# Introduction to Agent-Based Modeling

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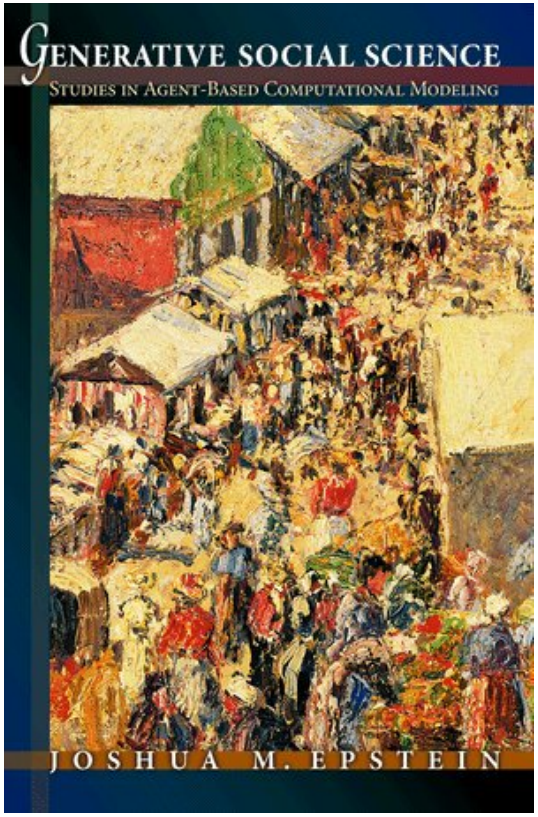
# Outline






ABM resembles French impressionist paintings.

# Systems Thinking

*"A change without a pattern is beyond science."*

Boris Zeide

## System

A "**meaningful**" collection of interacting parts.

## Patterns within real systems

Patterns are encoded in real world. Our purpose is to decode them.

# Complex Systems

*"More is different."*

*P. W. Anderson*

## Emergence

Emergence is the essential reason to study Complex Systems.

- Aggregate properties can not be attained by a simple sum

# Scientific Methodology

*"Simulation is a new way of doing science."*

*Robert Axelrod, 1997*

*"We can now simulate to understand."*

*Uri Wilensky, 2016*

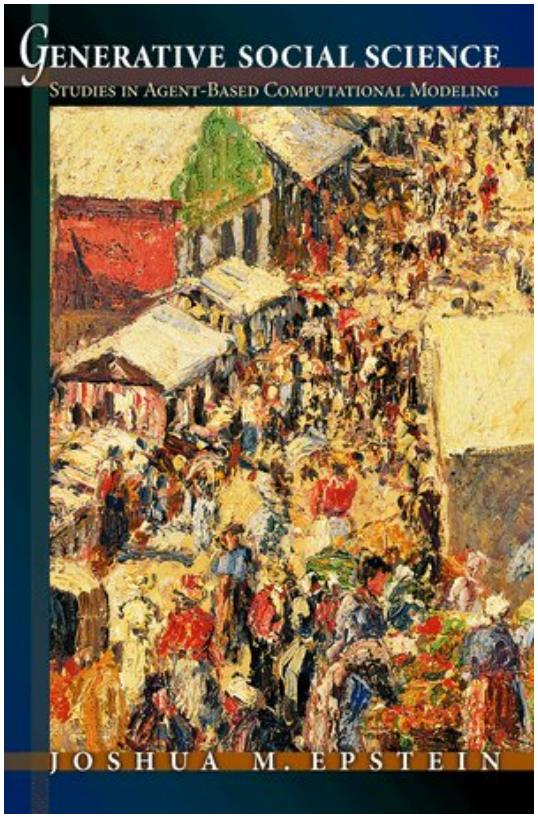
# Agent-based modeling (ABM)

## ABM perspective

ABM provides us a new way of thinking perspective (model) on how modeling should be done.

- multi-layered view
- bottom-up

Simple rules and properties at the micro-level can generate complex behavior at the macro-level.



