EEB C119/219 B

Discussion Week 3

Markov model example

How NOT to use models

This Math Model Is Predicting the Ebola Outbreak with Incredible Accuracy

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Written by
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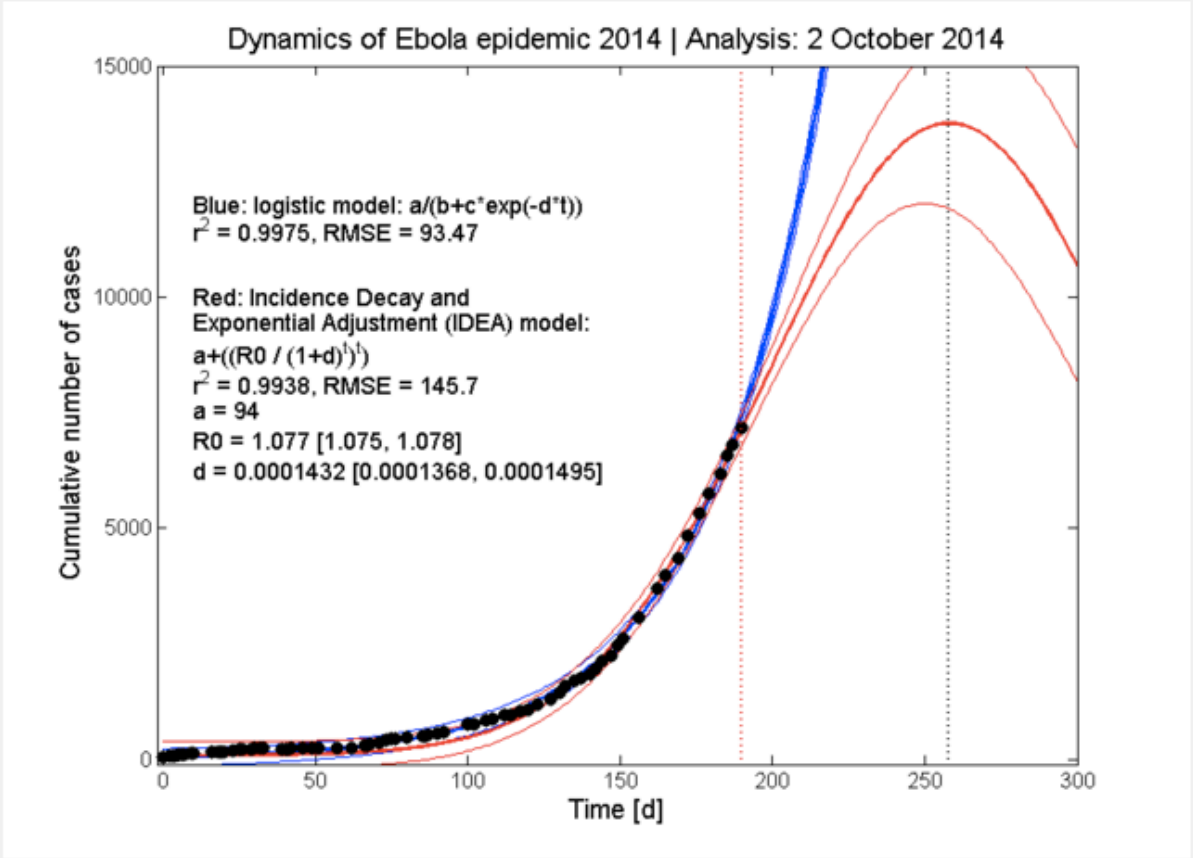
EDITOR

- VICE - http://motherboard.vice.com/read/this-math-model-is-predicting-the-ebola-outbreak-with-incredible-accuracy
- PLoS One - http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0083622

How NOT to use models



The graph above shows how the model is faring with the current Ebola outbreak. So far, it's nearly perfect. If the IDEA model continues to predict the epidemic with the same accuracy, we can expect Ebola to start burning out in December, with a total of 14,000 cases. Currently, according to the CDC there are or have been 8,400. We have a ways to go.

