Models of Social Dynamics
An Introductory Module

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Unit 6:
Cycles

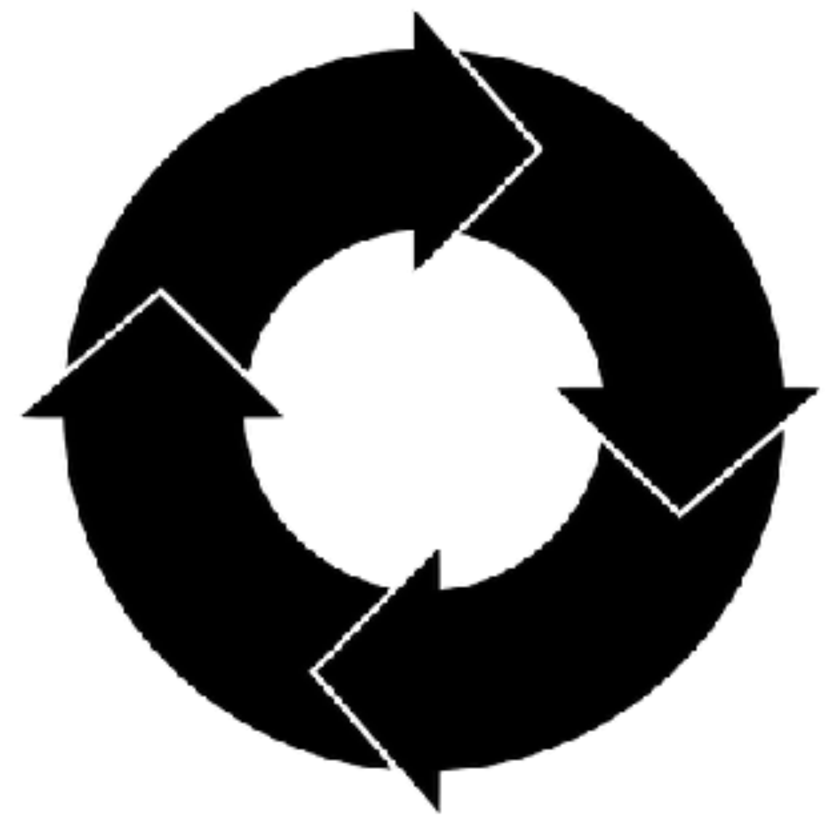
Much of life is cyclical

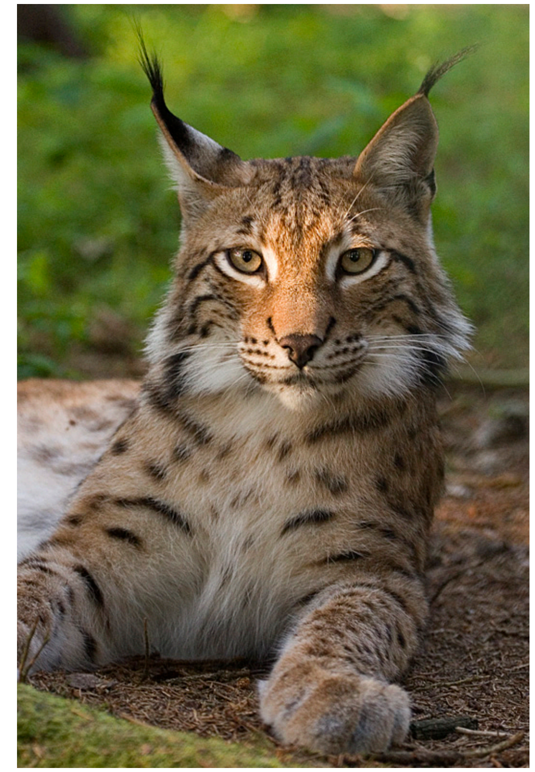
- Most of our models have gone to equilibrium.

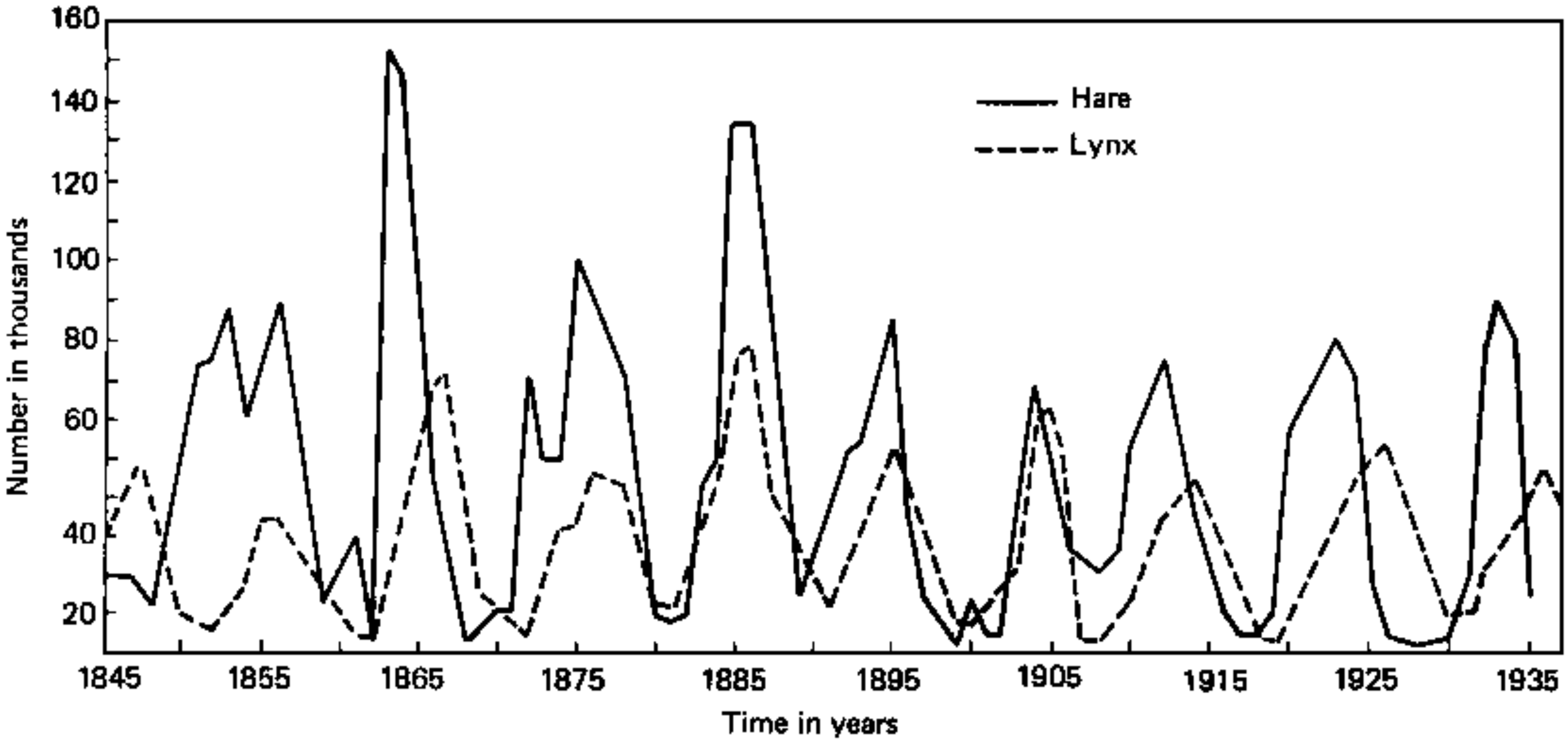
- Much of social life isn't described by equilibria, but by cycles

