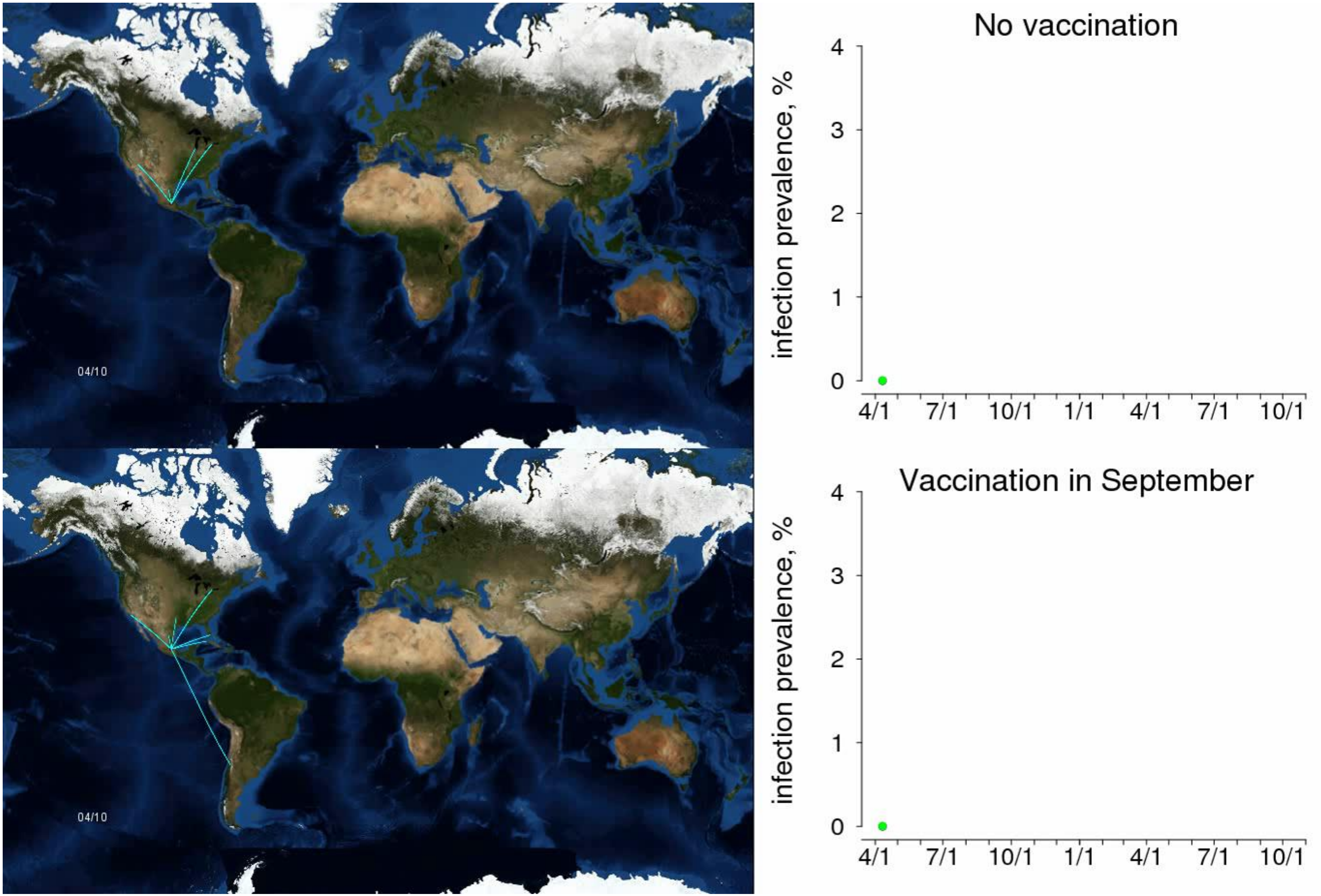
https://www.who.int/blueprint/priority-diseases/en/