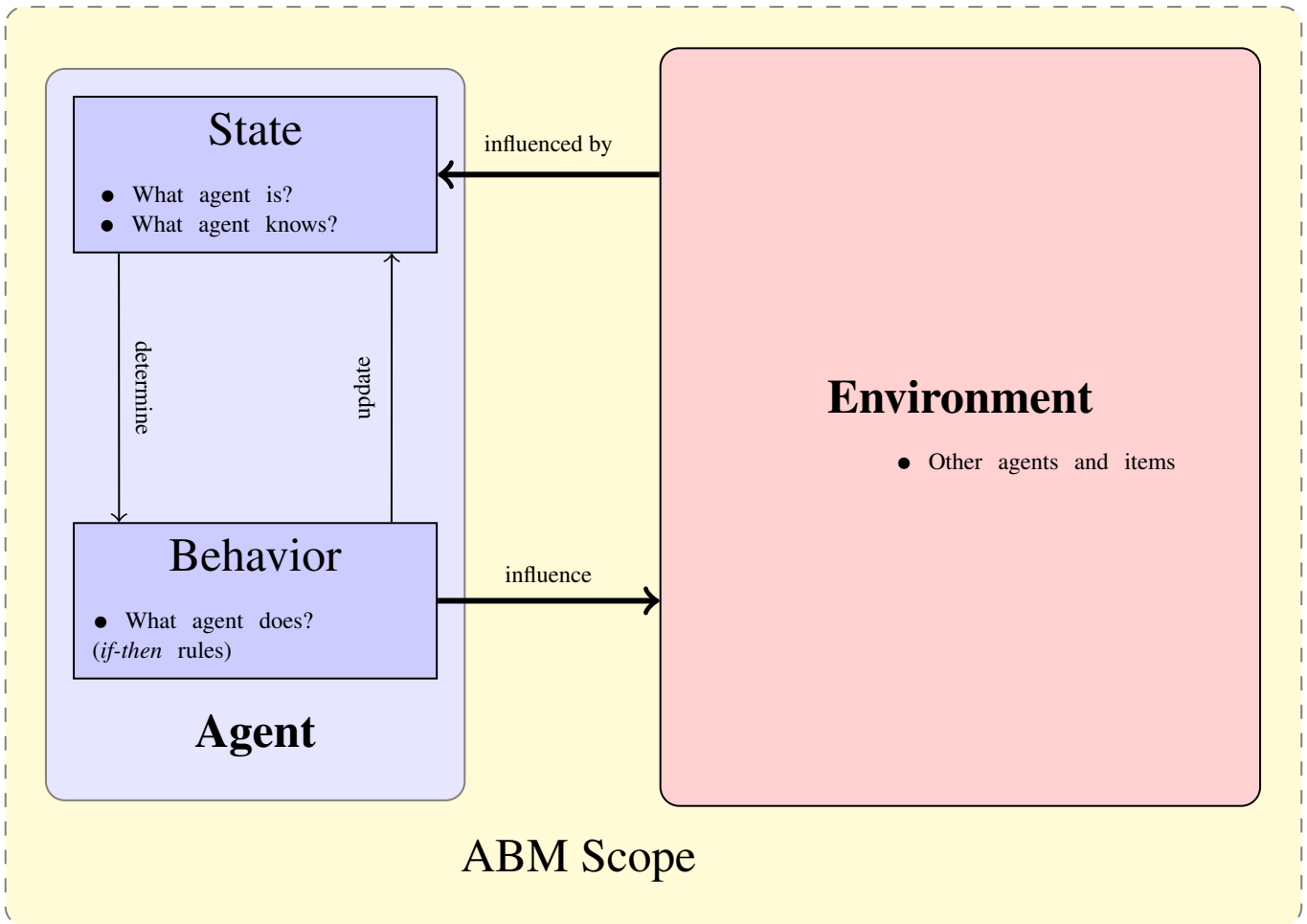

ABM resembles French impressionist paintings.

# Agent-based models

## An agent is a *autonomous* computational unit

- Autonomy in decision making
- Distinctive properties (heterogeneity)
- A set of rules to follow (conditional *if-then* rules)
- Clear goal (rationality)
- Limited knowledge and capacities (Bounded rationality)
- Reactivity or Pro-activity
- Social Skills - Sociability
- Embeddedness in a pyhsical of conceptual space.
- Adaptive behavior to environment.
- and so on.

# A Simple Agent



# Generative Social Science

## The Generativist's Experiment

Given some macroscopic explanandum - a regularity to be explained

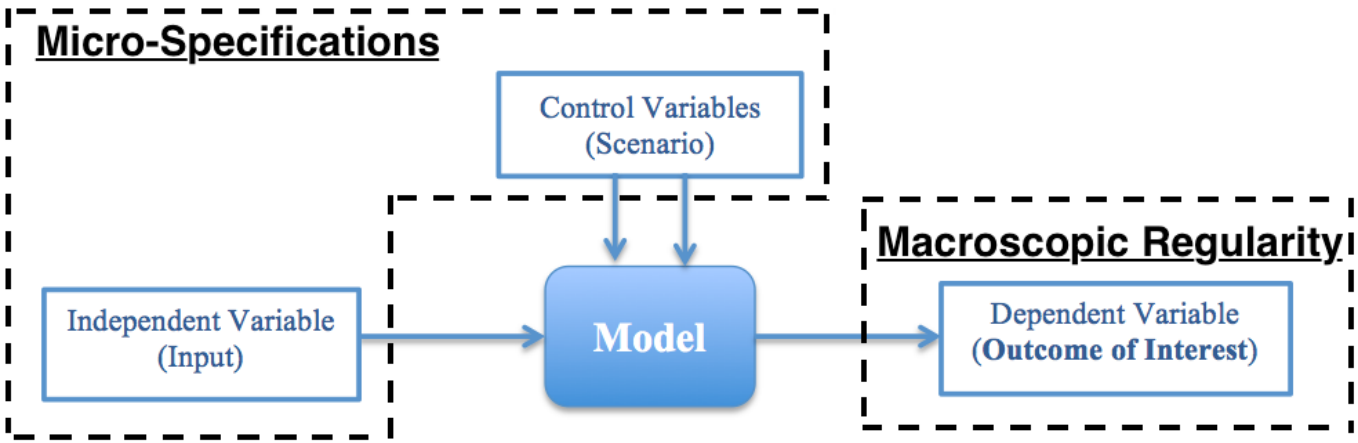
- Situate an initial population of autonomous heterogeneous agents in a relevant spatial environment; allow them to interact according to simple local rules, and thereby generate—or "grow"—the macroscopic regularity from the bottom up.