  A time of war, a time of peace
  A time to dance, a time to mourn
  A time to cast away stones, a time to gather stones together

- Cycles often require **feedback** and **delay**



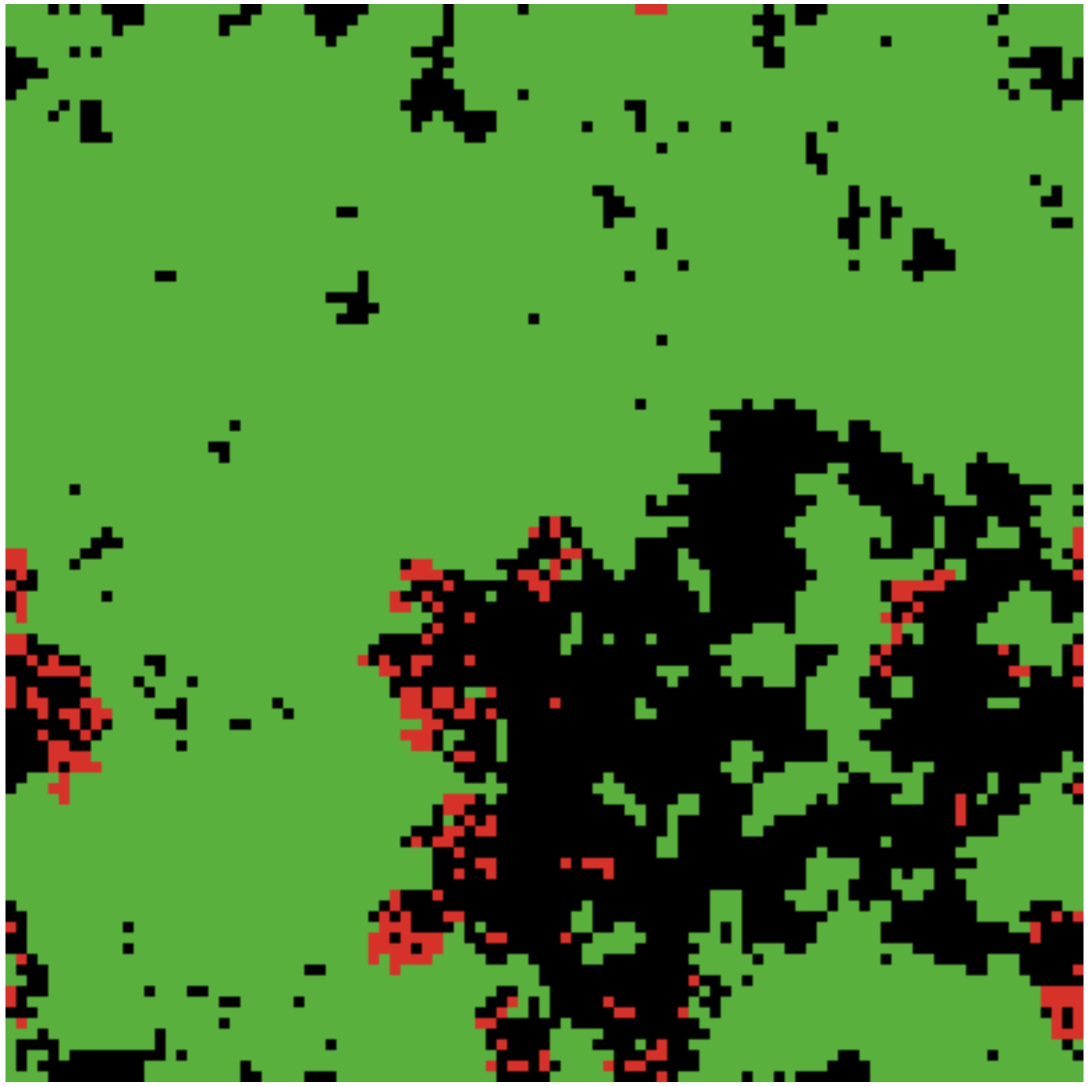



160
140
120
100
80
60
40
20
Number in thousands
Hare
Lynx
1845
1855
1865
1875
1885
1895
1905
1915
1925
1935
Time in years

Ecological Host-Pathogen Model

- A host species can become infected by a lethal pathogen, though contact with infected hosts.

- Only uninfected hosts can reproduce.



Ecological Host-Pathogen Model

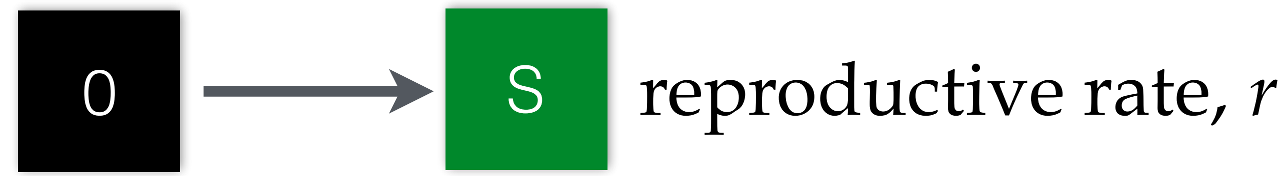
Three possible states

- 0 empty
- S susceptible host
- I infected host

Transitions

- 0 → S reproductive rate, r
- S → I transmissibility, τ
- I → 0 virulence, v

Empty cells can become susceptible hosts



- Each neighboring *S* cell has opportunity to reproduce into empty cell with probability *r*.

- Probability of transitioning increases with number of *S* neighbors. Let $\boldsymbol{n_S}$ be the number of *S* neighbors. The transition probability for an empty cell is:

$$\Pr(0 \to S) = 1 - (1 - r)^{n_S}$$

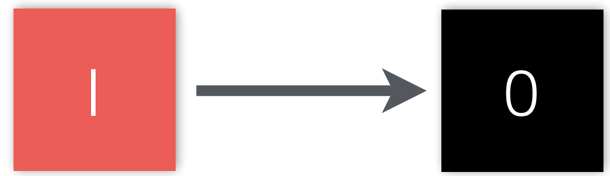
Susceptible hosts can become infected

- Each *S* cell can become infected by a neighboring *I* cell with probability τ.

