

Dynamical Modeling for Infectious Disease Policy

Importance and Challenges

Jonathan Dushoff, McMaster Biology
mac-theobio lab (with Earn and Bolker)

UNICEF McMaster, Mar 2025

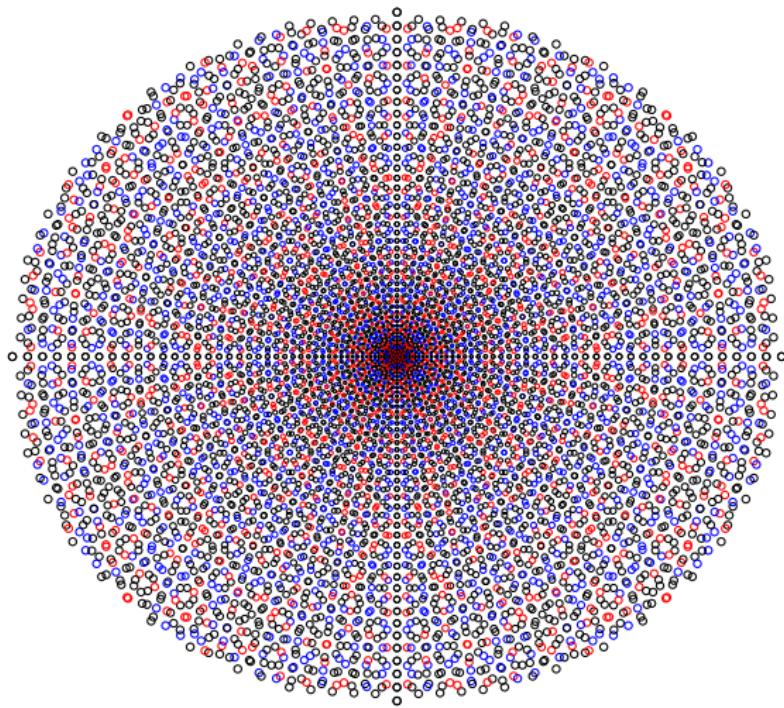
Origins



Exploration



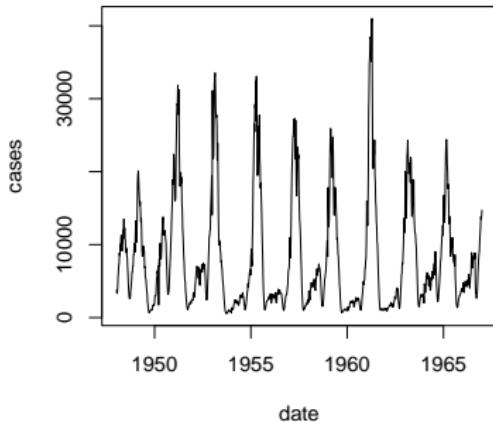
First love



Dynamical modeling connects scales



Measles reports from England and Wales

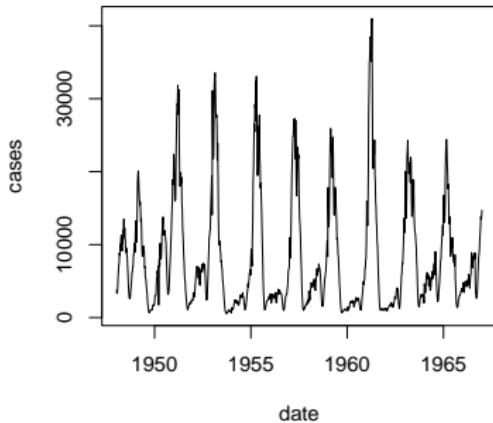


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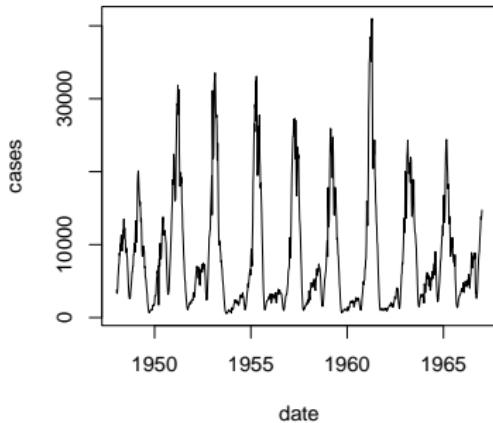


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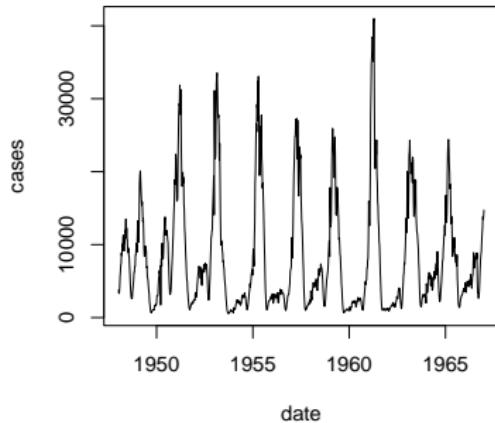


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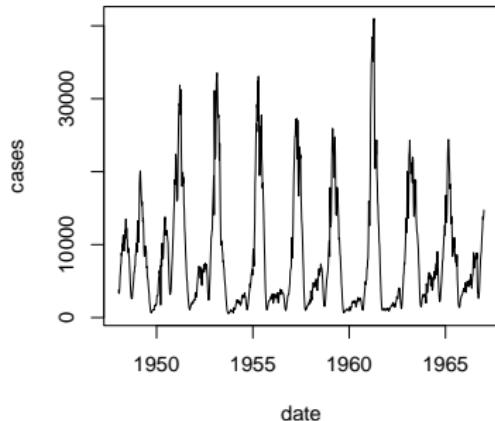


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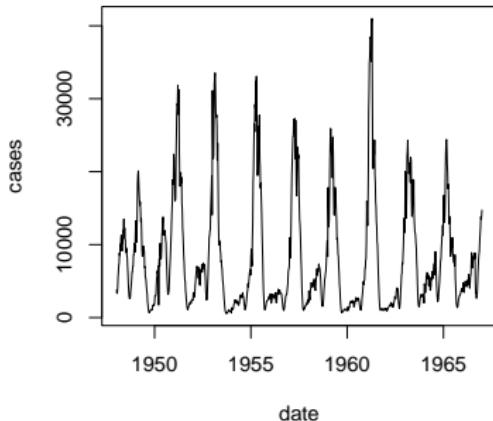


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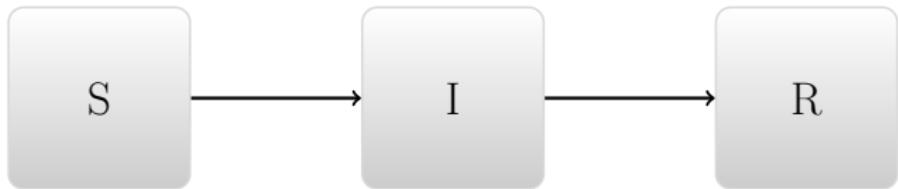
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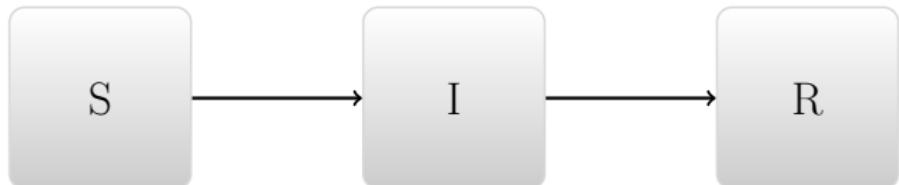
Simple models of disease spread

