

Emergence in complex systems: from physics to international relations

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Physics, UQ

condensedconcepts.blogspot.com

Changing international orders

- Arab Spring, Fake news, Wikileaks, CIA in Syria, Brexit, Trump, ISIS, mass people displacements, BRICs, Chinese `soft' power, Putin, Panama papers, climate change, ...
- Surprises!
- Multiple scales, from local to global
- Collective phenomena involving many interacting agents
- **Emergence** of new entities, agents, and interactions

Outline

- What is emergence?
- Agent-based modelling
- Social segregation
- Outbreaks of civil rebellion
- Geopolitical boundaries
- Possible implications for research, policy, and activism?

What is emergence?

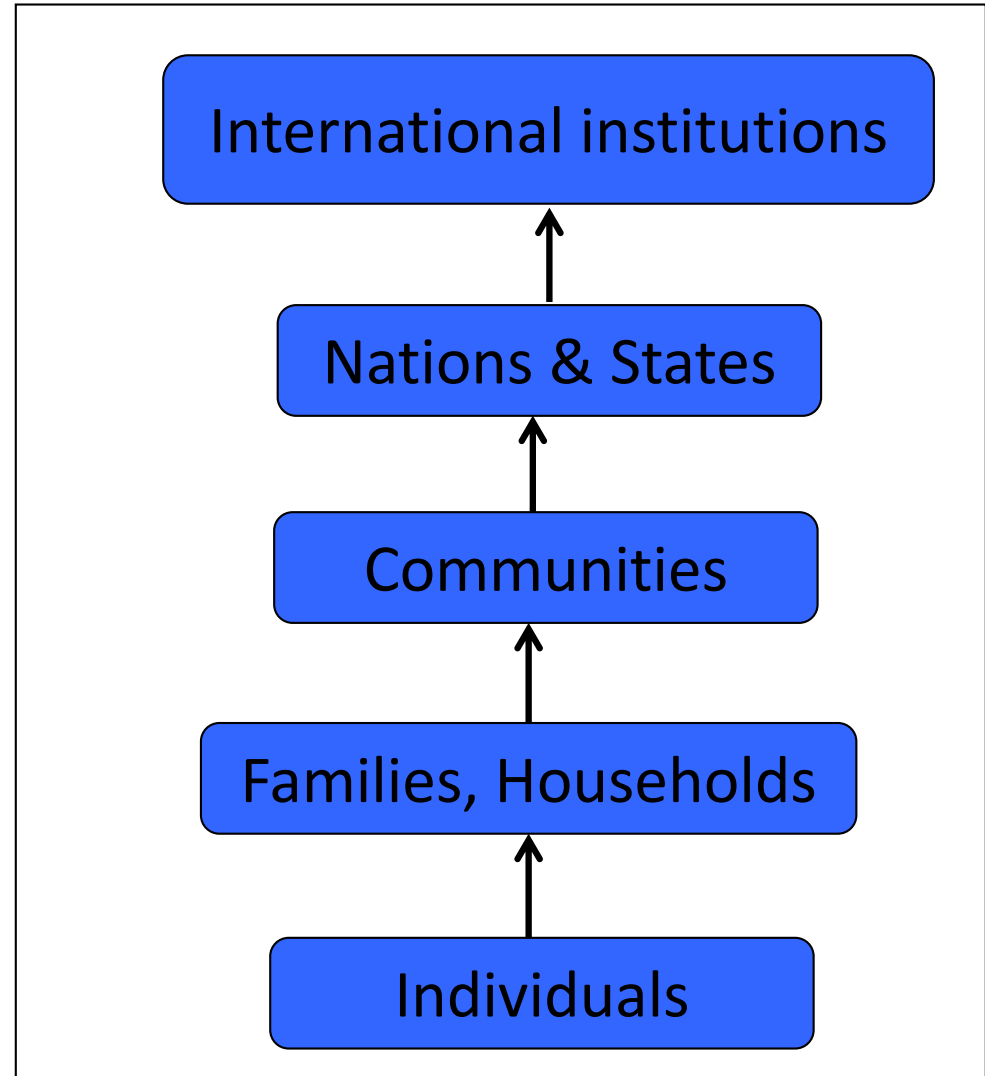
- The whole is greater than the sum of the parts. Moreover, more is different!
- A system composed of many **interacting** parts can have **emergent** properties that are
 - **qualitatively different** from,
 - not reducible to,
 - not anticipated from,
 - extremely difficult to predict fromthe properties of the constituent parts.