- Probability of transitioning increases with number of *I* neighbors. Let n_I be the number of *I* neighbors. The transition probability is:

$$\Pr(S \to I) = 1 - (1 - \tau)^{n_I}$$

Infected hosts can become empty cells



virulence, v

- Each *I* cell can perish with probability *v* and become empty.
- Probability of transitioning is independent of the neighboring cells:

$$\Pr(I \to 0) = v$$

Ecological Host-Pathogen Model

Three possible states

- 0 empty
- S susceptible host
- I infected host

Transitions

- 0 → S reproductive rate, r
- S → I transmissibility, τ
- I → 0 virulence, v

spatial host-pathogen model

CODE: hostpathogen.nlogo

Summary of results

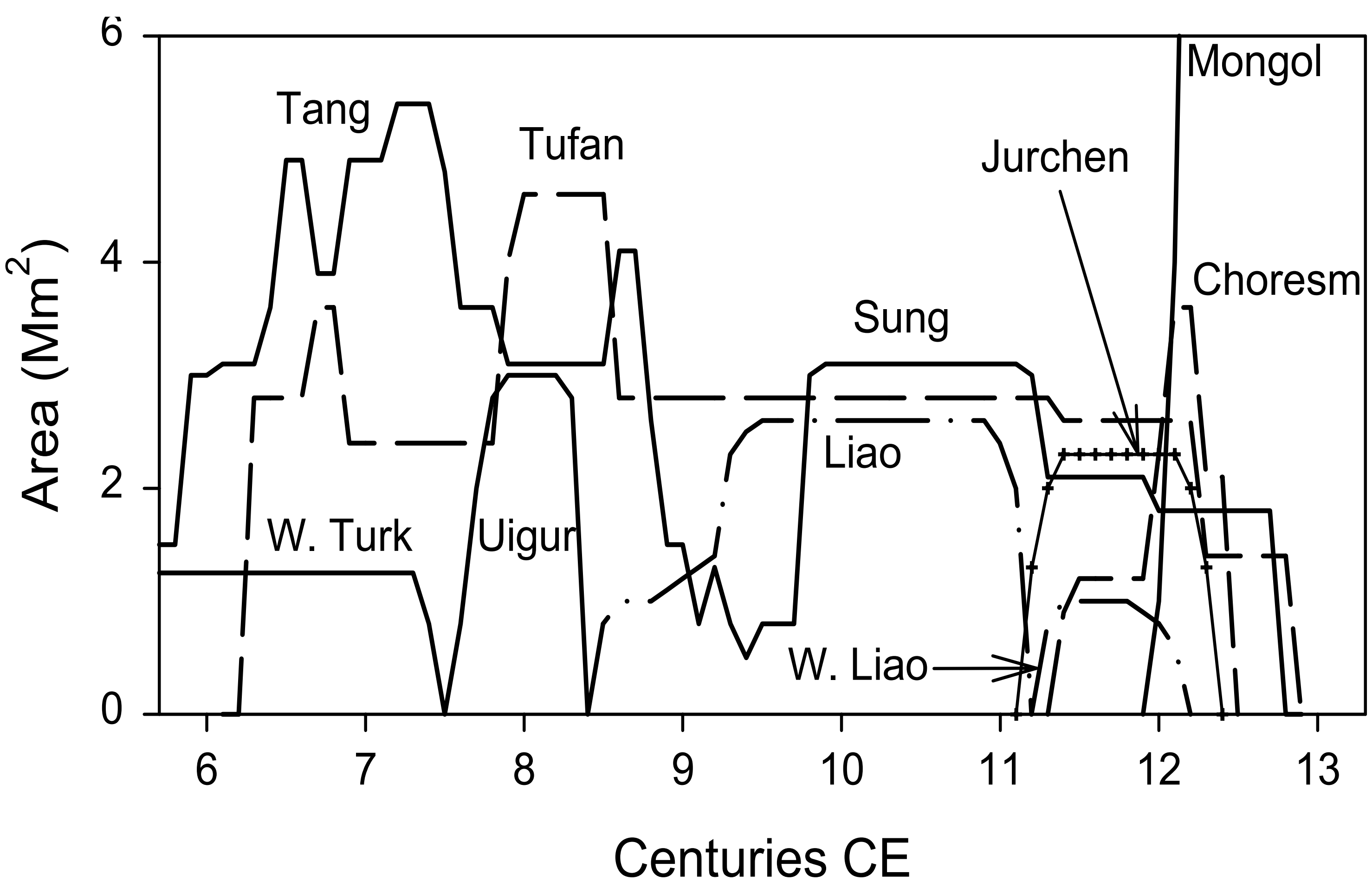
- The inhibitory/excitatory dynamics and spatial arrangement give rise to oscillations
- Increased reproductive rate leads to *decreased* host populations
- Decreased virulence can lead to *increased* chance the host population is wiped out.

Historical cycles

- Since agriculture, often talked about as if a story of continued growth

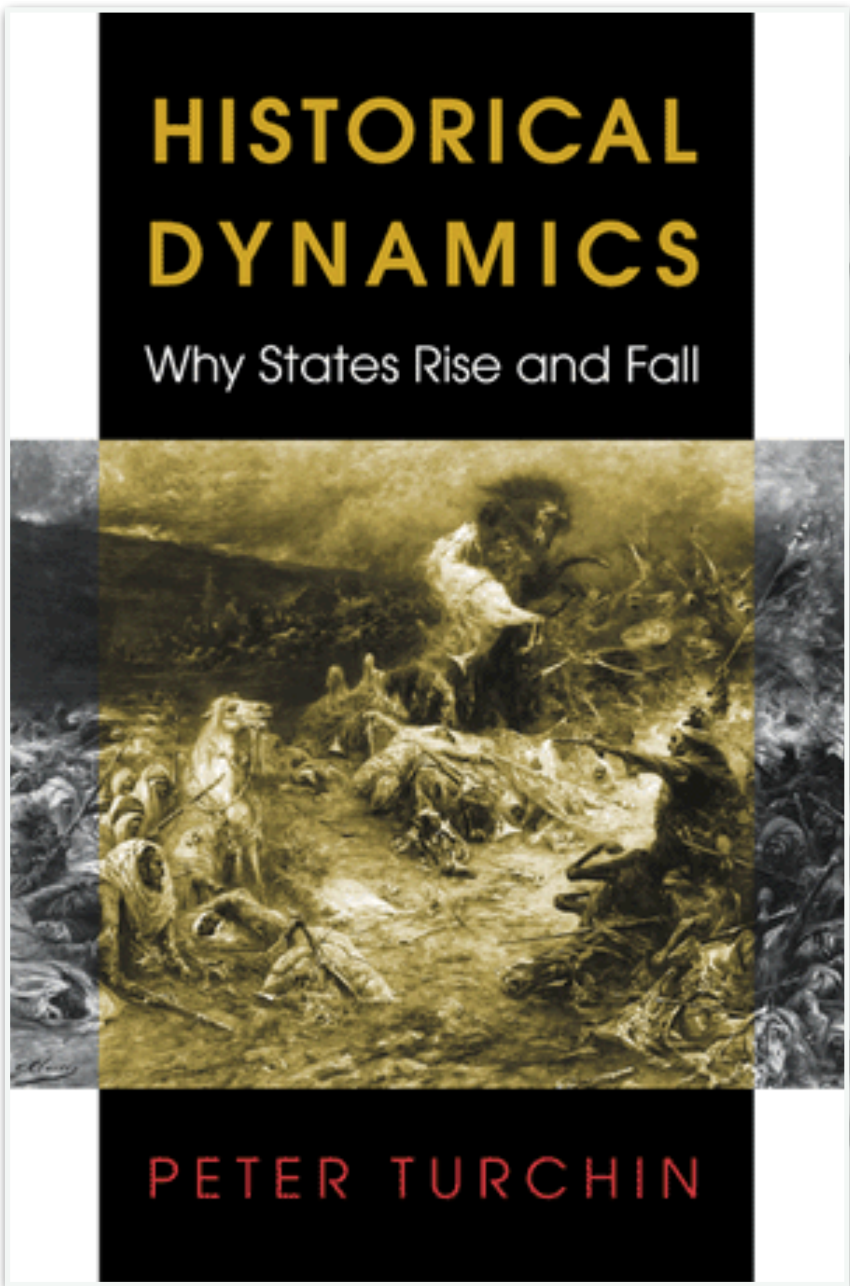
- However, rise and fall of empires appears cyclical

