Agent-based modeling and potential application to Scientific Workforce Diversity

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Overview

- Introduction to the agent-based modeling approach
- Two quick examples:
  - Public Health (cigarette smoking)
  - Anthropology (“Artificial Anasazi”)
- Potential application to modeling Diversity?

Agent-Based Models

- Instantiate population of individuals, “agents”, with plausible adaptive rules for interaction with each other and with the (possibly changing) environment
- Agents can be at any (or multiple) levels of aggregation
- Place agents in a spatial context, specify starting conditions
- Simulate from the “bottom up”, generally stochastically

Traditional Mathematical Modeling Approaches

- Homogeneity (“representative agent”)
- Random mixing (no structure or space)
- Equilibrium (no dynamics, or very simple)
- No feedback, learning or adaptation
- “Strong” rationality
- Straightforward aggregation from micro to macro phenomena, focus at one level of analysis

Potential Advantages of Agent-Based Computational Approach

- **Homogeneity** (“representative agent”)
  - No representative agent, homogeneous pools, or aggregation required
  - Every individual explicitly represented, with *diversity* in: demography, wealth, network, goals, decision-making, psychology, physiology, culture
- **Explicit Space, Network structures** (no structure or space)
- **Non-Equilibrium Dynamics** (or very simple)
  - Tipping Phenomena
  - Focus on *mechanisms*

Potential Advantages of Agent-Based Computational Approach (continued)

- **Adaptation, Evolution, Learning can be modeled explicitly**
  - feedback between micro and macro
  - "emergence"
- **"Bounded" Rationality:** Bounded Information, Bounded Computing
- **Multiple levels of analysis, dynamics across levels**

No feedback, learning, or adaptation

"Strong" rationality

Straightforward aggregation from micro to macro phenomena, focus at one level of analysis

Diverse Applications

- Epidemic Dynamics
  - Smallpox, Pandemic flu
- Civil Violence: Revolutions and Ethnic War
- Anthropology: The Anasazi
- Corruption and crime enforcement
- Ethnocentrism, prejudice, and inter-group conflict
- Retirement Decision-making
- Cigarette smoking and peer influence
- Obesity
- Artificial Stock Markets (NASDAQ)
- Demographic Games
- Social Norms

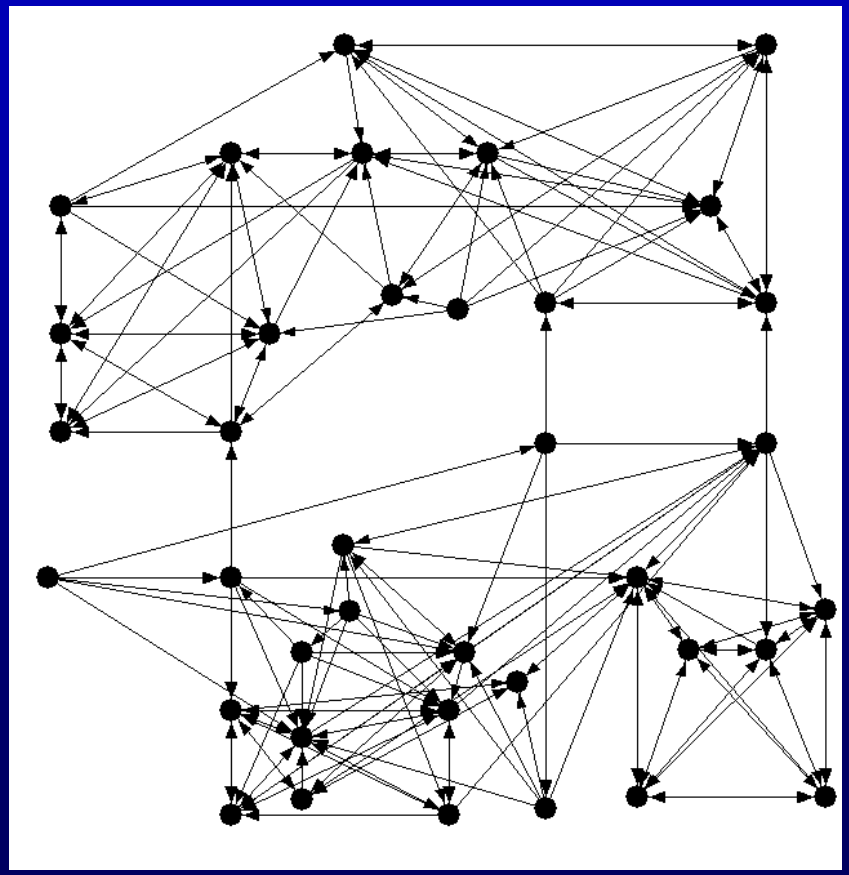
Example 1: Public Health Communication, Social Influence, and Cigarette Smoking

