THE OHIO STATE UNIVERSITY

Cities as complex systems: Leveraging data and experimentation for science and policy

Harvey J. Miller
Department of Geography &
Center for Urban and Regional Analysis
The Ohio State University
Columbus, Ohio USA
miller.81@osu.edu

Take home messages

Basic science: Mesogeography

- Human-environment systems are complex
- This should change our approaches to constructing geographic knowledge

Science + policy: Urban sustainability observatories

- Major societal challenges are wicked problems embedded in complex systems
- This should change our approaches to scientific engagement and policy

Spatial analysis and old-school social physics

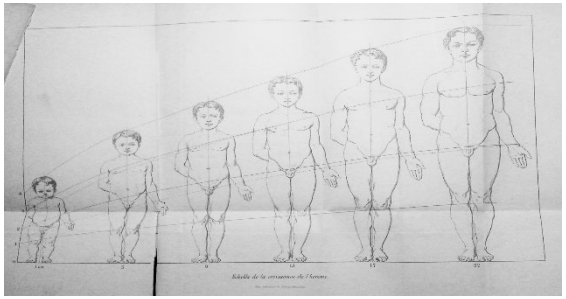
A search for grand social laws based on **classical mechanics**

Quetelet: Average man

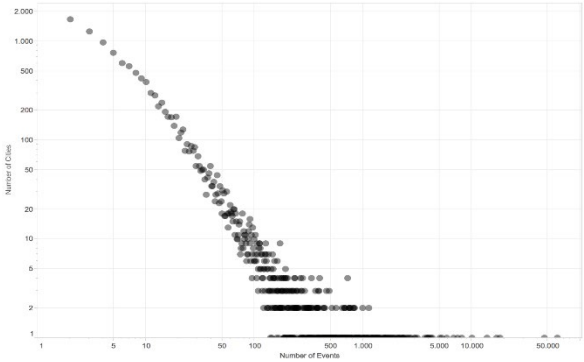
George K. Zipf: Power laws

John Q. Stewart and William Warntz: Demographic forces; Potentials

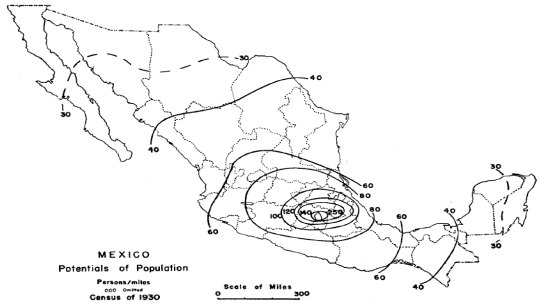
Direct path to spatial analysis and GIScience (via Harvard Graphics and U Western Ontario)



thefunambulist.net



medium.com



Stewart (1950)

The great debate in Geography

Microgeography

Idiographic (description-seeking)

Regional geography (20th century)

Human geography (21st century)

Macrogeography

Nomothetic (law-seeking)

Spatial analysis (20th century)