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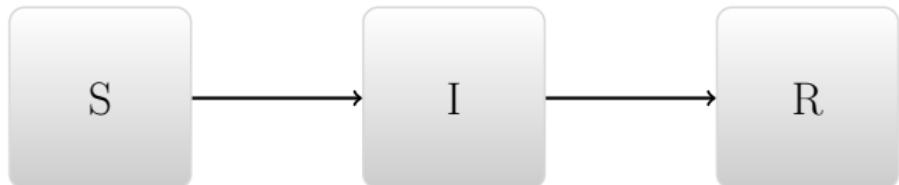
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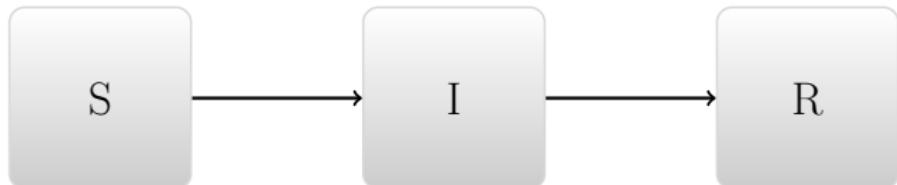
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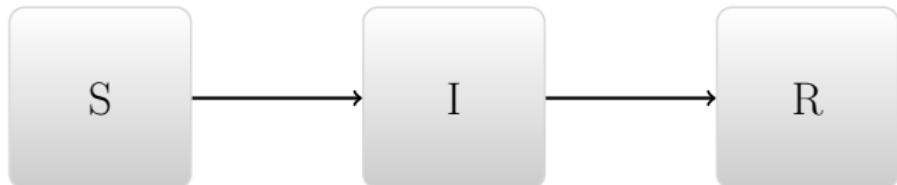
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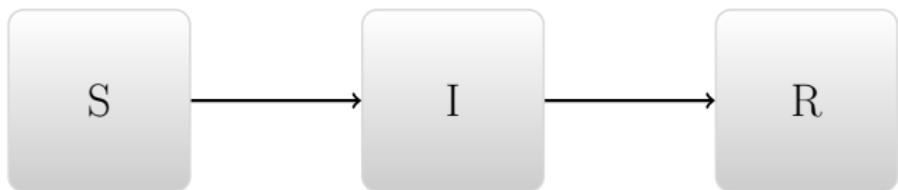
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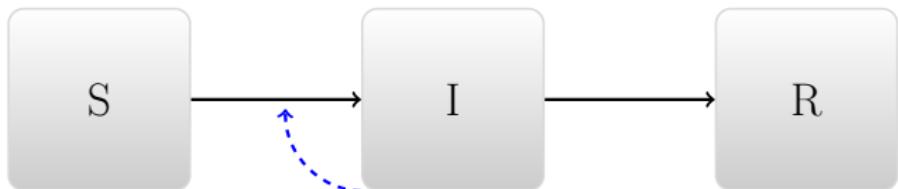


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What determines transition rates?

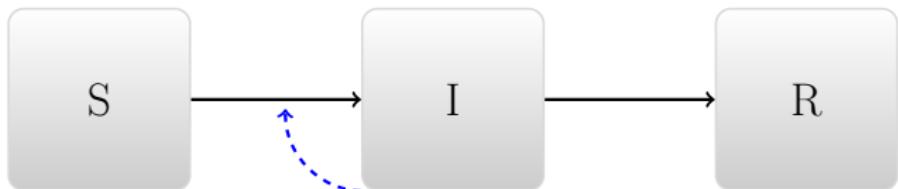


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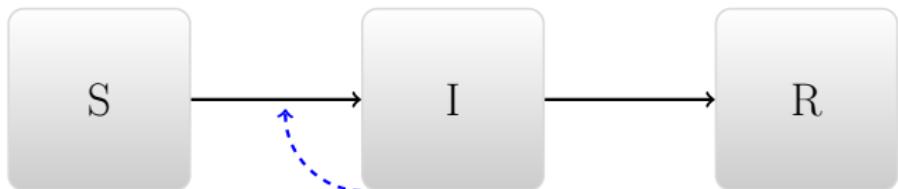
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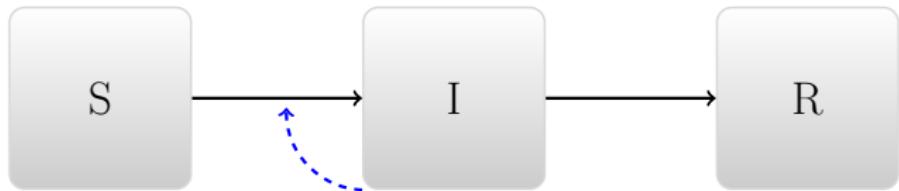
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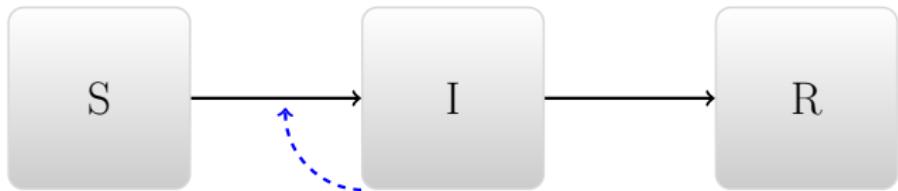
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Conceptual modeling



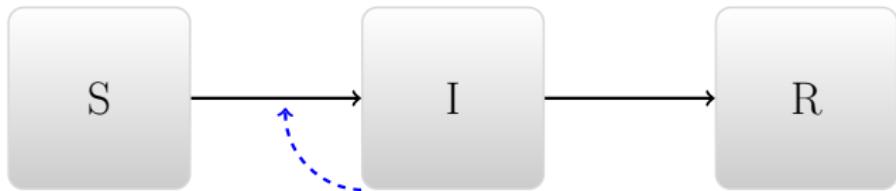
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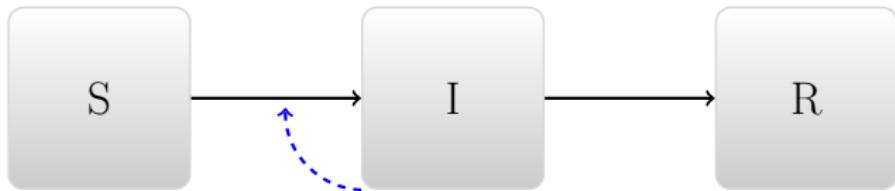
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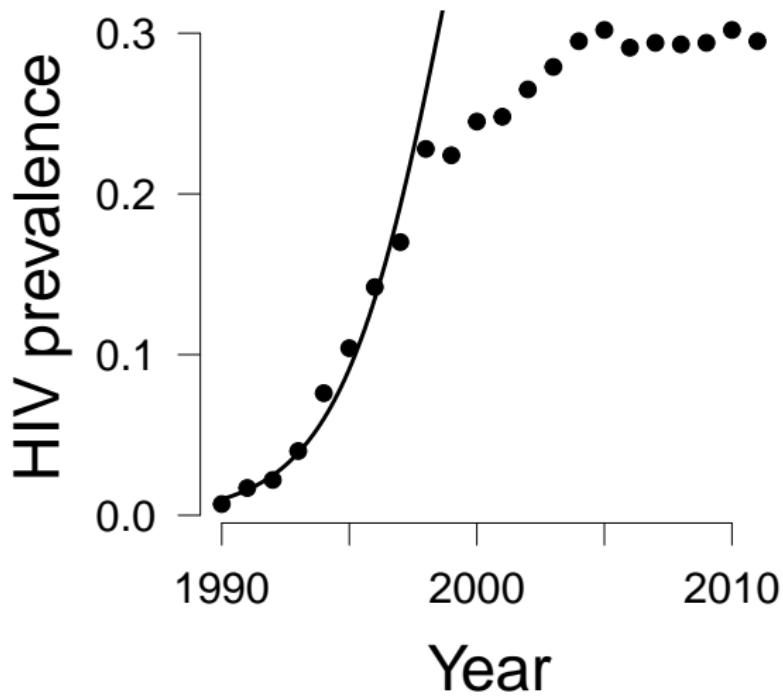
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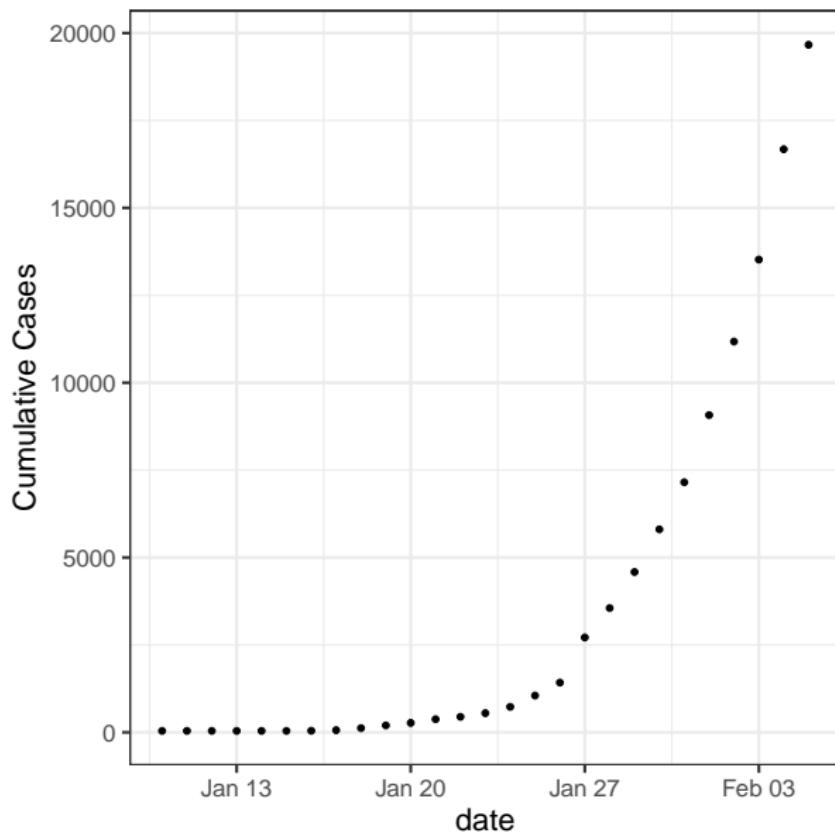
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Exponential growth (HIV in Africa)