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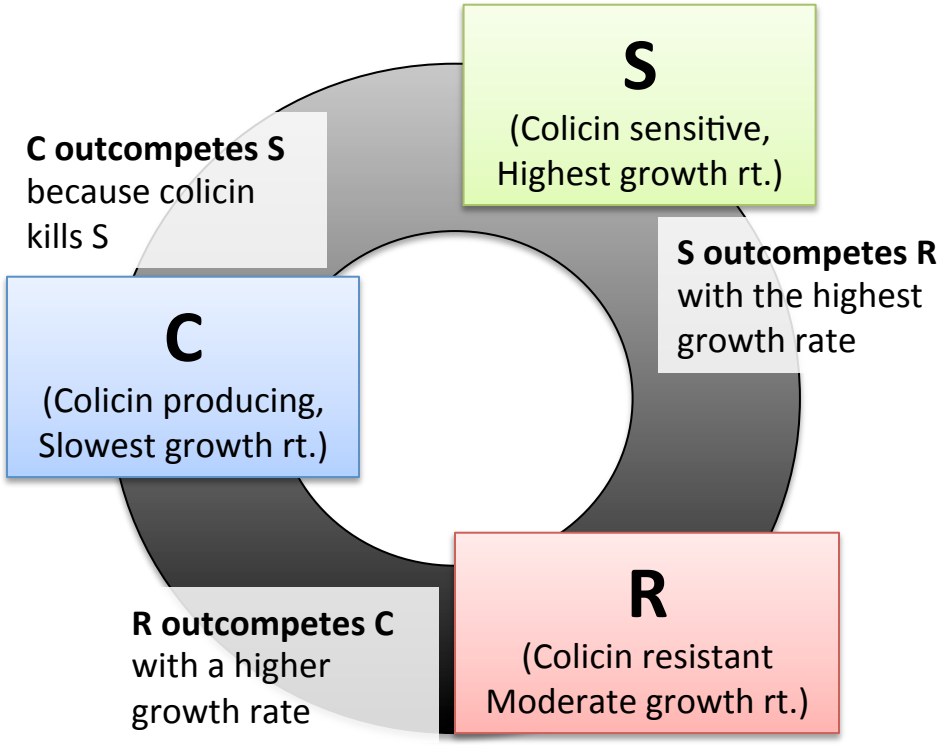
How to use models right

- Mechanism –
  - What processes in my system are essential/non-essential to the patterns I observe?
  - e.g. Bacterial competition and space

Mechanism example: **Spatial organization** changes the game in Rock – Paper – Scissors competition



Kerr, B., Riley, M., Feldman, M. & Bohannan, B. *Nature* (2002)

Based on work by:
Durrett, R. & Levin, S. *Jour. thero. Biology.* (1996)

What should happen if all three phenotypes attempt to coexist?

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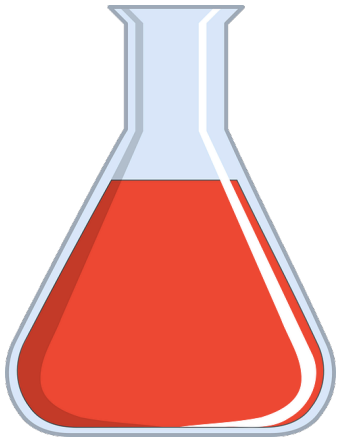
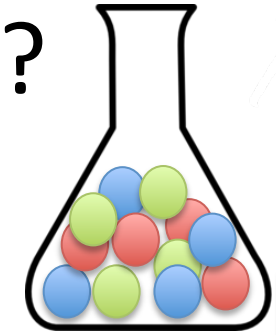
In a well-mixed population

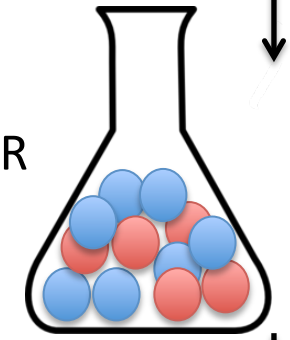


Resistant strain outcompetes all others

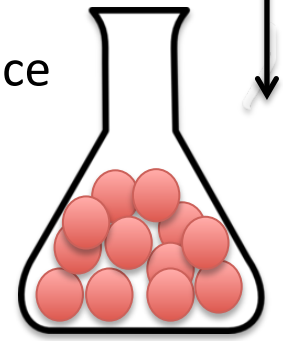
1. Start with C, S, R



2. C rapidly kills all S, leaving only C and R



3. R gradually outcompetes C, since R has a higher growth rate



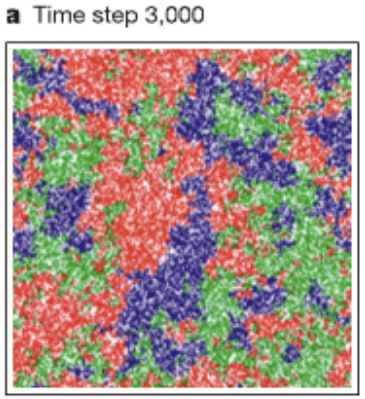
What should happen if all three phenotypes attempt to coexist?