Emergence leads to a hierarchy of agents

Increasing

- Complexity
- Number scales
- Length scales
- Time scales

At each level,
distinct phenomena,
concepts, theories

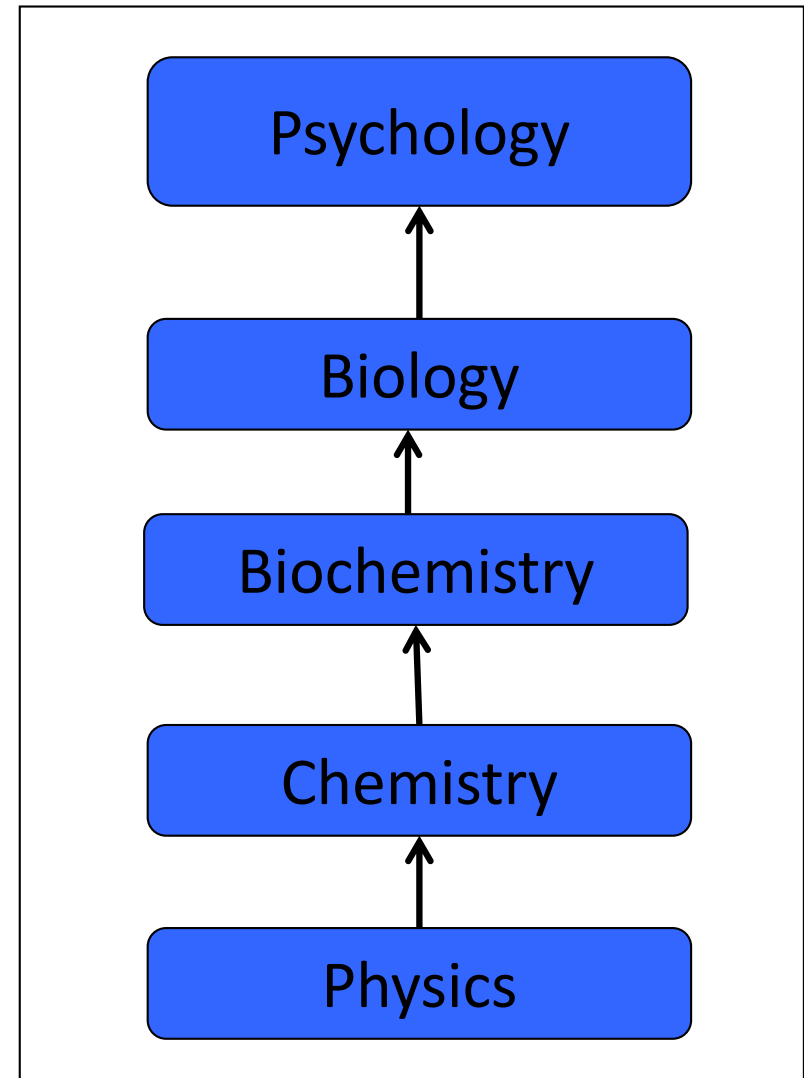


Emergence leads to a stratification of reality and distinct academic disciplines

Increasing

- Complexity (number of degrees of freedom)
- Length scales
- Time scales

At each level, distinct phenomena, concepts, theories, techniques



P.W. Anderson, *More is Different*
Science 177, 393 (1972).

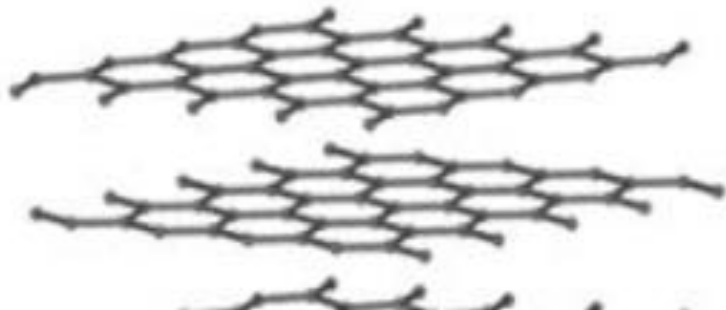
The central question of Condensed Matter Physics

How do the **macro**scopic properties of a material (e.g., hardness, conductivity, colour) **emerge** from its **micro**scopic properties (e.g., atoms and their interactions)?