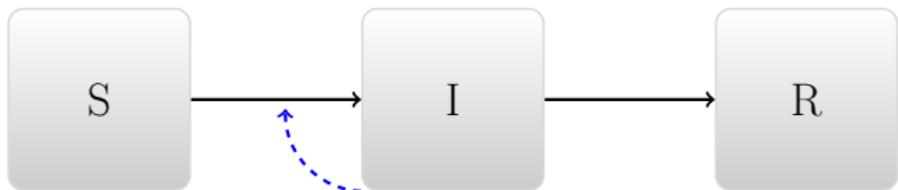
$R_0 = 5.66$



Exponential growth (COVID 2020)

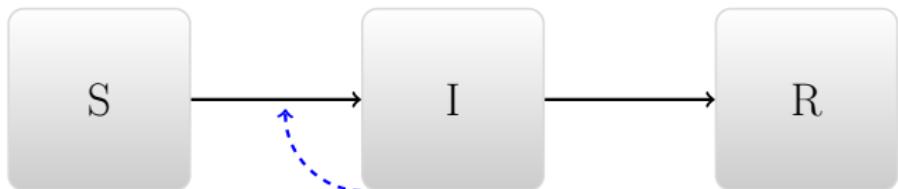


Result: disease does not always spread



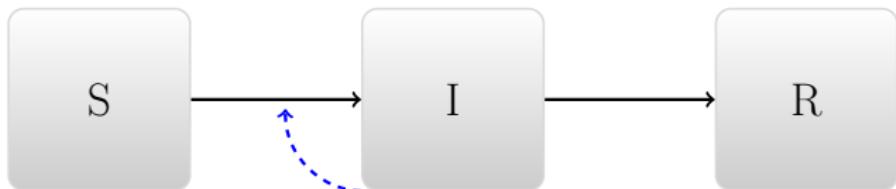
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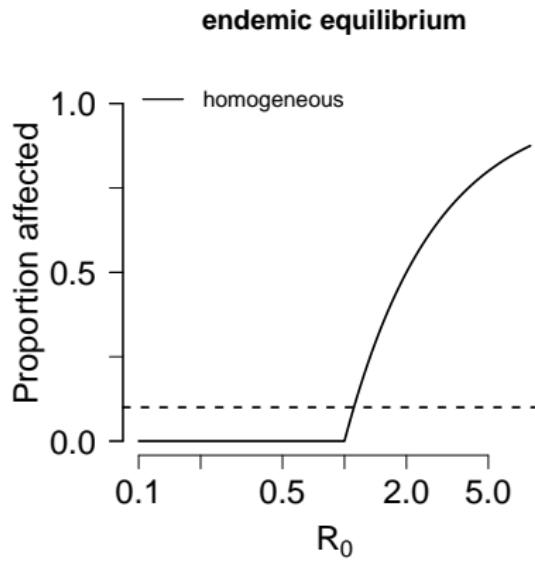
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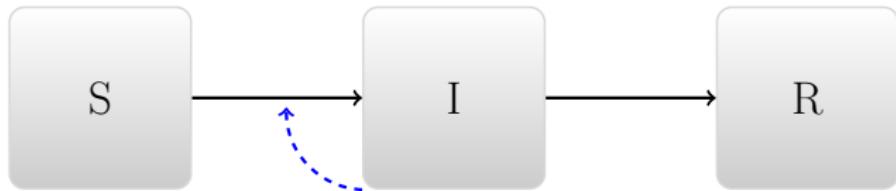
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Yellow fever in Panama