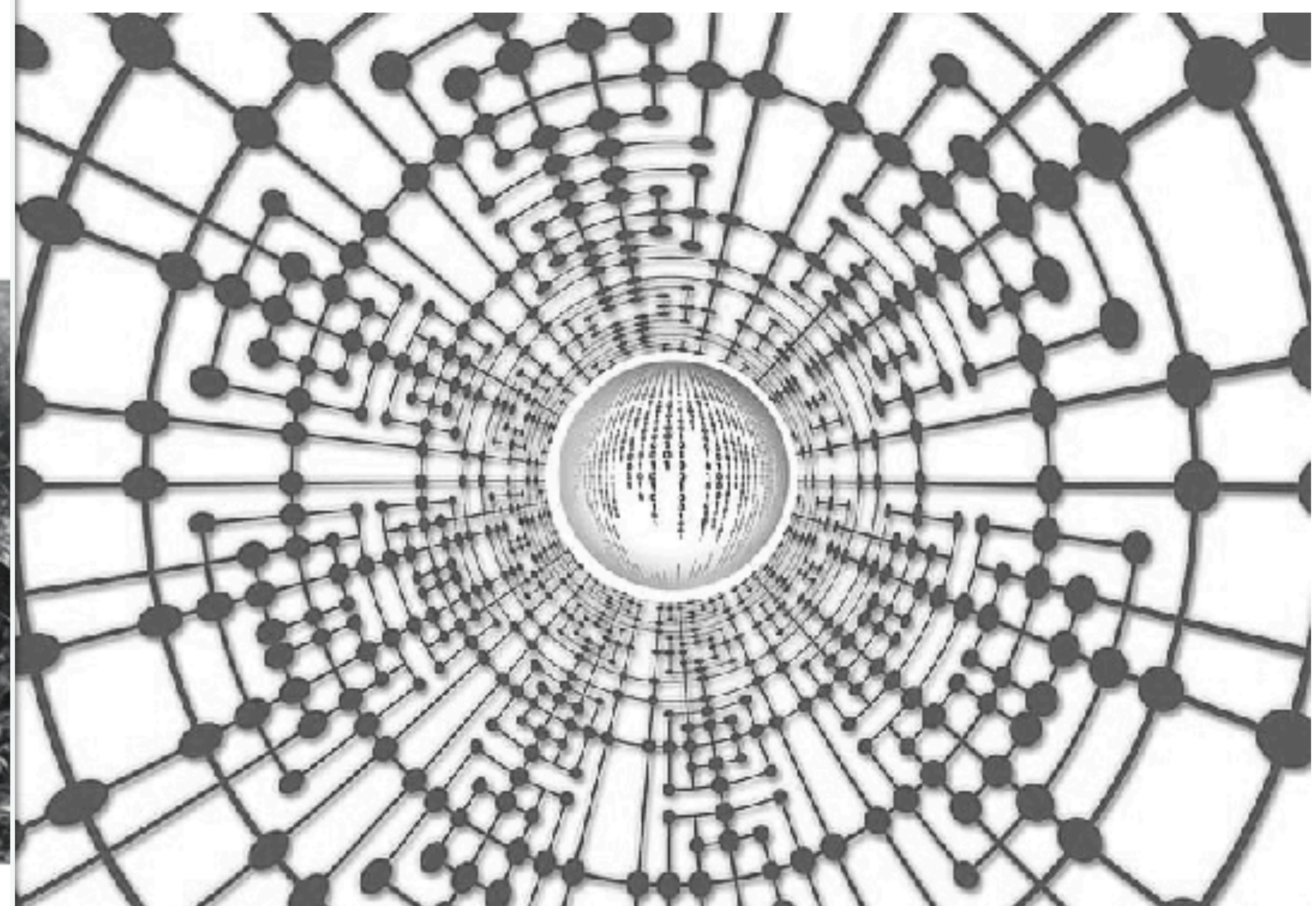
“War made the state and the state made war.” –Charles Tilly



Area controlled by polities in East and Central Asia, 600-1200 CE (from Turchin 2003)

History is complicated



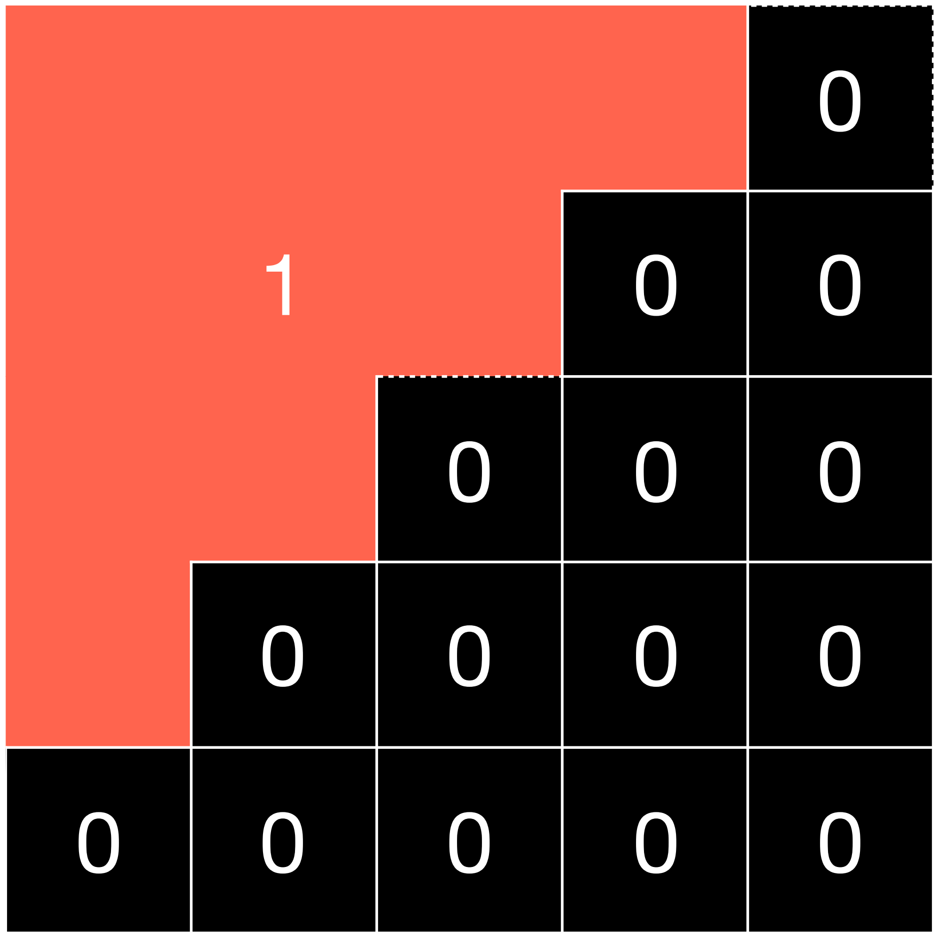


Metaethnic frontier theory

- Groups possess ***asabiya*** – social solidarity with a sense of shared purpose.
- Regions that share borders with other groups will have increased asabiya.
- High asabiya enhances the ability to wage war on neighboring groups, and assimilate them into an empire. The larger the frontier, the higher the empire's asabiya.
- As an empire expands,
  - increased access to resources drives further growth.
  - asabiya among those who live far from the frontier will decrease.
  - expanded size decreases ability to wage war along all frontiers.
- If an empire's asabiya decreases too much, it collapses.

