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CEMI 20

20ème Colloque sur le
Contrôle Epidémiologique des Maladies Infectieuses
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Mathematical modelling and the eradication of infectious diseases

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Mathematical modelling: what for?

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A tool to synthesize information and understand the interplay between the drivers of epidemics

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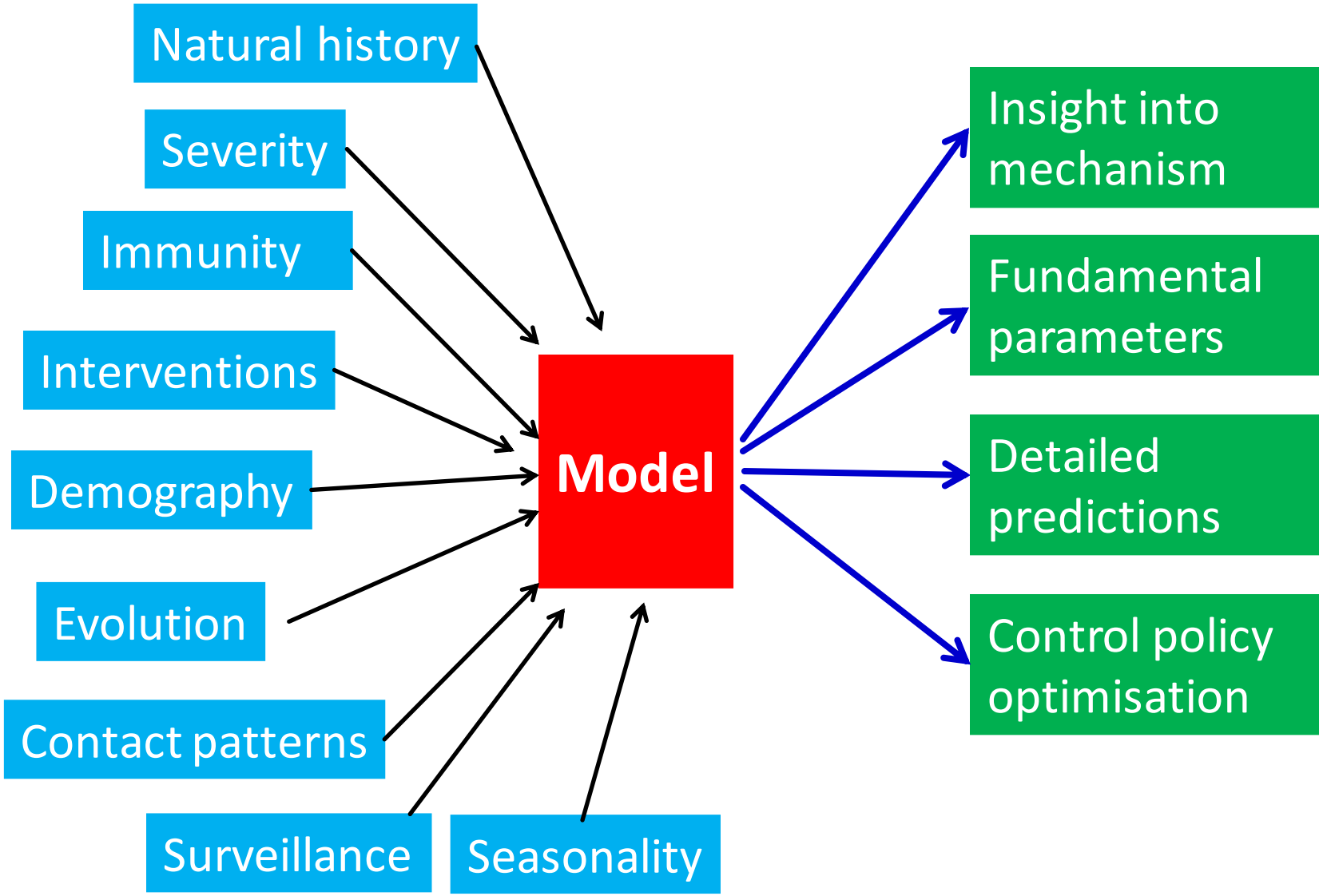

Overview

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- **Understanding mechanisms & synthesizing data.**
  - Studying the interplay between the drivers of malaria epidemics and implications for malaria elimination.

- **Interpreting surveillance data:**
  - Measuring the path towards malaria elimination.

Malaria elimination and eradication

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- 1955:
  - Global Malaria Eradication Program (GMEP) launched by WHO.

- 1969:
  - GMEP collapsed.
  - Target of imminent elimination replaced by indefinite control.
  - Malaria neglected for decades.

- More recently:
  - Bill and Melinda Gates called for malaria eradication in 2007.
  - Eradication reinstated as the long term goal by consensus decision of the Roll Back Malaria Partnership in 2008.
  - Elimination becomes target in many countries.

Any long term benefits for malaria elimination?

« There is no such thing as a partial success in species eradication: one either achieves glorious success or dismal failure. »

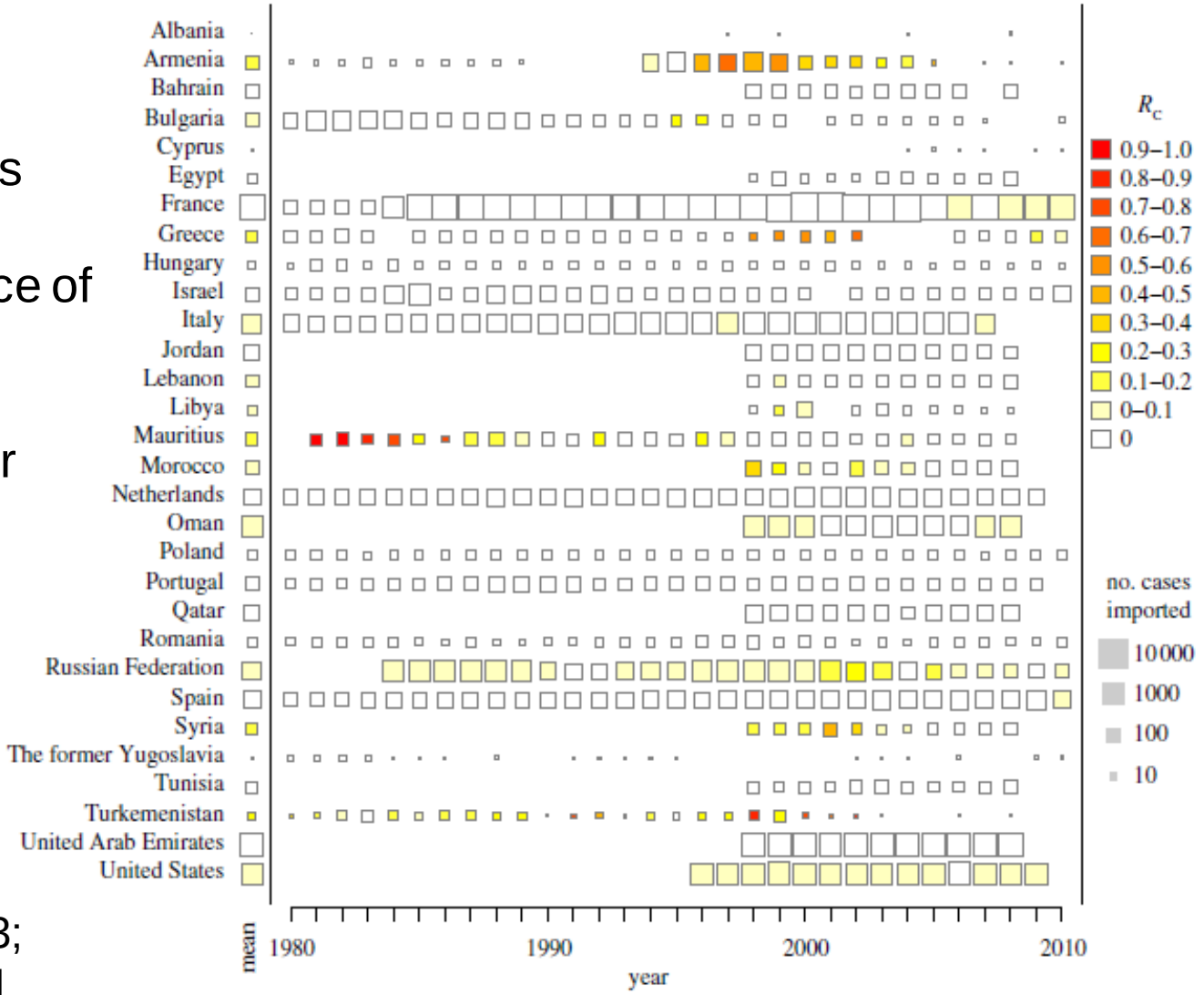
Soper

- Huge efforts required to reach elimination: vector control, treatment of cases, outbreak investigations…
- Not sustainable in the long term.
- Theory: If you stop the effort, you get back to the initial situation.
- What's the point?

