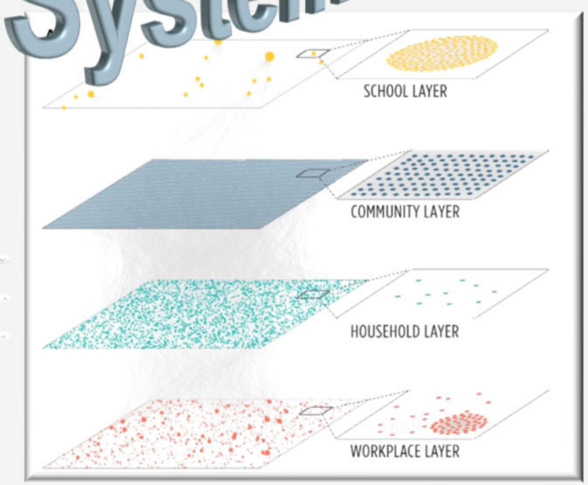
Multilevel Organization of Complex Systems

As the outbreak moved across China in early January, **international travel** continued as normal.

Recent air travel, based on first quarter 2019 data from O.A.G.



bit.ly/atBIC

evaluation

- Participation: 20%.
  - class discussion, everybody reads and discusses every paper
  - engagement in class
- Paper Presentation and Discussion: 20%
  - **SSIE501** students are assigned to papers individually or as group lead presenters and discussants
    - all students are supposed to read and participate in discussion of every paper.
  - Presenter prepares short summary of assigned paper (15 minutes)
    - no formal presentations or PowerPoint unless figures are indispensable.
  - Summary should:
    - 1) Identify the key goals of the paper (not go in detail over every section)
    - 2) What discussant liked and did not like
    - 3) What authors achieved and did not
    - 4) Any other relevant connections to other class readings and beyond.
  - **ISE440** students chose one of the presented papers to participate as lead discussant
    - not to present the paper, but to comment on points 2-3) above
  - Class discussion is opened to all
    - lead discussant ensures we important paper contributions and failures are addressed
- Black Box: 60%
  - Group Project (2 parts)
    - Assignment I (25%) and Assignment II (35%)

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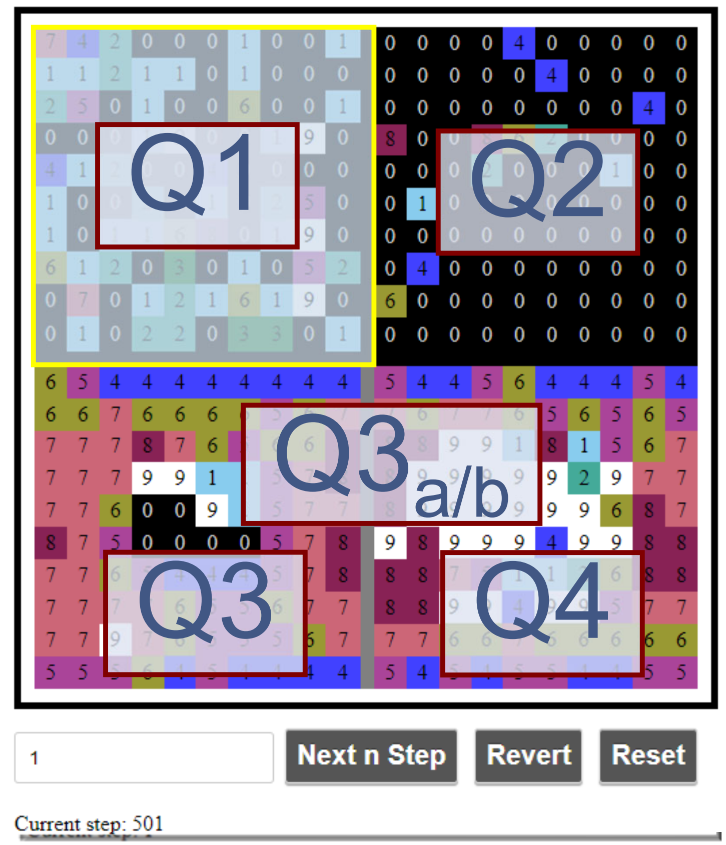
The Black Box II: Due: **November 26th, 2024**

Herbert Simon: Law discovery means only finding **pattern** in the data; whether the pattern will continue to hold for new data that are observed subsequently will be decided in the course of **testing the law**, not discovering it. The **discovery process** runs from particular facts to general laws that are somehow induced from them; the **process of testing** discoveries runs from the laws to predictions of particular facts from them [...] To explain why the patterns we extract from observations frequently lead to correct predictions (when they do) requires us to face again the problem of **induction**, and perhaps to make some hypothesis about the uniformity of nature. But that hypothesis is neither required for, nor relevant to, the theory of discovery processes. […] By separating the question of pattern detection from the question of prediction, we can construct a **true normative theory of discovery**-a logic of discovery.

- Focus on uncovering quadrants
  - using data collection, descriptive patterns & statistics, and induction.
- Propose a formal model or algorithm of what each quadrant is doing.
  - Analyze, using deduction, the behavior of this algorithm.
- Maximum 20 pages!!!
  - 4 per quadrant + 4
  - Supporting information in separate file



What is it!!??

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systems modeling

- Data and statistics provide **the essential basis to understand** (i) the ontogeny of systems and (ii) their evolution.
- **Machine Learning** is the **key technology** for the creation of **predictive models** and the eventual automation of decision making across different economic valuations.
- Providing analytical insights [from the currently available] huge amount of data, in real time, requires not only strong computational processing power and specific tools, but **awareness of the technical, ethical and legal complexities all along the processual pipeline.**
  - The philosophical implications of modeling from the perspective of complex systems science.

International Conference on Robot Ethics and Standards ICRES 2021

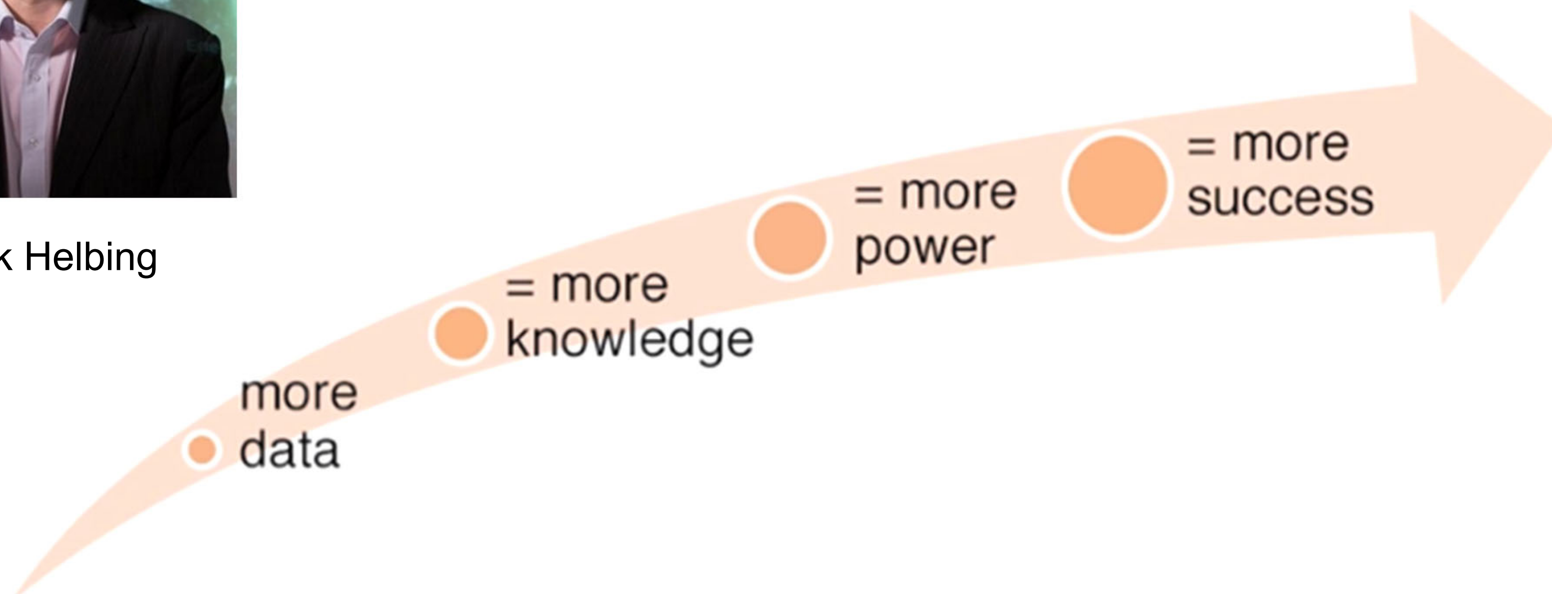
New York, USA, 26-27 July 2021

ICRES 2021

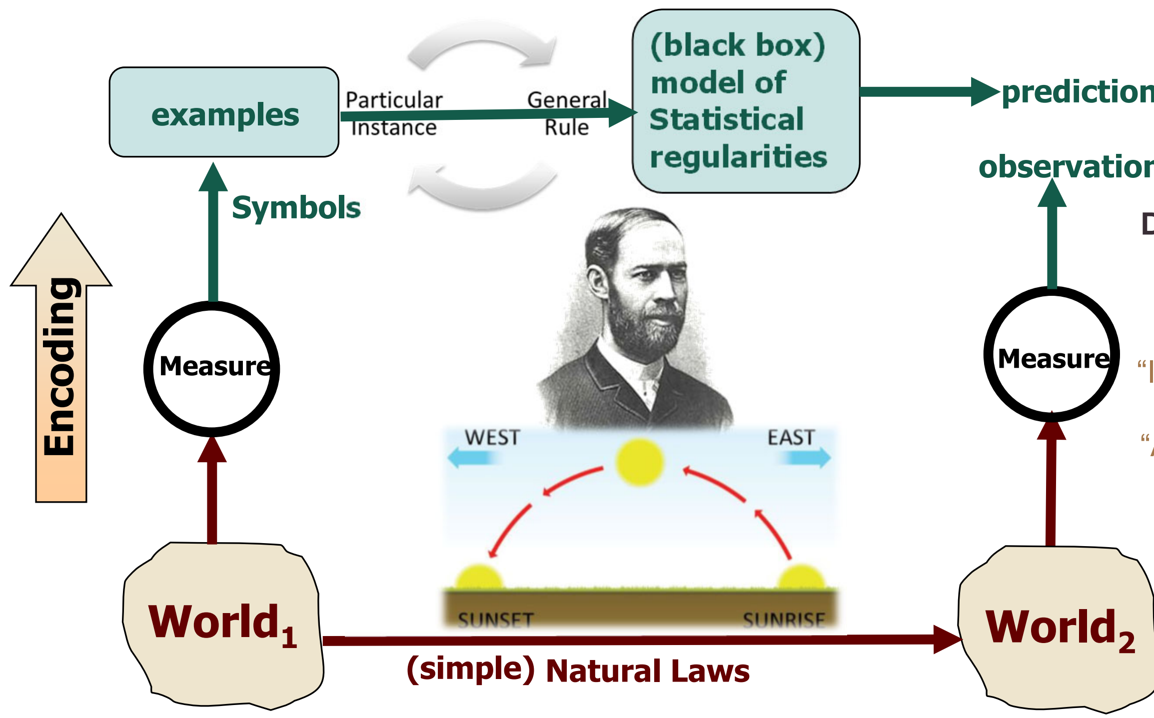
systems modeling

The Magic Formula ...