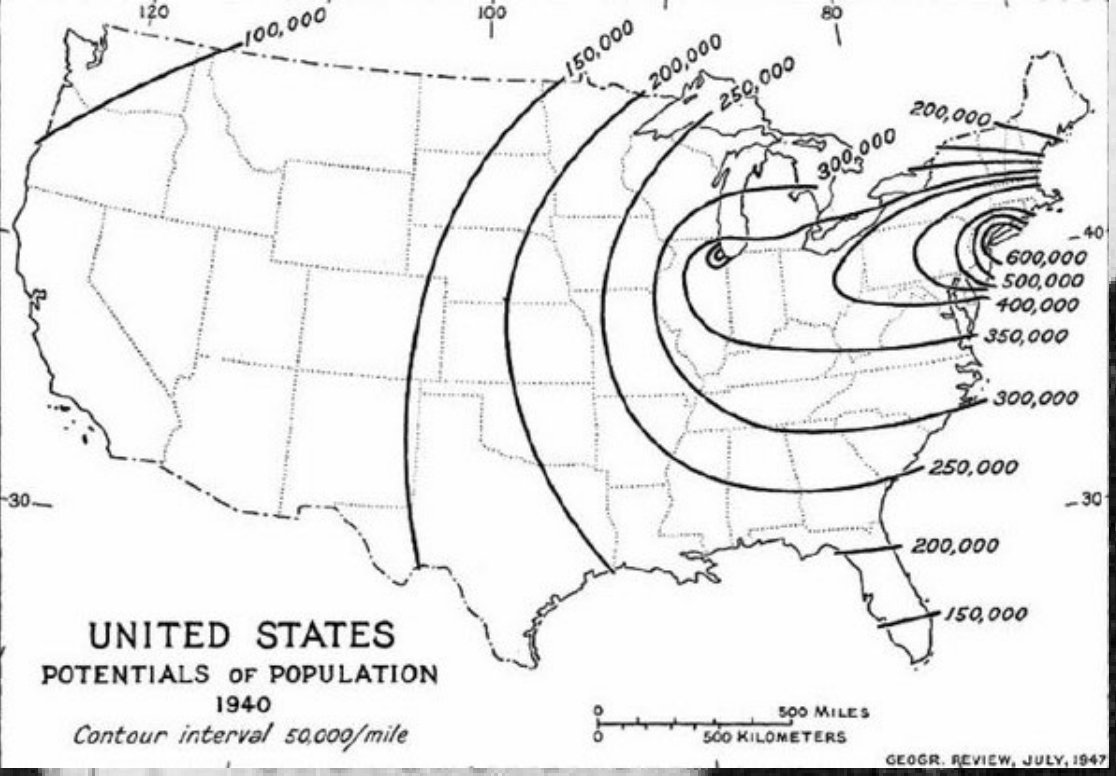
GIScience (21st century)

Geography,
In small degree,
Collects
The facts that be
On land and sea;
Expects
But little thought,
Nor is it sought.

Geography,
In large degree,
Is thus
The gift to see
Not thee and me
But us,
Summed up with grace
In mass and space.

Small vs large Geography (from Stewart and Warntz 1958)

Stewart JQ and Warntz W (1958) Macrogeography and social science. *Geographical Review* 48: 167–184


120
100
80
100,000
150,000
200,000
250,000
300,000
200,000
600,000
500,000
400,000
350,000
300,000
250,000
200,000
150,000
40
30
30
UNITED STATES
POTENTIALS OF POPULATION
1940
Contour interval 50,000/mile
0 500 MILES
0 500 KILOMETERS
GEOGR. REVIEW, JULY, 1947

Criticisms of social physics

- **People are not particles**
- **Monism**: One set of principles to explain all things
- **Big Data is more of the same:** Macrogeography writ large

Barnes & Wilson (2014). Big data, social physics, and spatial analysis: The early years. *Big Data & Society*, *1*(1).

The new social physics:

Spatial phenomena as **collective systems**

1. More is different

Emergent properties

Asymmetry: Reductionism and constructionism

Scientific hierarchy ultimately (*but not exclusively*) rooted in physics

> 'the ability to reduce everything to simple fundamental laws does not imply the ability to start from these laws and reconstruct the universe' (p. 393)