Metaethnic frontier model

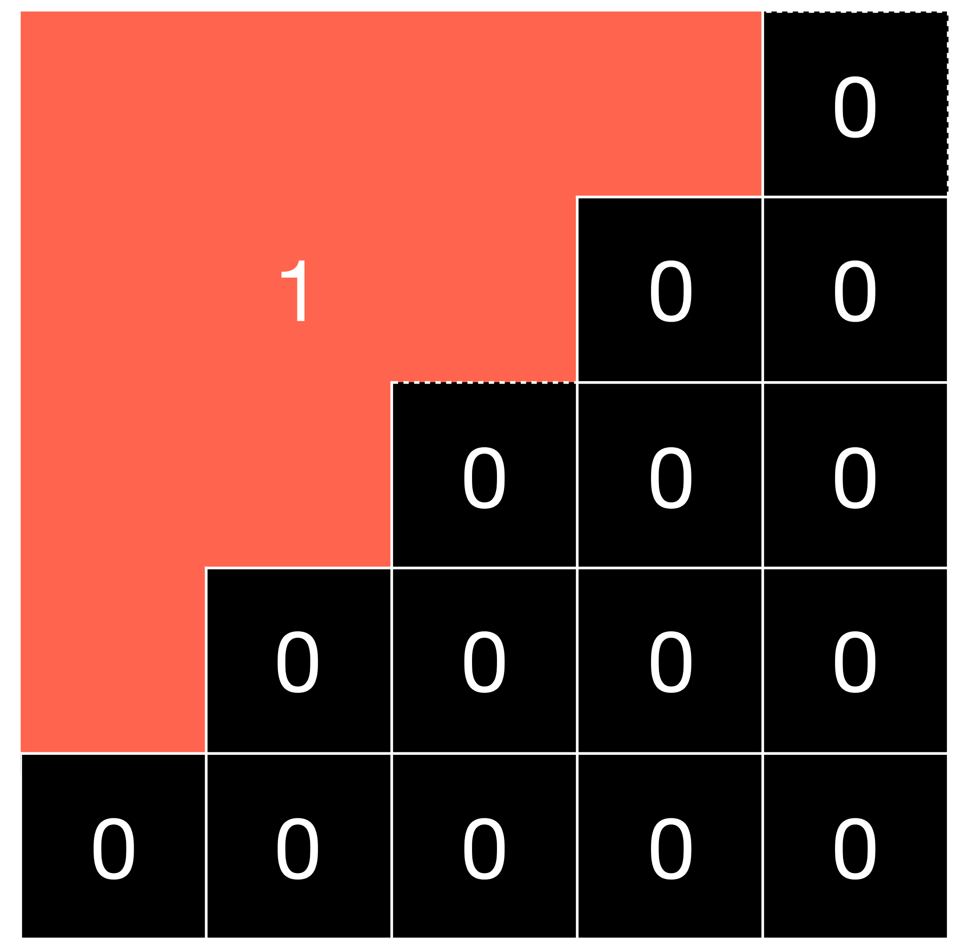
- Each cell correspond to a small regional polity, or ***chiefdom***, with an imperial index of 0. Chiefdoms can become absorbed into larger empire.
- Each cell has a level of asabiya, ***S*** in [0, 1]. If cell is on a boundary with another chiefdom or empire, *S* grows logistically. Otherwise, *S* decline exponentially.
- An empire is characterized by its area, ***A***, and by the average asabiya of its polities, $\bar{S}$.



Metaethnic frontier model

- Each time step, each cell considers an attack on its four neighbors if not in the same empire.
- An empire collapses if its average asabiya decreases below a threshold, $\bar{S} < S_{crit}$
- A successful attack adds the losing cell to the winner's empire. It occurs if the **power** of the attacking cell is sufficiently greater than the defender.
- Power depends on 3 factors:
  - Power increases with average asabiya
  - Power increases with total size
  - Power decreases with the region's distance from imperial center
- Power of cell *i* in empire *j* is:

$$P_i = A_i \bar{S}_i \exp\left[-\frac{d_{ij}}{h}\right]$$



metaethnic frontier model

CODE: metaethnic.nlogo

Is the theory *right*?