Individual decision function

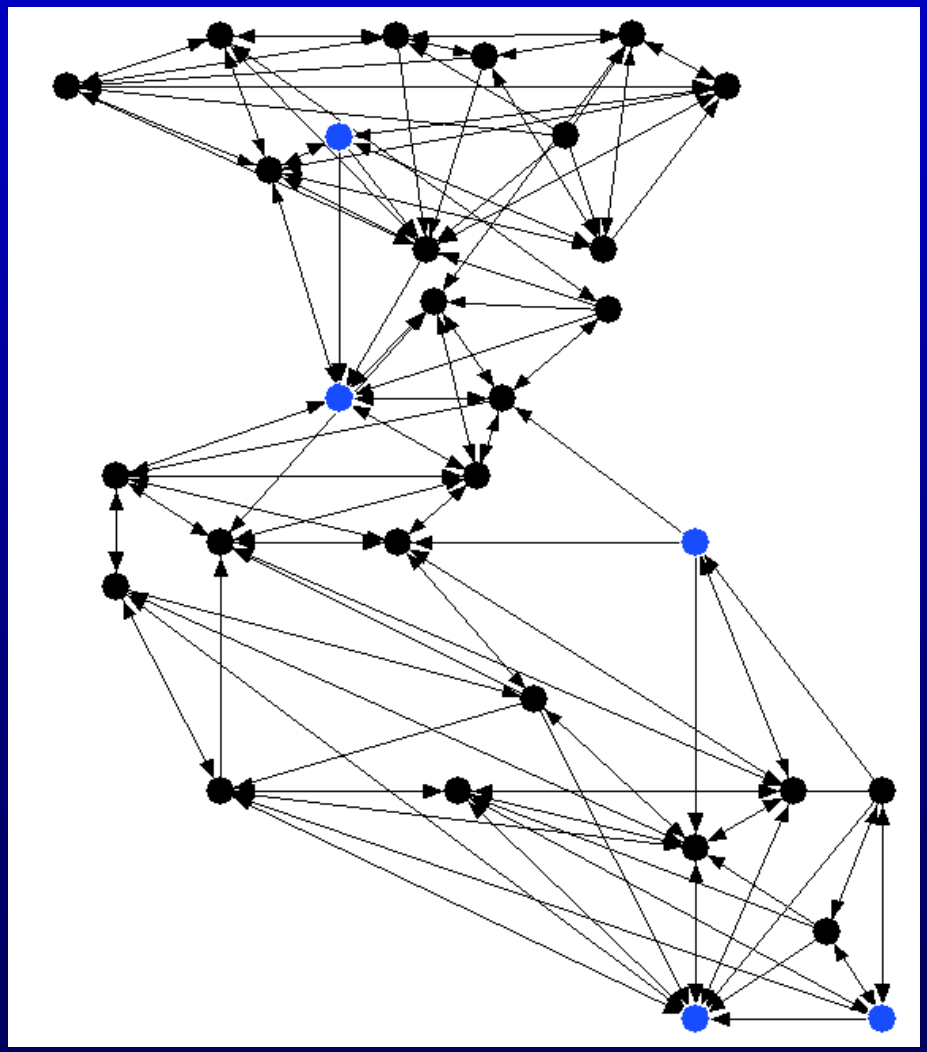
- Biology
  - Addiction Function
- Individual Psychology
  - Reactance, Skepticism
- Realistic Social Influence Networks
  - Weighted
- Information
  - Messages from authorities, media