## The Generativist's Motto

If you didn't grow it, you didn't explain its emergence.

# Generative Social Science

Are the given microspecifications sufficient to generate a macrostructure of interest?




## Micro-to-macro mapping

We get macro-surprises despite complete micro-knowledge.

# Model

## Reality

A real system is unknown, due to its infinitely many dimensions.

## Definition of a Model

Simplified representation of some selected aspects of a real system, w.r.t a clearly stated problem.

## Modeling

Like stone carving we remove *what we regard as* unneceassary, and like cartooning, we exaggerate *what we regard as* important.

# Modeling is more art than science.

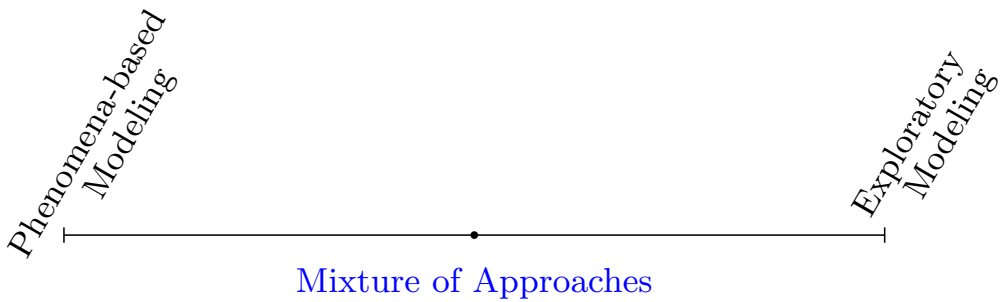
*"Things should be as simple as possible but not simpler."*

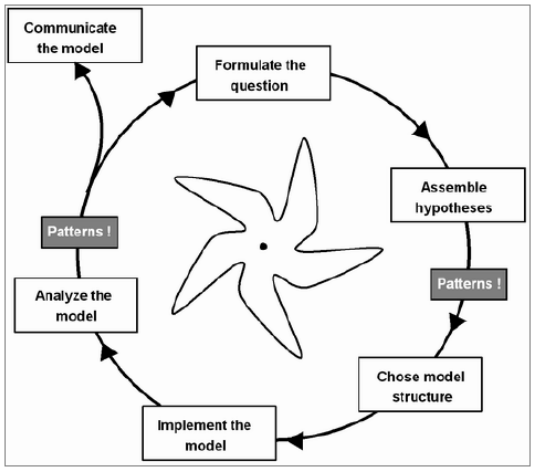
Albert Einstein

## Abstraction

- Scope reduction: What to include
- Detail reduction: How to include

# Two Modeling Approaches




Grimm's Modeling Cycle

## Modeling starts with

- an observation of a macro-phenomenon (top-down) or
- micro-specifications of agents (bottom-up)

To count as modeling, aggregate behavior of the model (output) correspond to a real macro-phenomena.

# Verification and Validation

## Verification

Correctness of the code

- debugging, unit tests etc..

## Validation

Usefulness of the model

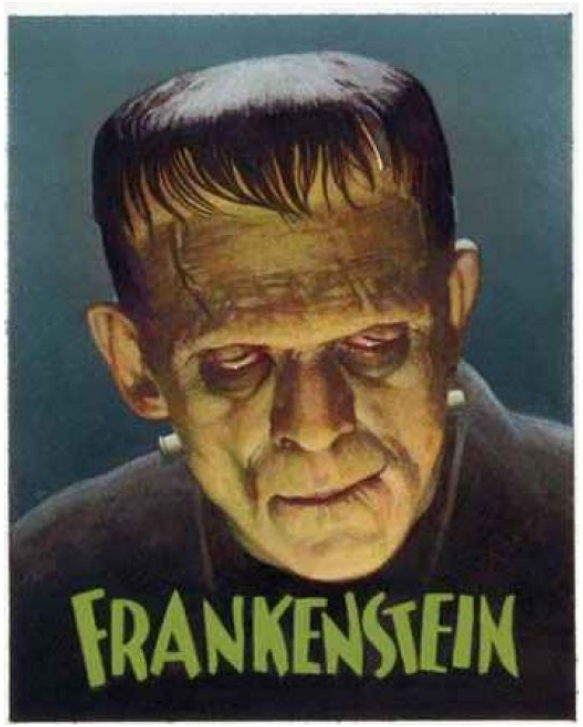
- Face Validation - qualitative agreement between the model output and reality
- Emprical Validation - quantitative agreement

There can not be such thing as general validity.

