



Designing Diversity

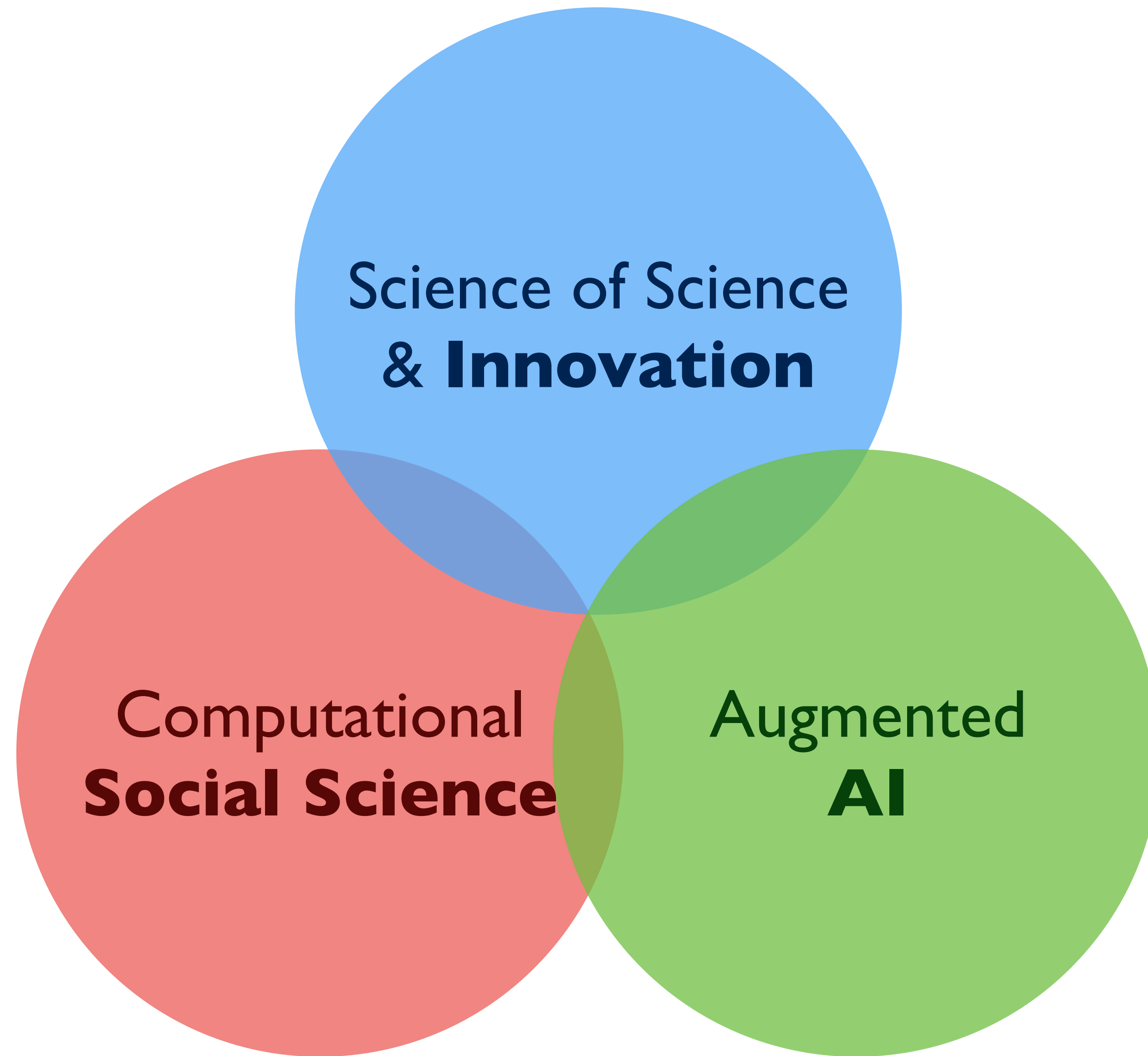
for

Sustained Innovation



james evans

KNOWLEDGE
LAB



Science of Science
& **Innovation**

Computational
Social Science

Augmented
AI

INTERNATIONAL CONFERENCE ON THE SCIENCE OF SCIENCE & INNOVATION

About Speakers Agenda Awards Logistics Calls Organizers

June 7-9, 2022

National Academy of Sciences
Washington, DC

Please join us for the inaugural International Conference on the Science of Science and Innovation (ICSSI), to be held in the National Academy of Sciences, Washington DC, in partnership with Kalloun School of Management's Center for Science of Science and Innovation.



KNOWLEDGE LAB

Big Data, Machine Learning and Intelligent Crowdsourcing enables us to:

1. Represent
2. Understand
3. Transform... the innovation process

computationally enhanced Knowledge²

Science Home News Journals Topics Careers

WEBINAR Taking your virus production to the next level: Achieving high-quality, high-titer recombinant AAV and lentiviruses. Recorded live on November 28, 2018. [CLICK TO VIEW](#)

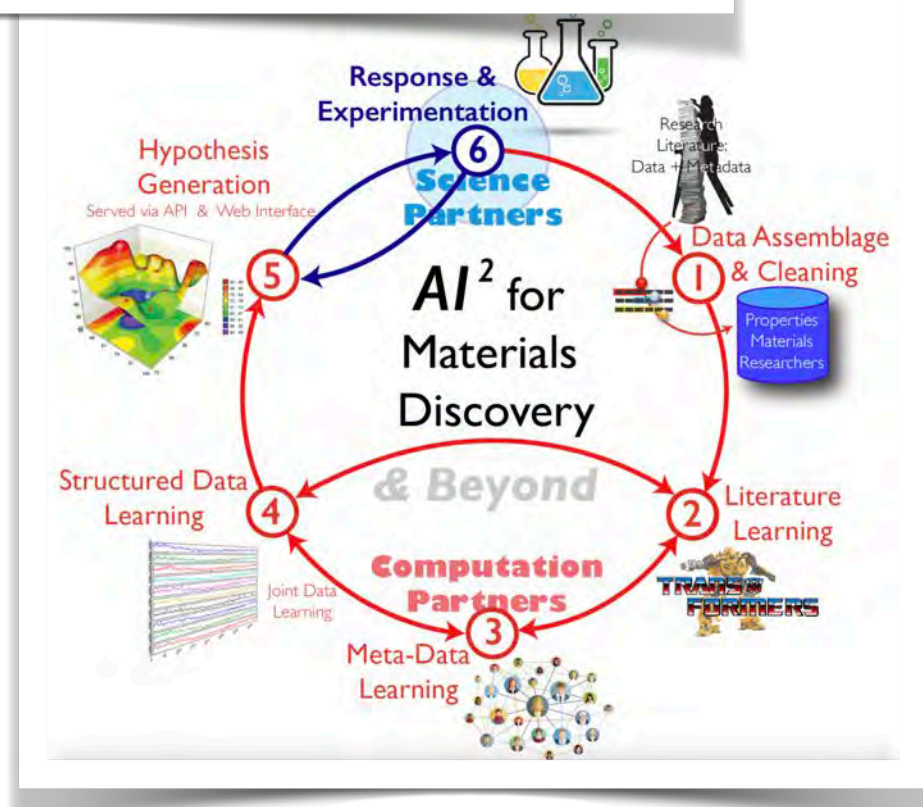
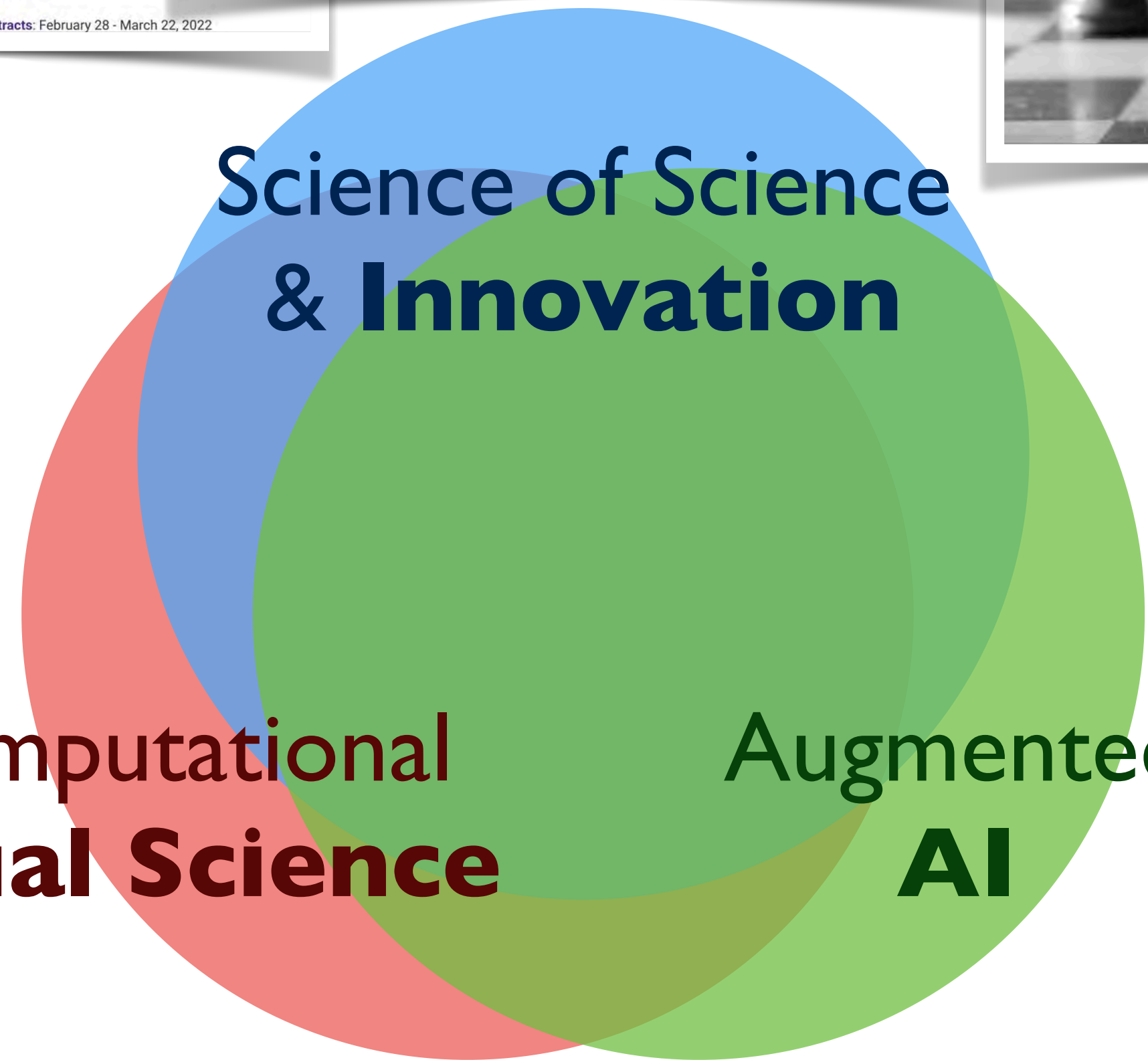
Science under scrutiny
Metaresearchers study how research is done—and why it goes wrong.
DAVIDE BONAZZI@SALZMANART

A crowded frontier
By James A. Evans⁷

Science is a complex system in which rapid circulation of advances has the same frontier of accumulated knowledge, constrained to imagine the same

Metaknowledge
James A. Evans⁷, Jacob G. Foster
• See all authors and affiliations
Science 11 Feb 2011
Vol. 331, Issue 6018, pp. 721-725
DOI: 10.1126/science.1207165

Science of science
Santo Fortunato^{1,2}, Carl T. Bergstrom³, Katy
• See all authors and affiliations
Science 02 Mar 2018
Vol. 359, Issue 6379, eaad7185
DOI: 10.1126/science.1251163



Computational Social Science

MASTERS IN COMPUTATIONAL SOCIAL SCIENCE
THE UNIVERSITY OF CHICAGO

APPLY CAREERS Request More Information Enter search terms NAVIGATION

Social Sciences Computing Services M Academic

Computational systems at SSCS help students social science problems.

jOscO Journal of Social Computing

IC²S²

Chicago, IL | July 19-22, 2022

8th International Conference on Computational Social Science

THE UNIVERSITY OF CHICAGO DATA SCIENCE INSTITUTE

About Research Outreach Education News Events Engage

DSI NEWS

Digital Divide: DSI Initiative Highlights Internet Inequities in Chicago

The Internet Equity Initiative launched its new data portal to guide research, policy, and community action.

[Read More >](#)

Plurality

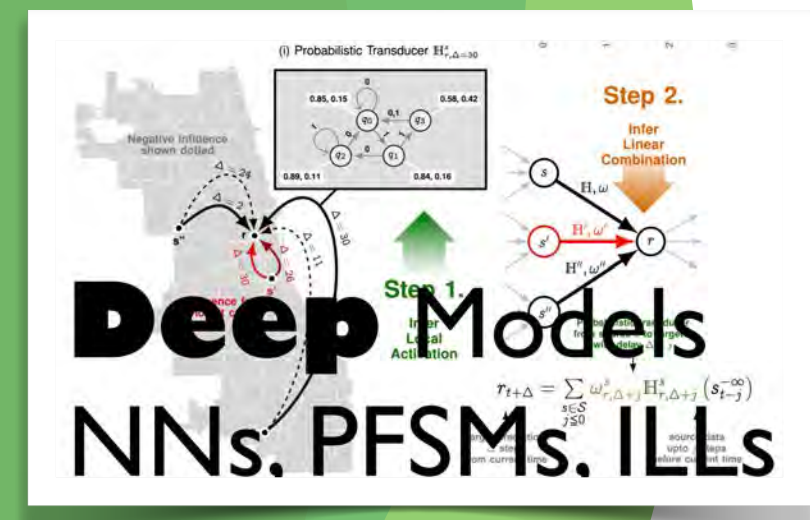
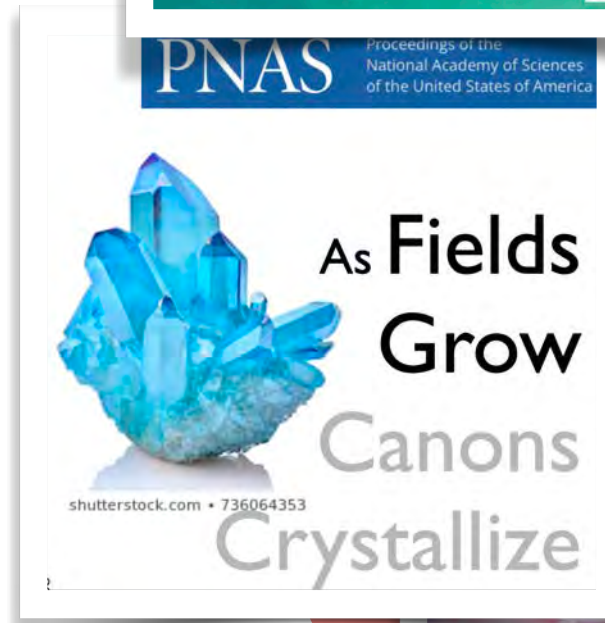
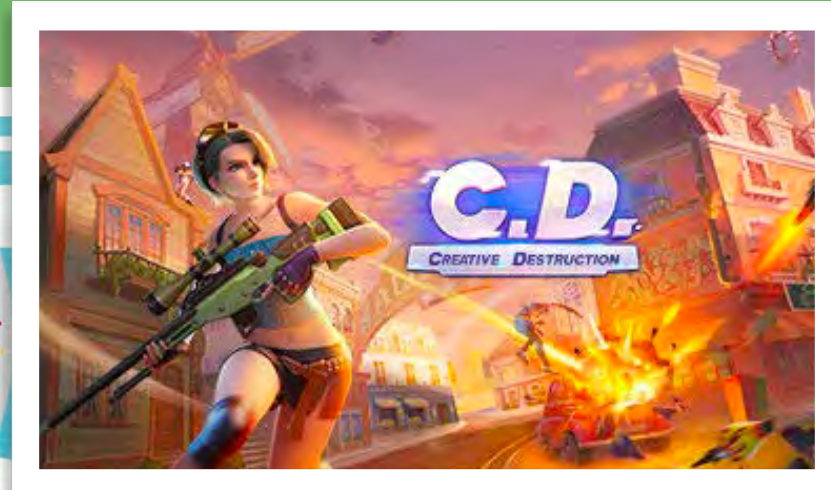
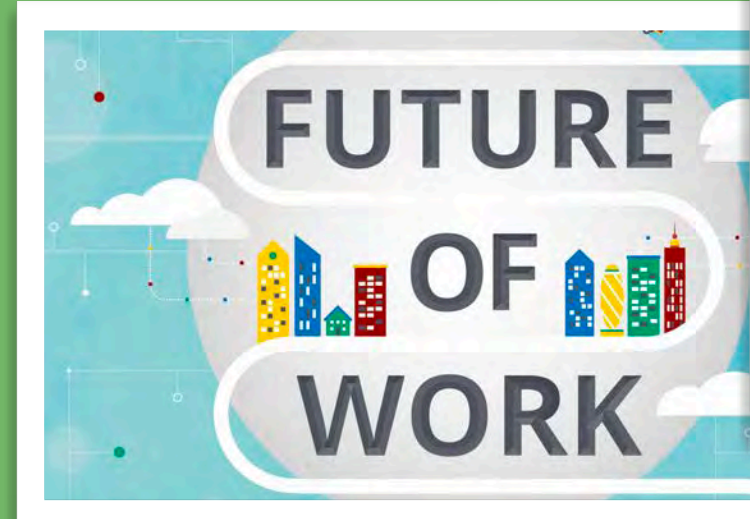
Institute for TRUSTED INTELLIGENCE in society

Science of Science & Innovation



PRINCETON UNIVERSITY PRESS

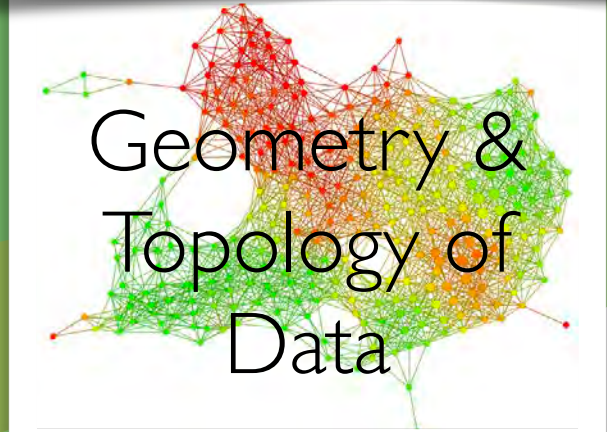
Knowing



Computational Social Science



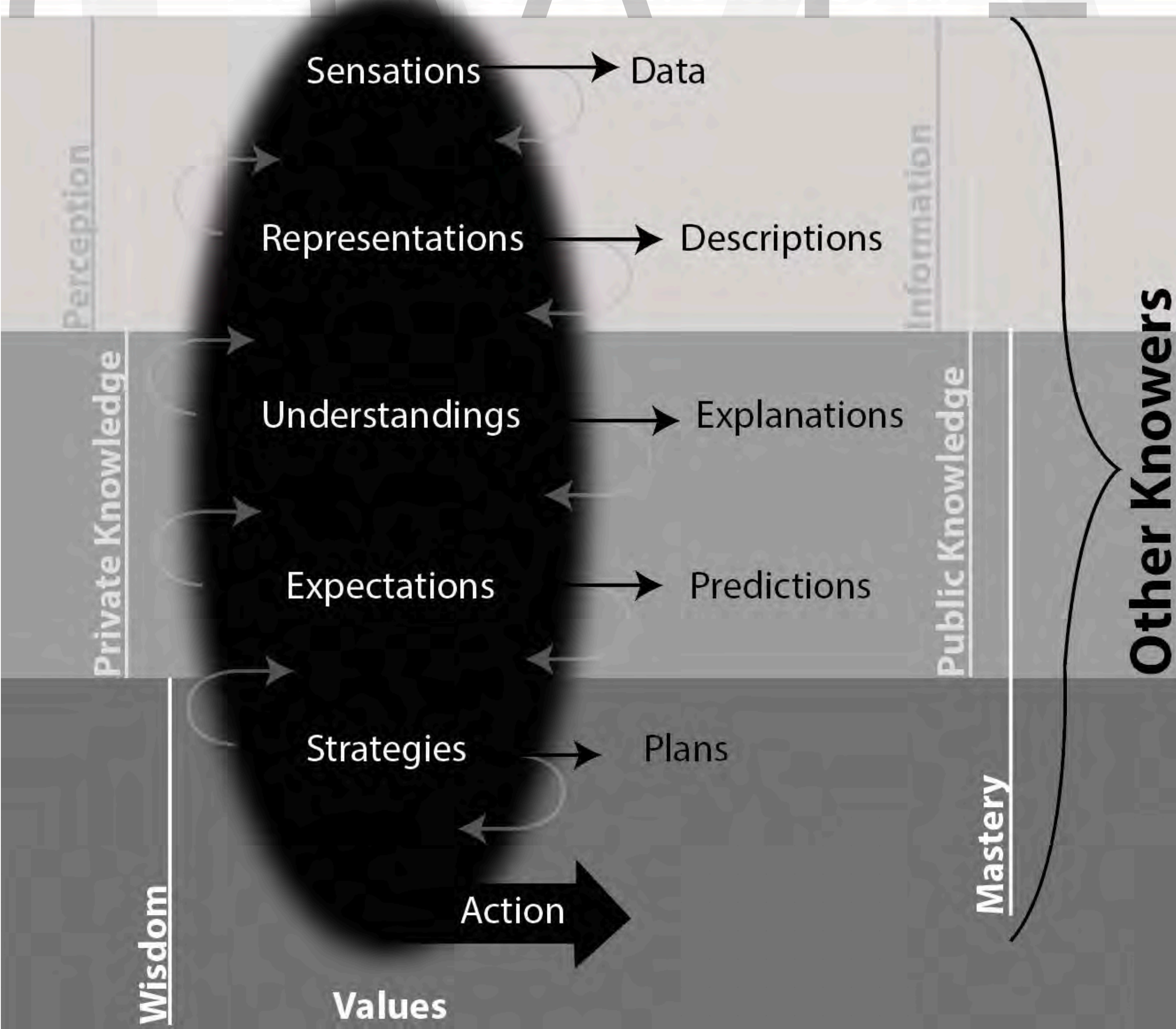
Augmented AI



A Complex System View of Knowledge

Knowing States

Knowing Signals

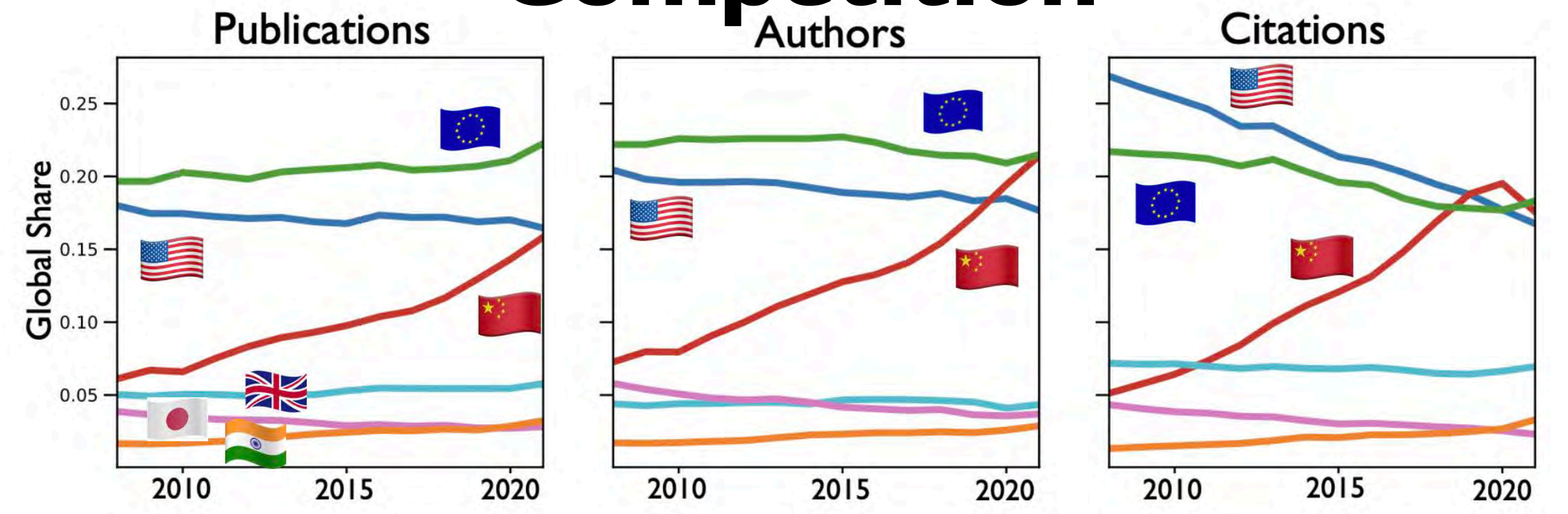


How Do Collectives
As Systems
Think?

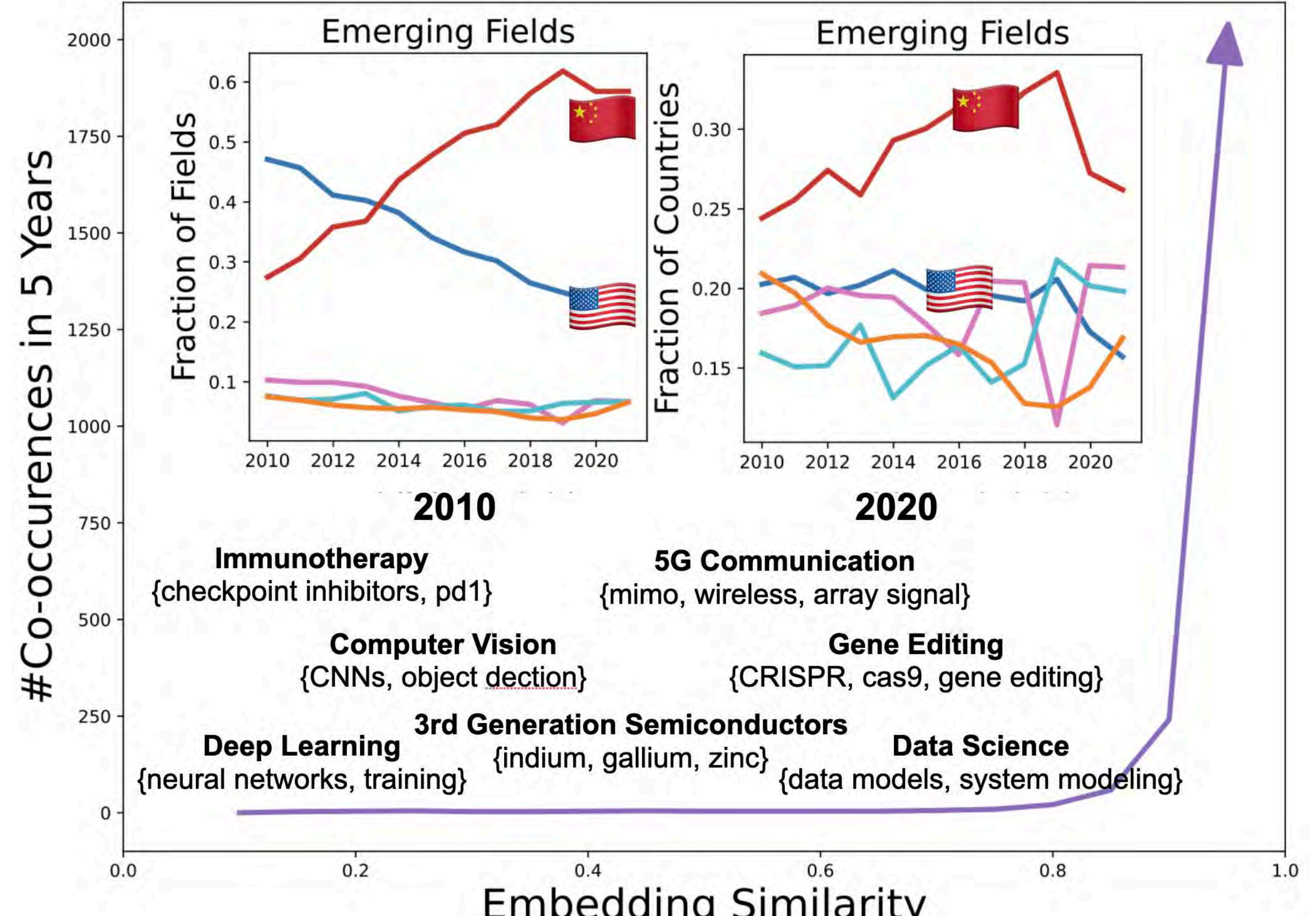
How Can We
Think Better



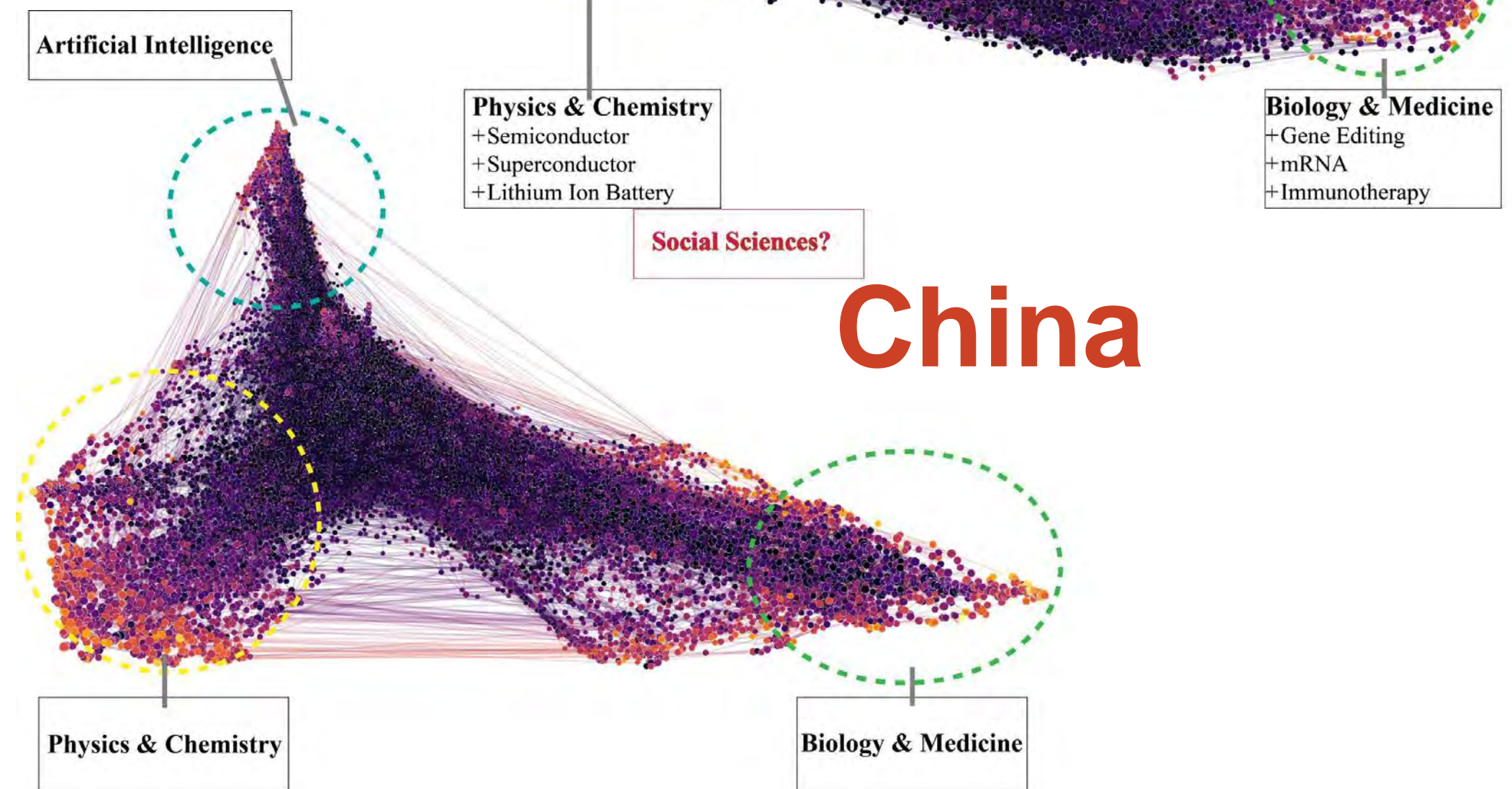
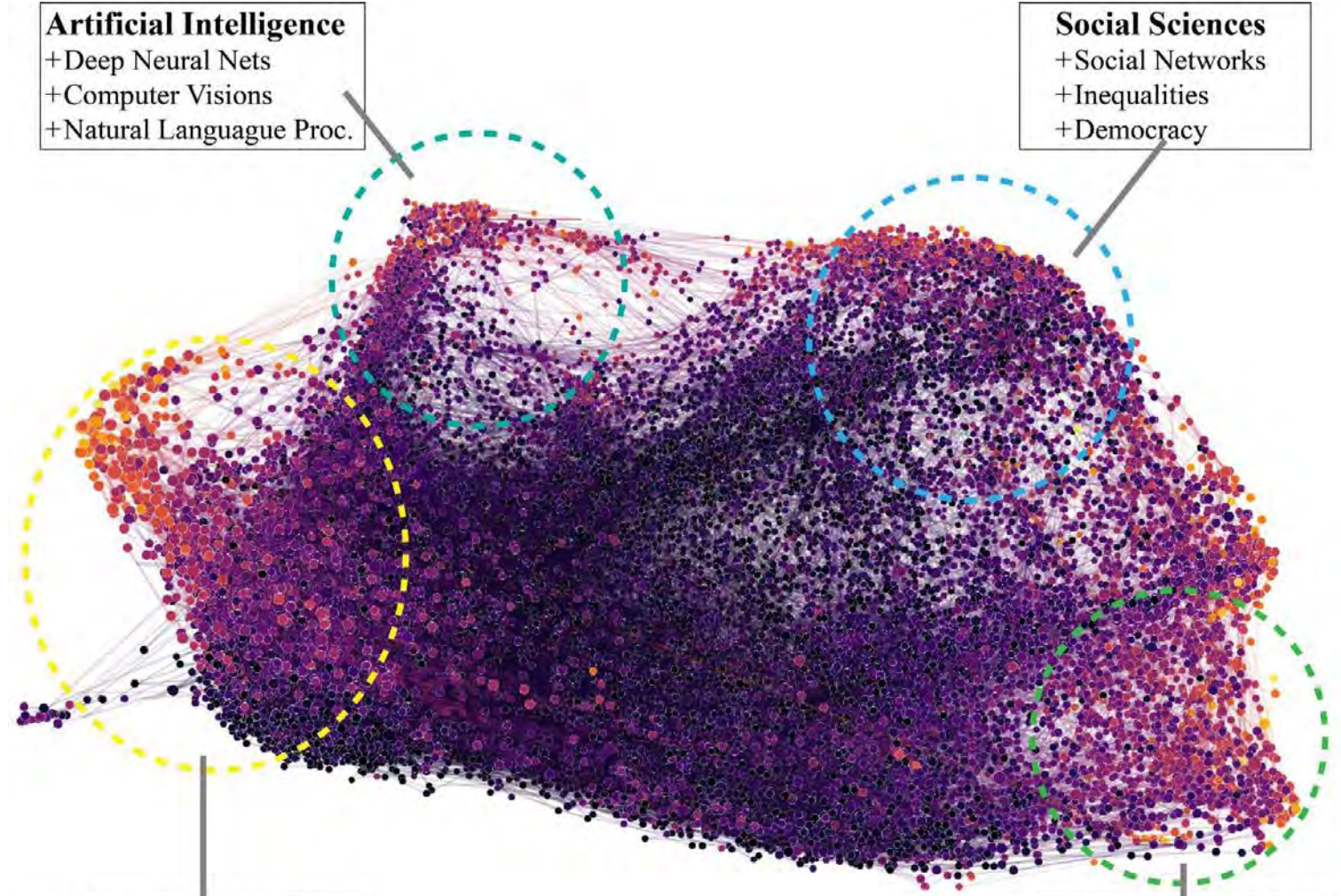
Competition



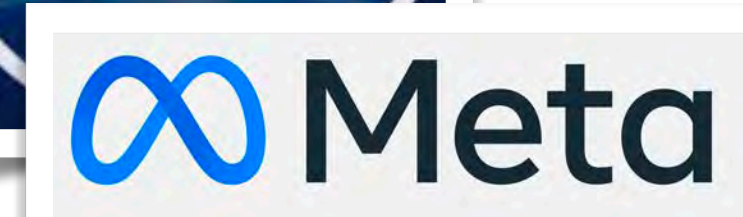
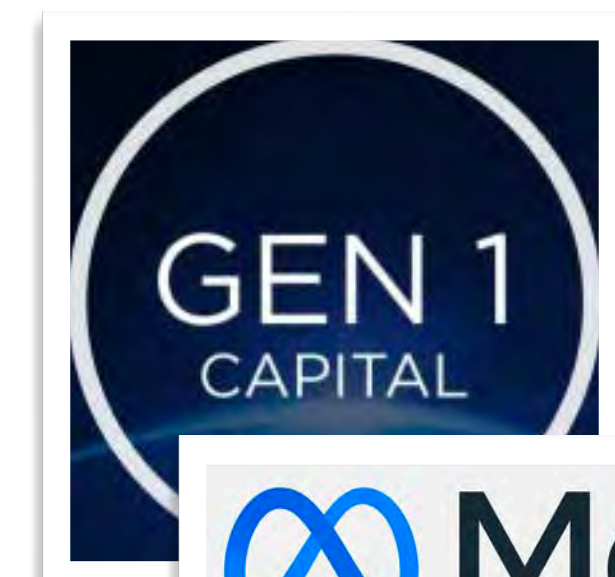
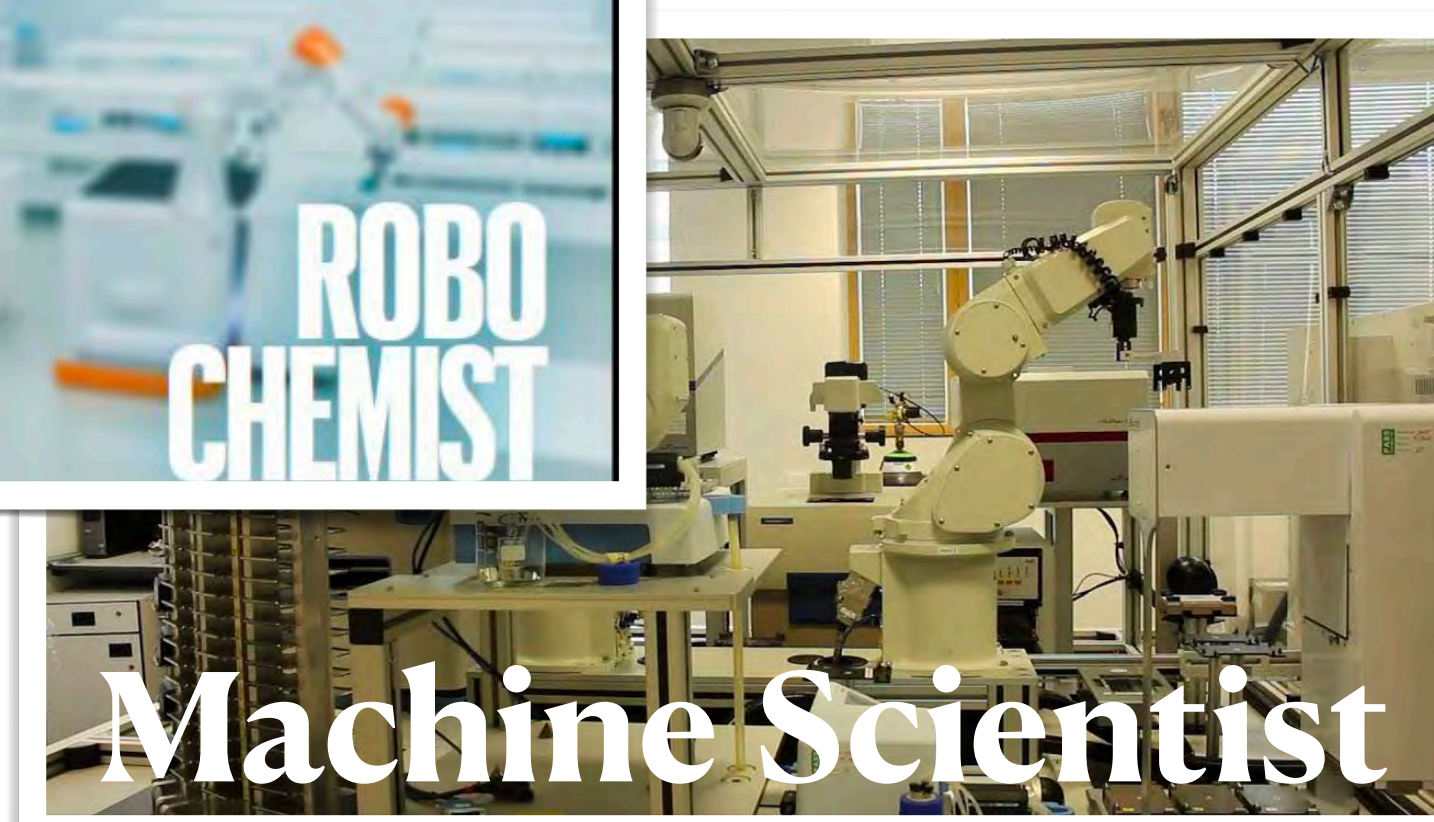
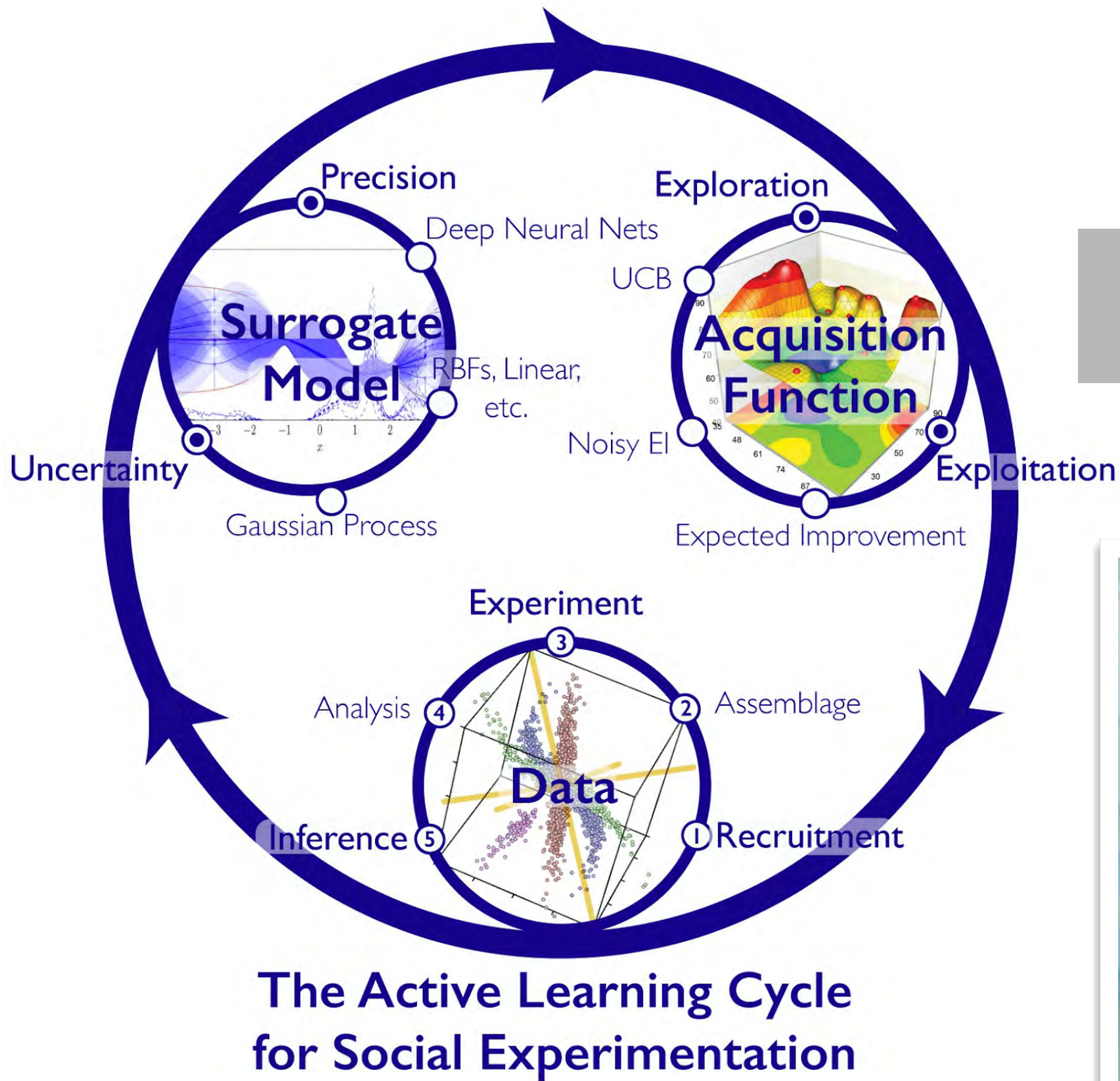
Collaboration



U.S.A.



Understand Innovation



Simulate/Automate Innovation



Wisdom of Crowds

Vox Populi

West of England
Fat Stock and Poultry Exhibition

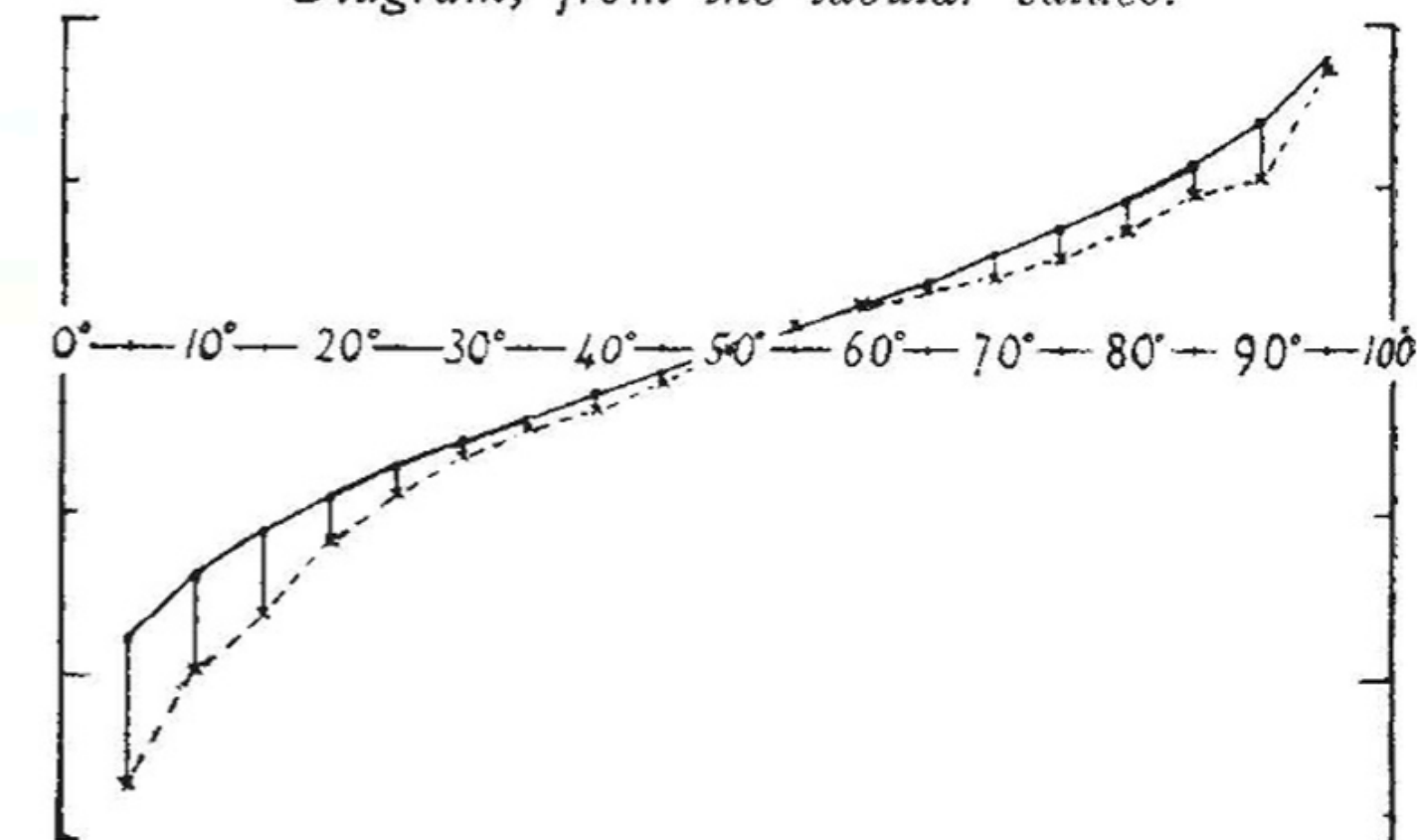


Distribution of the estimates of the dressed weight of a particular living ox, made by 787 different persons.

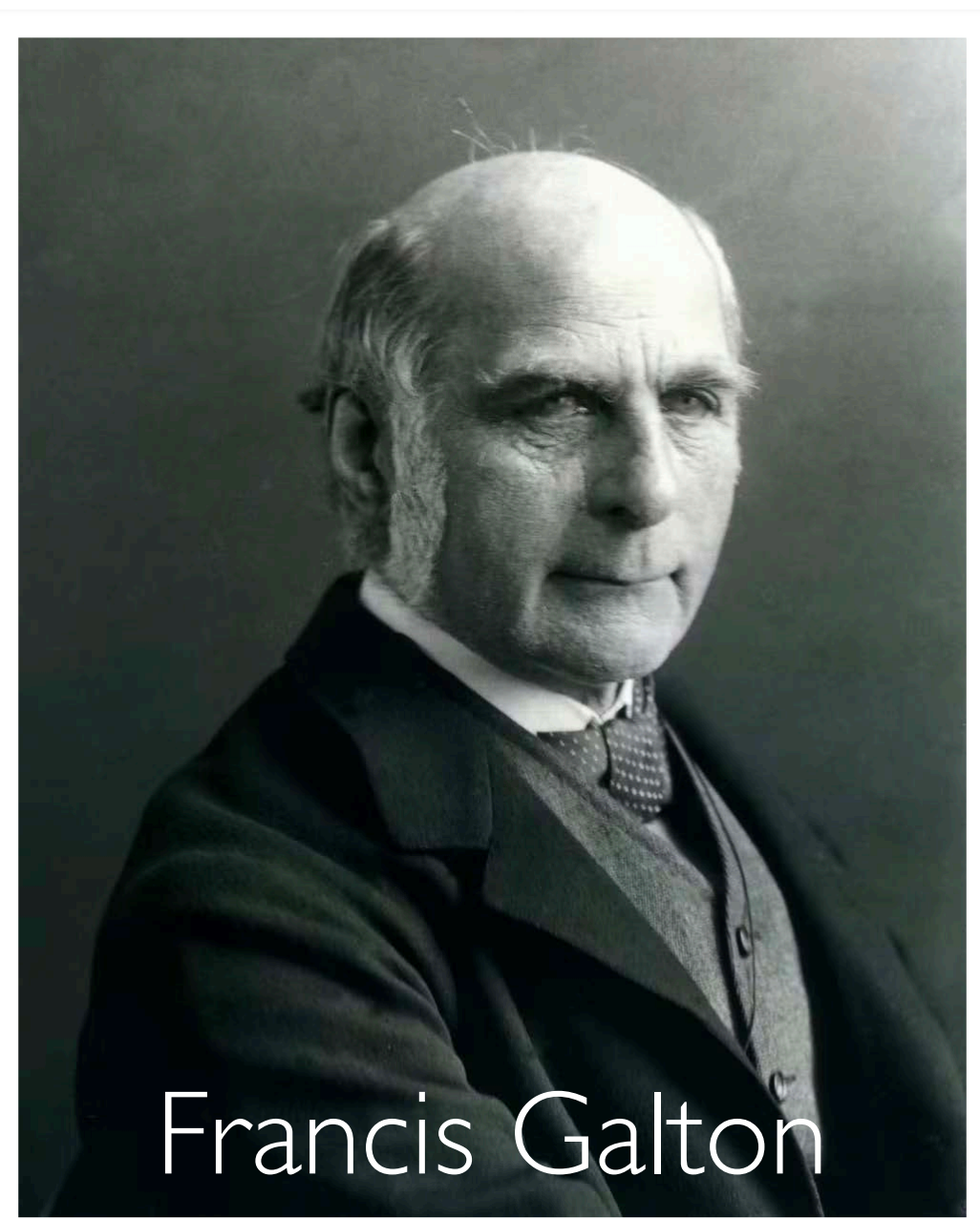
Degrees of the length of Array 0°—100°	Estimates in lbs.	Centiles		Excess of Observed over Normal
		Observed deviates from 1207 lbs.	Normal p.e = 37	
5	1074	- 133	- 90	+ 43
10	1109	- 98	- 70	+ 28
15	1126	- 81	- 57	+ 24
20	1148	- 59	- 46	+ 13
<i>q</i> ₁ 25	1162	- 45	- 37	+ 8
30	1174	- 33	- 29	+ 4
35	1181	- 26	- 21	+ 5
40	1188	- 19	- 14	+ 5
45	1197	- 10	- 7	+ 3
<i>m</i> 50	1207	0	0	0
55	1214	+ 7	+ 7	0
60	1219	+ 12	+ 14	- 2
65	1225	+ 18	+ 21	- 3
70	1230	+ 23	+ 29	- 6
<i>q</i> ₃ 75	1236	+ 29	+ 37	- 8
80	1243	+ 36	+ 46	- 10
85	1254	+ 47	+ 57	- 10
90	1267	+ 52	+ 70	- 18
95	1293	+ 86	+ 90	- 4

*q*₁, *q*₃, the first and third quartiles, stand at 25° and 75° respectively.
m, the median or middlemost value, stands at 50°.
The dressed weight proved to be 1198 lbs.