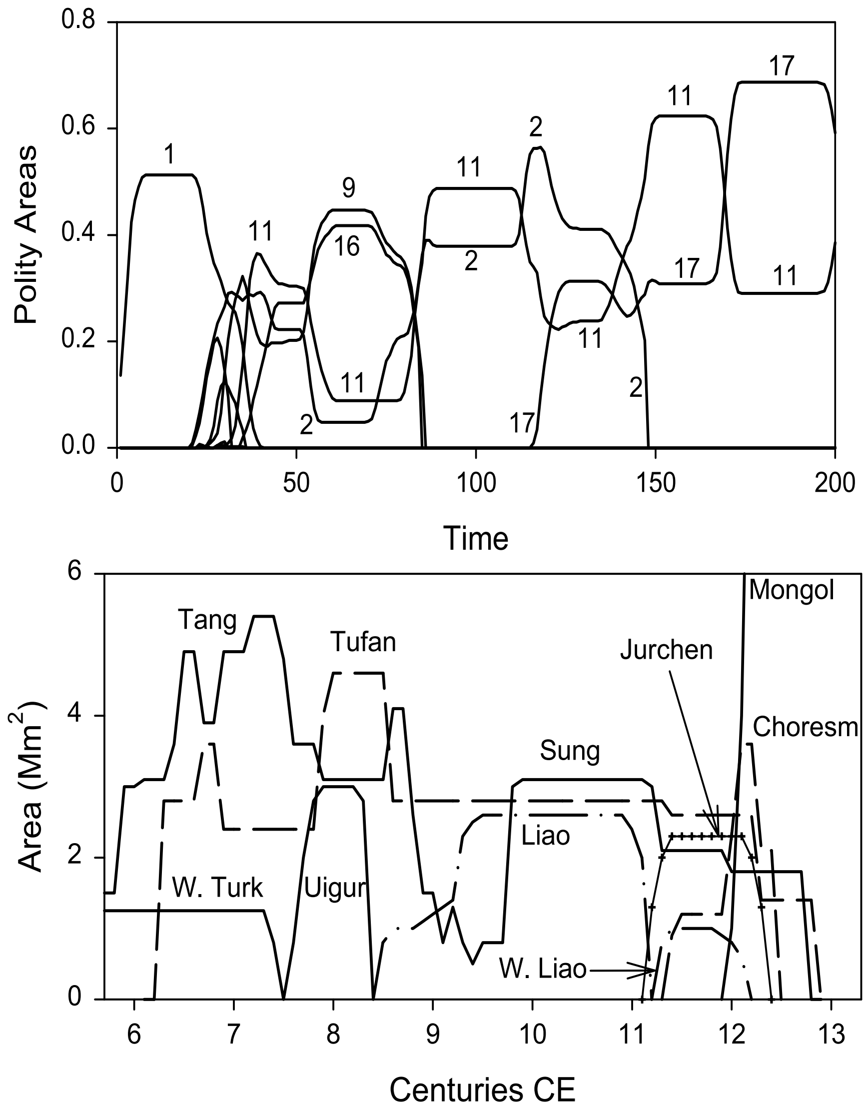


Figure 4.4 (a) Dynamics of the spatial asabiya-area model. Each curve depicts the territorial dynamics of simulated empires (polity area is expressed as a fraction of the total arena occupied). Model parameters are: $r_0 = 0.2$, $\delta = 0.1$, $h = 2$, $S_{\text{crit}} = 0.003$, and $\Delta_P = 0.1$. Numbers associated with trajectories are imperial indices of the polities. (b) Expansion-contraction curves of areas for polities in East and Central Asia, 600-1200 CE. (Data from Taagepera 1997: Appendix).

(Turchin 2003)

"If you didn't grow it, you didn't explain it."
–Epstein (1999)

The inverse is not necessarily true.

If you *did* grow it, you have not necessarily explained it, only failed to reject a possible explanation.

If you *did* grow it, you have not necessarily explained it, only failed to reject a possible explanation.

"The qualitative similarity between historical polity trajectories and the simulated ones does not, of course, constitute any 'proof' that the theoretical and empirical dynamics are driven by the same mechanisms… Nevertheless, the observation that several features of the model's output match the observed dynamics is, at the very least, an encouragement to further theory developing and testing." –Turchin (2003, p 71)

Further directions

The evolution of contagion

Evolution in Spatial Predator–Prey Models and the "Prudent Predator": The Inadequacy of Steady-State Organism Fitness and the Concept of Individual and Group Selection

C. GOODNIGHT,[1,2] E. RAUCH,[1,3] H. SAYAMA,[1,4] M. A. M. DE AGUIAR,[1,5] M. BARANGER[1,6] AND Y. BAR-YAM[1]

[1]*New England Complex Systems Institute, Massachusetts 02138;* [2]*University of Vermont, Burlington, Vermont 05401;* [3]*Massachusetts Institute of Technology, Cambridge, Massachusetts 02139;* [4]*Binghamton University, State University of New York, Binghamton, New York 13902-6000;* [5]*Universidade Estadual de Campinas, Unicamp 13083-970, Campinas, SP, Brazil;* and [6]*University of Arizona, Tucson, Arizona 85721*

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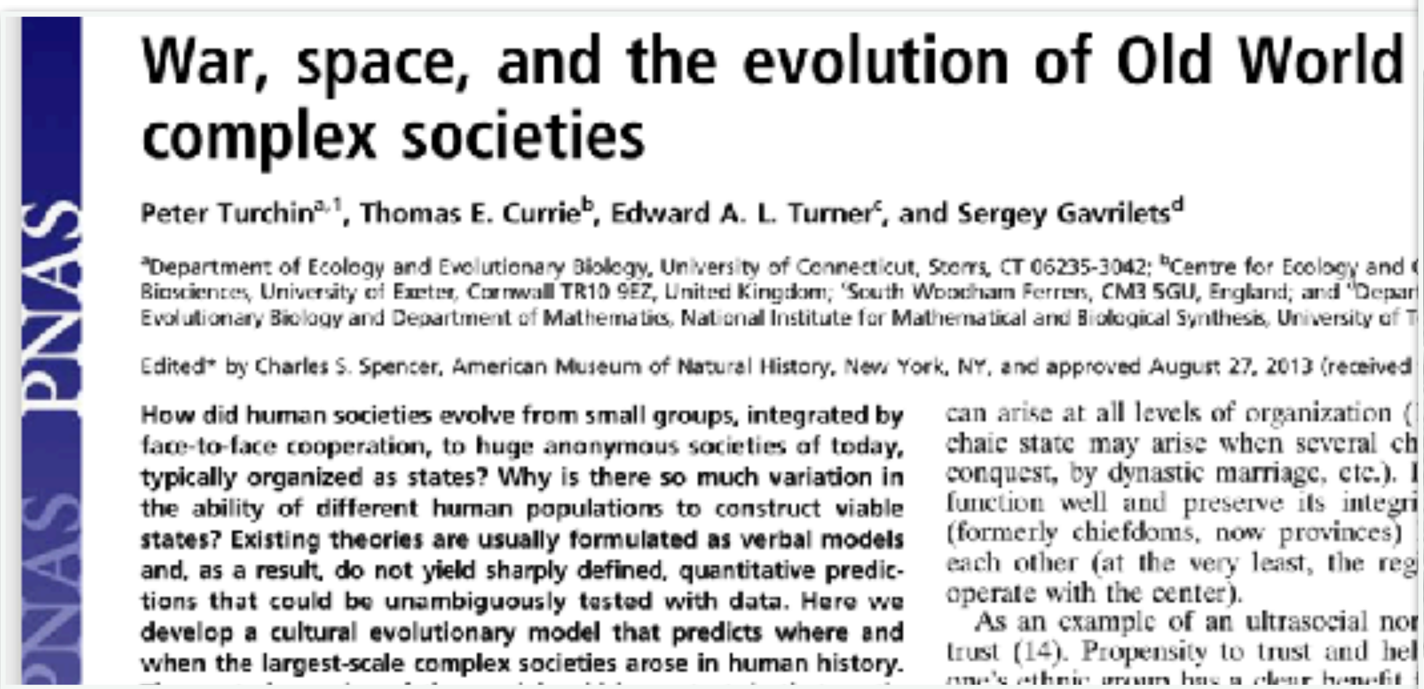
We review recent research which reveals: (1) how spatially distributed populations avoid overexploiting resources due to the local extinction of over-exploitative variants, and (2) how the conventional understanding of evolutionary processes is violated by spatial populations so that basic concepts, including fitness assignment to individual organisms, are not applicable, and even kin and group selection are unable to describe the mechanism by which exploitative behavior is bounded. To understand these evolutionary processes, a broader view is needed of the properties of multiscale spatiotemporal patterns in organism–environment interactions. We discuss measures that quantify the effects of these interactions on the evolution of a population, including multigenerational fitness and the heritability of the environment. *Complexity 13: 23–44, 2008*

Further directions

More on historical cycles



PNAS

War, space, and the evolution of Old World complex societies

Peter Turchin[a,1], Thomas E. Currie[b], Edward A. L. Turner[c], and Sergey Gavrilets[d]