# Analysing a Model

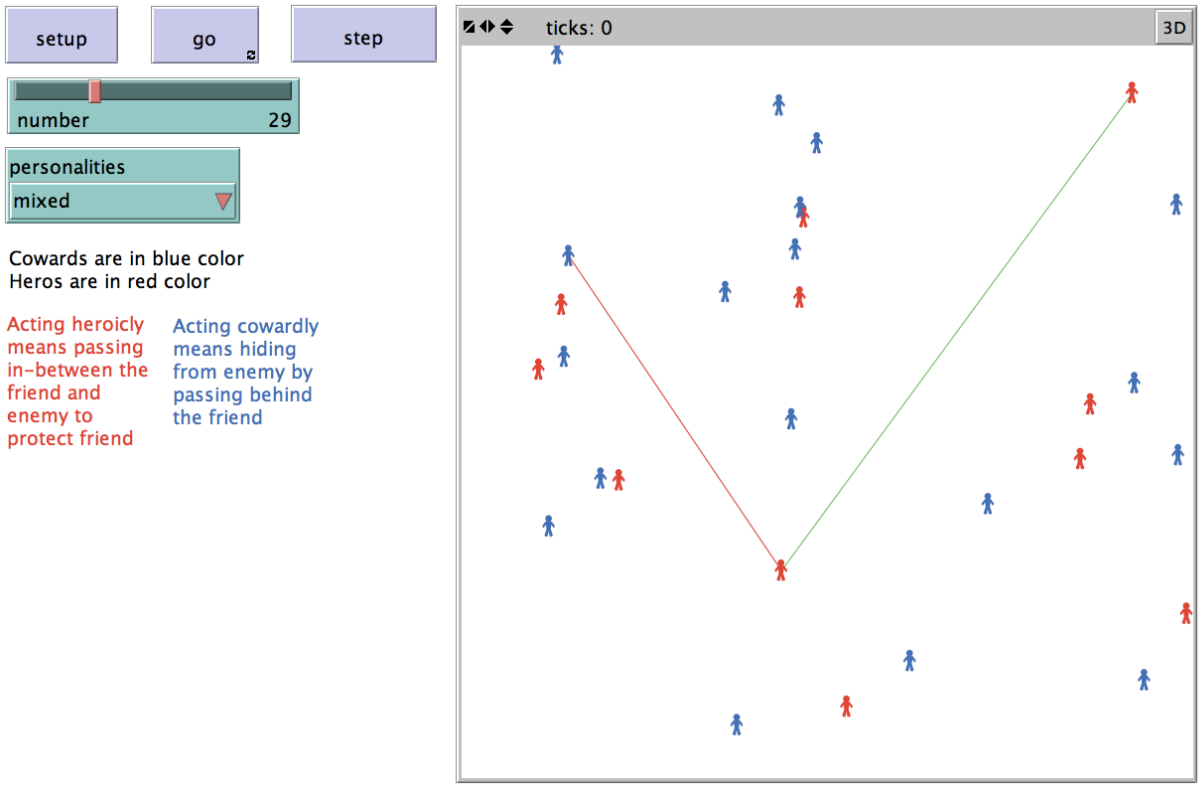
Creating a model and understanding what it actually does are completely different things.

Analysing a model takes %90 of the scientific efforts.