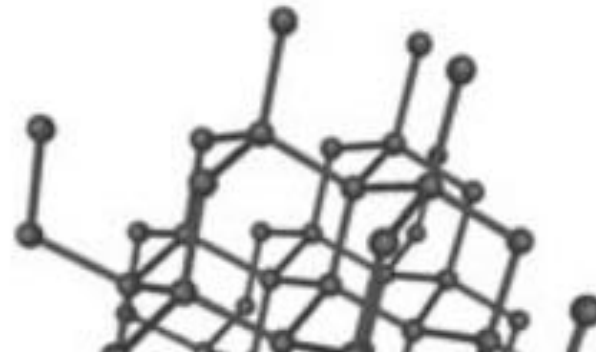
Carbon: graphite vs diamond



Soft, Black,
Conductor, Common



Hard, Transparent,
Insulator, Rare



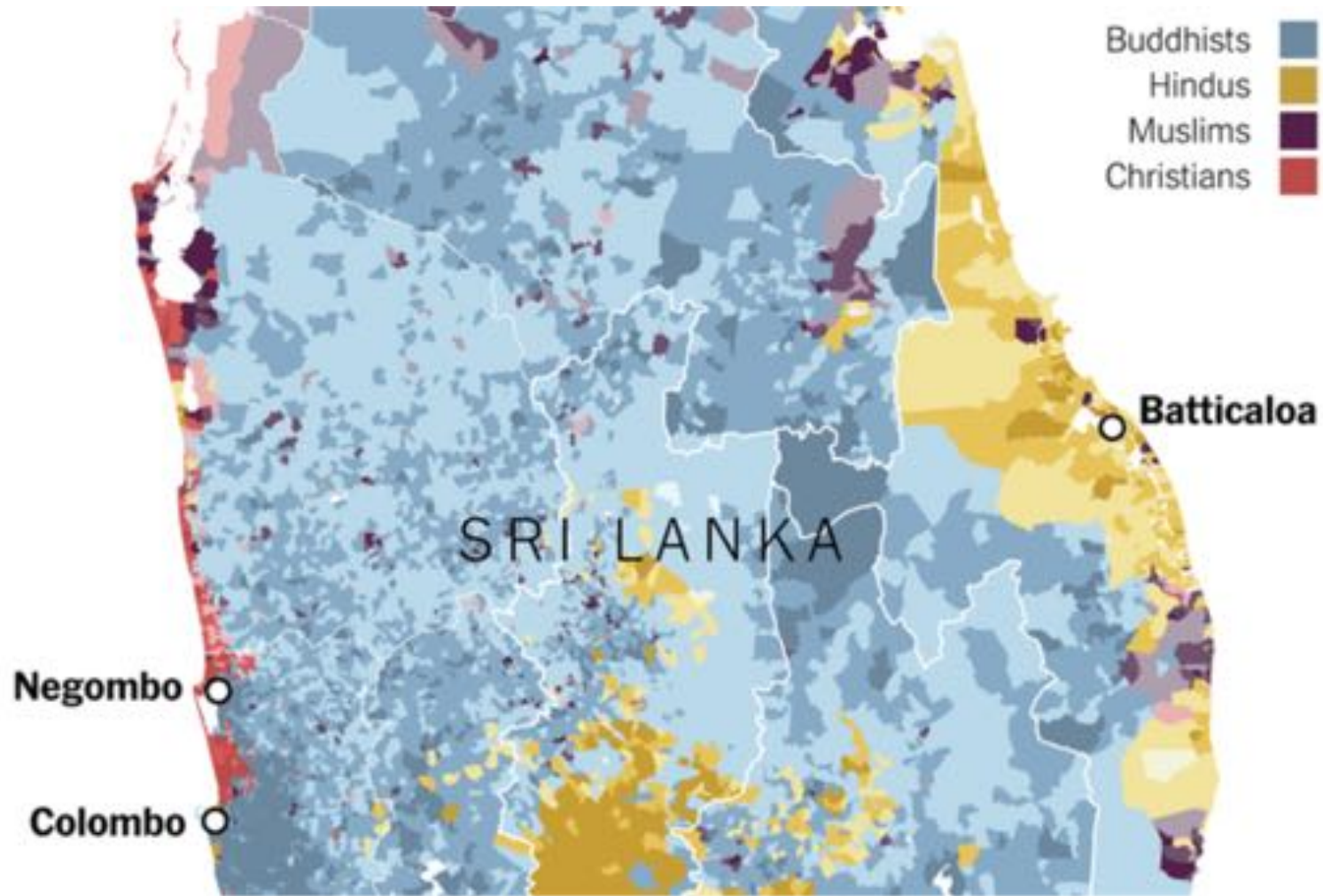
Agent based models

- Each agent is represented by a point on a grid.
- Agents make **simple** discrete choices based on **simple** rules.
- **Complex** phenomena **emerge**
- Simulated on a computer.

NetLogo



Religious segregation in Sri Lanka



New York Times, April 23, 2019

Segregated neighbourhoods in NYC

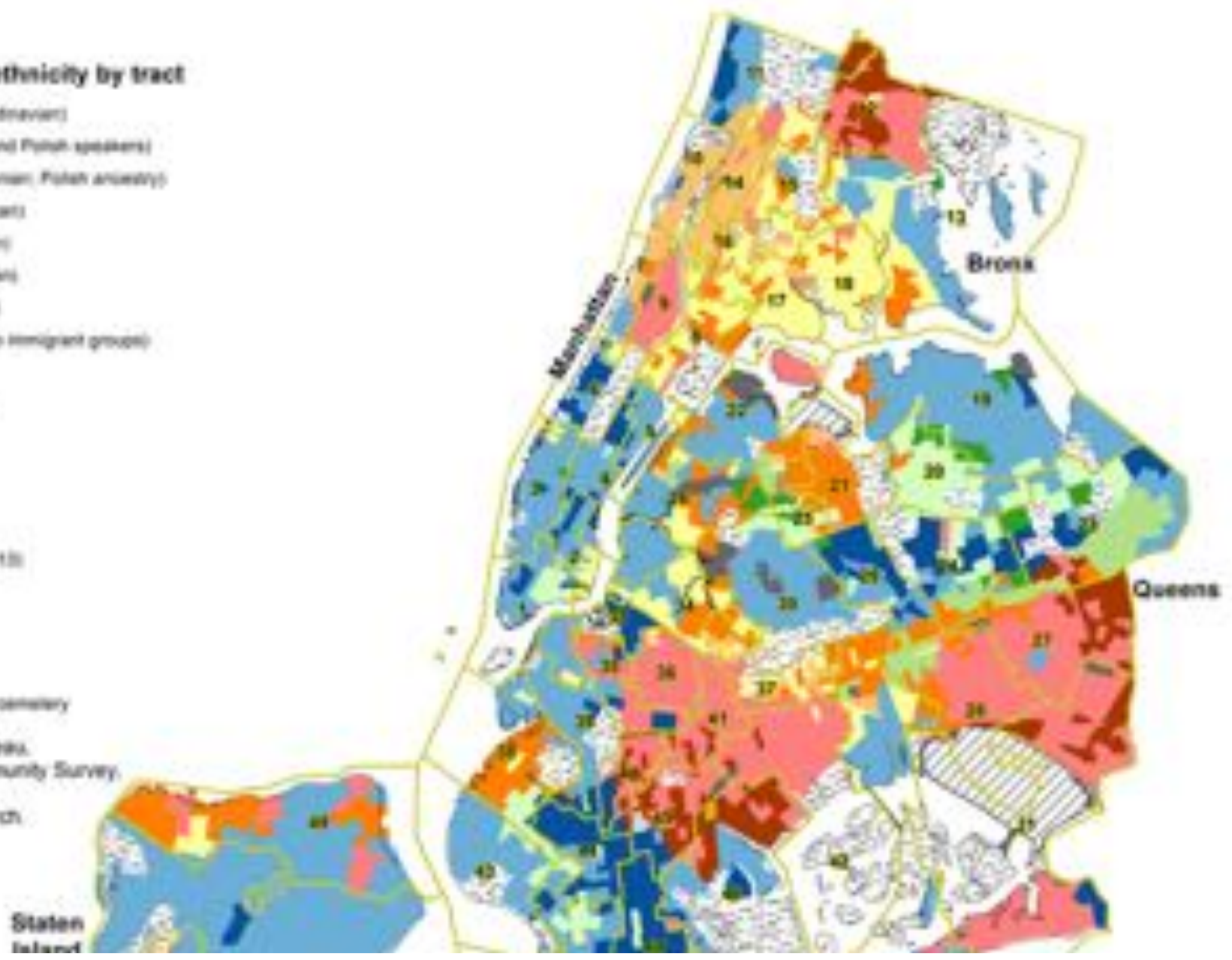
MAP 1
Predominant race/ethnicity by tract