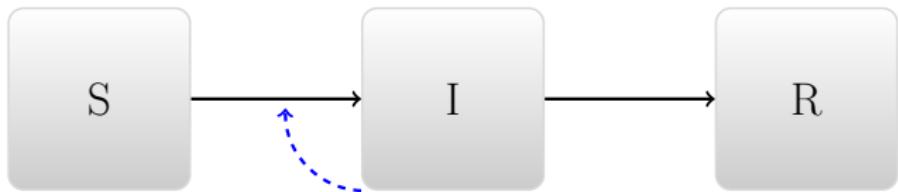


Result: not every one gets infected



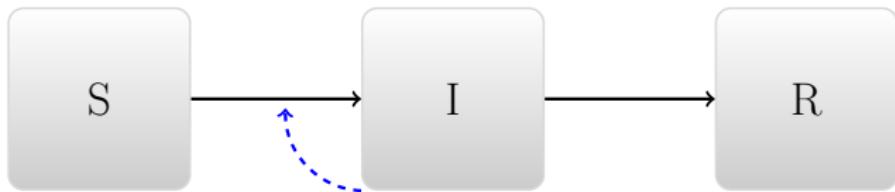
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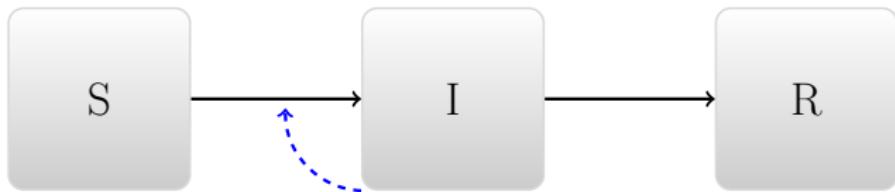
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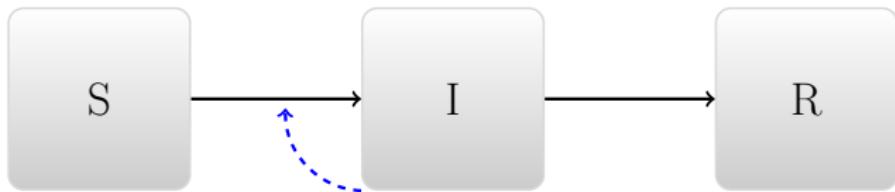
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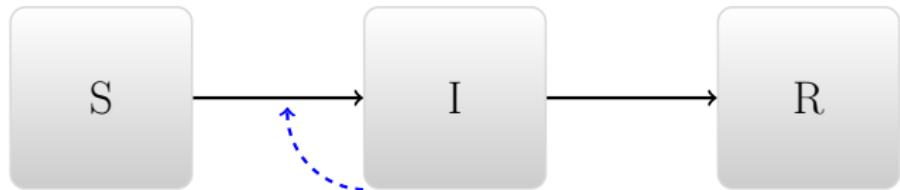
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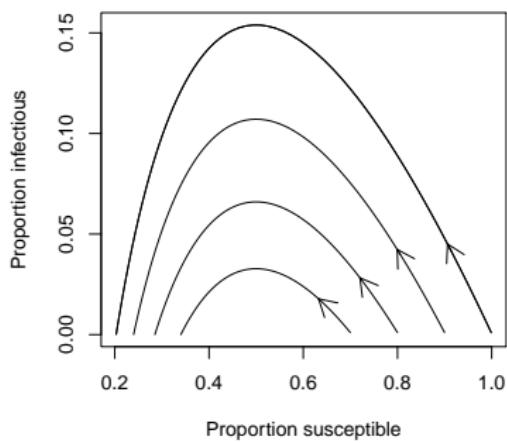
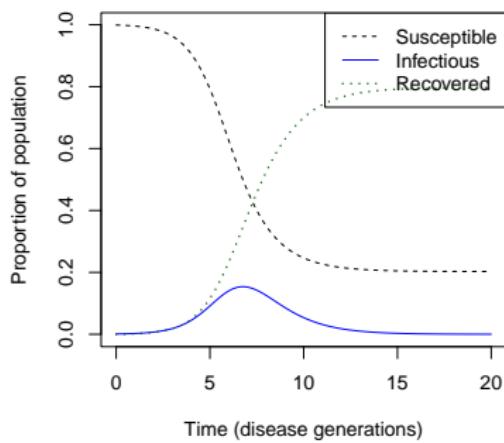
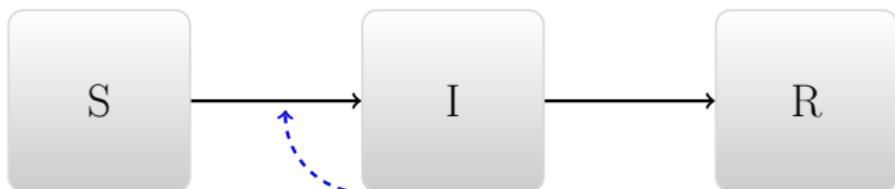


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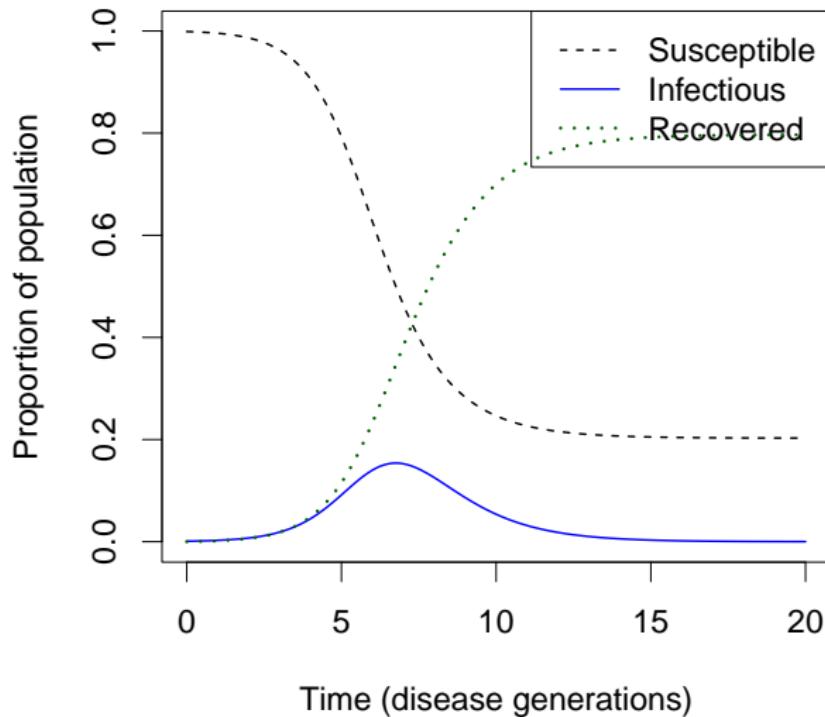
Simulations



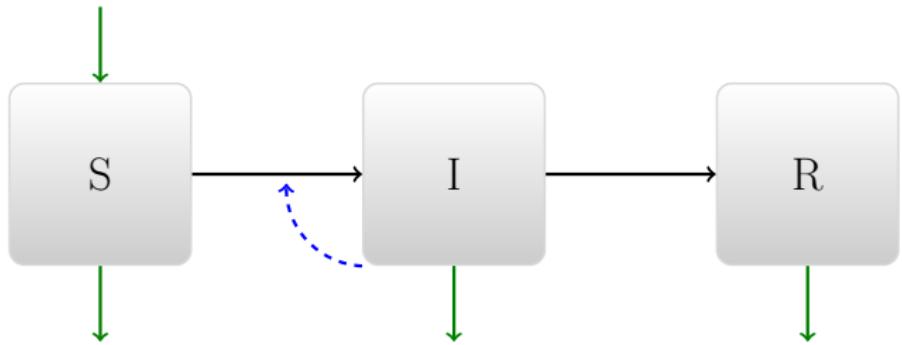
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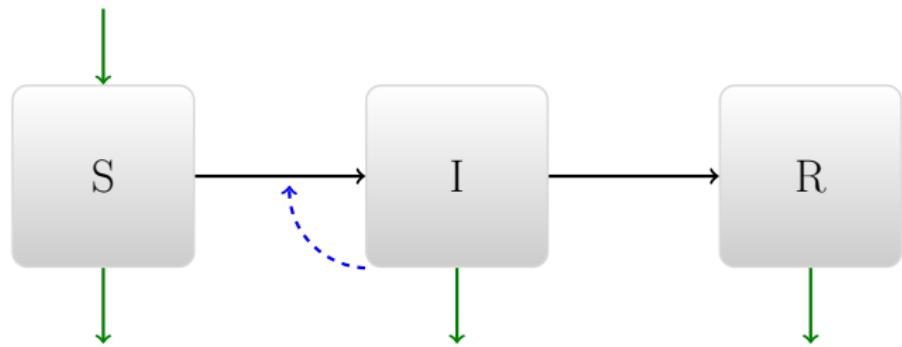