Frankenstein

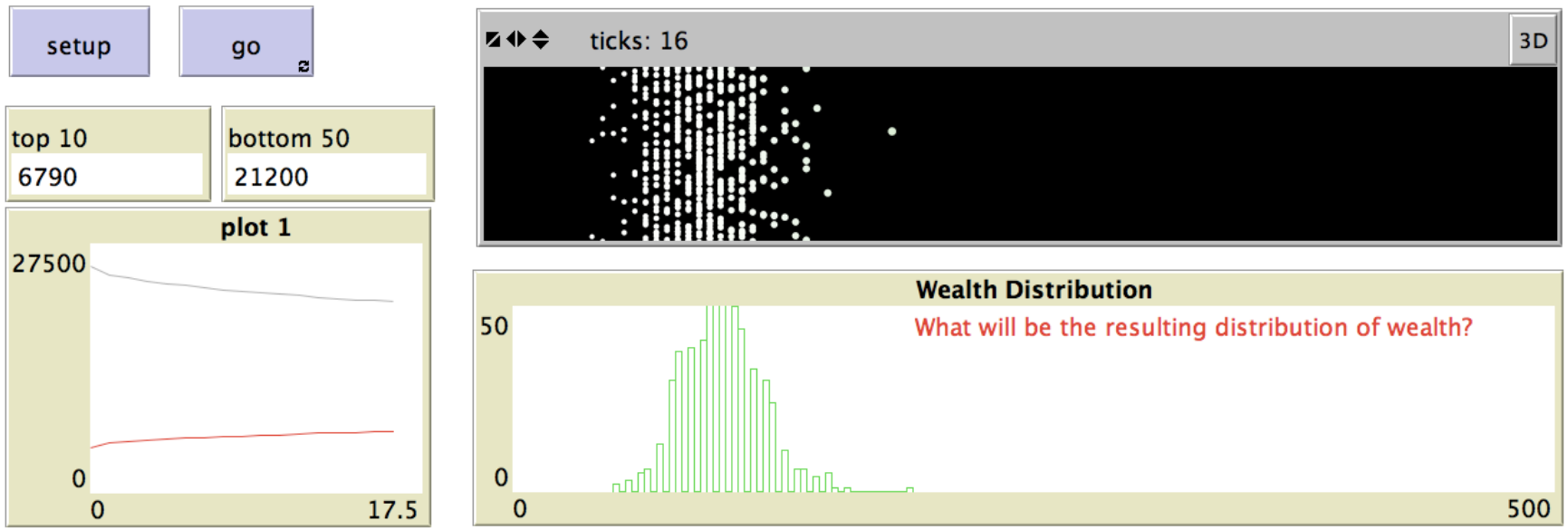
# Cowards and Heros




Exploration : What patterns will emerge?

- Even very simple rules can generate hard-to-predict complex behavior.

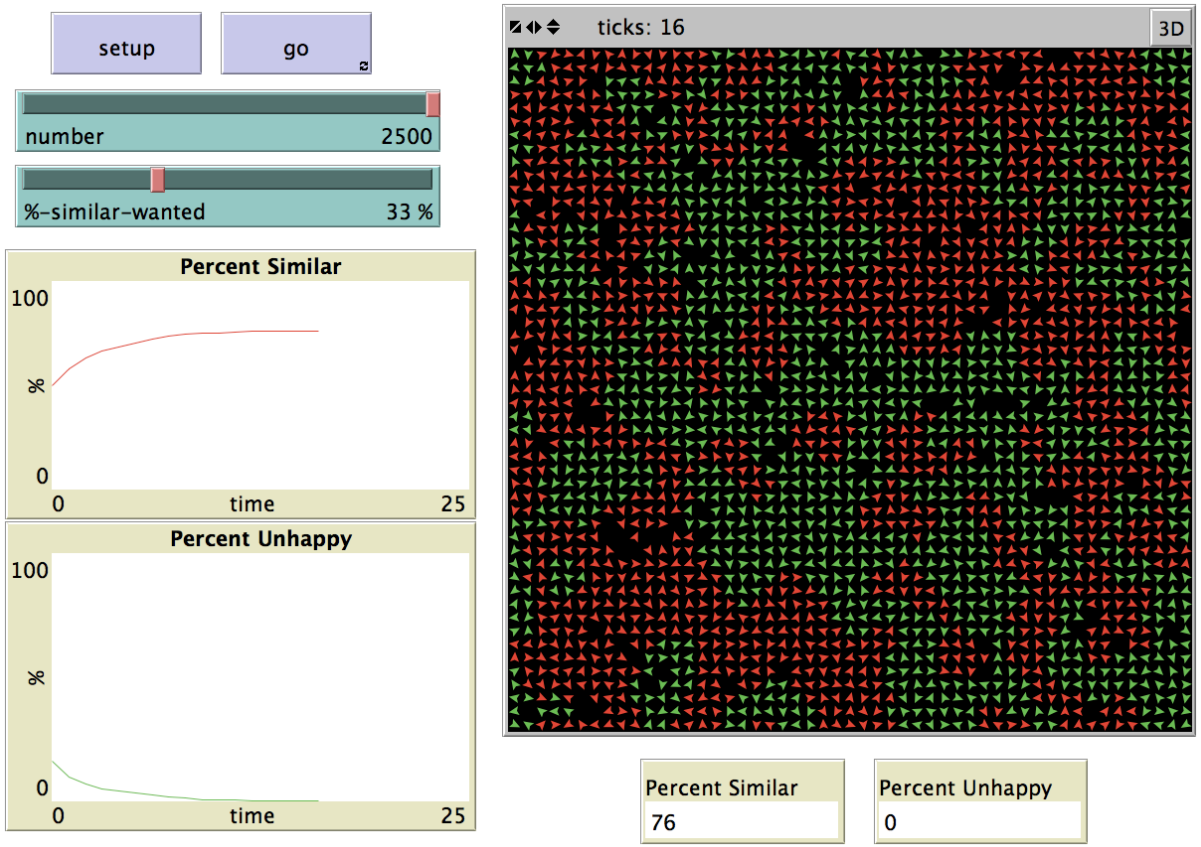
# Simple Economy




Each agent starts with 500$. At each tick, agents with non-zero wealth gives 1$ to a random agent.
Agent's xcor is their "wealth" in the black grid.