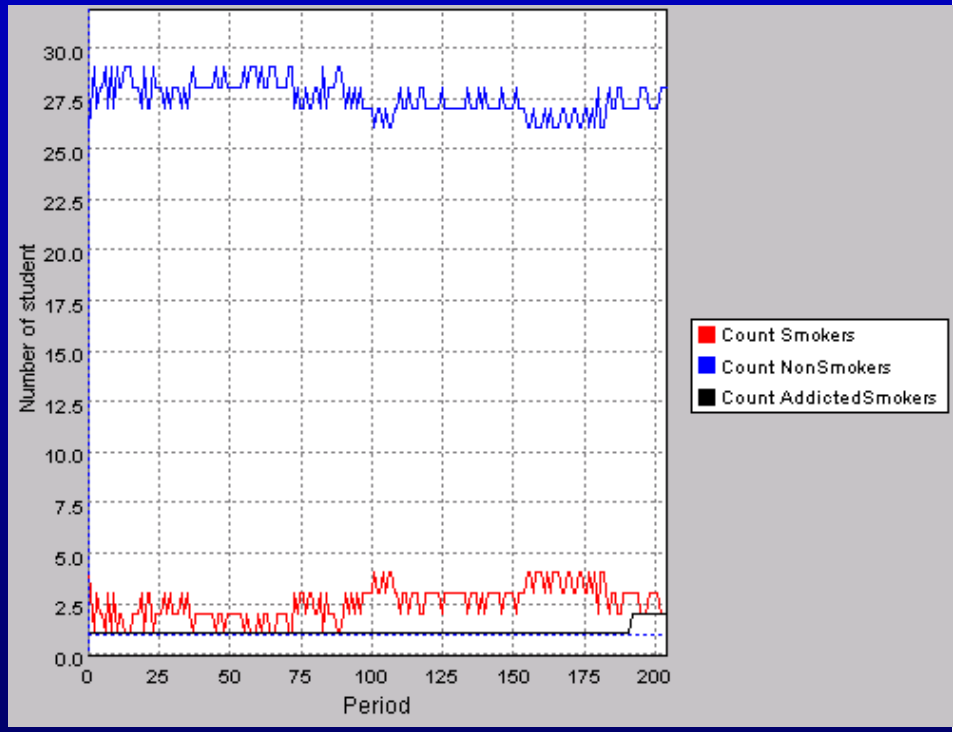
Social networks data

- USC data from large-scale school study
- Know full network for each of 86 classrooms