Closing the circle



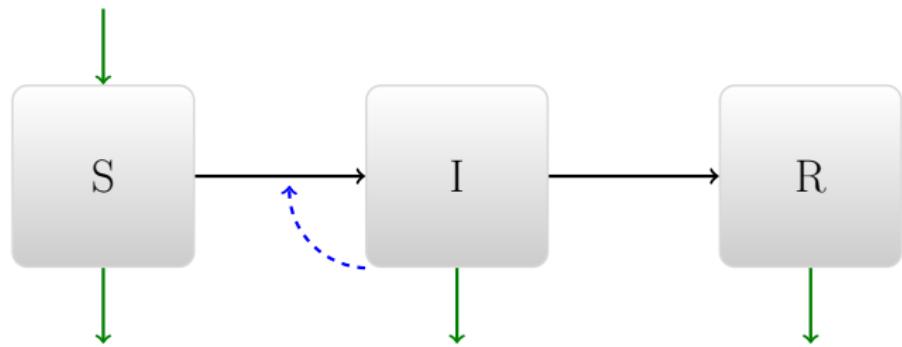
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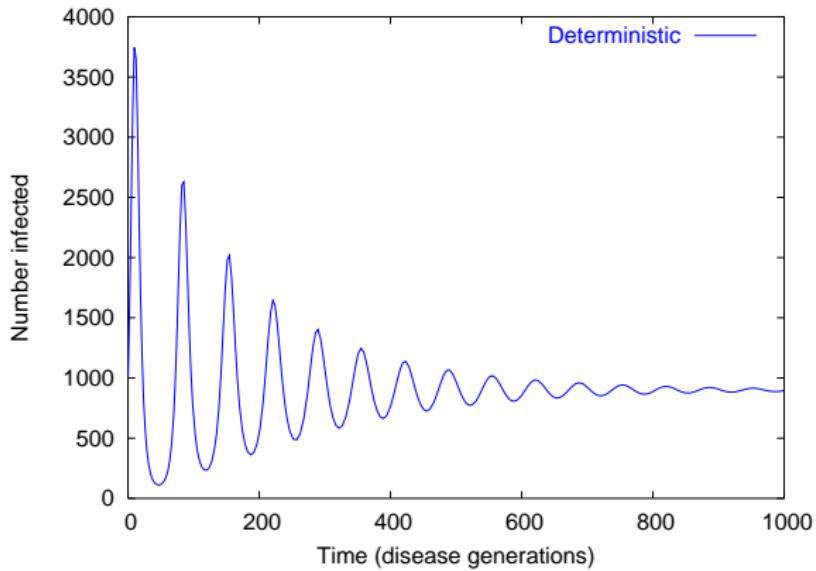
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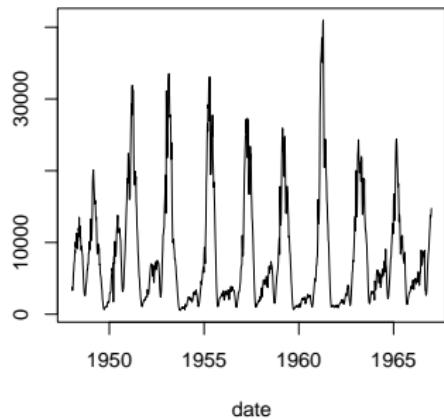
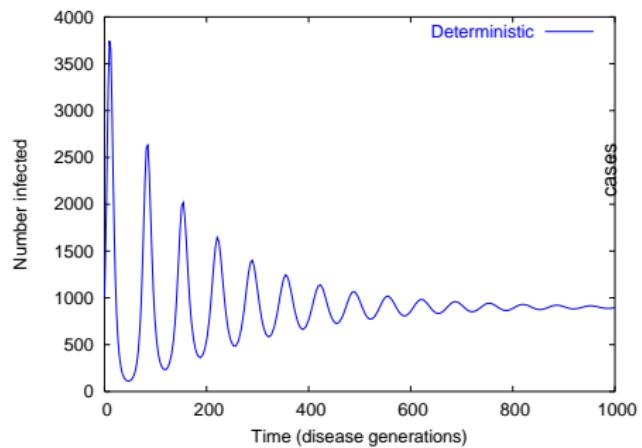
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Result: Oscillations tend to be damped



What is missing from our model world?

Measles reports from England and Wales



Example: Ebola transmission

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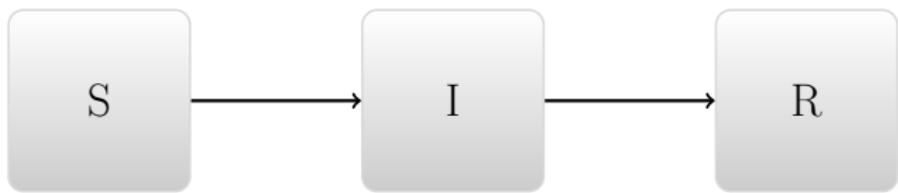


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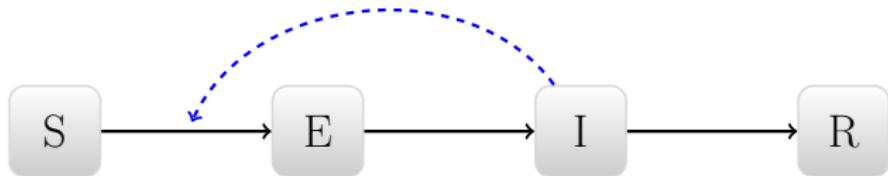
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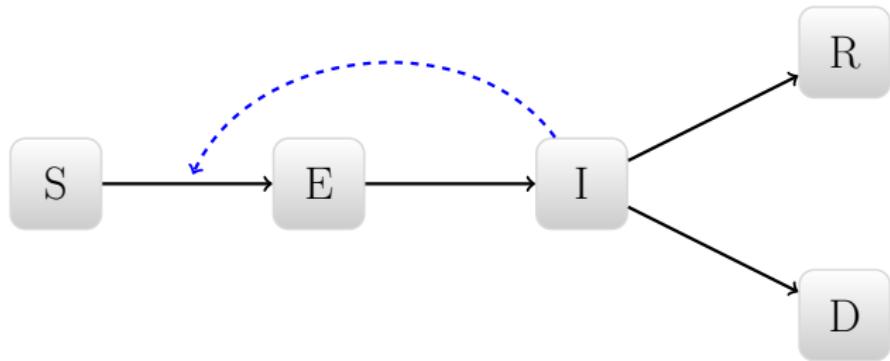
Simple disease model