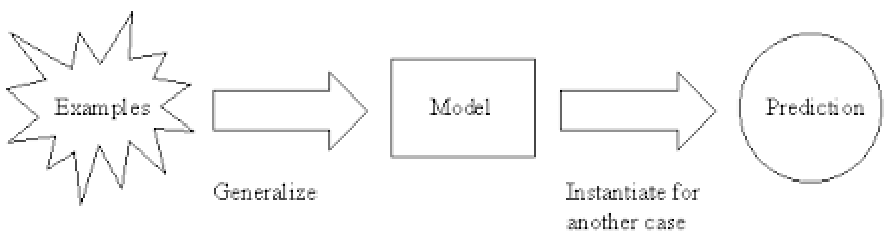
Dirk Helbing



good news I & II: near-decomposability and induction



David Hume’s Empiricism
Everyday knowledge depends on patterns of repeated experience
“It is not reason which is the guide of life, but custom.”
“A wise man proportions his belief to the evidence”



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Hume's and Hertz's World (of AI): Inductive learning

good news I & II: near-decomposability and induction

examples

Particular Instance → General Rule

(black box) model of Statistical regularities

predictions

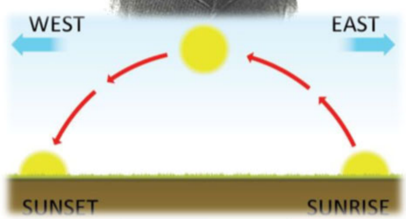
observations

Symbols

Encoding

Measure

Measure



World$_1$

World$_2$

(simple) Natural Laws

David Hume's Empiricism

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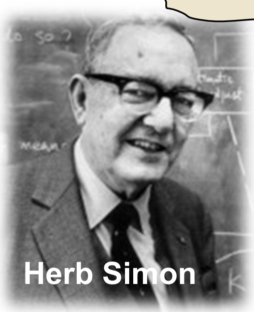

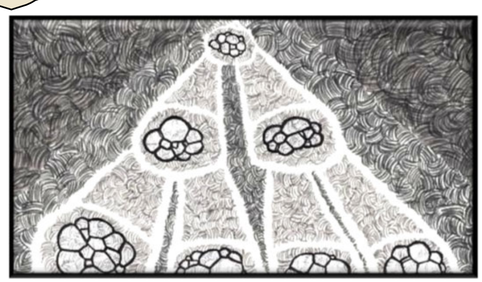

Studying (multilayered, contextual) complexity possible if world is near-decomposable and predictable from past examples

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General Rule

(black box) model of Statistical

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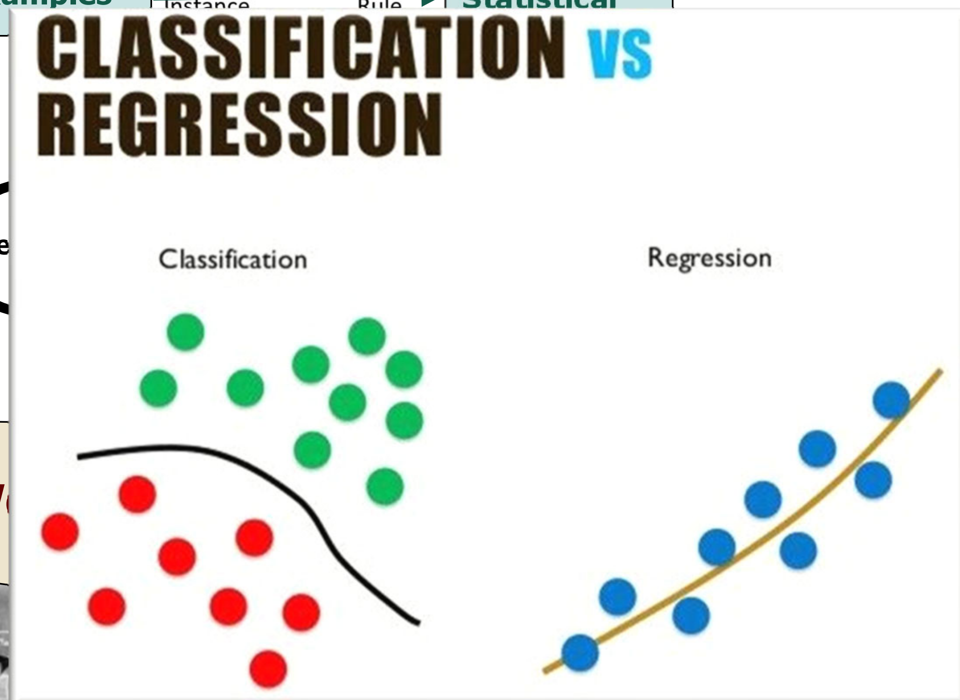

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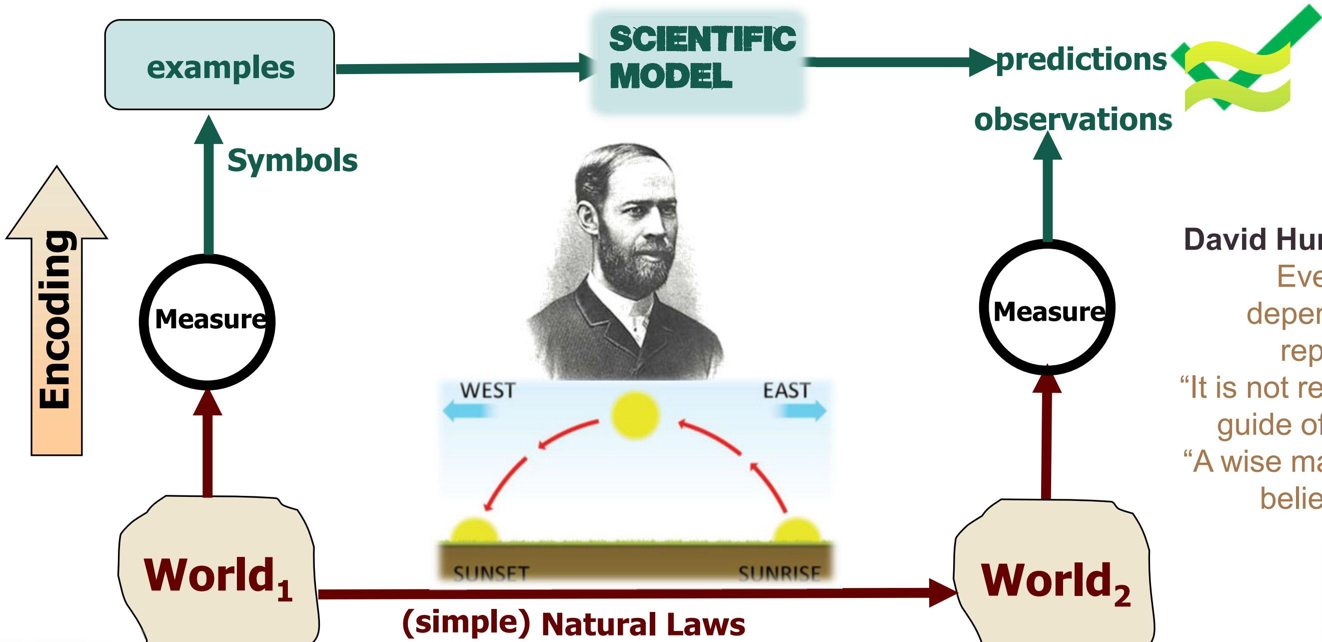
near-decomposable and predictable from past examples

Bad news I: computational limits



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Hans Bremmermann

Model complexity

We must simplify computational models

Tradeoff descriptive and uncertainty-based complexity

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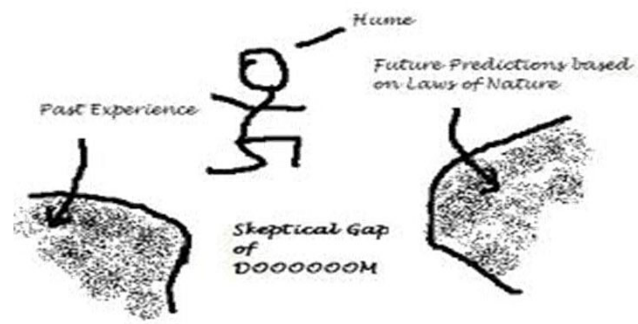
Bad news II: black swans

Bertrand Russell
On Hume's common sense practical skepticism



The Inductive Leap

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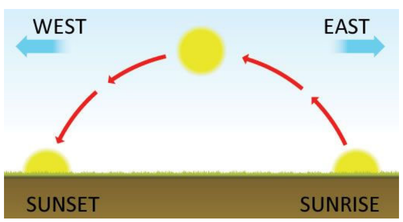

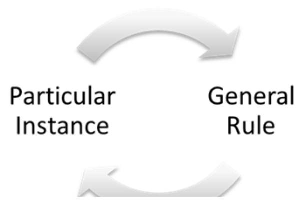

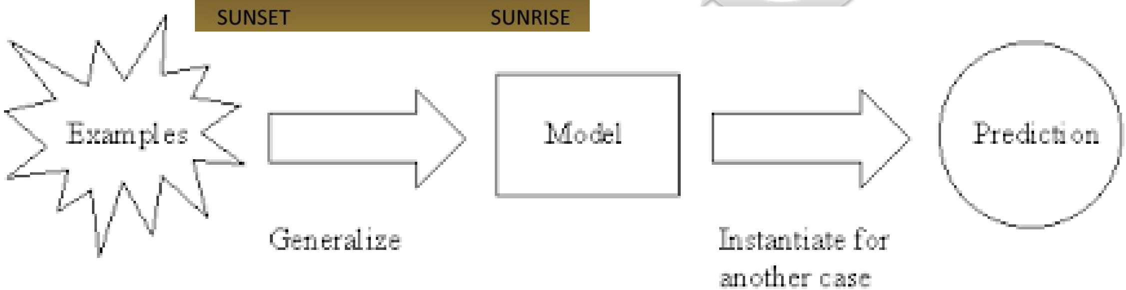

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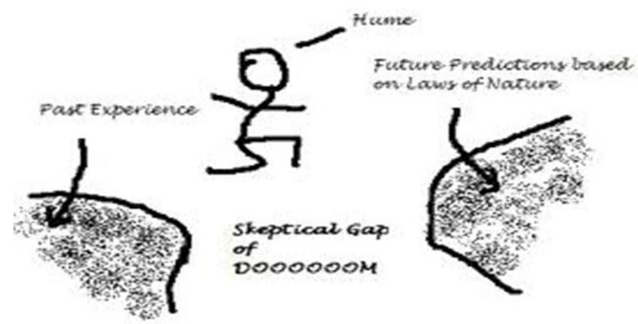

The Inductive Leap

Karl Popper’s Falsification Principle
logical asymmetry between verification and falsification: many observations do not derive (universal) theories, a single observation can falsify it: scientific theories (deduced) from induction are **testable**.

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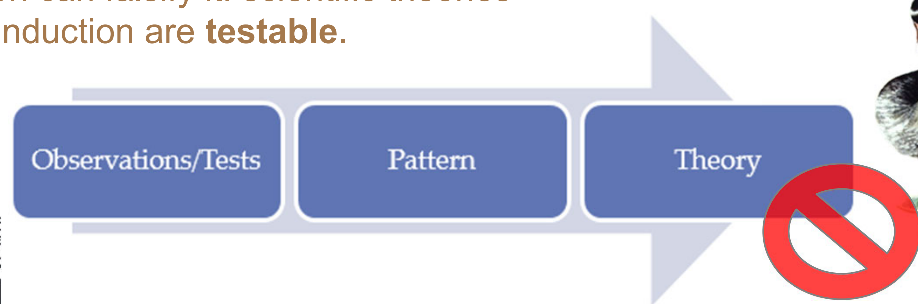

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Induction is dictated (biased) by previous observations

Bad news II: black swans

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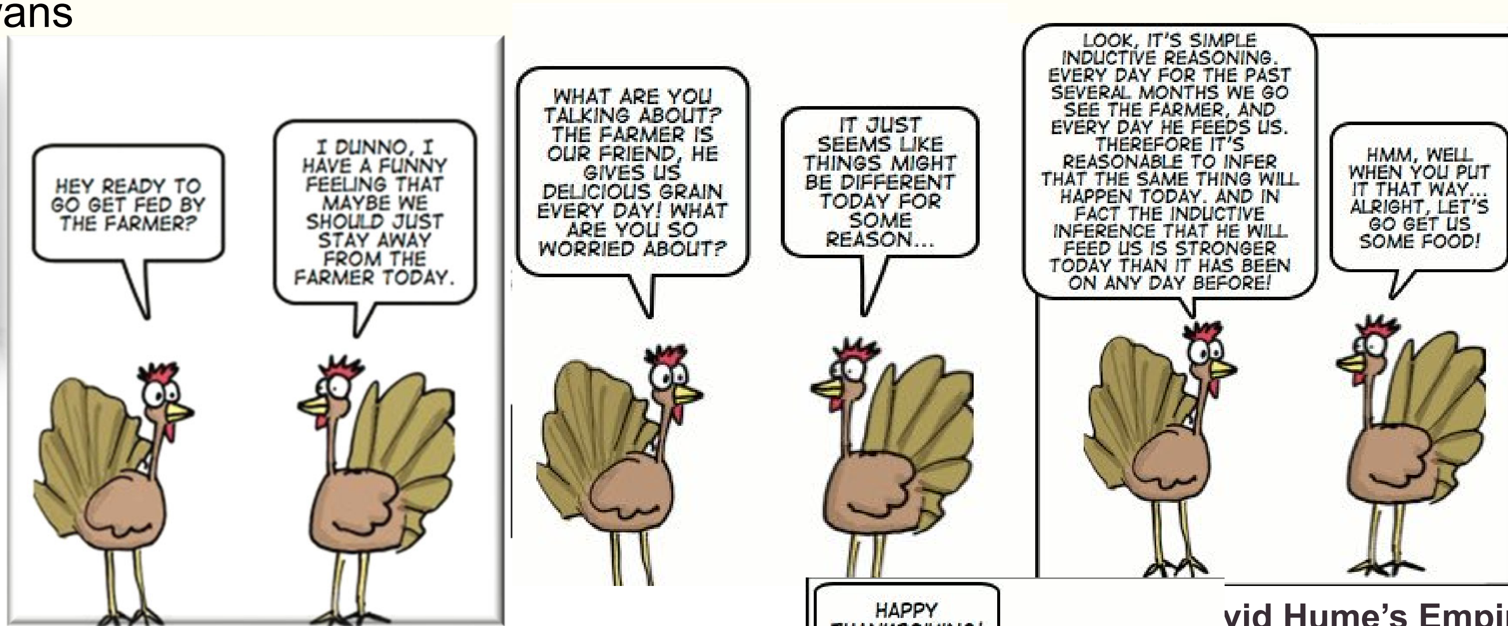
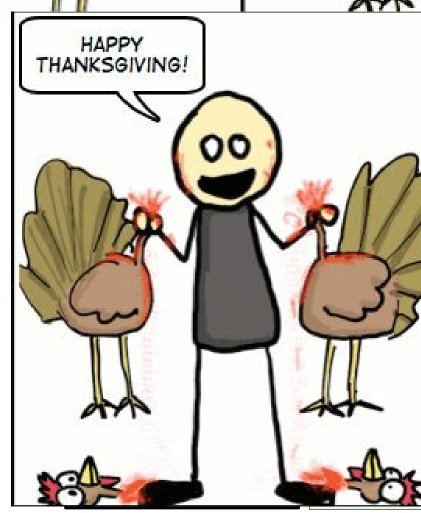
On Hume's common sense practical skepticism