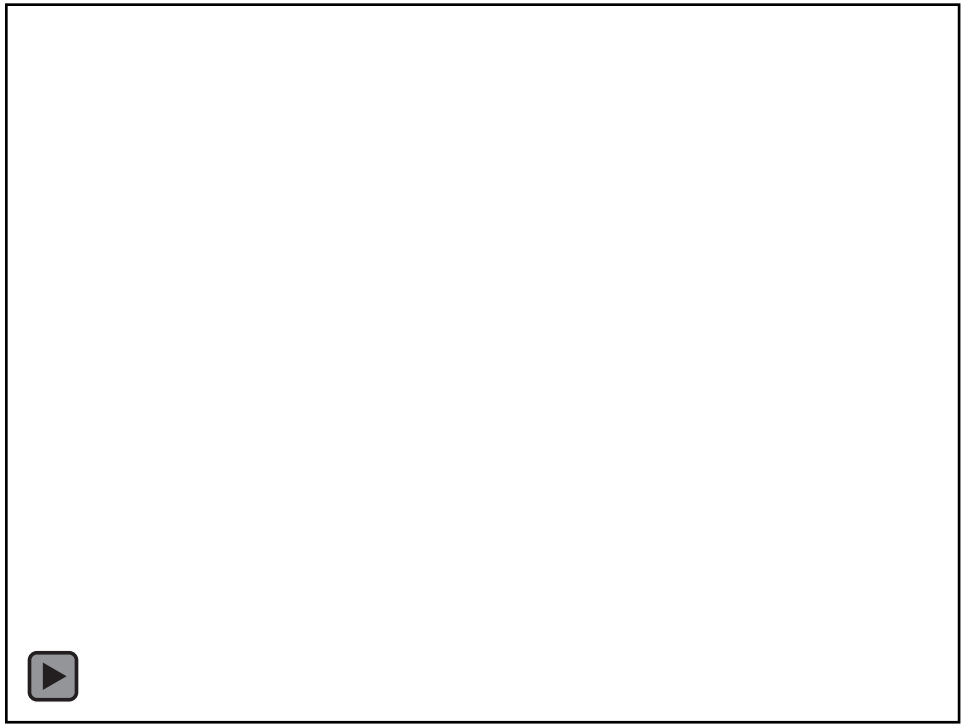
Anderson PW (1972) More is different. *Science* 177: 393–396

2. Context matters

Pattern of interactions among distributed/mobile components

Space facilitates order

Heterogeneity and context are key drivers of interesting behavior



Spatial evolutionary game theory

O'Sullivan D and Perry GLW (2013) *Spatial Simulation: Exploring Pattern and Process*.

Mesogeography: ***How context influences collective systems distributed in geographic space***

A middle ground

Description-seeking vs. law-seeking
Reductionist vs. aggregate

Seeks generalizations but not universals

Casual relations in a range of environments
Similar to middle-range theories (Robert Merton)

Comparative and experimental analysis

Compare and contrast across settings, times
Quasi and natural experiments

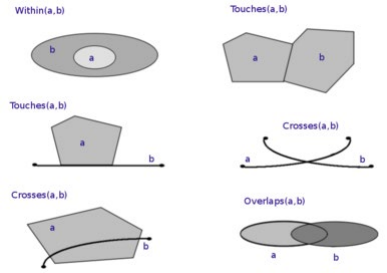
Spatial analysis and mesogeography

1. Measuring/analyzing spatial context

Spatial relations (set-based, topological, metric)

Disaggregate spatial statistics and modeling

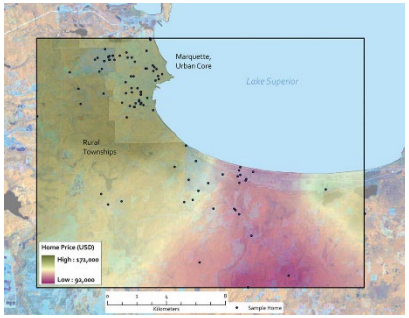
Spatial simulation

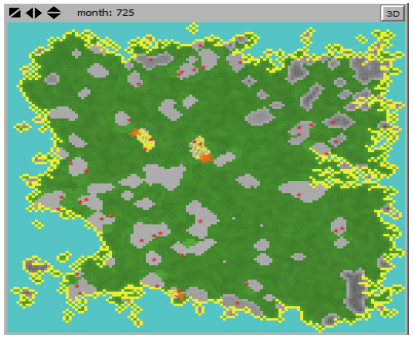


2. Experiments in real + simulated worlds

Opportunistic GIScience – based on ongoing data collection and analysis

Simulation = theory + experiment (O'Sullivan and Perry 2013)





3. Analytical time geography

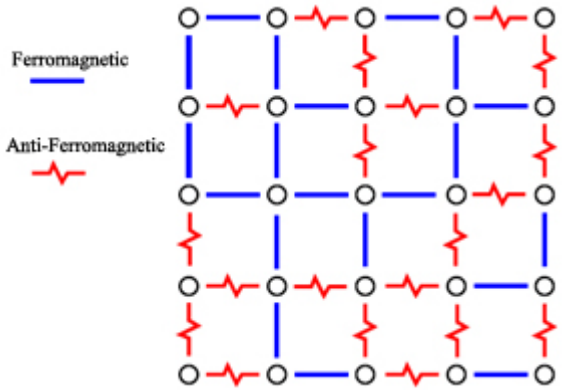
(Hägerstrand 1970)