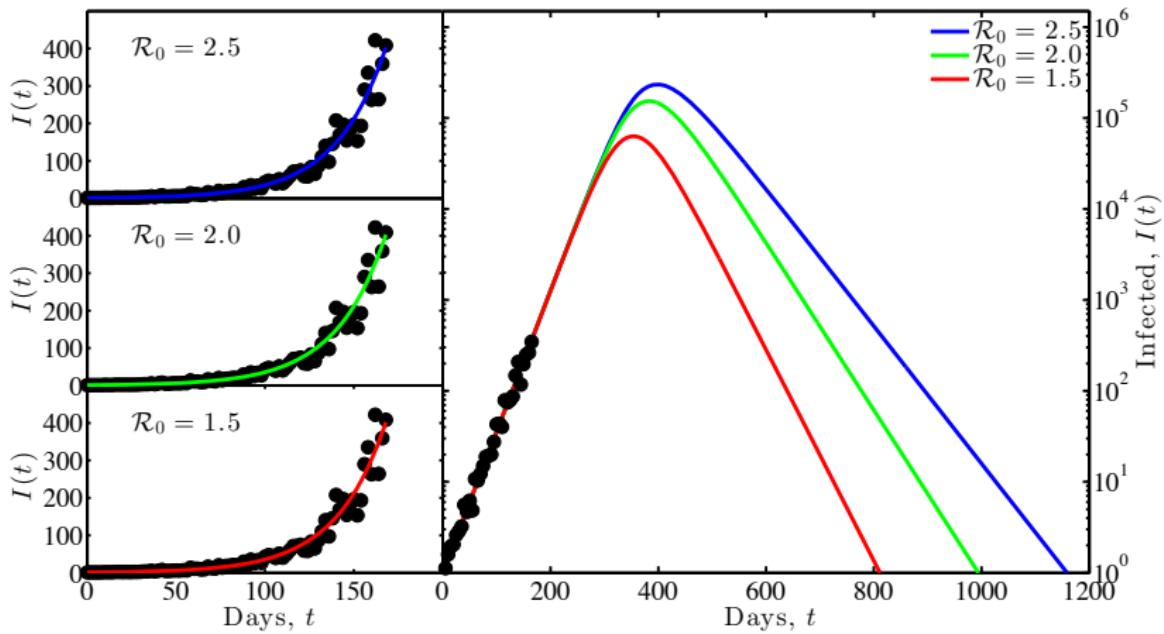
Model with latent period



Include post-death transmission

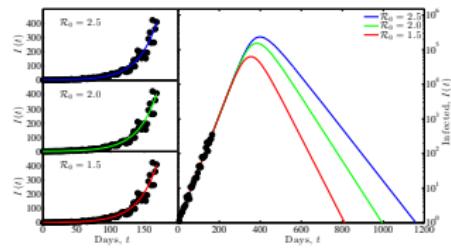


Result: generation interval links $r\mathcal{R}$



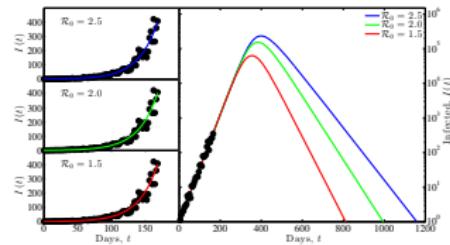
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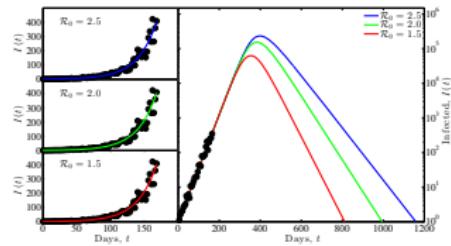
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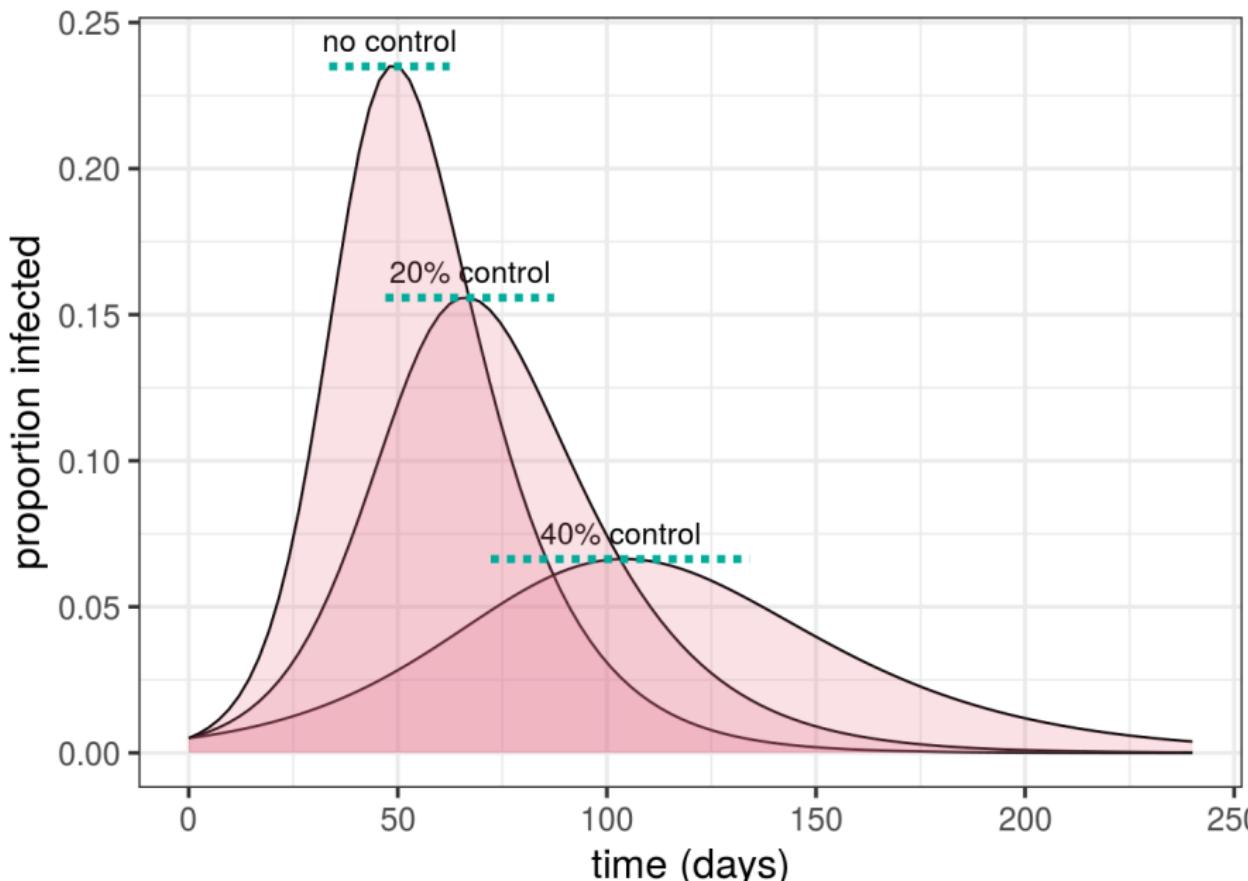