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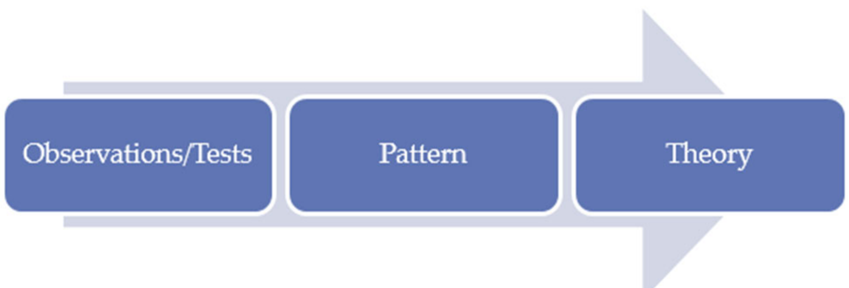

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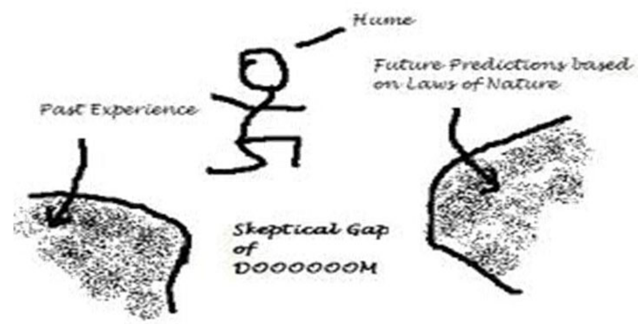

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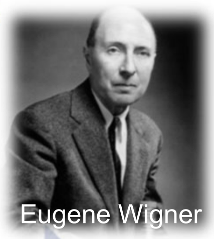

"Every empirical law has the disquieting quality that one does not know its limitations."
E. Wigner [1957] in "The Unreasonable Effectiveness of Mathematics in the Natural Sciences"

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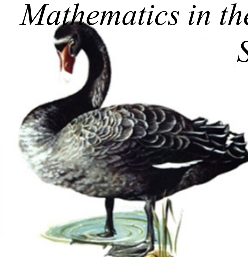

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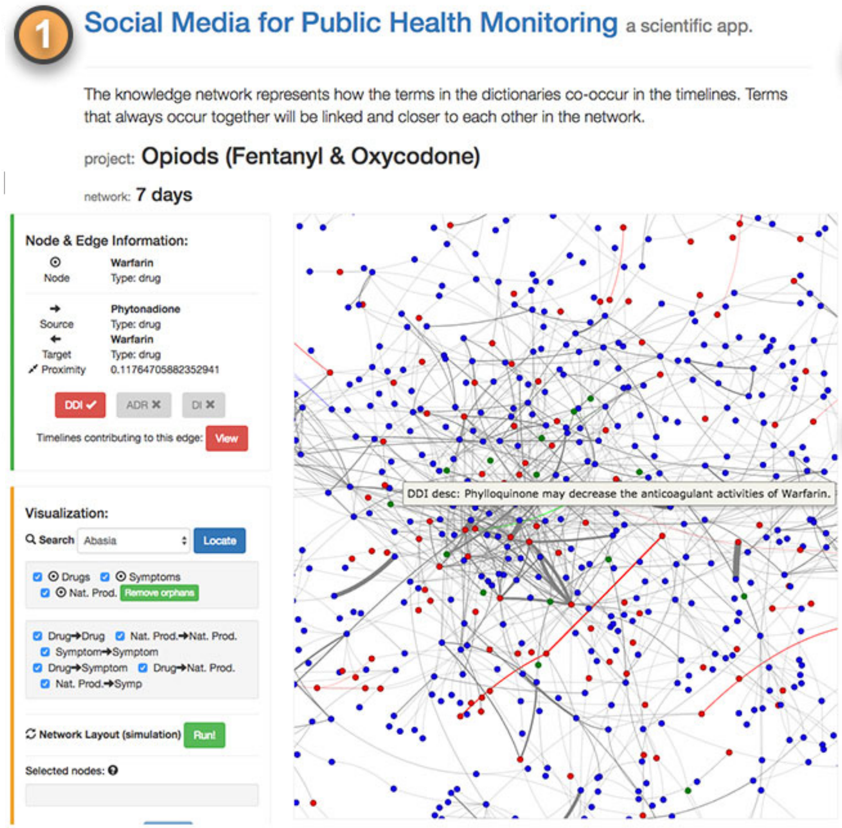
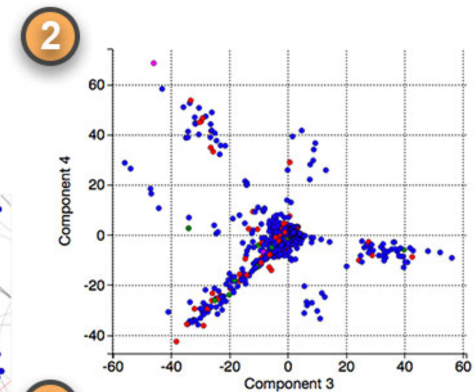
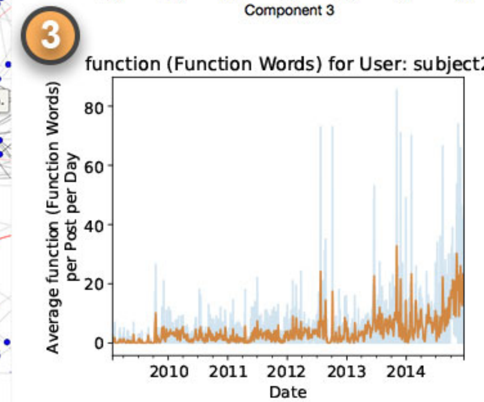
social media data pipelines for biomedicine







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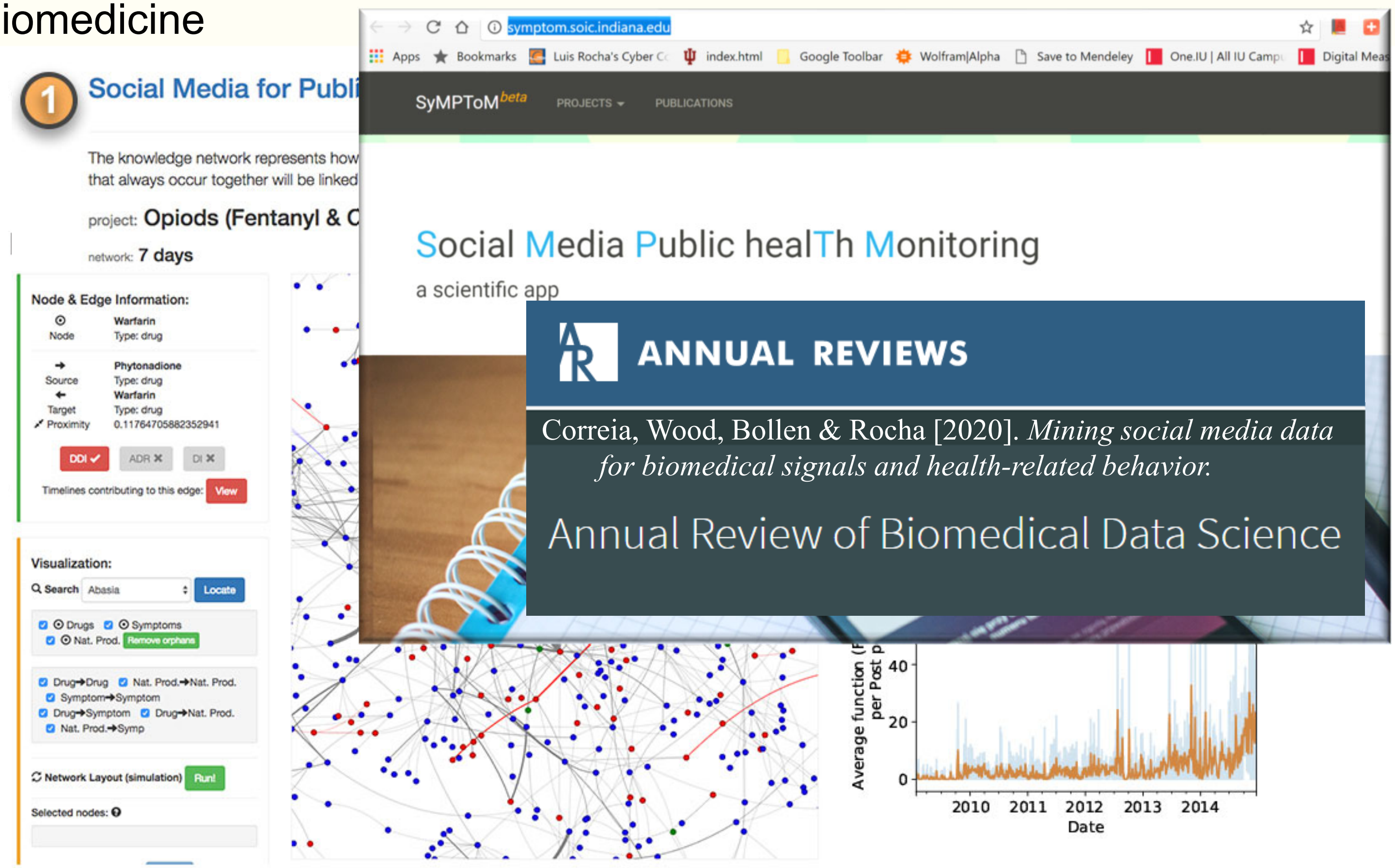

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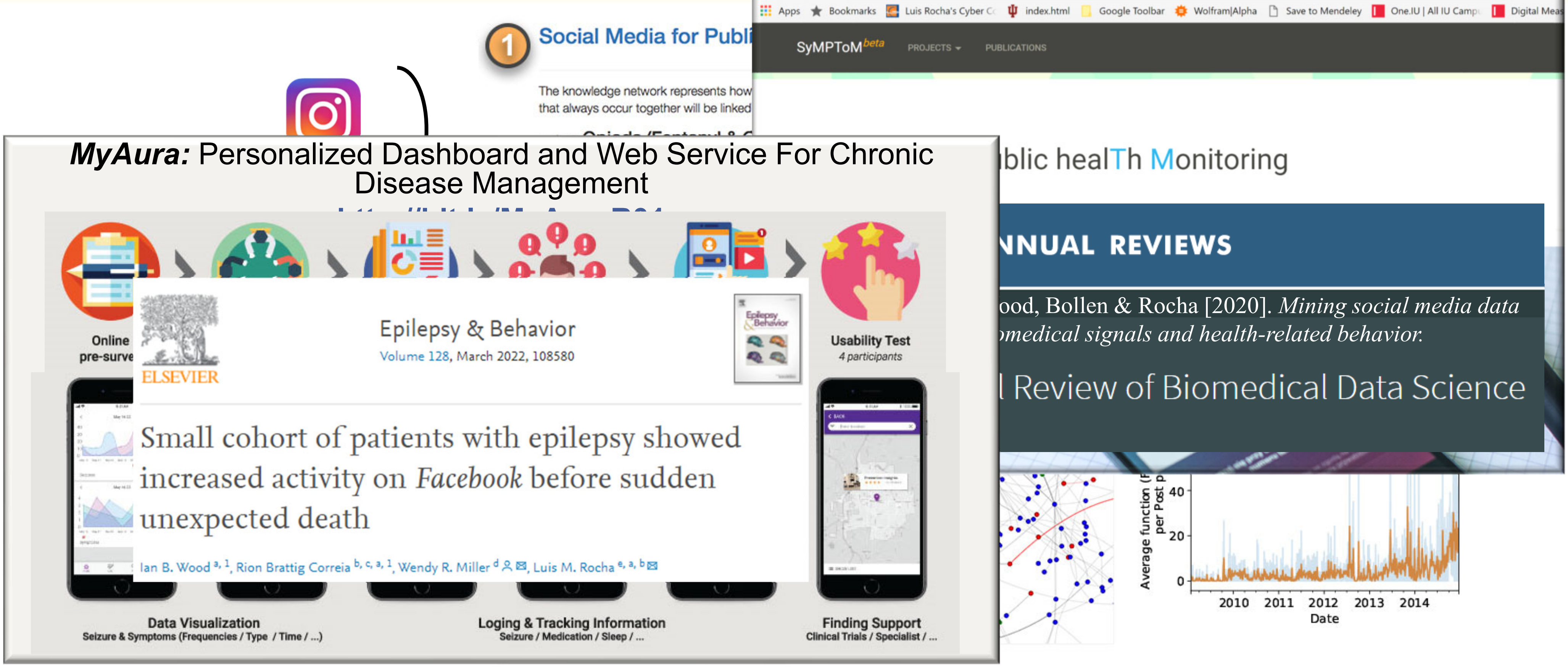

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resolving a sociobiology question on a planetary scale

- Social Media (Twitter) Mood and Web Searches
  - Understanding collective human behavior
  - Discovering mood transitions in health

SCIENTIFIC REPORTS

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Article | OPEN

Human Sexual Cycles are Driven by Culture and Match Collective Moods

Ian B. Wood, Pedro L. Varela, Johan Bollen, Luis M. Rocha & Joana Gonçalves-Sá

Wood, Varela, Bollen, Rocha & Sá [2017]. *Scientific Reports. 7: 17973 .*

Global Patterns of Seasonal Variation in Human Fertility[a]

DAVID A. LAM[b,d] AND JEFFREY A. MIRON[c]

Emerald Article: Summer nights: A review of the evidence of seasonal variations in sexual health indicators among young people

Wendy Macdowall, Kaye Wellings, Judith Stephenson, Anna Glasier

Annual Rhythm of Human Reproduction: I. Biology, Sociology, or Both?