[Smith et al, Phil Trans, 2013]

And yet…

- Out of 50 countries that eliminated malaria, resurgence of malaria in only 4 countries.
- Elimination stickier than expected.

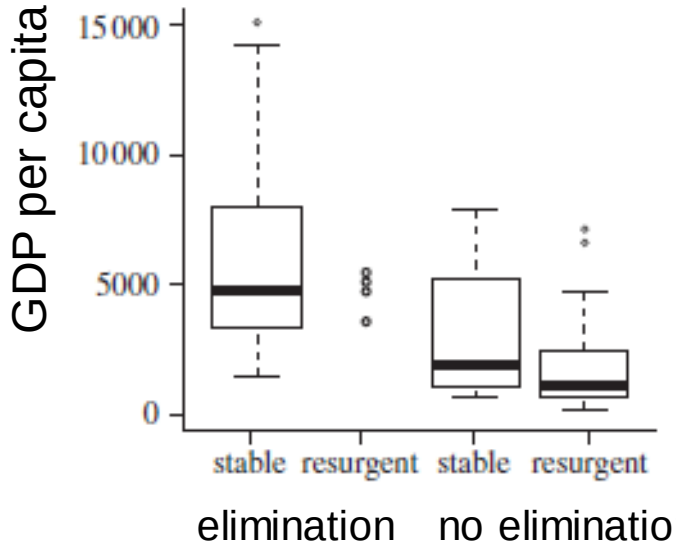


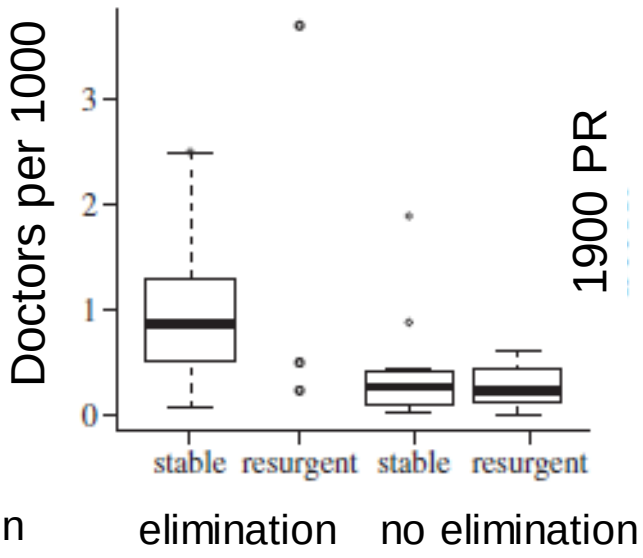
[Chiyaka, Science, 2013; Smith, Phil Trans, 2013]

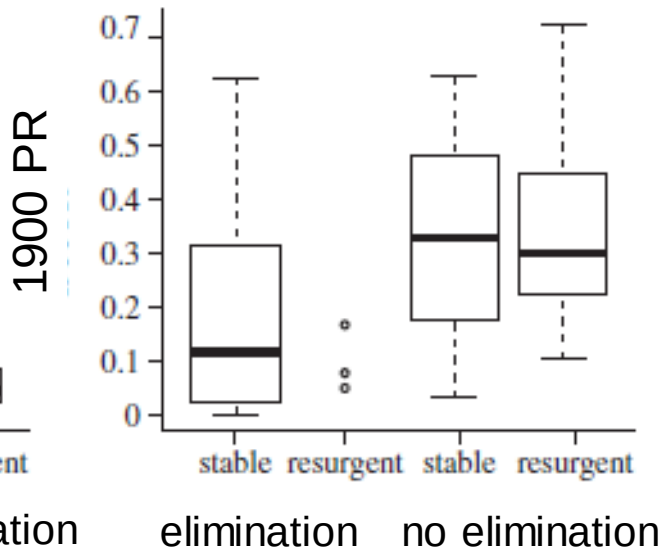
Why?

- **Hypothesis 1:** Is elimination stable because successful countries are different?
- **Hypothesis 2:** Is elimination stable because of changes that occur as a result of its achievements?
- **Hypothesis 3:** Is elimination stable because importation is not effective at rekindling transmission?

Hypothesis H1: Are successful countries different?







Hypothesis H2: Is elimination stable as a result of its achievements?

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Treatment, Transmission & Surveillance