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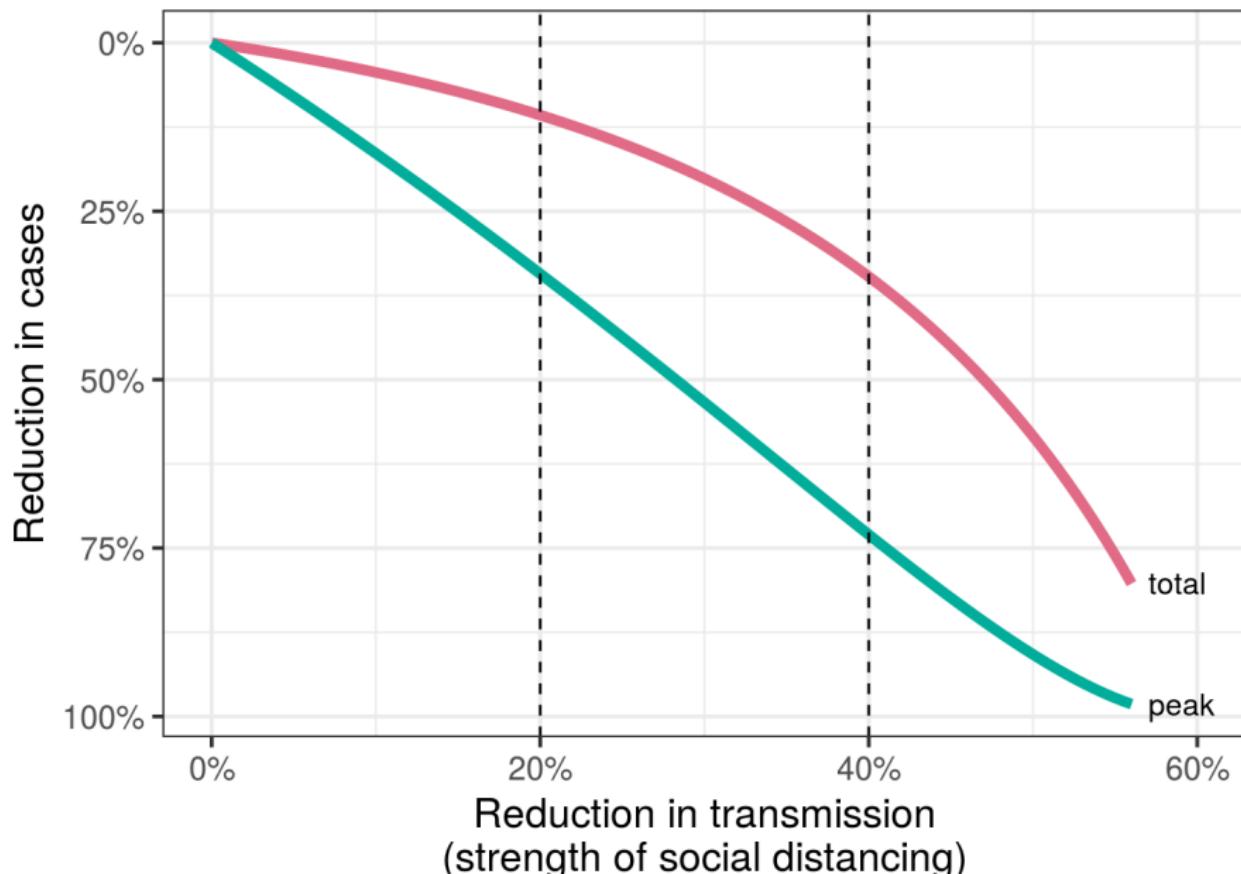
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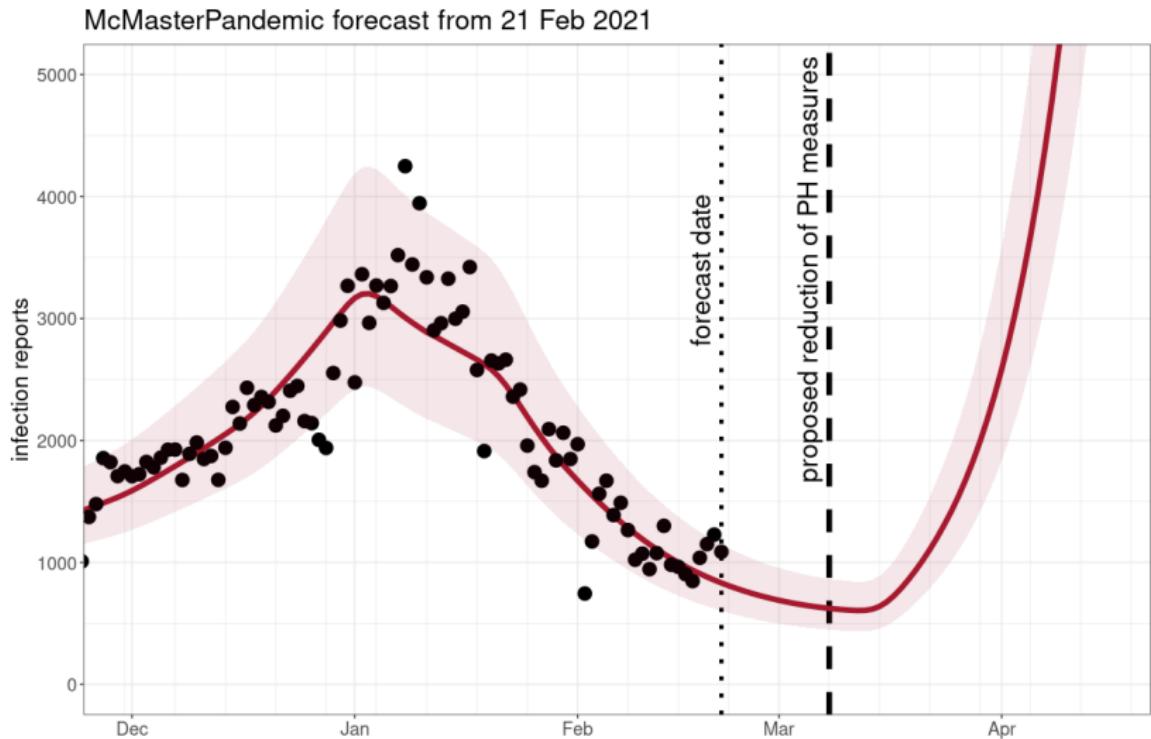
Example: COVID: flatten the curve



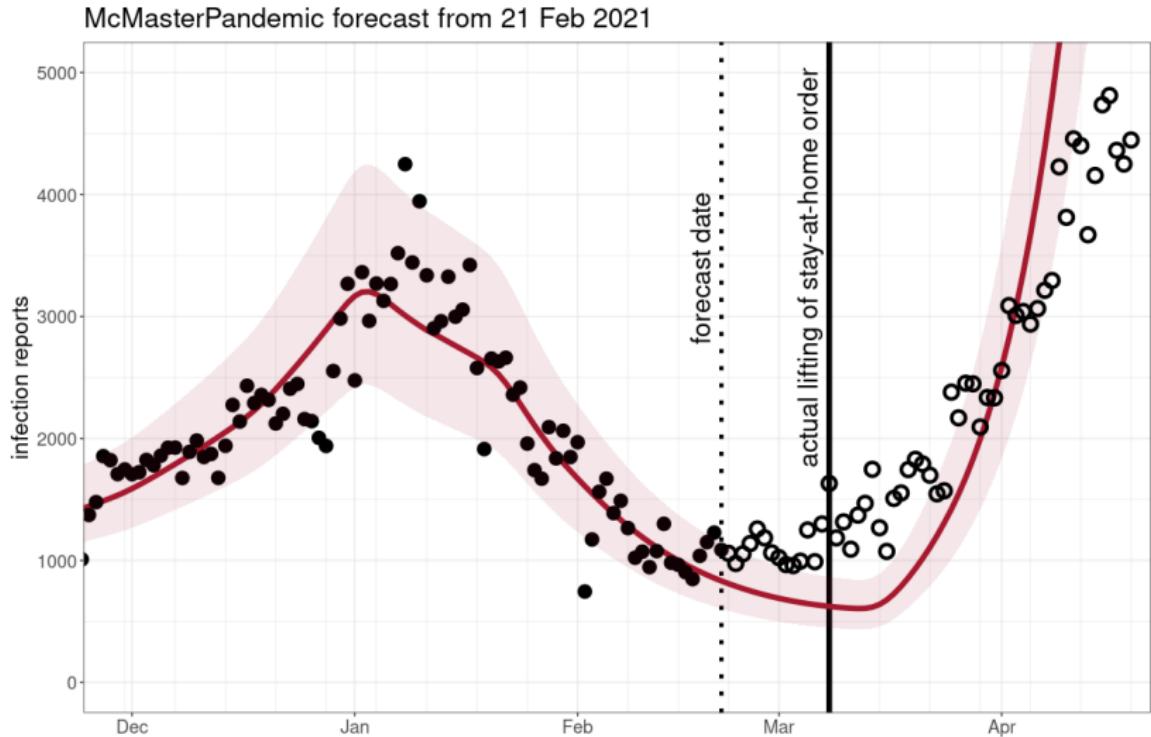
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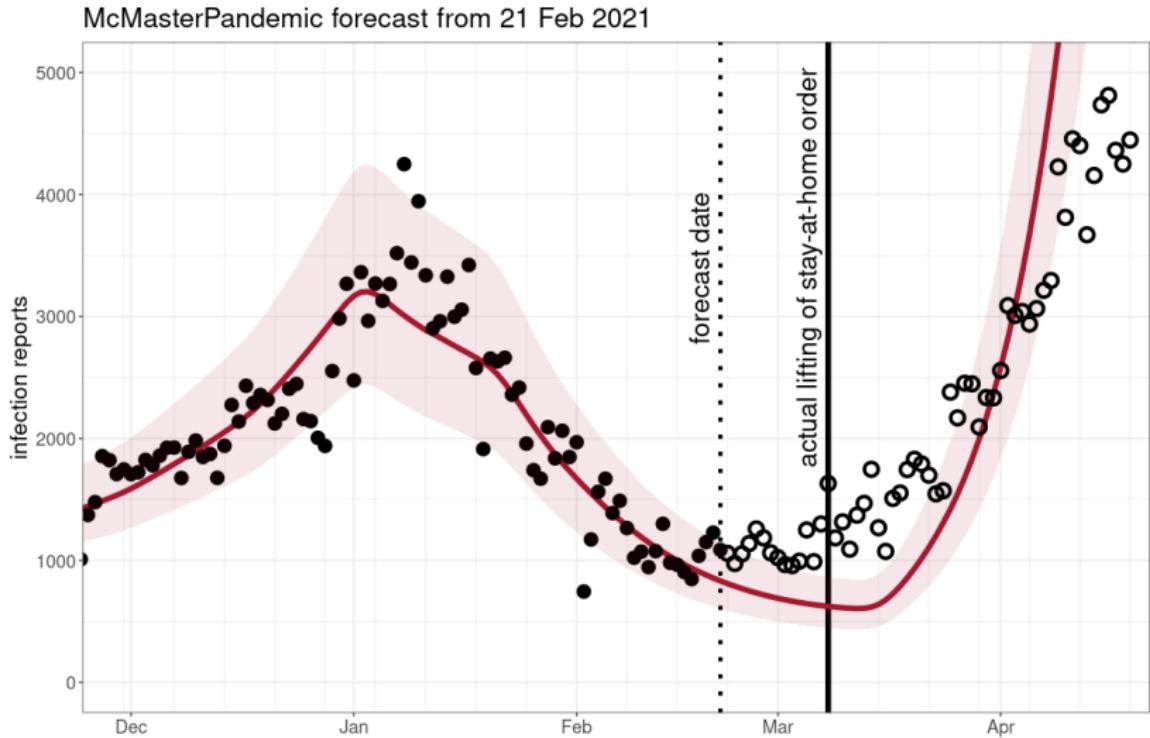
Example: COVID waves