Till Roenneberg* and Jürgen Aschoff†

The observed annual birth cycle (in countries where there is data). Is it driven by biological adaptation or culture?

THE EFFECTS OF TEMPERATURE ON HUMAN FERTILITY*

DAVID A. LAM AND JEFFREY A. MIRON

resolving a sociobiology question on a planetary scale

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Global Patterns of Seasonal Variation in Human Fertility[a]

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A review of the evidence of seasonal ...tors among young people

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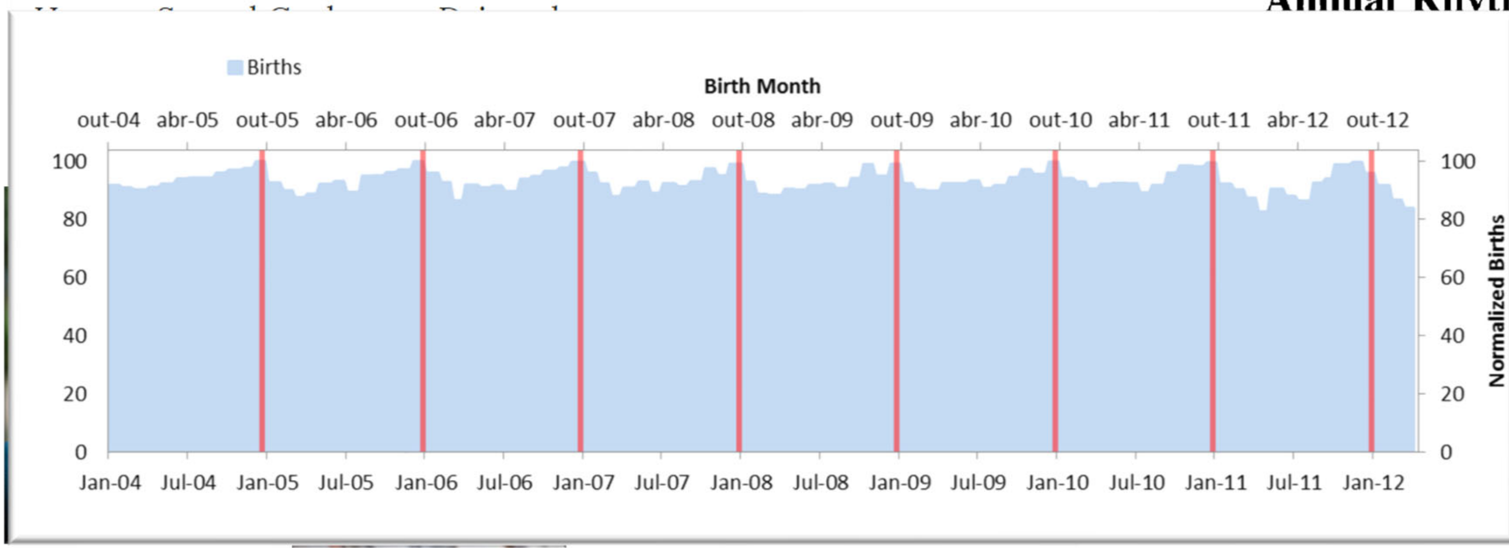
Western Northern countries, Canada, Denmark, Finland, France, Germany, Italy, Lithuania, Mas: Austrialta, Netherlands, Poland, Portugal, Spain, Sweden and USA

...Annual Rhythm of Human Reproduction: ...ciology, or Both?

...nd Jürgen Aschoff[†]



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...TURE ON HUMAN FERTILITY*

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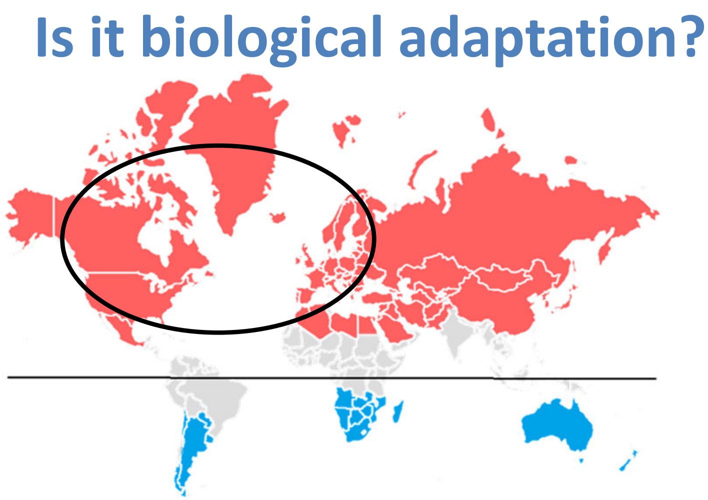
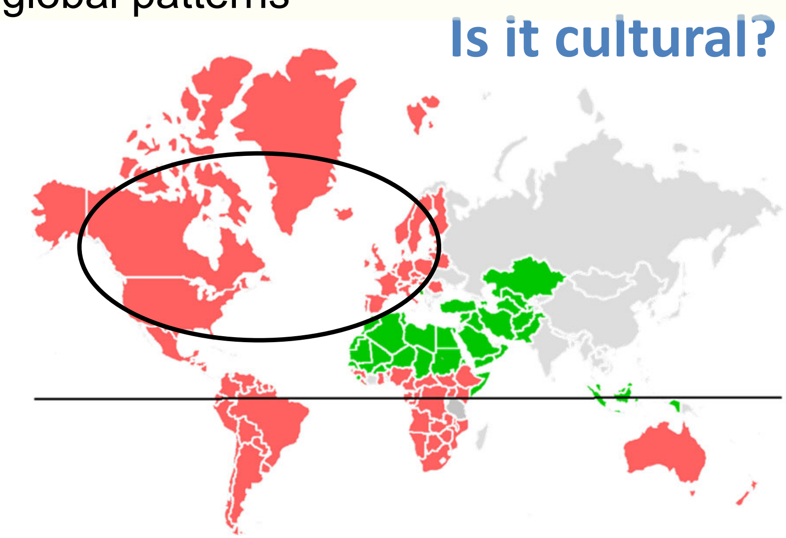
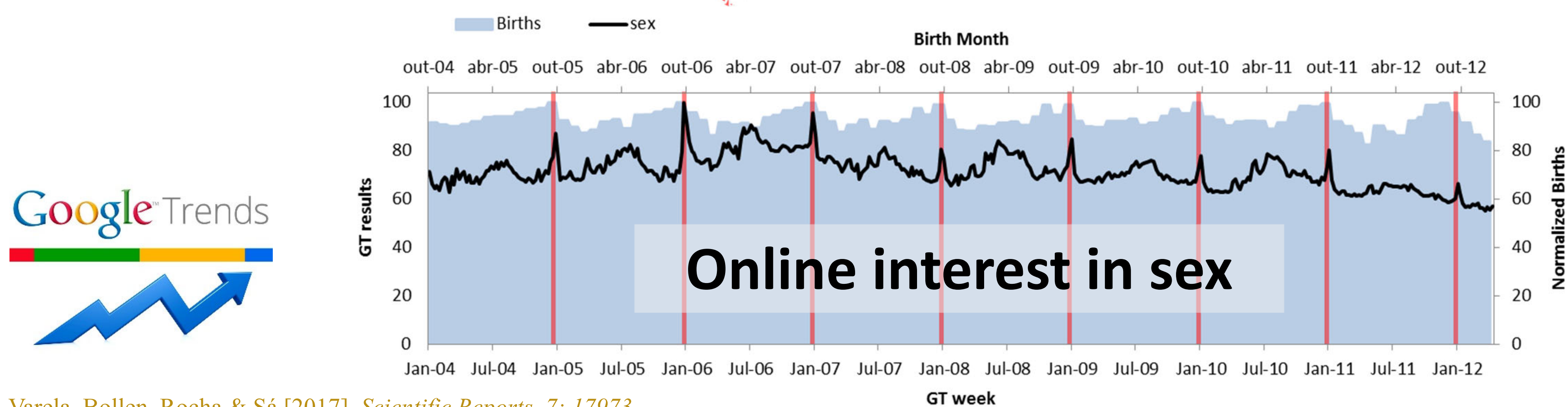
search and social media mood provide global patterns







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resolving a sociobiology question on a planetary scale

- Social Media (Twitter) Mood and Google Searches
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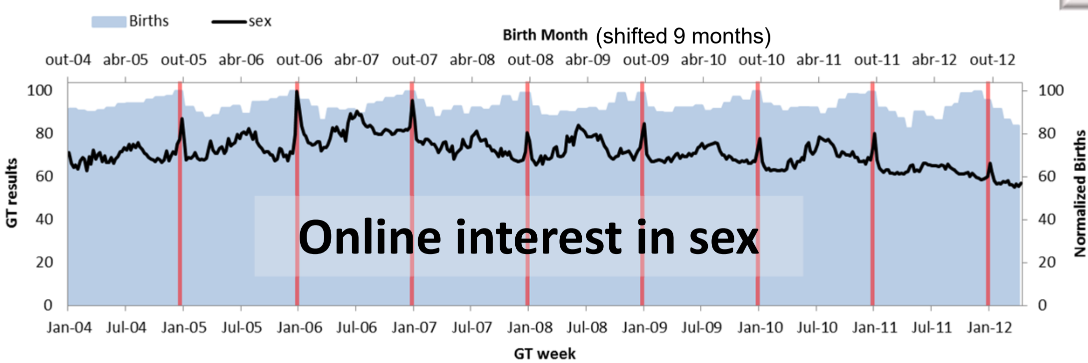
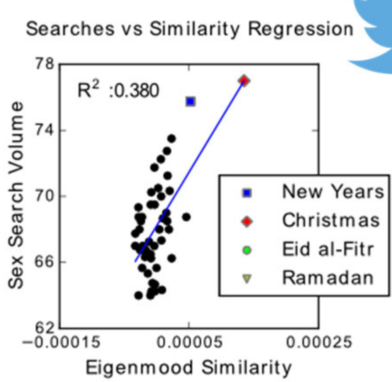
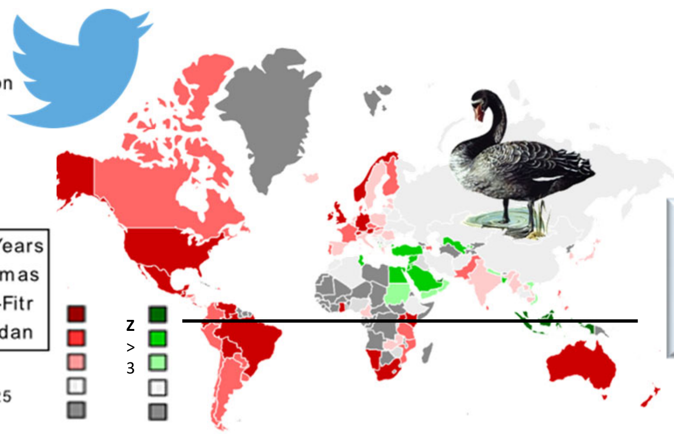
Sex search patterns (proxy for interest in sex and births) are **culturally-driven** and correlate with distinct **mood patterns** on social media



Why? child-centered and gift-giving holidays?