- White (English, Scandinavian)
- White (Italian, Irish, and Polish speakers)
- White (Russian, Ukrainian, Polish ancestry)
- Black (African American)
- Black (Afro-Caribbean)
- Hispanic (Puerto Rican)
- Hispanic (Dominican)
- Hispanic (other Latino immigrant groups)
- Asian (Chinese)
- Asian (South Asian)
- other Asian
- No population

Council districts
Proposed (Feb. 6, 2013)

Reference
Airports
Parks / open space / cemetery

Source: US Census Bureau, 2007-11 American Community Survey, as analyzed by the Center for Urban Research.



Schelling's segregation model

1971, *J. Math. Sociology* 1, 143

Each agent is only happy if more than a certain fraction of their neighbours are like them.

If they are unhappy they move to a vacant house.

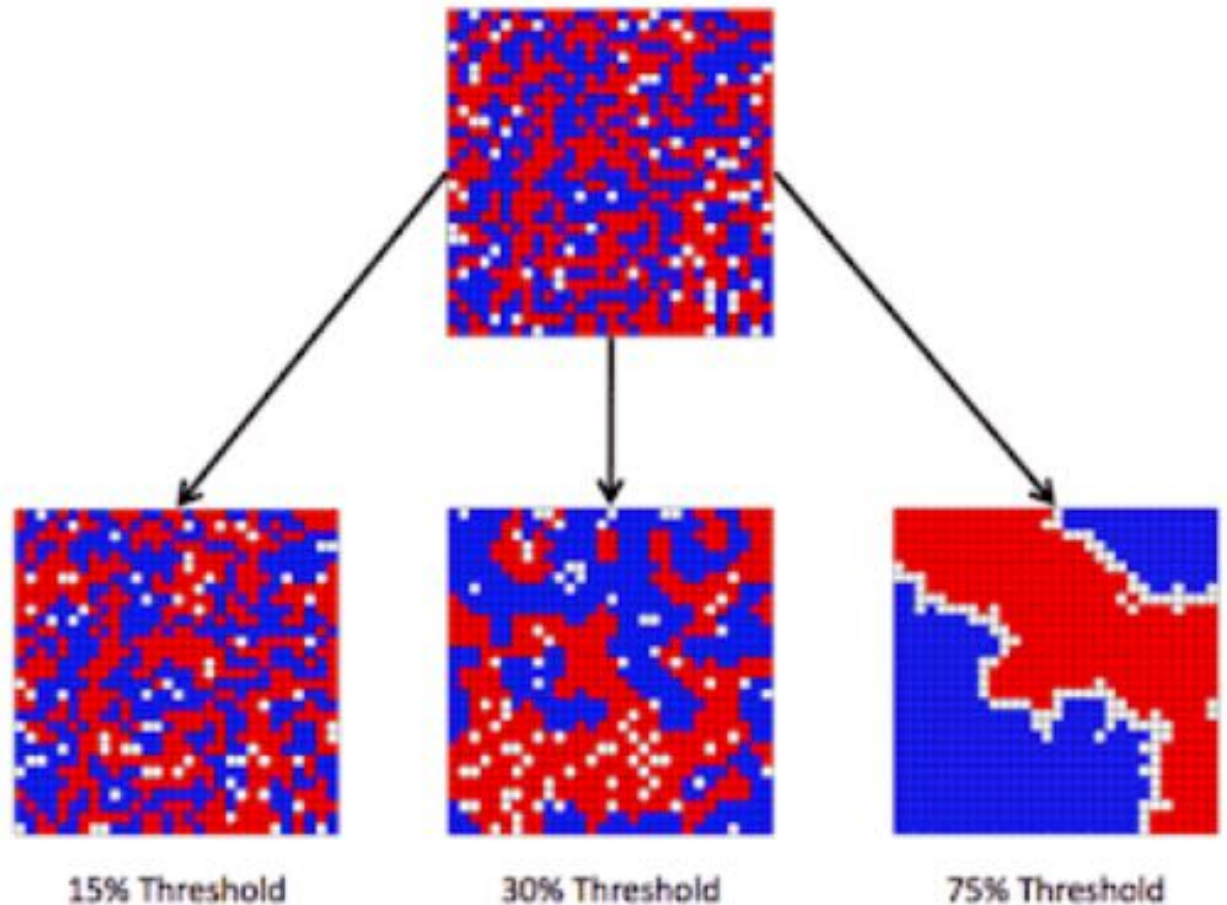
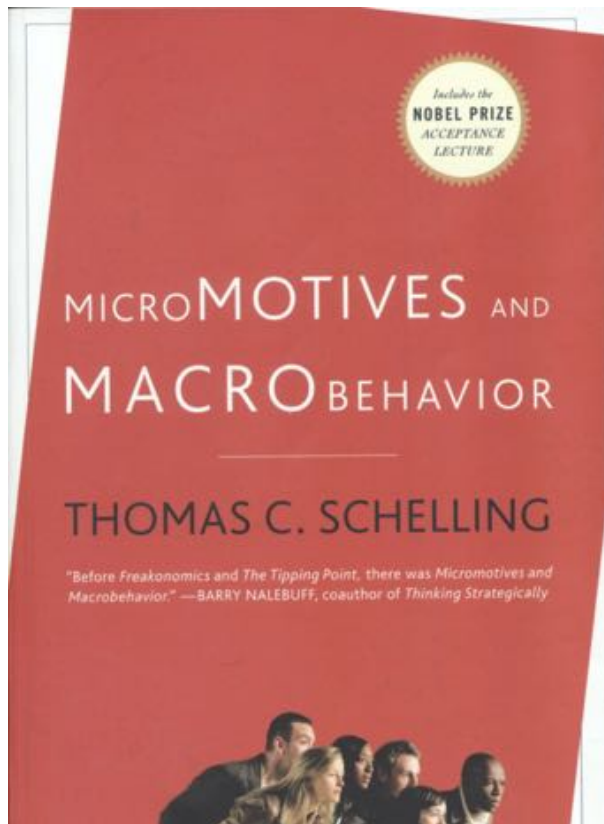
[../../Desktop/Segregation.nlogo](#)