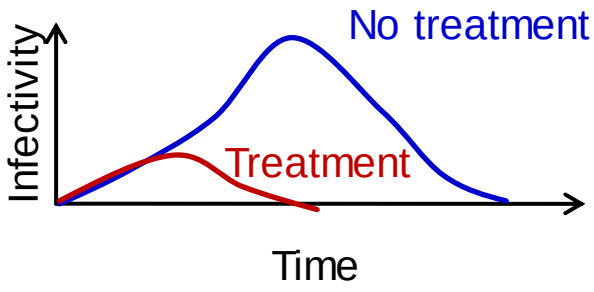
At a population level

Low % treated

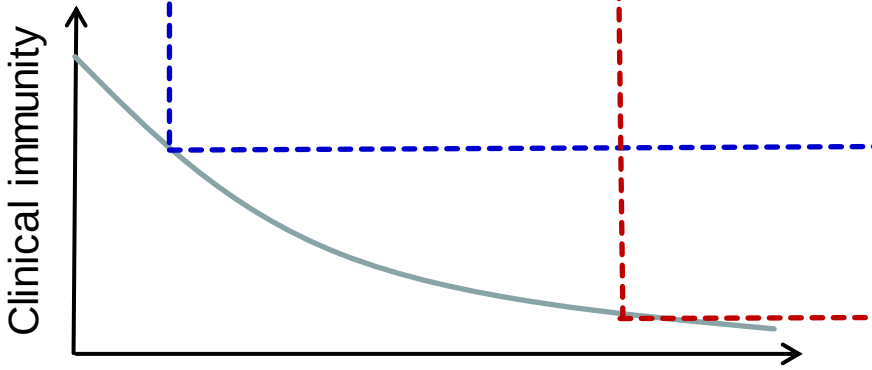
High % treated

More successful at maintaining elimination

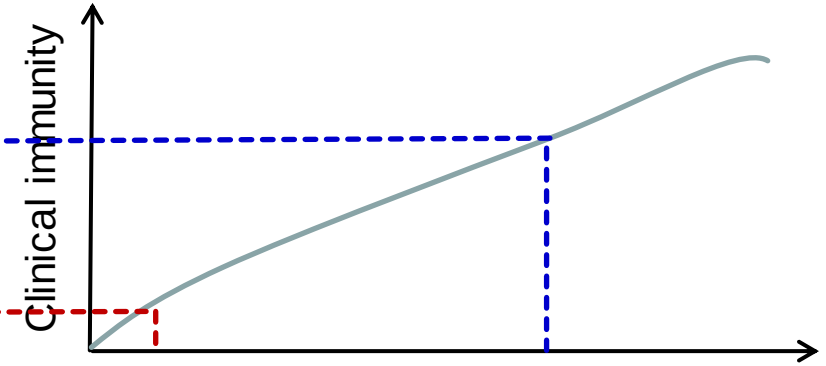
At an individual level



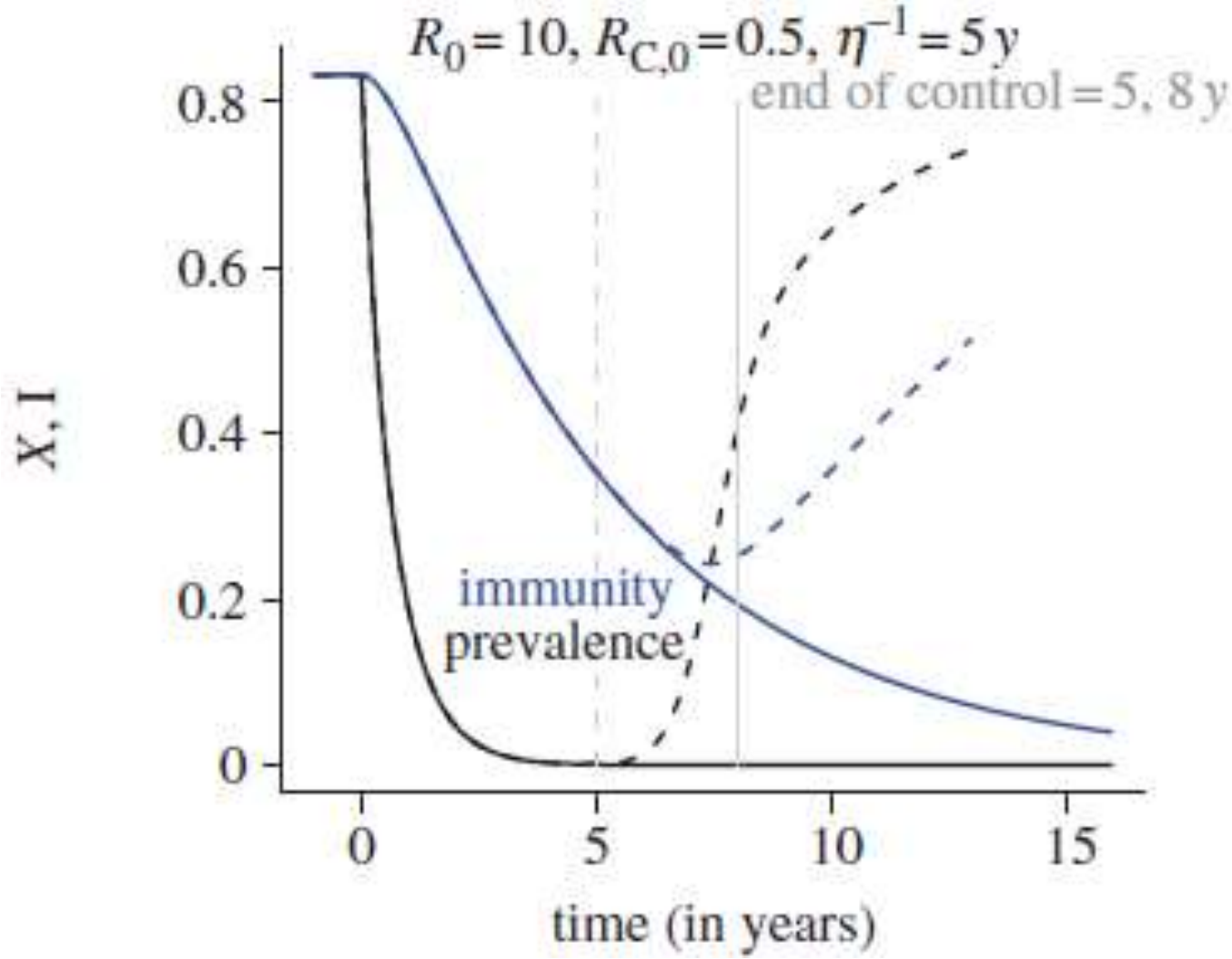
Surveillance and Immunity



Immunity and Prevalence



Potential long lasting effect of elimination…



… but depends on the country

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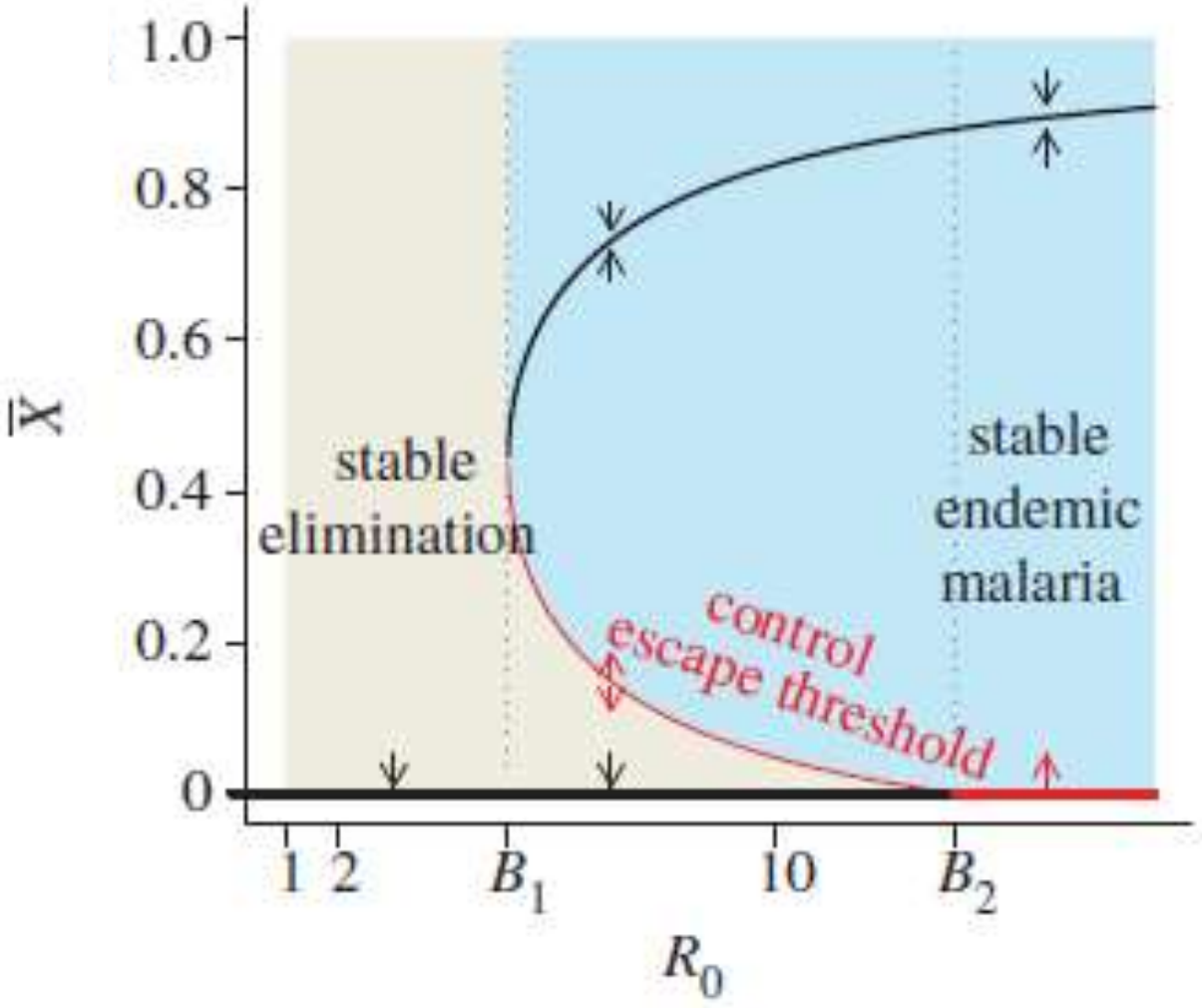