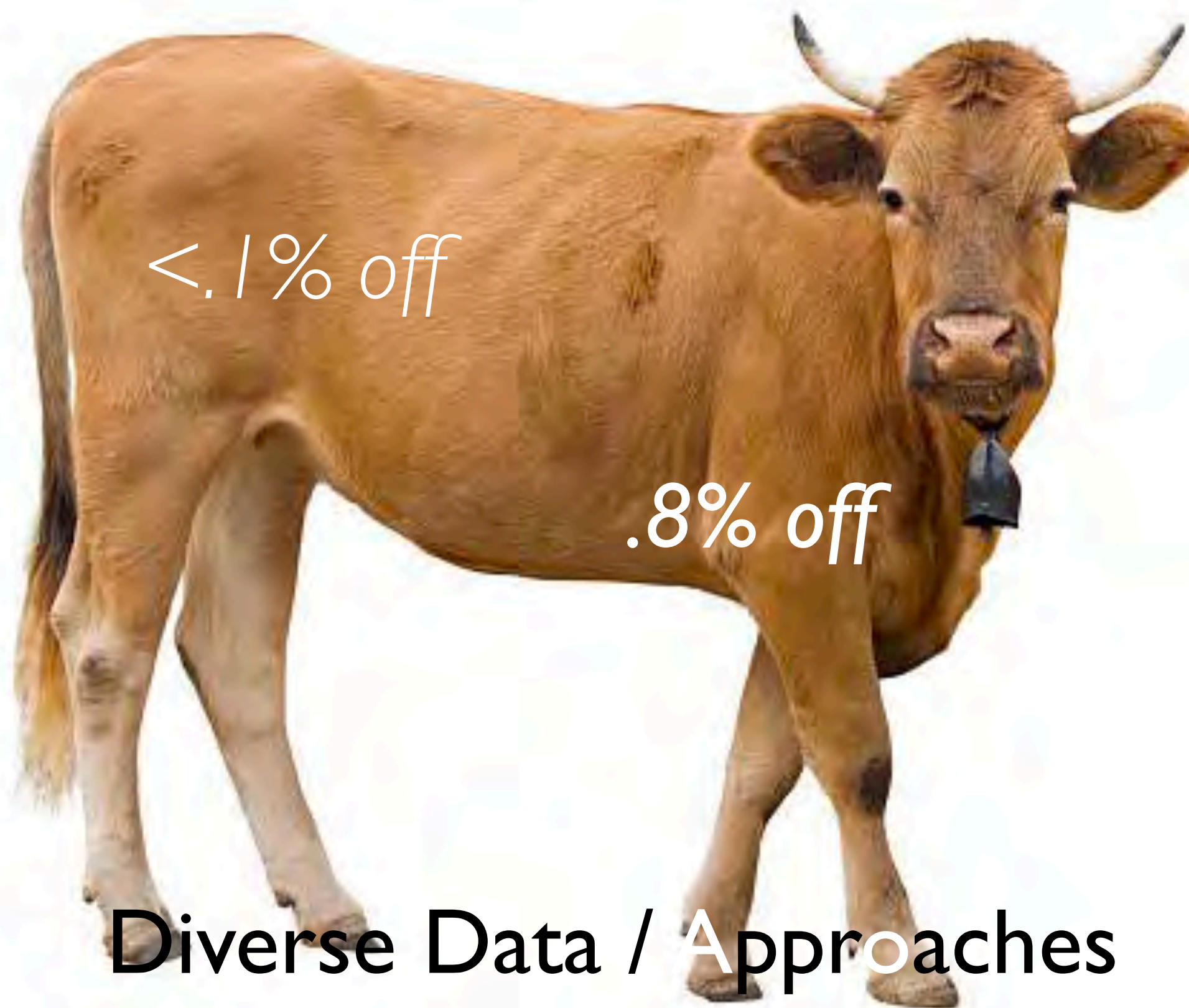
Diagram, from the tabular values.



The continuous line is the normal curve with p.e. = 37.
The broken line is drawn from the observations.
The lines connecting them show the differences between the observed



Francis Galton



Diverse Data / Approaches

Diversity

Cognitive

Perceptual

Experiential

Identity



McFarland
*Diversity-Innovation
Paradox*

Konning
*Participation-
Relevance*



Wisdom of

Science Technology Business

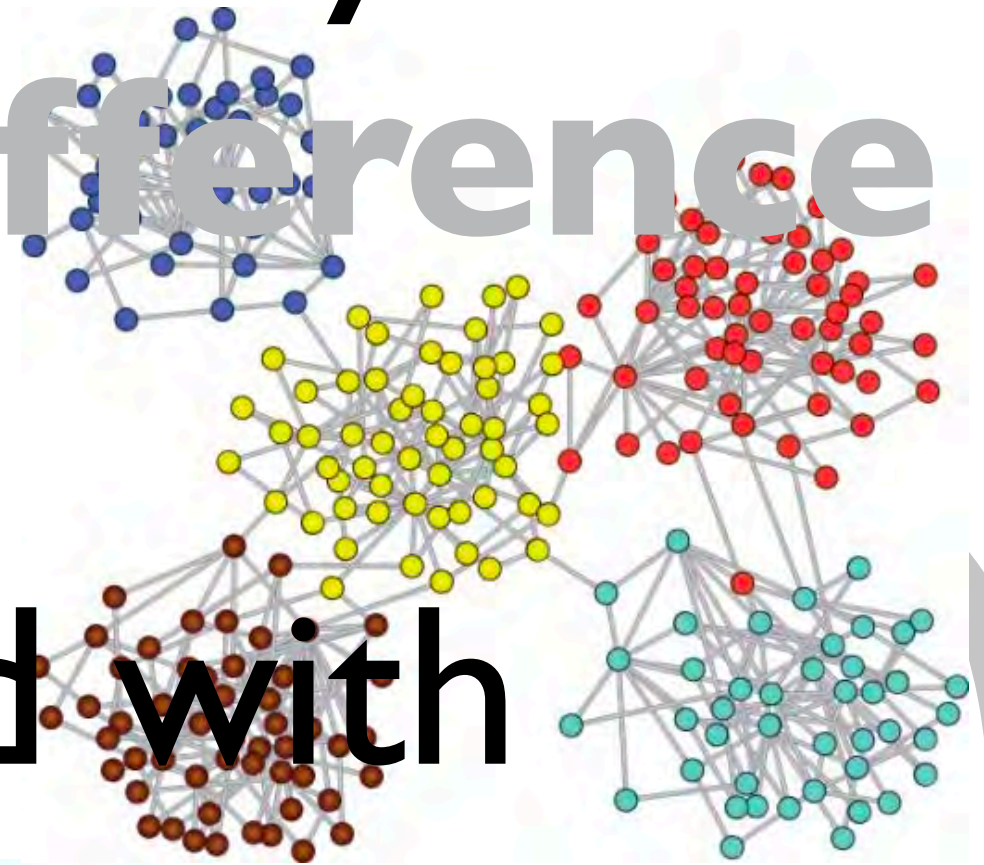
Innovating

Crowds

Chapters

SFI

1. Innovative Scientific Crowds characterized by
Collective Abduction & Bridged Difference

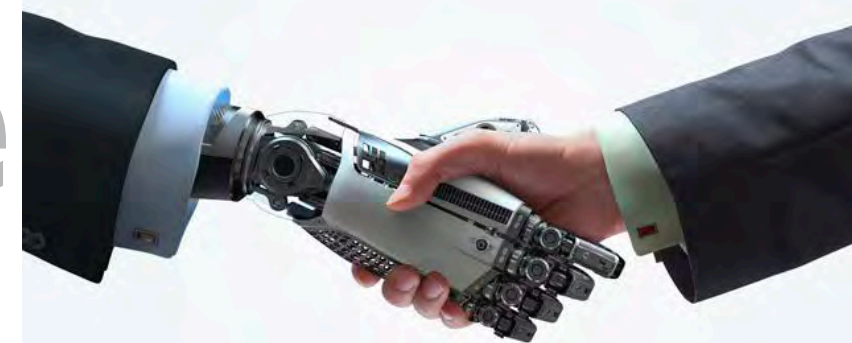


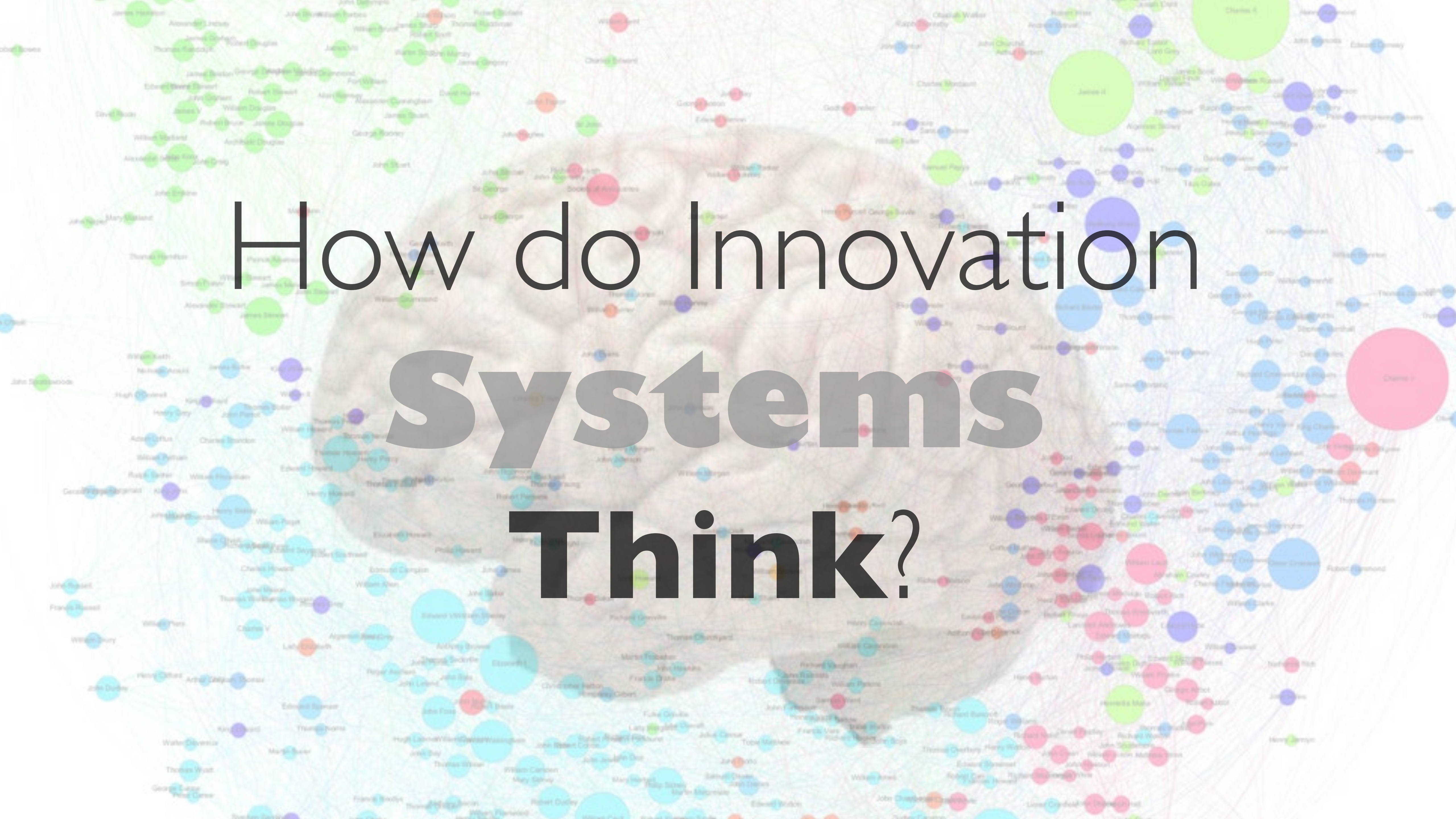
*
2. Connection and Conformity is associated with
Reduced Replication & Impeded Innovation



AI

3. AI that Designs Diversity Beyond Human Limits to
Accelerate and Punctuate Advance

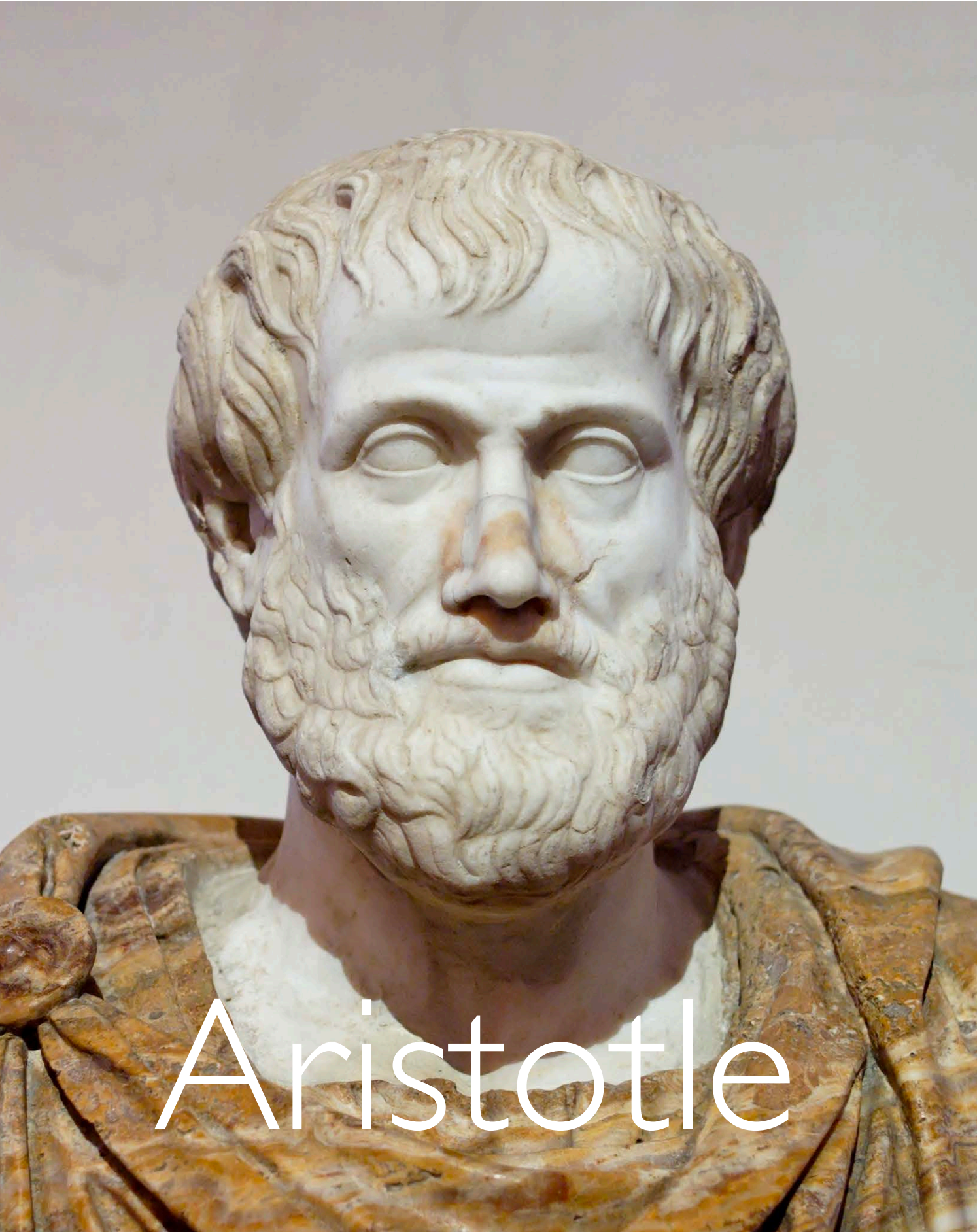




How do Innovation **Systems** **Think?**

Deduction

Logically extend from
facts/axioms



Aristotle



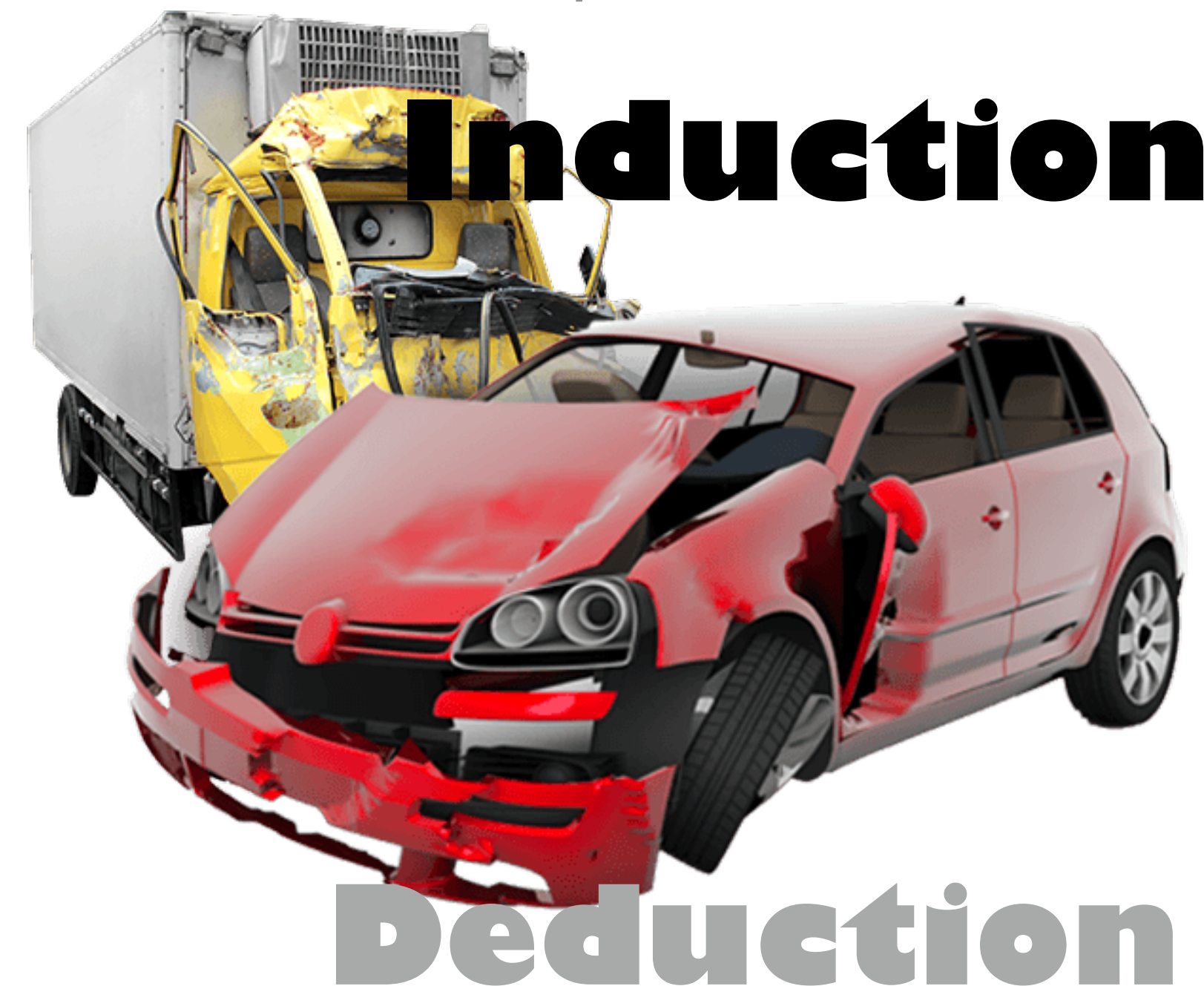
Imaginatively generalize from
observations

Induction



Abduction

surprise



Induction

Deduction



PubMed

APS
physics™

UNITED STATES
PATENT AND TRADEMARK OFFICE

uspto

20M PubMed articles (1865-2015)

15,000 MeSH term Concepts (e.g., PCR, hypertension, DNA, testosterone)

.5M APS articles (1880-2015)

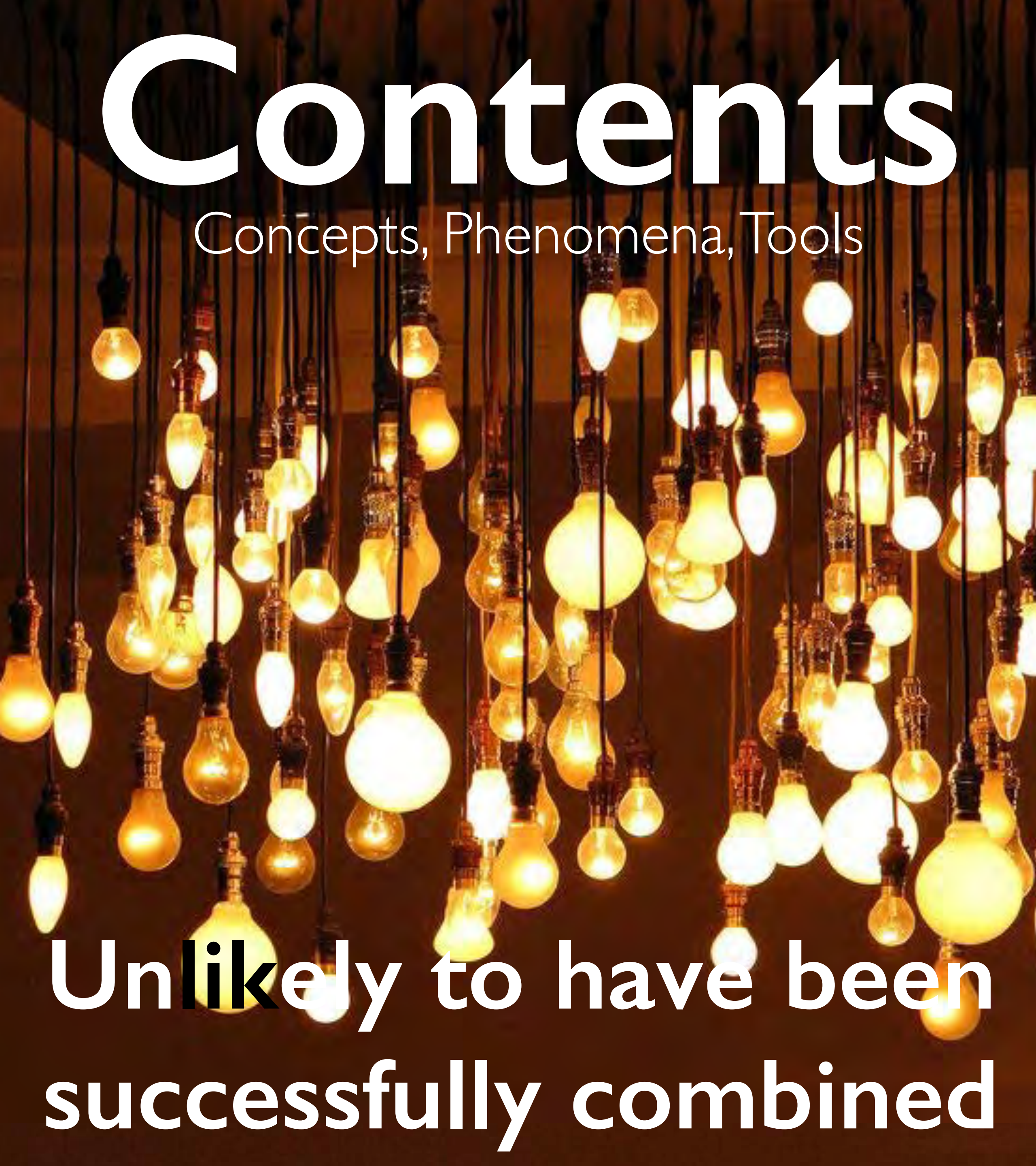
80,000 PACS code Concepts (e.g., neutron star core, lie algebras, polarization)

1.5M US Patents

45,000 USPC subclasses (e.g., arc lamp, electrolytic condenser, paper, button)

Contents

Concepts, Phenomena, Tools



Unlikely to have been
successfully combined

Unlikely to have been
previously imagined



Contexts

Journals, Conferences, Conversations

To Identify
Surprise



requires a

AI-

Driven

Sufficient Model

Digital

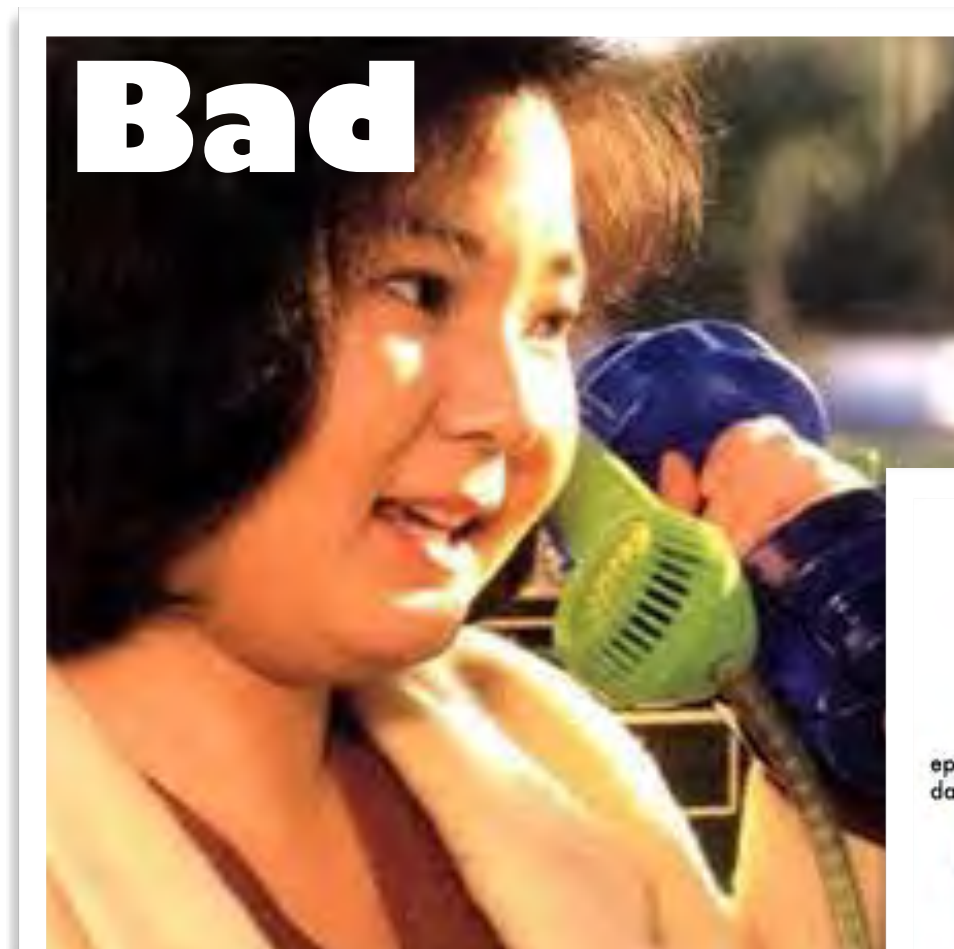
Double

Almost Everything

Surprising (improbable) outcomes

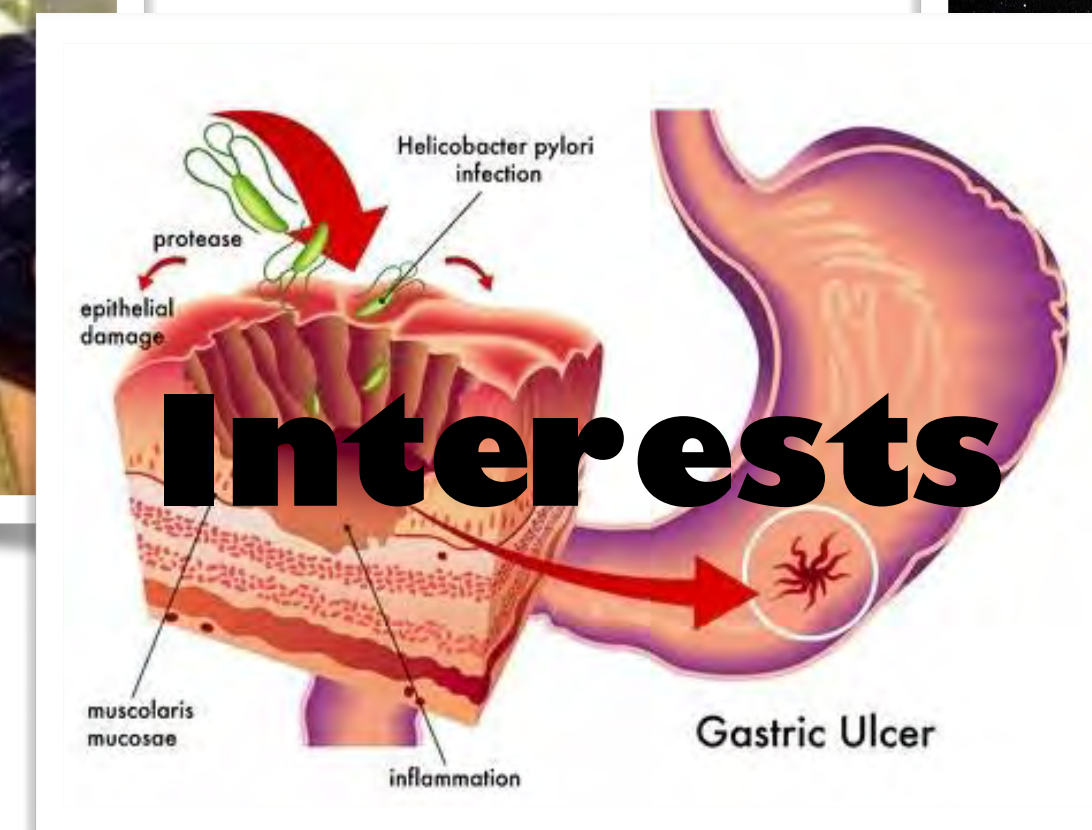
$$Novelty \propto \frac{1}{P(I|A, S)}$$

Decreasing
Function



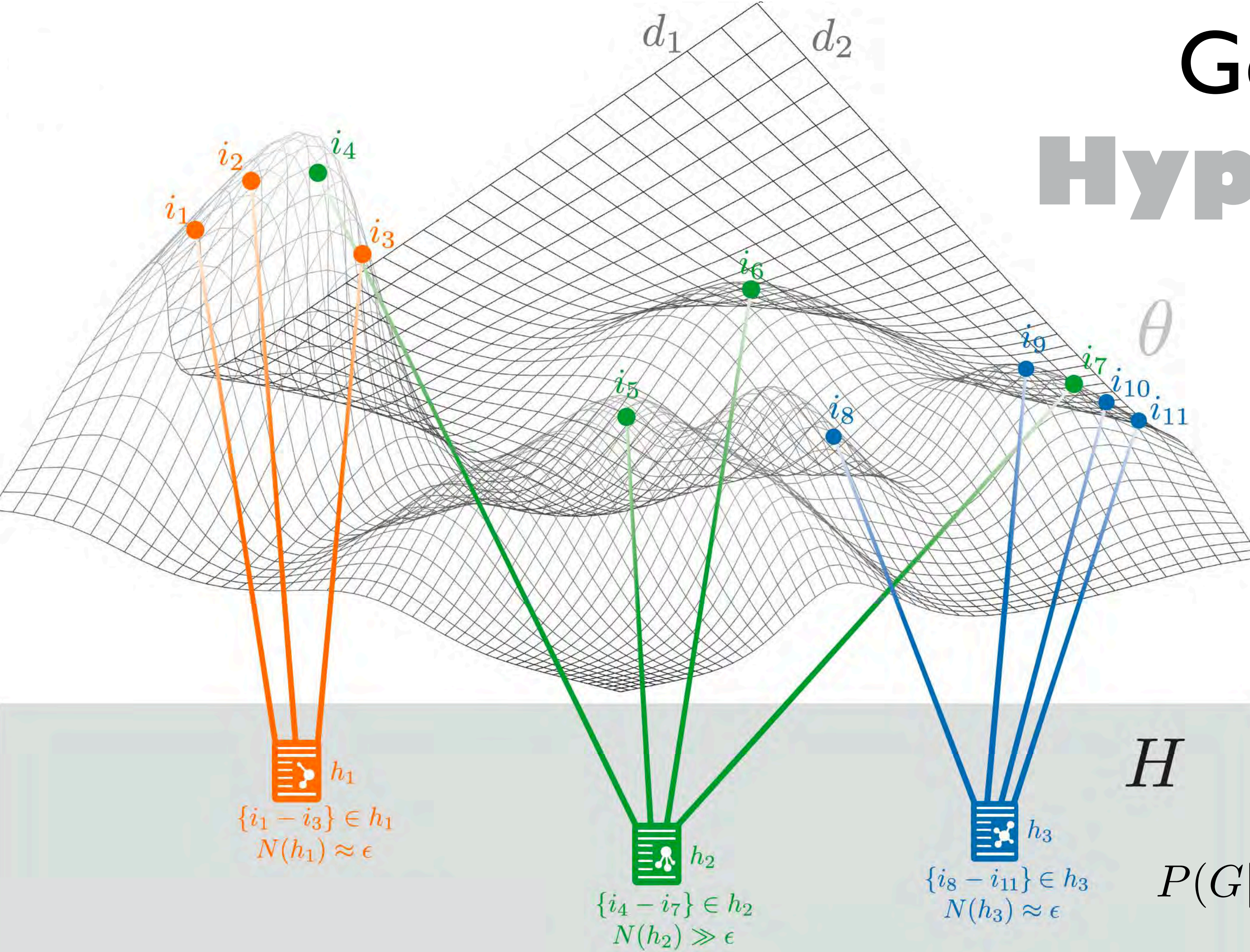
Dumbphone

Helicobacter pylori



Oumuamua

Generative Hypergraph Model



1.

$$\lambda_h = \sum_d \prod_{i \in h} \theta_{id} \times \prod_{i \in h} r_i$$

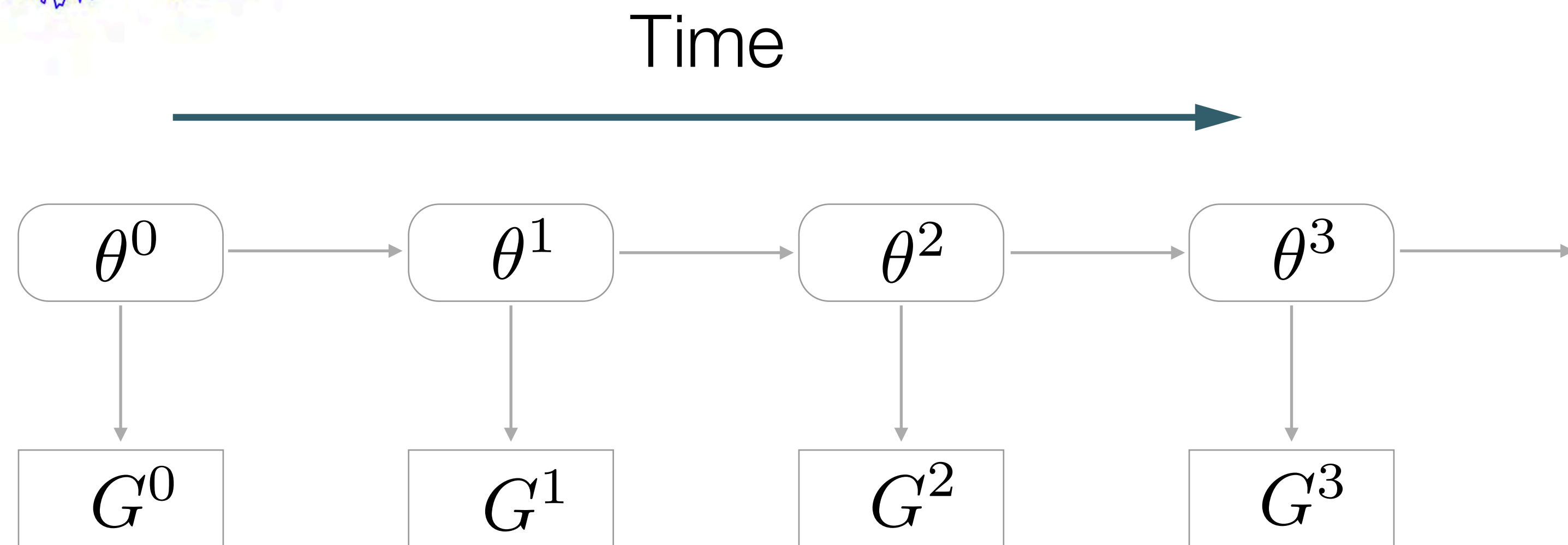
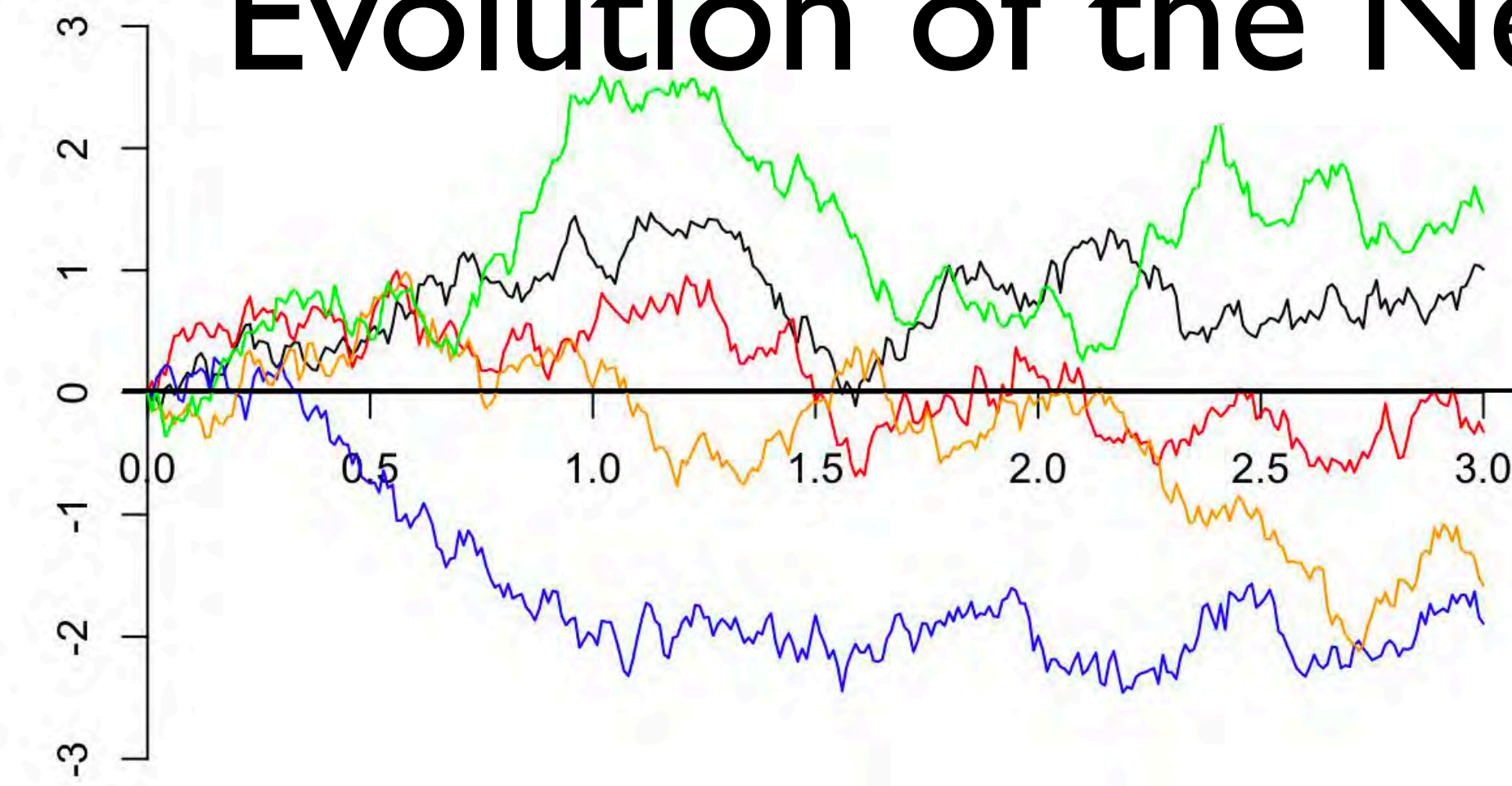
2.

$$X_h \sim \text{Poisson}(\lambda_h)$$

3.

$$P(G|\Theta, R) = \prod_{h \in H} P(x_h|\Theta, R)$$

Evolution of the Network



G^t : observed network at time t

θ^t : latent positions of the elements at time t

Complete Model

- Log-likelihood function

$$l(\theta_1, \dots, \theta_T) = \log P(G_1, \dots, G_T | \theta_1, \dots, \theta_T)$$

$$= \sum_{t=1}^T [\log P(\theta^t | \theta^{t-1}) + \log P(G^t | \theta^t)]$$

Gaussian Density for Brownian motion

Poisson Density for Hyperedge Section

$$= \sum_{t=1}^T \left[\sum_i \sum_k (\theta_{ik}^t - \theta_{ik}^{t-1})^2 / 2\sigma^2 + \sum_{h \in G^t} (x_h \log \sum_k \prod_{i \in h} \theta_{ik}^t - \sum_k \prod_{i \in h} \theta_{ik}^t) \right]$$

- Impossible to optimize!

Incomputable

2^N possible combinations

Maximal Likelihood Estimate

Theorem

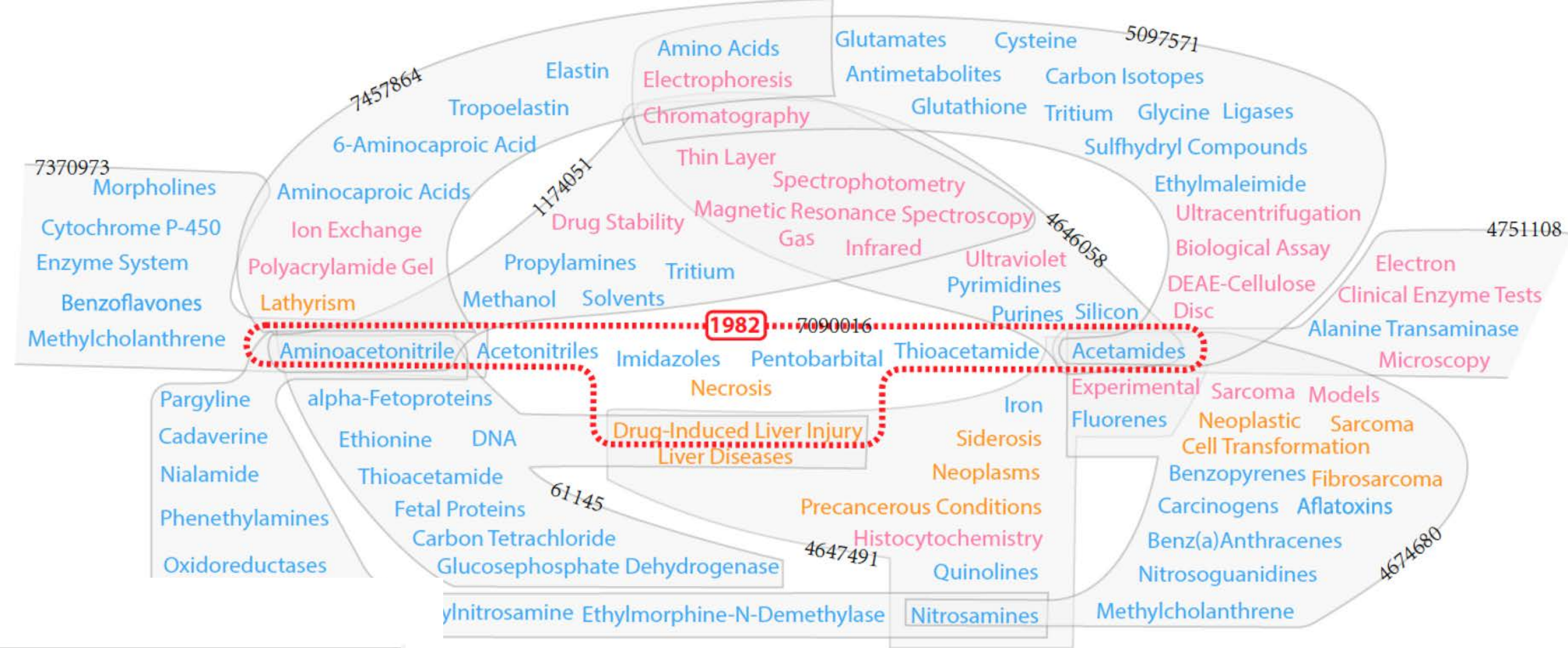
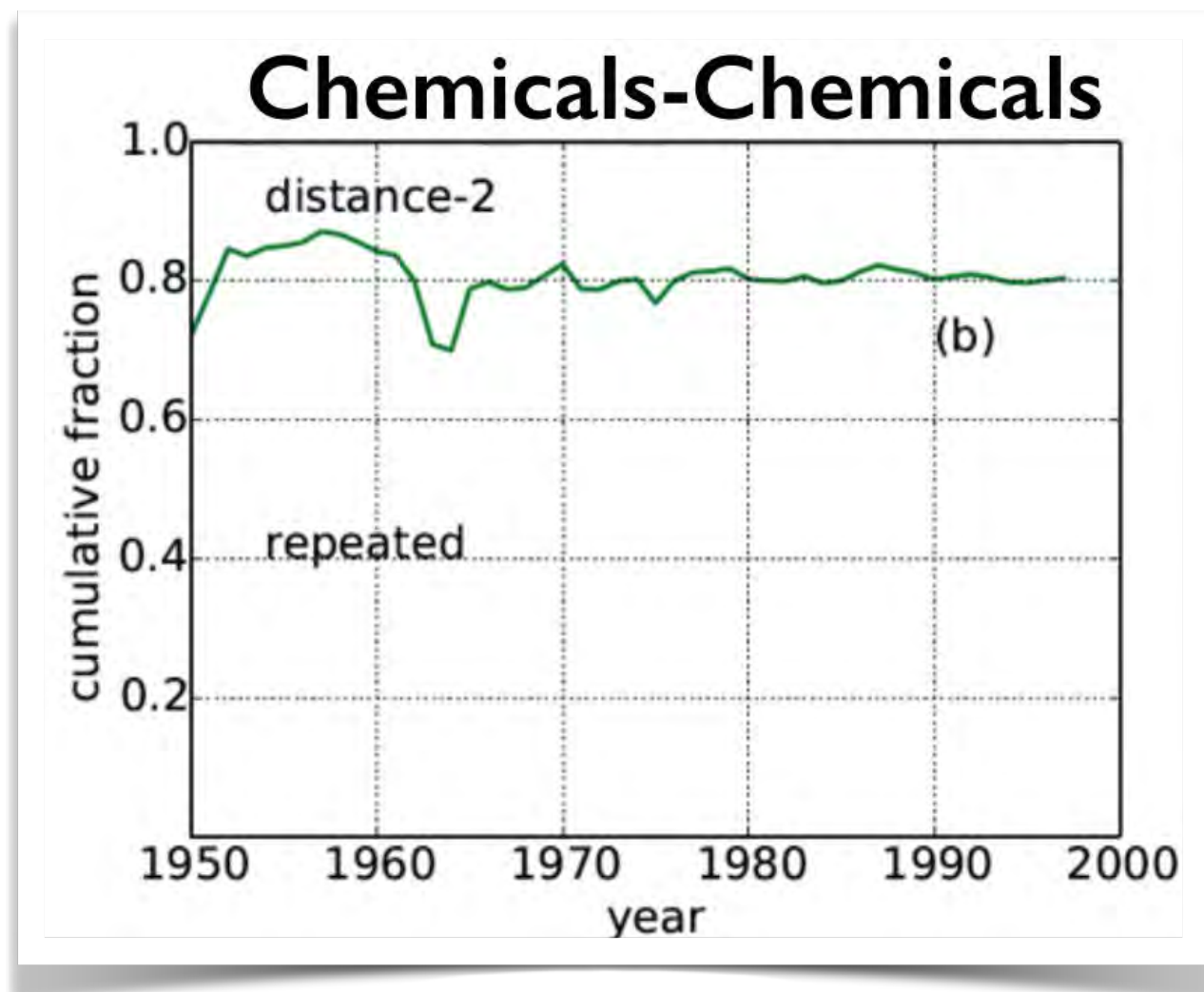
Let $f(\theta, t) = \sum_{d=2}^D S_d^t$ and $t \sim \text{randint}(1, T)$, then

$$E[\nabla f(\theta, t)] = \nabla l(\theta)$$

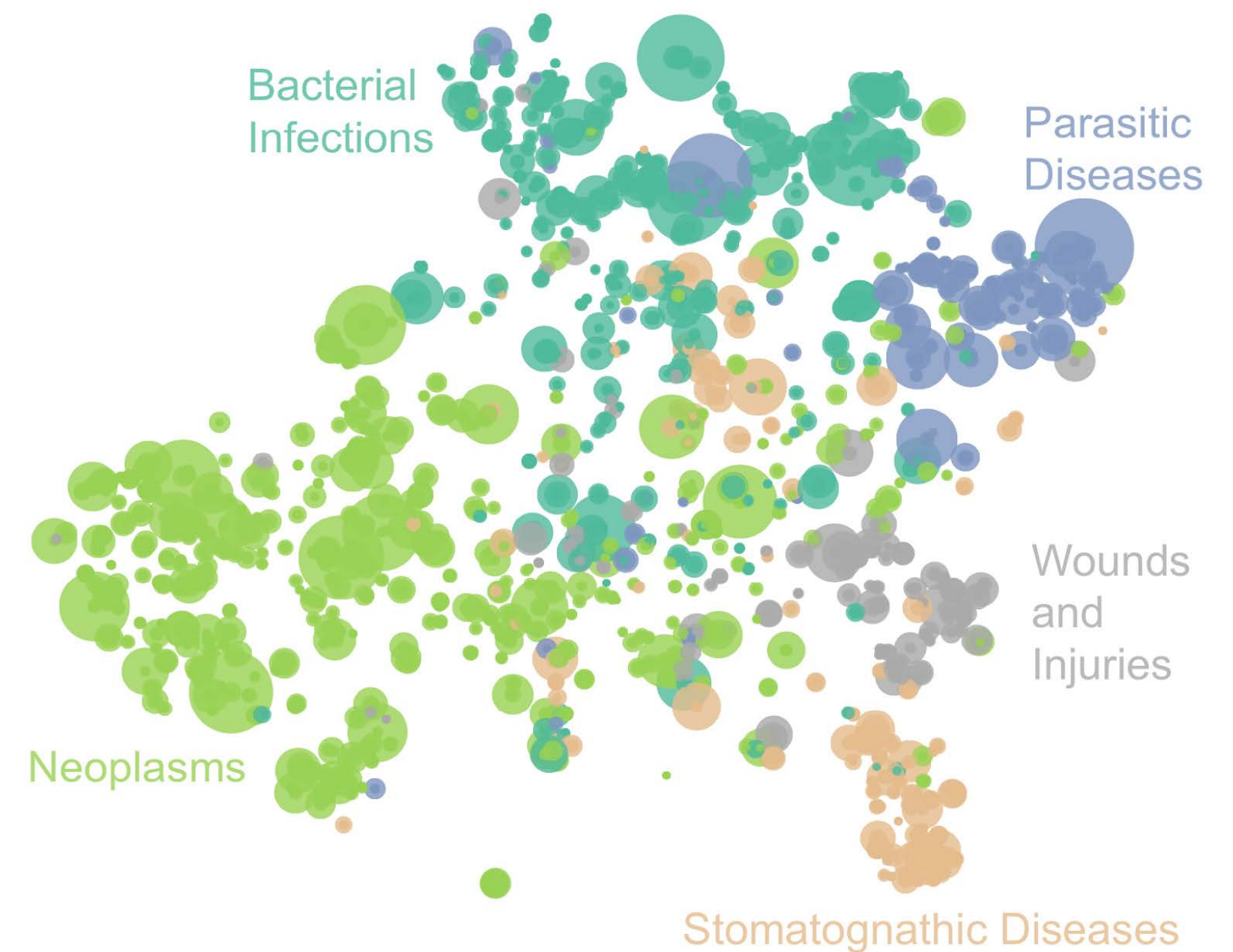
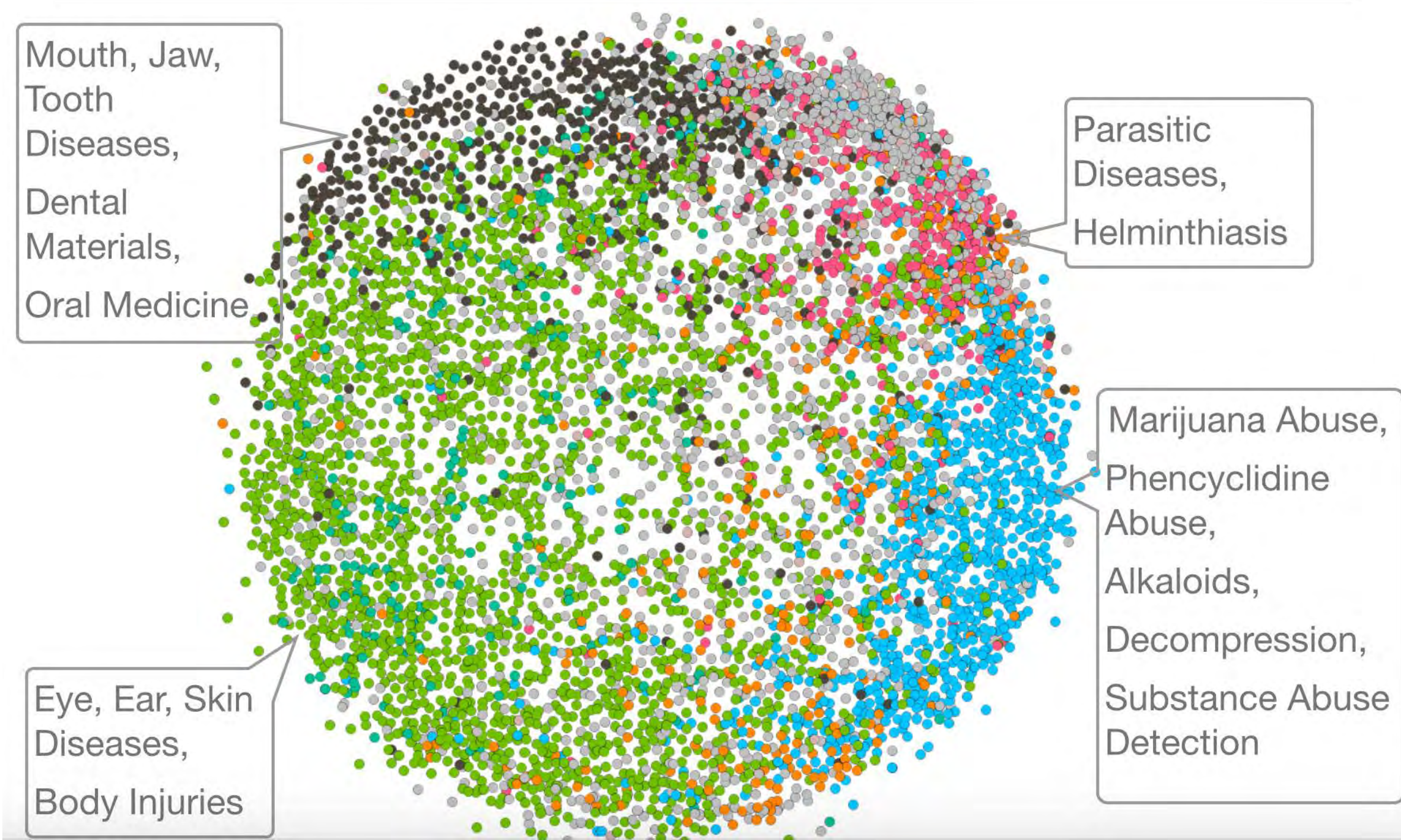
Corollary

$\hat{\theta}$ will converge to the maximal likelihood estimate.