Christmas - USA





granger causality analysis suggests that mood causes interest in sex

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Hypothesis falsification in data and complexity science

resolving a sociobiology question on a planetary scale

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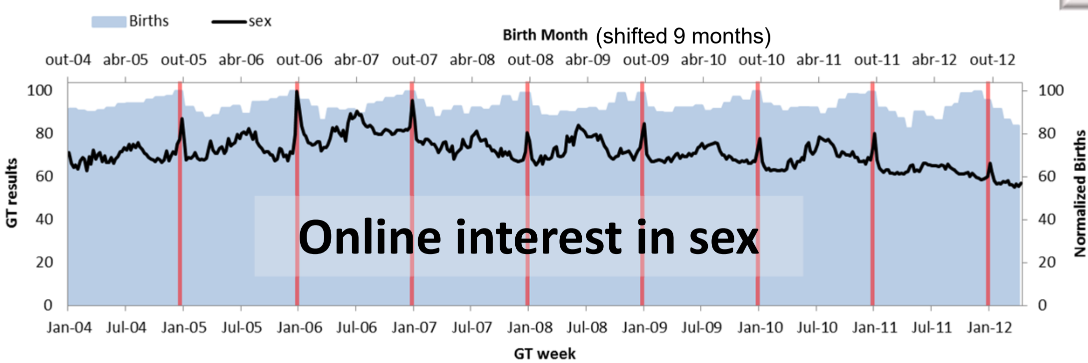

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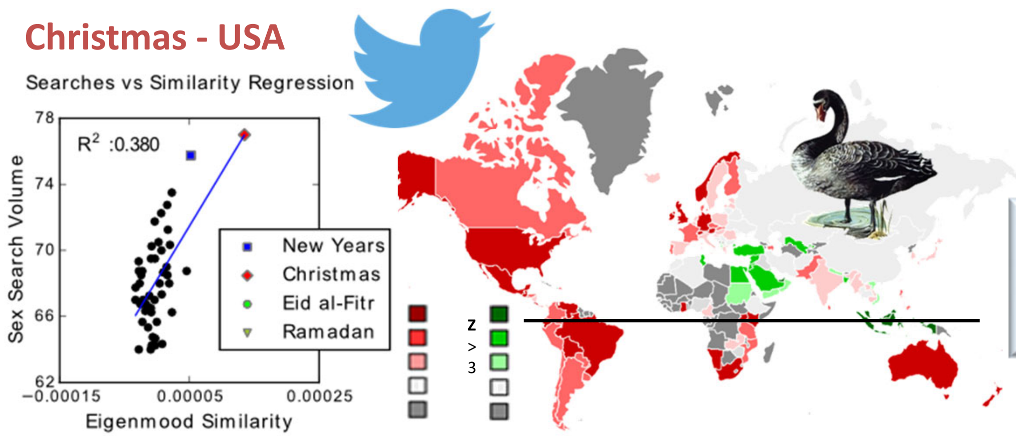

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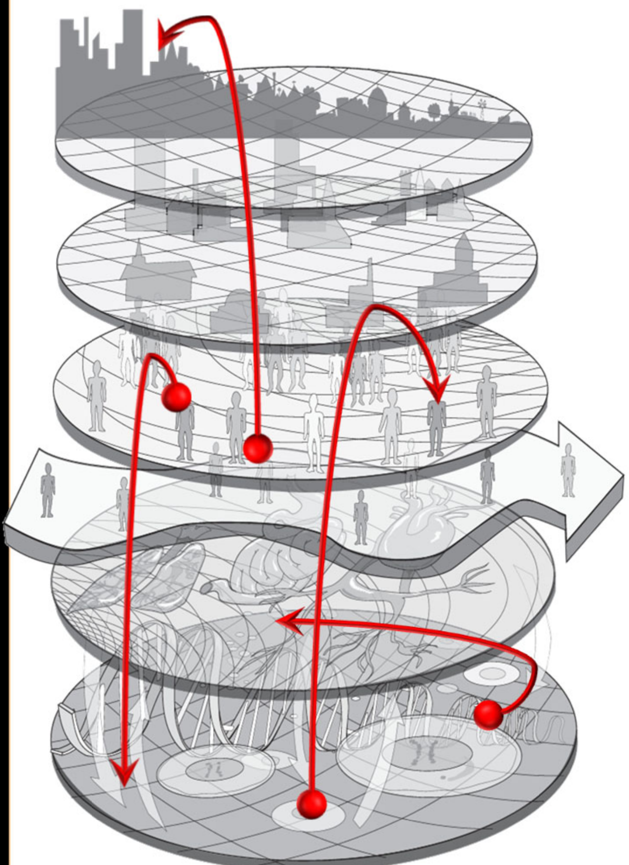
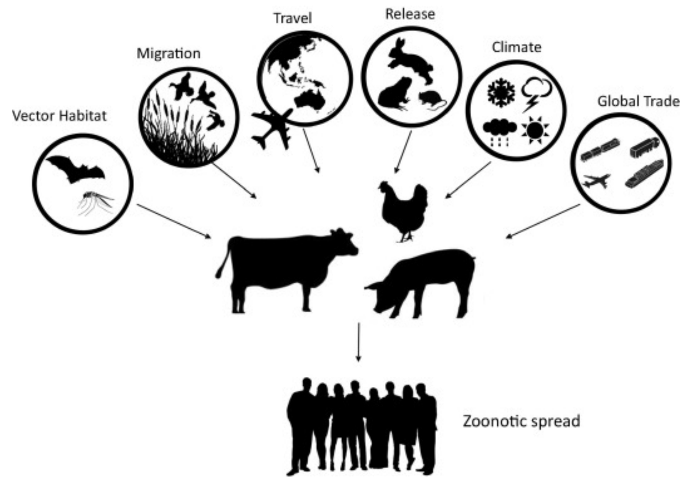
Bad news III: inductive, "boxed" model failure with complex systems





Pescosolido, B.A. 2006. Journal of Health and Social Behavior 47: 189-208.

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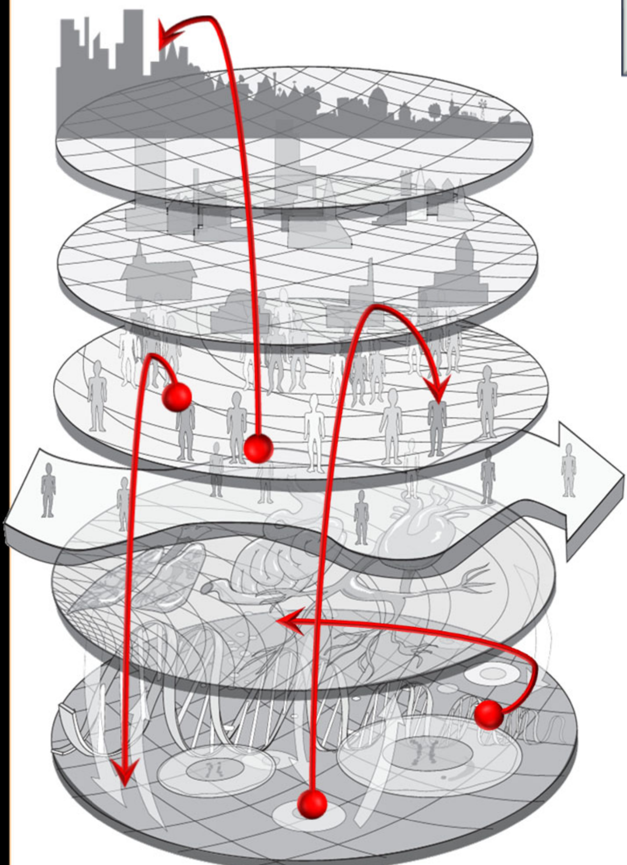
Bad news III: inductive, “boxed” model failure with complex systems

Key insight: complex systems need multi-level, contextual/actionable **models and theory** to predict rare, major transitions (not predictable by empirical evidence from single layer)



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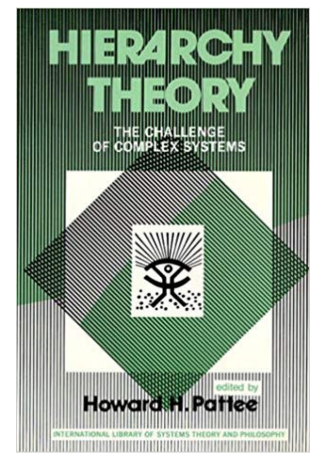
Howard Pattee



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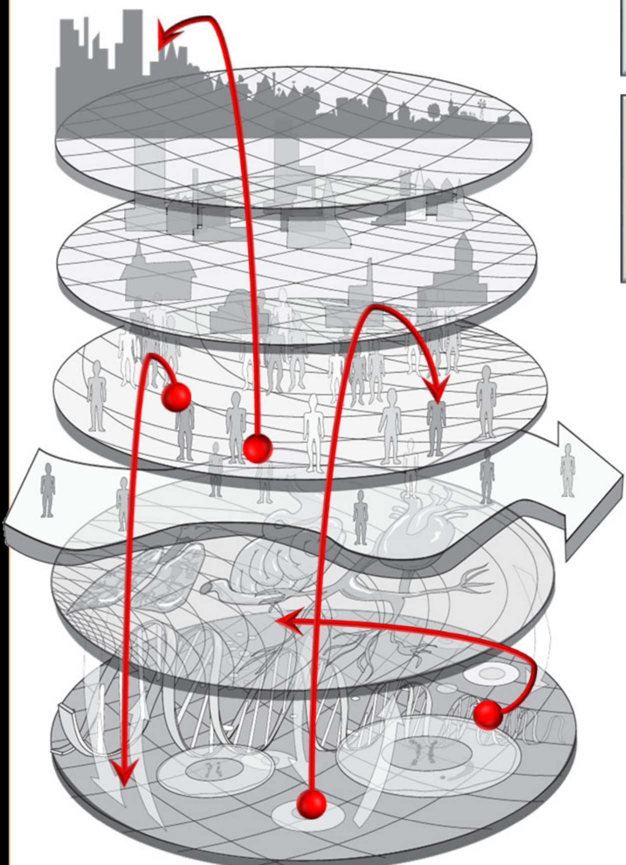
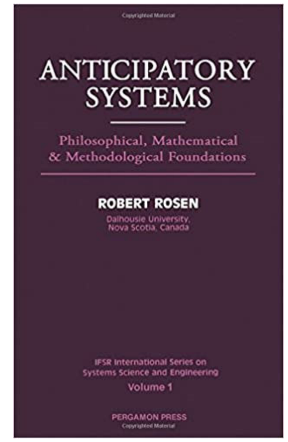


Key insight: complex systems need multi-level, contextual/actionable **models and theory** to predict rare, major transitions (not predictable by empirical evidence from single layer)

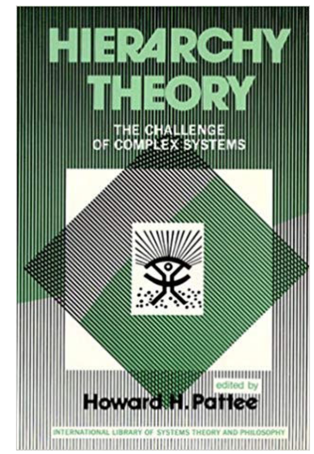
Key insight: complex systems are: 1) not reducible to self-contained multivariate structure or dynamics (boxed mechanisms), 2) not predictable from past data when it matters.



Howard Pattee

A model of any complex system will deviate as emergent properties arise from (rare) external controls

Robert Rosen



Pescosolido, B.A. 2006. Journal of Health and Social Behavior 47: 189-208.