From general principles to quantitative assessments

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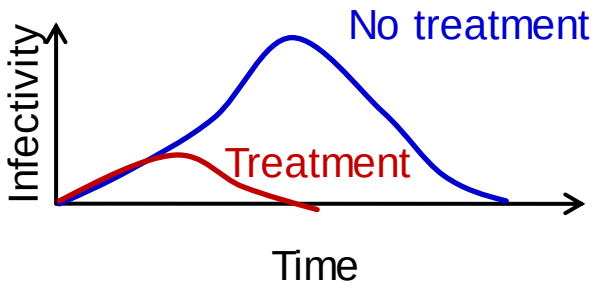
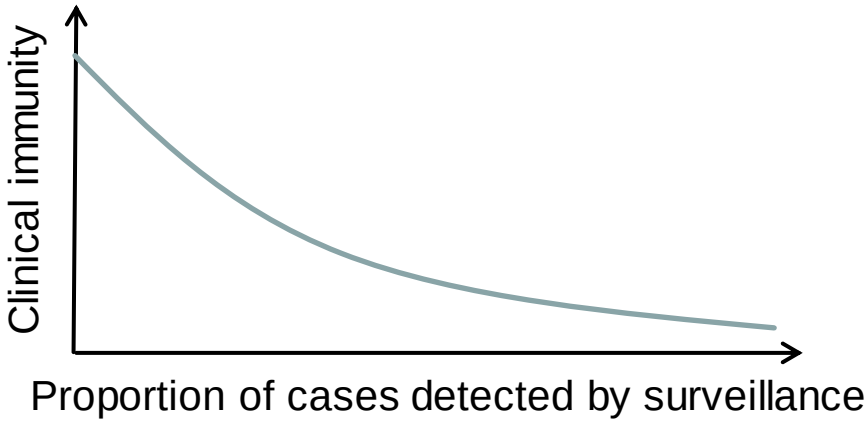
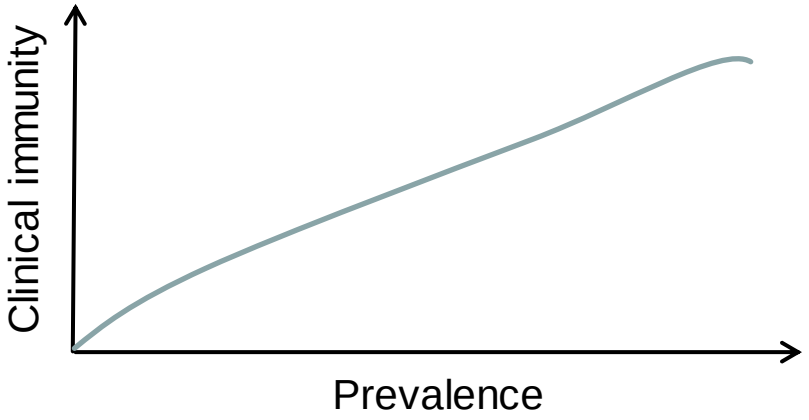
Treatment and Transmission