Choice: Negative Sampling vs. Contrastive Noise



Community Structure

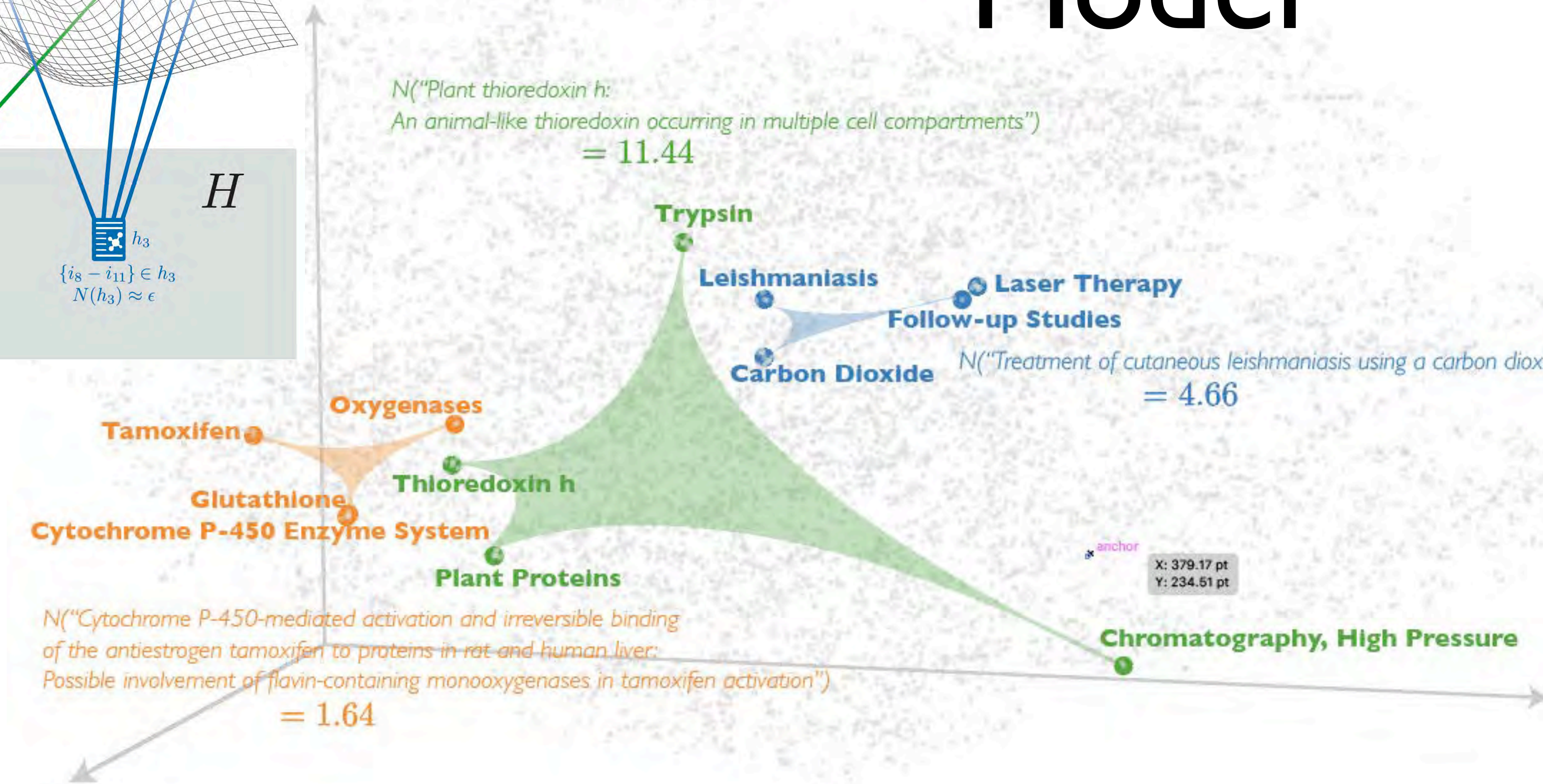
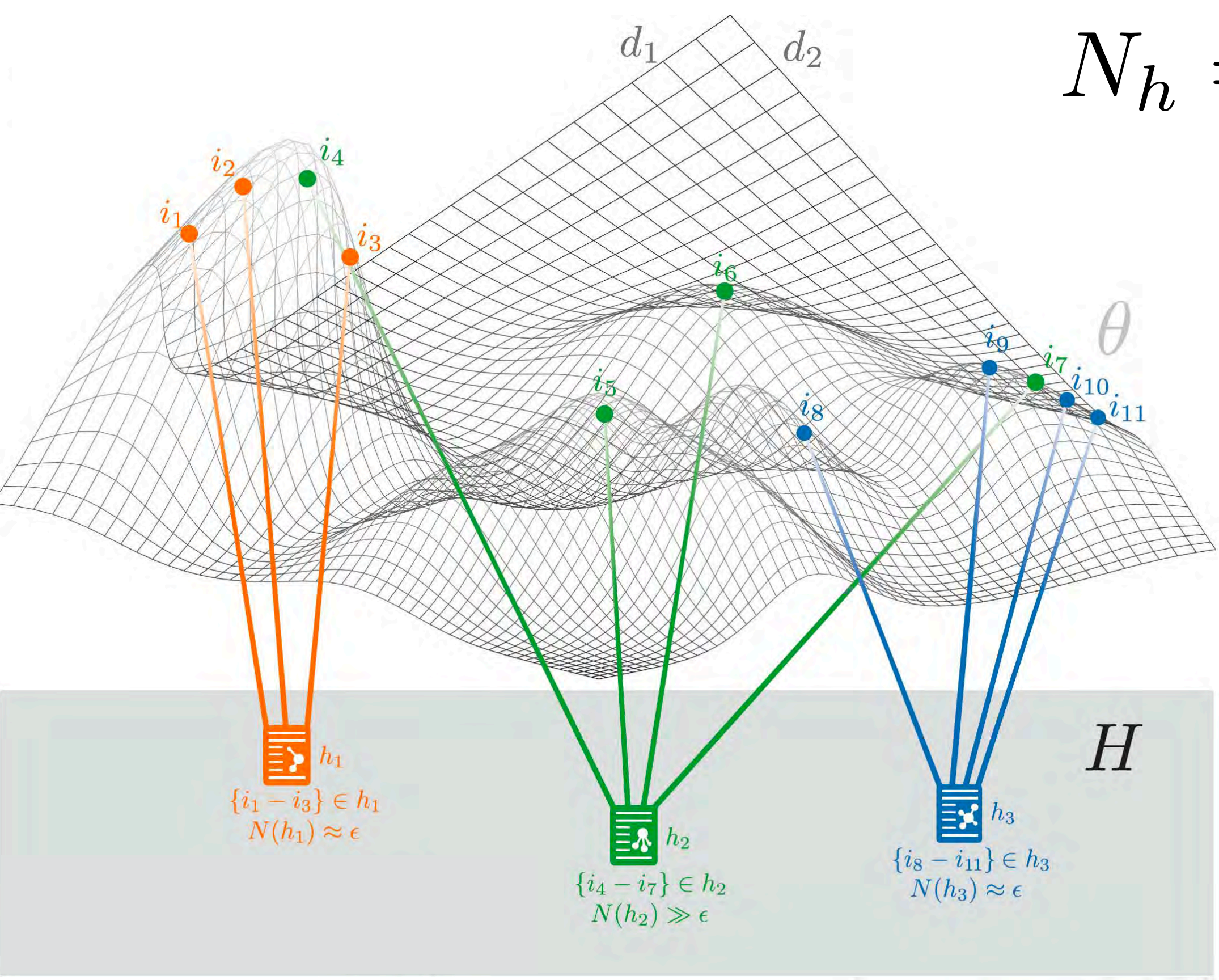


Static

Measure

Model

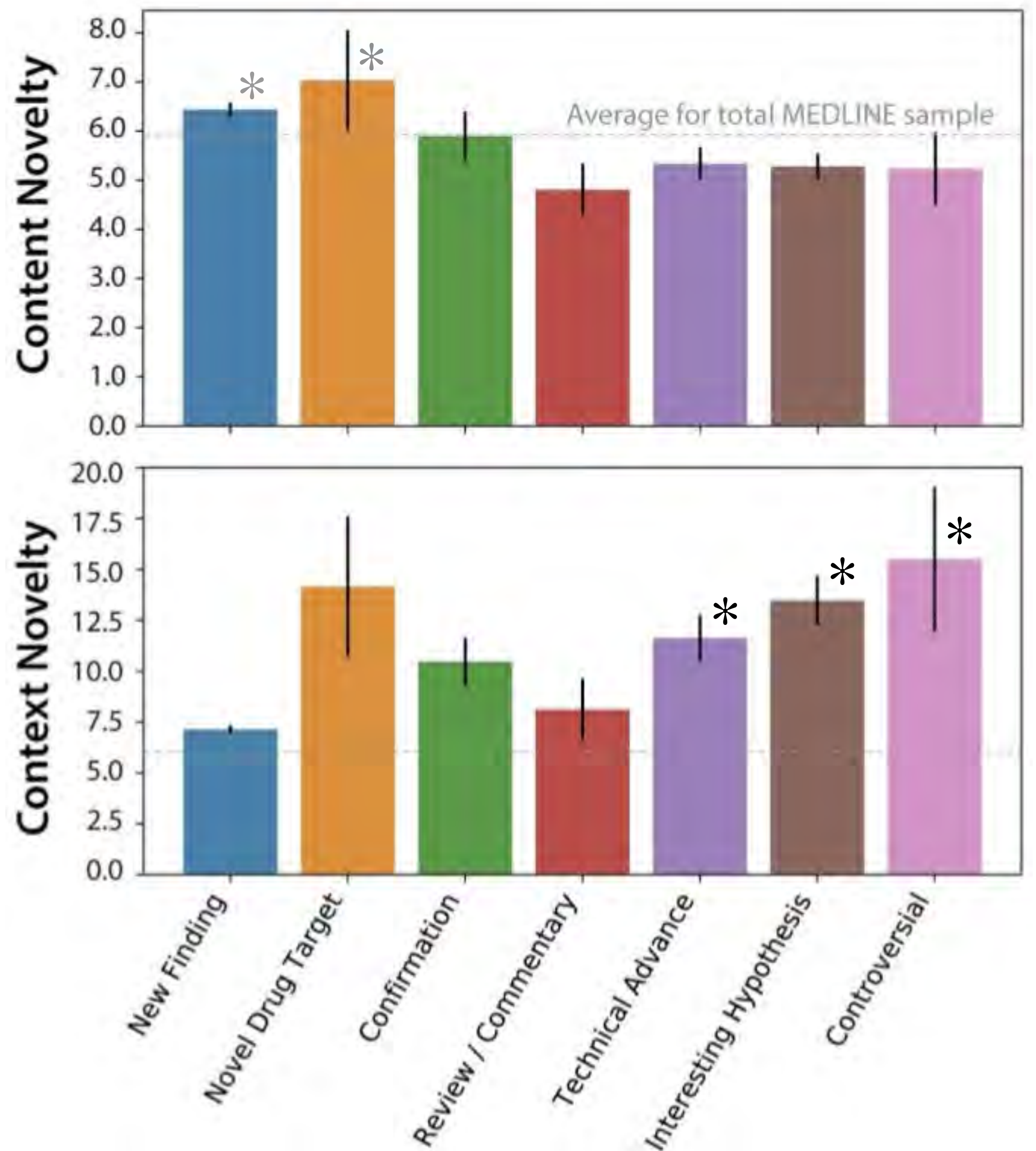
$$N_h = -\log \sum_d \prod_{i \in h} \theta_{id}$$



Faculty 1000

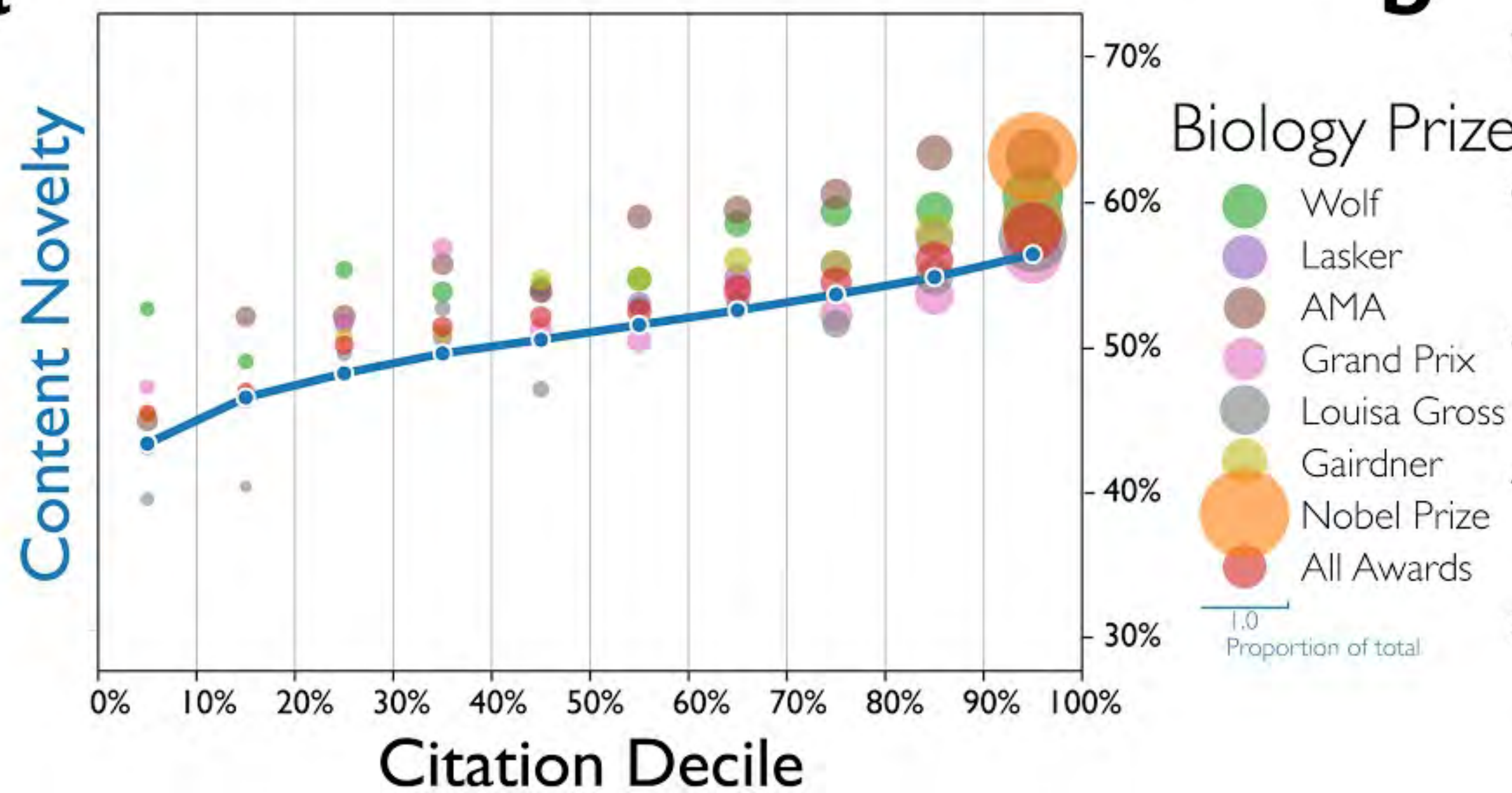
Content novelty is most associated with **New findings** and **Drug targets** emerge from within-domain investigation.

Context novelty is most associated with **Controversial, Interesting hypothesis** and **Technical advance** emerge from cross-domain investigation.

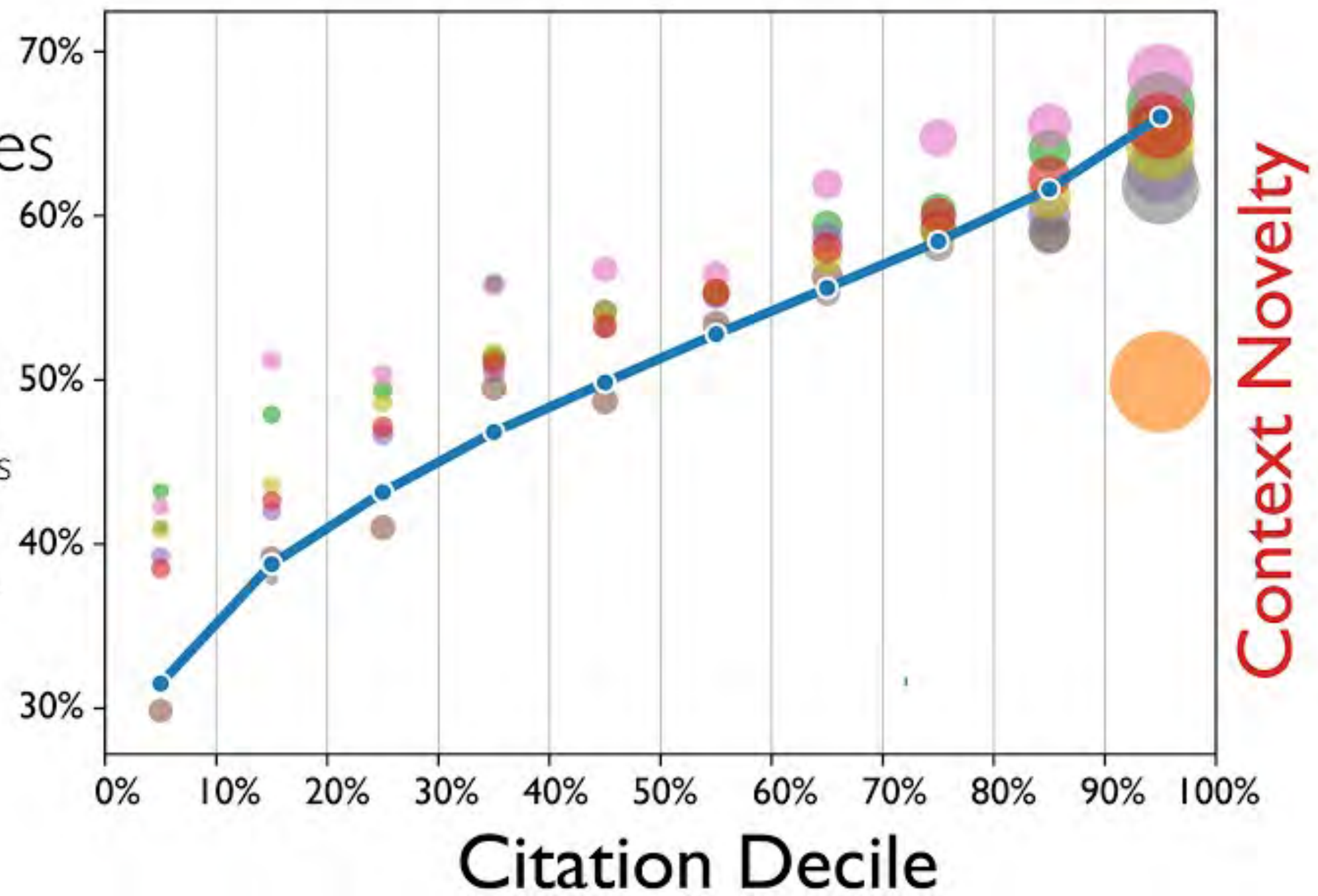


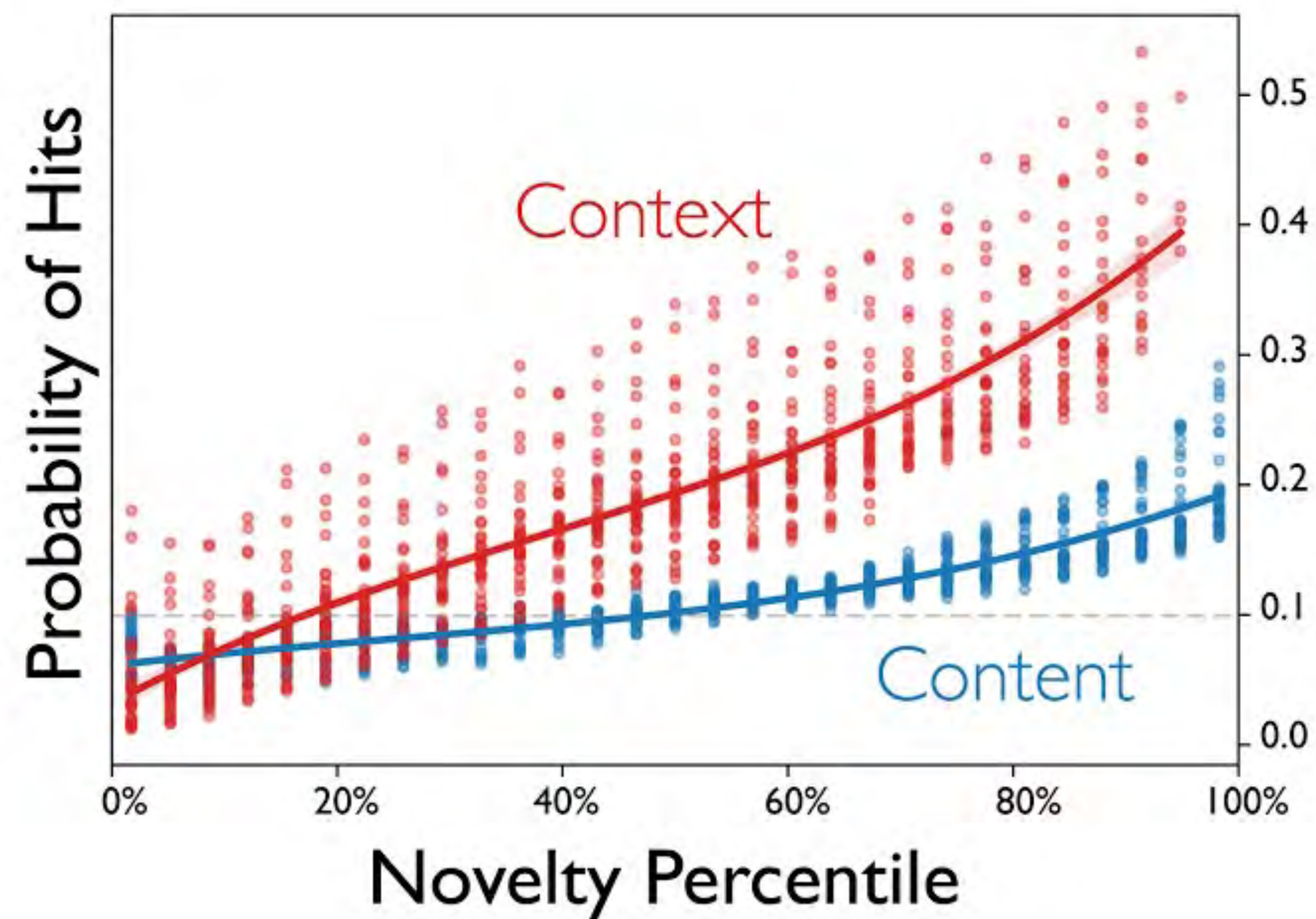
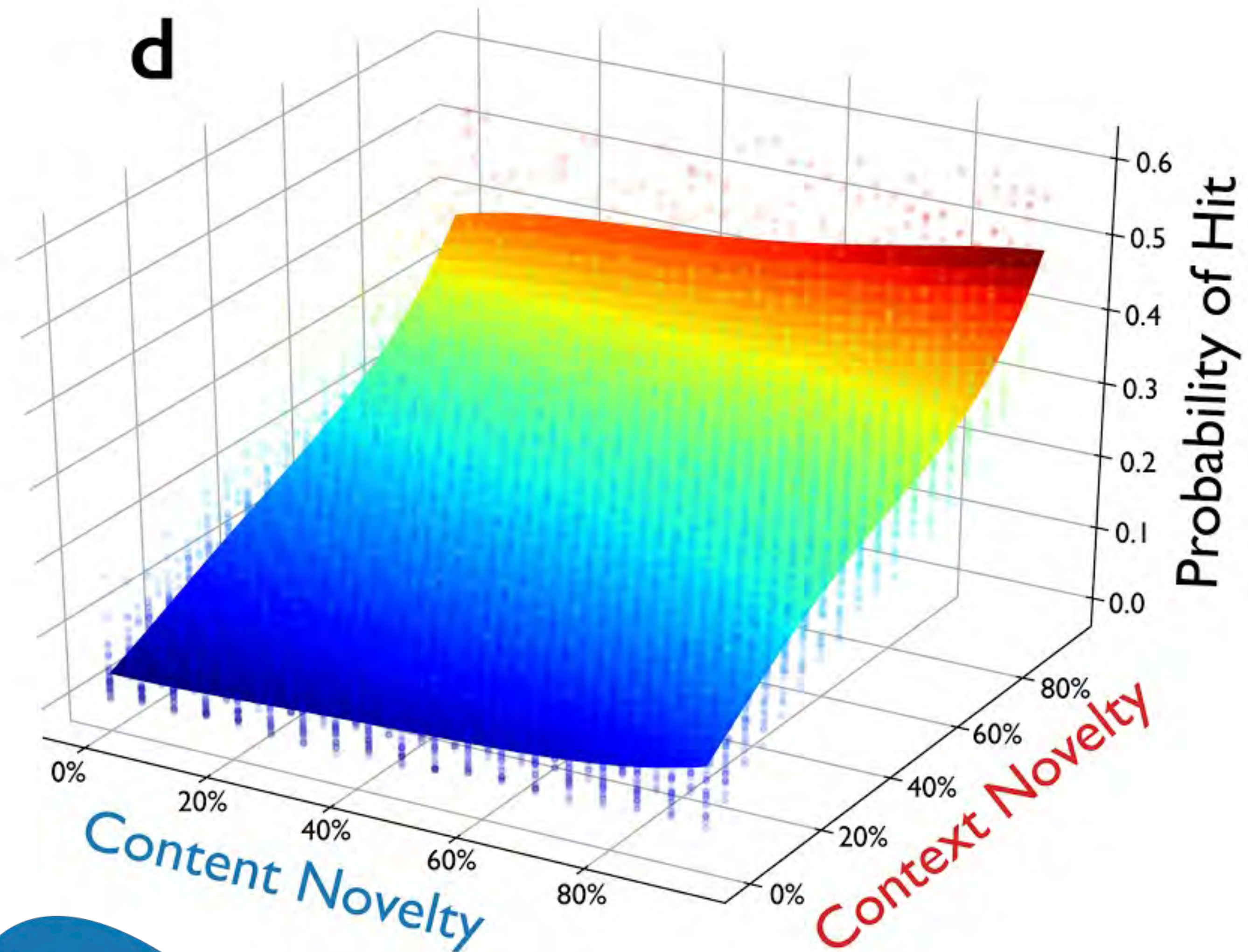
PublMed

a



b

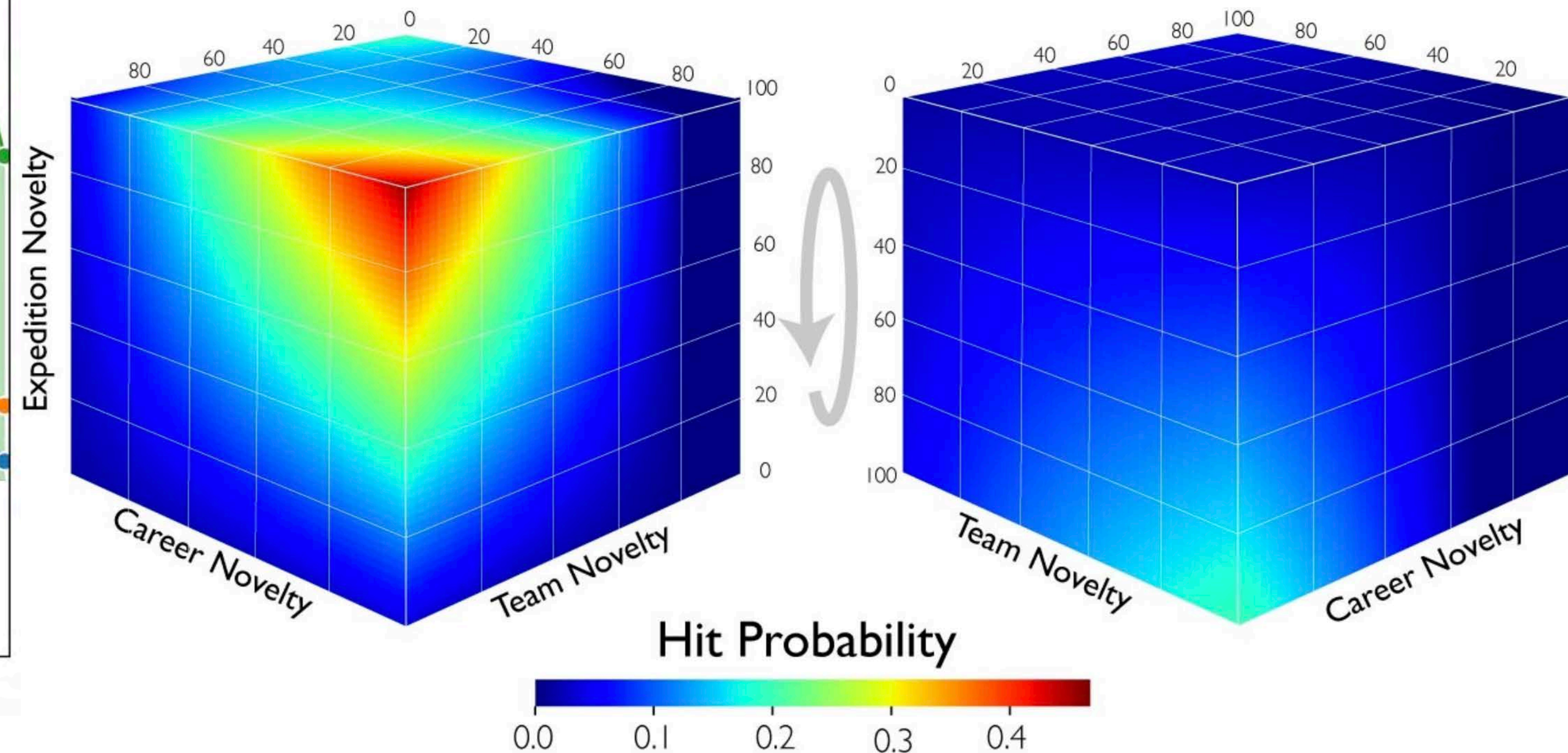
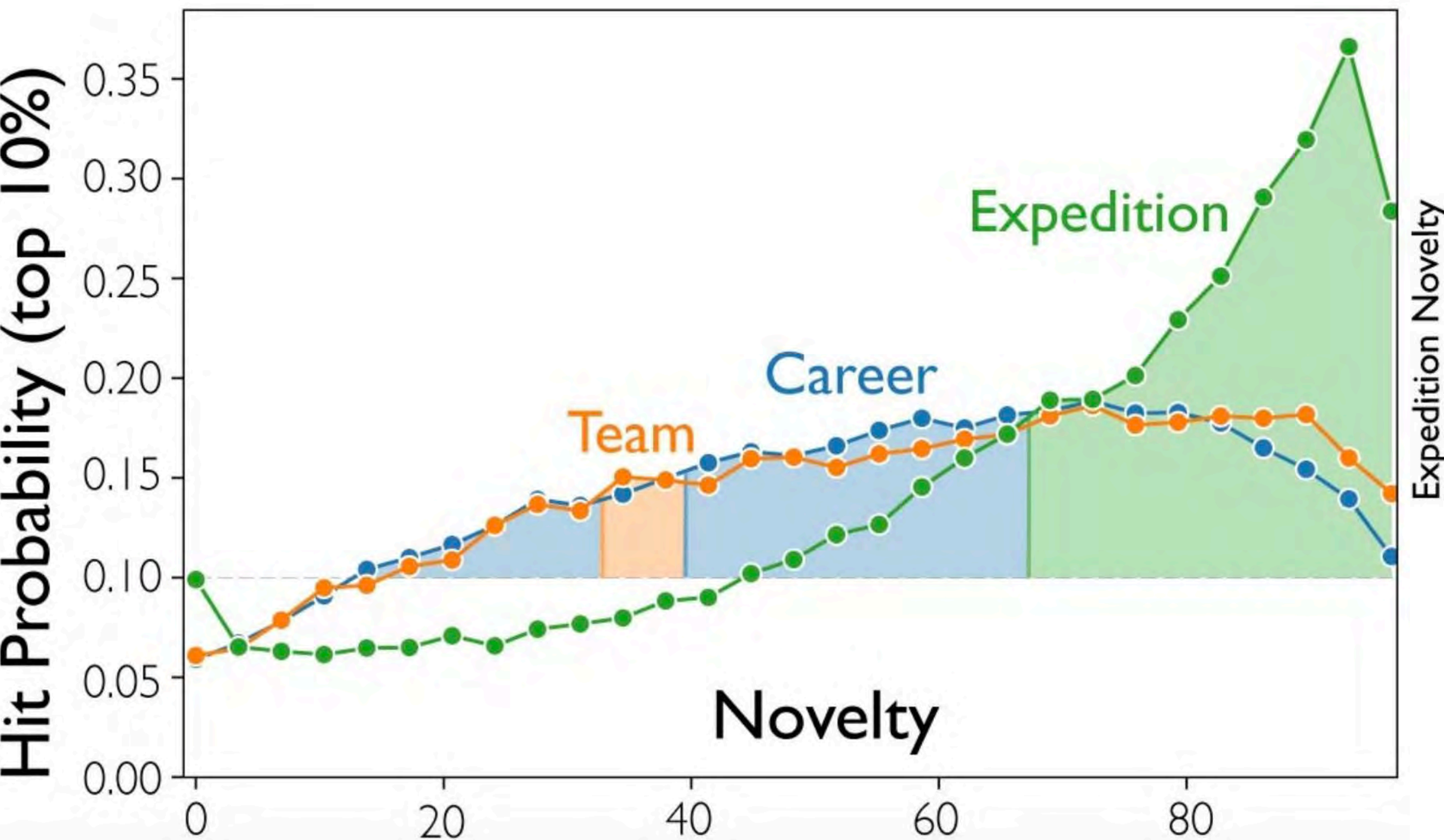


c**d**

PubMed

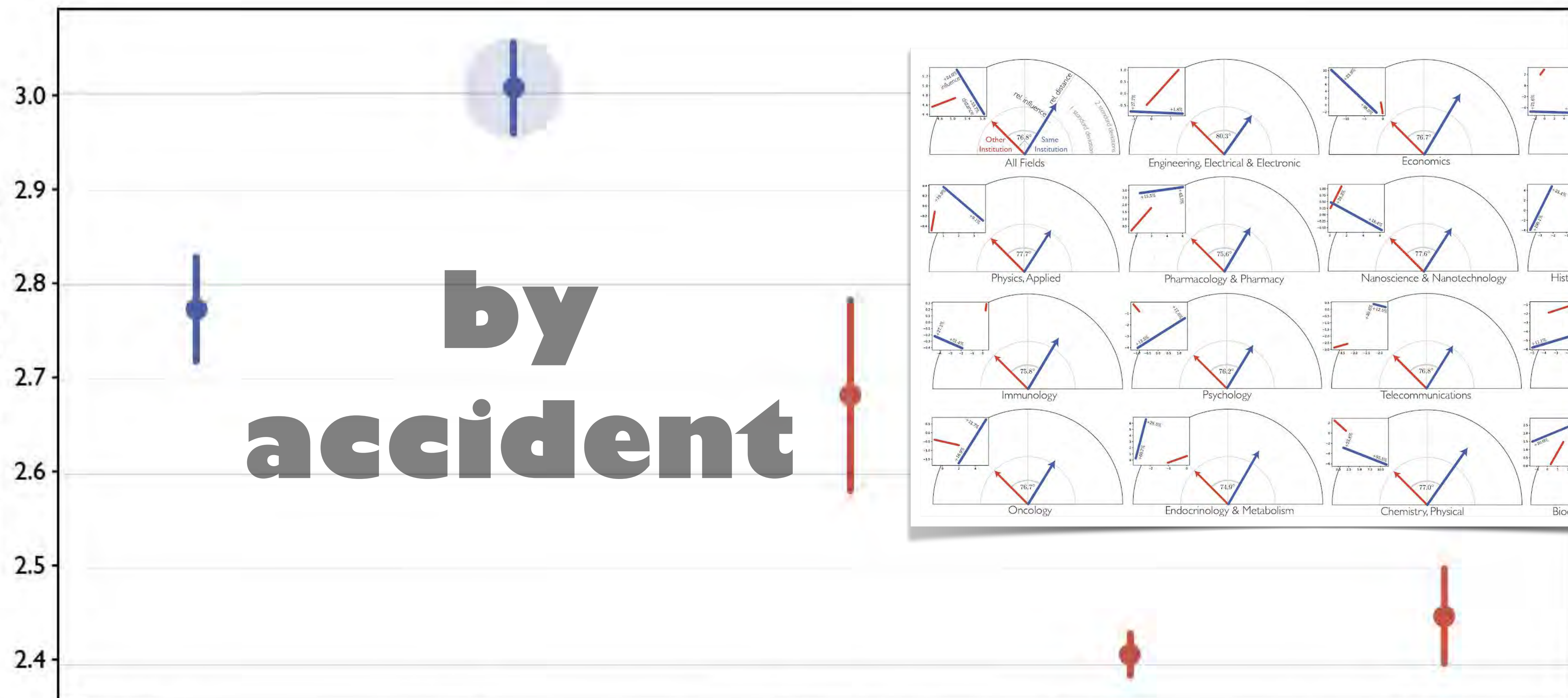
Disconnection through Disciplines

Career, Team, & Expedition Novelty

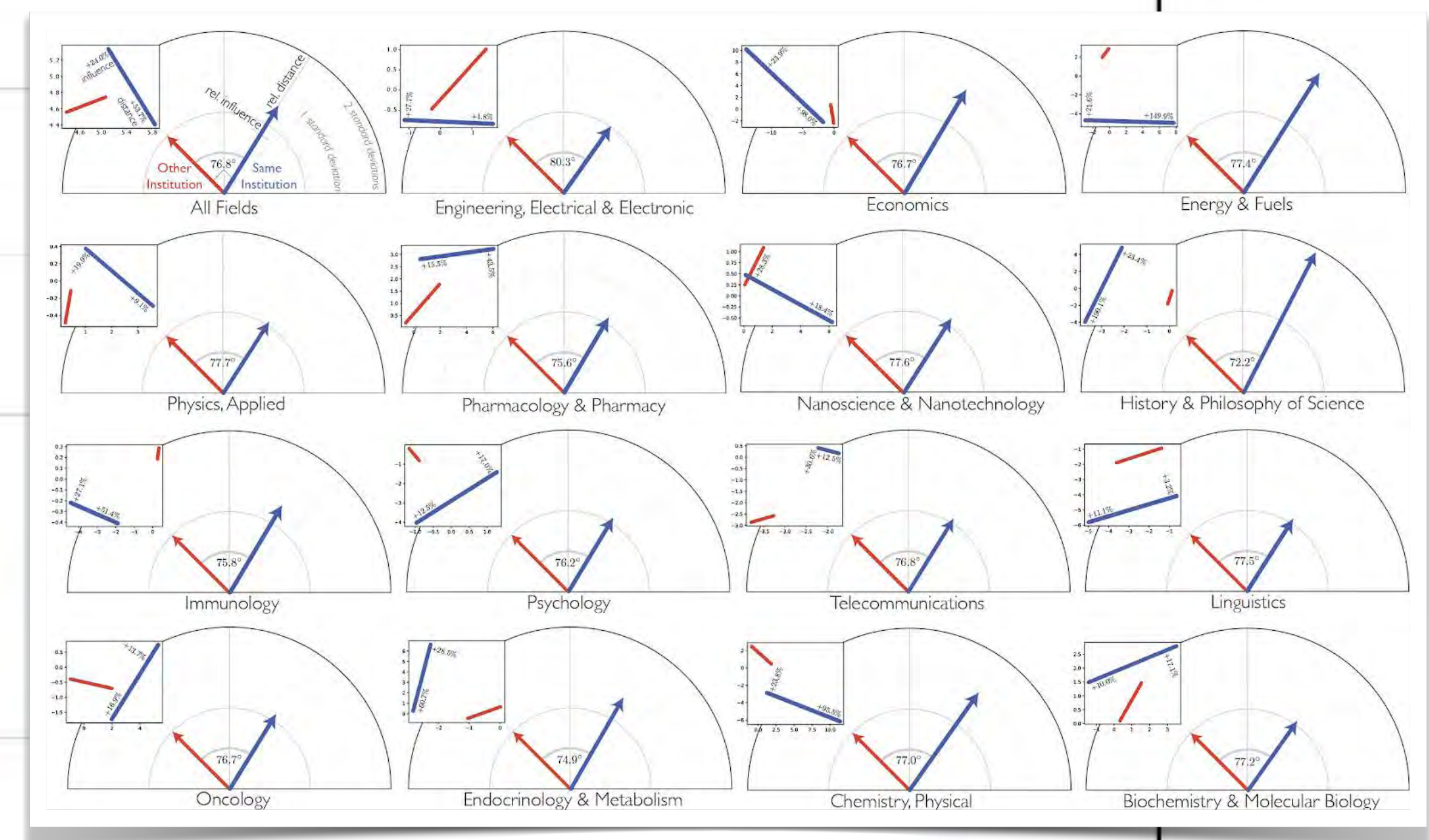


Radical Insight comes in conversation
with **Outsiders / Aliens**

intellectual influence



by
accident



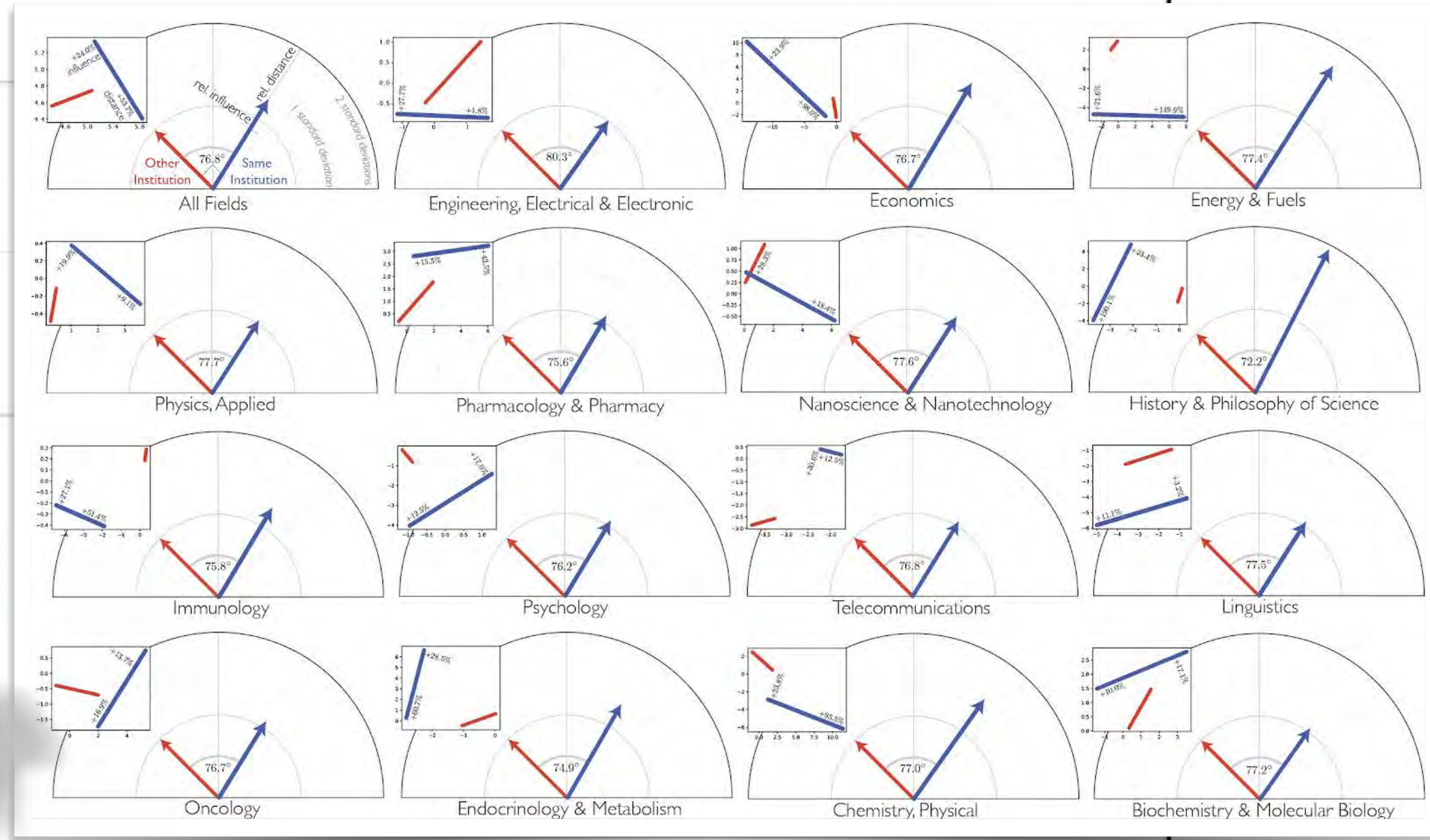
same **department** € same **institution** € same **city** € same **country** € same **world**
 \ same department \ same institution \ same city \ same country