Counter-intuitively, it goes to an exponential distribuiton (great inequality in wealth)

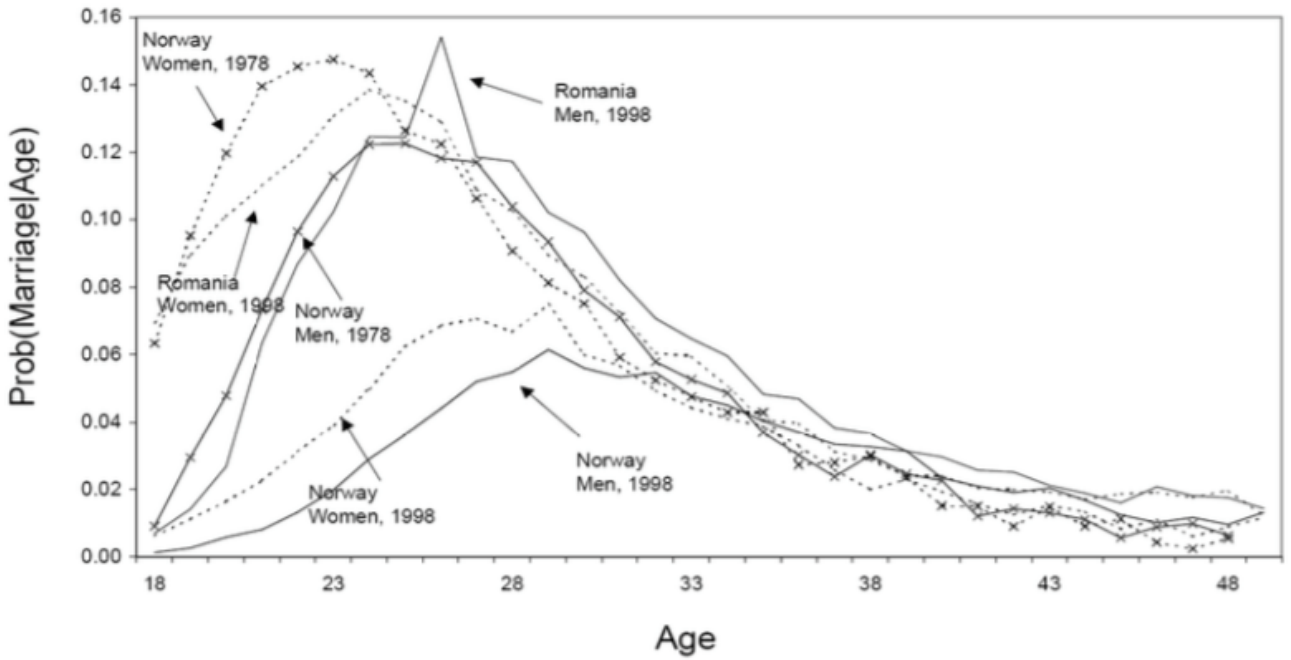
# Seggregation Model




Thomas Schelling took a more exploratory approach (1971).

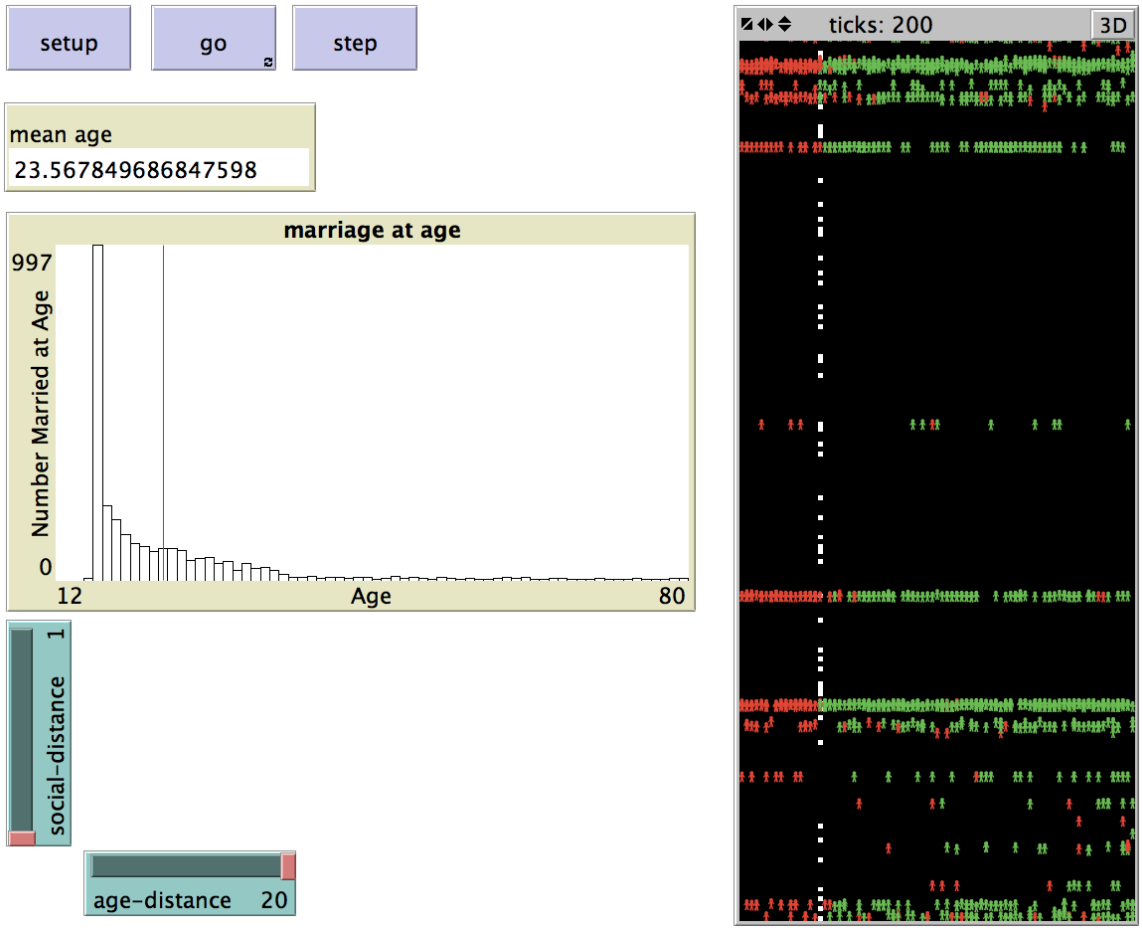
- Even very weak prejudice can create the dynamics of segregation.
- Micro-motives and macro-behavior can fail to align.