Necessary spatial and temporal conditions for human activities

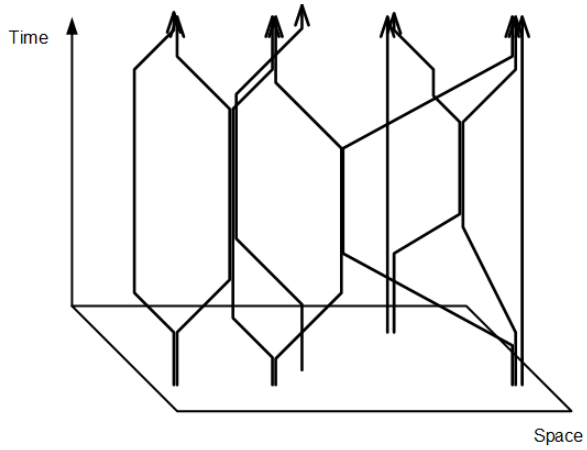
Ground human geography/regional science in physical reality

Constraints generate order in collective systems

Regularity and order in social systems are not a lack of free will: these result from the limited choices facing individuals in many life situations



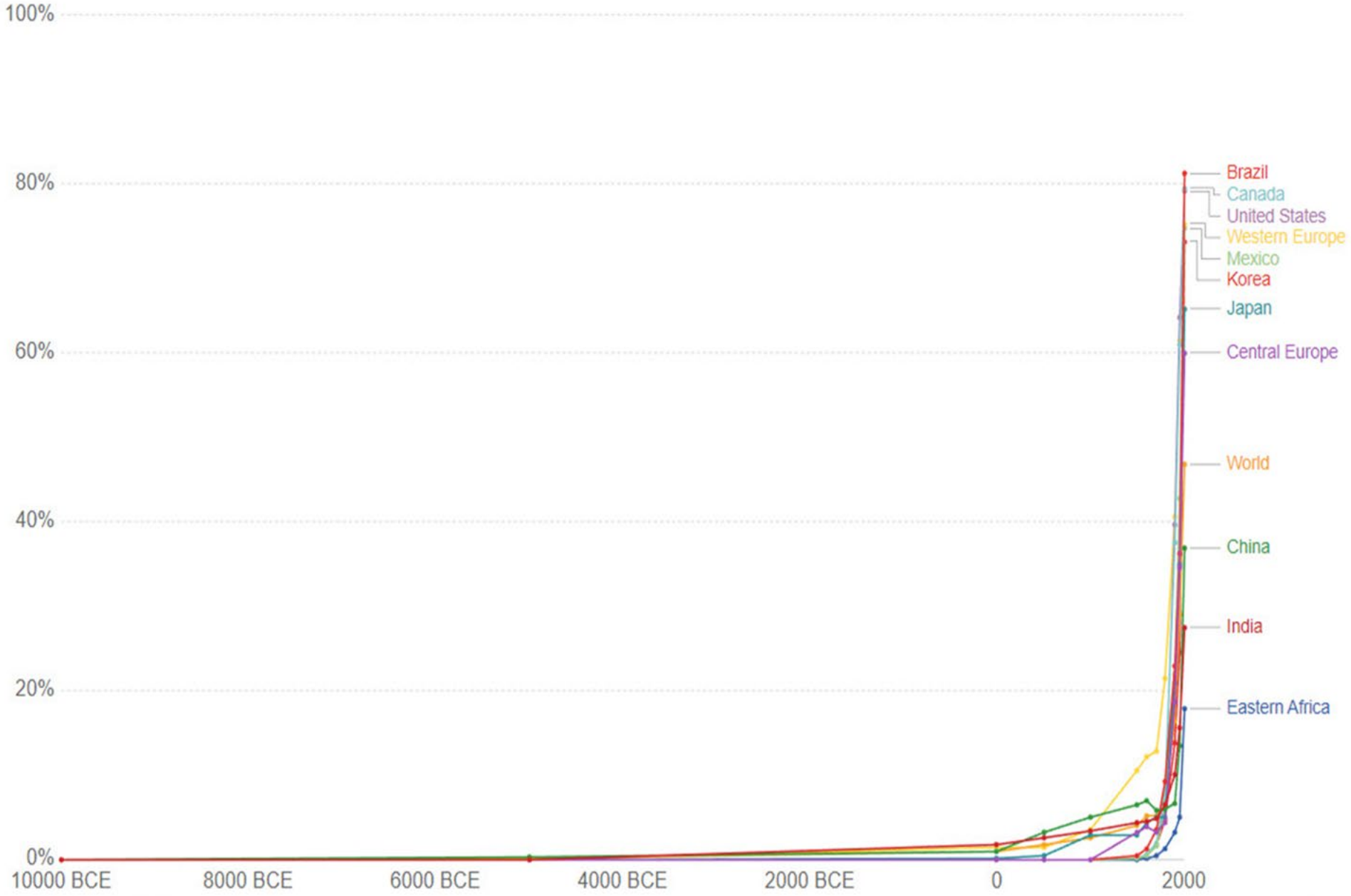
Spin glass



Coordinated activities represented by space-time paths (Thrift 1977)

Share of the population living in urbanized areas

Share of the total population, in a particular region or country, who live in urbanized areas.



Source: HYDE 3.1 (2010)

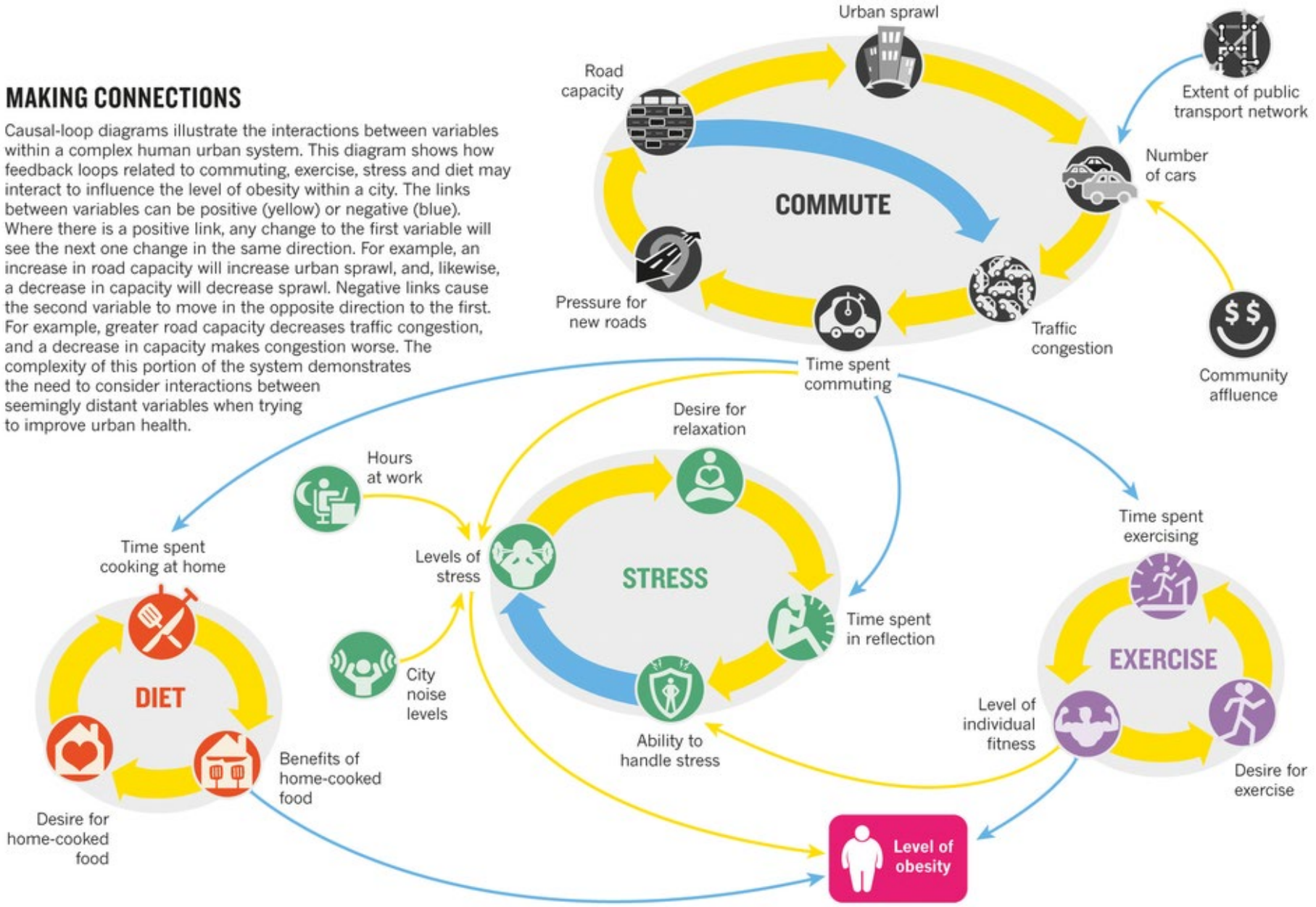
Challenge: Cities and regions are complex!