NetLogo



Lessons from Schelling

- Segregated neighbourhoods emerge, even for relatively low preference levels.
- **Micromotives** \neq **macro**behavior
- Tipping points



Outbreaks of civil rebellion

“a single spark can cause a prairie fire”

Mao Tse Tung

“it is not always when things are going from bad to worse that revolutions break out,... On the contrary, it often happens that when a people that has put up with an oppressive rule over a long period without protest suddenly finds the government relaxing its pressure, it takes up arms against it.

... liberalization is the most difficult of political arts”

Alexis de Tocqueville (1856)

Agent based model for civil rebellion

J.M. Epstein, *PNAS (USA)* 99 (3), 7243 (2002).

Agents grievance $G = H (1-L)$

H = perceived level of hardship

L = perceived legitimacy of government

R = agents level of risk aversion

Cops have a range of visibility

[././Desktop/Rebellion.nlogo](#)

NetLogo



Model insights about rebellion: emergent phenomena

- Punctuated equilibrium

Periods of civil peace interspersed with outbursts of rebellion.

- Distribution of waiting times between outbursts
- Salami corruption

Legitimacy can fall much farther incrementally than it can in one jump, without stimulating large-scale rebellion.

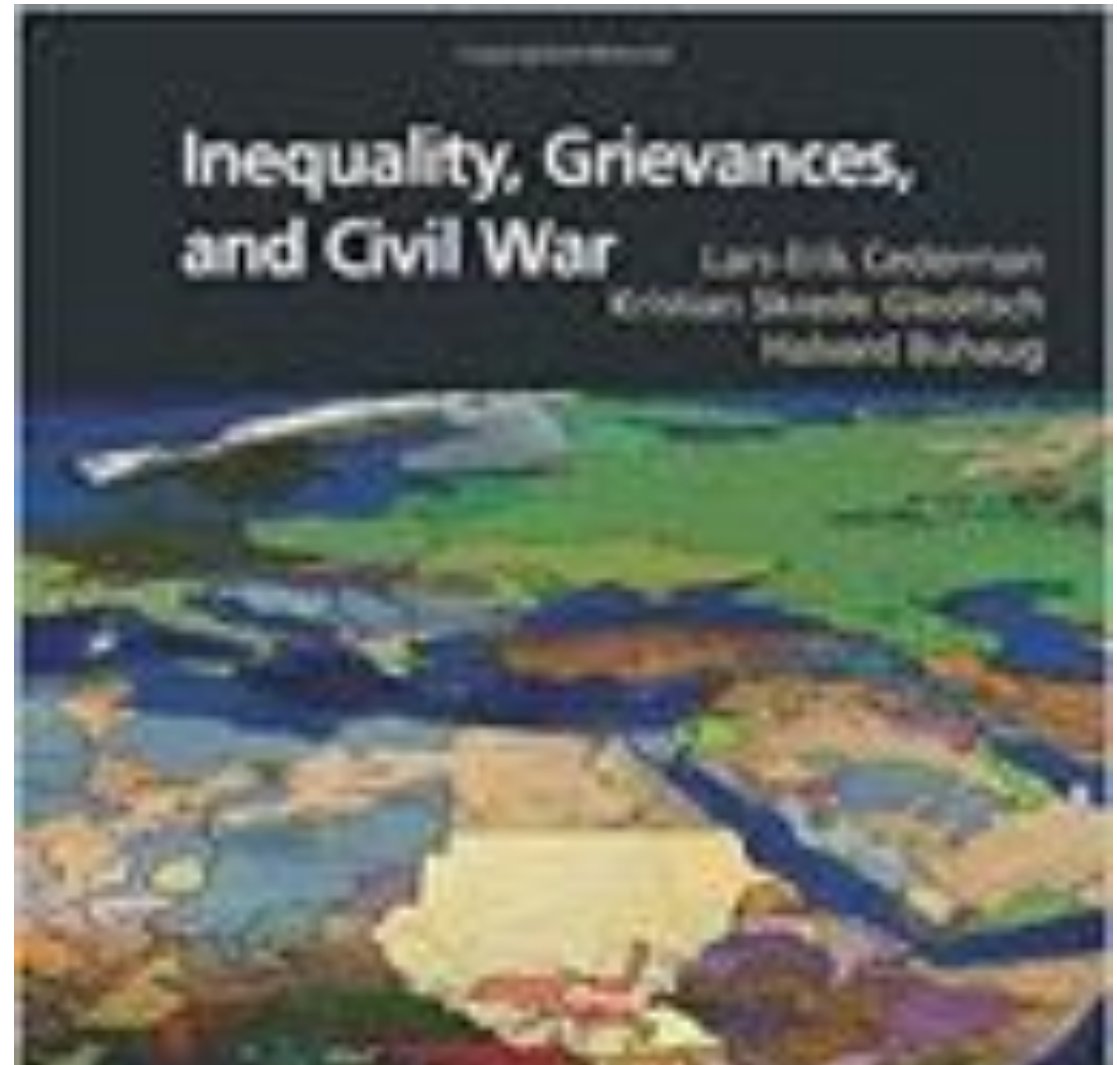
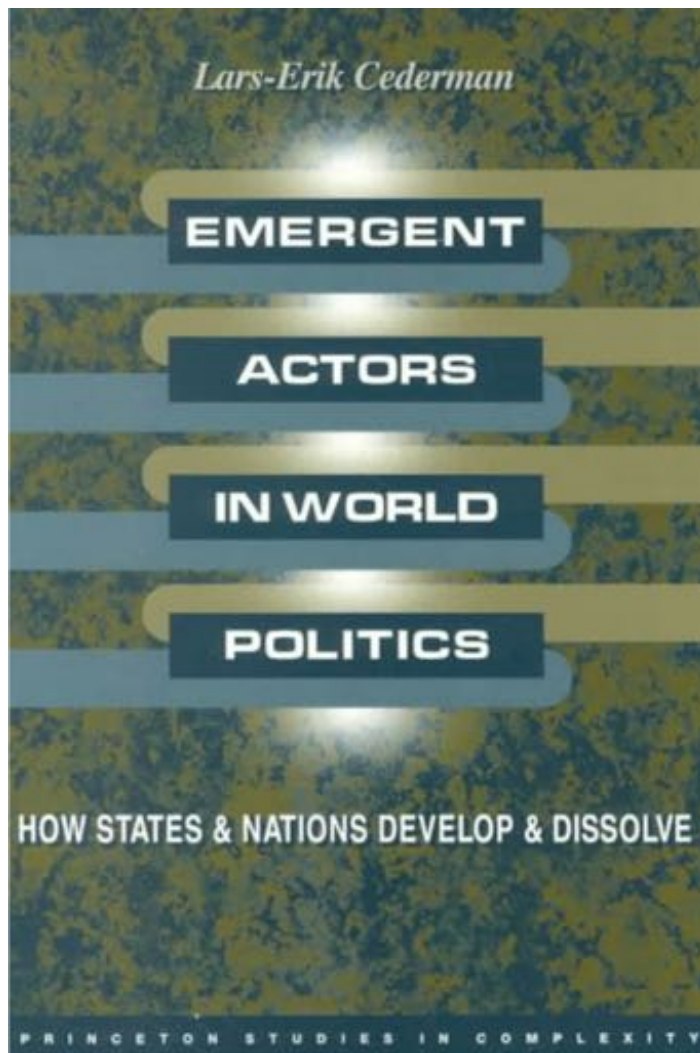
- de Tocqueville effect