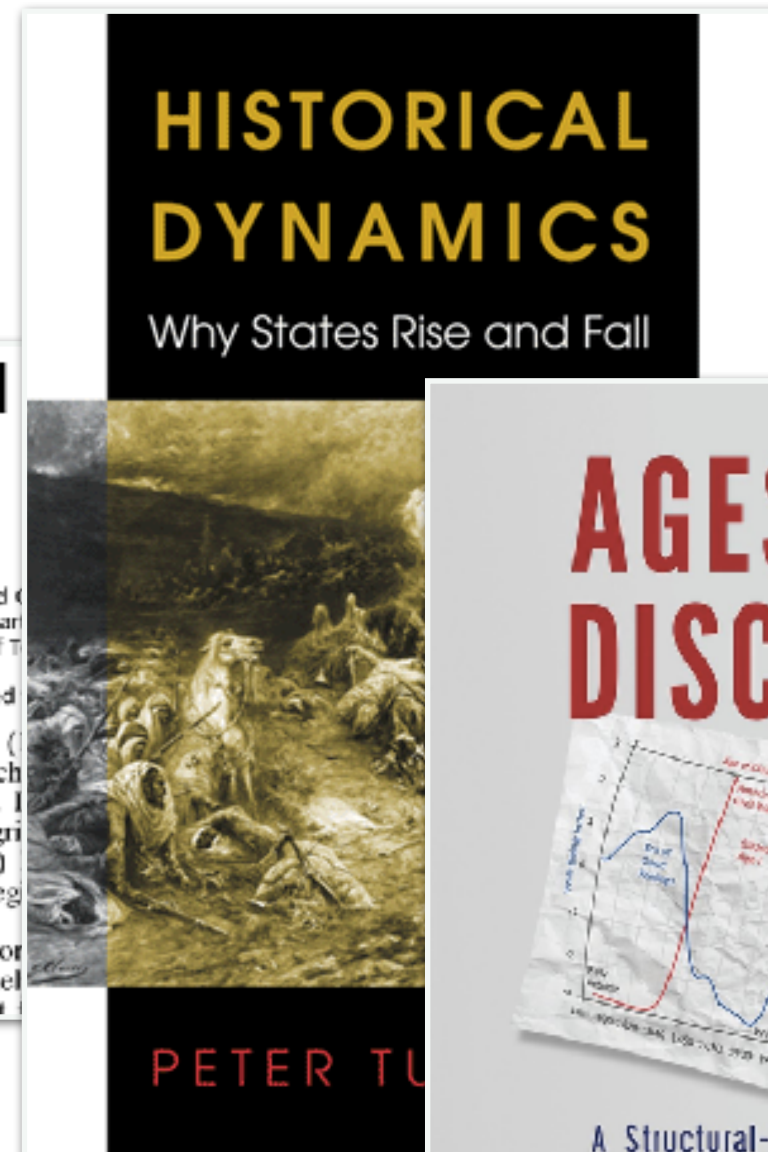
[a]Department of Ecology and Evolutionary Biology, University of Connecticut, Storrs, CT 06235-3042; [b]Centre for Ecology and Biosciences, University of Exeter, Cornwall TR10 9EZ, United Kingdom; [c]South Woodham Ferrers, CM3 5GU, England; and [d]Depar Evolutionary Biology and Department of Mathematics, National Institute for Mathematical and Biological Synthesis, University of T

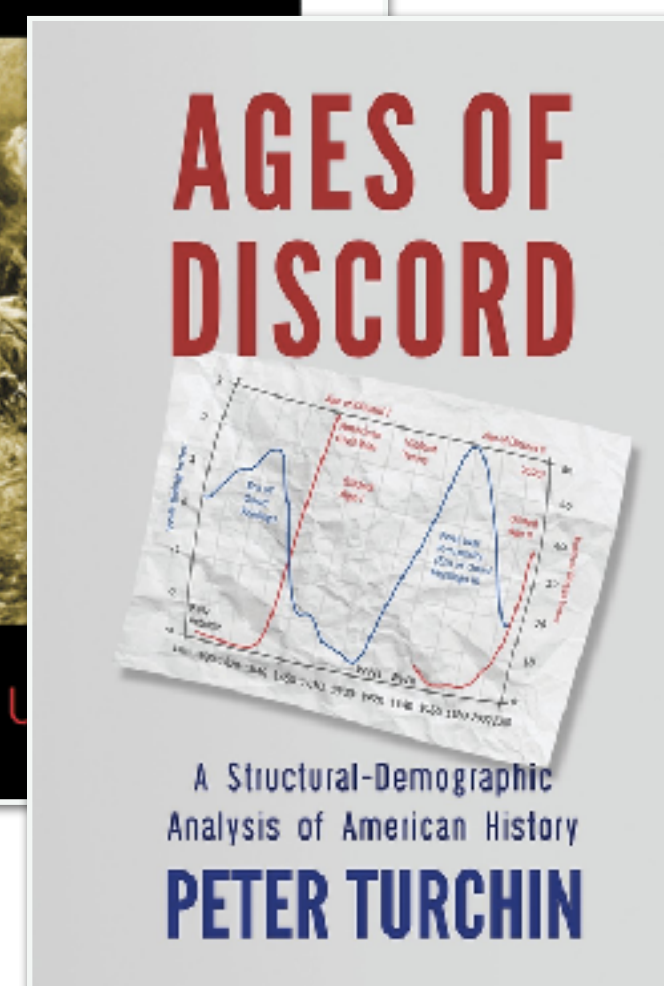
Edited* by Charles S. Spencer, American Museum of Natural History, New York, NY, and approved August 27, 2013 (received

How did human societies evolve from small groups, integrated by face-to-face cooperation, to huge anonymous societies of today, typically organized as states? Why is there so much variation in the ability of different human populations to construct viable states? Existing theories are usually formulated as verbal models and, as a result, do not yield sharply defined, quantitative predictions that could be unambiguously tested with data. Here we develop a cultural evolutionary model that predicts where and when the largest-scale complex societies arose in human history.

can arise at all levels of organization (chaic state may arise when several ch conquest, by dynastic marriage, etc.). I function well and preserve its integri (formerly chiefdoms, now provinces) each other (at the very least, the reg operate with the center).