intellectual influence

3.0
2.9
2.8
2.7
2.6
2.5
2.4

SFI



same **department** €

same **institution** €
\ same department

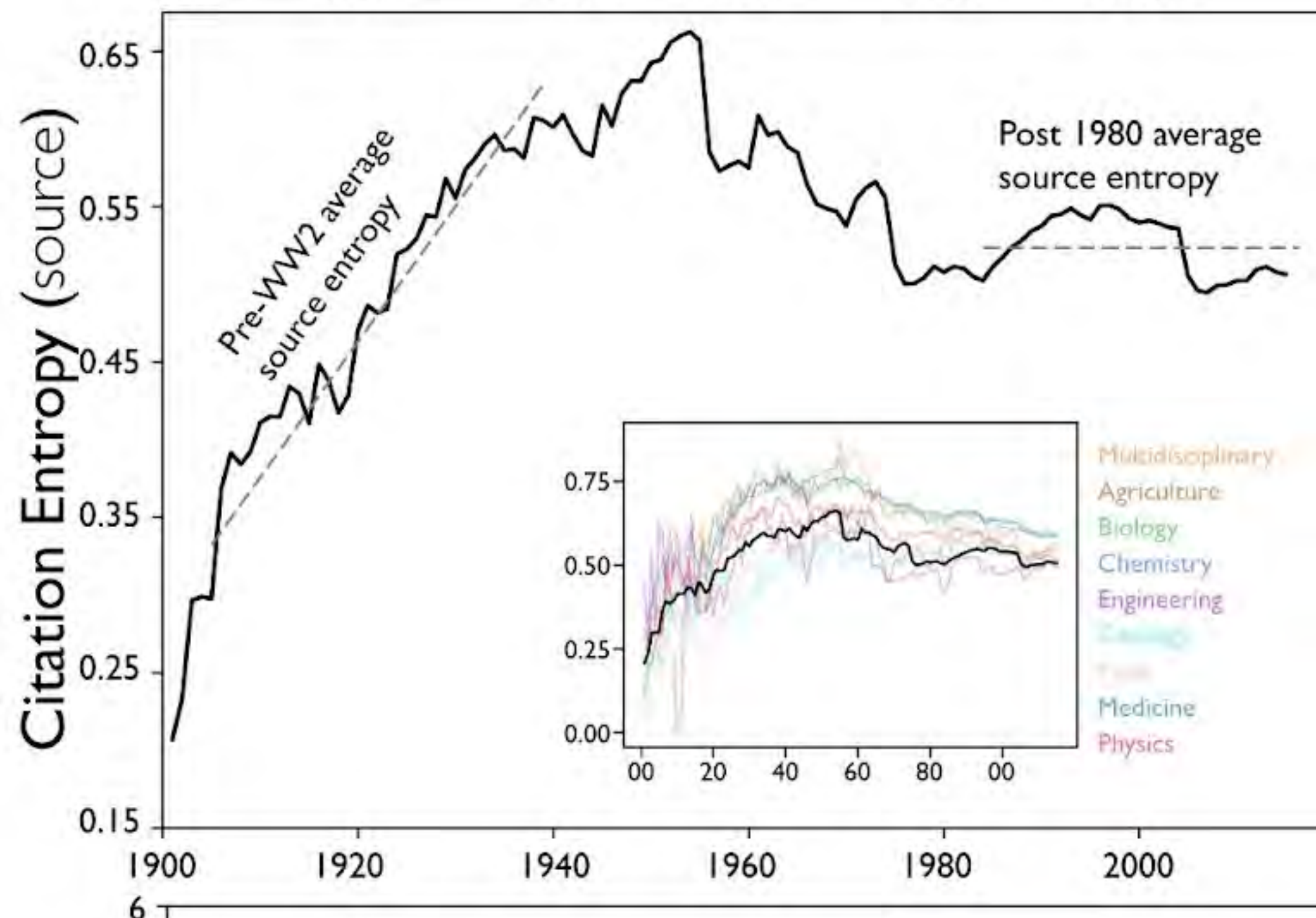
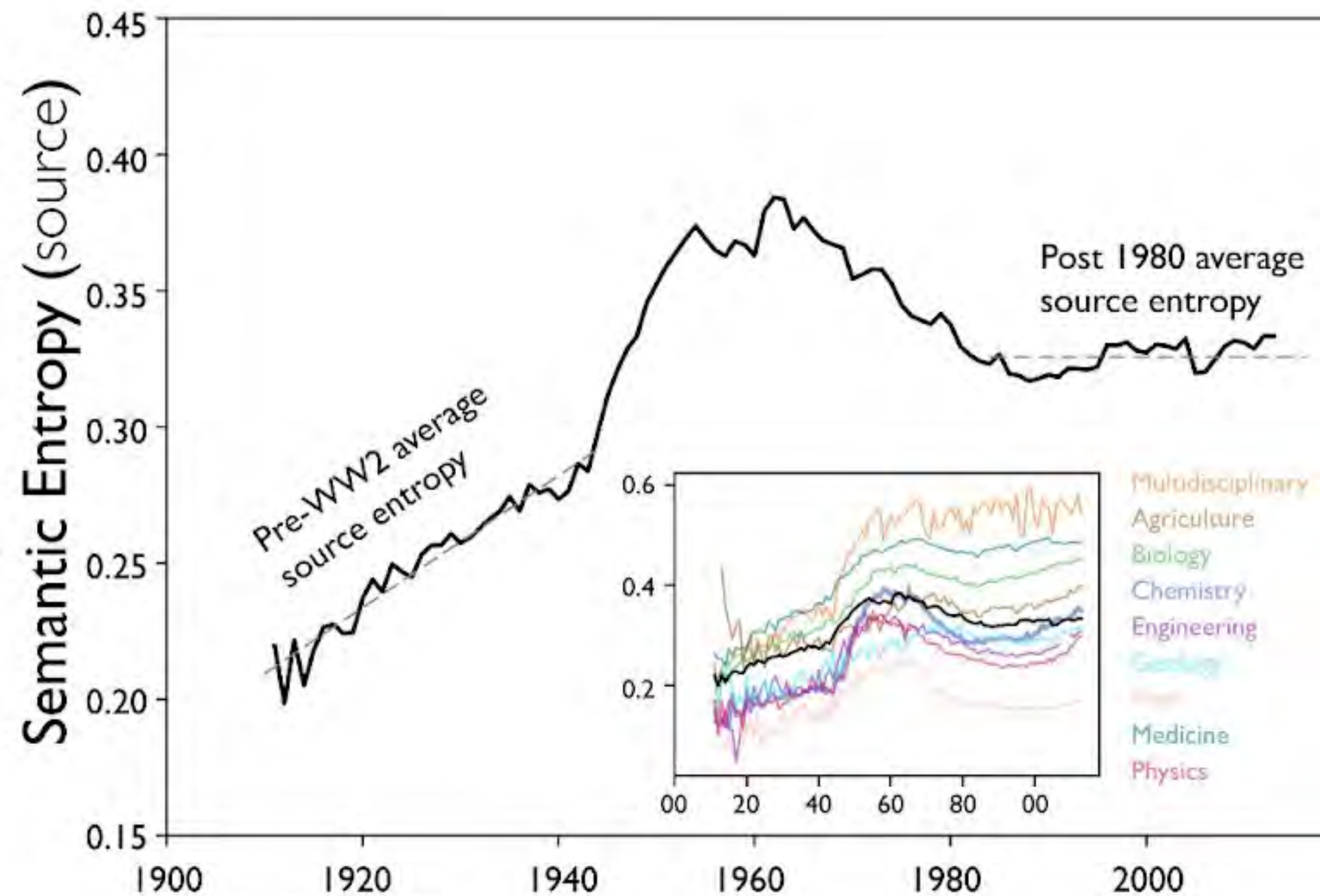
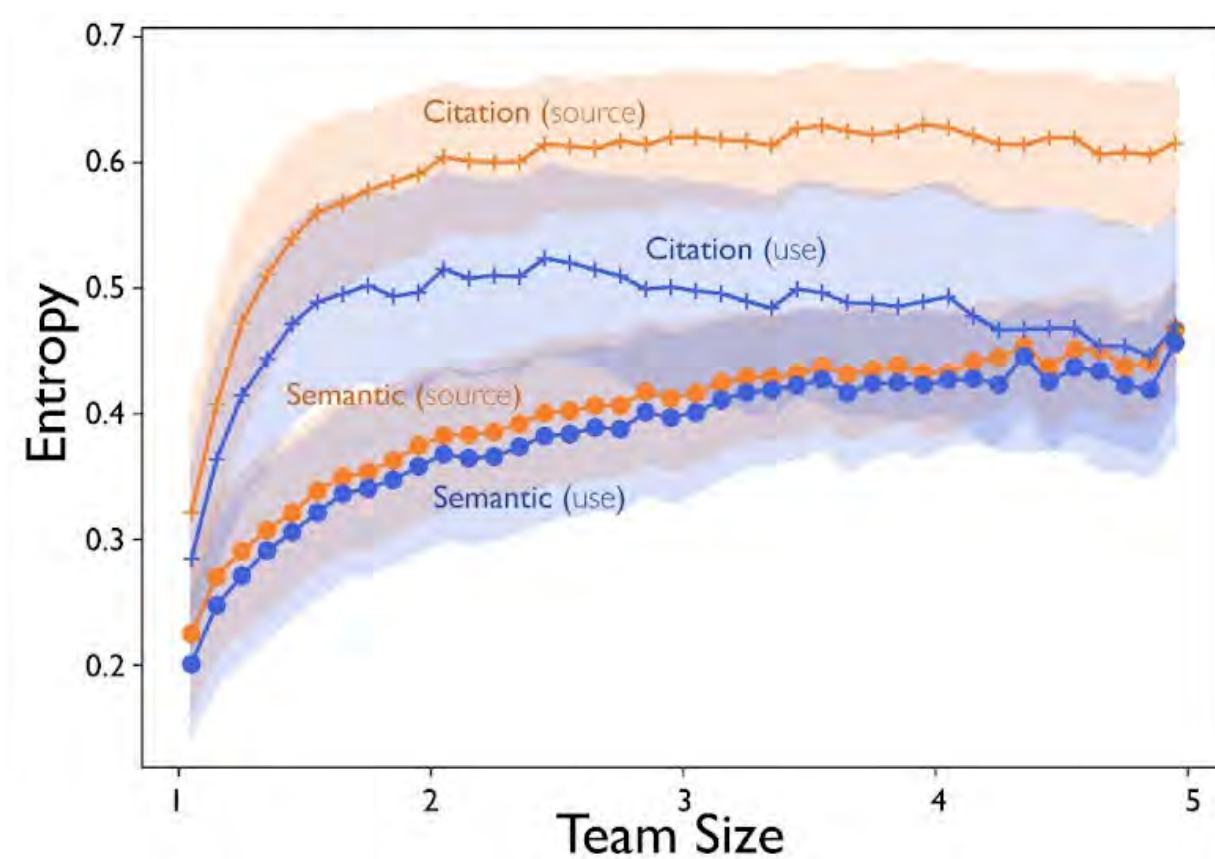
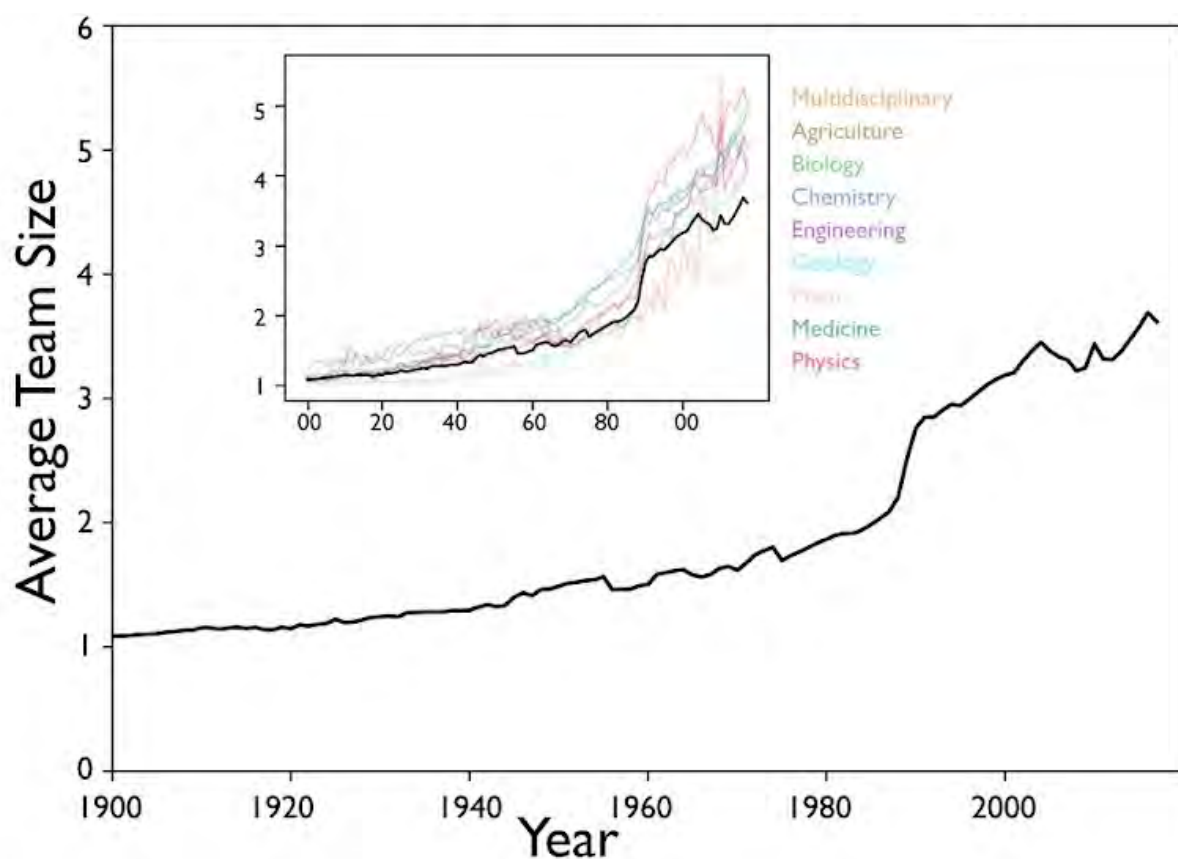
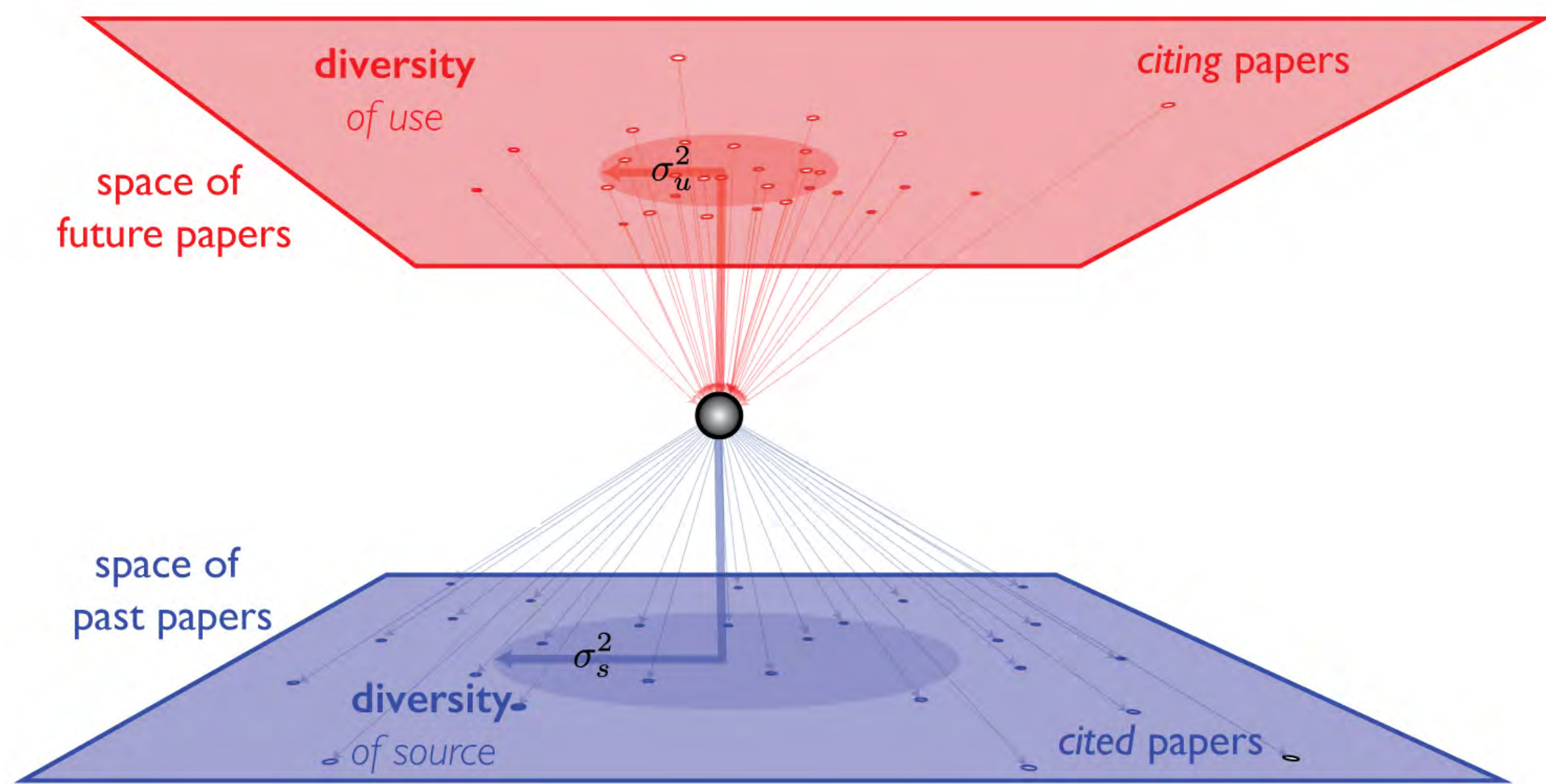
same **city** €
\ same institution

same **country** €
\ same city

same **world** €
\ same country



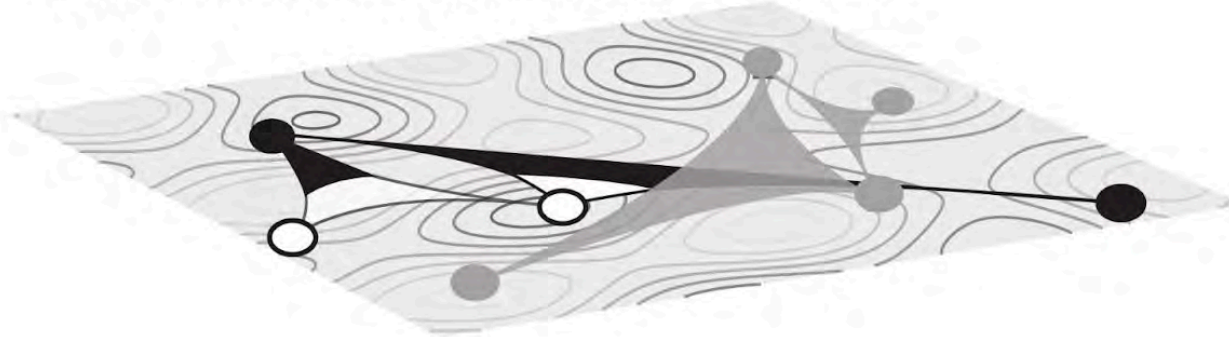
Broad reach of *modern* science



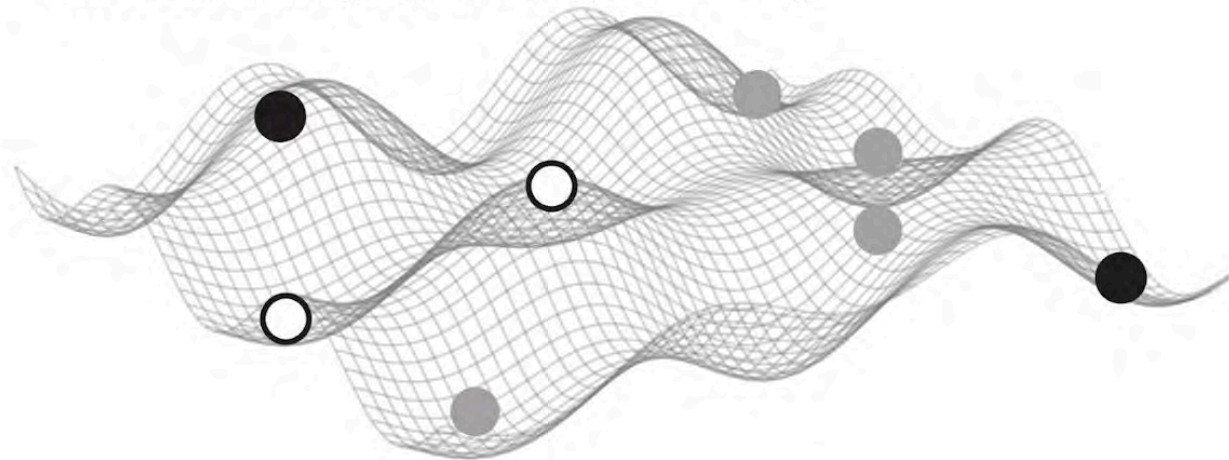
Venture-funded

Start-Ups

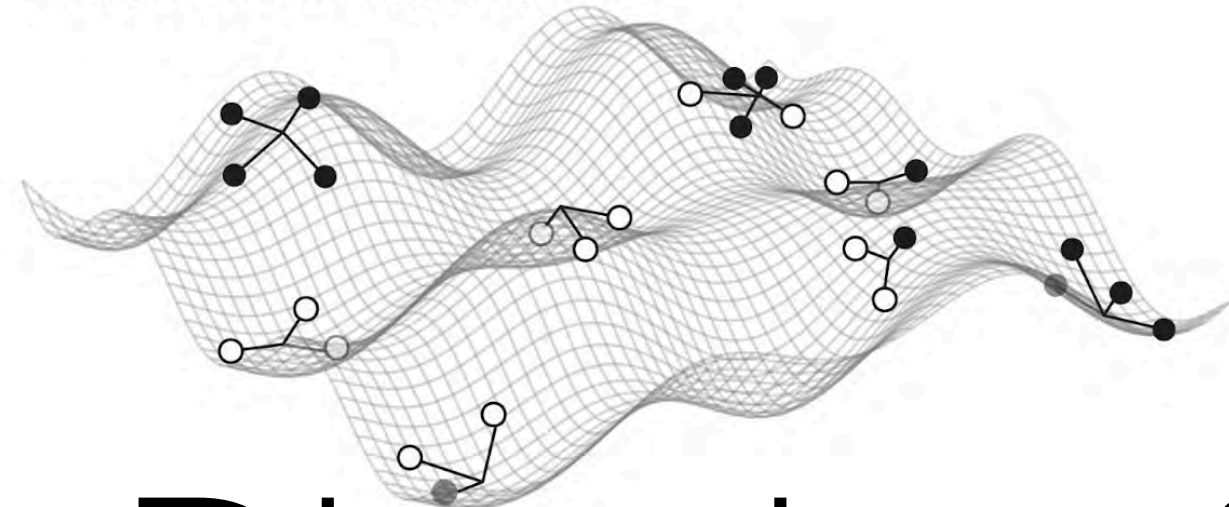
Companies: First-Order Invention, Second-Order Invention



Clusters: Technology, Application, Applied Technology



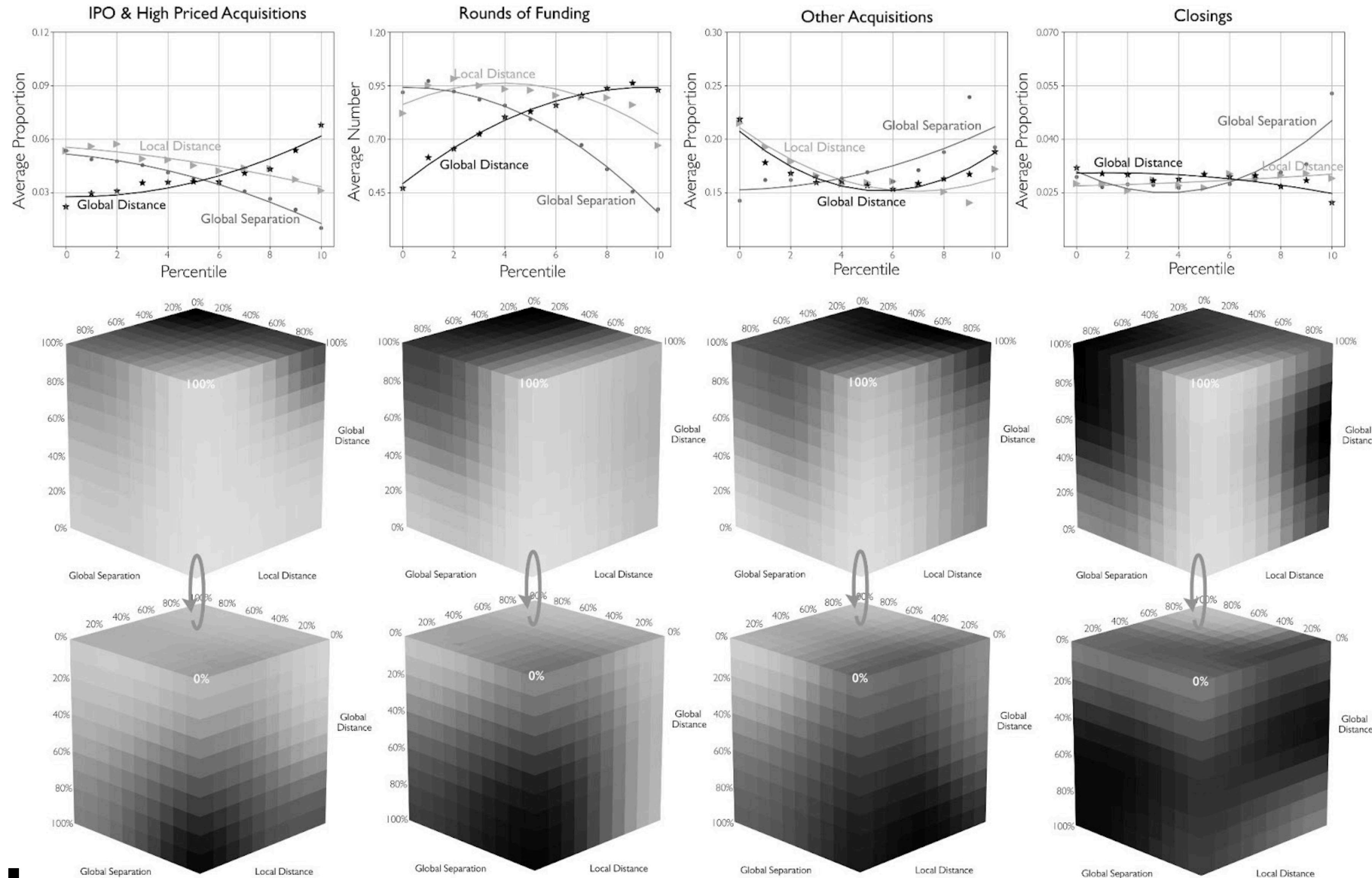
Components: Technologies, Applications



Diversity of

Applied Tech.

Innovation Strategies and Performance Outcomes



rapid invention

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Barack Obama

From Wikipedia, the free encyclopedia

"Barack" and "Obama" redirect here. For other uses, see *Barack (disambiguation)* and *Obama (disambiguation)*.

Barack Hussein Obama II
 (/bəˈrɑːk huːˈseɪn oʊˈbɑːmə/ (ⓘ listen))^[1] born August 4, 1961) is an American politician who served as the 44th President of the United States from 2009 to 2017. The first African American to assume the presidency, he previously was the junior United States Senator from Illinois from 2005 to 2008. He also served in the Illinois State Senate from 1997 until 2004.

Obama was born in 1961 in Honolulu, Hawaii, two years after the territory was admitted to the Union as the 50th state. Raised largely in Hawaii, Obama also spent one year of his childhood in Washington State and four years in Indonesia. After graduating from Columbia University in New York City in 1983, he worked as a community organizer in Chicago. In 1988 Obama enrolled in Harvard Law School, where he was the first black president of the Harvard Law Review. After graduation, he became a civil rights attorney and professor, and taught constitutional law at the University of Chicago Law School from 1992 to 2004. Obama represented the 13th District for three terms in the Illinois Senate from 1997 to 2004, when he ran for the U.S. Senate. Obama received national attention in 2004 with his unexpected March primary win, his well-received July Democratic National Convention keynote address, and his landslide November election to the Senate. In 2008, Obama was nominated for president a year after his campaign began and after a close primary campaign

Barack Obama
 44th President of the United States
 In office January 20, 2009 – January 20, 2021
 Vice President Joe Biden
 Preceded by George W. Bush
 Succeeded by Donald Trump
 United States Senator from Illinois
 In office January 3, 2005 – November 16, 2008
 Preceded by Peter Fitzgerald
 Succeeded by Roland Burris
 Member of the Illinois Senate from the 13th district

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Ronald Reagan

From Wikipedia, the free encyclopedia

"Reagan" redirects here. For other uses, see *Reagan (disambiguation)* and *Ronald Reagan (disambiguation)*.

Ronald Wilson Reagan (/rˈreɪɡən/; February 6, 1911 – June 5, 2004) was an American politician and actor who served as the 40th President of the United States from 1981 to 1989. Prior to the presidency, he had a long and distinguished three-decade career as a Hollywood actor and union leader before serving as the 33rd Governor of California from 1967 to 1975.

Reagan was raised in a poor family in small towns of northern Illinois. He graduated from Eureka College in 1932 and worked as a sports announcer on several regional radio stations. After moving to Hollywood in 1937, he became an actor and starred in a few major productions. Reagan was twice elected President of the Screen Actors Guild—the labor union for actors—where he worked to root out Communist influence. In the 1950s, he moved into television and was a motivational speaker at General Electric factories.^[1] Reagan had always been a Democrat until 1962, when he became a conservative and switched to the Republican Party. In 1964, Reagan's speech, "A Time for Choosing", supported Barry Goldwater's founding presidential campaign and earned him national attention as a new conservative spokesman. Building a network of supporters, he was elected Governor of California in 1966. As governor, Reagan raised taxes, turned a state budget deficit to a surplus, challenged the protesters at the University of California, ordered in National Guard troops during a period of protest movements in 1969, and was re-elected in 1970. He twice ran unsuccessfully for the

Ronald Reagan
 40th President of the United States
 In office January 20, 1981 – January 20, 1989
 Vice President George H. W. Bush
 Preceded by Jimmy Carter
 Succeeded by George H. W. Bush
 33rd Governor of California
 In office January 2, 1967 – January 6, 1975
 Lieutenant Robert Finch
 Edwin Reinecke
 John L. Harmer
 Preceded by Pat Brown
 Succeeded by Jerry Brown



153

4

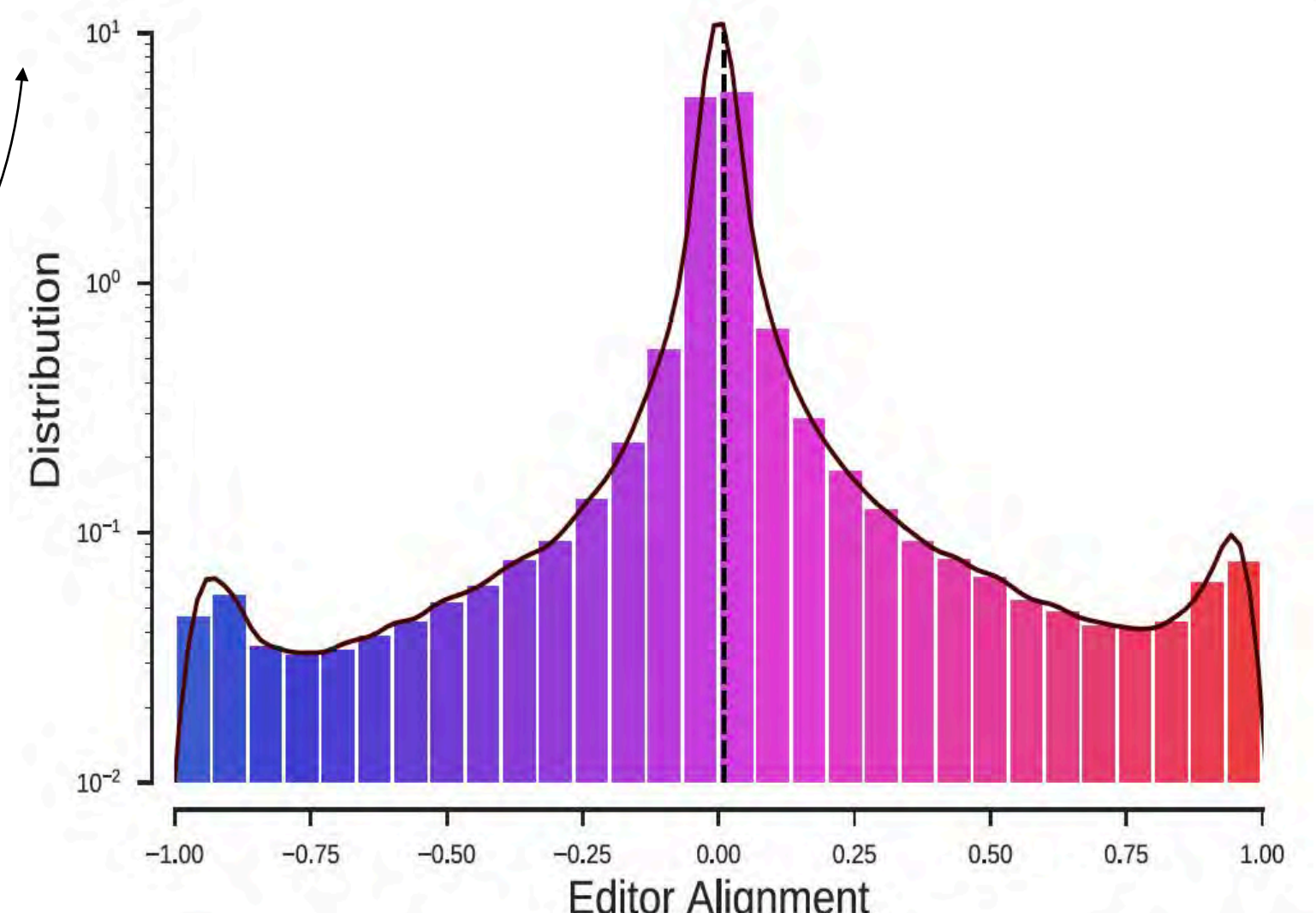
prior
update
posterior

$$P(p) = \text{Beta}(a, b)$$

$$p|X \sim \text{Beta}(a + X, b + K - X)$$

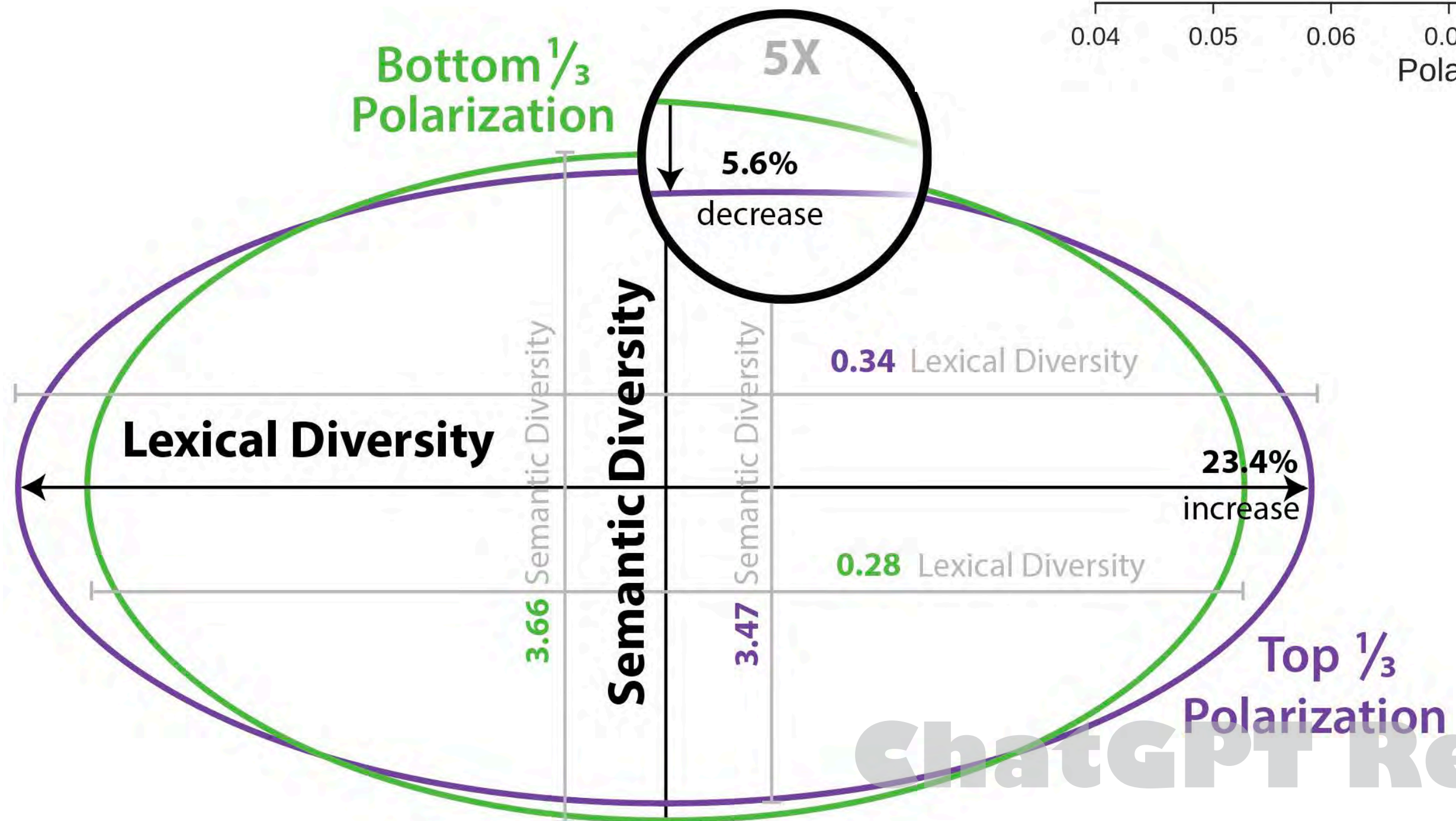
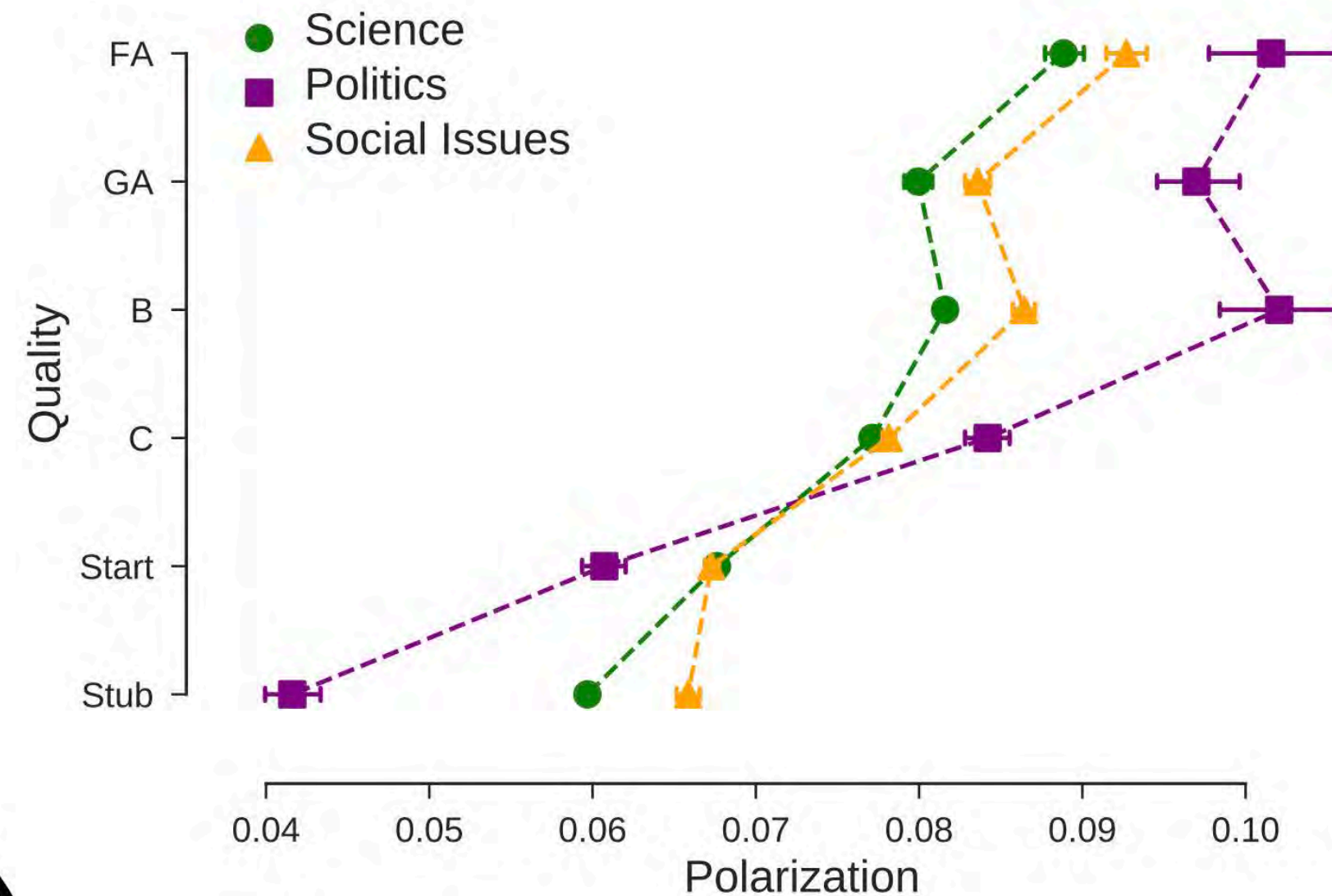
$$E[p|X] = (X + a)/(K + a + b)$$

X = bytes to conservative pages; K = bytes to political pages

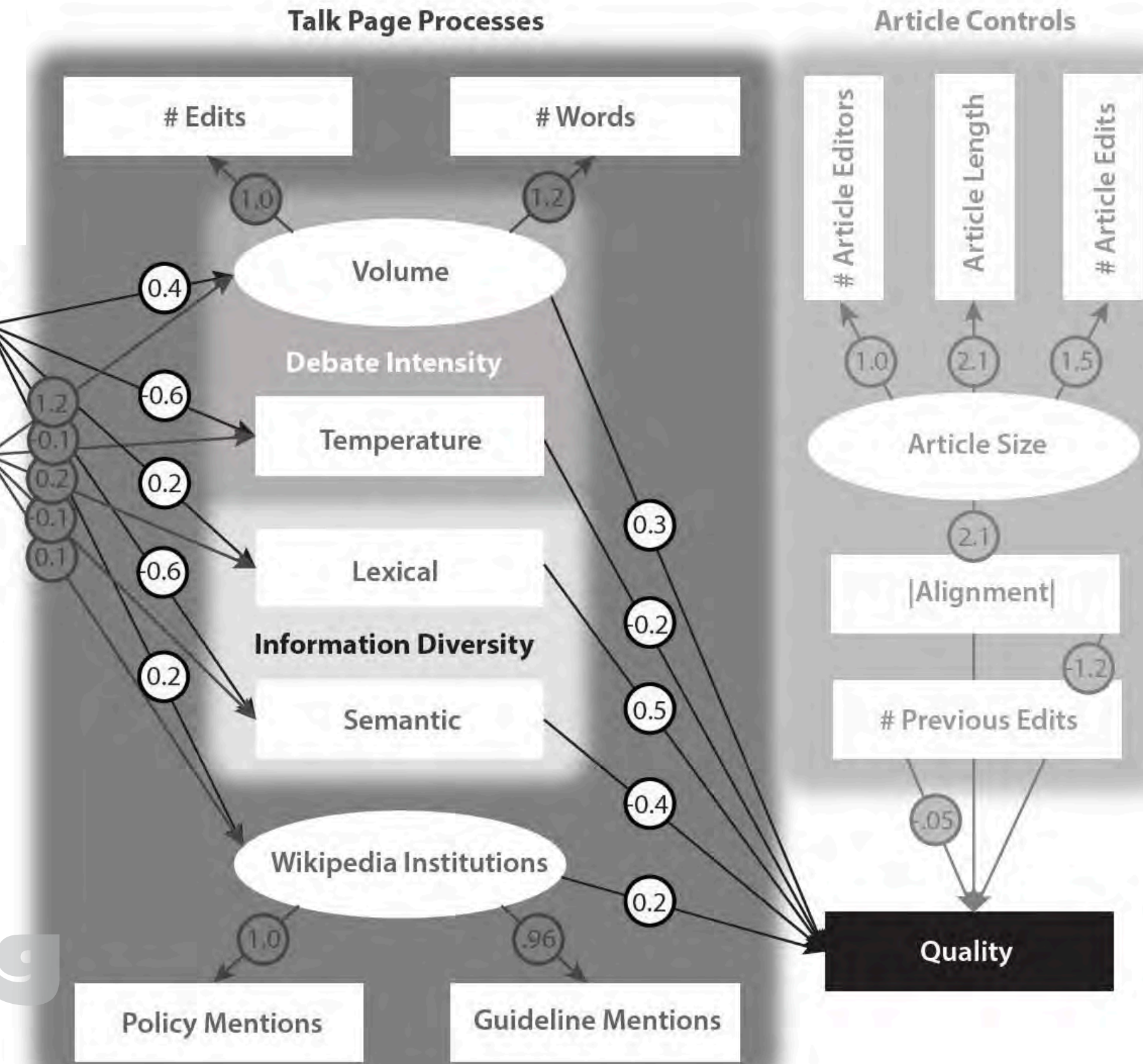


Improvement Through Polarized Reconnection

Encyclopedic Monopoly



Political Polarization
Editors



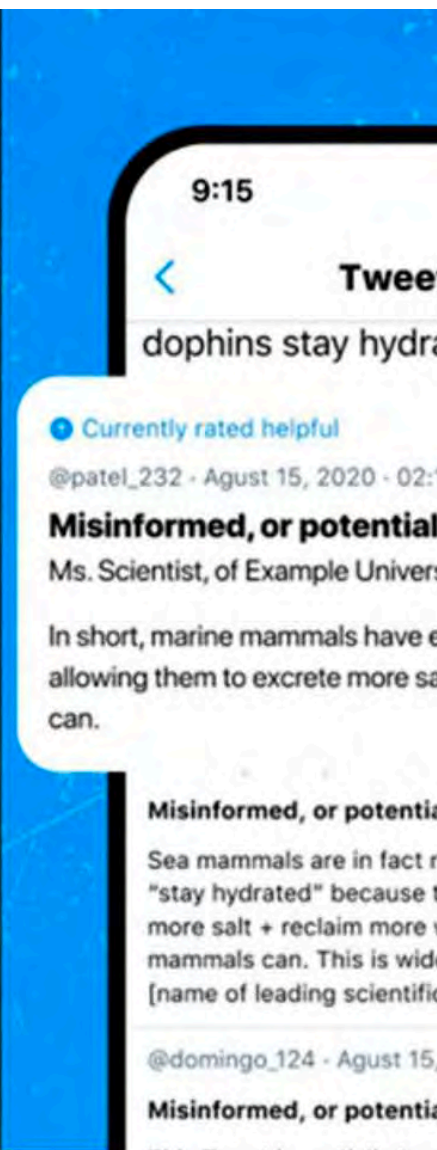
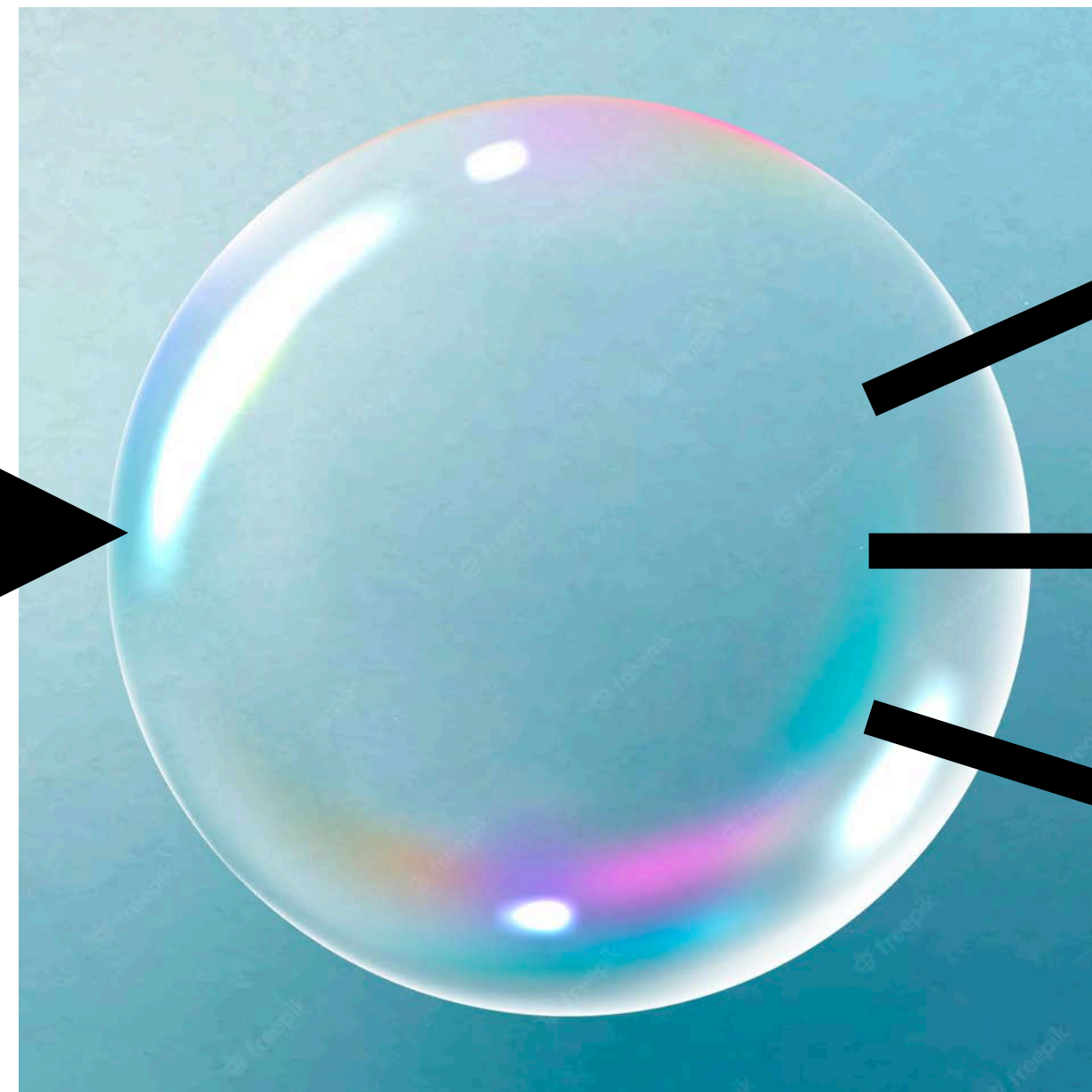
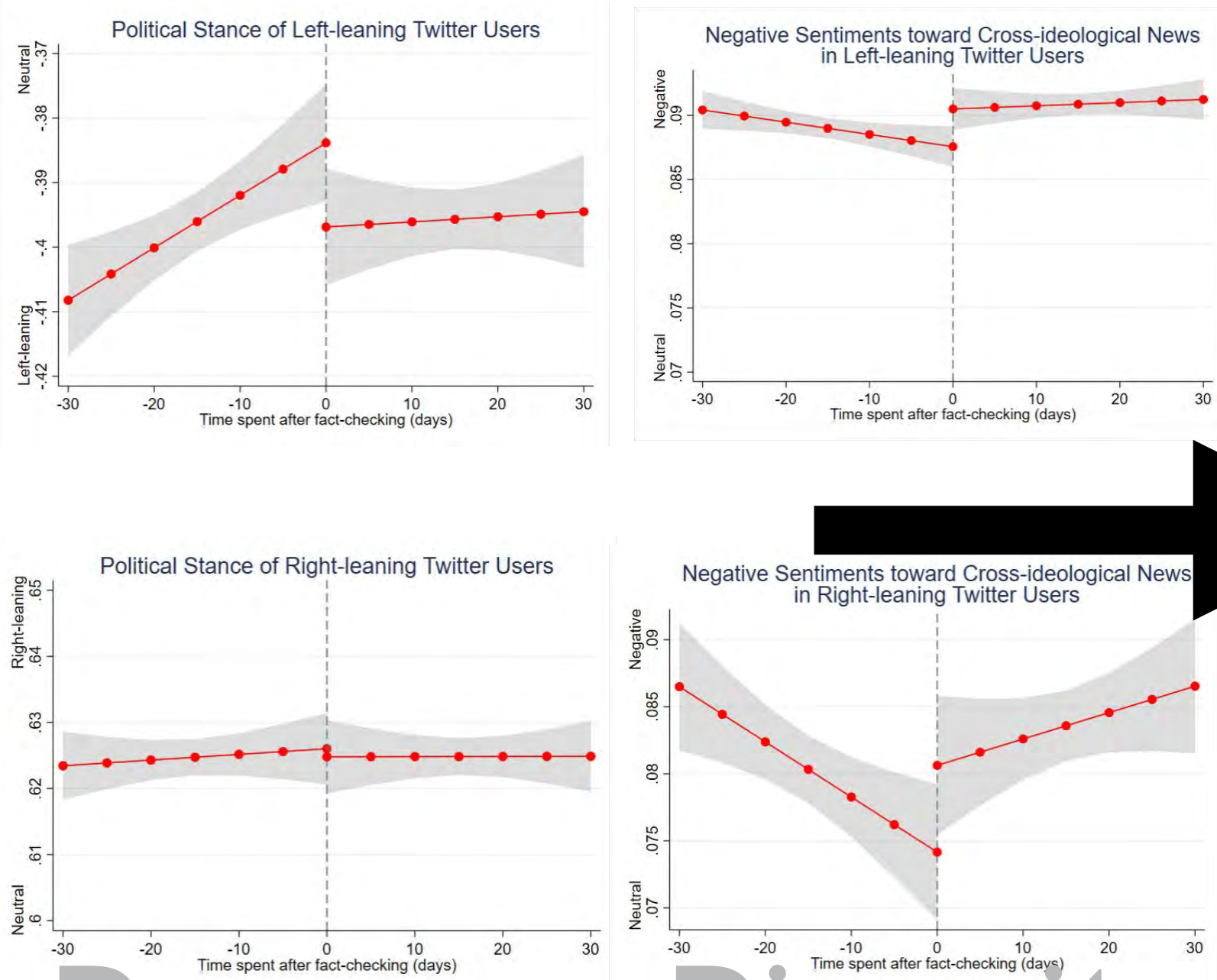
ChatGPT Recruiting Experiment