"Cities are complicated. They comprise large numbers of people, and the many ecological, cultural, social and economic entities that make up their environment. **All these factors interact in time and space to form complex systems that constantly evolve in response to changes in climate, environment and people**."

Pollock, K. (2016) "Urban physics," Nature, 531, S64–S66 (17 March 2016)

MAKING CONNECTIONS

Causal-loop diagrams illustrate the interactions between variables within a complex human urban system. This diagram shows how feedback loops related to commuting, exercise, stress and diet may interact to influence the level of obesity within a city. The links between variables can be positive (yellow) or negative (blue). Where there is a positive link, any change to the first variable will see the next one change in the same direction. For example, an increase in road capacity will increase urban sprawl, and, likewise, a decrease in capacity will decrease sprawl. Negative links cause the second variable to move in the opposite direction to the first. For example, greater road capacity decreases traffic congestion, and a decrease in capacity makes congestion worse. The complexity of this portion of the system demonstrates the need to consider interactions between seemingly distant variables when trying to improve urban health.



Pollock, K. (2016) *Nature*, 531, S64–S66 (17 March 2016)


GROCERIES, LIQUORS,
DRY-GOODS, HARDWARE &C.
crowwinghistory.org

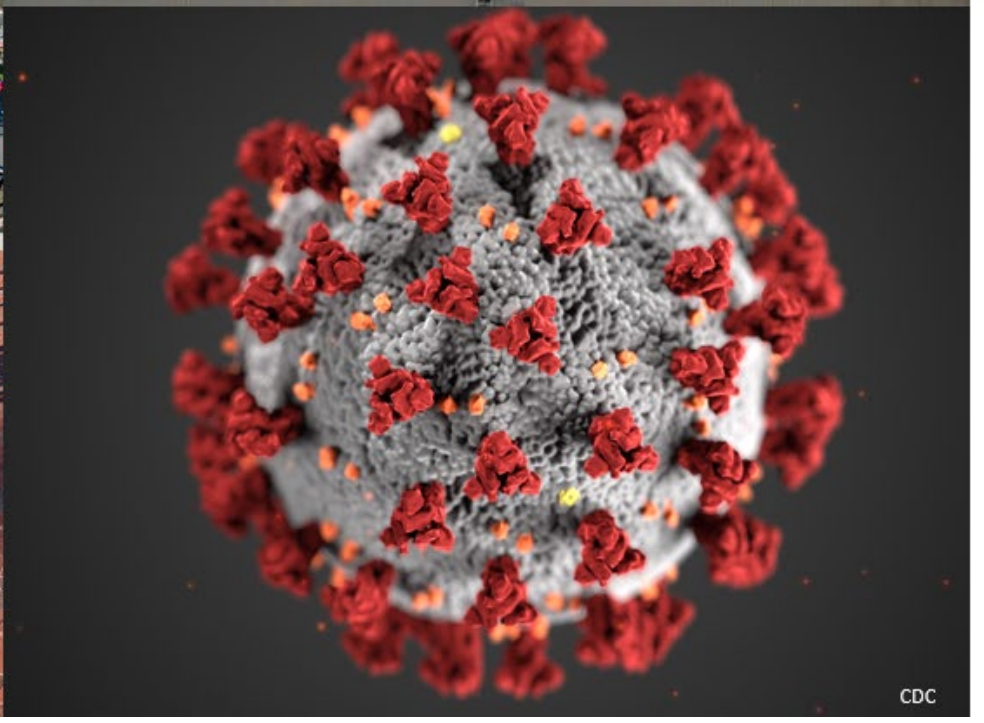

TICKETS
parcitypatory.org


archinect.com

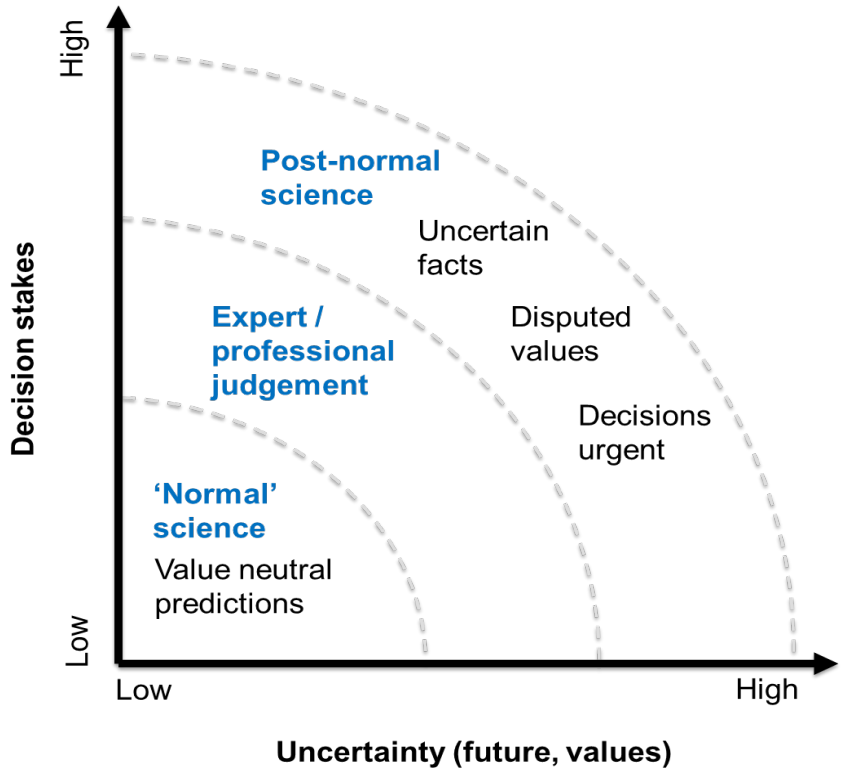
Washington Post

Ohio Department of Transportation


Wikipedia


CDC

Graphic: Daniel Christian Wahl
medium.com/age-of-awareness/



Funtowicz, S.O. and Ravetz, J.R. (1994) Uncertainty, complexity and post-normal science. Environmental Toxicology and Chemistry, 13, 1881-1885

A way forward

Respect the complexity: Treat geographic systems such as cities as constantly emerging and contextual

Opportunistic science: Leverage real-world events and experiments via ongoing observation and analysis

Post-normal science: Embrace uncertainty and heterogeneous values by decentering prediction in favor of scientific storytelling