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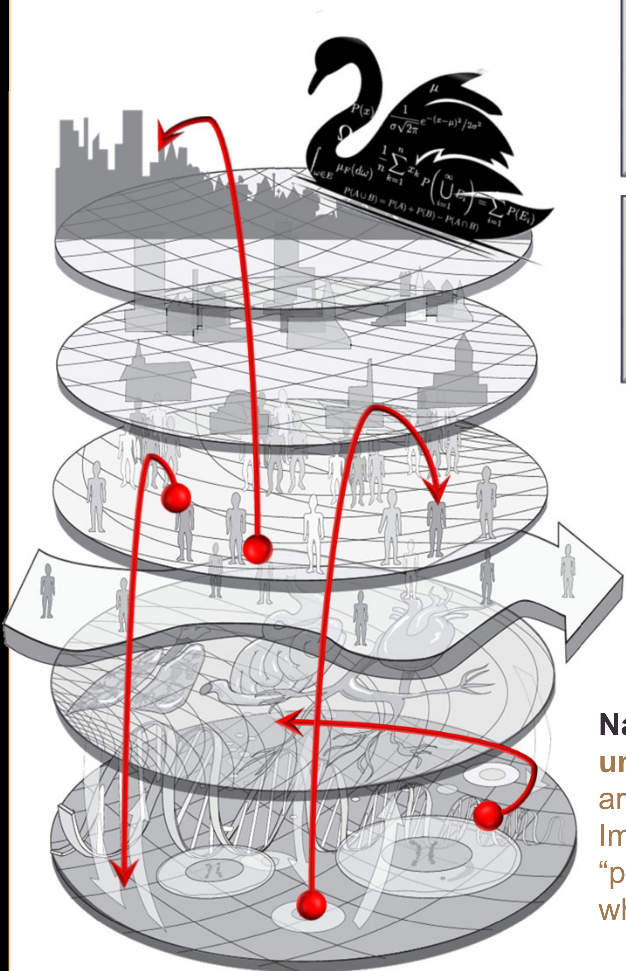
Bad news III: inductive, "boxed" model failure with complex systems



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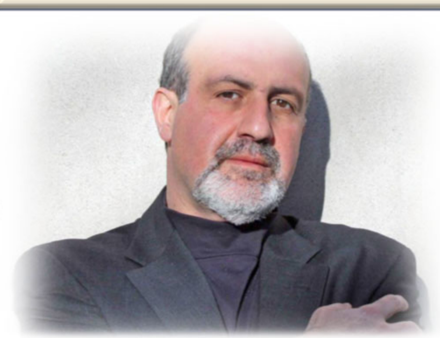
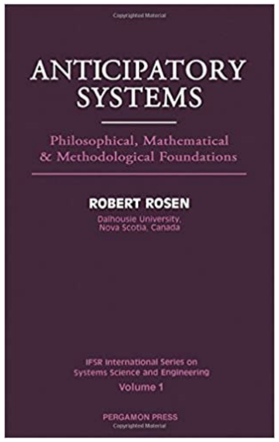


Nassim Nicholas Taleb

unexpected events of large magnitude and consequence are dominant in history.

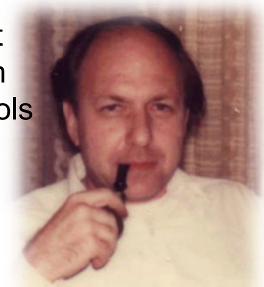
Importance of studying robustness/resilience/evolvability

"predictions of events **depend** more and more **on theories** when their probability is small and system is **complex**"

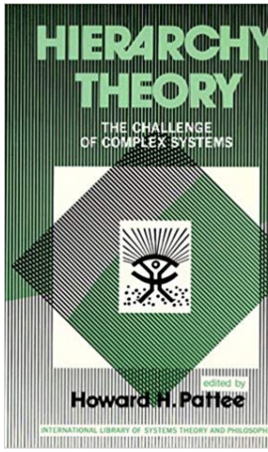


Howard Pattee

A model of any complex system will deviate as emergent properties arise from (rare) external controls



Robert Rosen



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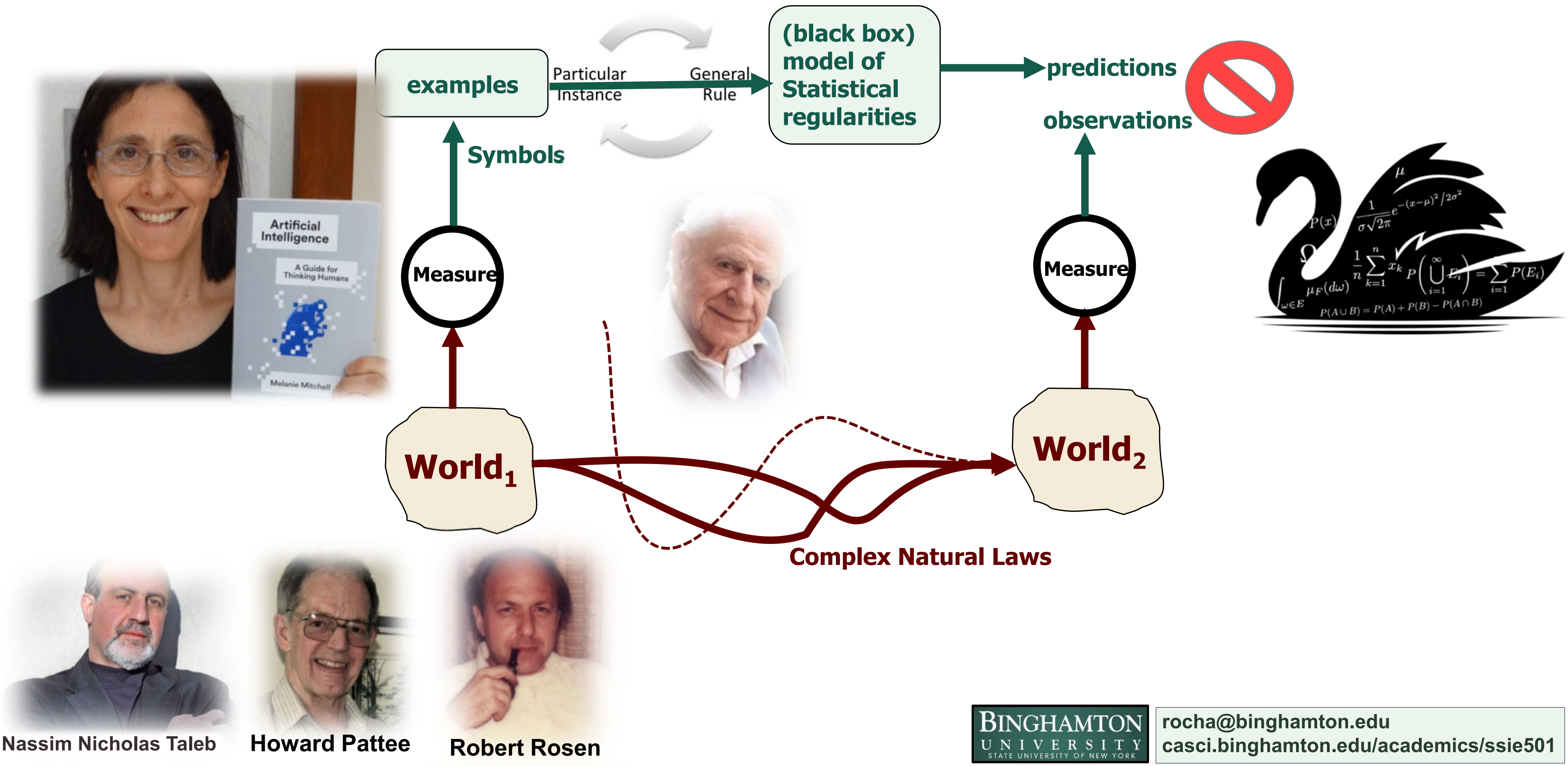
inductive models can be falsified but cannot predict black swans



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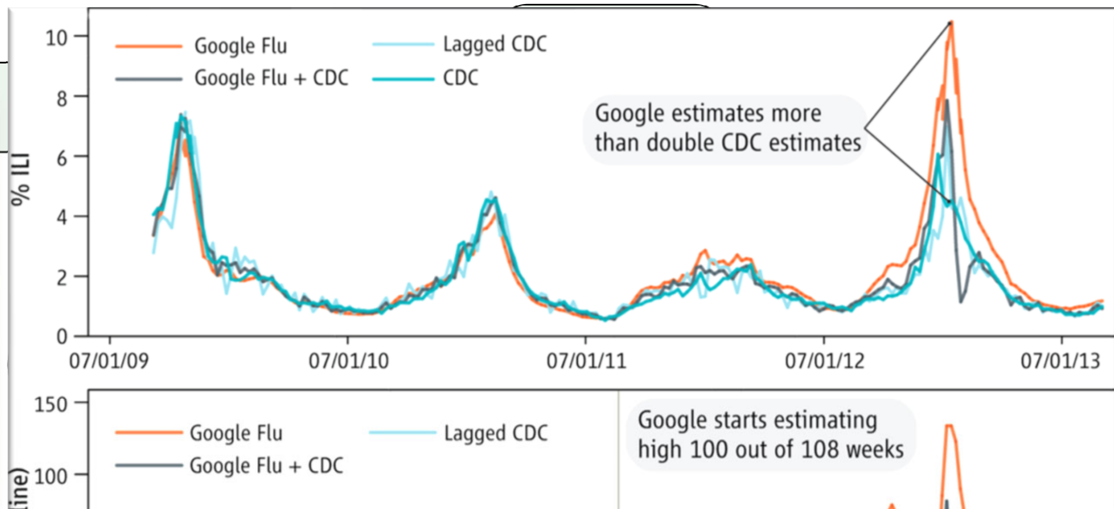
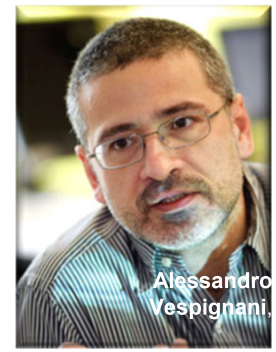


The Parable of Google Flu: Traps in Big Data Analysis

David Lazer[1,2,*], Ryan Kennedy[1,3,4], Gary King[3], Alessandro Vespignani[5,6,3]
+ See all authors and affiliations

Science 14 Mar 2014:
Vol. 343, Issue 6176, pp. 1203-1205
DOI: 10.1126/science.1248506

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Howard Pattee


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machine learning depends on training data that is contextual

Angwin, Larson, Mattu & Kirchner, “Machine Bias”. *ProPublica*, May 23, 2016
propublica.org/article/machine-bias-risk-assessments-in-criminal-sentencing

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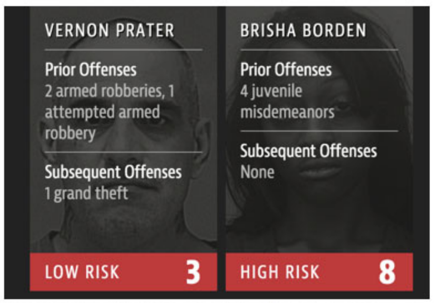
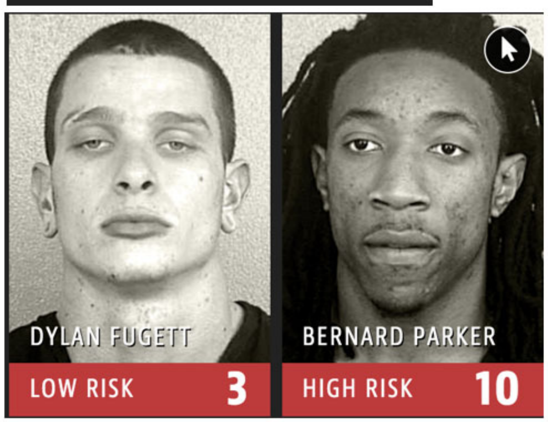
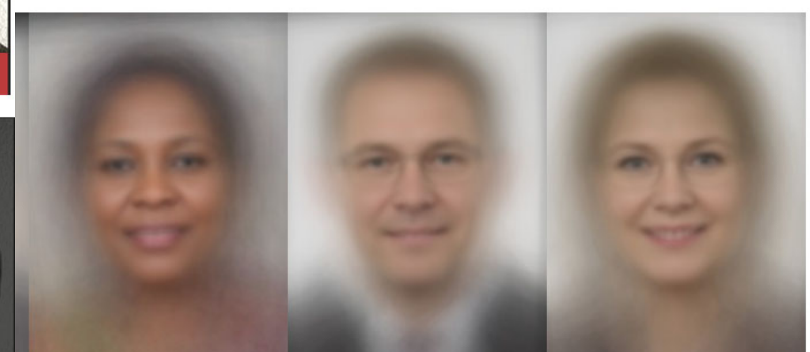
machine learning depends on training data that is contextual

Gender Classifier	Darker Male	Darker Female	Lighter Male	Lighter Female	Largest Gap
Microsoft	94.0%	79.2%	100%	98.3%	20.8%
FACE++	99.3%	65.5%	99.2%	94.0%	33.8%
	8.0%	65.3%	99.7%	92.9%	34.4%







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Comparing 3 distinct health systems

Indianapolis (private)
1,228 unique *DrugBank* IDs dispensed to **264,607** patients during **2 years** (Jan 2017–Dec 2018).

Catalonia
814 unique *DrugBank* IDs administered to **5,555,924** patients during **11 years** (Jan 2008-Dec 2018).

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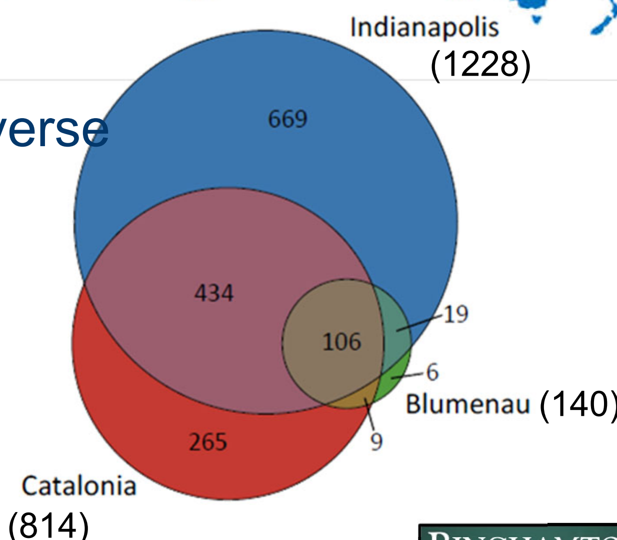
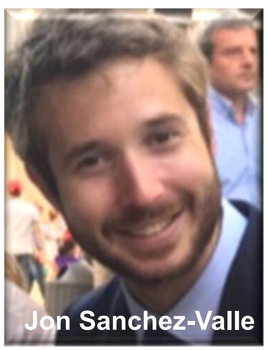
drug universe





Sanchez-Valle et al [2024].. *BMC Medicine* **22**: 166.
Correia, Araujo, Mattos, Wild & Rocha [2019]. *NPJ Digital Medicine*. 2:74.