Misinformation & Fact-Checking



Vigilante Diversity

Balanced, Curated Diversity

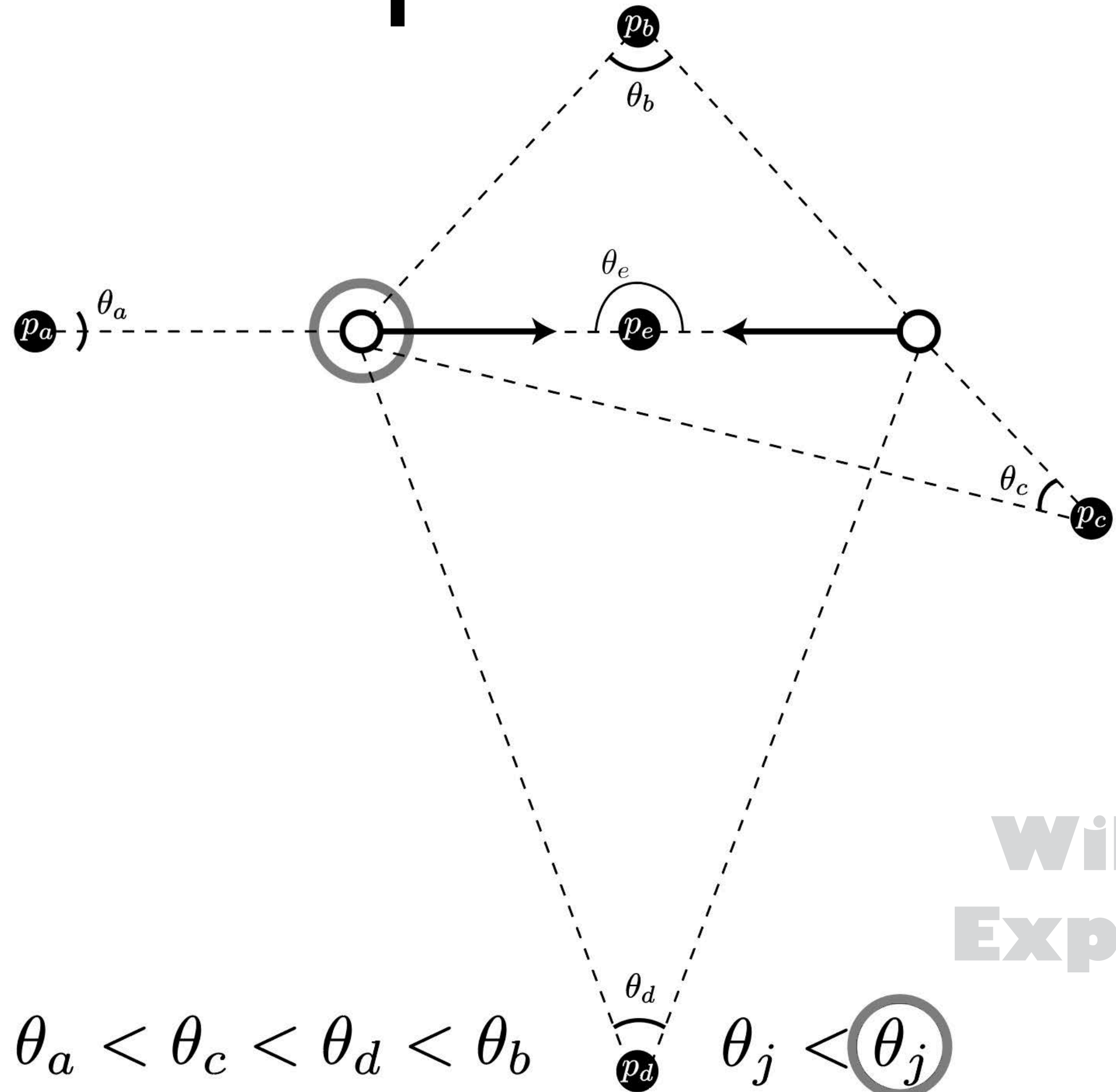


Welcome to Birdwatch

Decreases Diversity

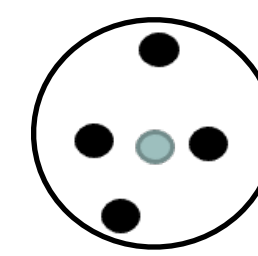
Increases Diversity

Diversity of Perspectives

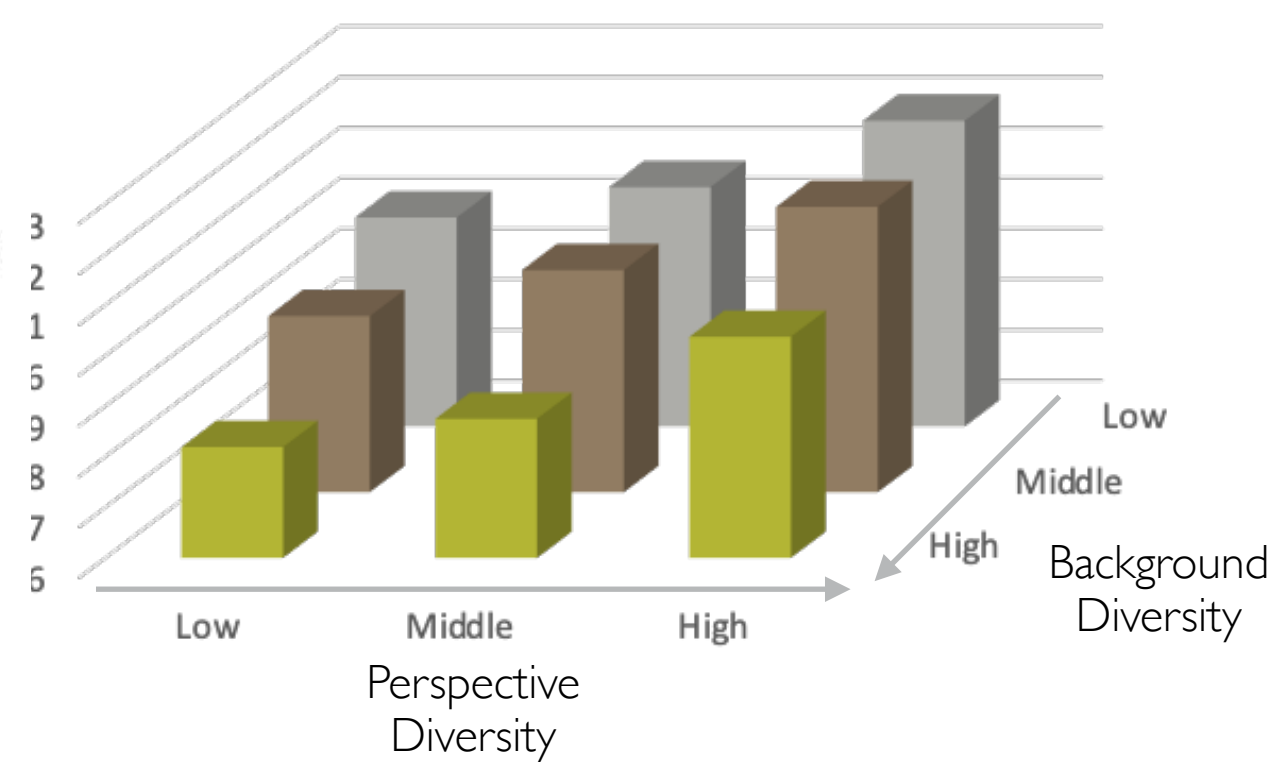


Perspective Diversity

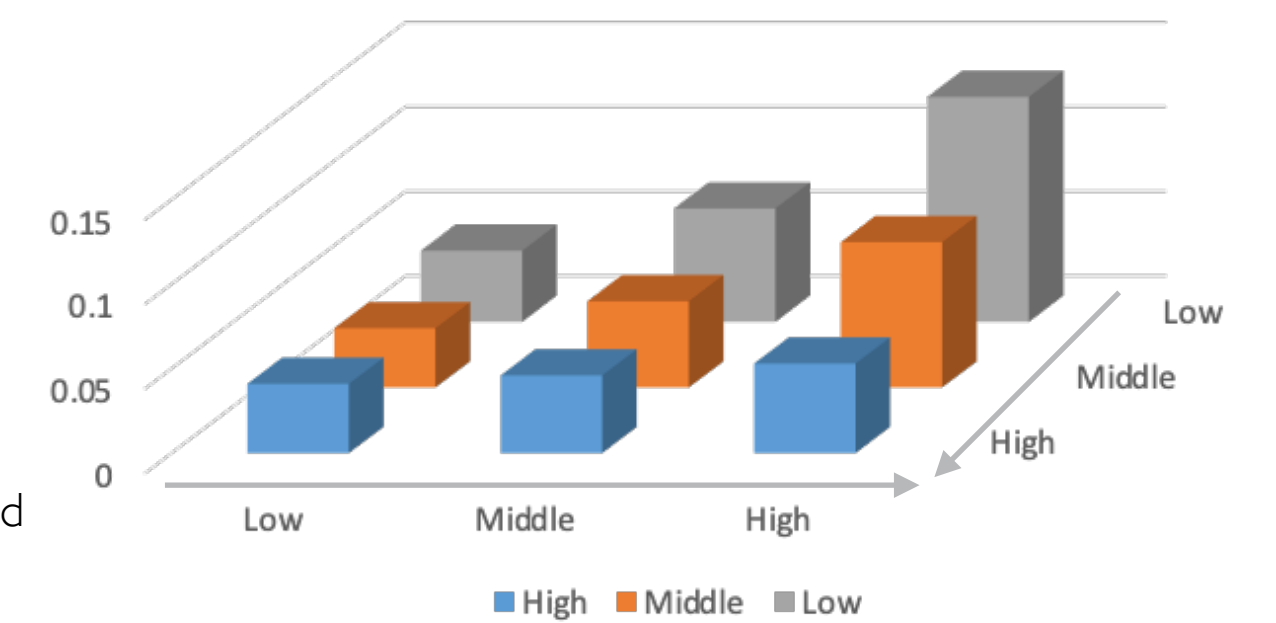
Background Diversity



Average Rating for Movies with Writer Collaborations



Average Probability of Achieving IPO for New Ventures with Multiple VCs



Wikipedia Experiment

Optimal

Diversity

Danish Experiment



Across innovators, teams, and fields

Dense (Social) Connections

Distort

Collective Certainty

& Slow

Novel Discovery/Invention

nature

THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE

THE ECOLOGY OF RESEARCH

Small teams disrupt and big teams consolidate to drive progress in science and technology PAGES 330 & 378

EPIDEMIOLOGY

DISEASE CONTROL

Meet Nigeria's prime protector of public health

PAGE 310

PLANETARY SCIENCE

NEPTUNE'S NEW MOON

Discovery of Hippocamp hints at history of impacts

PAGES 328 & 350

NEUROSCIENCE

LEARNING NOT TO FEAR

Neural pathway sheds light on therapy for stress disorder

PAGES 335 & 339

NATURE.COM

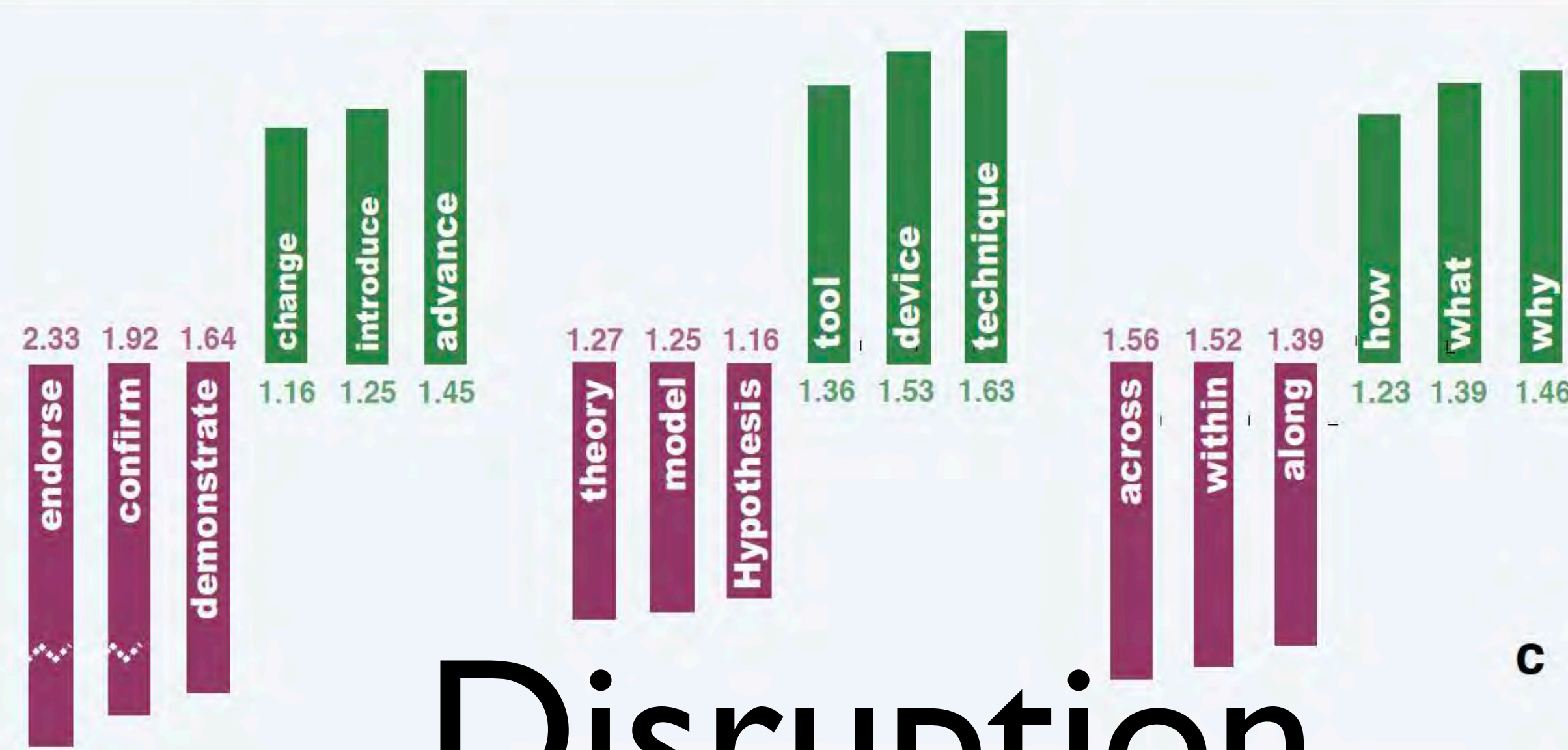
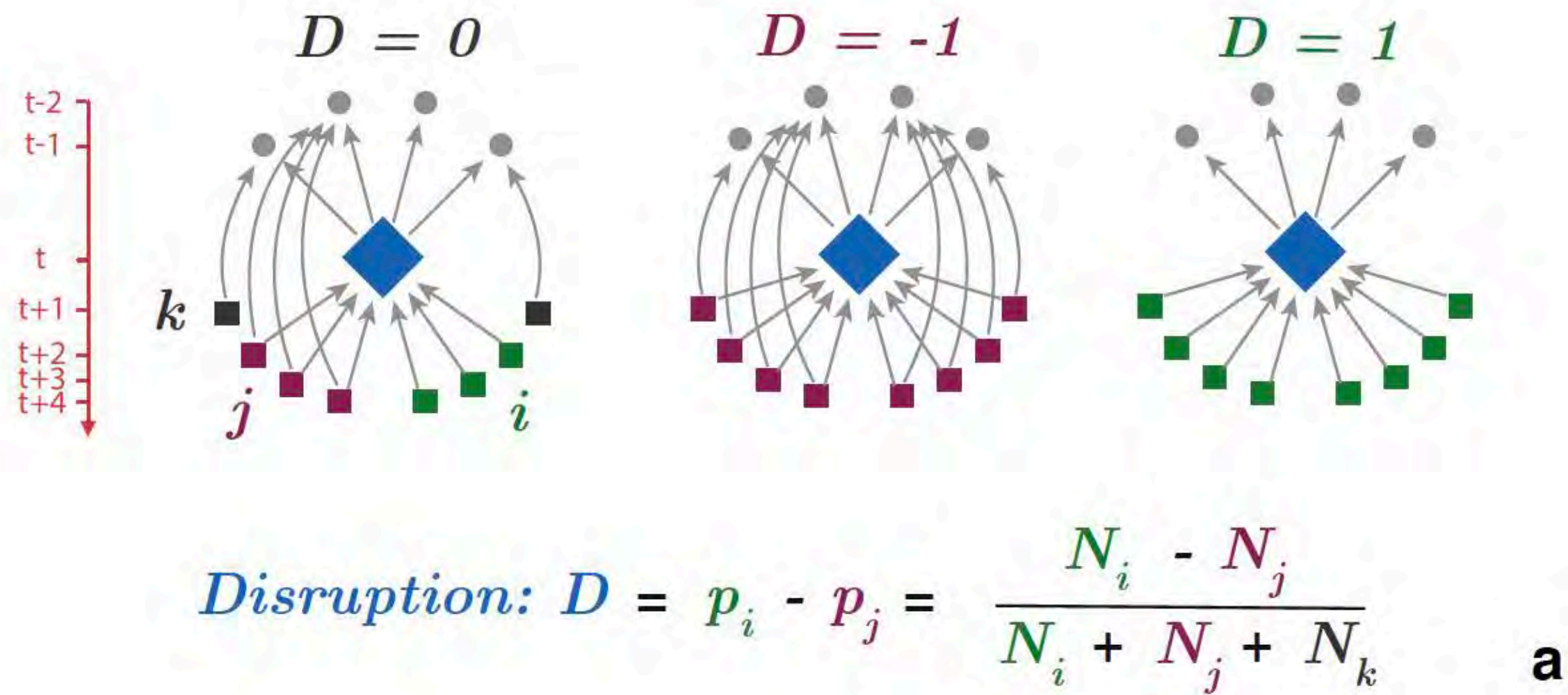
21 February 2019 £10

Vol. 566, No. 7744

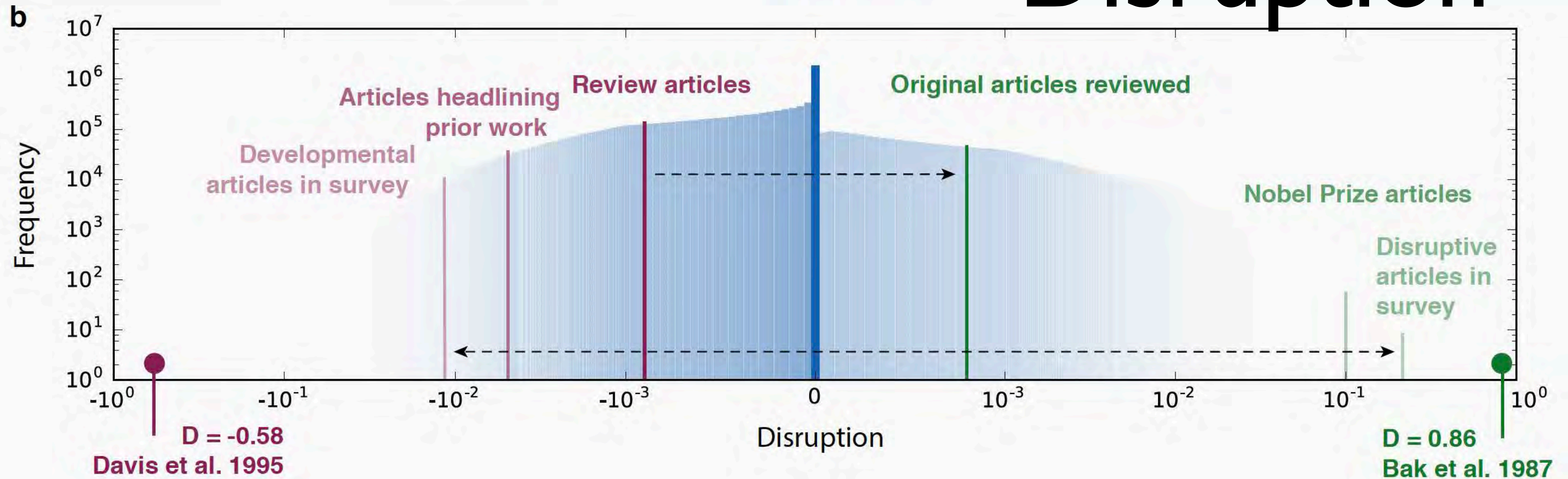


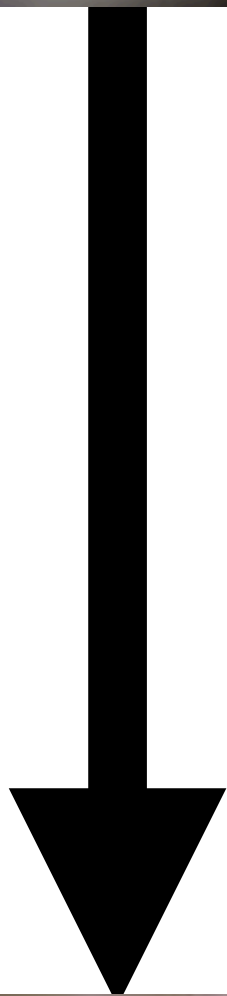
Large, Tall, Smooth Teams
Dampen Disruption

Small, Flat, Sparse Teams
Amplify It

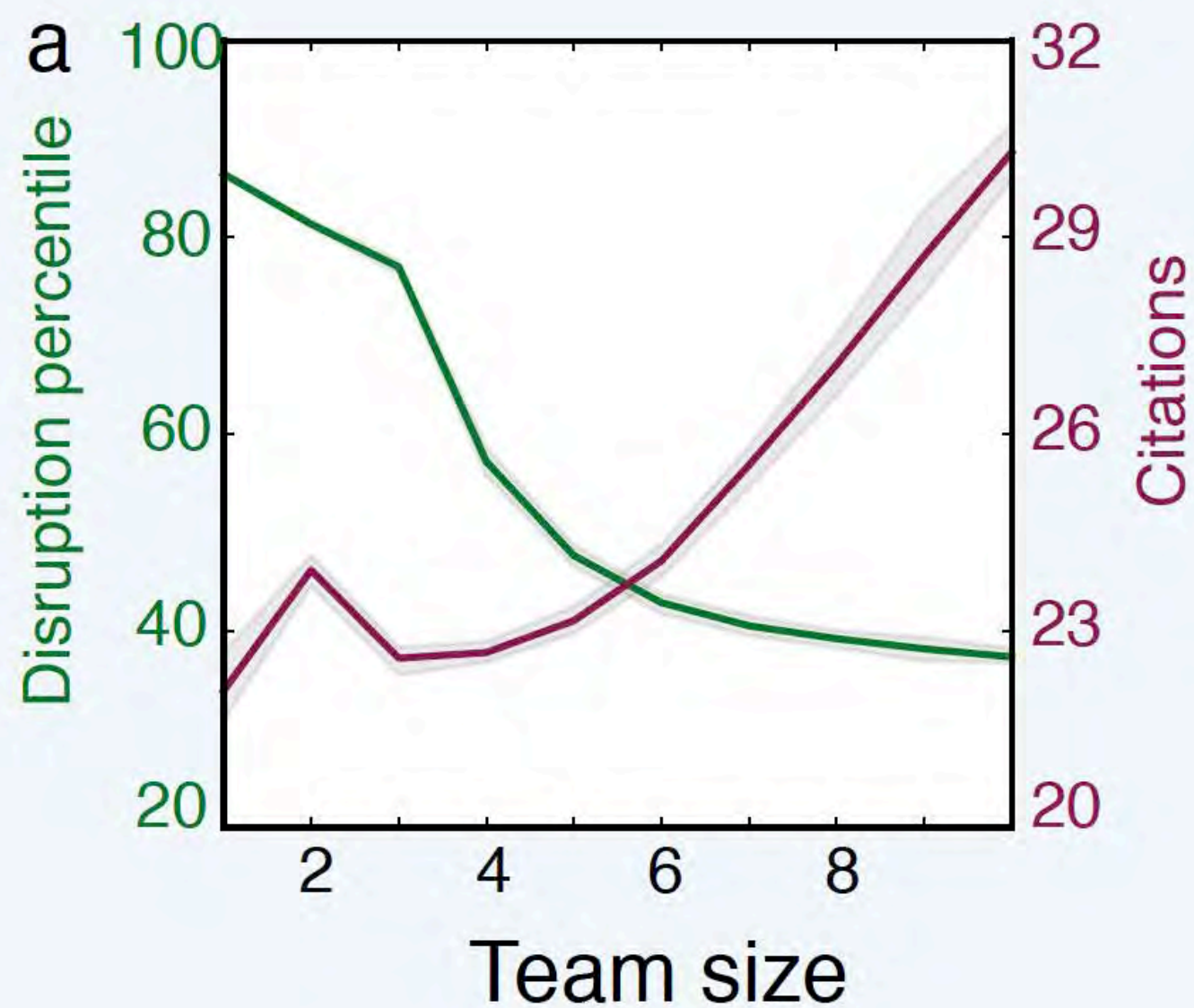


Disruption

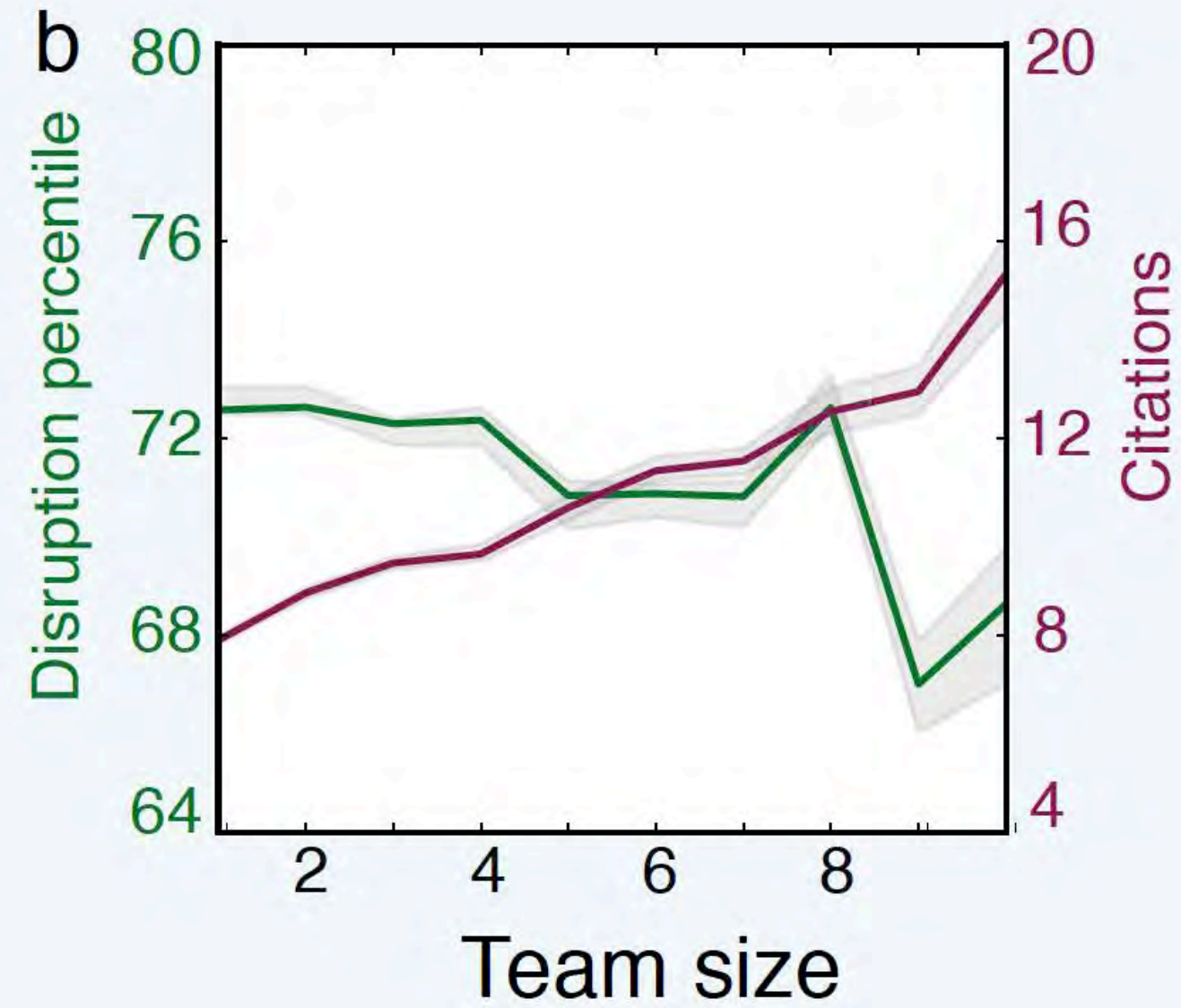




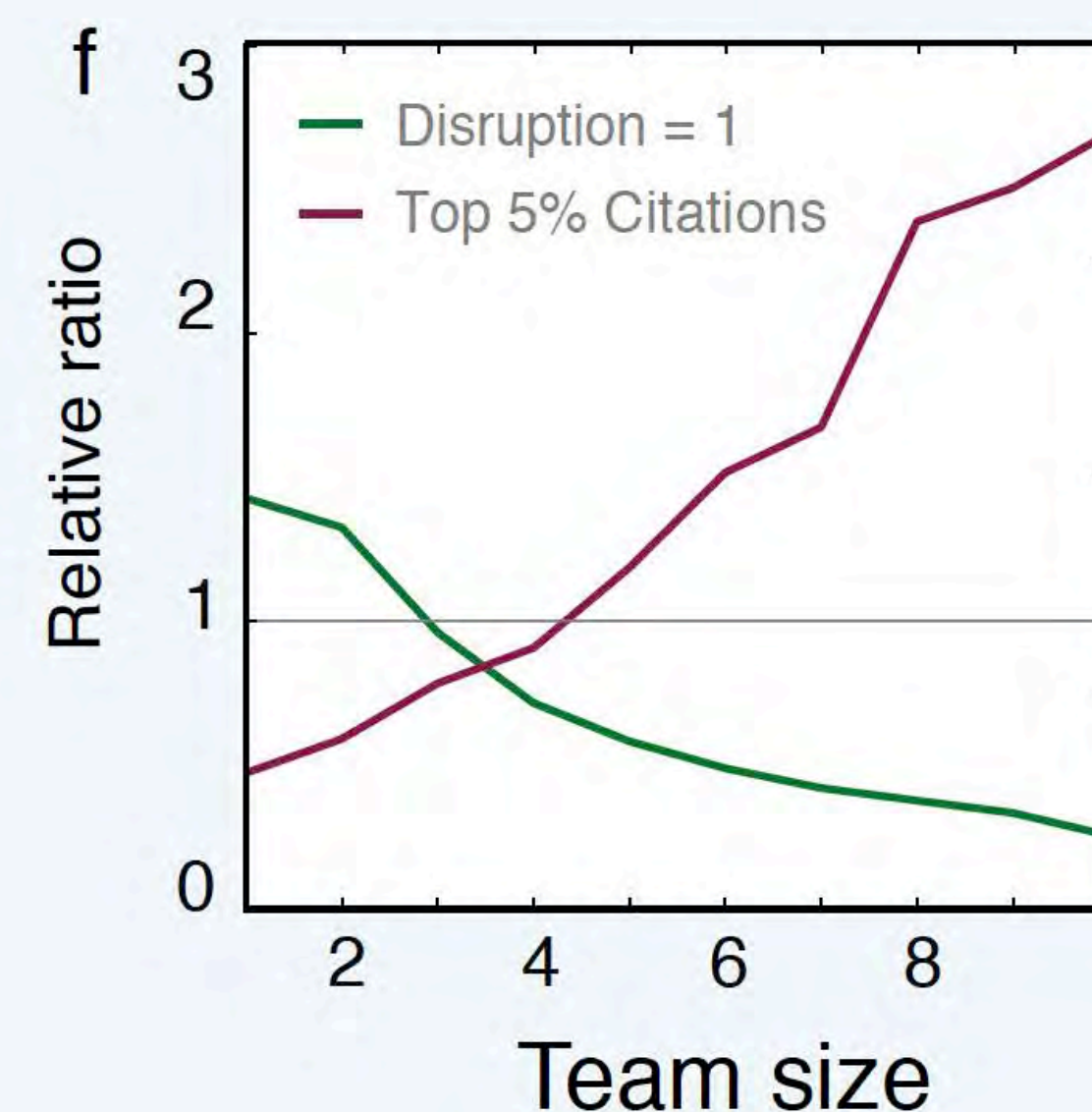
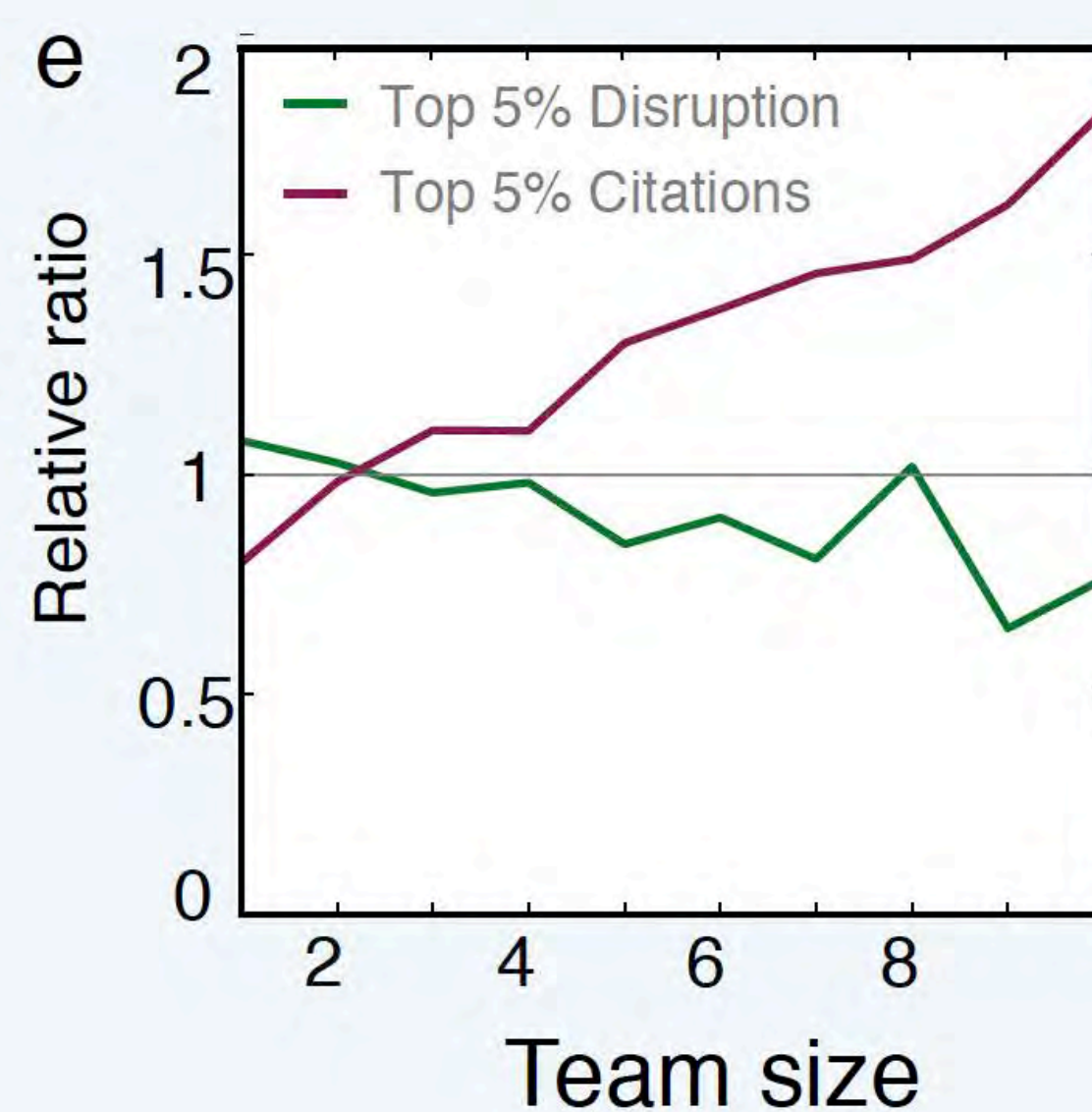
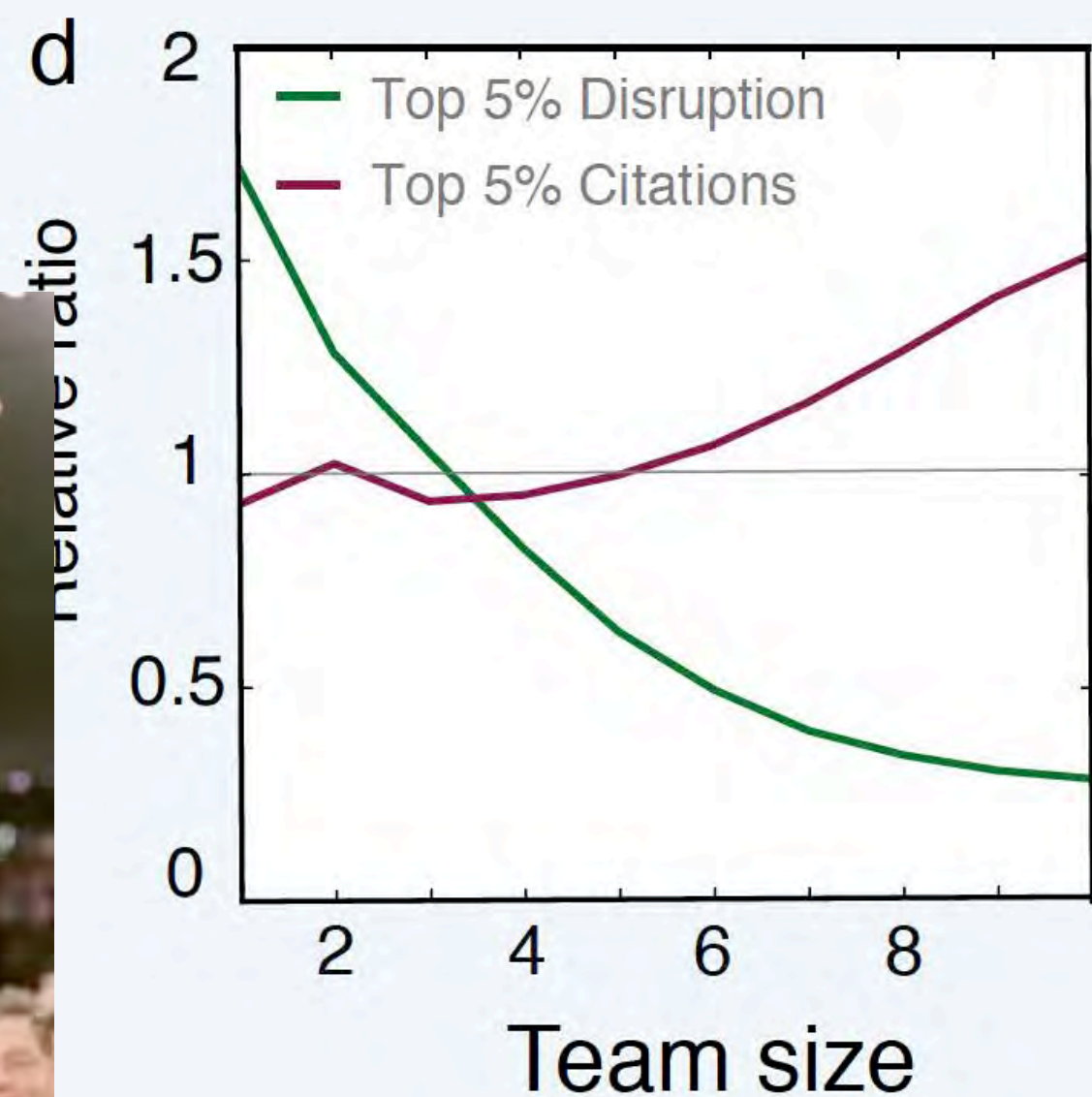
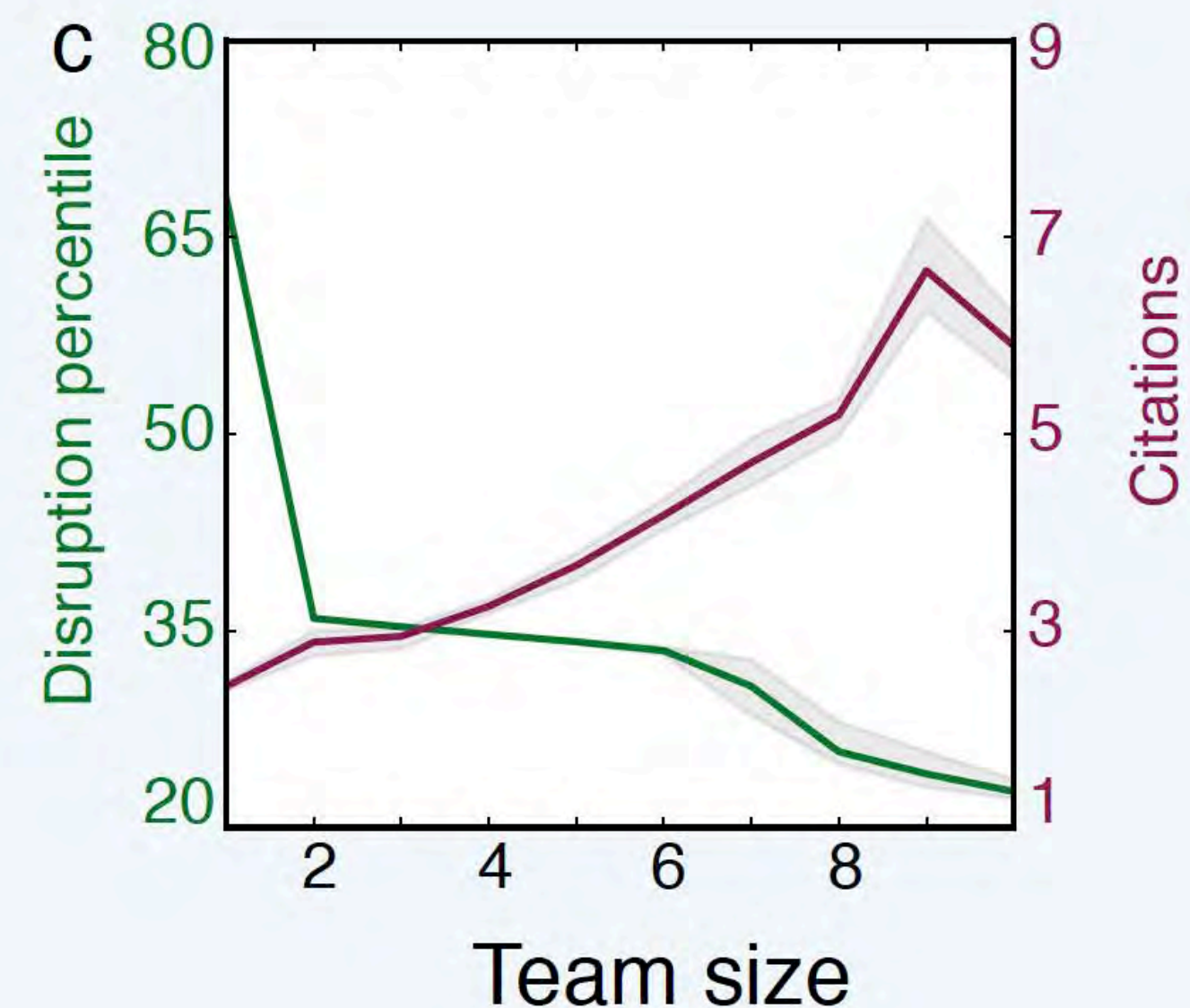
Articles



Patents

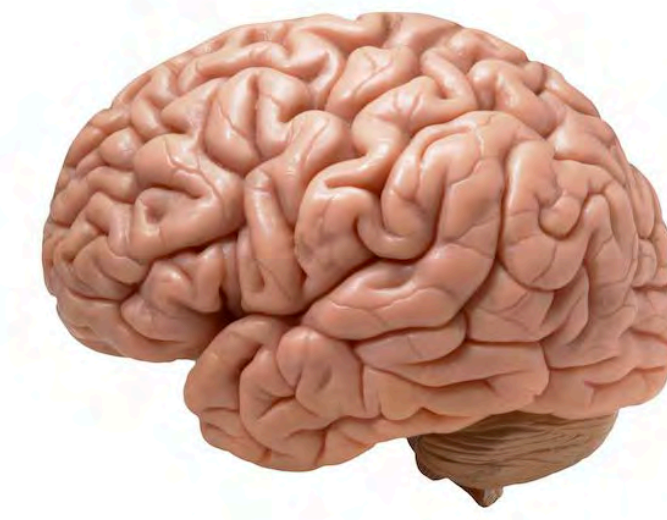


Software

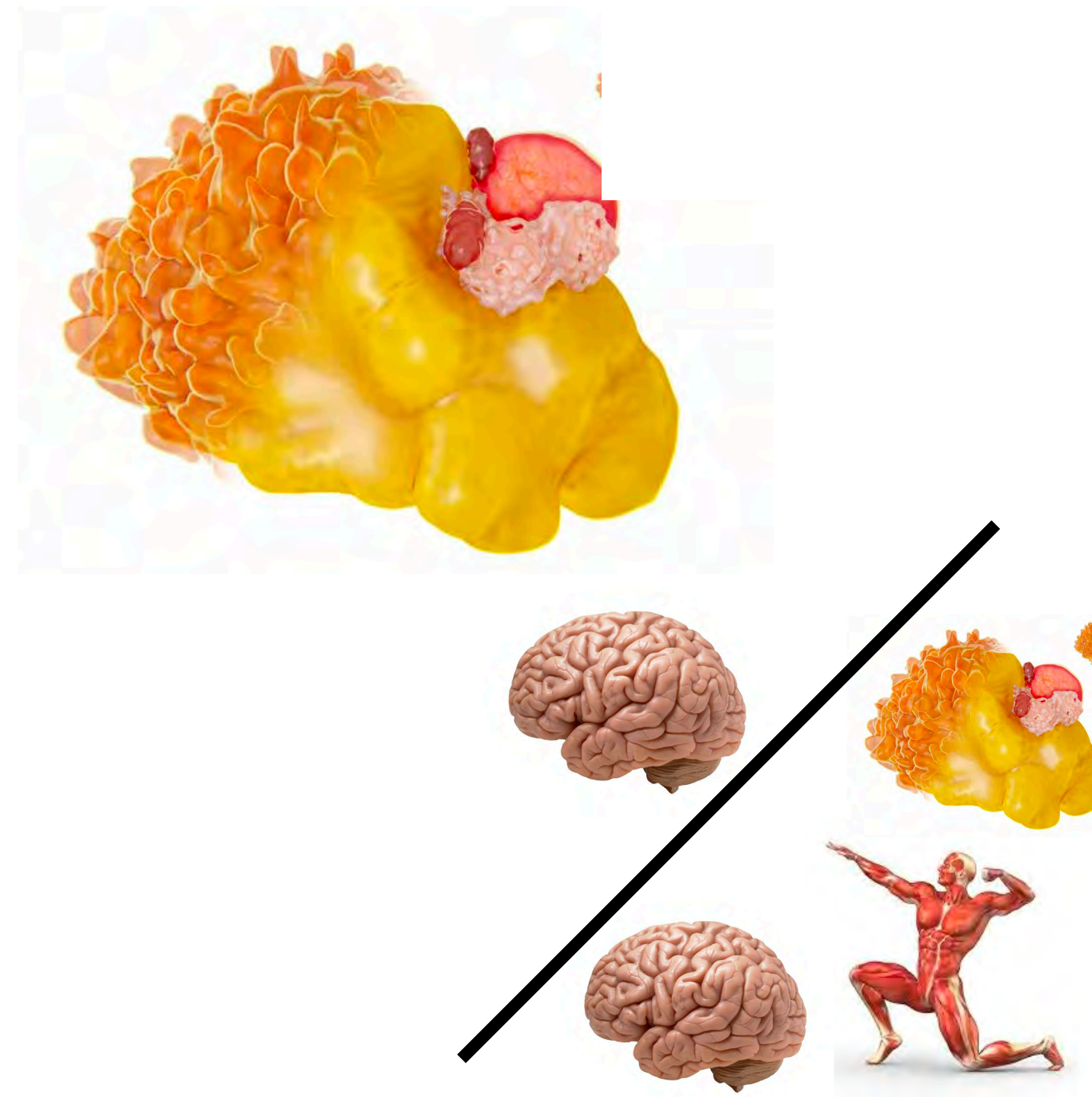
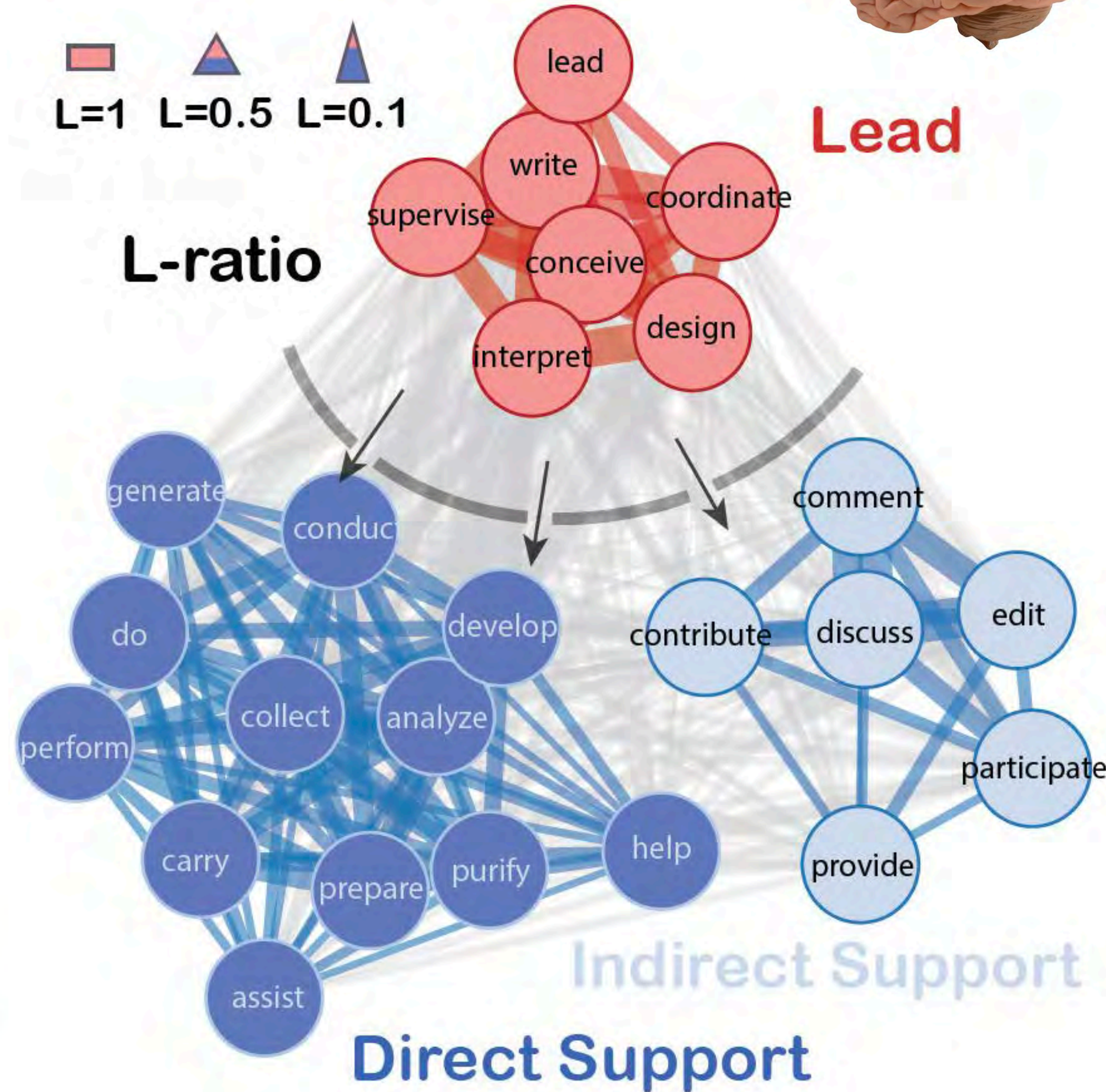