In a well-mixed population

Resistant strain outcompetes all others

But in a spatially-structured population

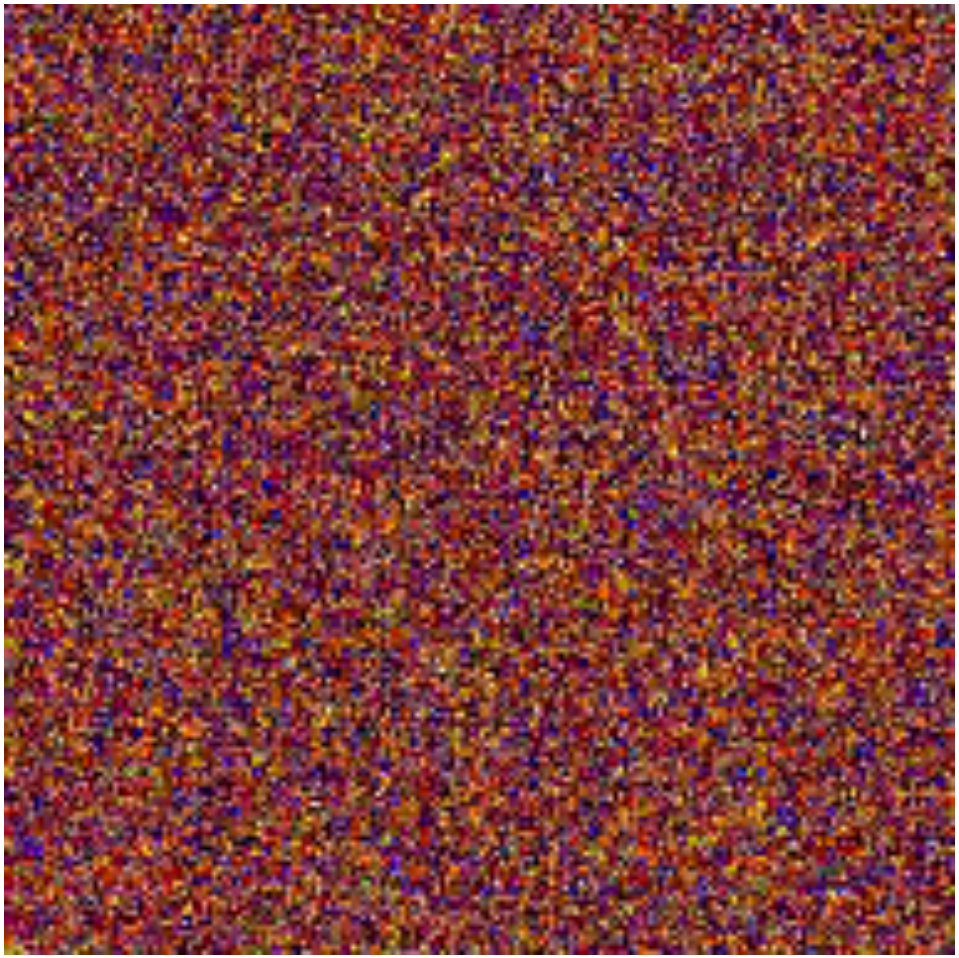
(Where individuals interact only with their nearest neighbors)



All can coexist by chasing each other around the petri dish.

Durrett, R. & Levin, S. J. Theor. Biol. 185, 165–71 (1997).
Kerr, B., Riley, M. A, Feldman, M. W. & Bohannan, B. J. M. Nature 418, 171–4 (2002).

With spatial structure



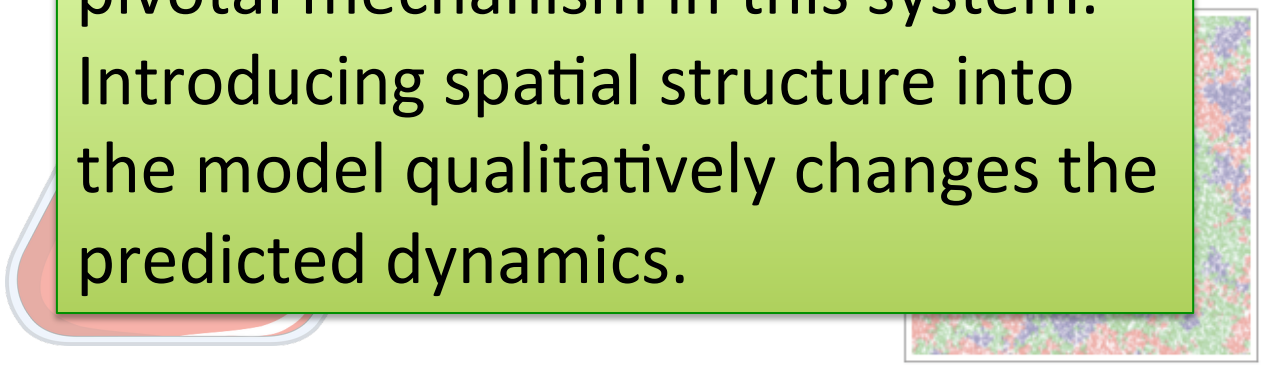
What should happen if all three phenotypes attempt to coexist?

