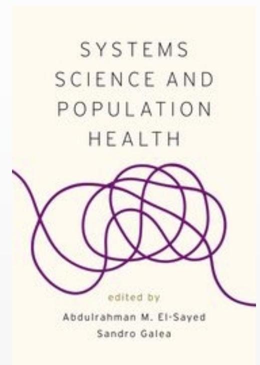
Washington State University

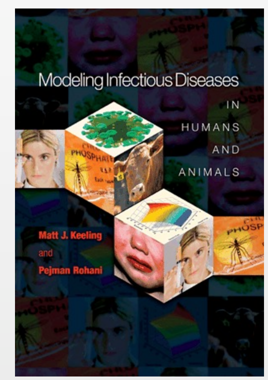
Systems Thinking and Models

Questions from Last Class?

Some Resources for the Curious

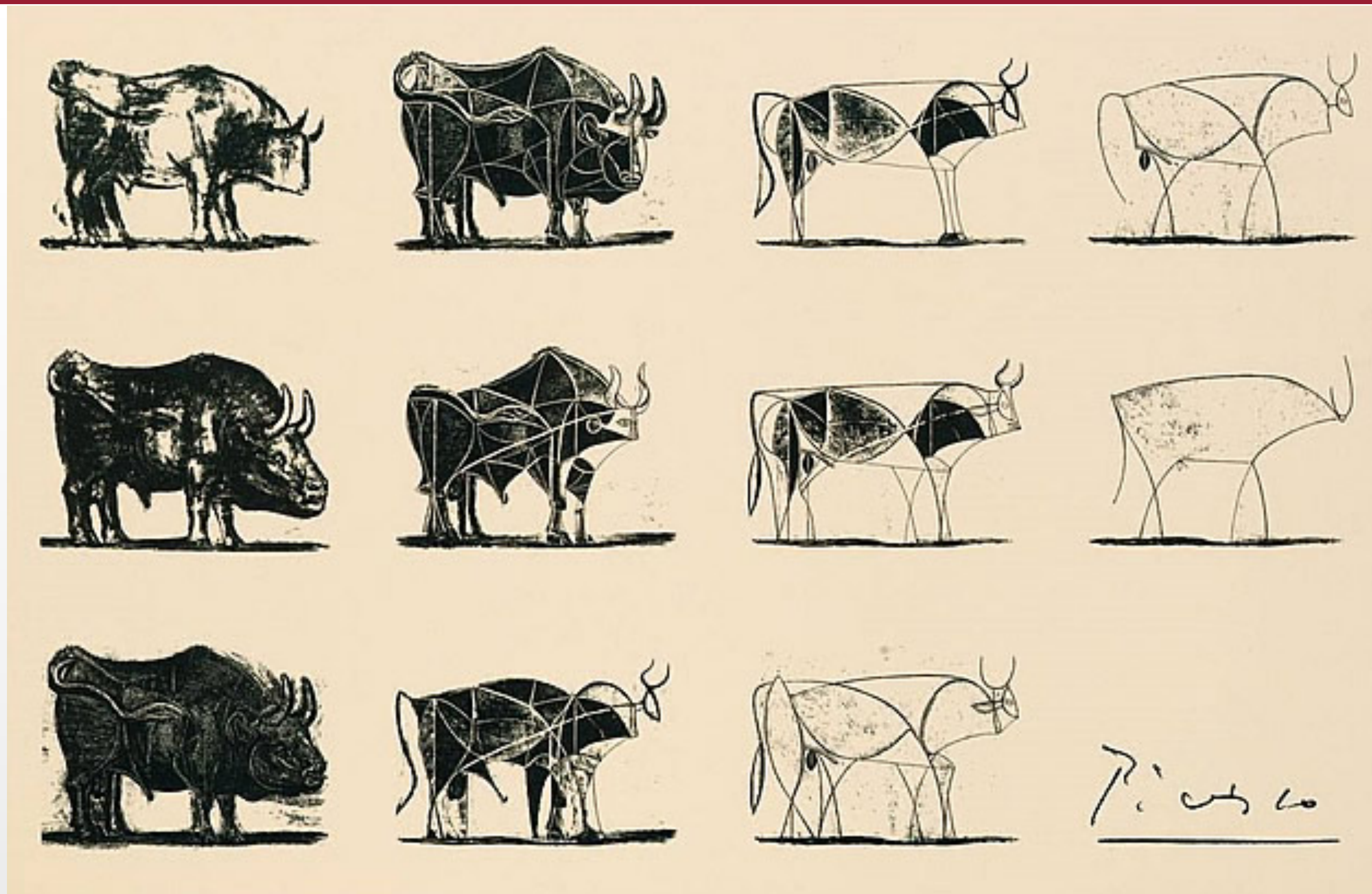
- I have many, many books on infectious disease modeling – if you have a specific interest, come schedule a time to talk
- SISMID – UW course on modeling infectious disease
  - http://www.biostat.washington.edu/suminst/sismid
- Network Modeling also at UW
  - http://statnet.github.io/nme/





What Do We Mean By Model?