Team Structure

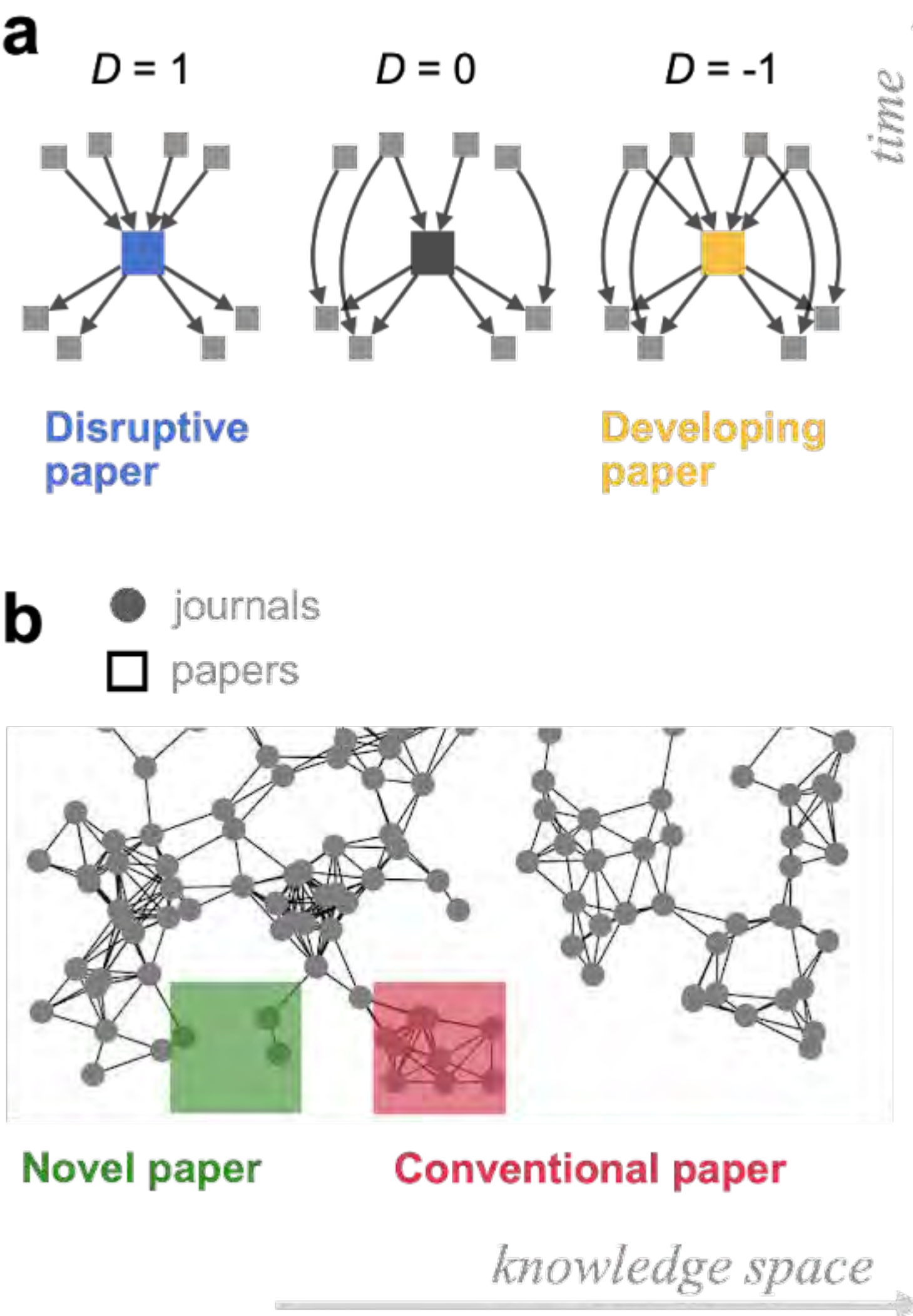
a Team Roles & Hierarchy



■ L=1 ▲ L=0.5 ▲ L=0.1



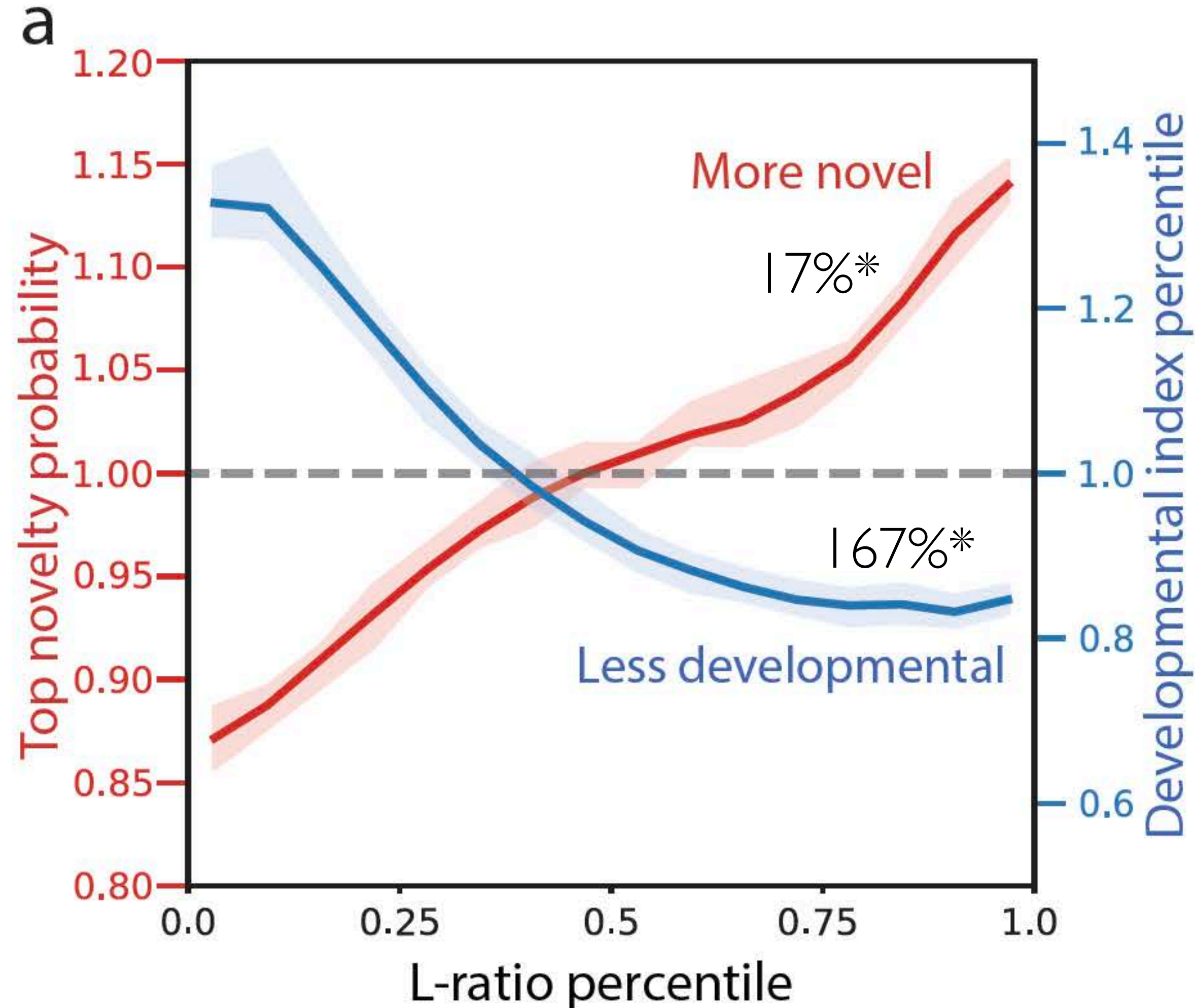
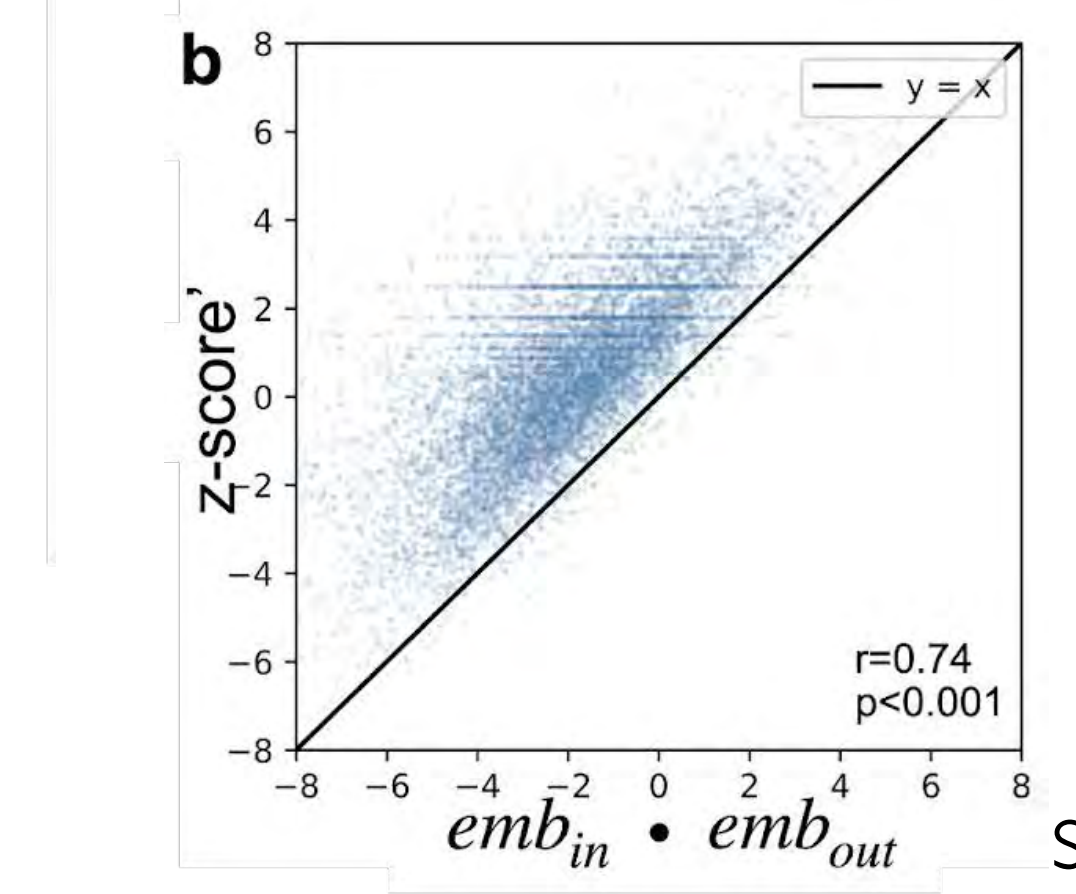
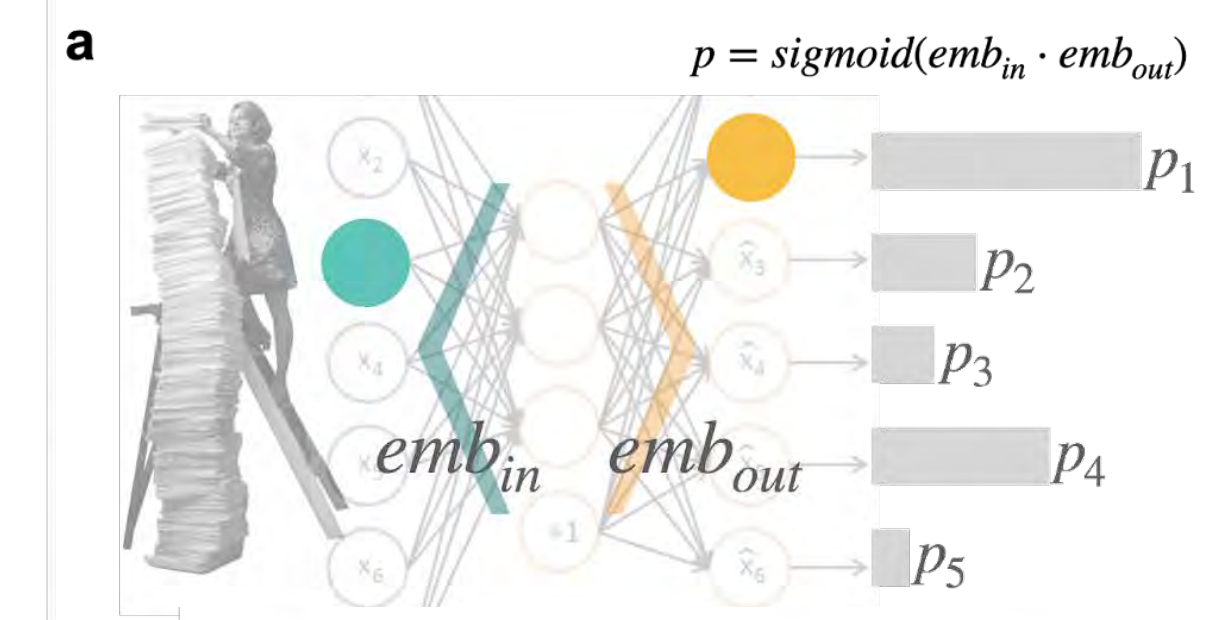
Team Structure Matters for Innovation



Disruption: $D = p_i - p_j = \frac{N_i - N_j}{N_i + N_j + N_k}$

Novelty: $z_{ij} = \frac{obs_{ij} - exp_{ij}}{\sigma_{ij}}$ MCMC

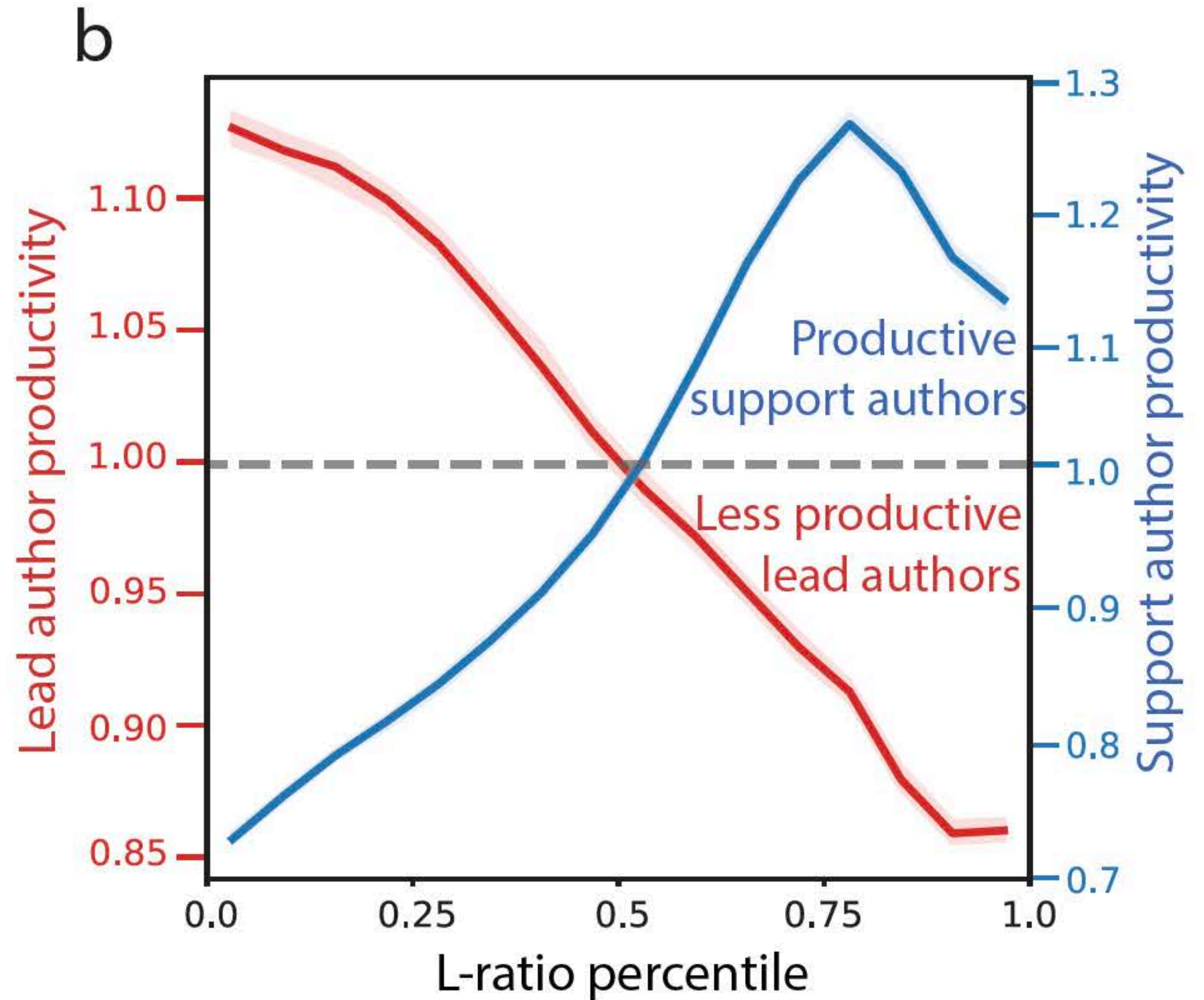
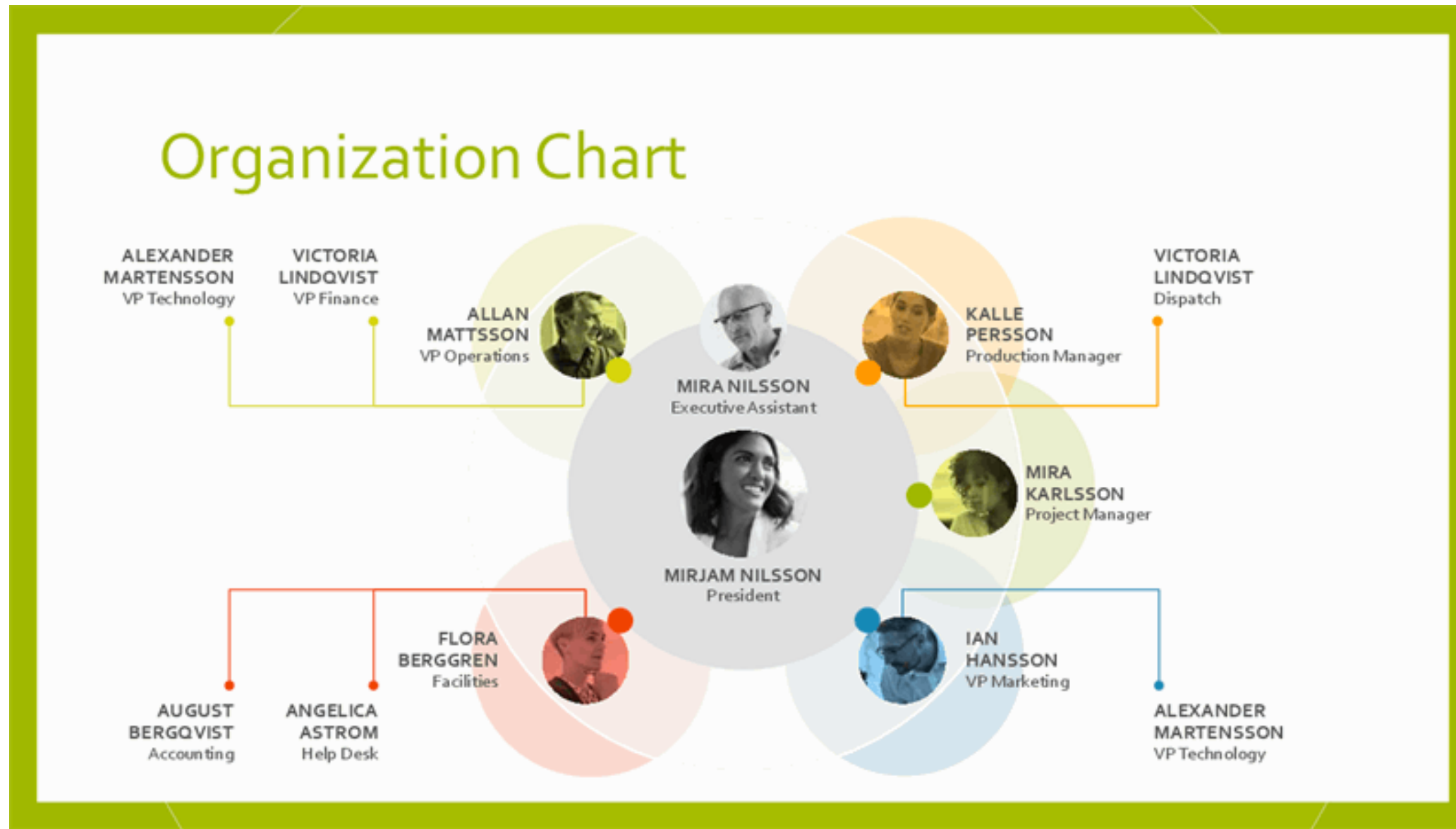
Pointwise mutual information (PMI) between two items = inner product of two vectors representing items within a latent semantic space



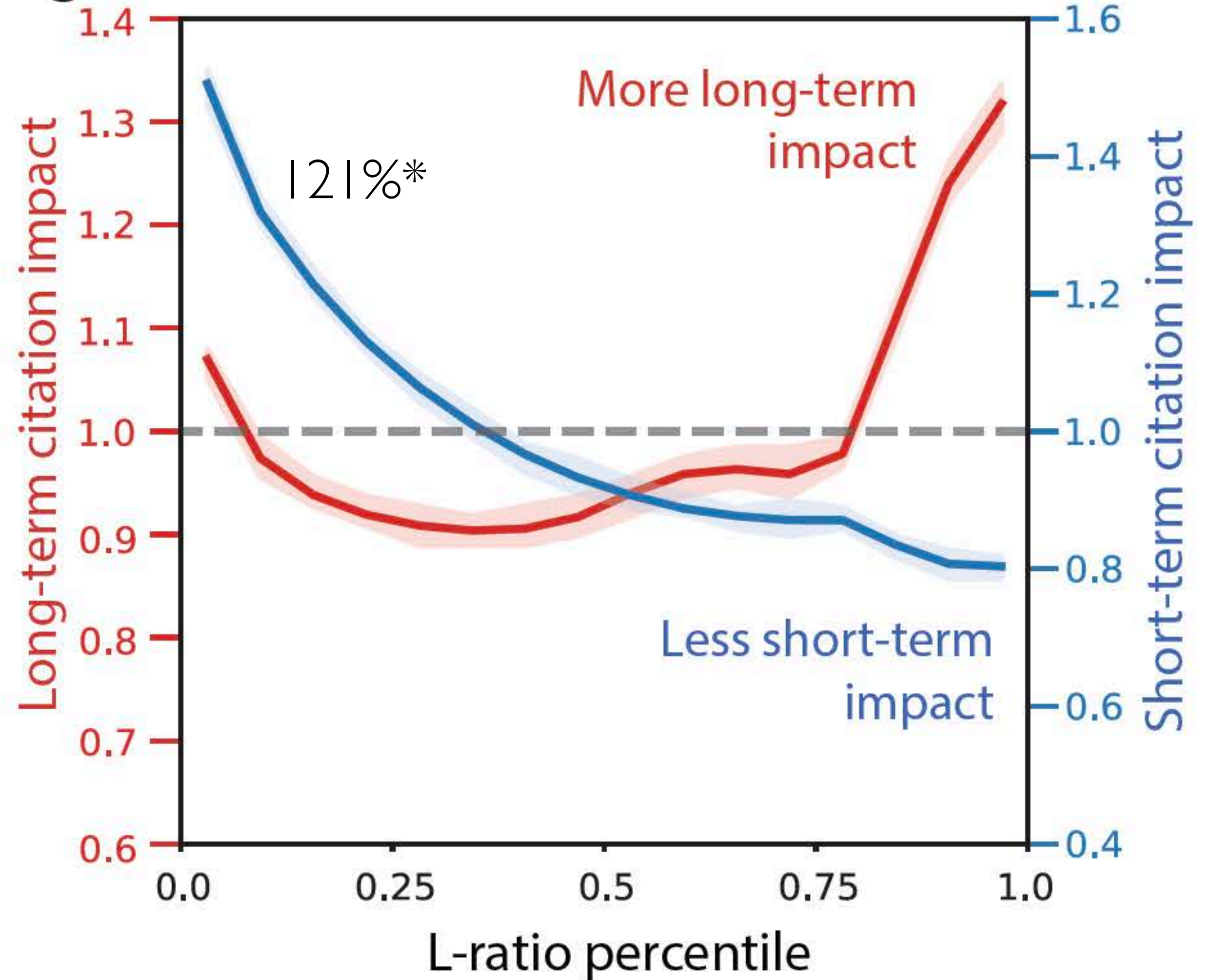
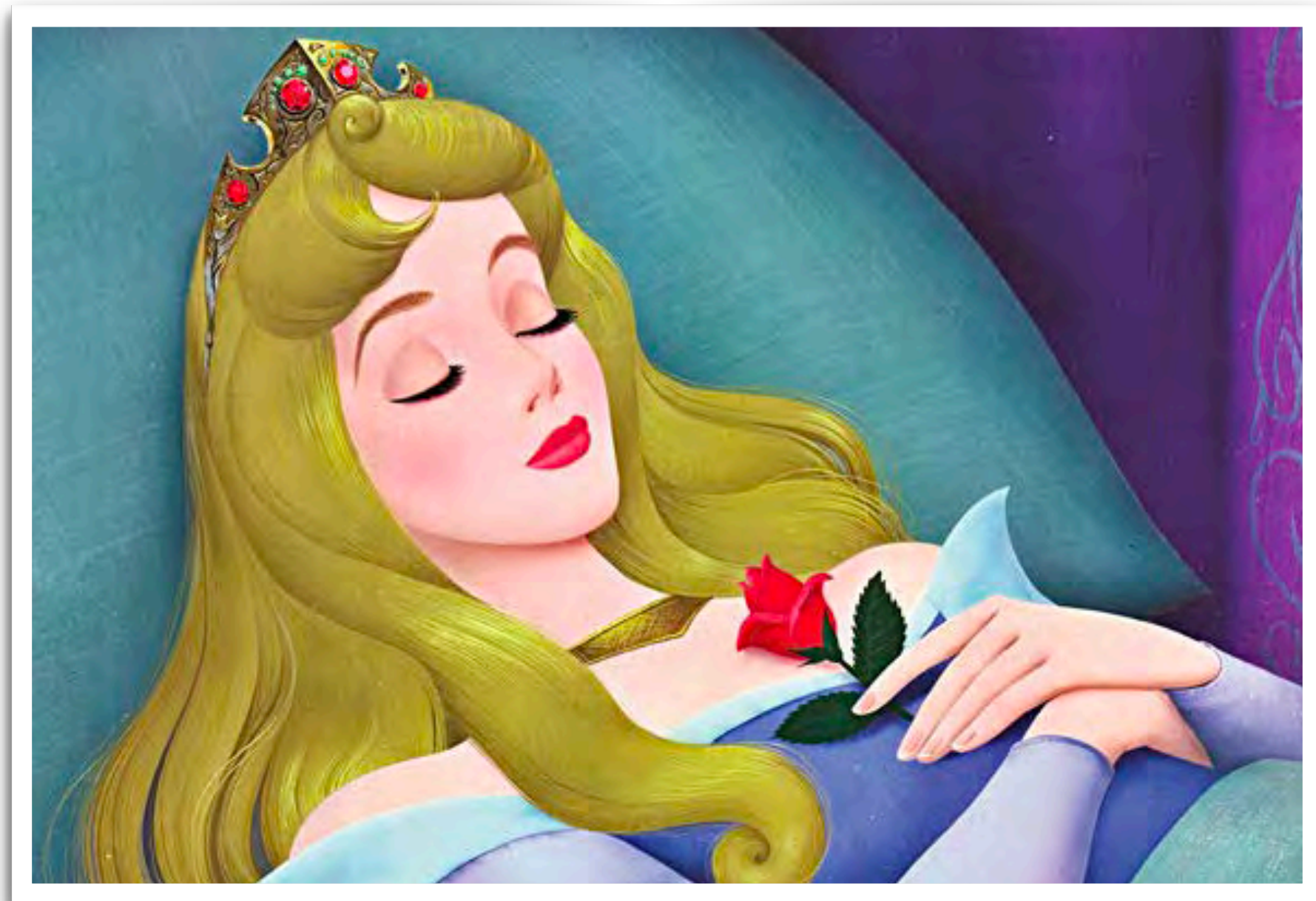
Fixed Effects by author & by field

Controlling for: team size, mean, stdev & max career age, supported by funding agencies, # & award amount of funding

Team Structure Matters for Credit



Team Structure Matters for the Future



Fixed Effects by author & by field

Controlling for: team size, mean, stdev & max career age, supported by funding agencies, # & award amount of funding

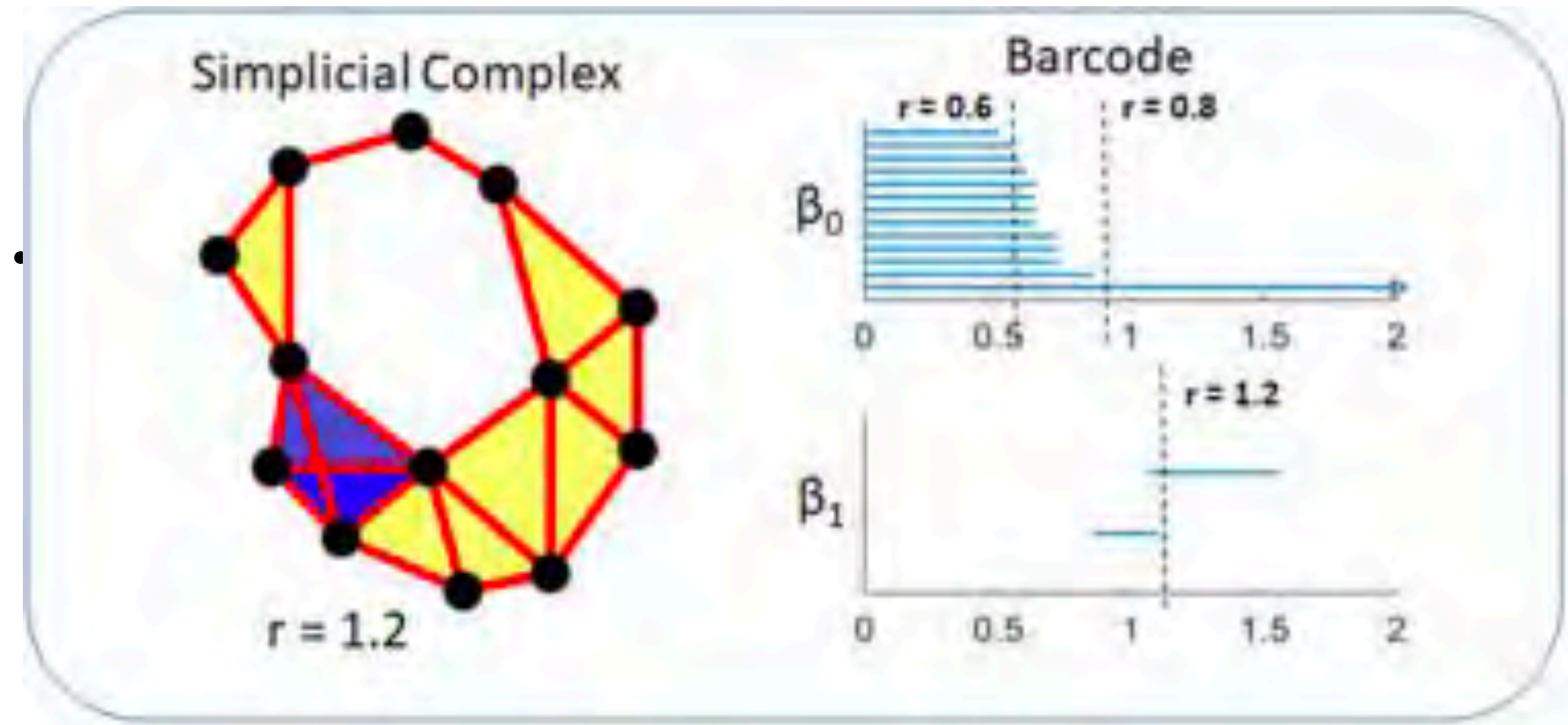
Activating Search

Collective Composition Matters

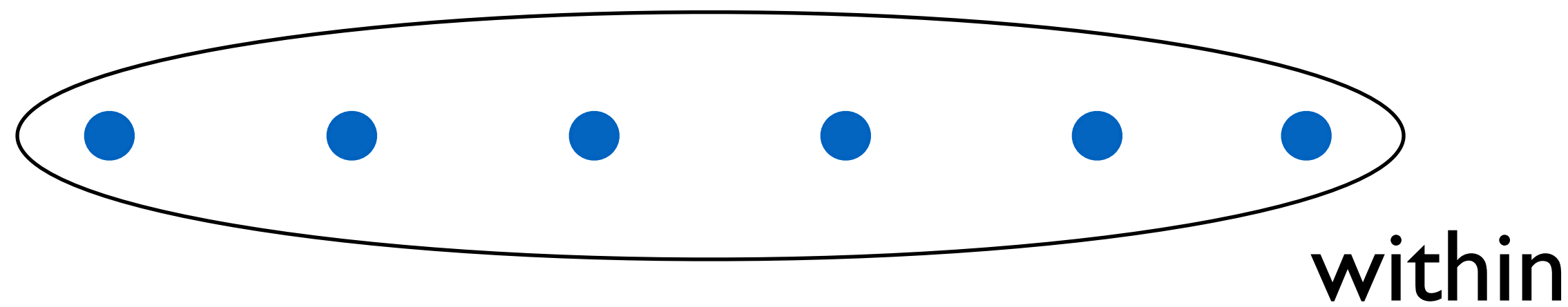
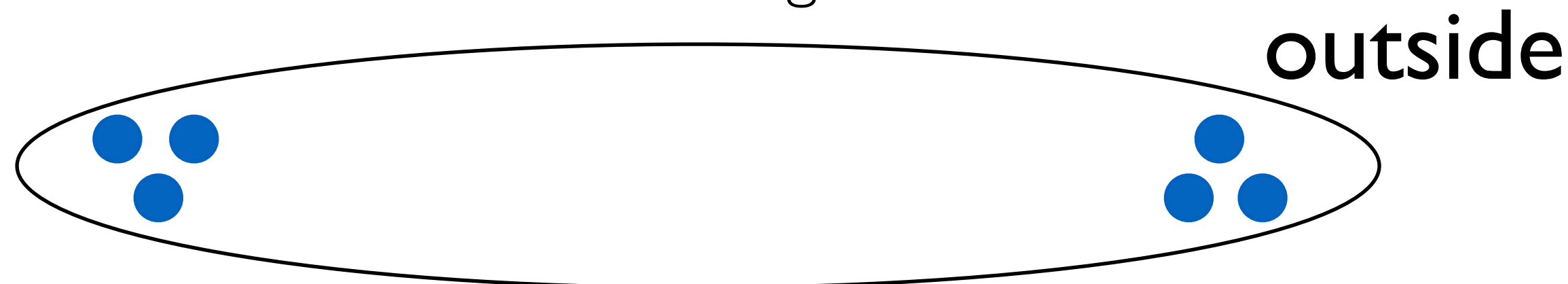
Persistent Homology

Concept/Tech **Diameter** matters...

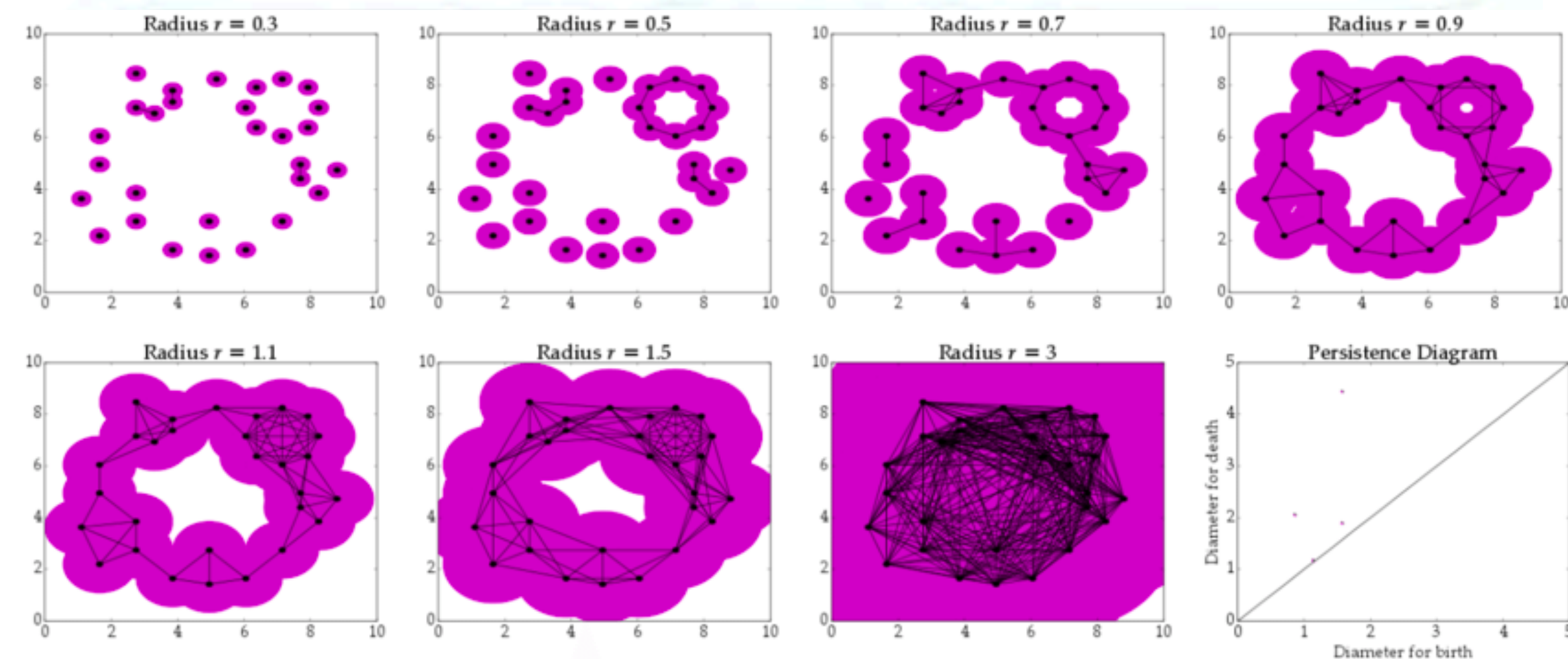
But so do **Holes** in the structure



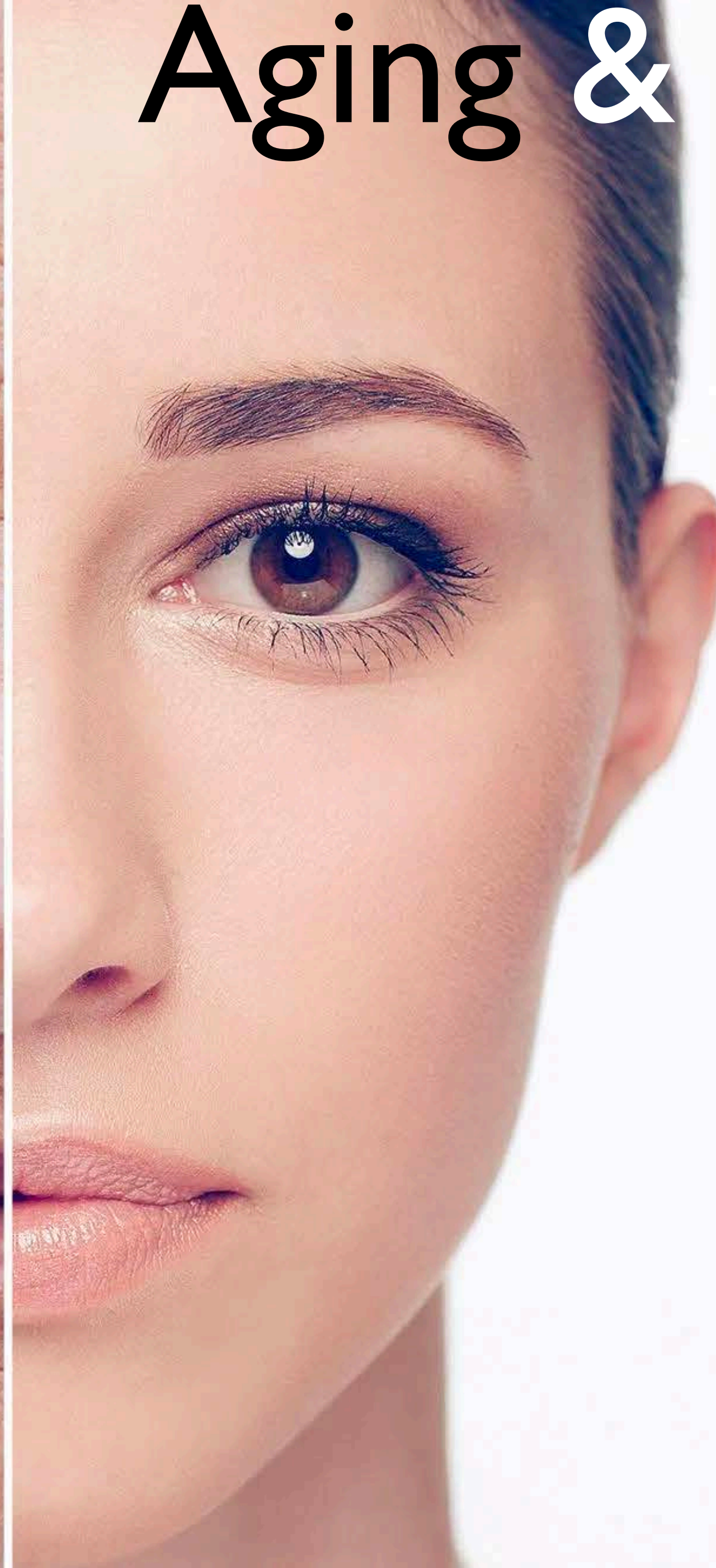
Diameter = Largest Hole



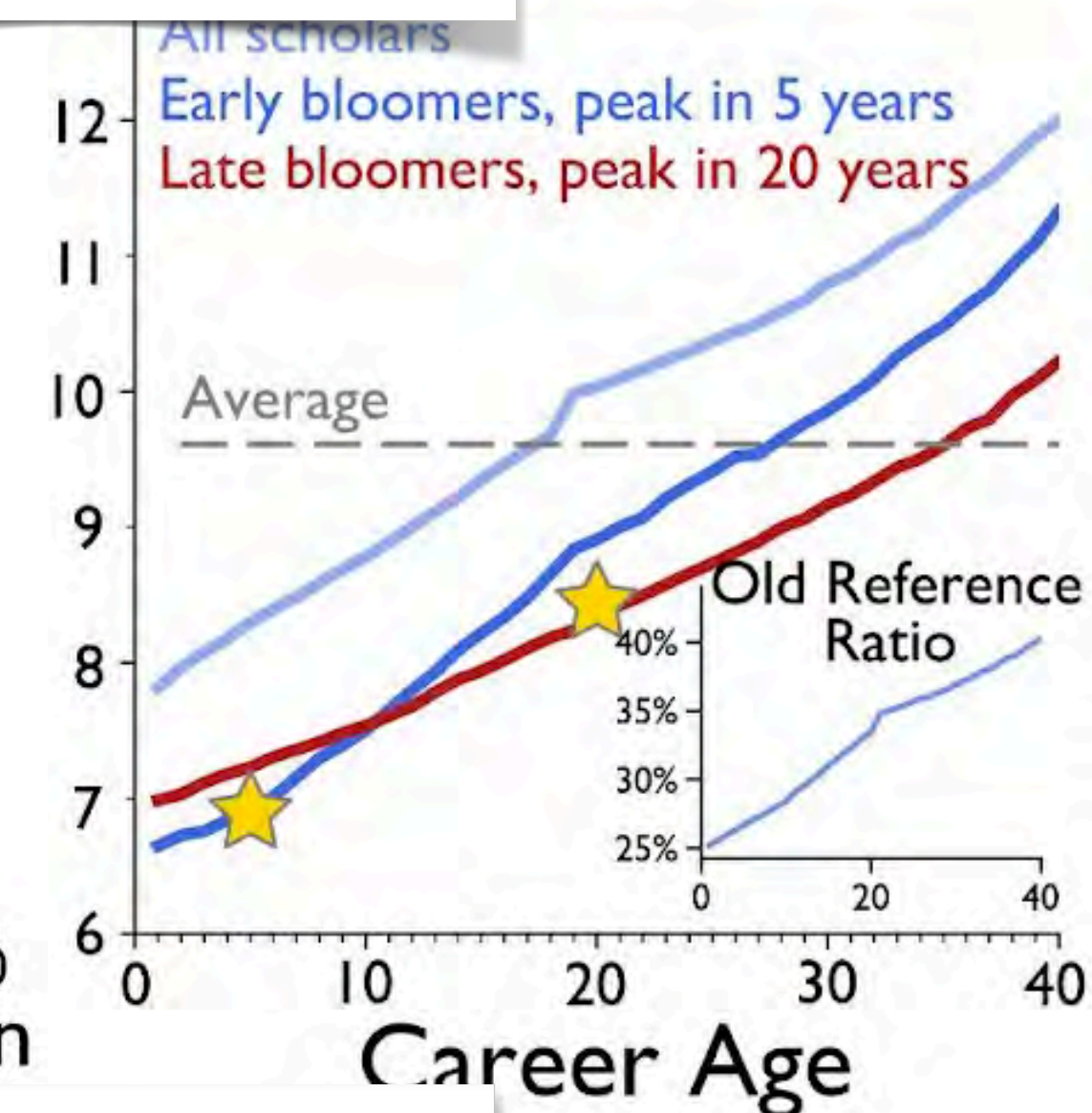
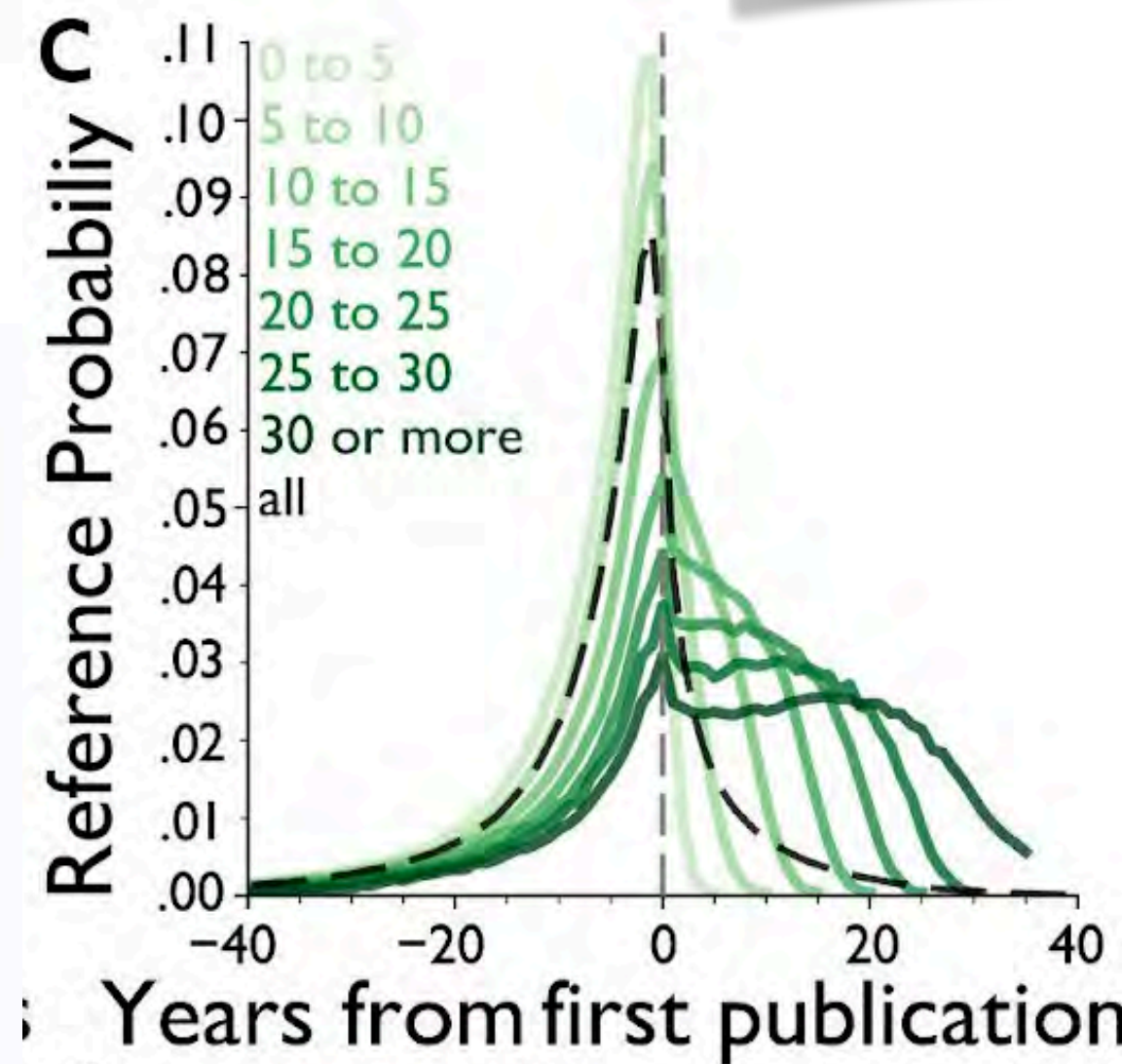
Diameter = Largest Hole * N