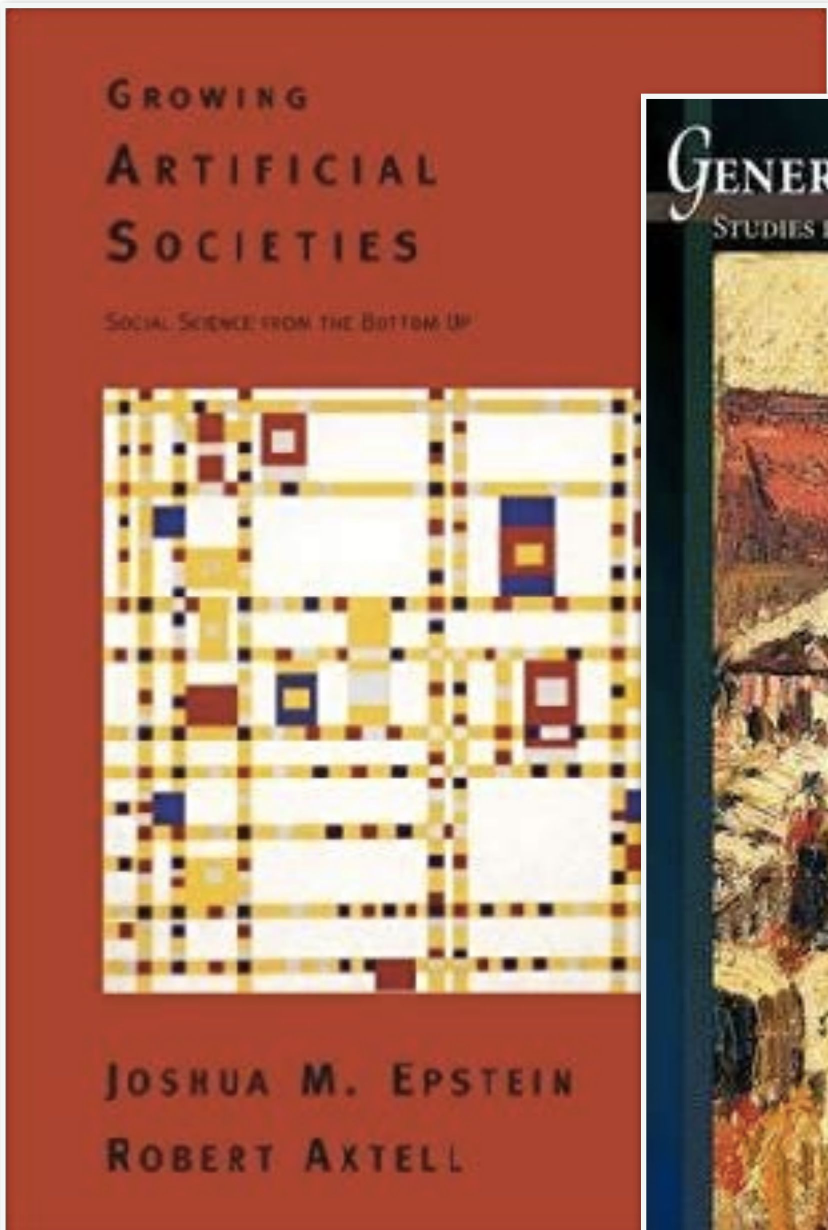
As an example of an ultrasocial nor trust (14). Propensity to trust and hel

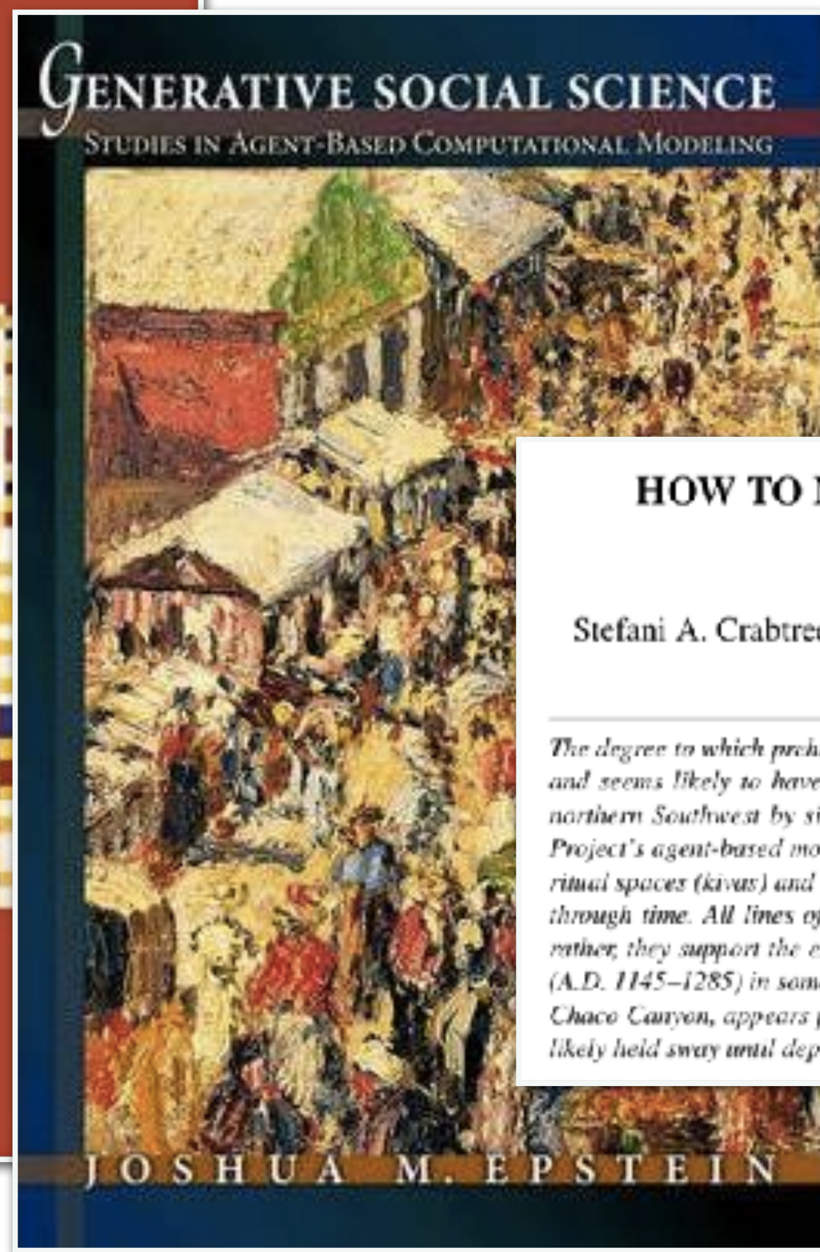




Further directions

Growing artificial societies





HOW TO MAKE A POLITY (IN THE CENTRAL MESA VERDE REGION)

Stefani A. Crabtree, R. Kyle Bocinsky, Paul L. Hooper, Susan C. Ryan, and Timothy A. Kohler

The degree to which prehispanic societies in the northern upland Southwest were hierarchical or egalitarian is still debated and seems likely to have changed through time. This paper examines the plausibility of village-spanning polities in the northern Southwest by simulating the coevolution of hierarchy and warfare using extensions to the Village Ecodynamics Project's agent-based model. We additionally compile empirical data on the population size distribution of habitations and ritual spaces (kivas) and the social groups that used them in three large regions of the Pueblo Southwest and analyze these through time. All lines of evidence refute an "autonomous village" model during the Pueblo II period (A.D. 890–1145); rather, they support the existence of village-spanning polities during the Pueblo II and probably into the Pueblo III period (A.D. 1145–1285) in some areas. One or more polities connecting the northern Southwest, with tribute flowing to an apex in Chaco Canyon, appears plausible during Pueblo II for the areas we examine. During Pueblo III, more local organizations likely held sway until depopulation in the late thirteenth century.

Further directions

Autocatalysis

Reaction-Diffusion Model as a Framework for Understanding Biological Pattern Formation

Shigeru Kondo[1*] and Takashi Miura[2]

The Turing, or reaction-diffusio
used to explain self-regulated
real-world relevance was long d
much of the skepticism surrou
spatial patterns, and mathema
each, giving this model the po
a wide variety of morphologica
for experimental biologists unf
in which the RD model is effe

Characteristics of Pattern Formation and Evolution in Approximations of *Physarum* Transport Networks

Jeff Jones*
University of the West of England

Keywords
Pattern formation, transport networks, *Physarum polycephalum*, reaction-diffusion, emergent behavior

Next up:
Coda