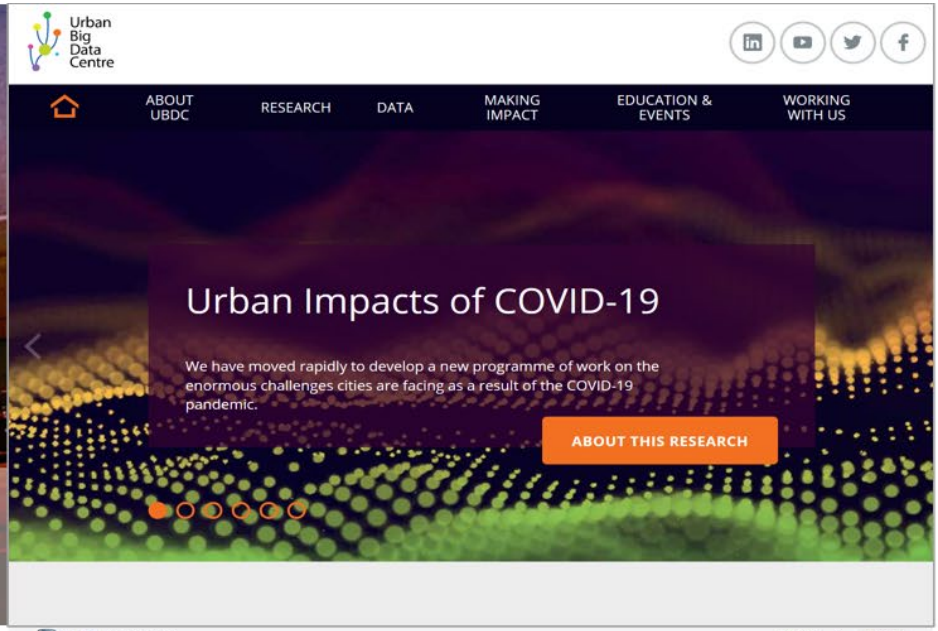
Urban observatory science

What?

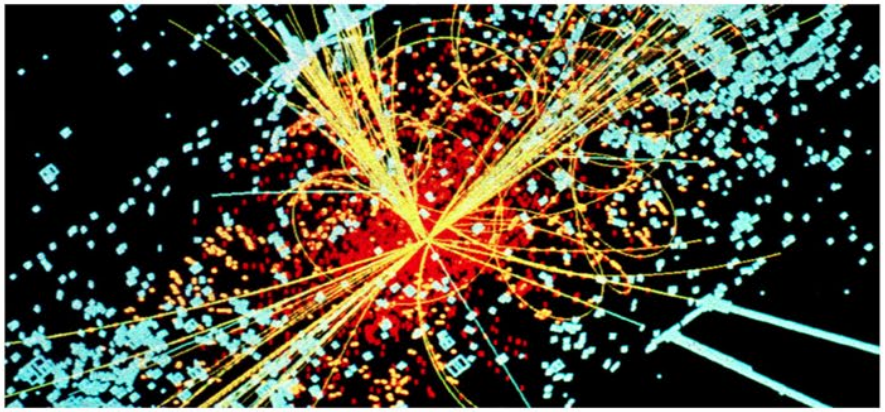
Ongoing data collection and analysis based on a favored view, supported by technology and organizational processes

Why?

Discovery: Generate new, surprising hypotheses
Dynamics: Complex multi-scale dynamics
Engagement: to minimize harms, e.g., volcano observatories
Ready when something happens!



Urban Data Platform

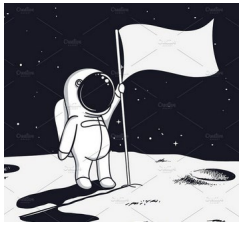


Flickr user KamiPhuc

Scientific challenges

1) How do we build tools and protocols for opportunistic geospatial science?
2) How do we build knowledge in complex geographic systems?
3) How do we achieve shared understanding given uncertainty and heterogeneous values?
4) How do we resolve barriers to geographic knowledge co-production?
5) How do we create authoritative knowledge from novel geospatial data sources with unclear sampling frames, data quality and veracity?

Scientific Merit



New insights into:

- Behavior of complex urban and other geographic systems
- Interactions among natural, human-built and social systems that drive sustainability across multiple scales
- Deeper understanding of how people interact with geographic data and information

Broader Impacts: a sustainable world

Thank you!

Papers

- Miller H.J. (2017) "Geographic information observatories and opportunistic GIScience," ***Progress in Human Geography***, 41, 489-500.
- Miller, H.J. (2018) "Mesogeography: Social physics, GIScience and the quest for geographic knowledge," ***Progress in Human Geography***, 42, 600-609.
- Miller, H.J., Clifton, K., Akar, G., Tufte, K. Gopalakrishnan, S., MacArthur, J., Irwin, E., Ramnath, R., Stiles, J. (2021) "Urban sustainability observatories: Leveraging urban experimentation for sustainability science and policy," ***Harvard Data Science Review***, 3.2.

Blog and contact

- u.osu.edu/miller.81/
- miller.81@osu.edu