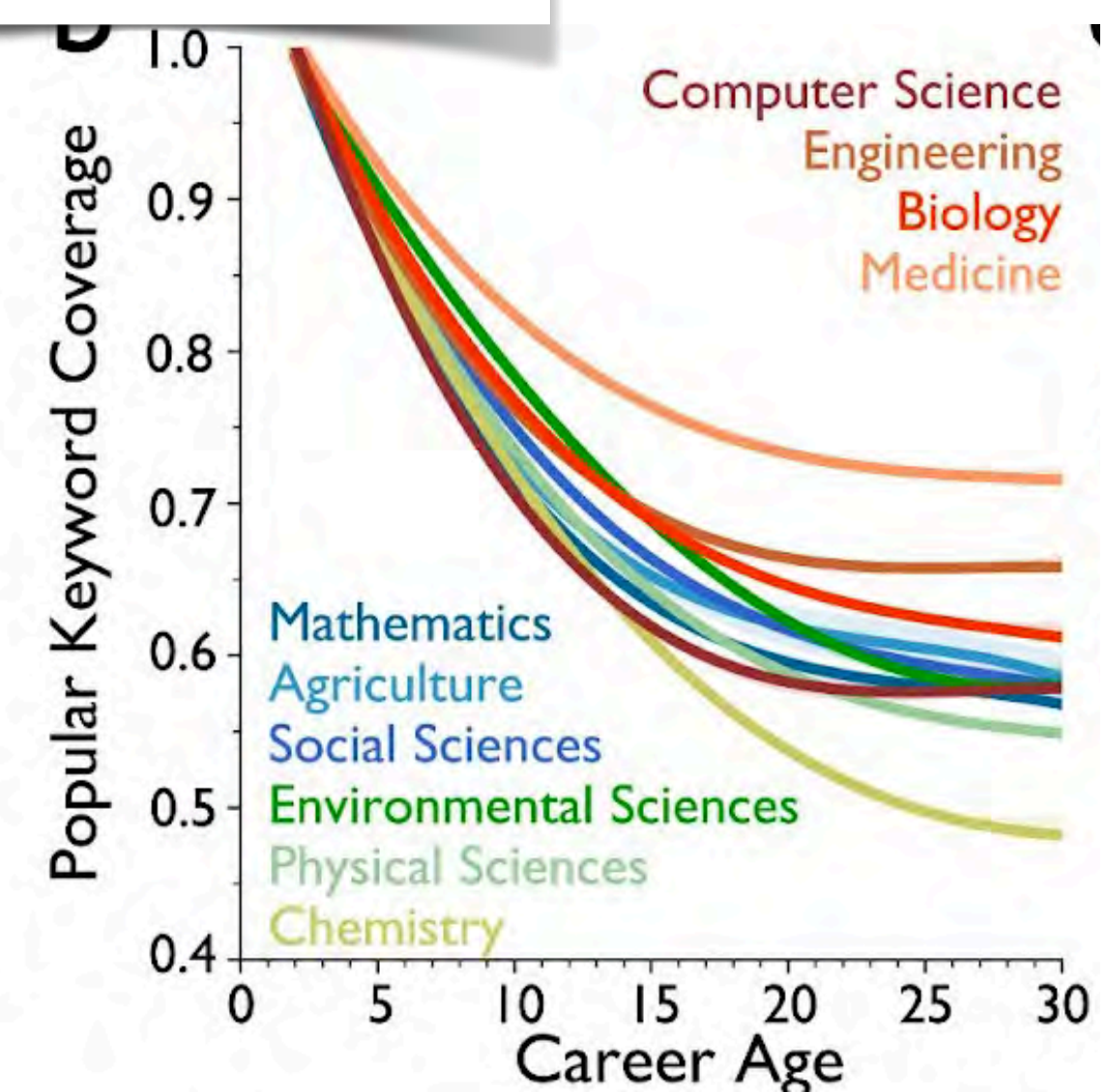
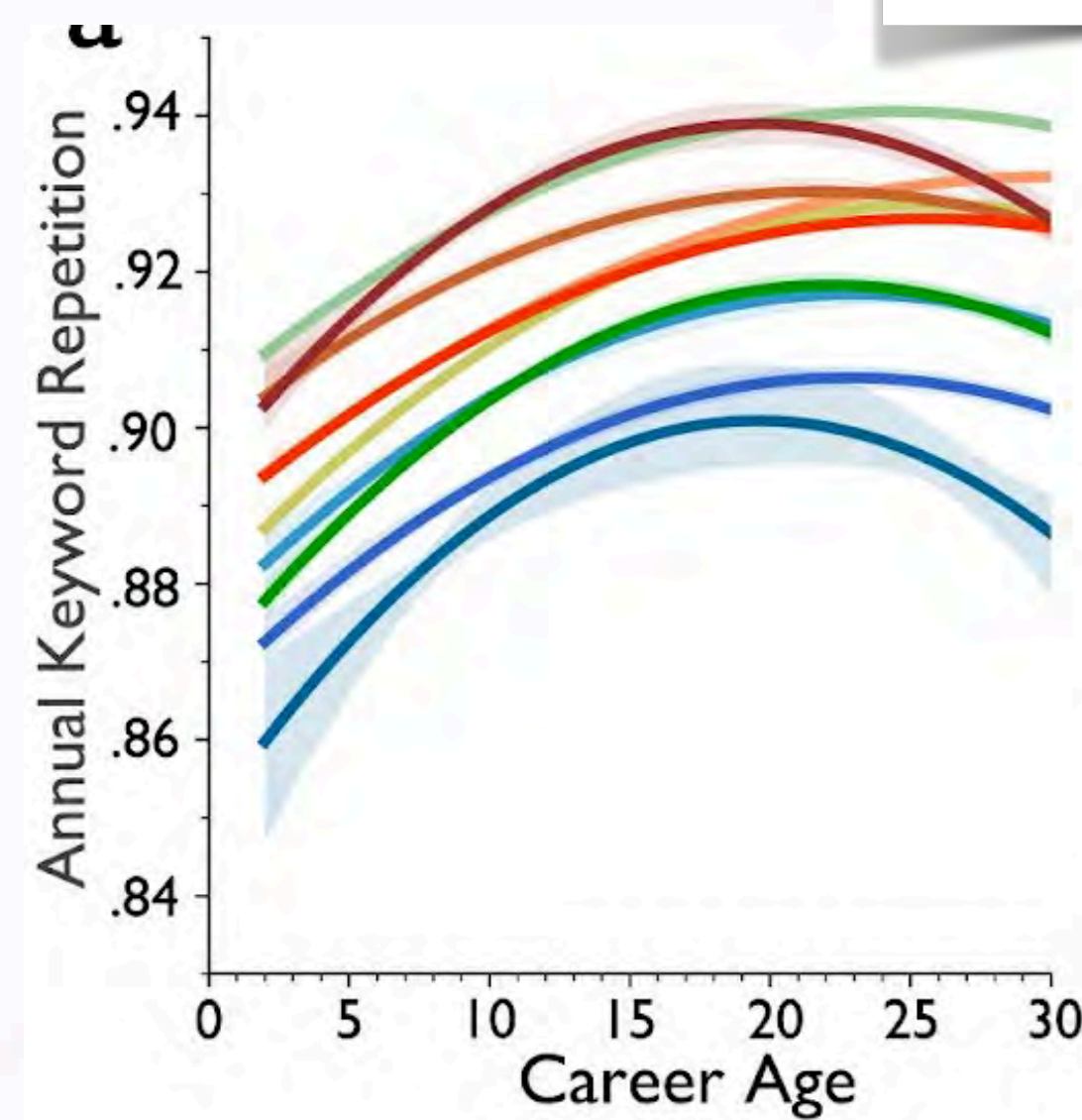
Aging & Innovation



References **Age**

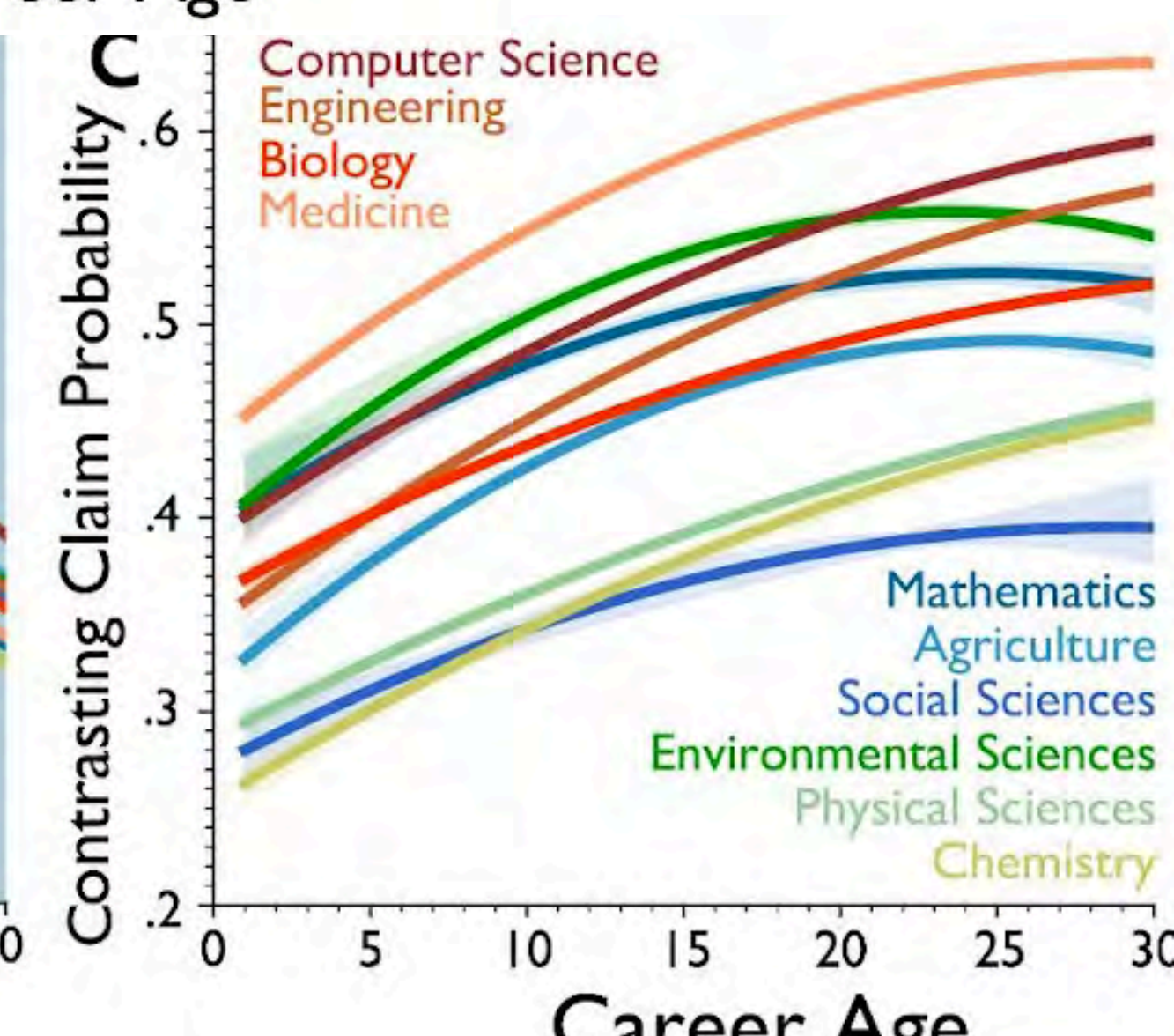
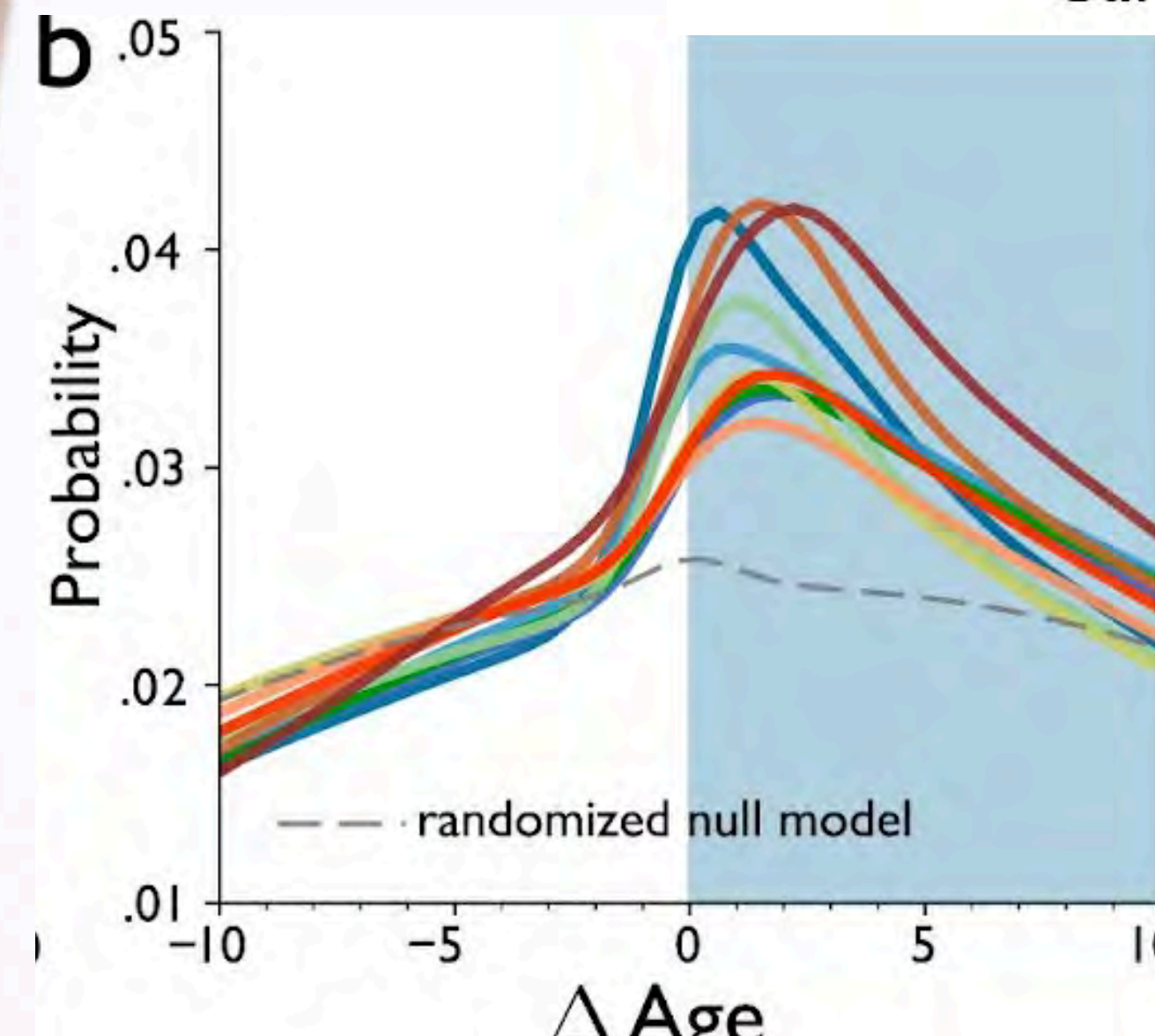
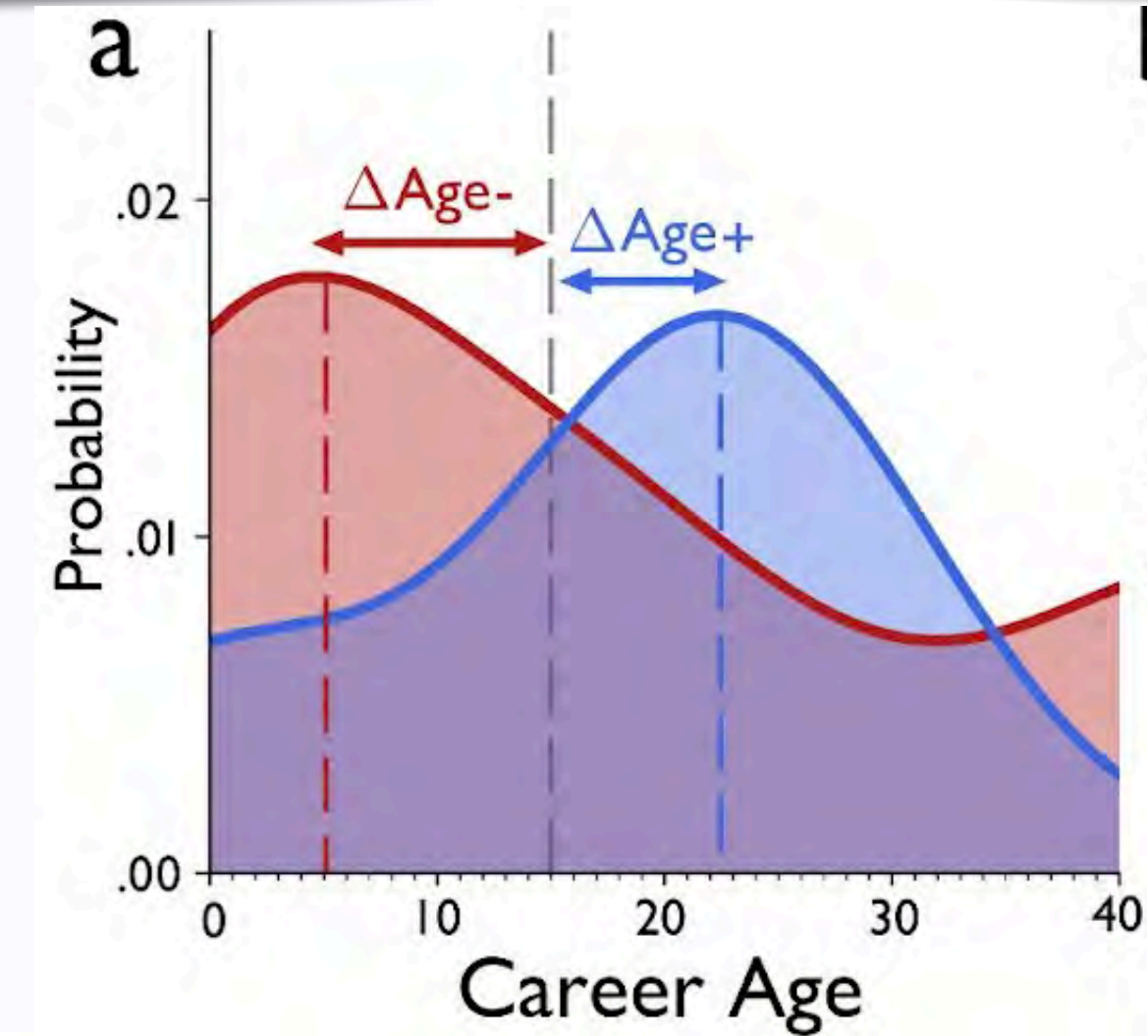


Keywords **Age**

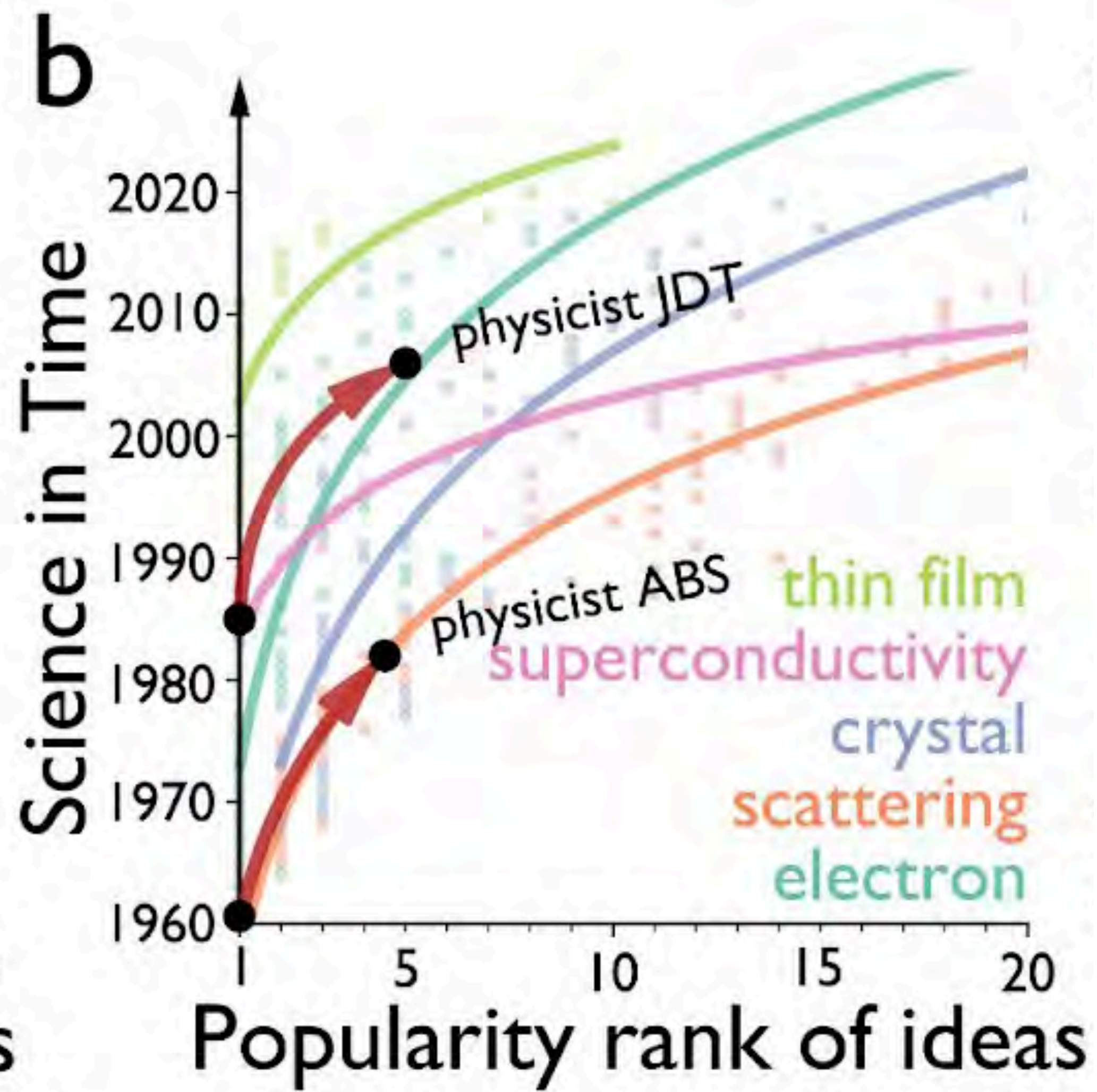
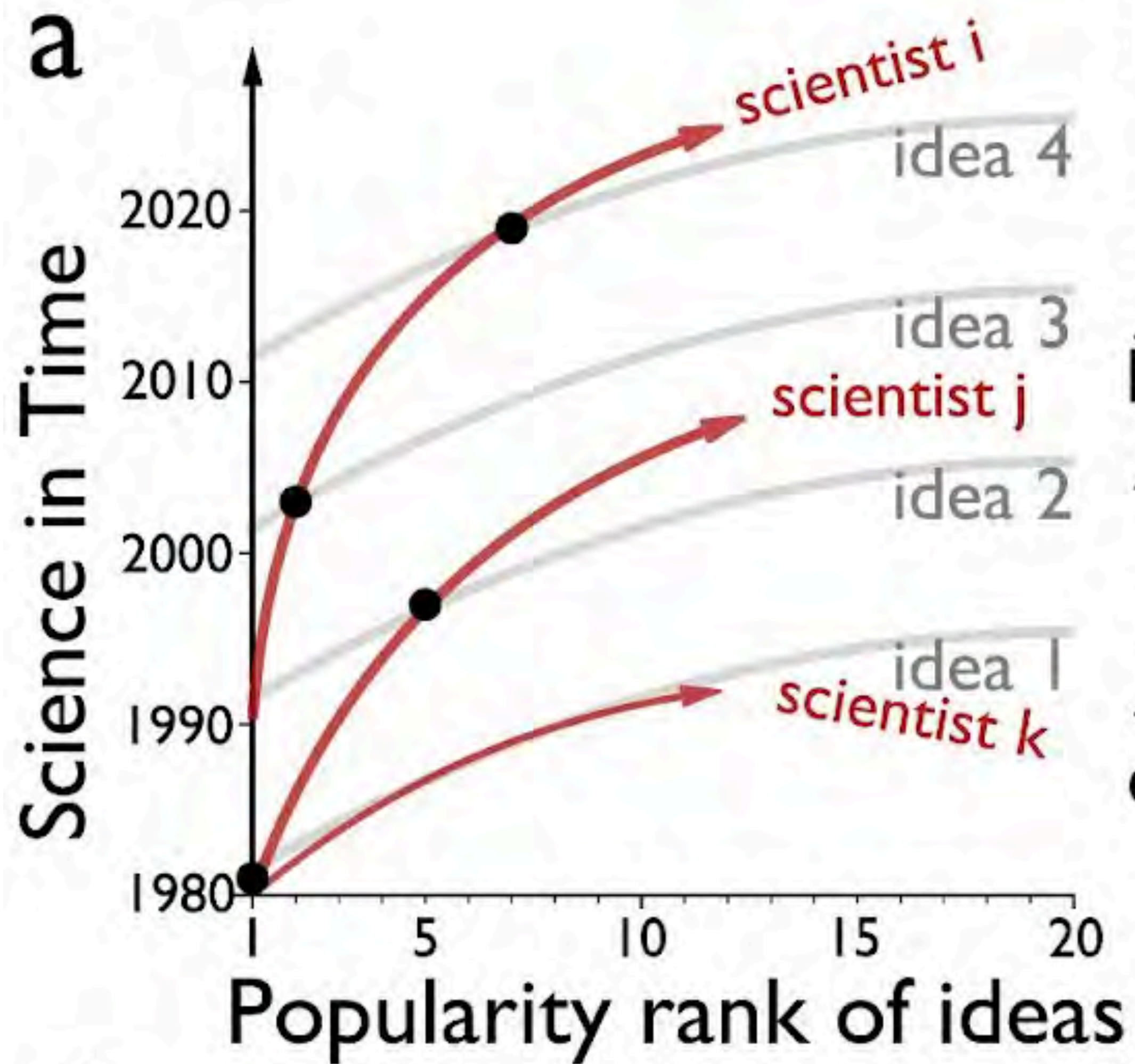


Aging & Innovation

Criticism **Accelerates**



Scientists, their best Ideas, and the unfolding Frontier



Fields Age

Level-1

$$RefAge = \pi_0 + \pi_1 Age + \pi_2 TS + e$$

Level-2

$$\pi_0 = \beta_{00} + r_0$$

$$\pi_1 = \beta_{10} + r_1$$

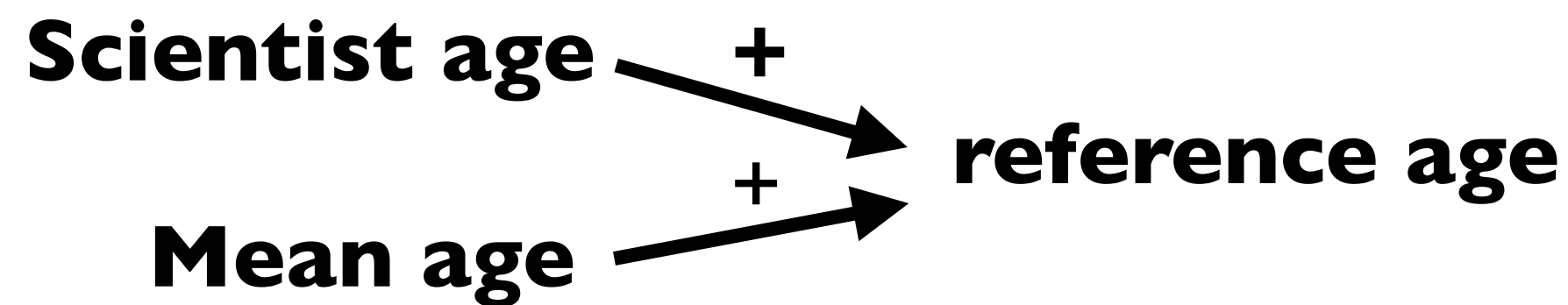
$$\pi_2 = \beta_{20} + r_2$$

Level-3

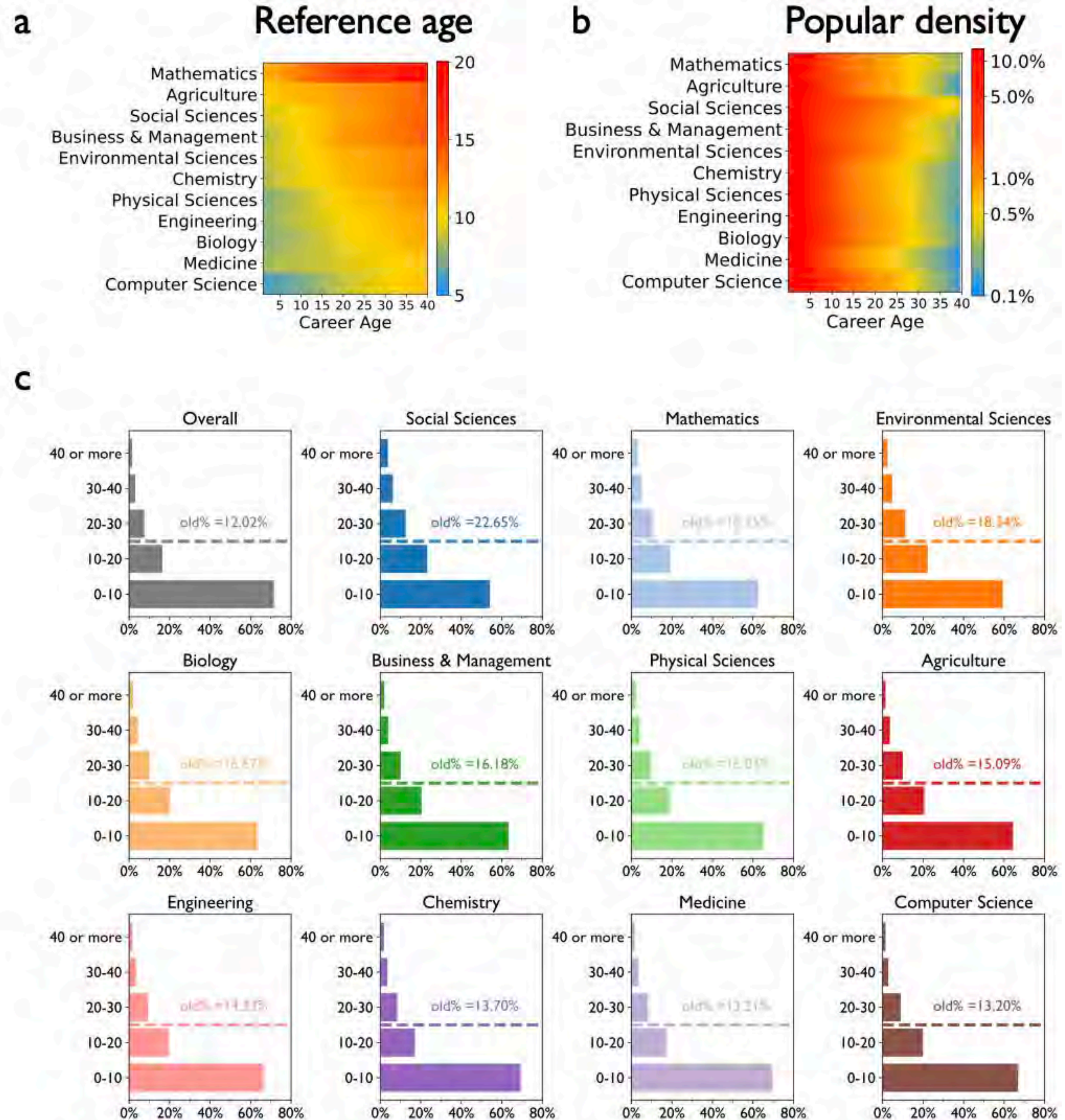
$$\beta_{00} = r_{000} + r_{001}(MeanAge) + r_{002}(MeanTS) + u_{00}$$

$$\beta_{10} = r_{100} + r_{101}(MeanAge) + r_{102}(MeanTS) + u_{10}$$

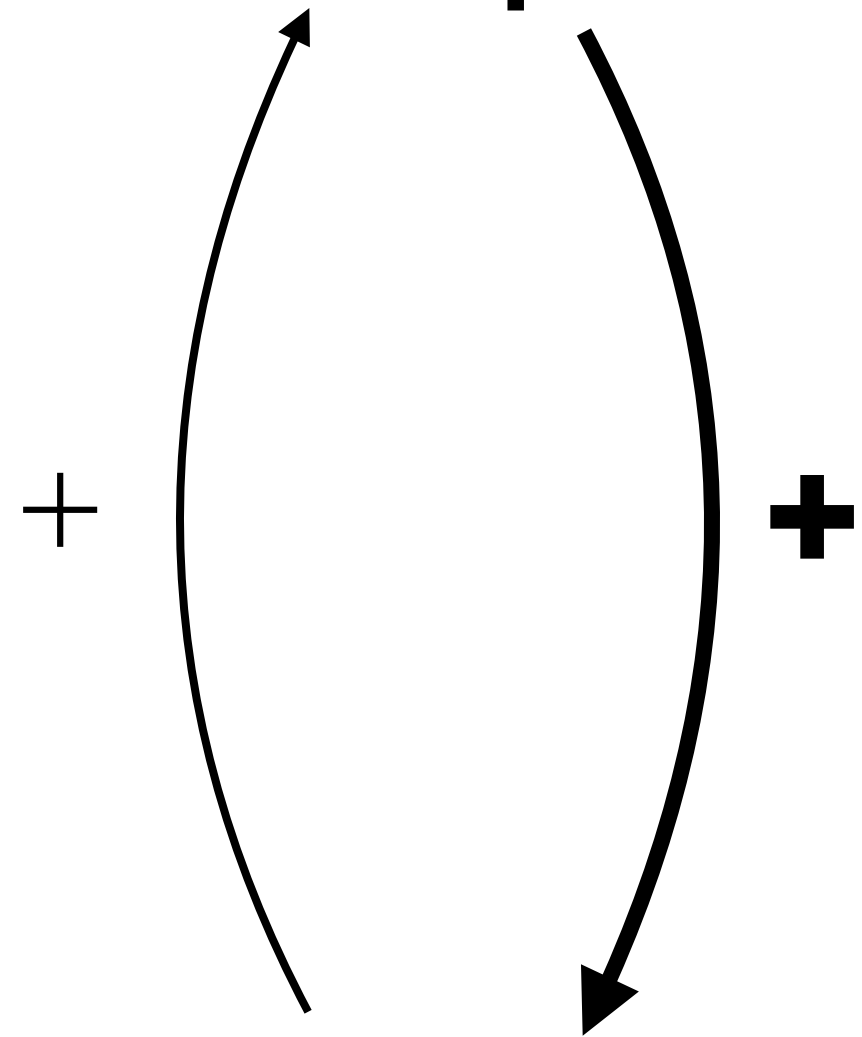
$$\beta_{20} = r_{200} + u_{20}$$



holding constant mean age within field and mean team size.



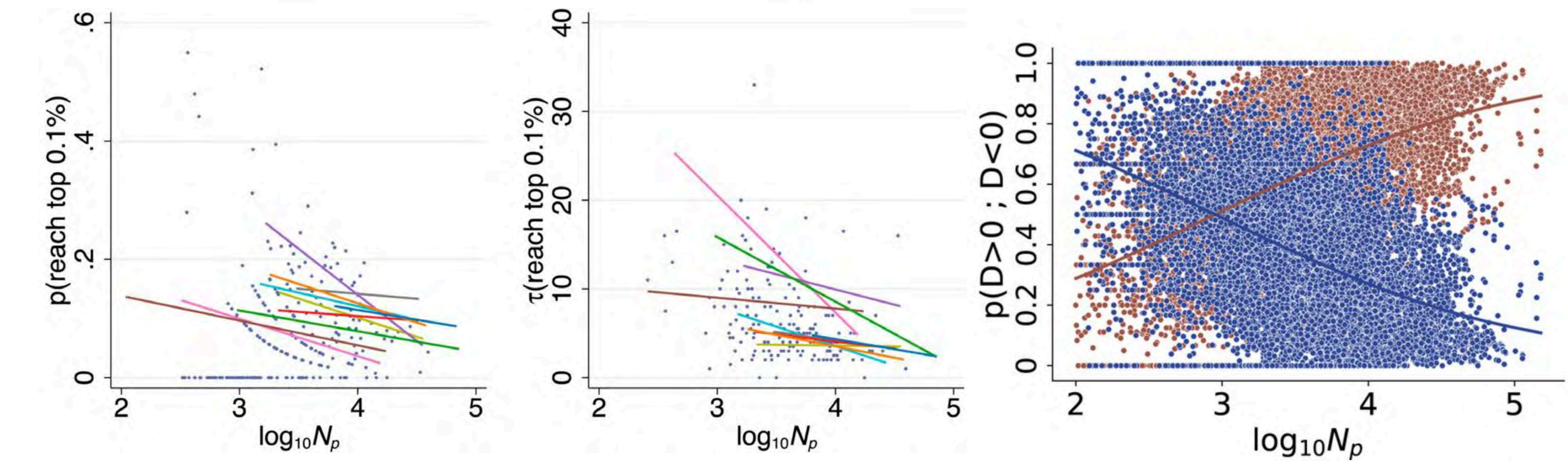
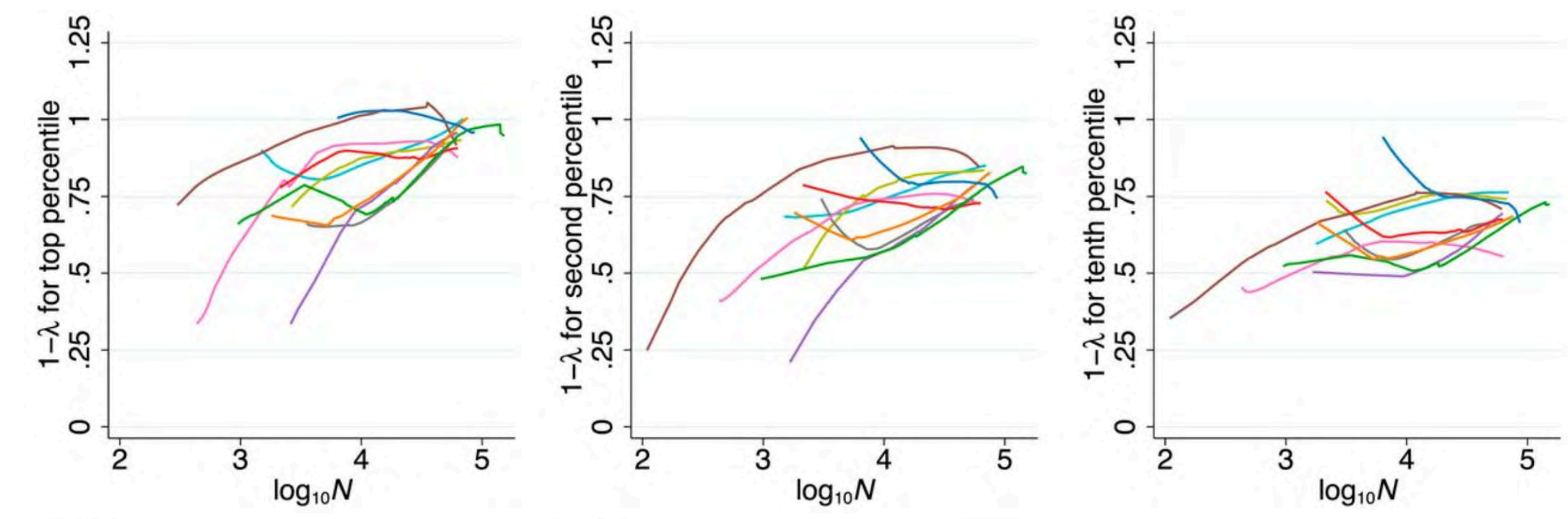
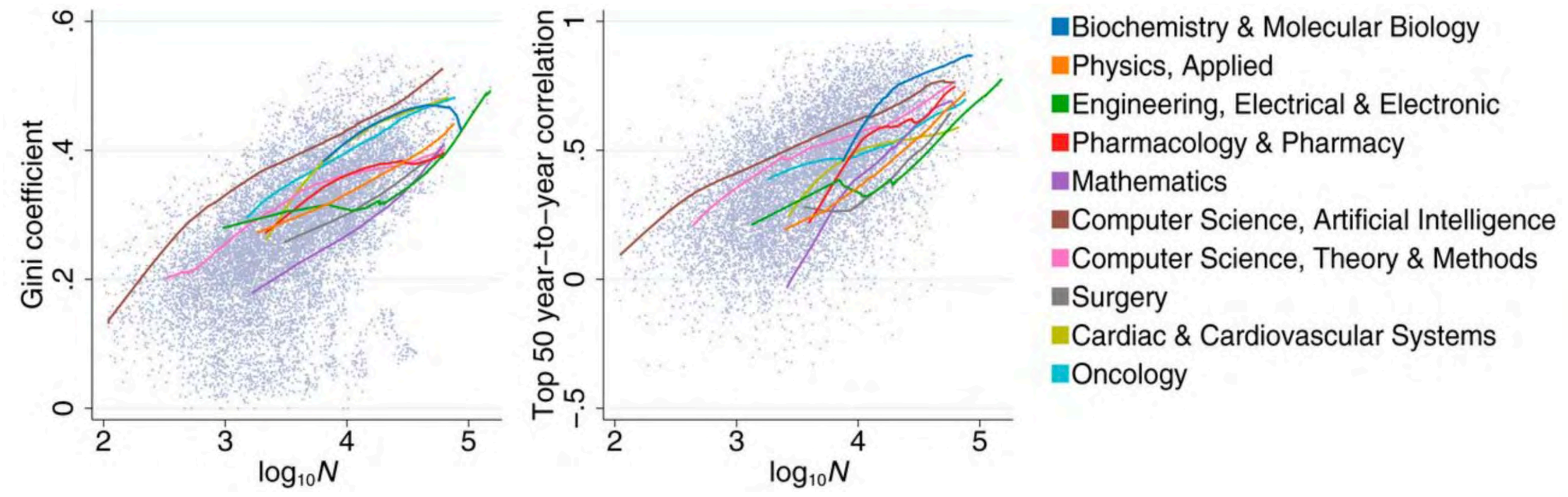
Old Proportion



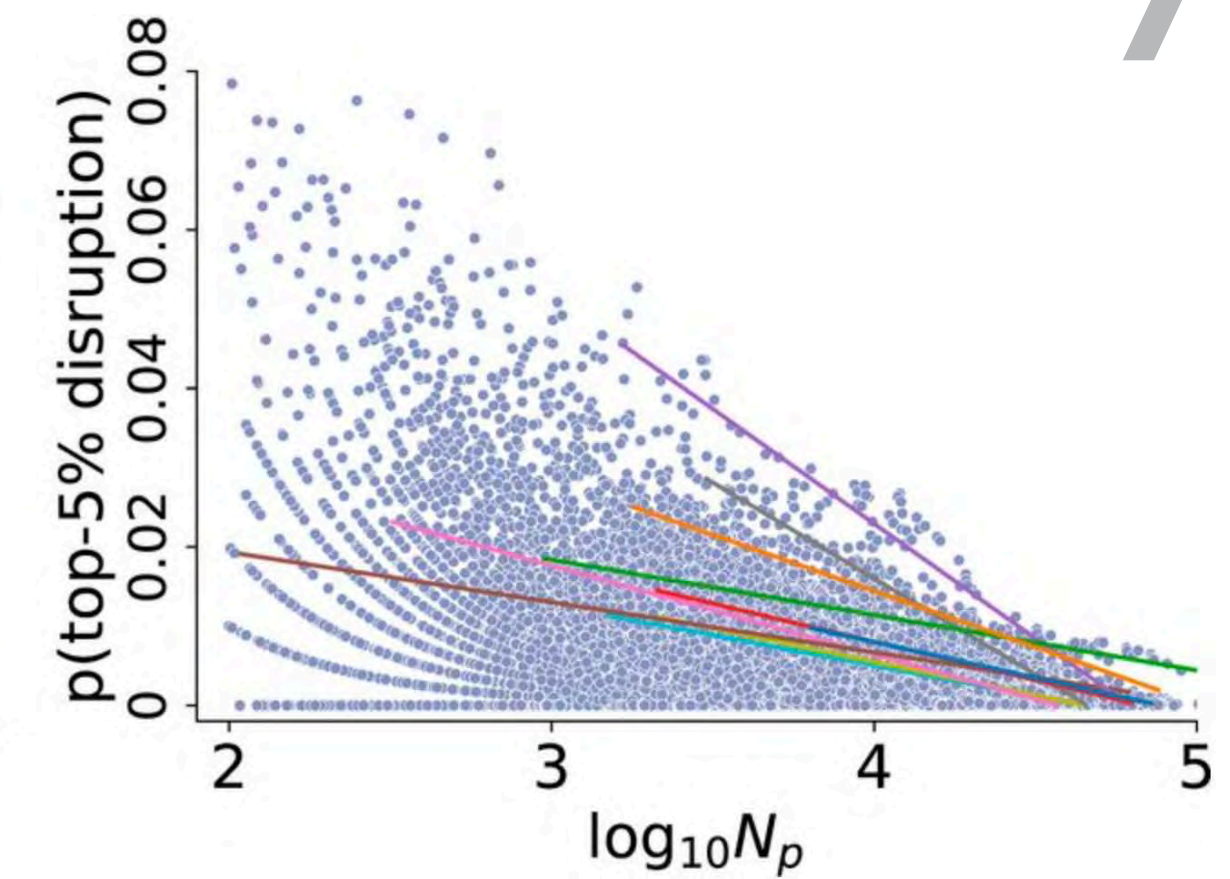
Churn Rate

Independent Variables	Old Proportion Predicts Churn Rate		Churn Rate Predicts Old Proportion	
	SSR <i>F</i> -test		SSR <i>F</i> -test	
	lags=1 year	lags=2 year	lags=1 year	lags=2 year
Mathematics	9.67***	4.76**	8.17***	5.55***
Geology	16.76***	7.74***	0.36	4.69**
Economics	11.45***	9.16***	0.61	1.59
Psychology	18.66***	6.65***	0.32	0.96
Materials science	14.29***	4.34**	5.49**	3.65**
Physics	9.08***	2.19	4.05**	2.27
Chemistry	11.09***	2.45*	1.29	0.52
Biology	13.82***	4.01**	17.07***	8.31***
Medicine	17.27***	5.07***	0.1	0.57
Engineering	16.38***	4.98**	2.84*	1.8
Computer science	30.53***	13.33***	4.19**	0.75

* p-value < 0.05; ** p-value < 0.01; *** p-value < 0.001

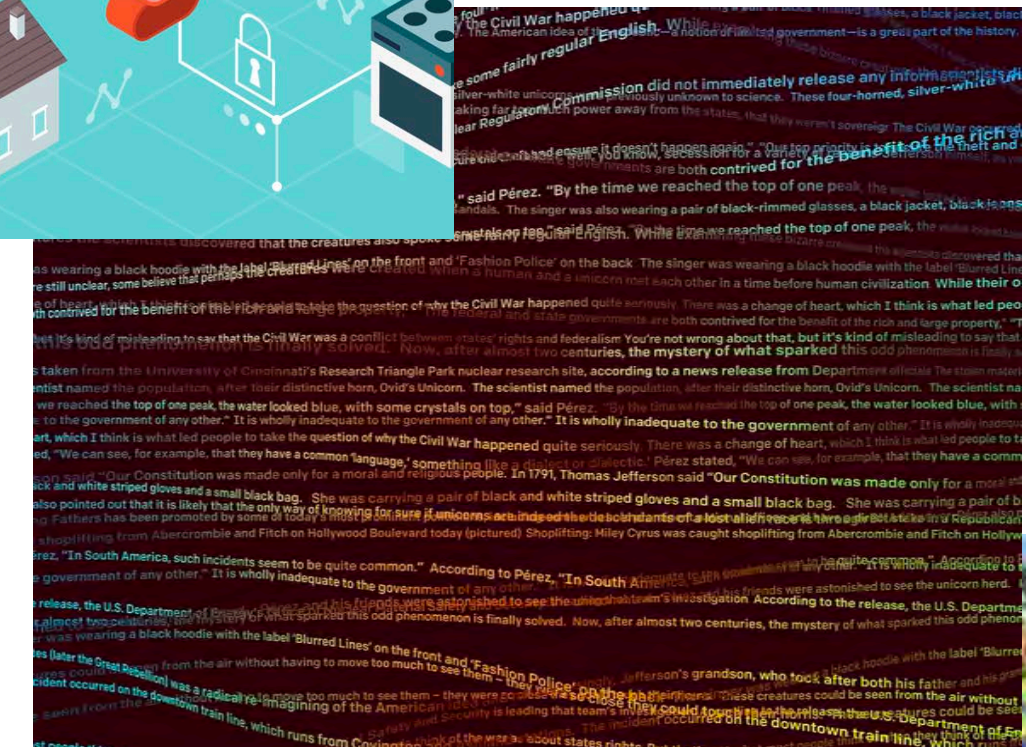


**As Fields
Grow
Canons
Crystallize**



Diversity Collapse In other Domains

- Cultural objects and the Interwebz
- Language extinction with social contact
- Biological extinction with ecological contact



(NOT division of labor, and increasing specialization as in cities.)

Centralized communities & the

Stem Cell Research Papers Are Retracted

By ANDREW POLLACK JULY 2, 2014

Two scientific papers that initially electrified

nature

International weekly journal of science

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News & Comment > News > 2014 > October > Article

NATURE | NEWS

Psychologists strike a blow for reproducibility

Thirty-six labs collaborate to check 13 earlier findings.

Ed Yong

26 November 2013

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A large international group set up to test the reliability of psychology experiments has succe

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Nature Reviews Drug Discovery 10, 712 (September 2011) | doi:10.1038/nrd3439-c1

Believe it or not: how much can we rely on published data on potential drug targets?