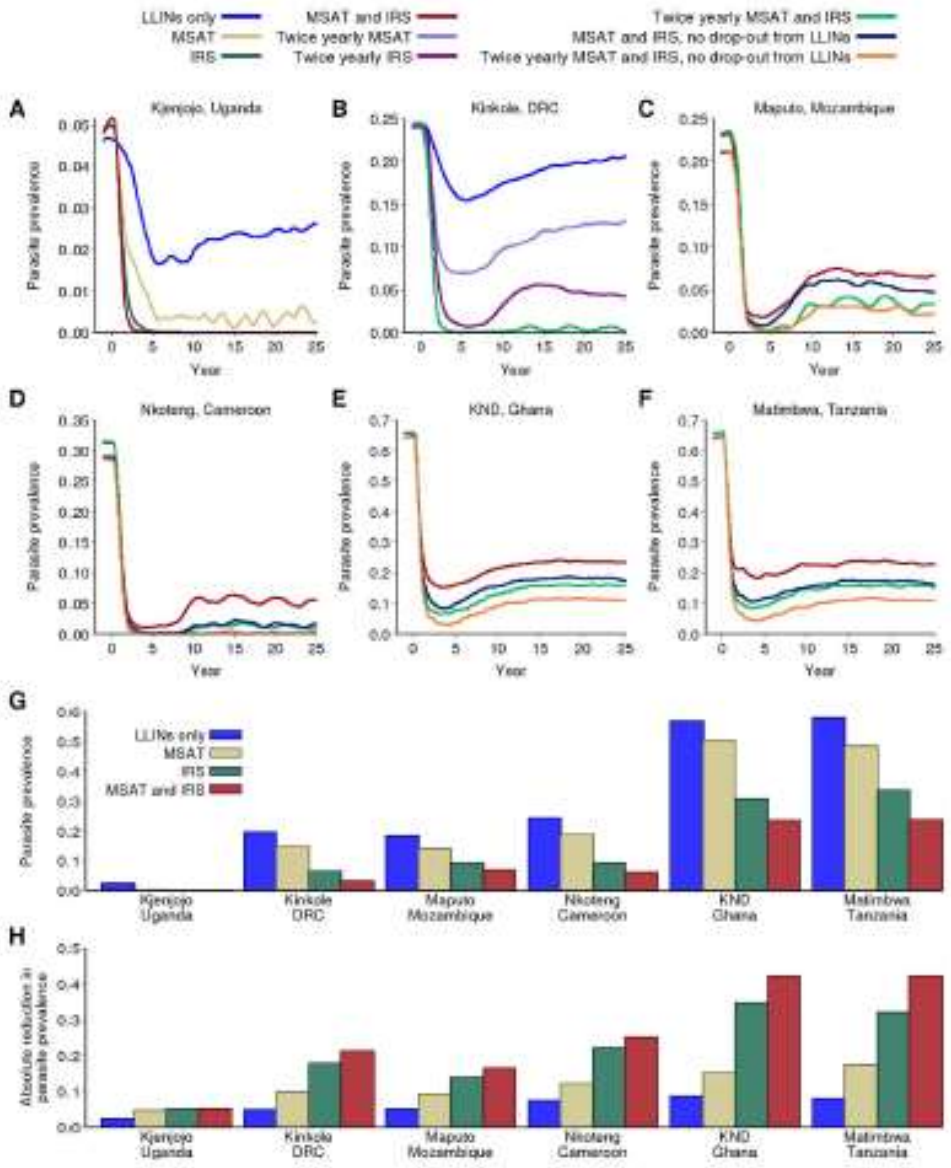
Surveillance and Immunity



Immunity and Prevalence

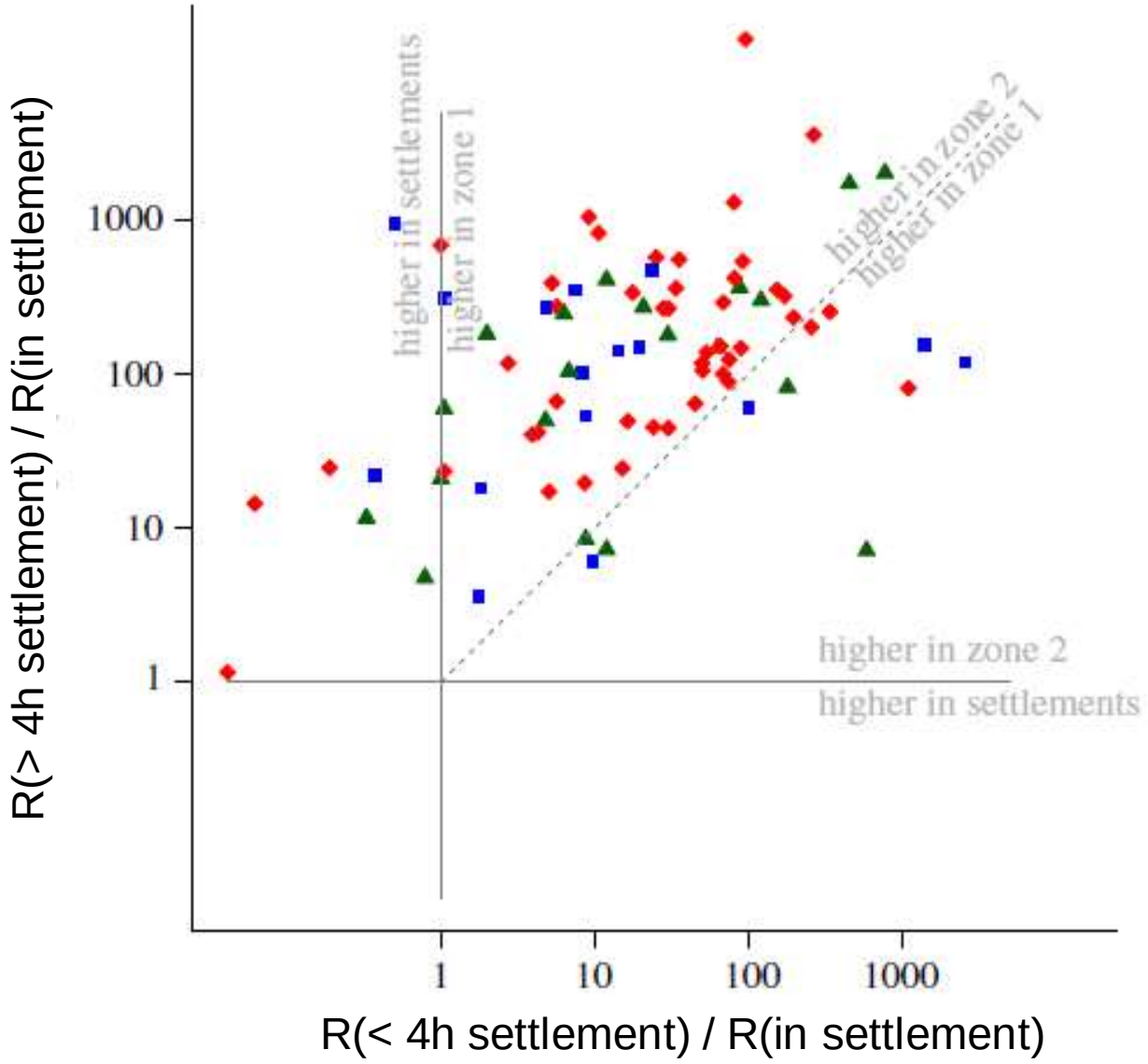


From general principles to quantitative assessments



[Griffin et al, PLoS Med, 2010]

Hypothesis H3: Are introductions effective at restarting transmission?



Measuring the path towards malaria elimination

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- Elimination:
  - Absence of locally acquired malaria cases.
  - A target that is increasingly being considered for programs.

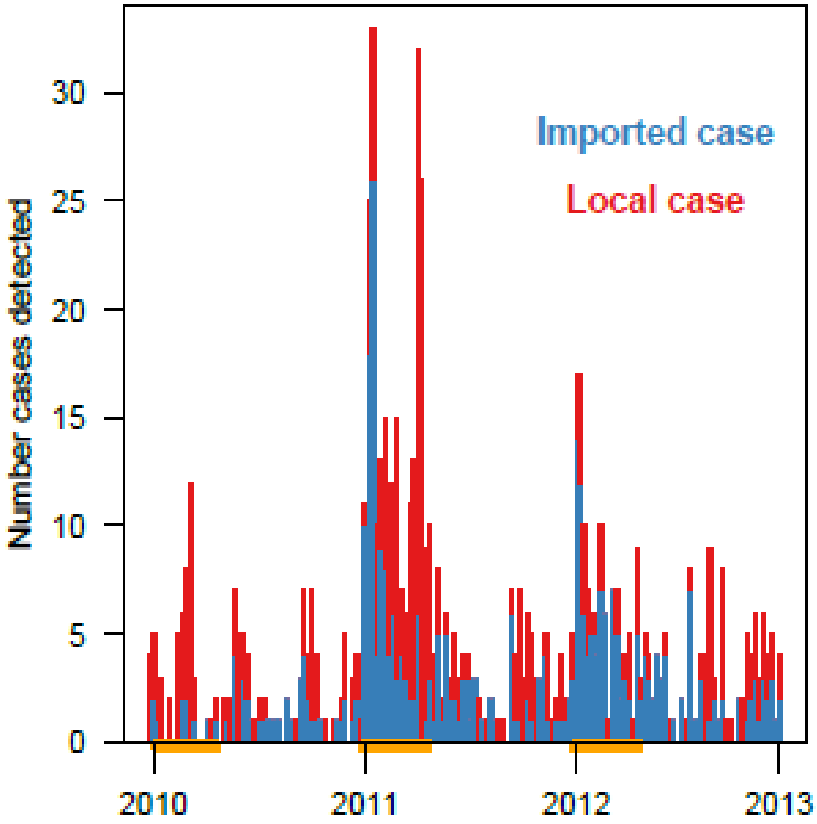
- Evaluation of programs:
  - Essential to ensure long-term financial and political support.
  - But how do we assess success / failure?
    - ✓ Counting number of locally acquired cases?
    - ✓ Countries that are successful at controlling local transmission but receive a lot of imported cases will see locally acquired cases.
    - ✓ Risk of failing successful programs.
    - ✓ Need for more nuanced measures of local transmission.

[Churcher et al, Science, 2014]

The case of Swaziland

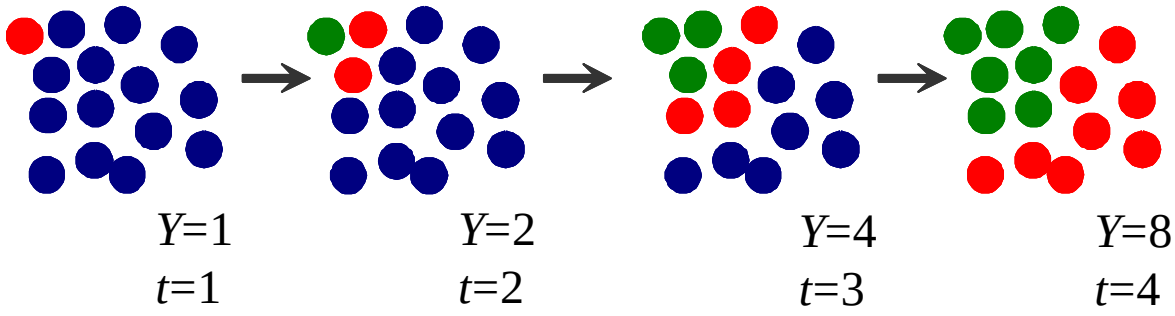
- Malaria noticeable disease.
- Good routine surveillance and outbreak investigations.
- Travel history ascertained.