# Age-at-Marriage Model




The "Wedding Ring" Article

# Age-at-Marriage Model




- More married friend in one's social surroundings, more likely to get married.
- Social surrounding is given by the rectangle with social distance and age distance

# Prey-predator Model

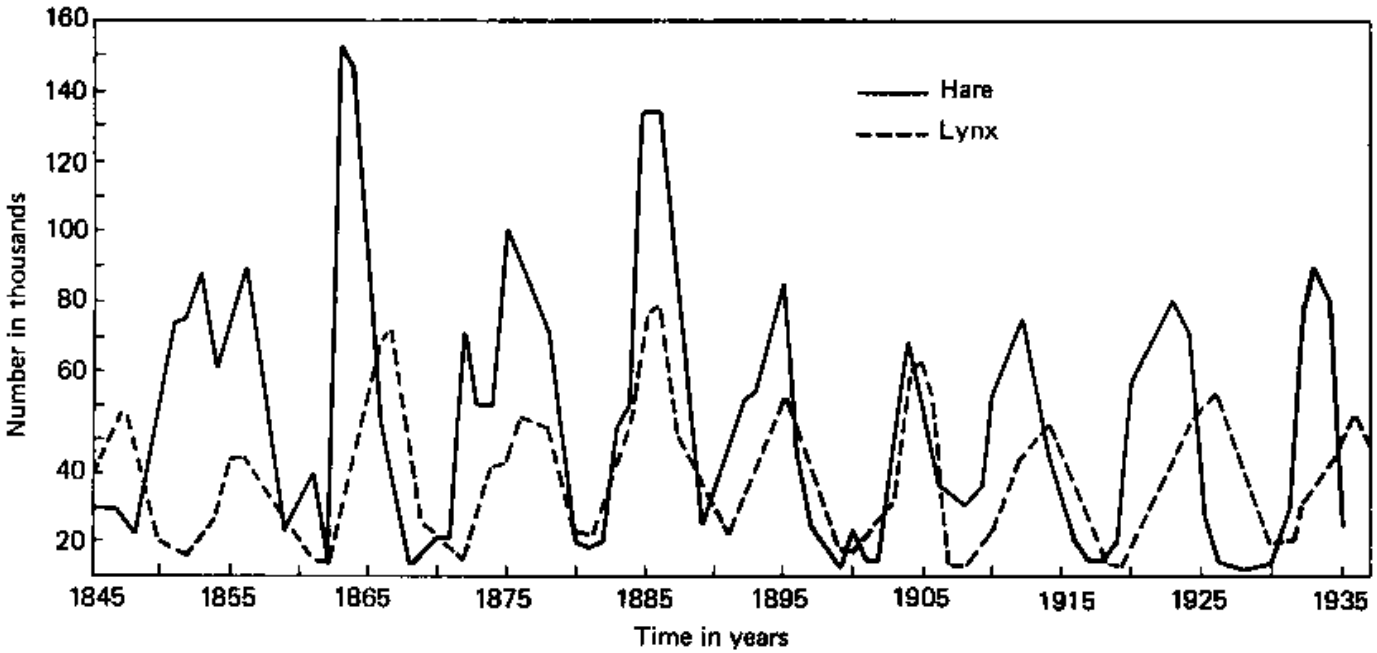
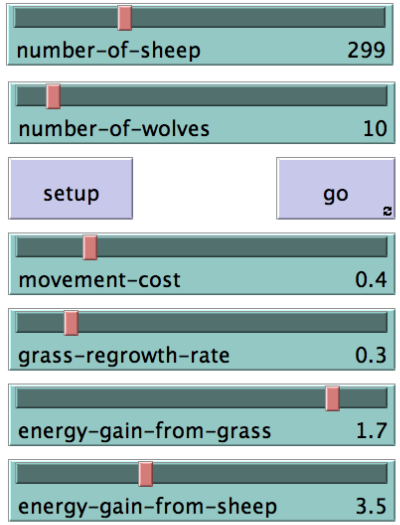
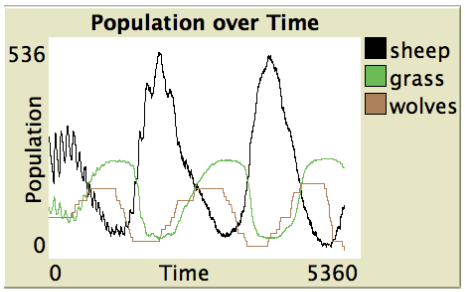