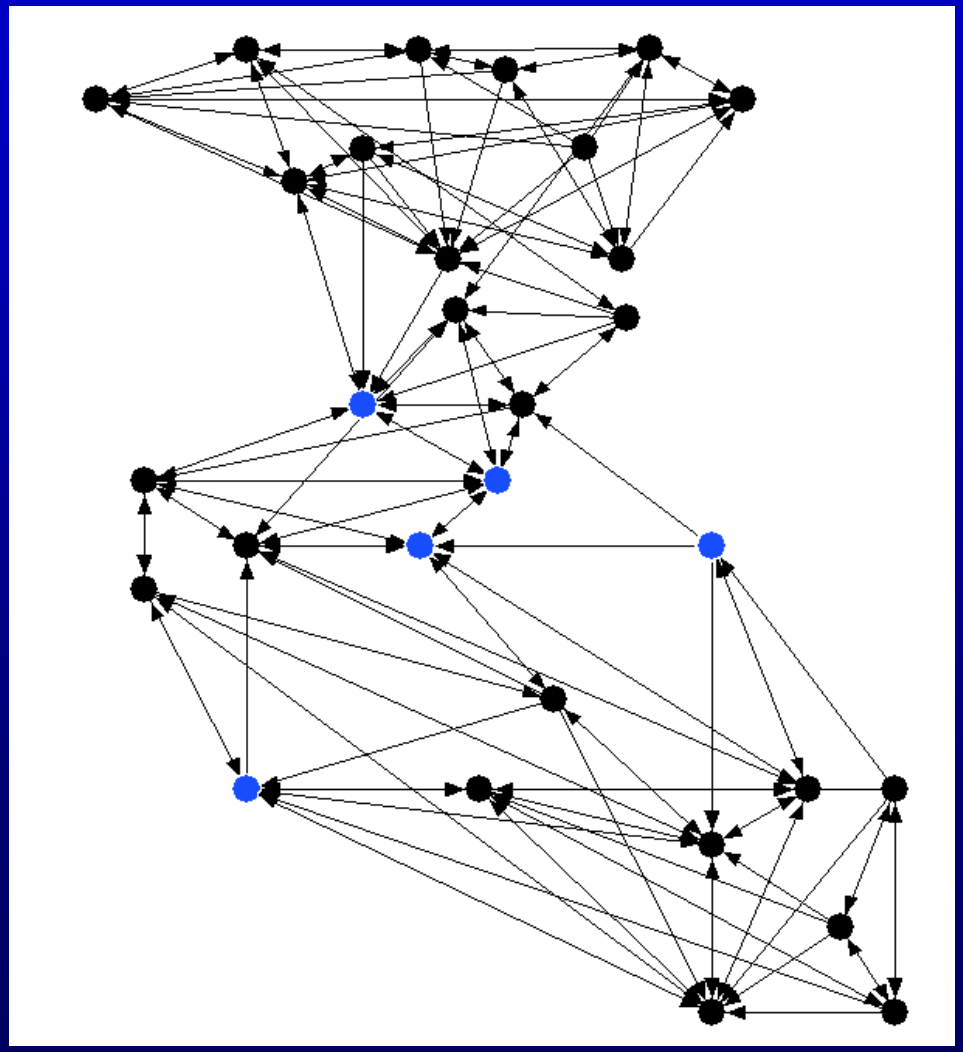


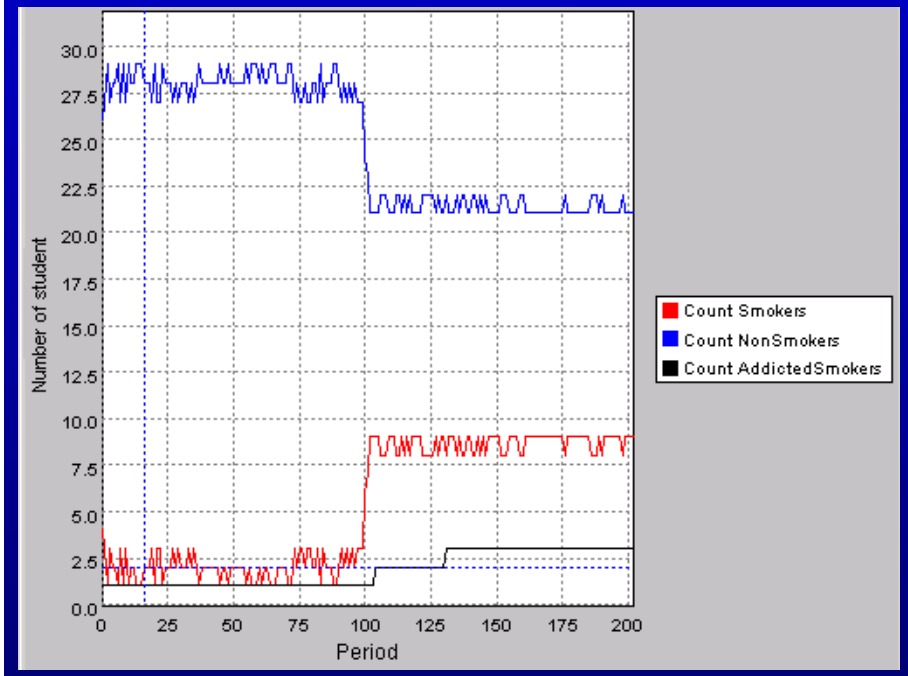
Case 1: Dispersed reactance, Strong message





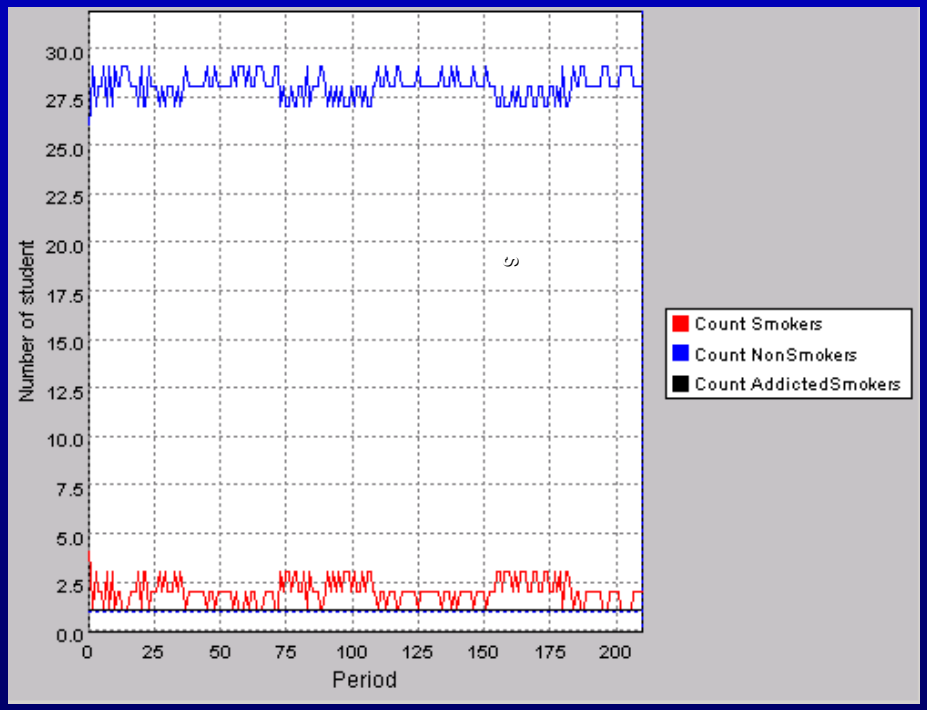
Case 2: Concentrated reactance, Strong Message