	# **Local**	# **Imported**
2010	91	52
2011	207	170
2012	76	153



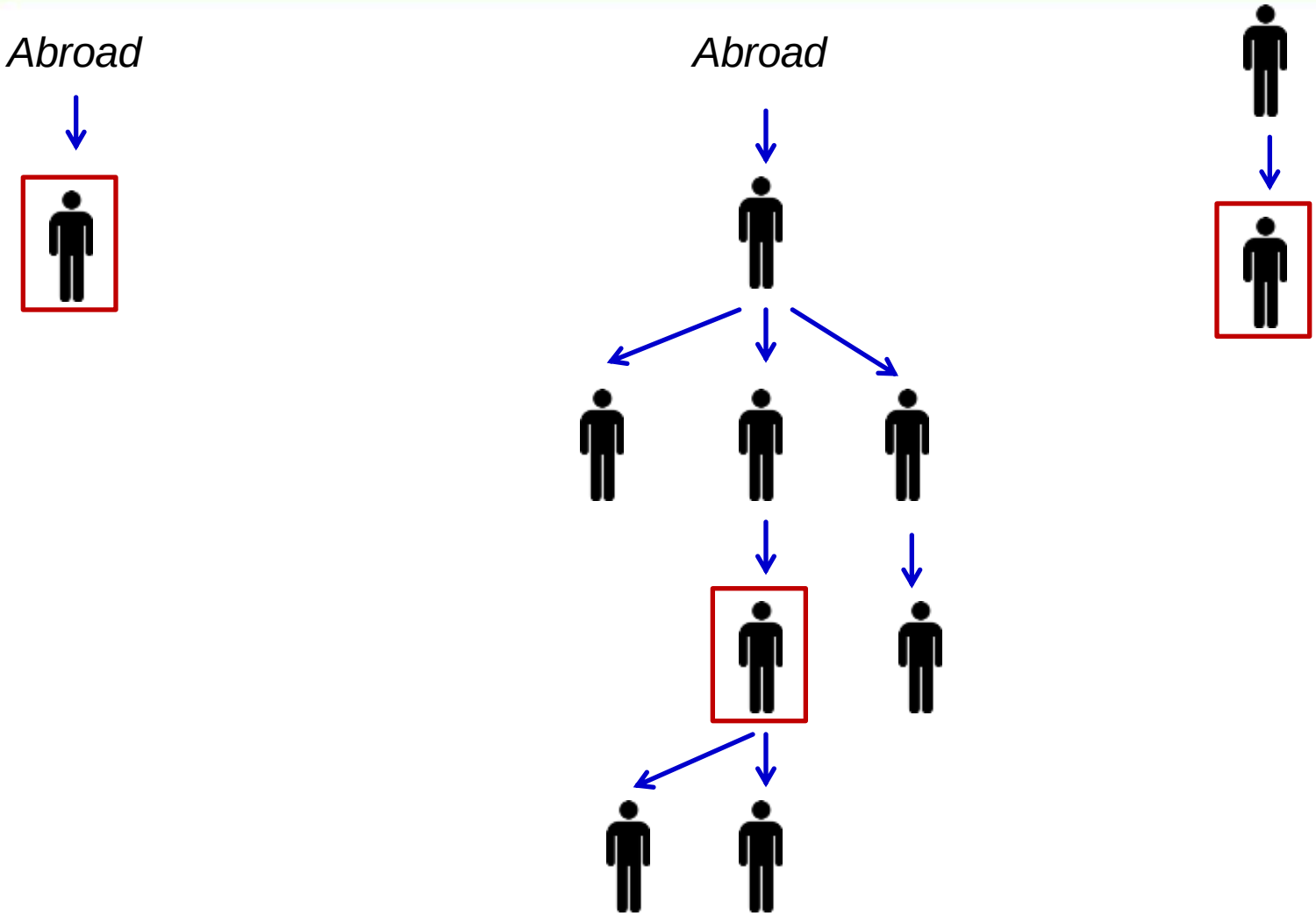
How to measure local transmission?

- Estimating the human-to-human reproduction number *R*:
  - Mean number of cases generated by a human case.

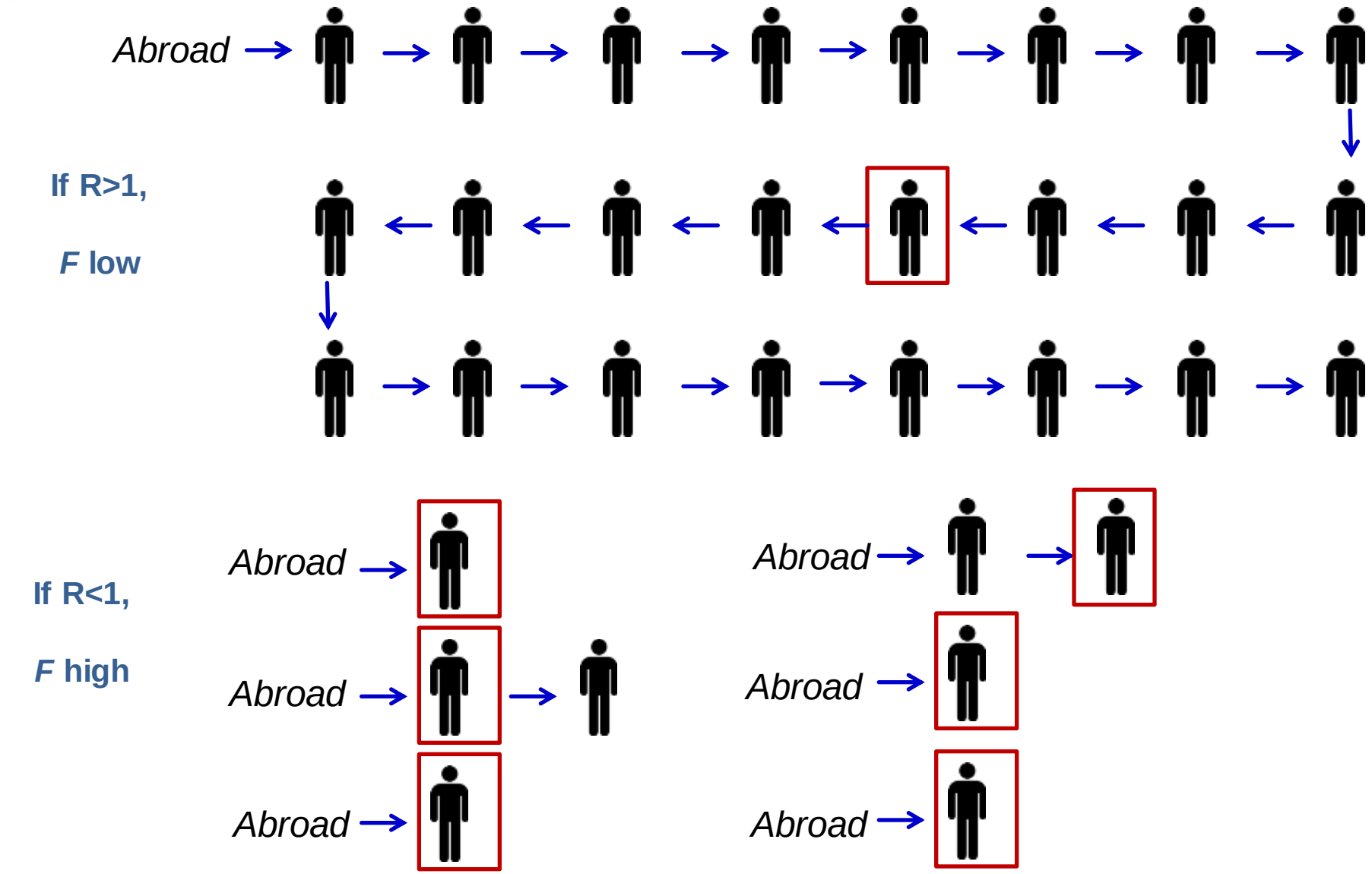


Large and sustained epidemics in humans possible only if *R*>1.

How to estimate *R*?



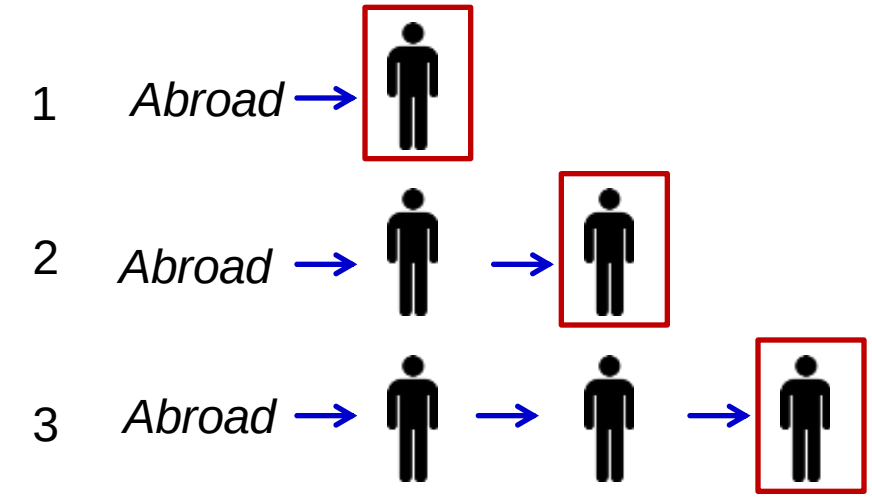
Probability *F* that case detected by surveillance was a traveler