Incremental reductions in repression can lead to large-scale rebellion.

J.M. Epstein, *PNAS (USA)* 99(3), 7243 (2002).

Agent based models for Geopolitical dynamics

Lars-Erik Cederman (ETH-Zurich)



Emergent geopolitics

Cederman, Endogenizing geopolitical boundaries with agent-based modeling, *PNAS (USA)* 99(3), 72 43 (2002).

- Nations and states are emergent actors
- Interplay of agency, culture, and identity
- “actions produce interactions that in turn transform actors”
- Emergent polarization model
- Democratic peace model
- Nationalist systems change
- Simulations available in GROWlab

Value of models

- Everyone use models implicitly.
- ``All models are wrong, some are useful’
George Box
- Assumptions are clearly stated
- Elucidate key parameters and entities
- Universality classes: diverse phenomena can be described by the same model.
- Reveal the apparently simple (complex) to be complex (simple).

Model Thinking, Scott Page, U. Michigan, Coursera

Possible implications for research on international orders?

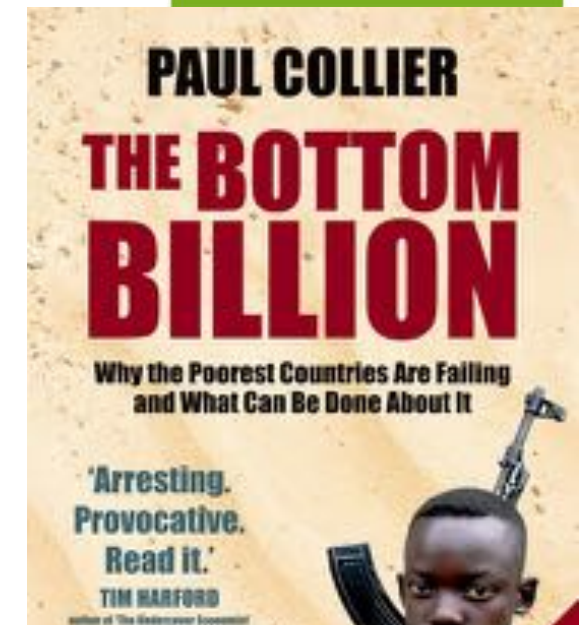
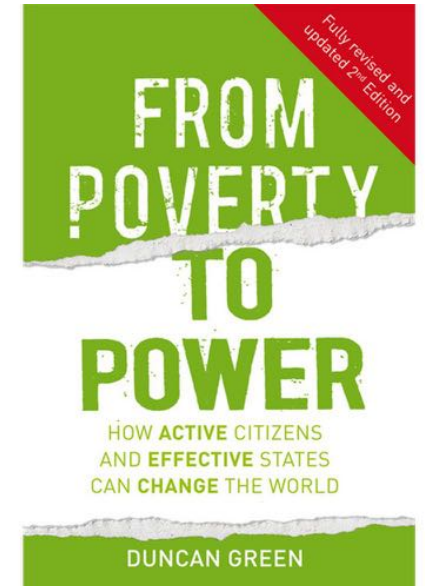
- Epistemic humility
- Take into account multiple scales and interactions
- Multi-disciplinarity (law, history, politics, economics, sociology, psychology, modelling, ...)
- Interplay of data, models, concepts, and theories

- What is the nature of human and social agents?