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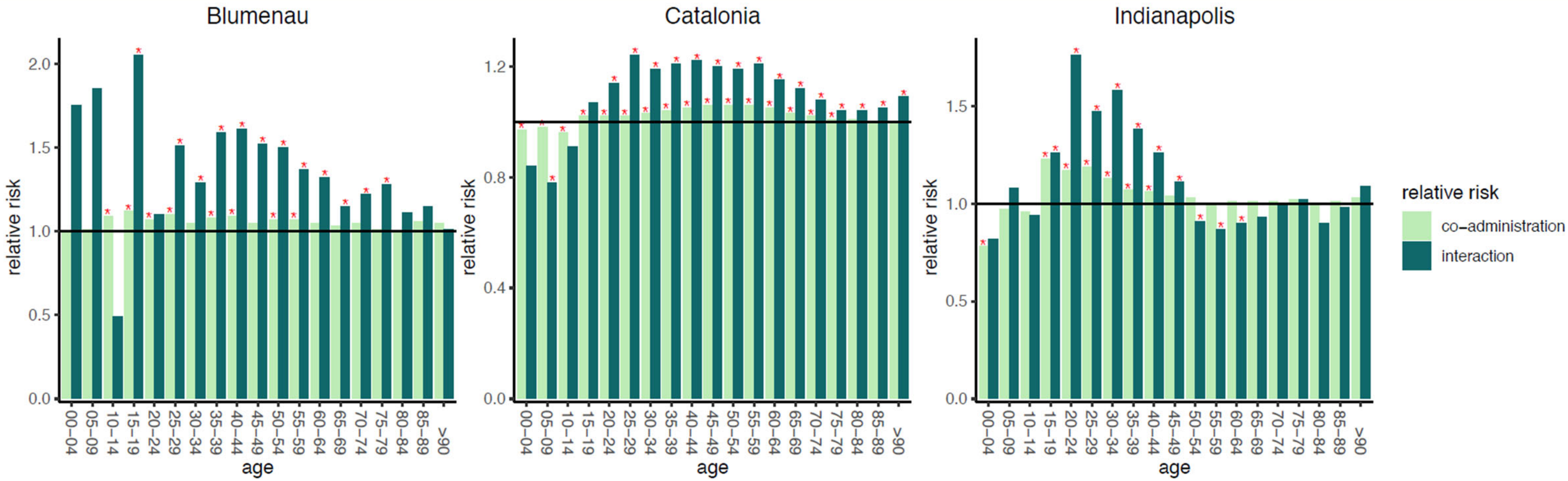
gender and age biases in drug-drug interactions



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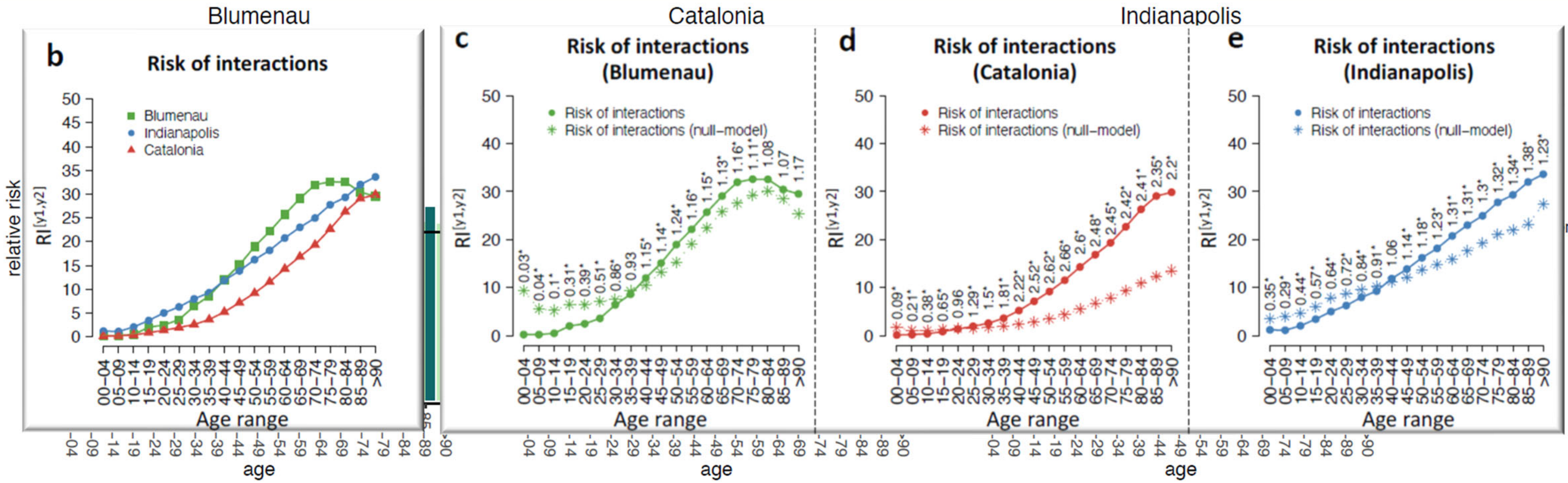
electronic health records from 3 World regions

gender and age biases in drug-drug interactions



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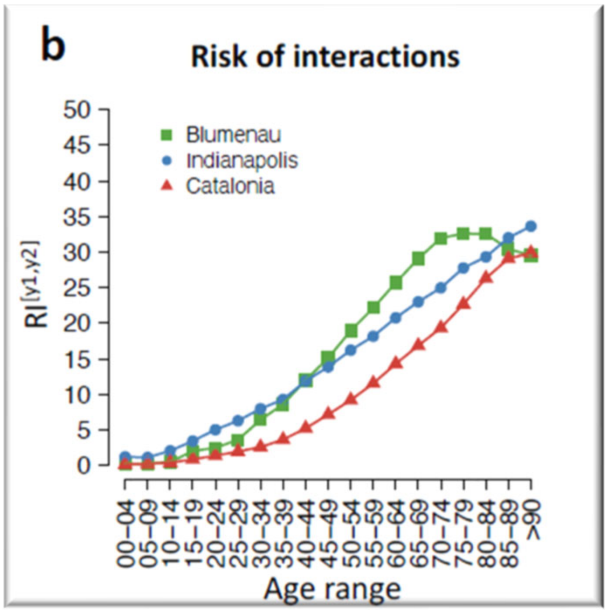

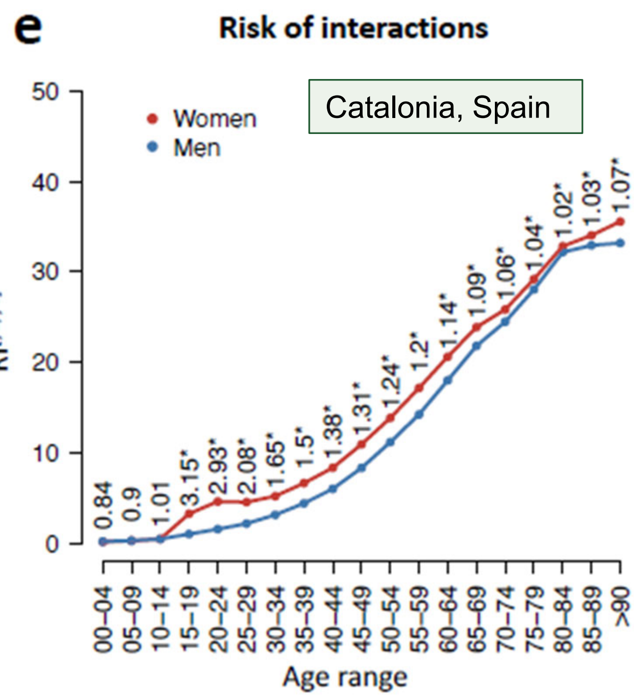

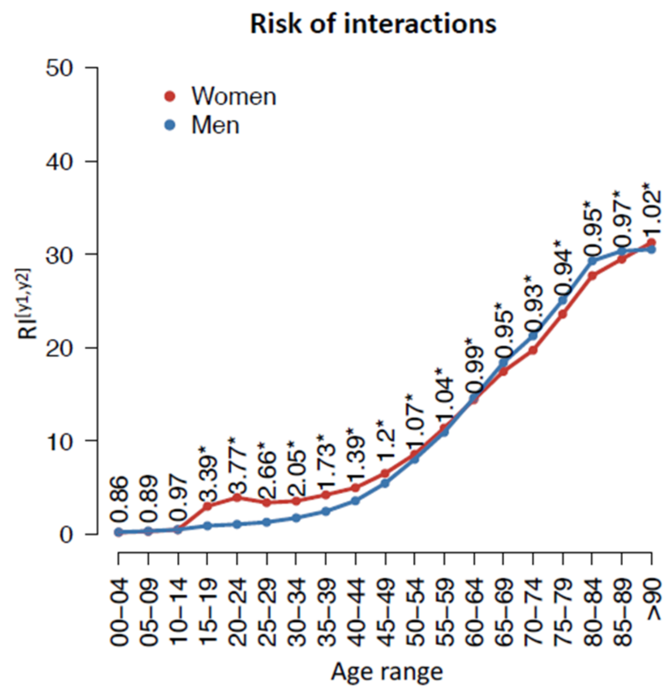

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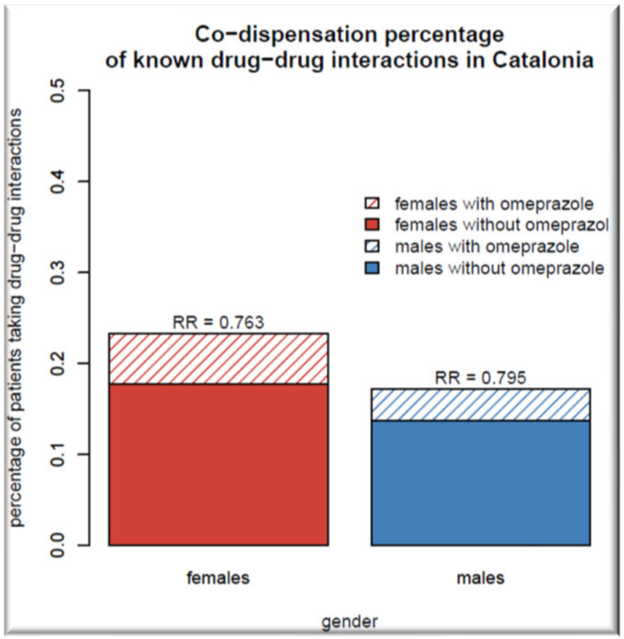

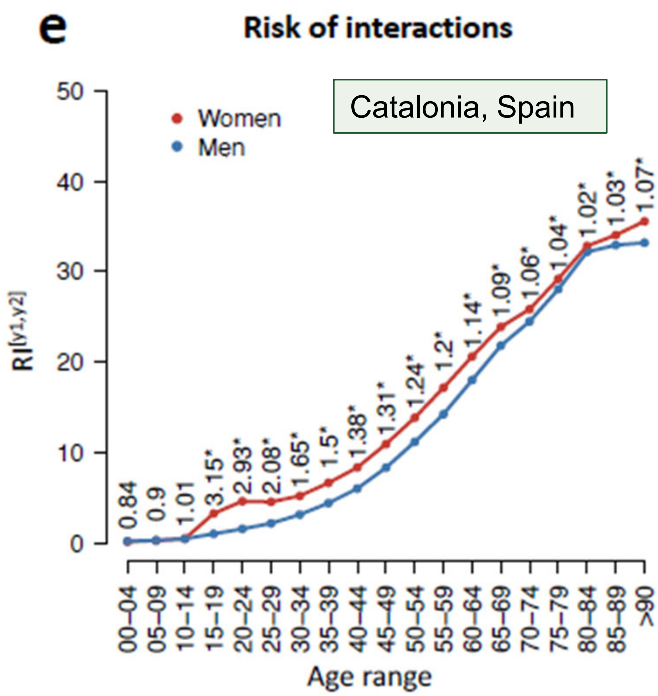

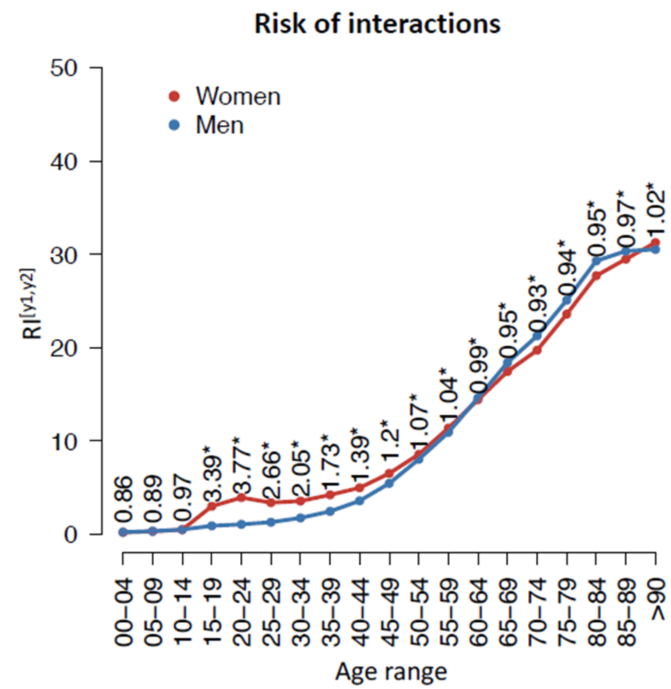

what actionable interventions?