Some Examples

Pandemic H1N1, 2009-2010

Stochastic, Compartmental, Patch

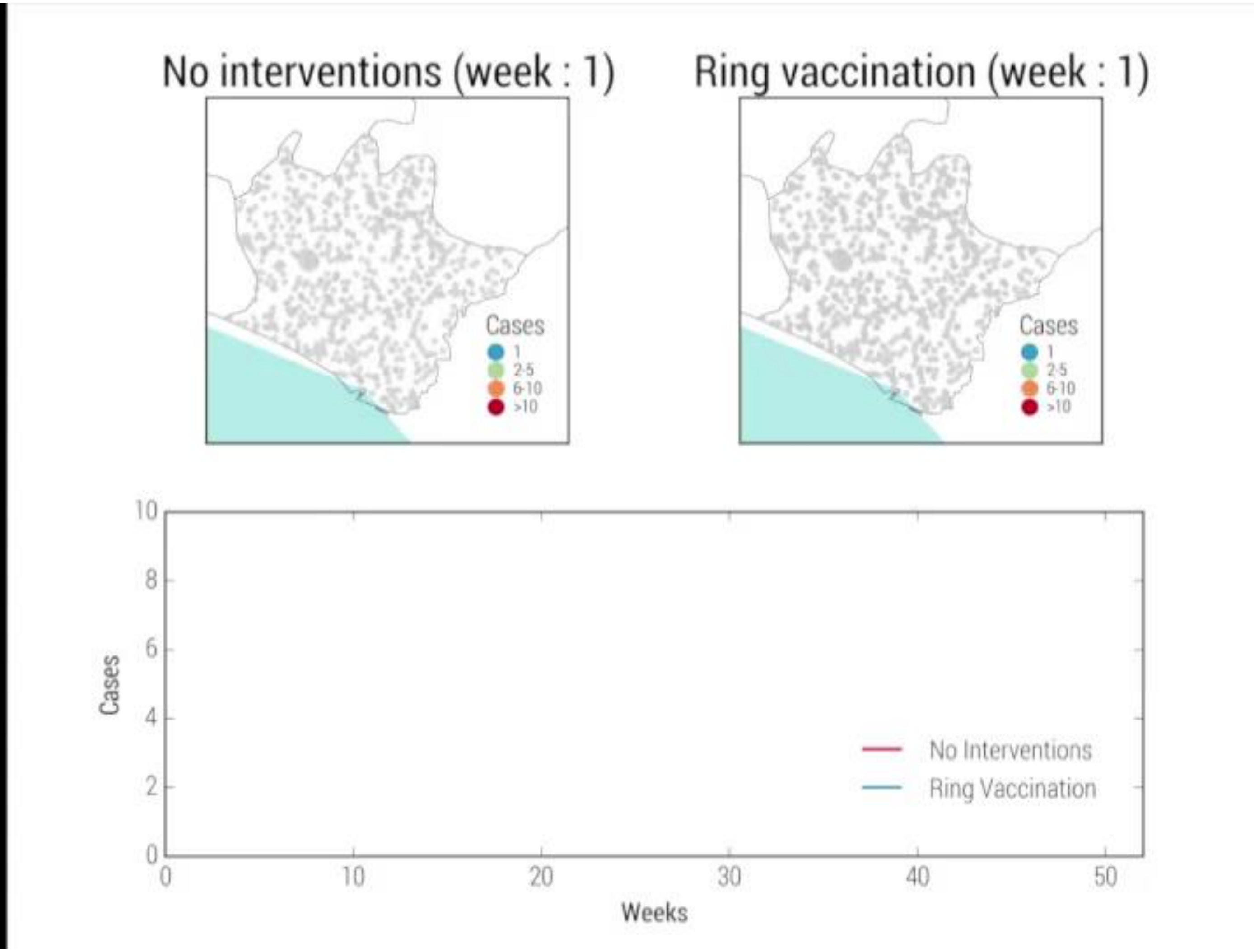
Pandemic H1N1 With Vaccination



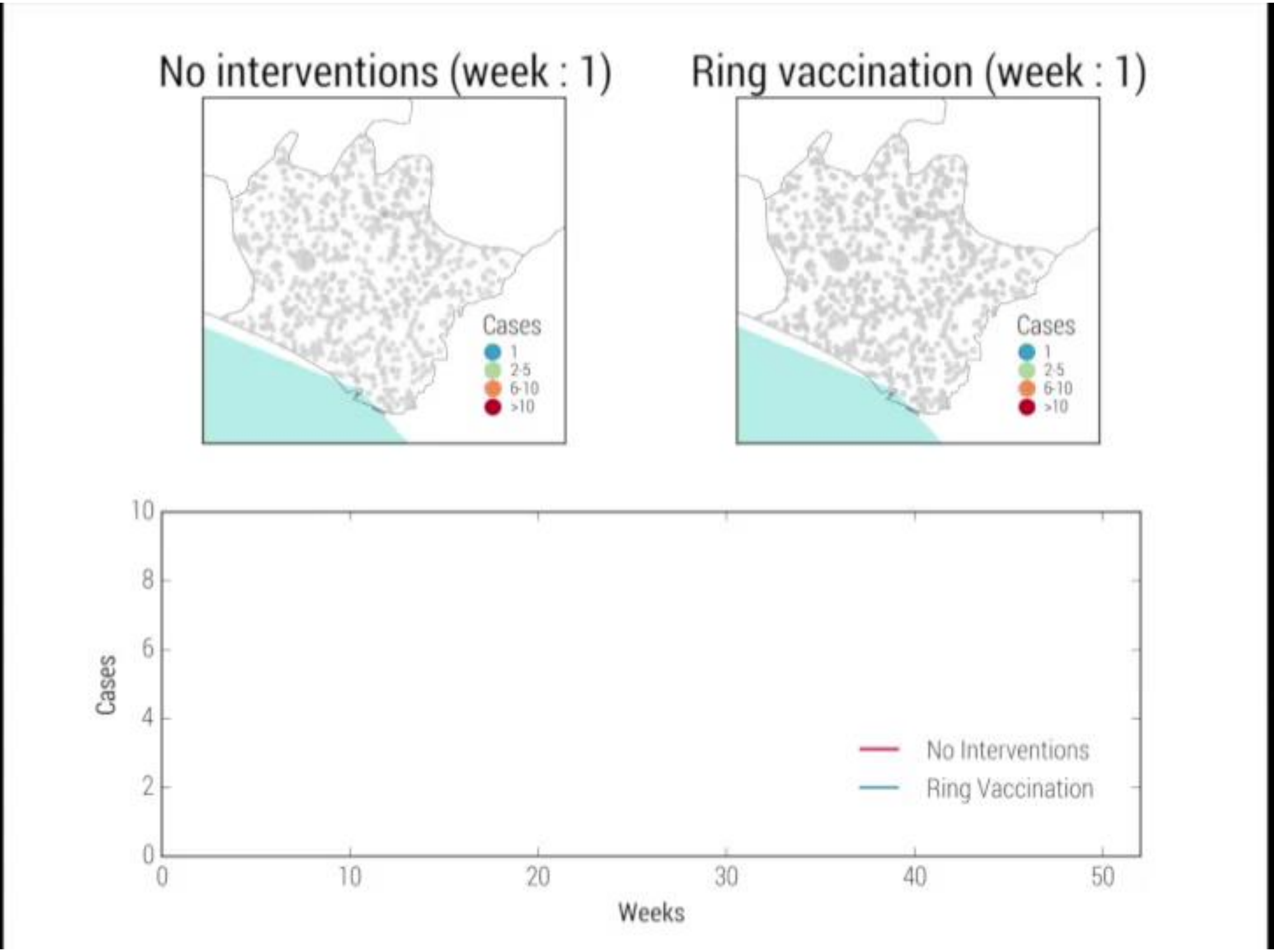
Ebola vaccine trials

- Phase III Ebola ring vaccination efficacy trial in Guinea – VSV vaccine estimated to have 100% efficacy.
- Stochastic transmission models have been used to help estimate vaccine efficacy and effectiveness
- Ring vaccination is used to eliminate Ebola in human populations, e.g., smallpox eradication

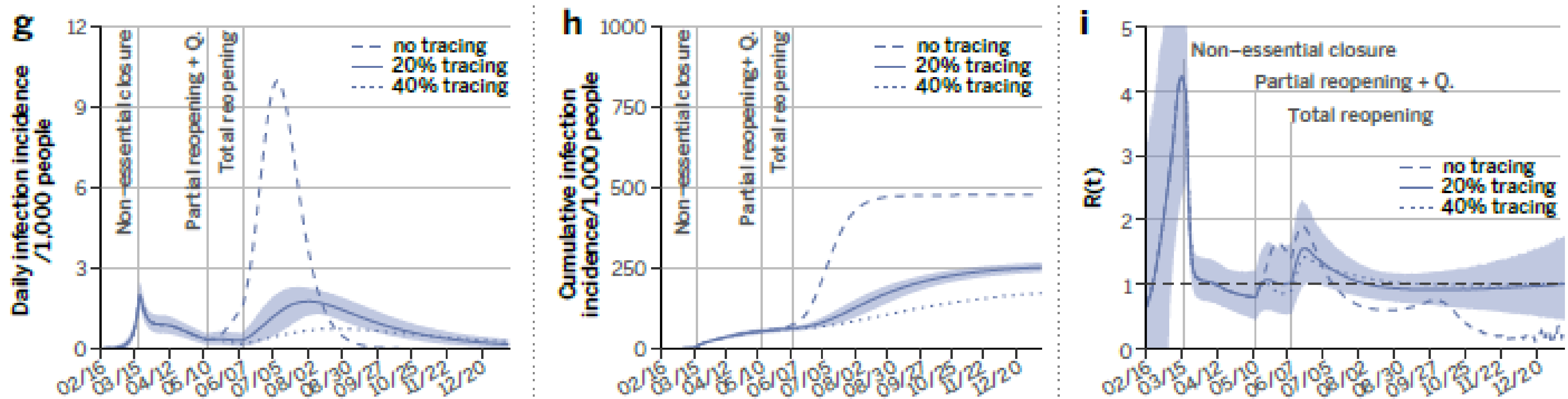
Ring vaccination contained



Ring vaccination not contained



COVID-19: What could have happen in the Fall of 2020?



- Staged reopening without testing with contact tracing results in a large second wave
- With 50% symptomatic cases tested , and 20% or more or more of the contacts of the detected symptomatic individuals are traced and put into quarantine, the epidemic is controlled

Source: Aleta, et al. Modeling the impact of social distancing, testing, contact tracing and household quarantine on second-wave scenarios of the COVID-19 epidemic. Nature Human Behavior. 4, 964–971 (2020). https://doi.org/10.1038/s41562-020-0931-9.

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Thanks

On with the course!