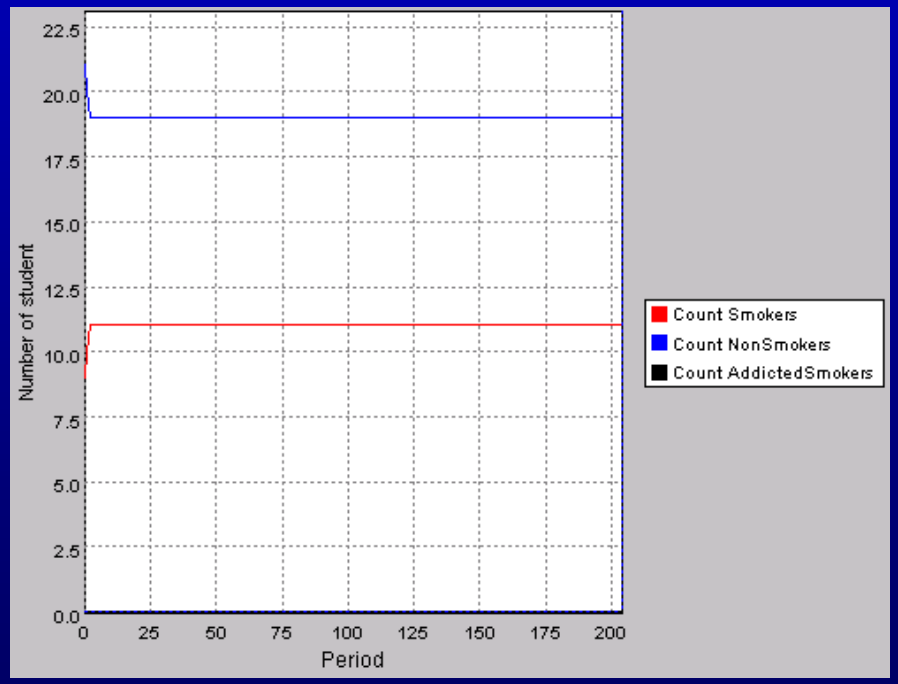


Moderate Message

With concentrated reactance, a weaker message does NOT backfire.



With dispersed reactance (Case 1), this weaker message can be as effective as the extreme one.



Tailored interventions

- Extreme messages can backfire

- Optimal message will vary among communities, and will depend on:

  --network structure (topology and weights),

  --psychological patterns (skepticism, reactance, risk attitudes)

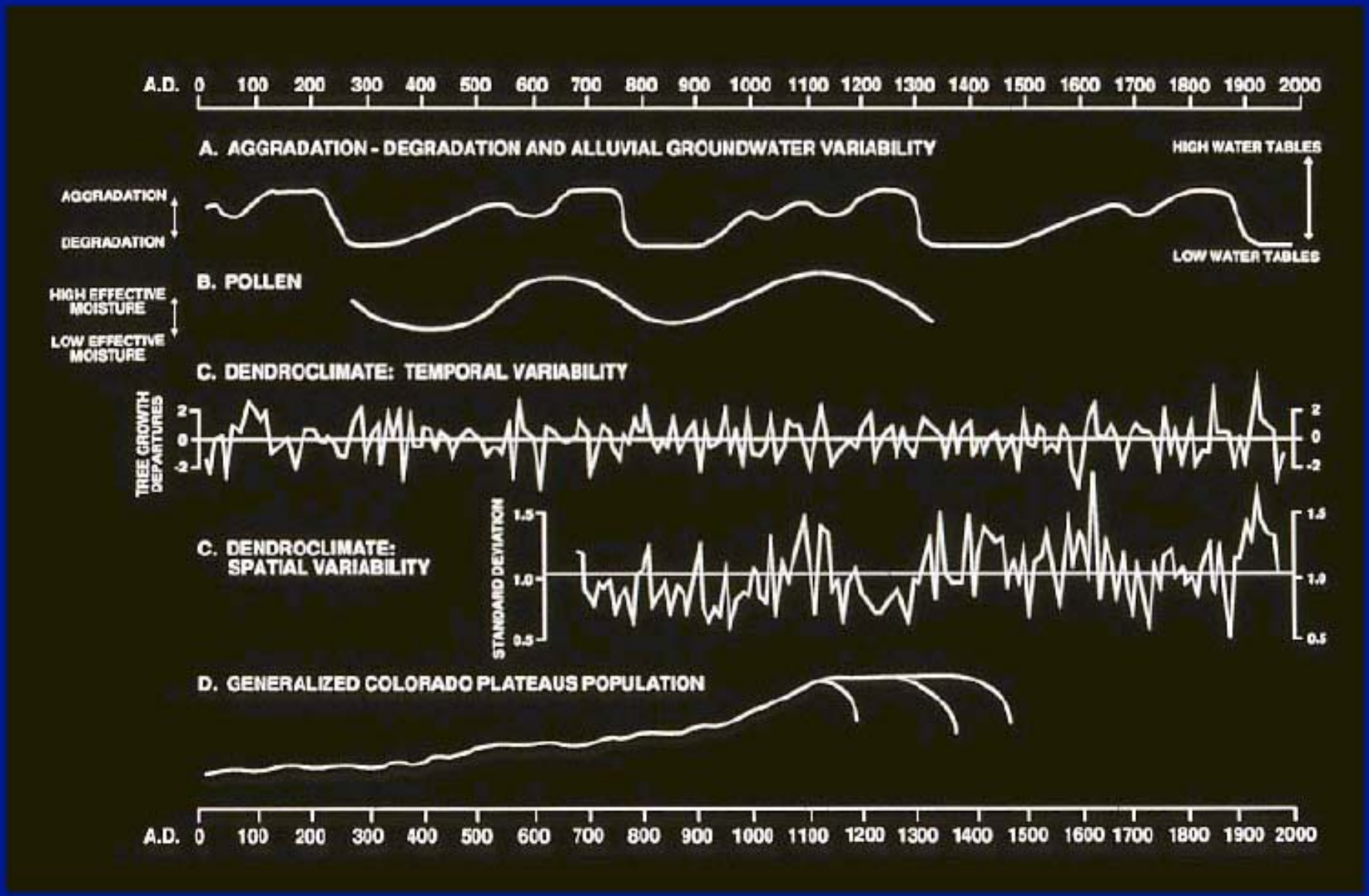
  --biological patterns (addiction functions).