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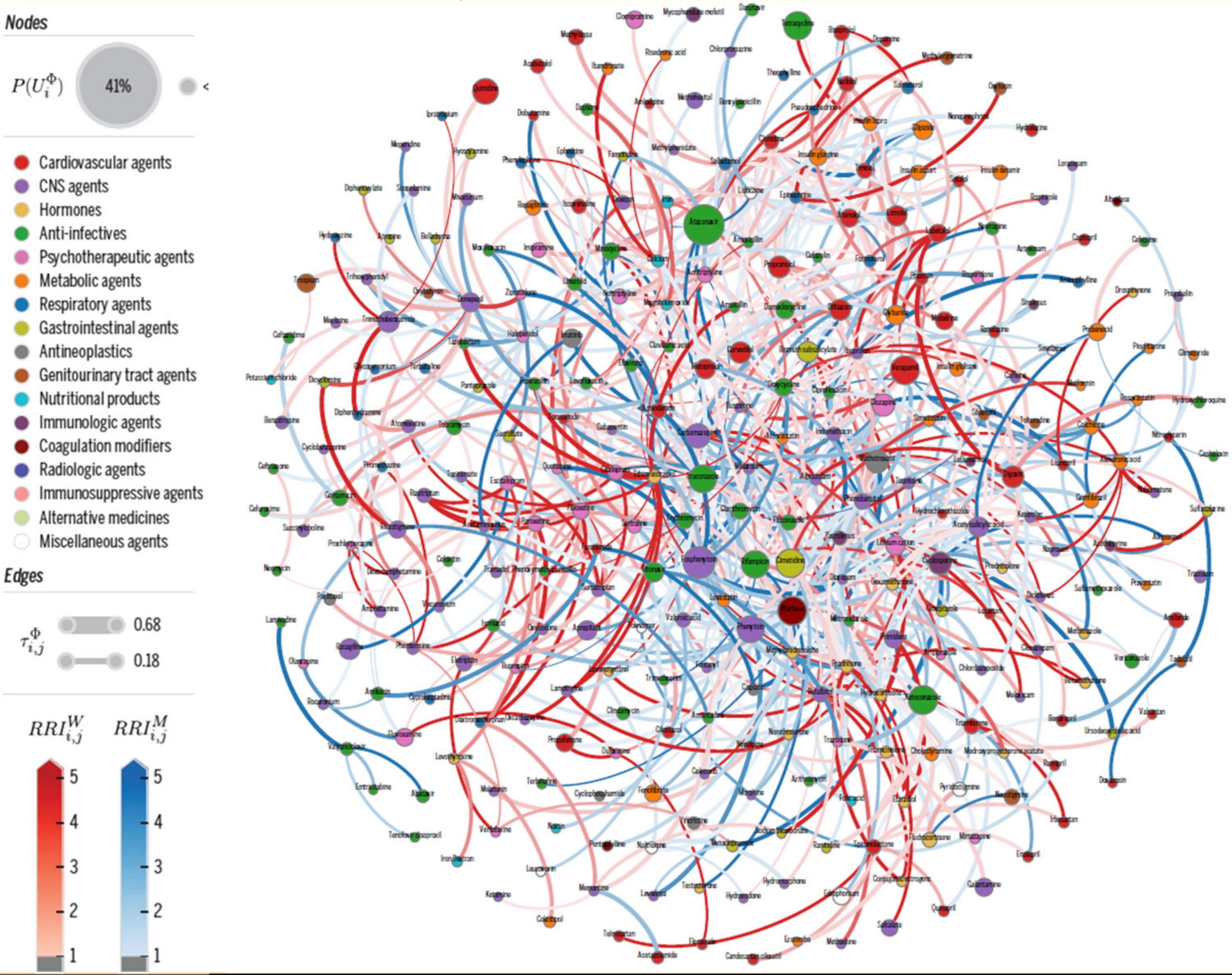
Browsable networks to synthesize information and aid actionable interventions



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Strength of interaction $\geq$ ***0.18:*** likelihood of joint administration, given administration of i or j).

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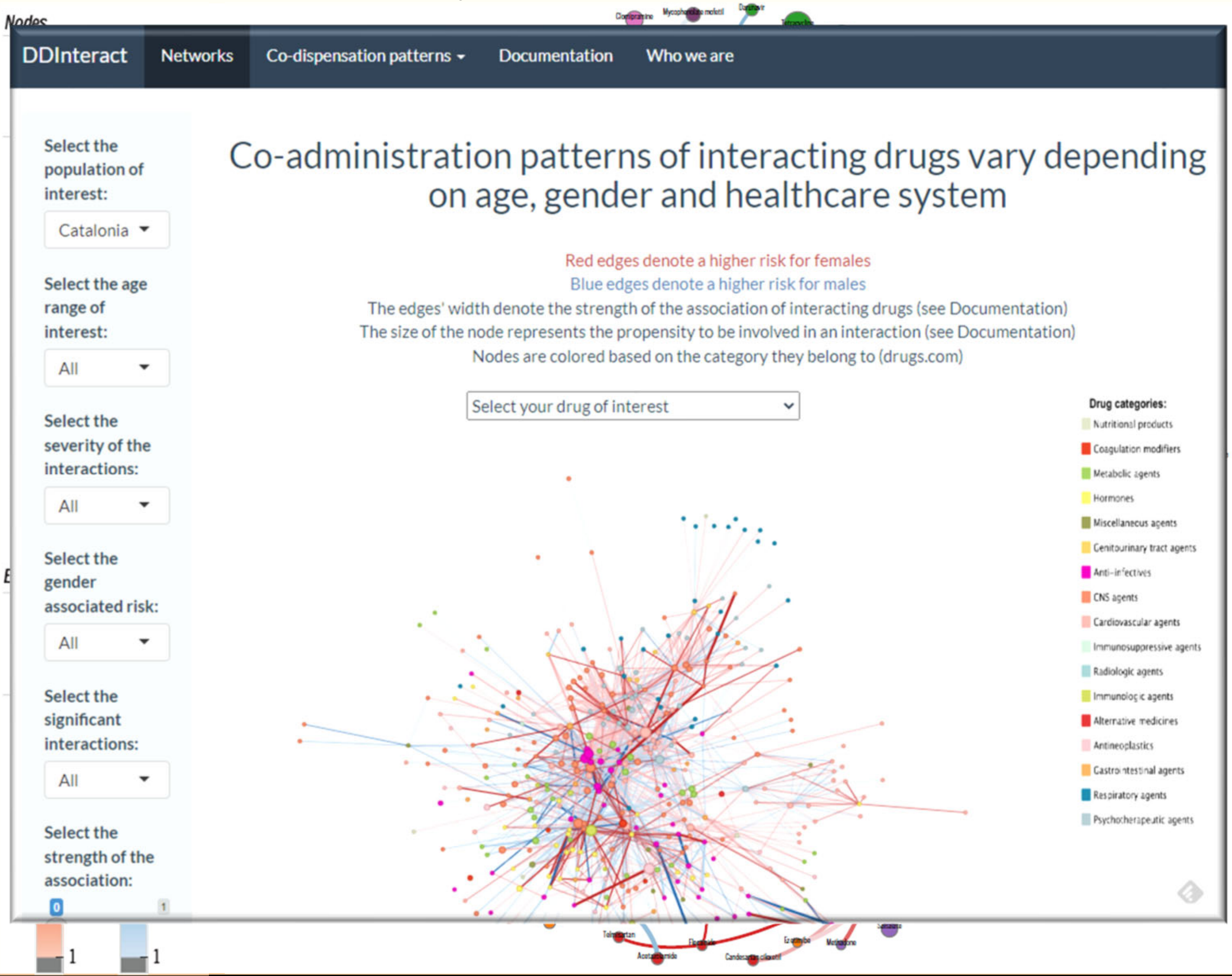

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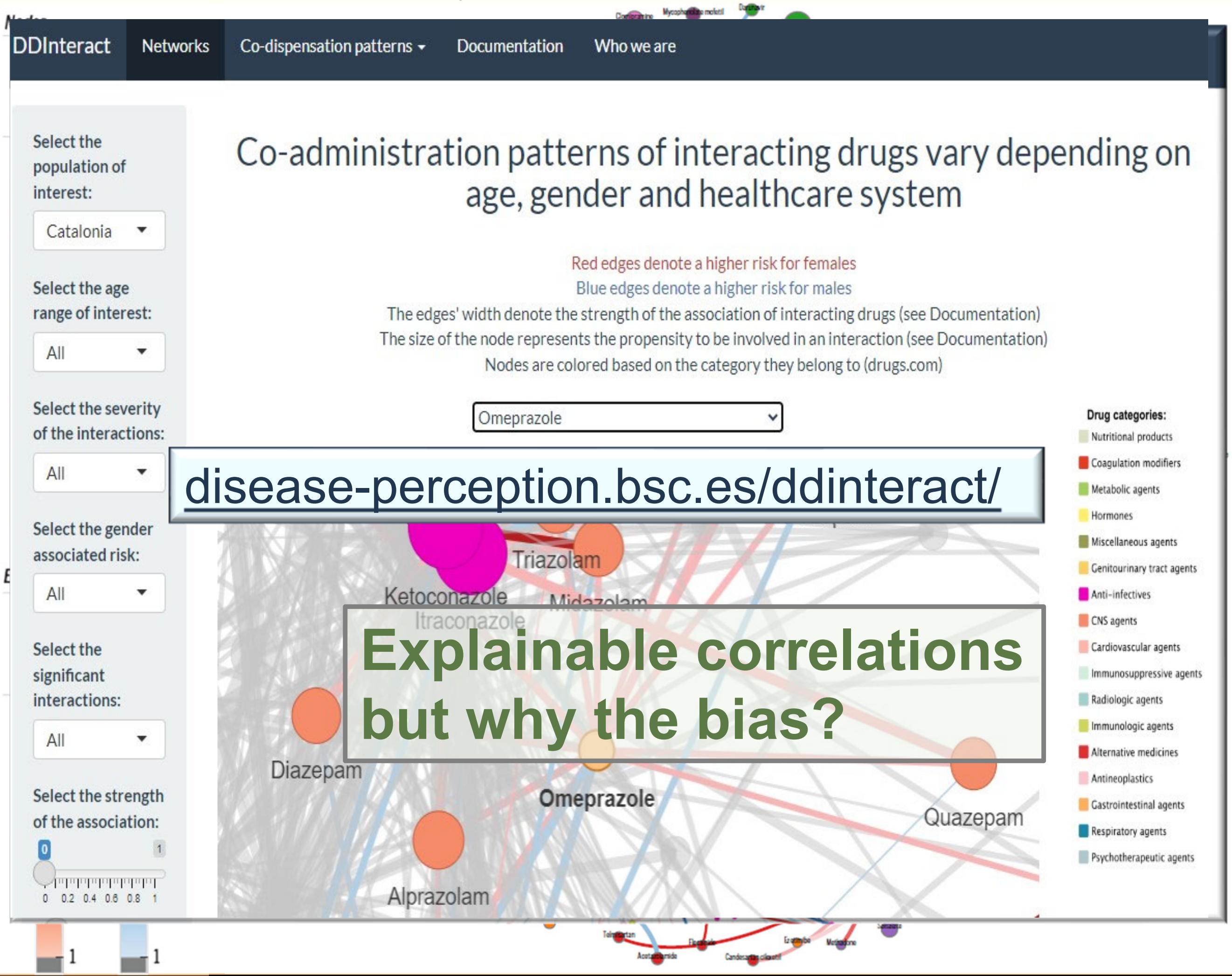
How is the DDI phenomenon in human populations?

Browsable networks to synthesize information and aid actionable interventions



disease-perception.bsc.es/ddinteract/

Explainable correlations but why the bias?

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