Question Western liberal secular assumptions?

Implications for policy and activism

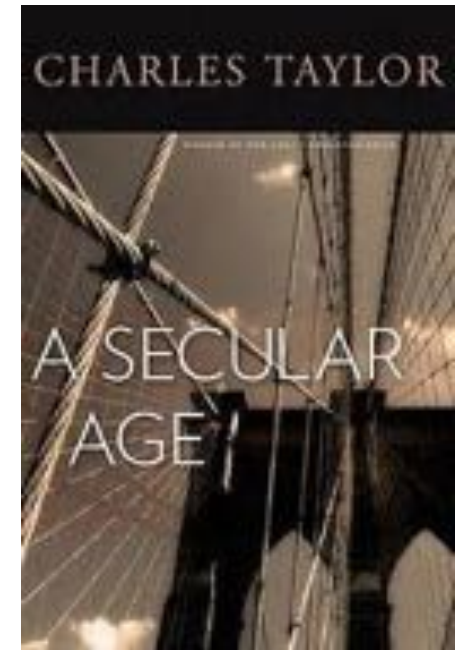
- Think globally, act locally
(Jacques Ellul)
- Integrated policies that are multi-faceted and multi-scale
- Combine instruments of aid, security, laws and charters, trade



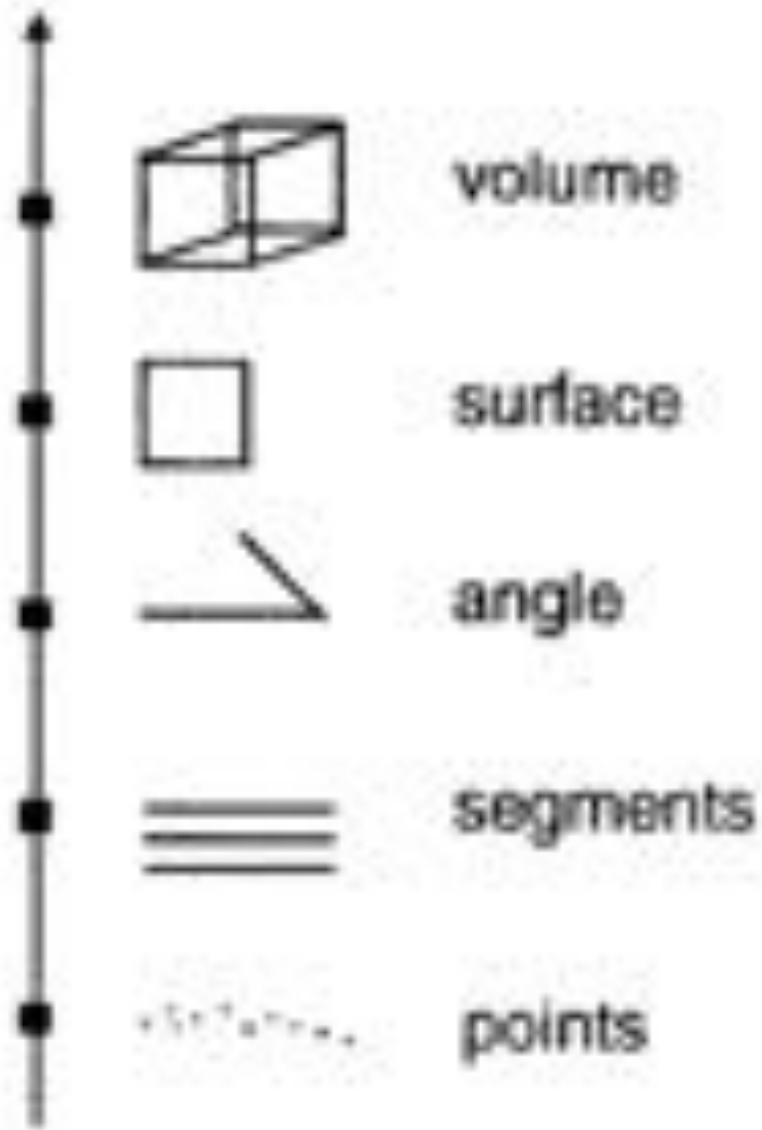
Questions

Conflicting conceptions of secularism

- The public sphere (from government to speech) should not show preference with respect to particular religions.
- Religion has no place in the public sphere.
- The transcendent is irrelevant. The only realities are material, political, and economic.



Geometrical emergence



P. Luisi, *Foundations of Chemistry* 4, 183 (2005).

Geometry illustrates signatures of emergent properties

- At each strata there are unique properties and concepts not present at lower strata.
- Although they can sometimes be rationalised *a posteriori* they are difficult to predict *a priori* from a knowledge of lower strata.
- They are associated with a modification of properties and relationships between constituent components.
- They are universal (i.e. independent of details of constituents from lower strata).