- Hence, optimal messages must be heterogeneous, tailored to specific communities, and adaptive over time.

Example 2: “Artificial” Anthropology

Generating and Explaining The Rise and Fall of a Civilization: The Artificial Anasazi (PNAS, 2002)

- Kayenta Anasazi of Longhouse Valley: 800-1350
- Digitize Actual Environmental and Demographic History
  - Hydrology, Top Soil, Drought Severity, Maize Potential
  - Household Sizes and Locations
- Use an Agent-Based Model to Test Whether Various Micro-specifications (movement, farming, reproduction rules) Suffice to Generate--or “Grow”--the Actual History.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HIGH WATER TABLES
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B. POLLEN
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LOW EFFECTIVE MOISTURE
C. DENDROCLIMATE: TEMPORAL VARIABILITY
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D. GENERALIZED COLORADO PLATEAUS POPULATION
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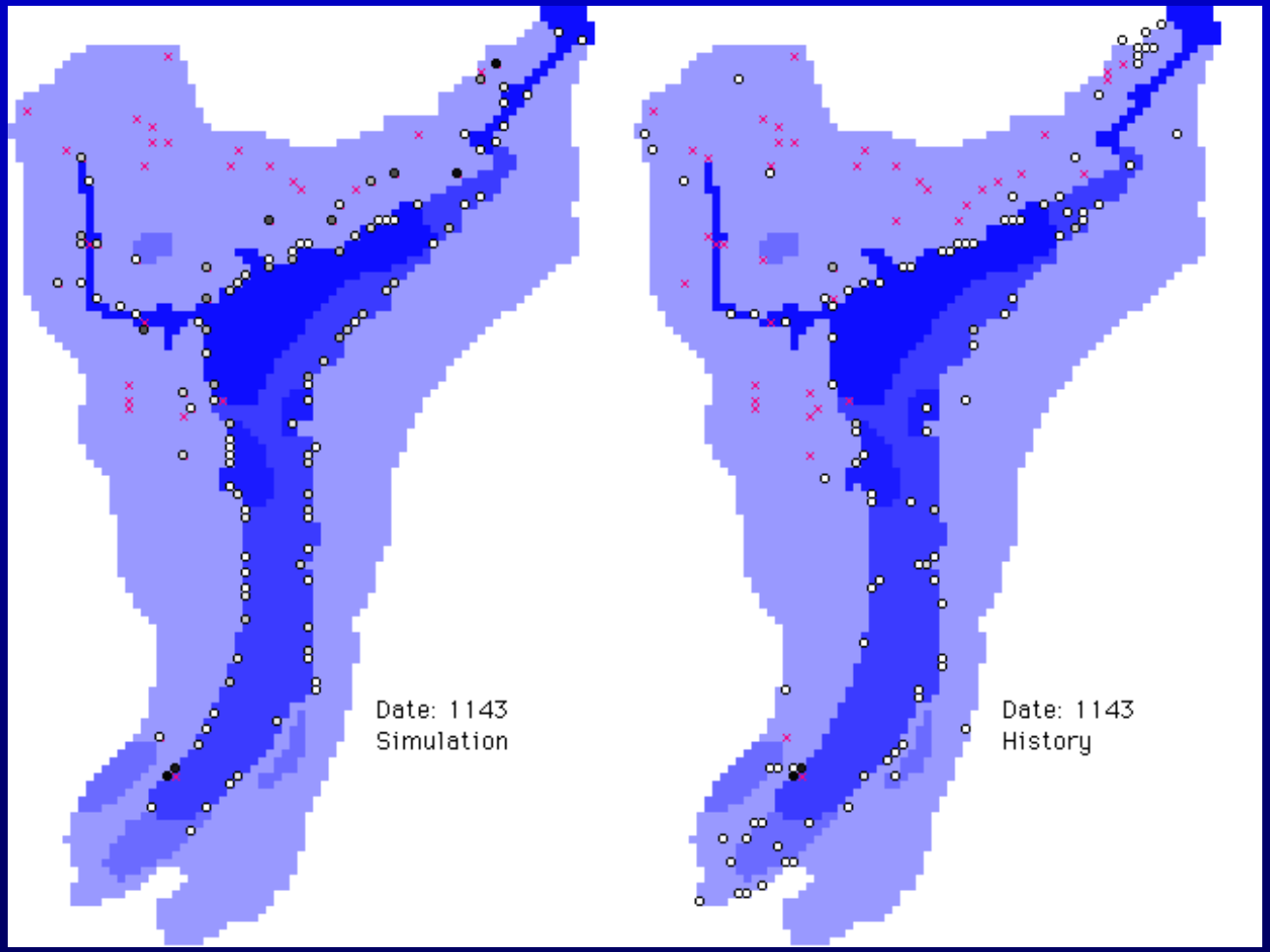
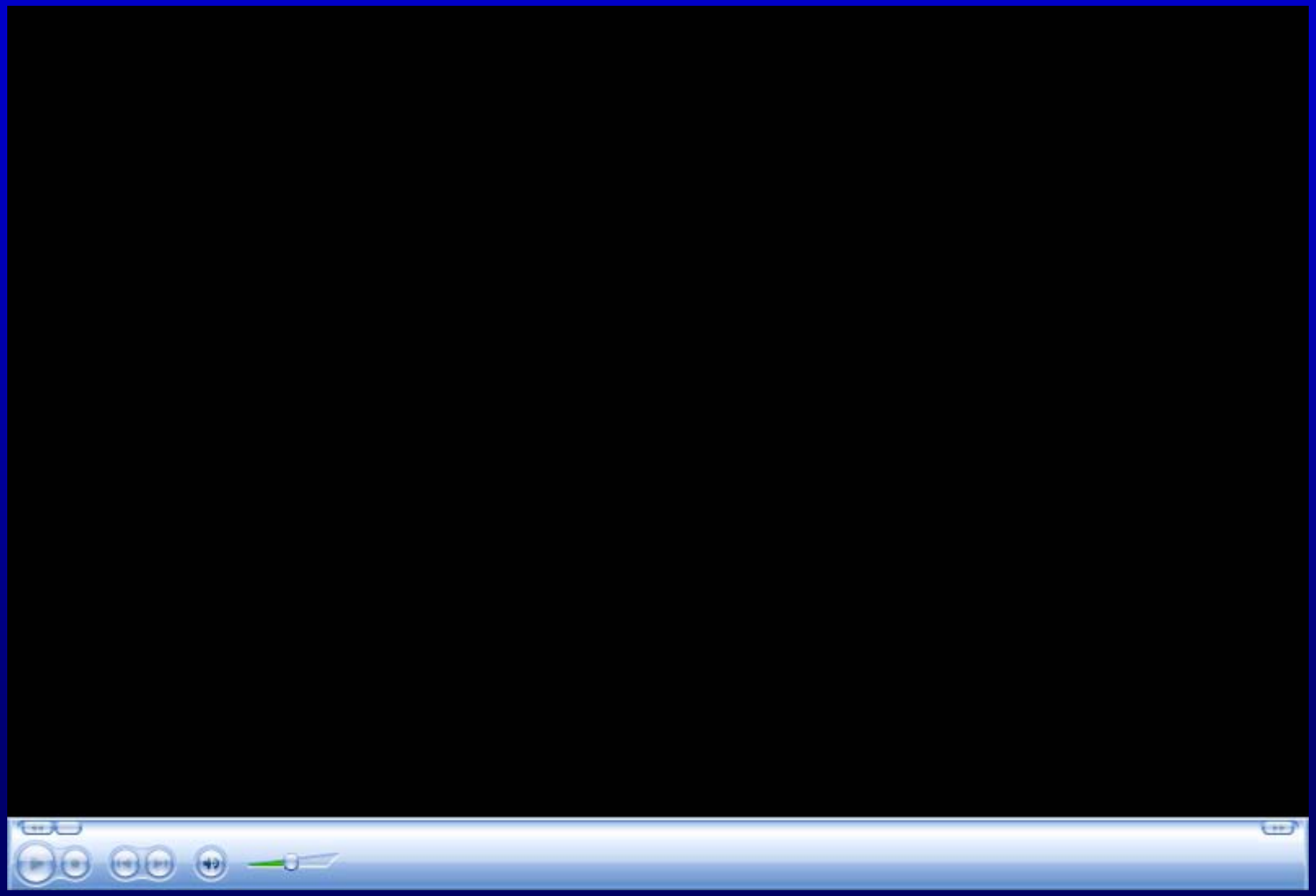
Rules for Artificial Anasazi

- Live within *X* km of your fields (but not in them), and near potable water
- Move after *Y* periods of unsuccessful harvests to a new and sufficiently fertile site (nearby, if available)
- Have offspring once married and nutrit-ionally satisfied with annual probability *P*
- If nutritionally unsatisfied for *Z* years in a row then dead