Probability *F* that case detected by surveillance was a traveler

Length of the chain of transmission

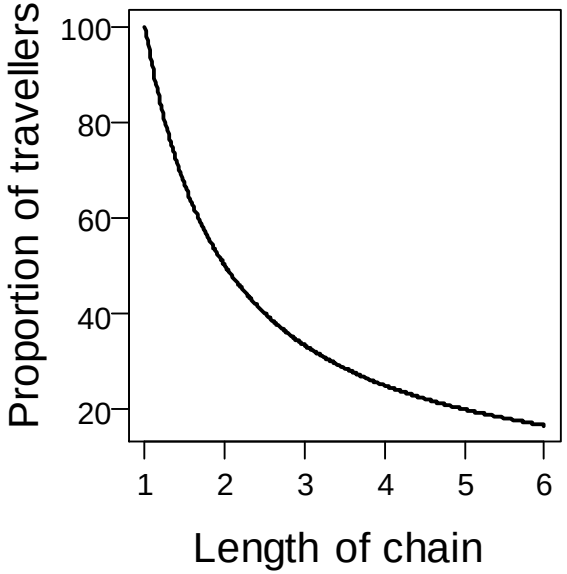
Proportion F of surveillance case who are travellers



1/1=100%

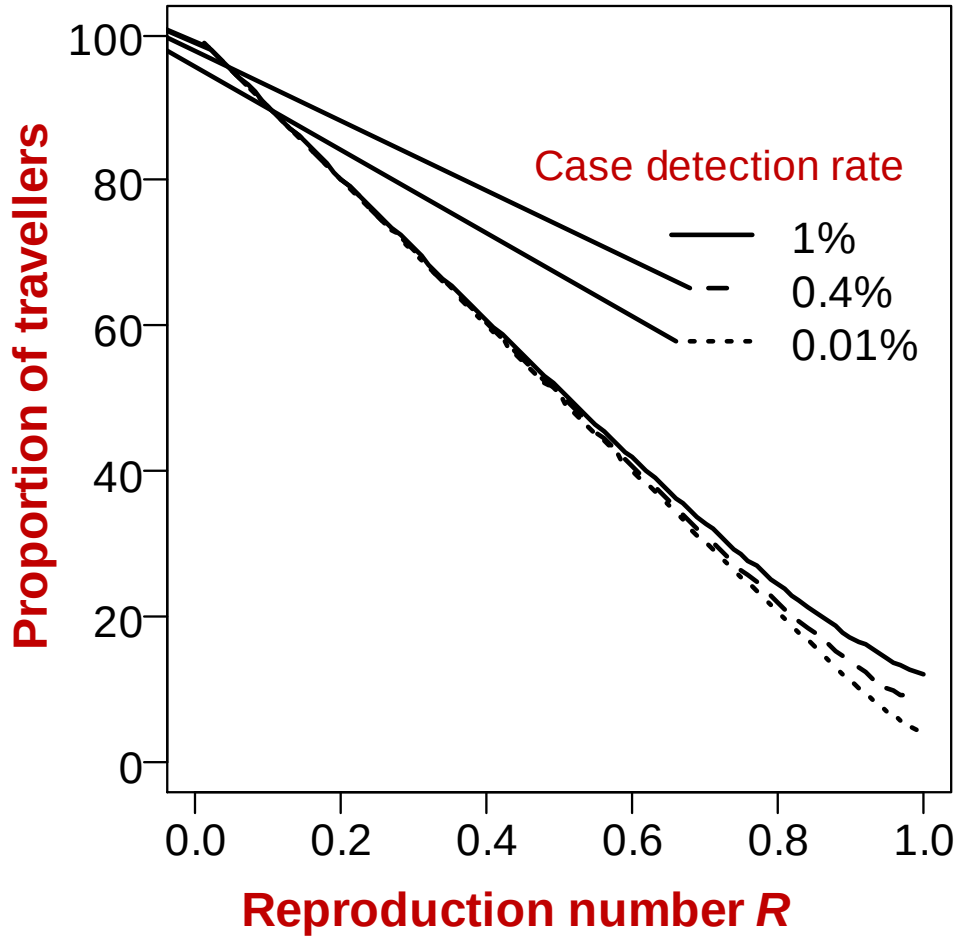
1/2=50%

1/3=33%

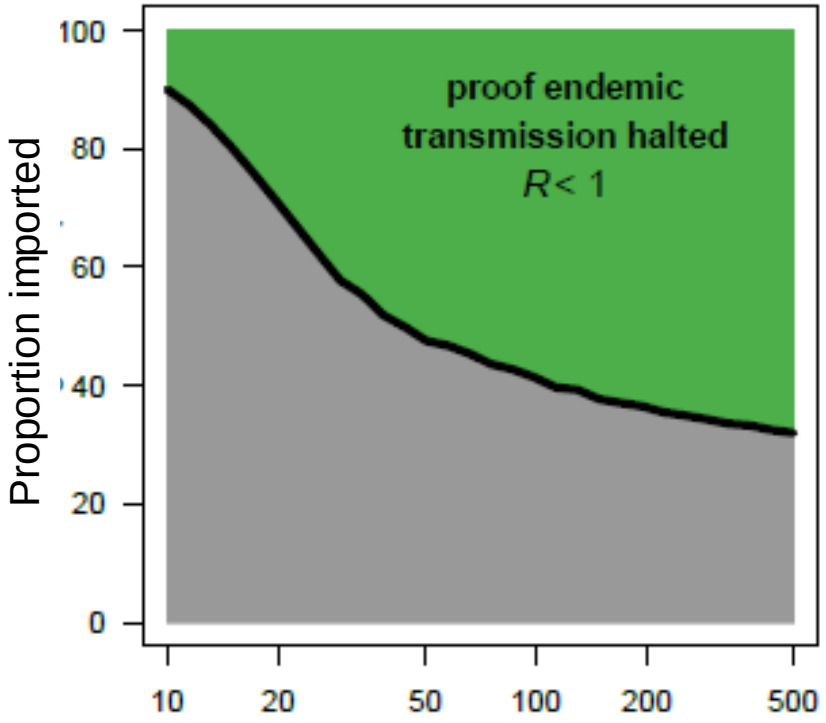


- From proportion, can estimate length of chain;
- From length of chain, can estimate the reproduction number.

Inferring *R*


Proportion of travellers
100
80
60
40
20
0
0.0
0.2
0.4
0.6
0.8
1.0
Reproduction number *R*
Case detection rate
1%
0.4%
0.01%

Assessing local transmission from the proportion of imported cases



The case of Swaziland

	# Local	# Imported	% Imported
2010	91	52	36%
2011	207	170	45%
2012	76	153	67%

Endemic transmission halted

Simple Excel tools for program managers

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Measuring the Path Towards Malaria Elimination

This tool is designed to help users determine their current level of
For full details please refer to the main text and supplementary met

Number of cases identified	100
Number of cases imported	60

Is there evidence that *R* is less than 1	VRAI
Is there evidence that *R* is less than 0.9	VRAI
Is there evidence that *R* is less than 0.8	VRAI
Is there evidence that *R* is less than 0.7	VRAI
Is there evidence that *R* is less than 0.6	INCONCLUSIVE
Is there evidence that *R* is less than 0.5	INCONCLUSIVE
Is there evidence that *R* is less than 0.4	INCONCLUSIVE
Is there evidence that *R* is less than 0.3	INCONCLUSIVE
Is there evidence that *R* is less than 0.2	INCONCLUSIVE
Is there evidence that *R* is less than 0.1	INCONCLUSIVE