In a well-mixed population

But in a spatially-structured population

(Where individuals interact only with their ors)

Takeaway: Spatial structure is a pivotal mechanism in this system. Introducing spatial structure into the model qualitatively changes the predicted dynamics.



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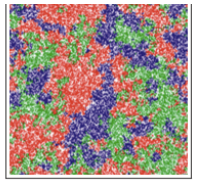
Differences in model formulation

No spatial structure

- **Assume population is well-mixed**
- **Model can be deterministic or stochastic**
- **ODE model or Markov chain model**

Spatially-structured



- **Assume heterogeneous mixing**
- **Model is stochastic**
- **Markov chain model**

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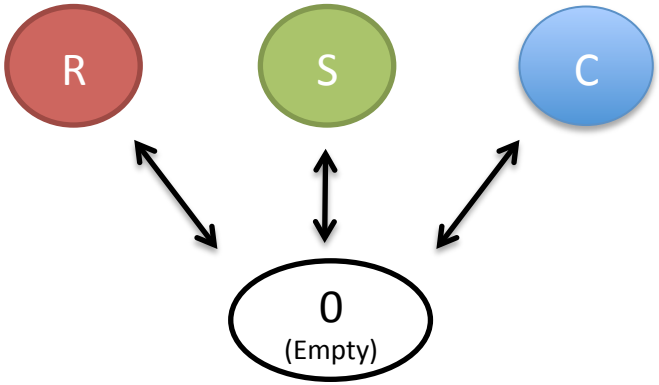
Markov model formulation



If empty...	Birth probability	If full...	Death probability
0 -> S	$\beta_S f_S$	S -> 0	$\mu_S + \tau f_C$
0 -> R	$\beta_R f_R$	R -> 0	μ_R
0 -> C	$\beta_C f_C$	C -> 0	μ_C

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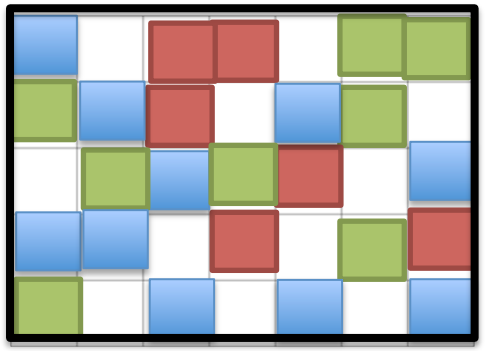
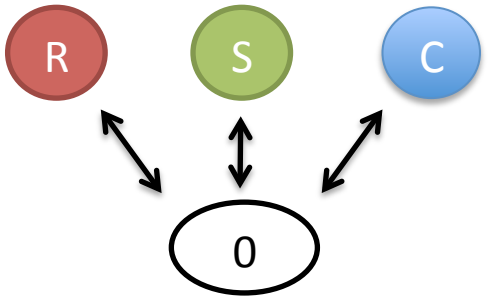
Markov model formulation

Well-mixed:



f_i describes the fraction of type i in the WHOLE POPULATION



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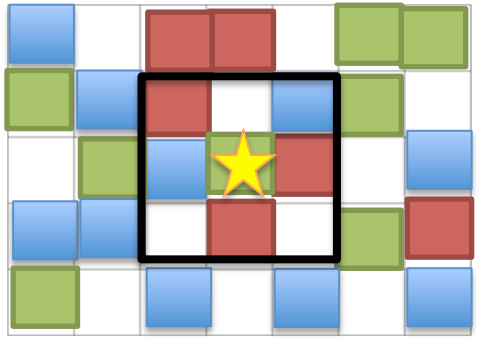
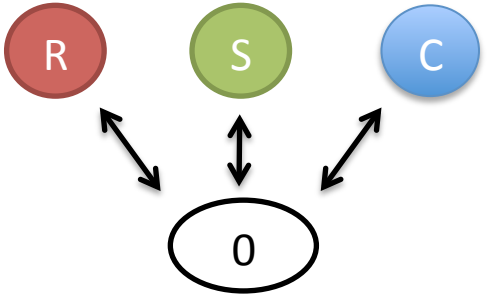
Markov model formulation

Spatially structured



f_i describes only the fraction of type i surrounding a particular cell of interest



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