P. Luisi, *Foundations of Chemistry* 4, 183 (2005).

Multiple dimensions to human flourishing

Tyler VanderWeele, PNAS 114, 8148 (2017)

- Happiness and life satisfaction
- Mental and physical health
- Meaning and purpose
- Character and virtue
- Close social relationships

Promotion of human flourishing is a problem

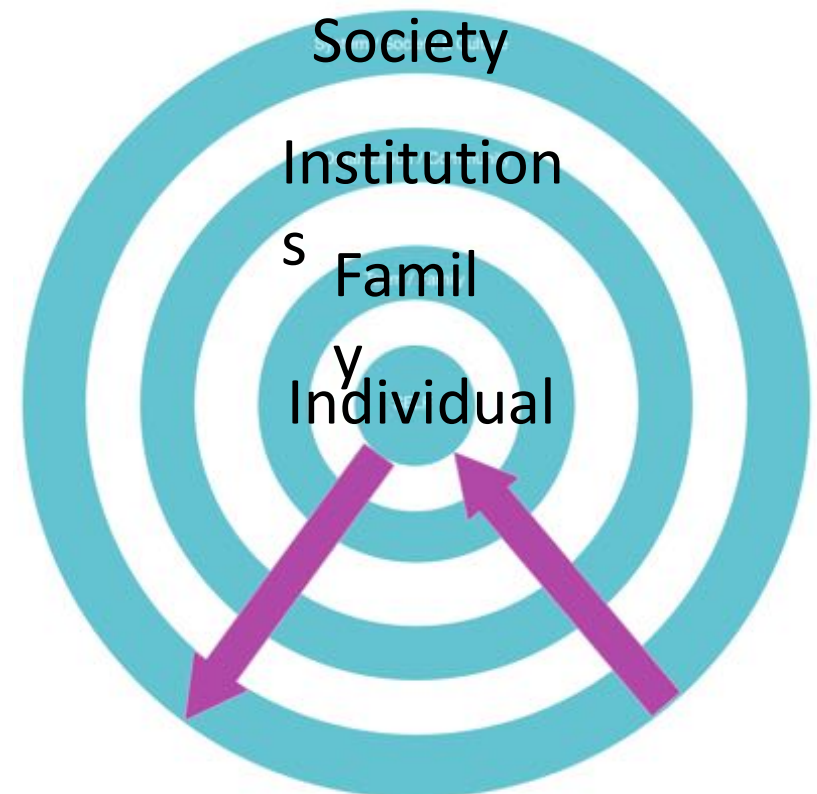
of multiple scales

- Institutions occur at multiple scales

from the family to global

- They interact strongly with one another, for better or for worse.

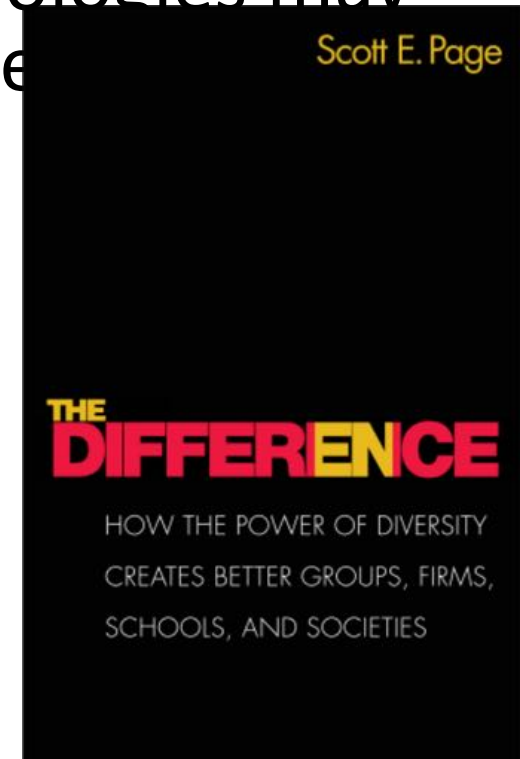
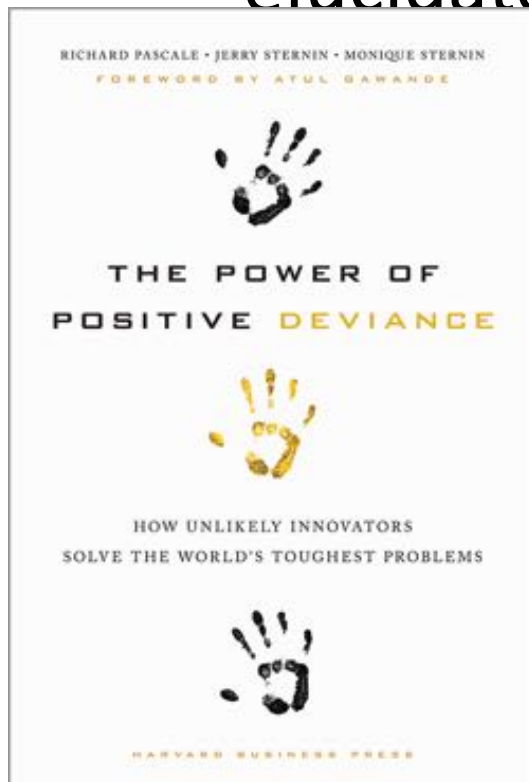
Systems Thinking: Connecting Self to Society



Adapted from Urie Bronfenbrenner, (1979), *The Ecology of Human Development: Experiments by Nature and Design*, Cambridge, MA: Harvard University Press.

How can science help build institutions that promote human flourishing?

- Complexity theory may provide insights.
- Studies with social science methodologies may elucidate ingredients and impediments to human flourishing.



Social science empirical method 1: positive deviance

In any community there are people whose uncommon but successful behaviors or strategies enable them to find better solutions to a problem than their peers, despite facing similar challenges and having no extra resources or knowledge than their peers.

These individuals are referred to as positive deviants.