Instructions

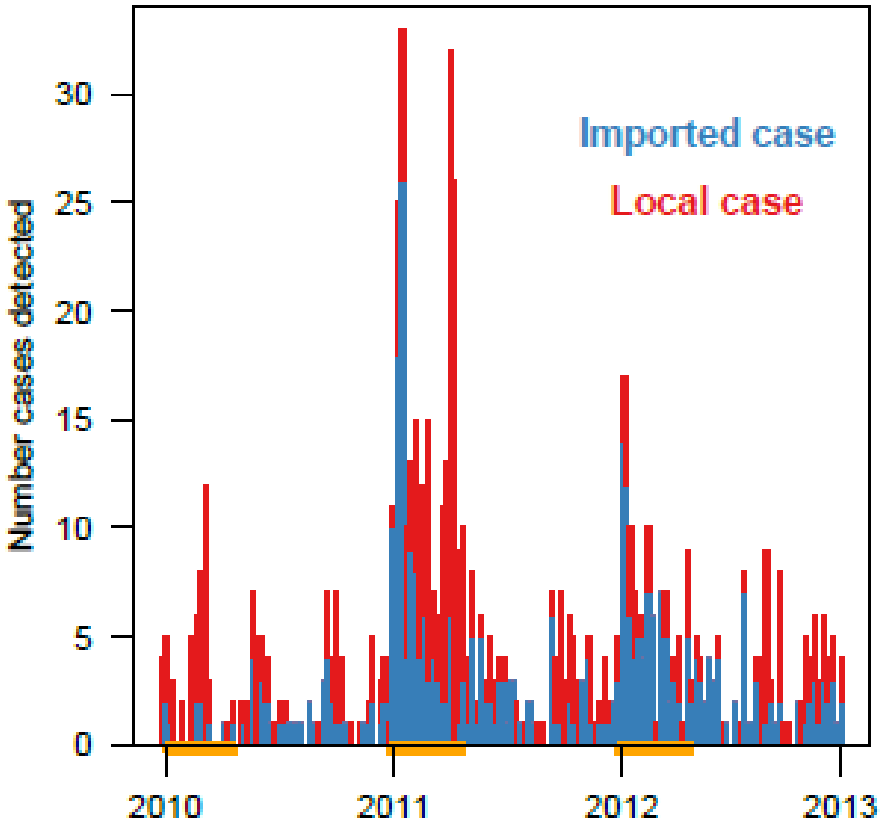
1. Enter the num
into Box C8.

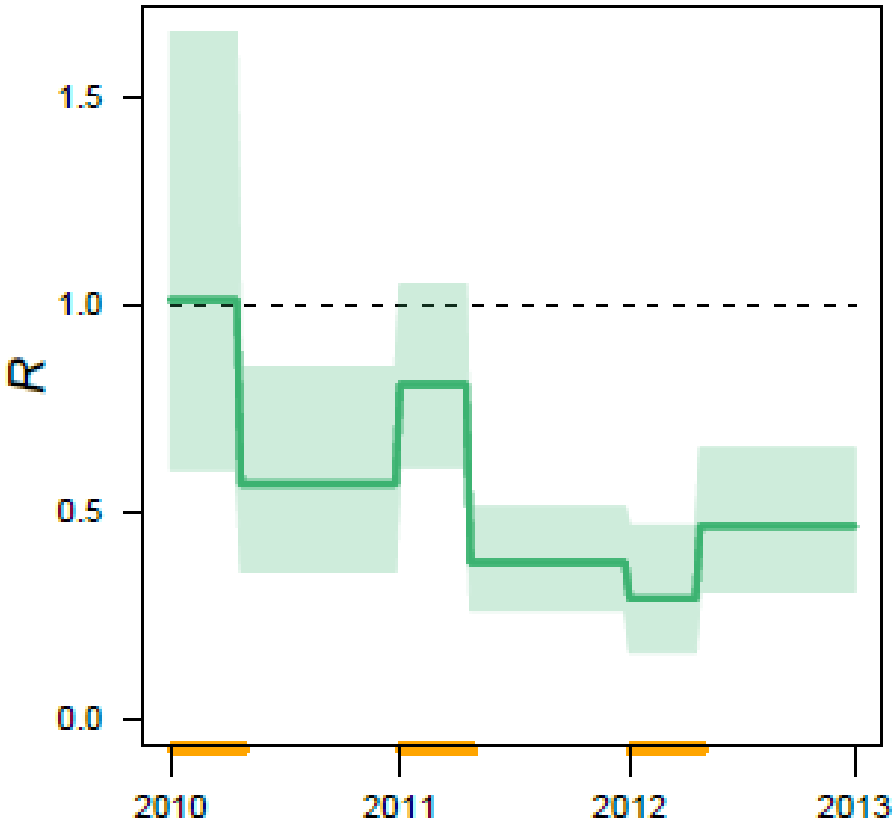
2. Enter how mar
into Box C9.

3. If the result
that endemic tra

4. Boxes C12 to
of transmission

Monitoring seasonal variations in transmission





Conclusion

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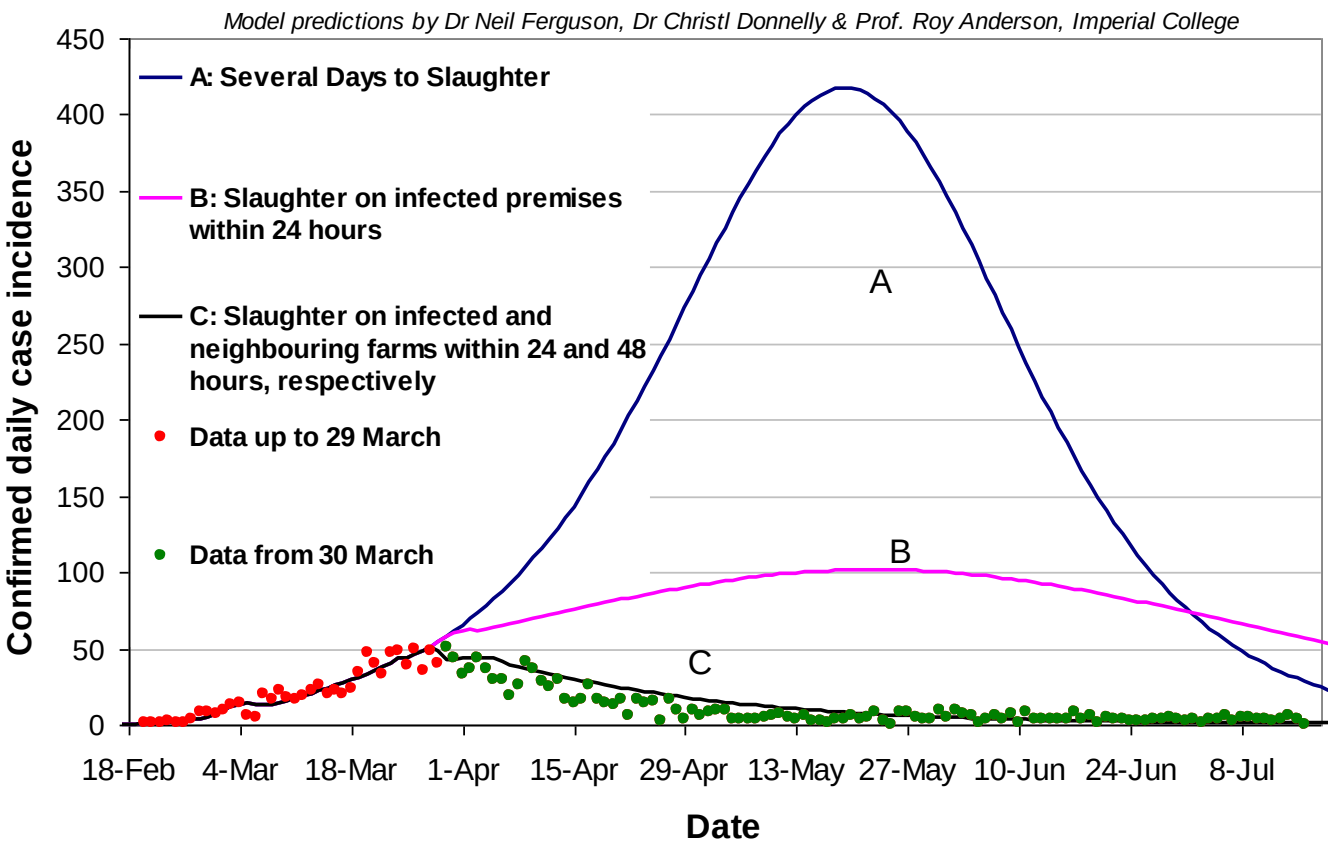
- A framework to think about mechanisms and synthesize information from multiple datastreams.

- A set of methods to estimate key parameters from data.

Foot and mouth disease in the UK



Explored effect of two types of culling:

- Faster slaughter of farms on which infection reported
- Ring-culling = slaughter of farms within certain distance of infected farm.

(Contiguous culling = ring culling of neighbours only.)

Predictions (as released by OST) made using data up to 29-March.