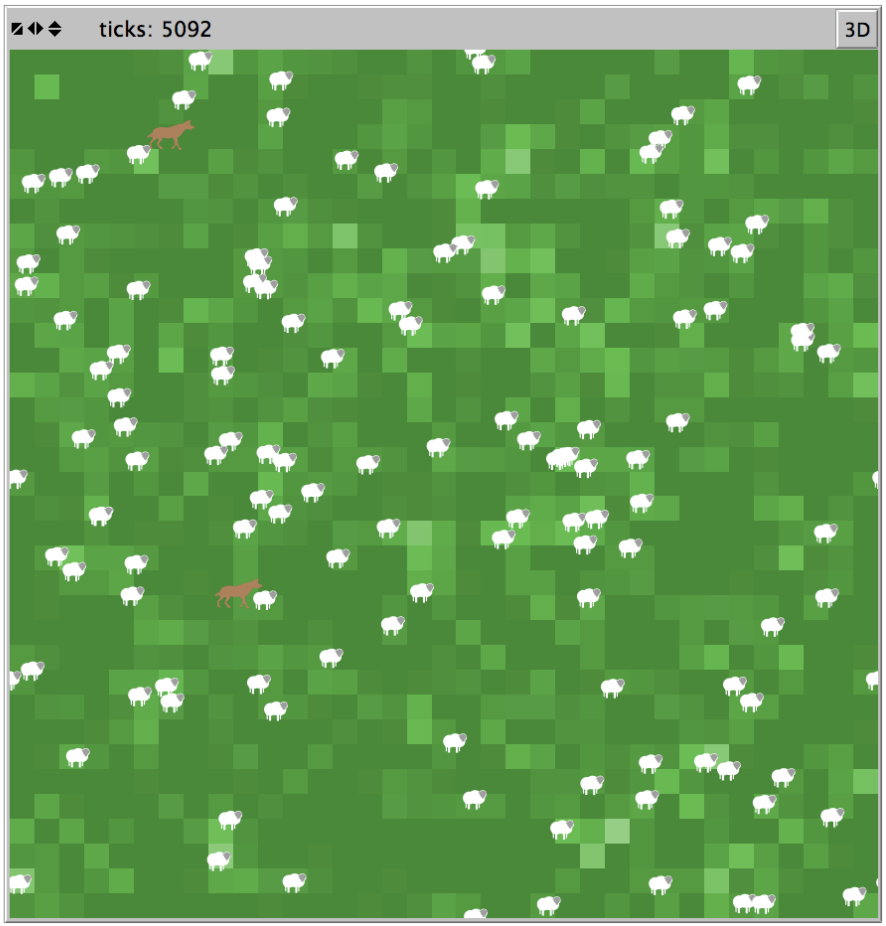

**Figure 9-3.** Changes in the abundance of the lynx and the snowshoe hare, as indicated by the number of pelts received by the Hudson's Bay Company. This is a classic case of cyclic oscillation in population density. (Redrawn from MacLulich 1937.)

Prey-predator dynamics

# Prey-predator Model



# Model

*"All models are wrong, but some are useful."*

*George Box.*

*"Art is a lie that helps us see the truth."*

*Picasso*

# ODD Protocol for ABM

## Remark: ODD and NetLogo match well

| | Elements of the updated ODD protocol | NetLogo elements |
|---|---|---|
| Over-view | 1. Purpose | Information tab |
| | 2. Entities, state variables, and scales | breeds, turtles-own, patches-own, globals |
| | 3. Process overview and scheduling | "go" procedure |
| Design concepts | 4. Design concepts<br>• Emergence<br>• Adaptation/Adaptive traits?<br>• Objectives<br>• Learning<br>• Prediction<br>• Sensing<br>• Interaction<br>• Stochasticity<br>• Collectives<br>• Observation | • Information tab<br>• primitives<br>• plots, monitors, agent monitors, file output |
| Details | 5. Initialization | "setup" procedure |
| | 6. Input data | file input |
| | 7. Submodels | procedures, reporters |

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A comprehensive checklist for doing ABM.

(Overview, Design concepts, and Details) ODD, Volker Grimm's Talk

# Ideal Multi-disciplinary Research Environment for ABM

Ideal ABM require interdisciplinary research.

- *Purpose* - Social scientist, ecologist or etc.
- *Programming* - Computer Scientist
- *Analysis* - Statistician

# References

## Generative Social Science


- Epstein, J. M., Agent-based computational models and generative social science", Complexity, Vol. 4, No. 5, pp. 41-60, 1999.


## Netlogo Models


- Wilensky, U. and W. Rand, An Introduction to Agent-Based Modeling, The MIT Press, 2015.
- Billari, F., et al. "The Wedding-Ring: An agent-based marriage model based on social interaction", Demographic Research, Vol. 17, No. 3, pp. 59-82, 2007,


## ODD protocol


- Grimm, V. et al. (2010). The ODD protocol: a review and first update. Ecological modelling, 221(23), 2760-2768.