- All Models: A simplified placeholder for a more complex reality
- Statistical vs. Mathematical vs. Computational Models
  - Statistical Models: What does our data tell us about the world? *Descriptive*
  - Mathematical Models: How can we use our data to describe how the world works in equations? *Mechanistic*
  - Computational Models: How can we use our data to **simulate** how the world works? *Mechanistic*
- This categorization presents things as having starker divisions than they do in practice, especially for the last two types of models



Where Models Are Strong

- Inherently counterfactual
  - Different scenarios are made by changing the code/equations that govern the model
- Very good at handling nonlinear systems
  - Feedback loops
  - Dependent Happenings
- Can make inferences outside data sets
  - Risky, but possible
- Data synthesis
  - “Meta-analysis” but of a system as a whole

Stepping Outside a Data Set

- Statistical methods have a major constraint: the analysis is confined to a single study's data set
  - Any attempt to model complex behaviors, indirect effects, etc. can only emerge from the statistical relationship between outcome, exposure, and covariates
- Accompanying assumptions:
  - **The data set exists**
    - The data set can be ethically collected
  - The models are properly specified, etc.
  - **All relevant contact patterns, indirect effects, etc. are adequately captured within the study's data**
    - Emergent behaviors of the system are fully measurable (and were measured)

What Models Are (And Are Not):

- Are:
  - A powerful tool for public health planning and research
  - Something every epidemiologist should be passingly familiar with
  - A rigorous, systematic way to try and describe how an entire disease process works
  - Capable of providing truly counterfactual estimates*
- Are Not:

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The Limits of Modeling

- Theoretical:
  - Inherently counterfactual, but can still be *wrong*
  - "A Slightly Wrong Universe"
  - Balancing complexity and tractability
- Practical:
  - Can be extremely data intensive
  - Stepping outside of data means you're not supported by data
    - It's easy to elide or obfuscate this in a model

The Value of Theory

- Epidemiology is a “theory-light” field
- This is not inherently a good thing
- Lose the ability to make general statements about categories of problems
- Not every problem is entirely unique, but we commonly treat them like they are

- If you can build a model of a system and express its behaviors and outcomes, you can start asking questions that go beyond what data you can measure
- You can use basic physics to describe an egg being dropped from my hand and hitting the ground
  - $K=1/2mv^2$, the force needed to break an egg, etc.
- Once you have this model, you can predict, without needing to do the experiment:
  - What will happen if Kobe Bryant drops the egg
  - If I (or Kobe…) drop the egg on a planet with twice the gravity of Earth
  - If I drop an egg from a genetically engineered chicken with a 25% stronger shell

On “All Models are Wrong”

- This quote is correct, but not the whole story
- The end of the quote is “…but some models are useful.”
- We use incorrect models every day to make decisions
- You can all tell me what would happen if I dropped a raw egg onto the floor
  - All of those answers would be wrong
  - There has never been an extensive empirical study of chicken eggs dropped from Eric’s Arm Height onto the floor of Allen Center 301
  - And yet, none of you are going to urge me to do it…

Other Quotes

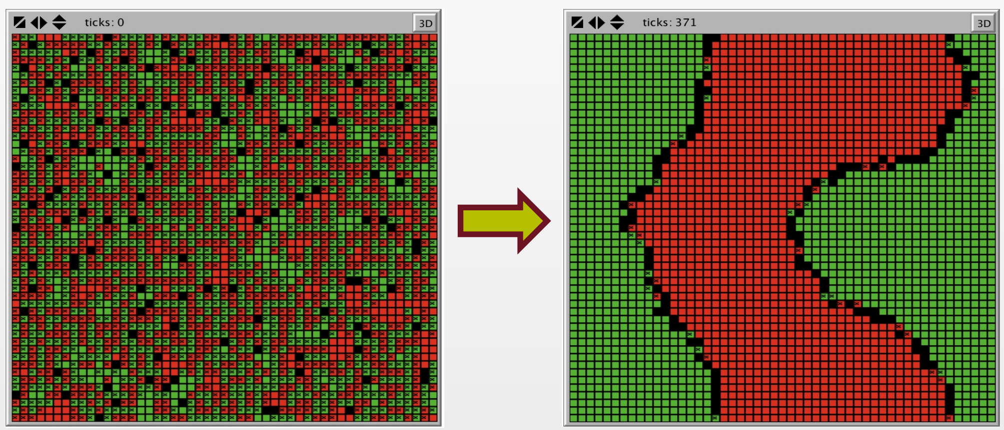
- “A model is a lie that helps you see the truth.” – Howard Skipper
- “Data do not speak for themselves - they need context, and they need skeptical evaluation.” – Allen Wilcox
- “It is inappropriate to be concerned about mice when there are tigers abroad.” – George Box

Systems Thinking

- Modeling requires "systems thinking", but systems thinking can be useful outside just modeling
- "So, what is a system? A system is a set of things—people, cells, molecules, or whatever—interconnected in such a way that they produce their own pattern of behavior over time."
- Systems science is thus logically the study of the complex and dynamic interaction between *things* and the patterns that emerge from their interactions
- Systems can exist at multiple levels – a single sick human contains several systems on the microbiological/cellular level, may be experiencing symptoms on the organ system level, is interacting with other humans through work, relationships, etc., and may exist within a system of healthcare providers, etc.

Schelling Segregation Model

- Remarkably simple model of preference for “like living with like”
- Two types of agent
  - Satisfied if at least *p* percent of neighbors are the same as them
  - Dissatisfied if lower, move to a new vacant location



Segregation without Strong Preferences

p = 0.30

Percent Similar: 74%