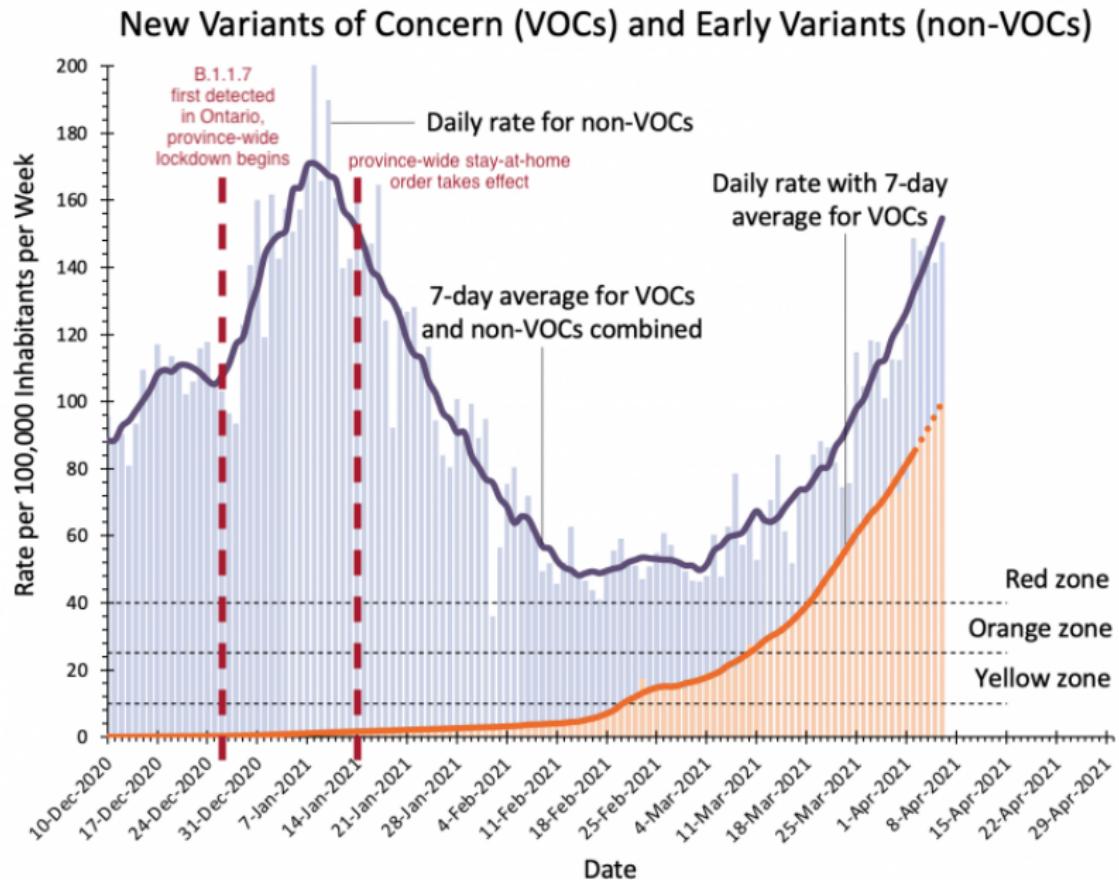
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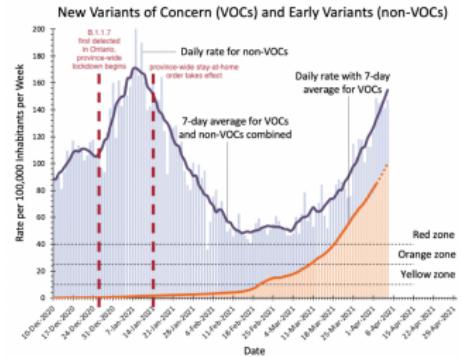


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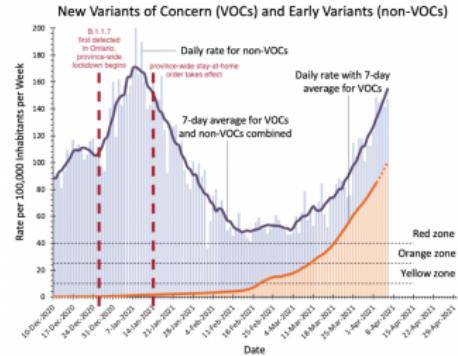
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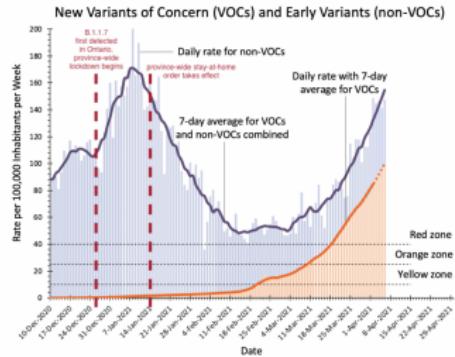
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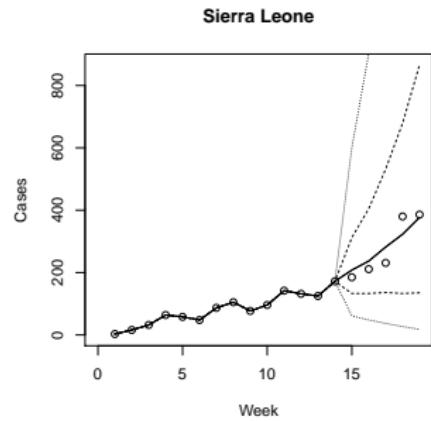
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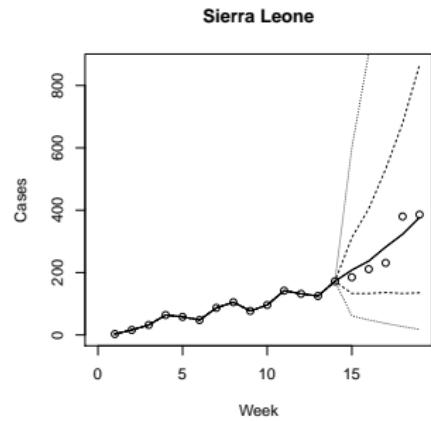
Statistical fitting

- ▶ How certain or uncertain are our projections?



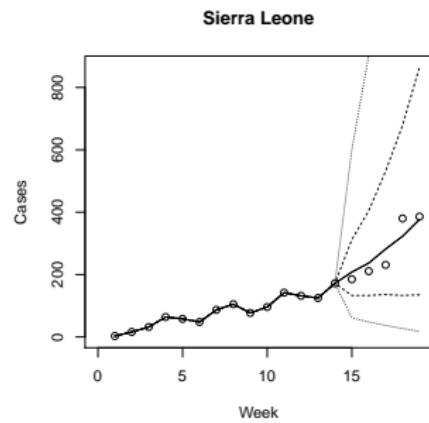
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Educational outreach



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