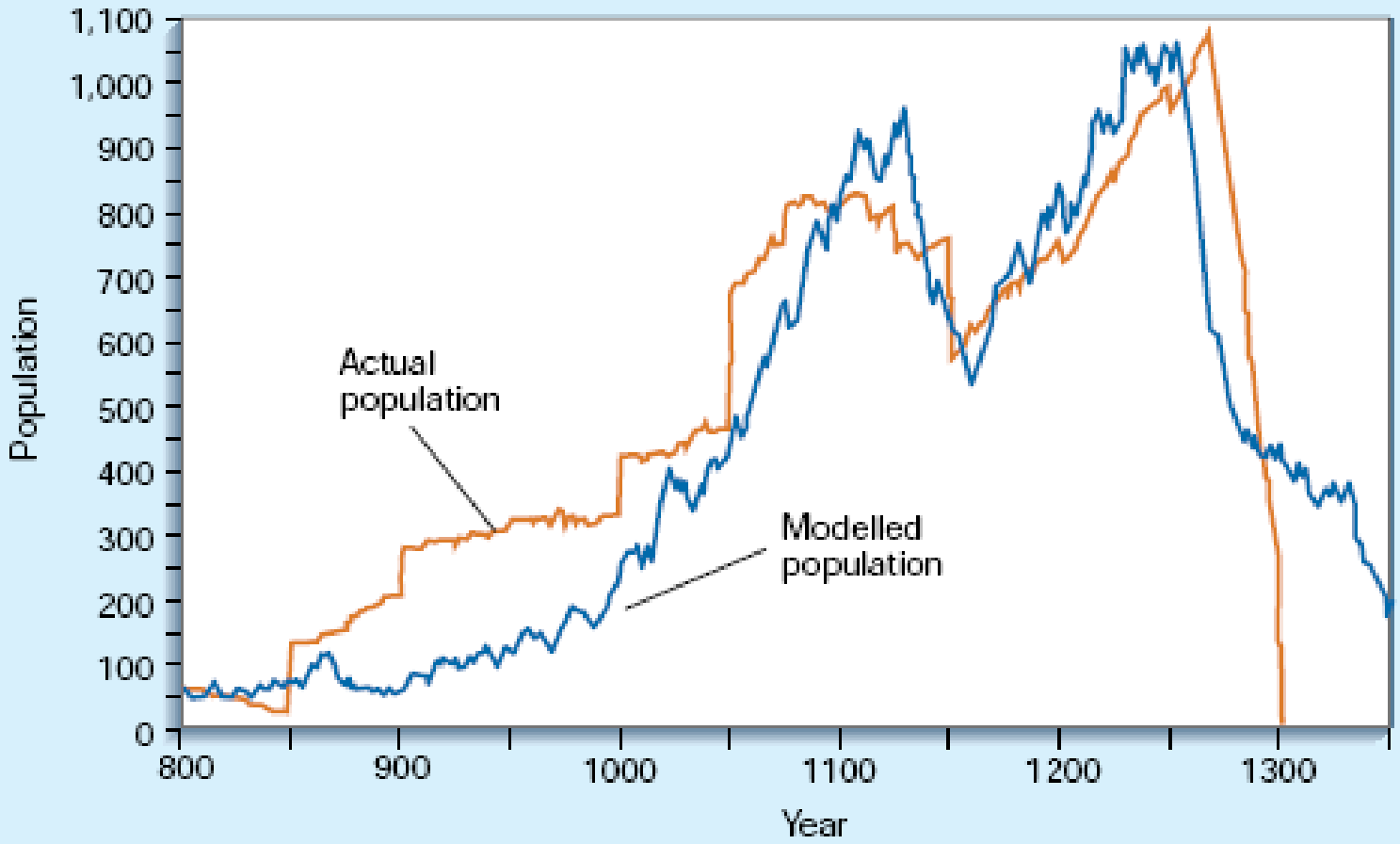
The Artificial Anasazi



The Artificial Anasazi



Population Dynamics: Simulated vs. Historical



Scientific Workforce Diversity – Why Model?

- Many “moving pieces” to consider – social, economic, institutional
- Anecdotes compelling, but hard to extrapolate or generalize. Data more rigorous, but lack of longitudinal or dynamic data. Models can provide compelling, dynamic stories with rigorous translation from micro to macro

Modeling Scientific Workforce Diversity

- “critical mass” – Tipping
- “lag” or delay across generations or even just across cohorts – Dynamics
- Importance of *transitions* between levels in the system
- Diversity in the factors that play a role in decision-making – prospects, debt, social networks, signals
- Many levels of analysis, aggregation: students, peers, families, universities, employers, government

….. Agent-Based Modeling a potentially useful approach?