See also: [News and Analysis by Arrowsmith](#)

The Quarterly Journal of Experimental Psychology

Volume 65, Issue 11, 2012

Select Language

Translator disclaimer

A peculiar prevalence of p values just below .05

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Psychological
SCIENCE

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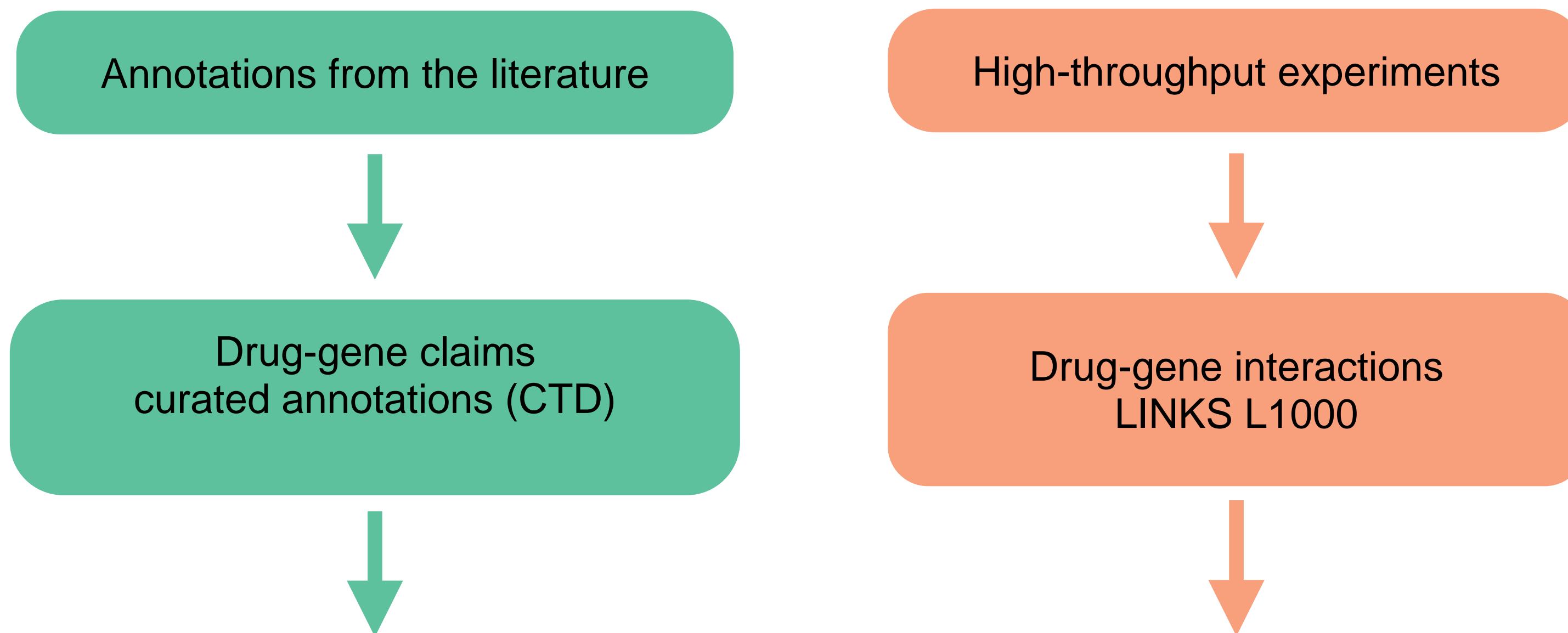
Editors' Introduction to the Special
Section on Replicability in Psychological
Science

A Crisis of Confidence?

Harold Pashler¹ and
Eric-Jan Wagenmakers²

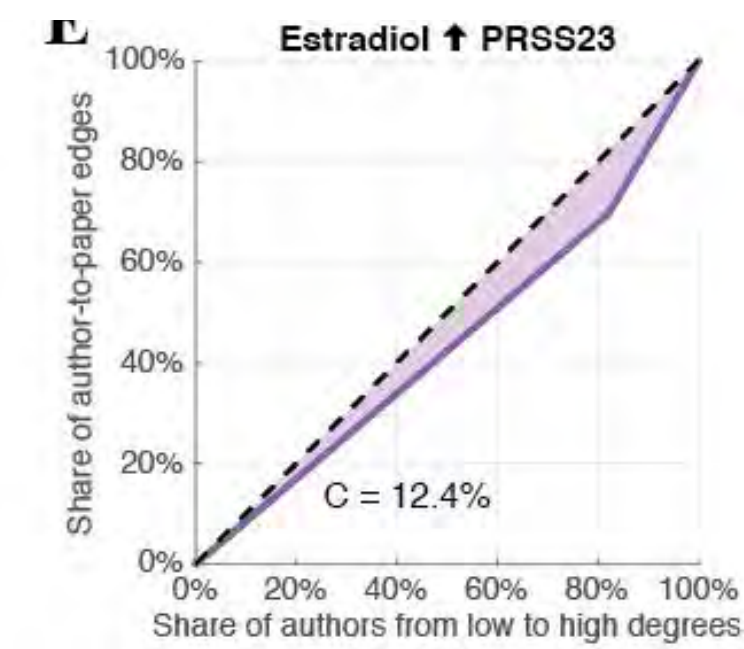
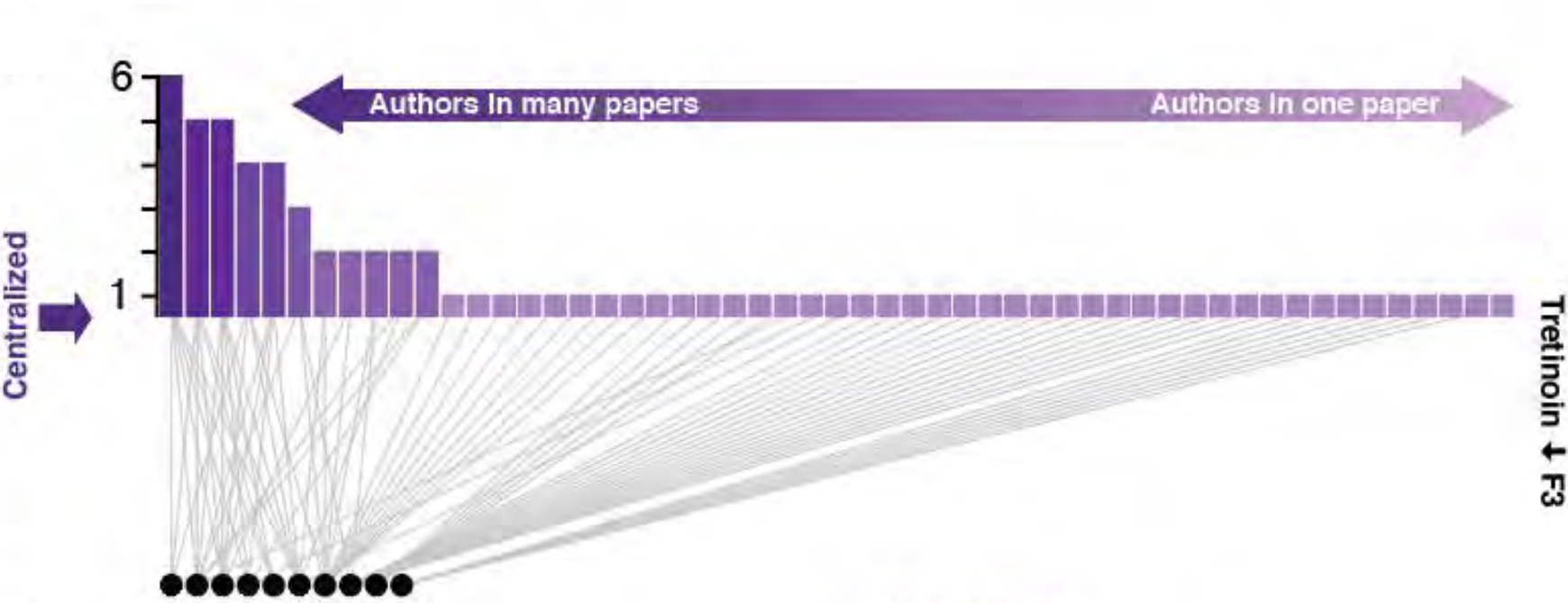
Replication Crisis

Aligning **published claims** with **high-throughput experiments**

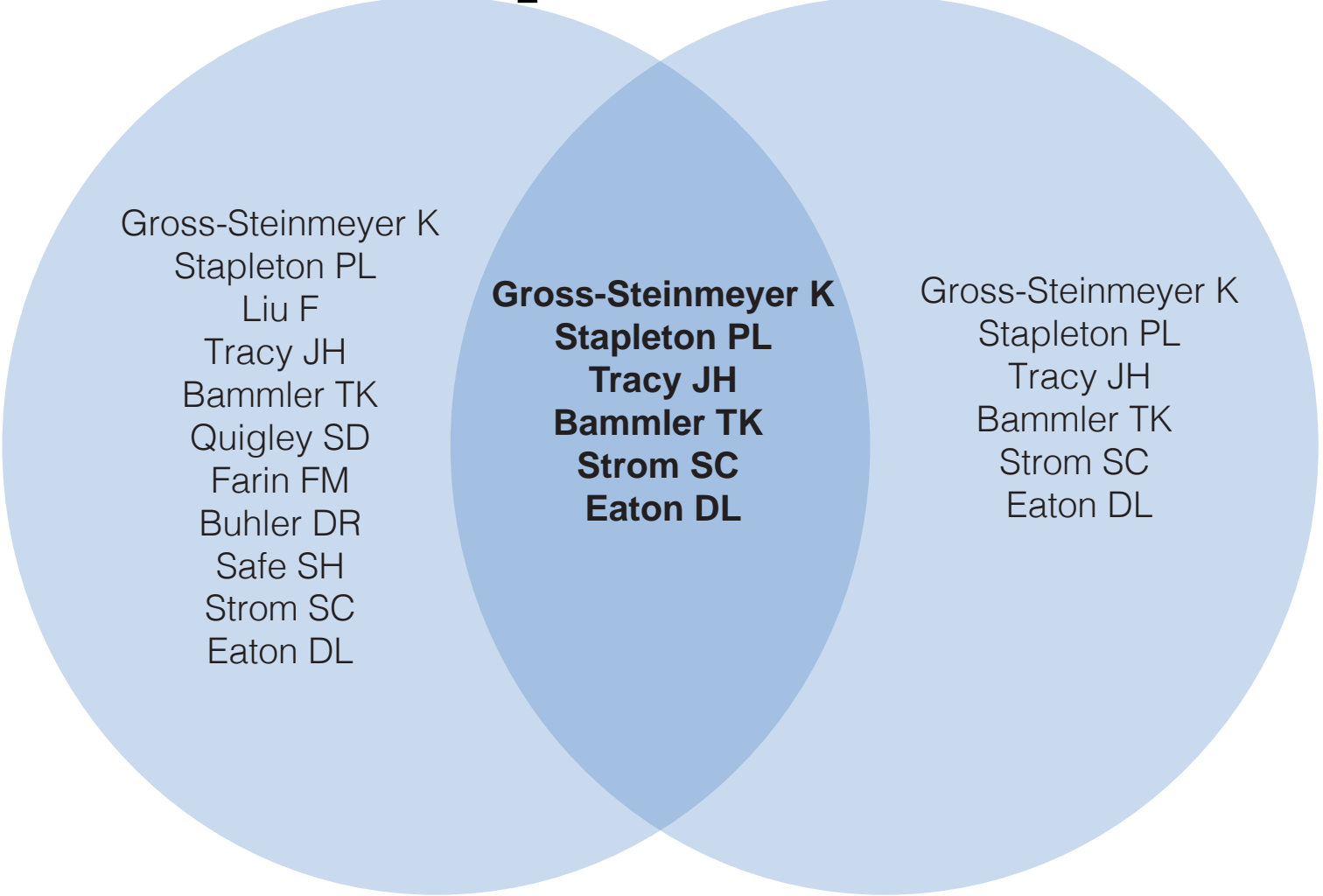


<i>Drug</i>	<i>Gene</i>	<i>Interaction</i>	<i>Support # papers</i>	<i>Oppose # papers</i>	<i>Papers IDs</i>	<i>Effect size</i>	<i>Statistical Significance</i>	<i>Variability cell, dose, time</i>
<i>Benzo(a)pyren</i>	<i>SLC22A3</i>	<i>Decreases expression</i>	<i>5</i>	<i>0</i>	<i>21224254, 19188863</i>	<i>+1.646</i>	<i>Y</i>	<i>0.783</i>
<i>Sulforafan</i>	<i>NQO1</i>	<i>Increases expression</i>	<i>16</i>	<i>0</i>	<i>1001256; ...</i>	<i>+8.405</i>	<i>Y</i>	<i>1.719</i>
<i>Estradiol</i>	<i>PRSS23</i>	<i>Increases expression</i>	<i>6</i>	<i>2</i>	<i>21224254; 10022439</i>	<i>+10.524</i>	<i>Y</i>	<i>2.097</i>
<i>Tretinoin</i>	<i>MYC</i>	<i>Decreases expression</i>	<i>12</i>	<i>0</i>	<i>10023685; ...</i>	<i>-2.654</i>	<i>N</i>	<i>11.848</i>

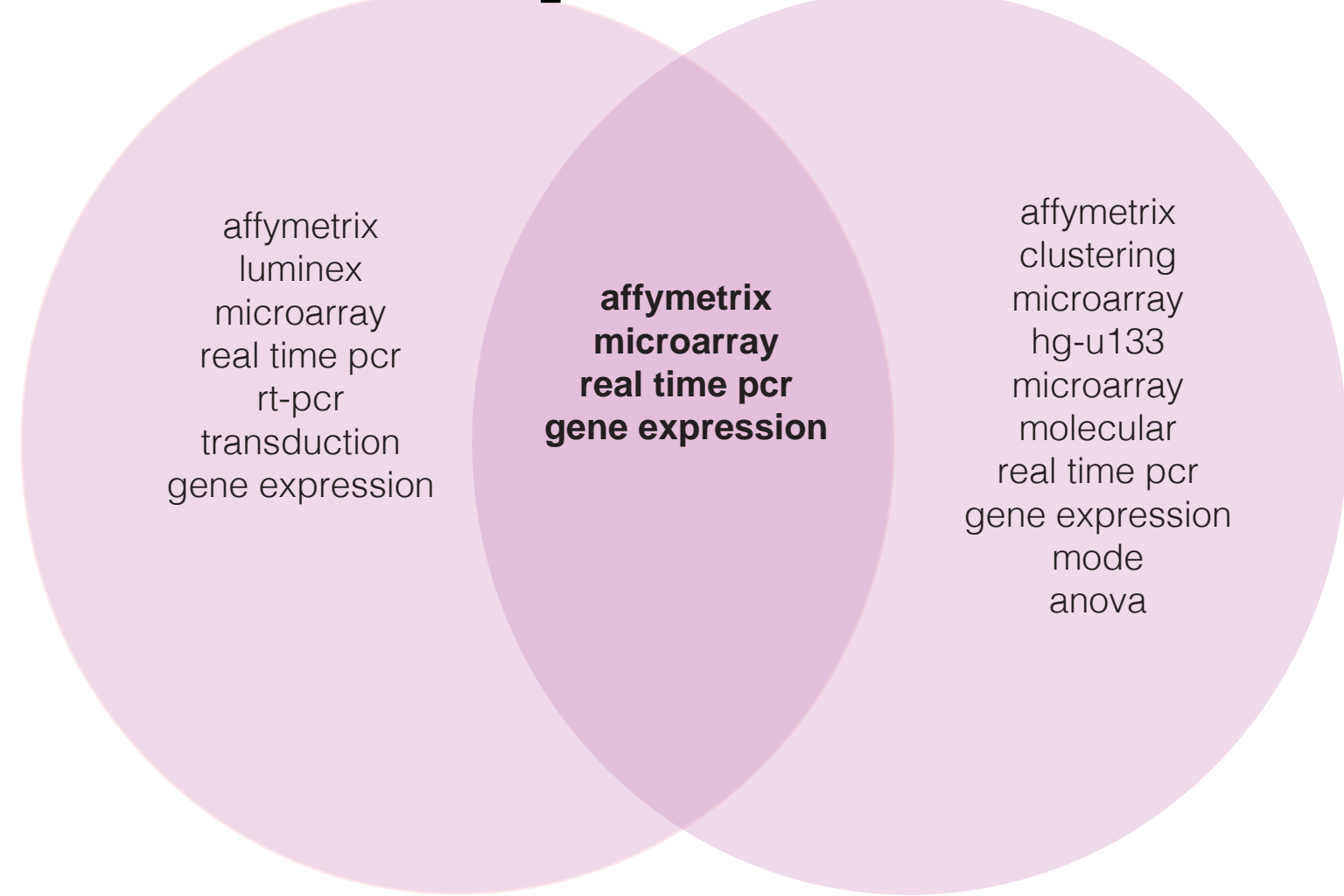
Centralization of Scientific Communities



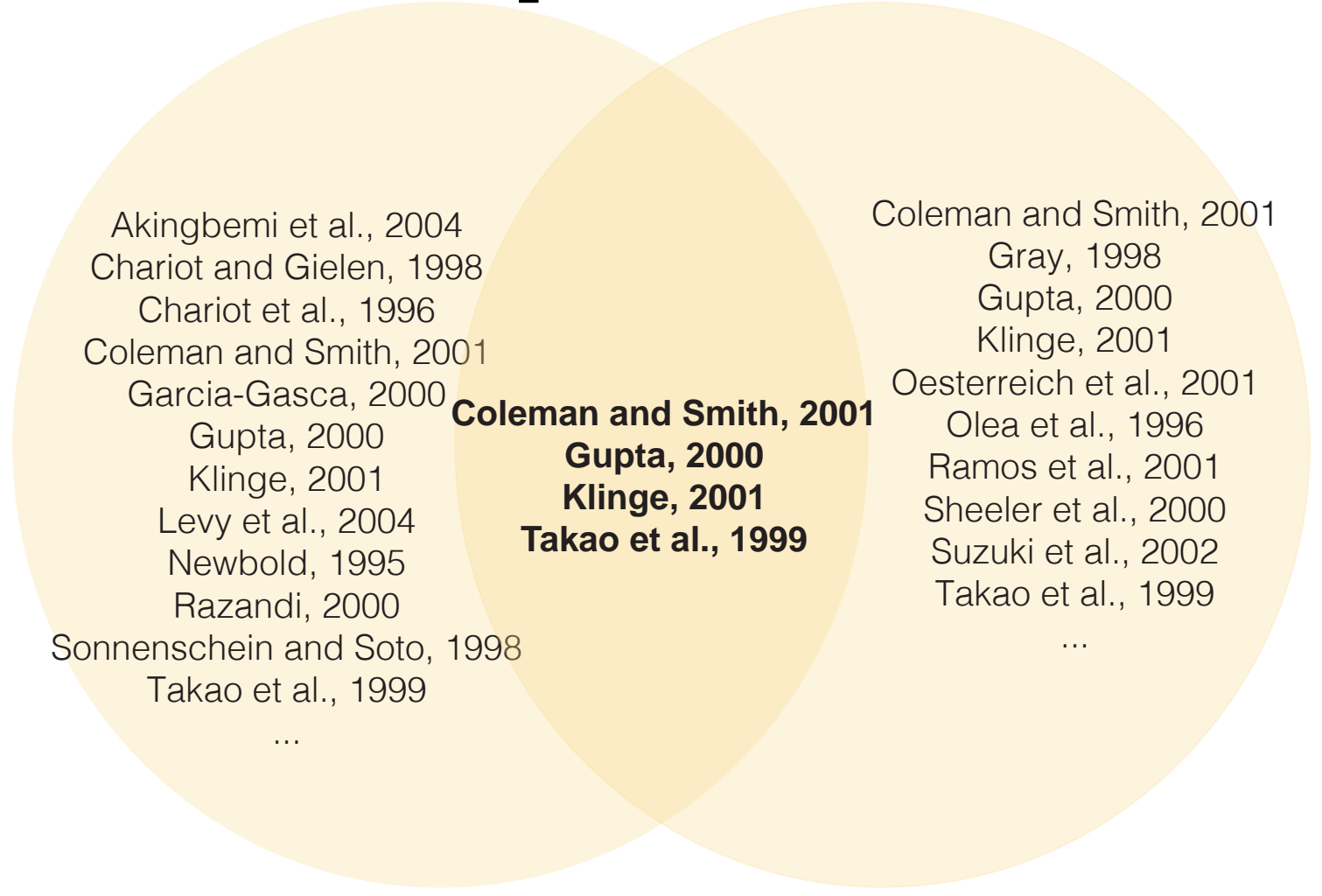
Social independence



Methodological independence



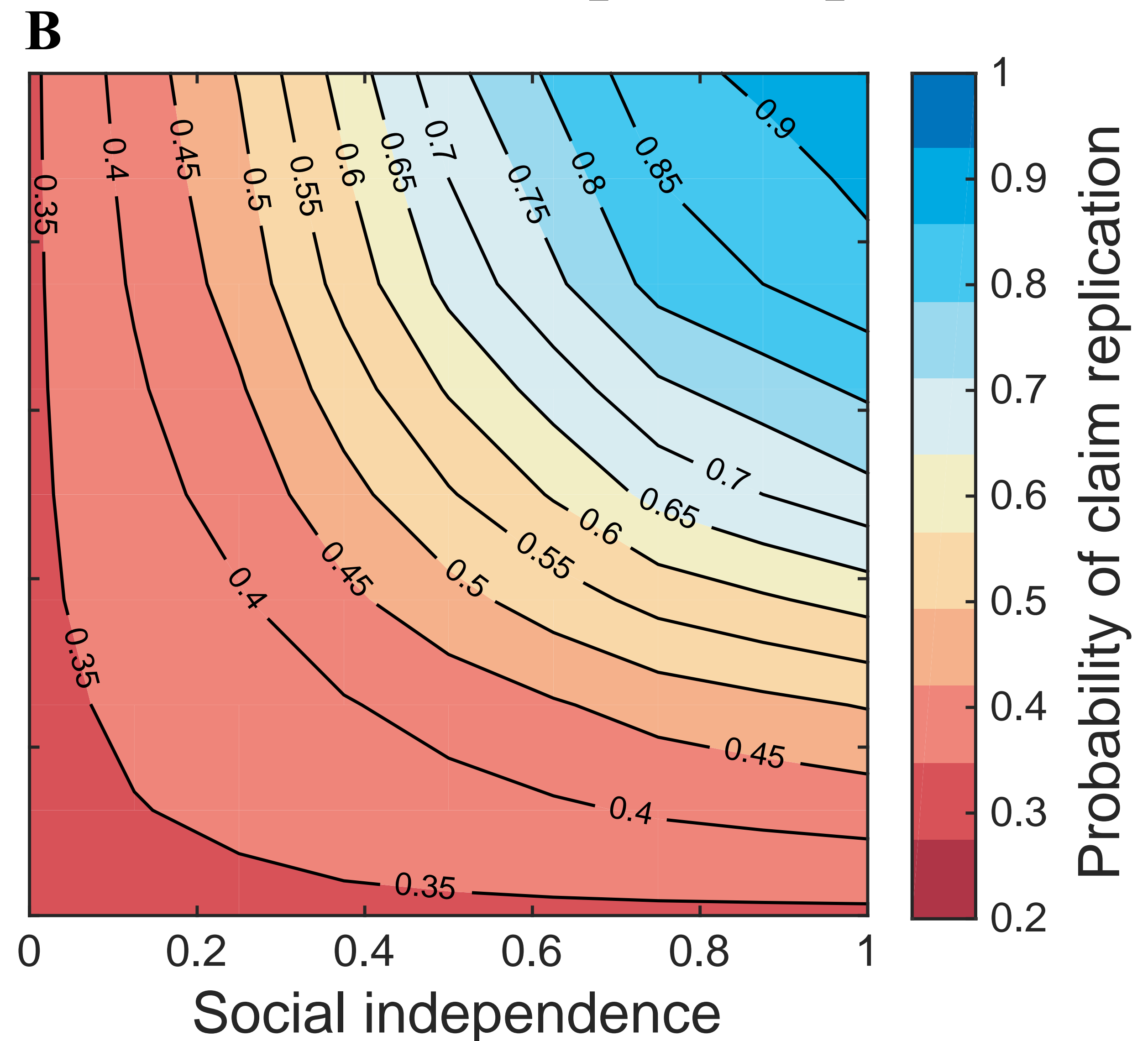
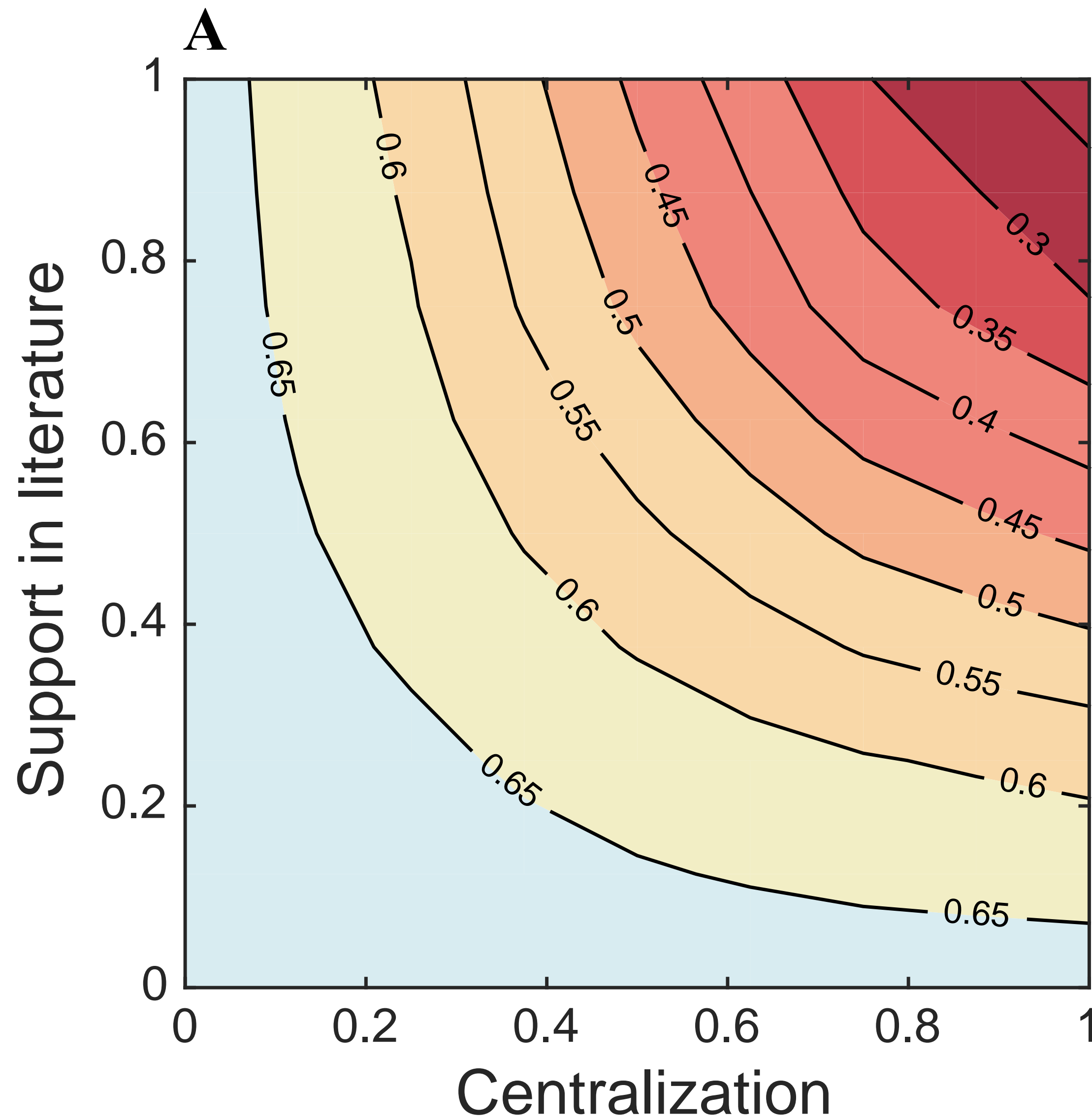
Prior Knowledge independence



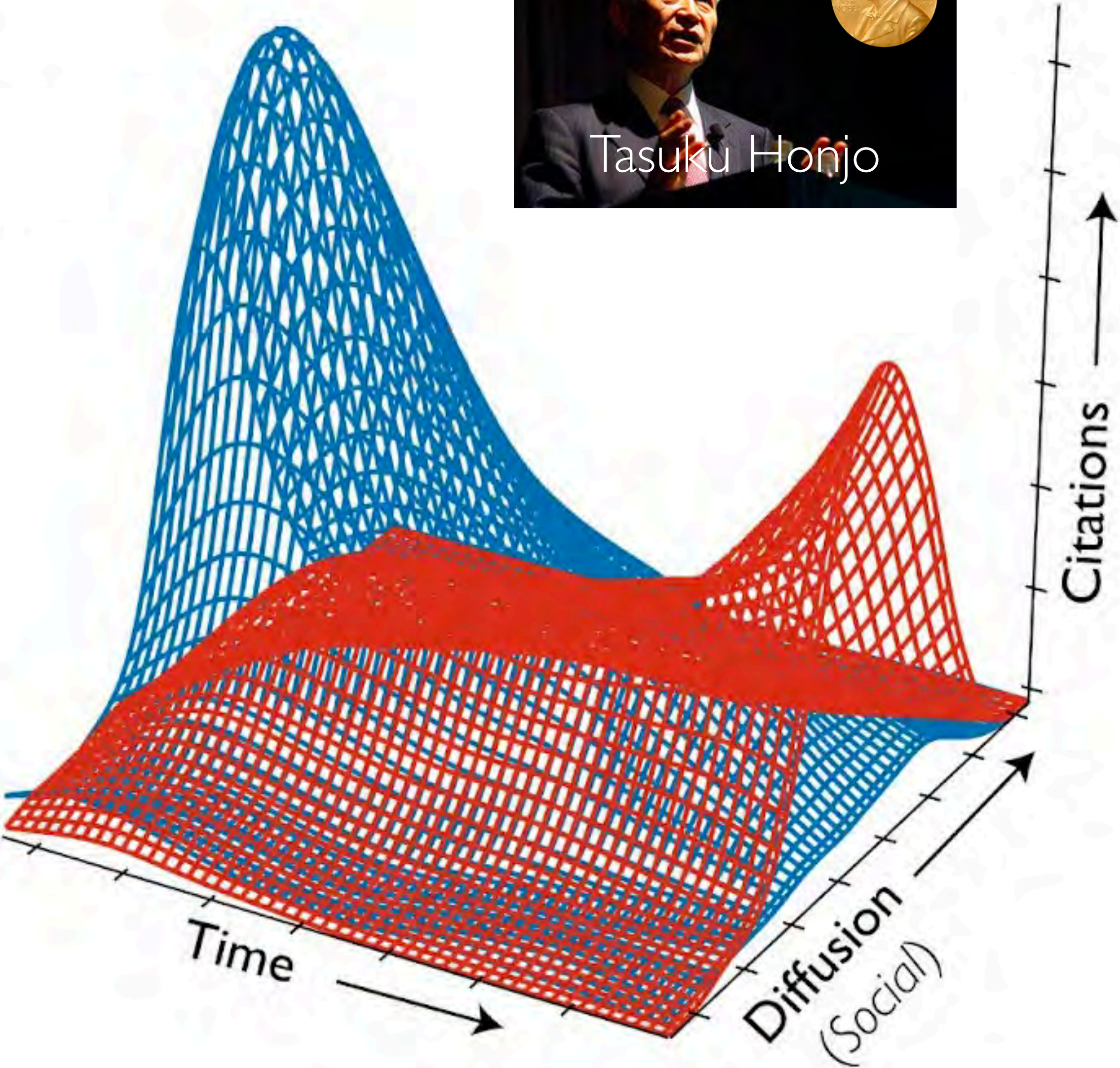
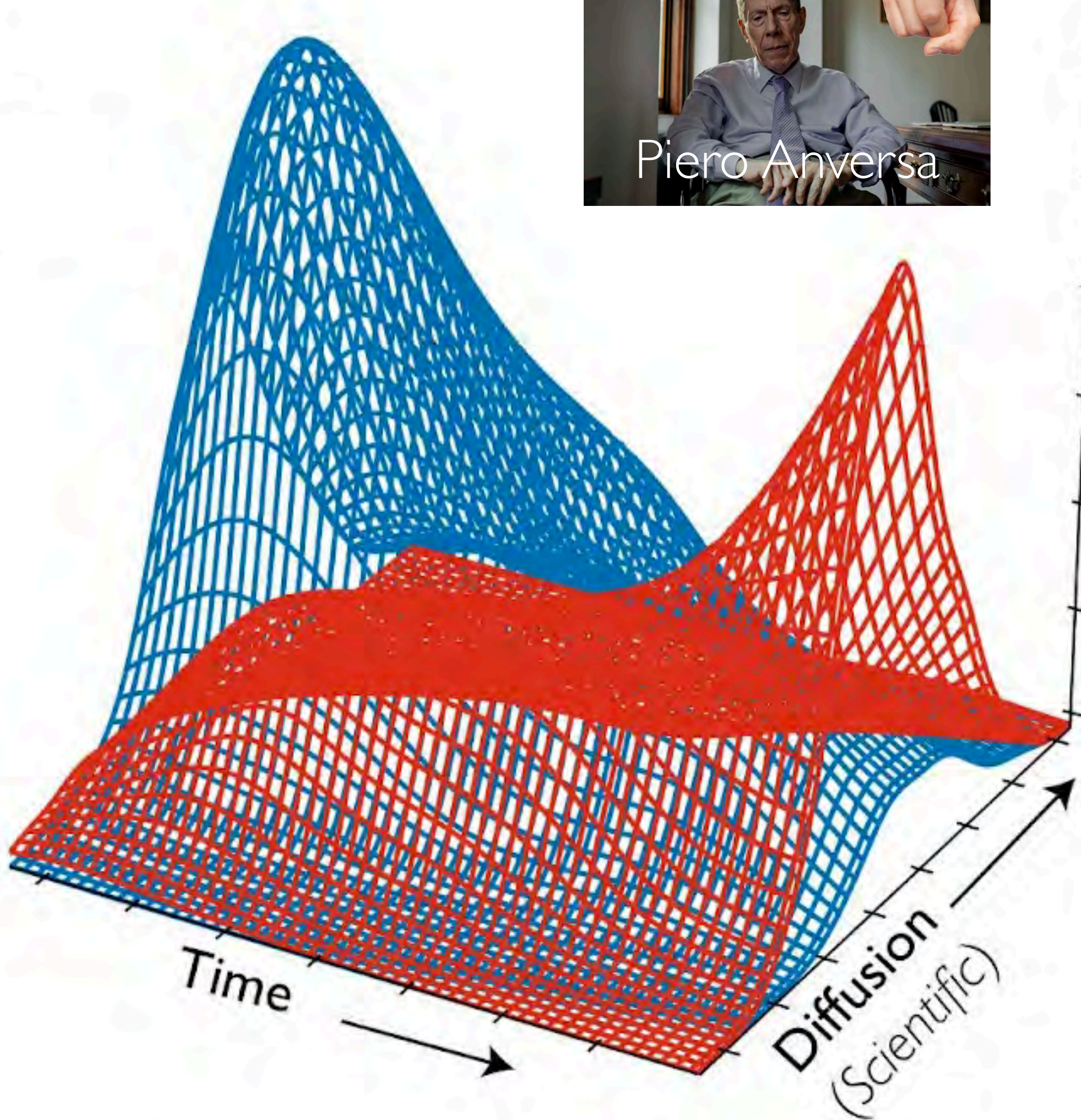
$$J(A, B) = \frac{|A \cap B|}{|A \cup B|} = \frac{|A \cap B|}{|A| + |B| - |A \cap B|}$$

Findings from Decentralized Communities

More Likely Replicate

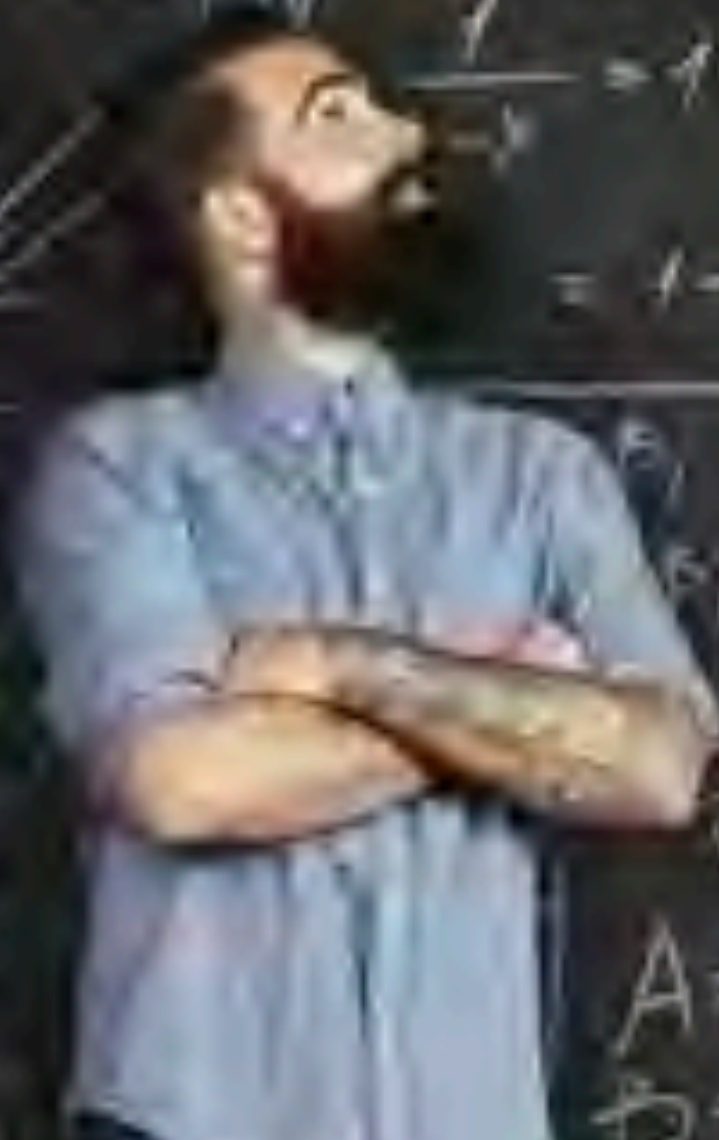


Locate (& **Burst**) Academic Bubbles

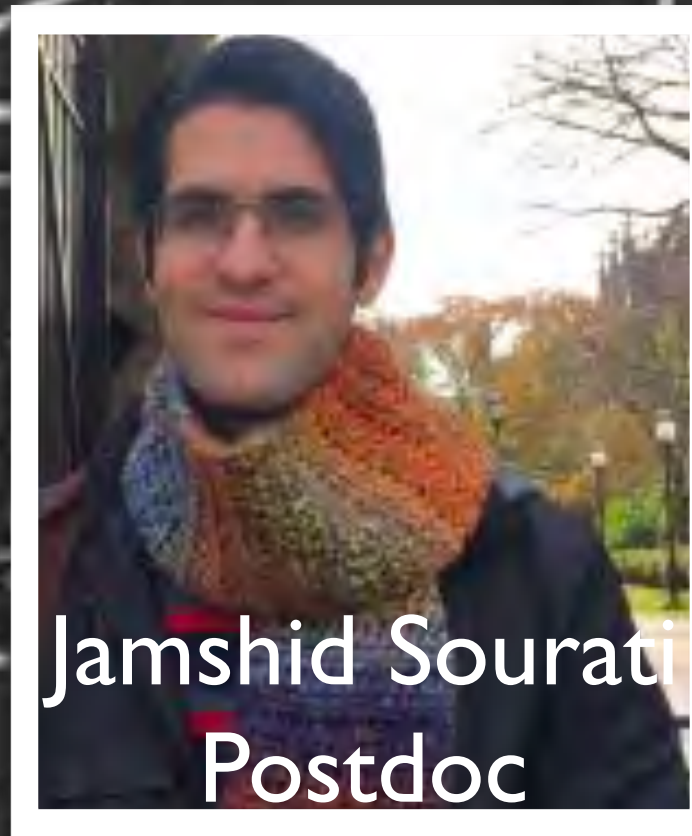


■ PMID:11777997 - Cardiac Regeneration ■ PMID:11015443 - Cancer Immunotherapy

Can we design diversity to increase collective imagination

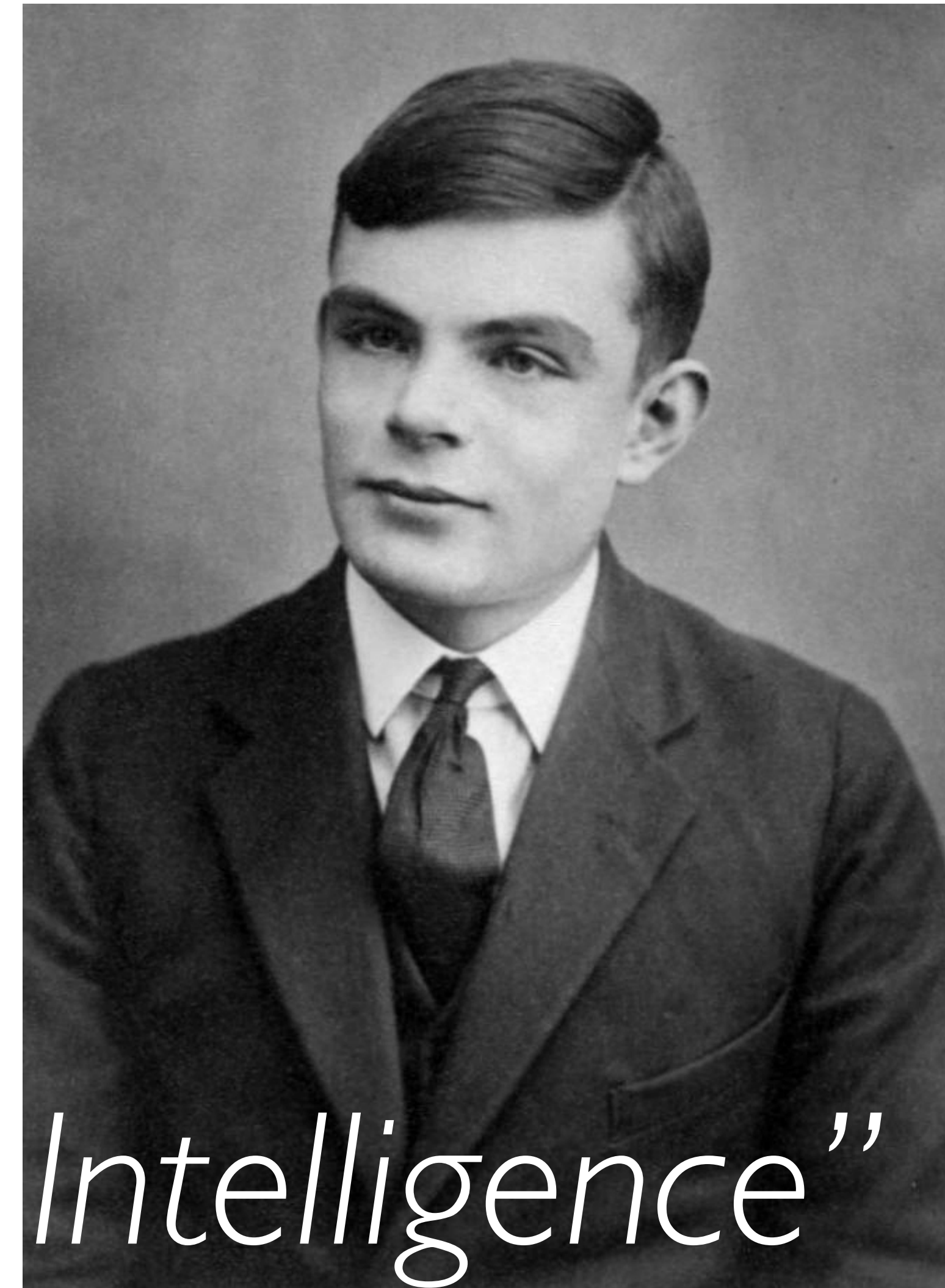
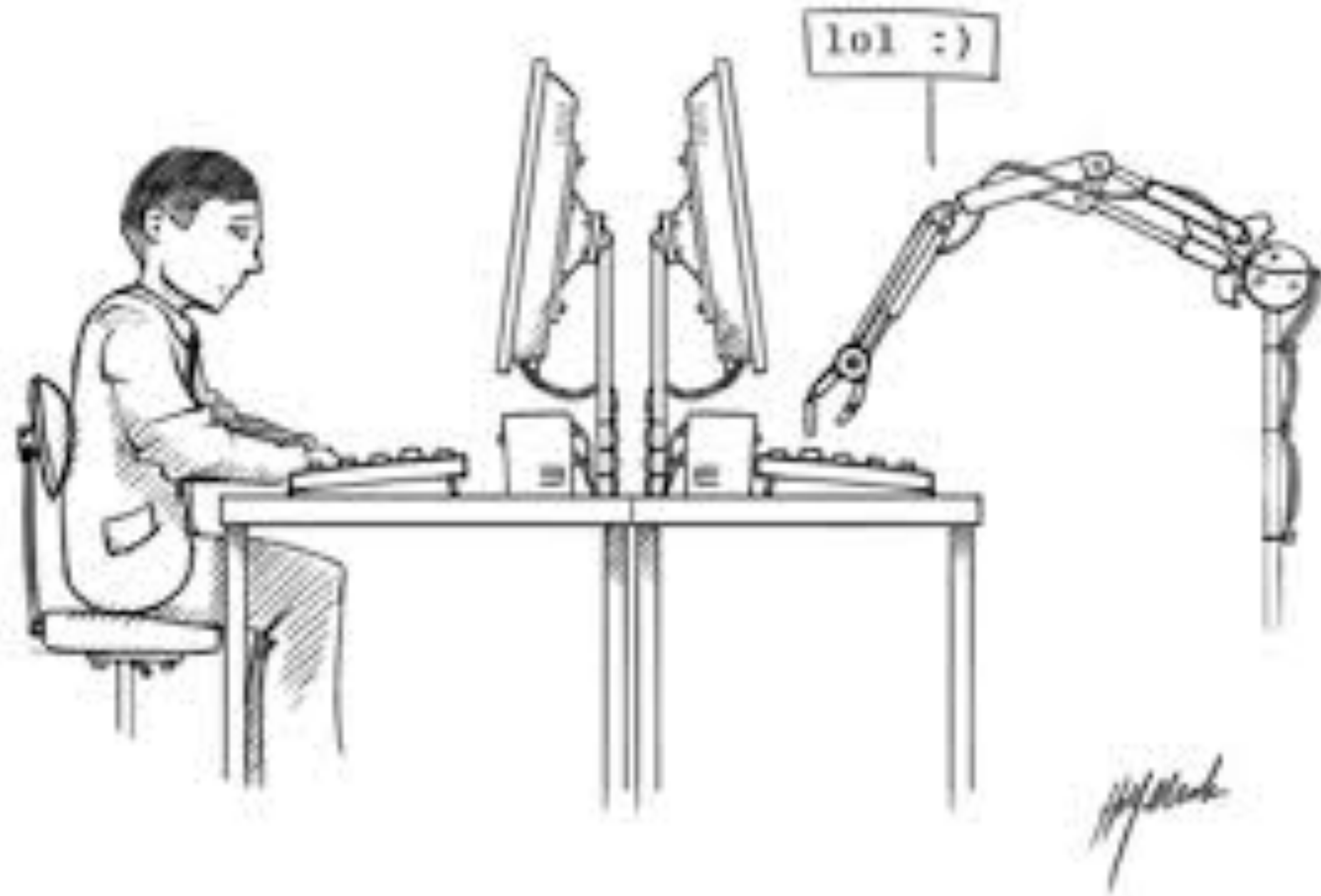


Hybrid Vigor



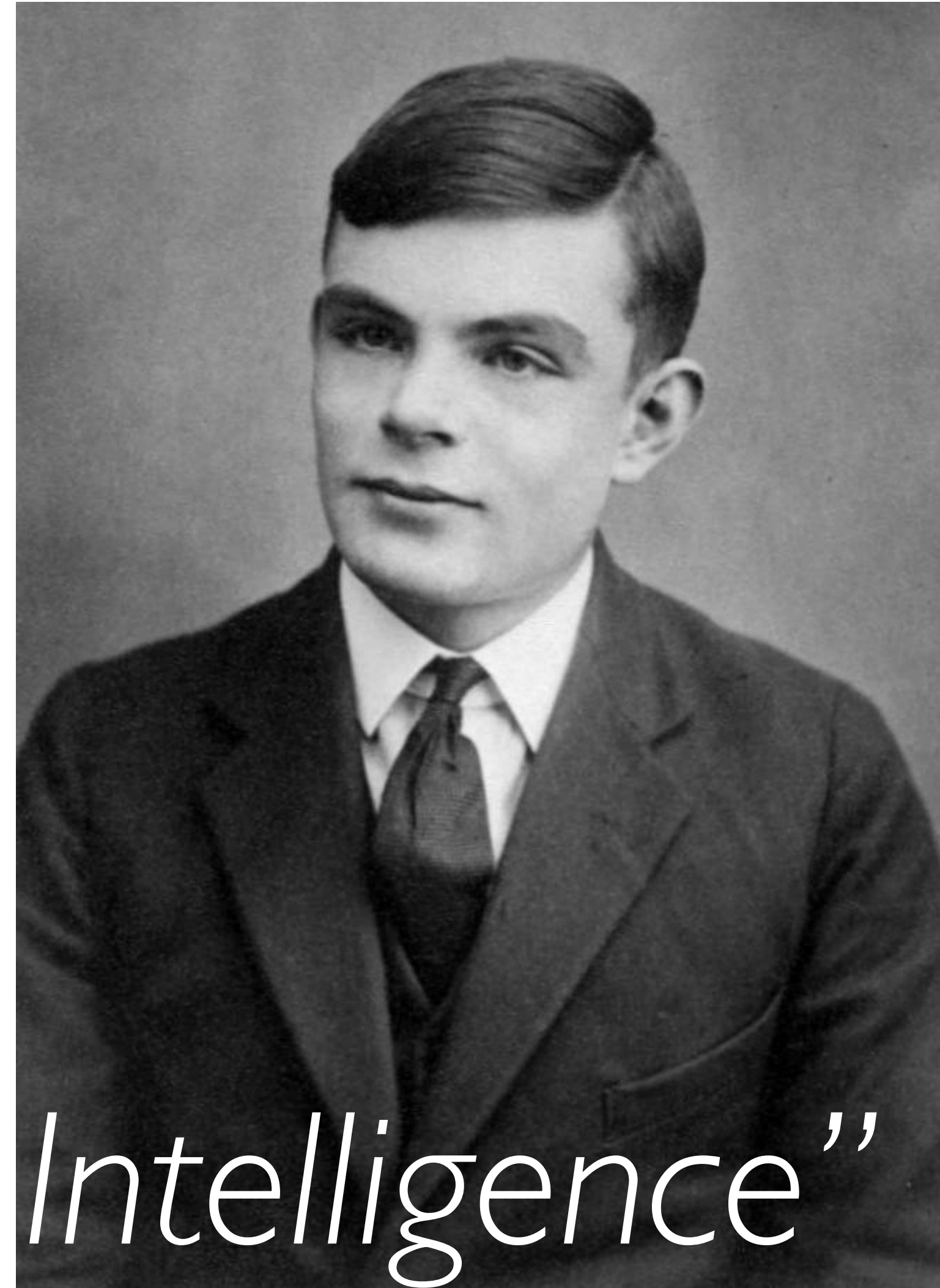
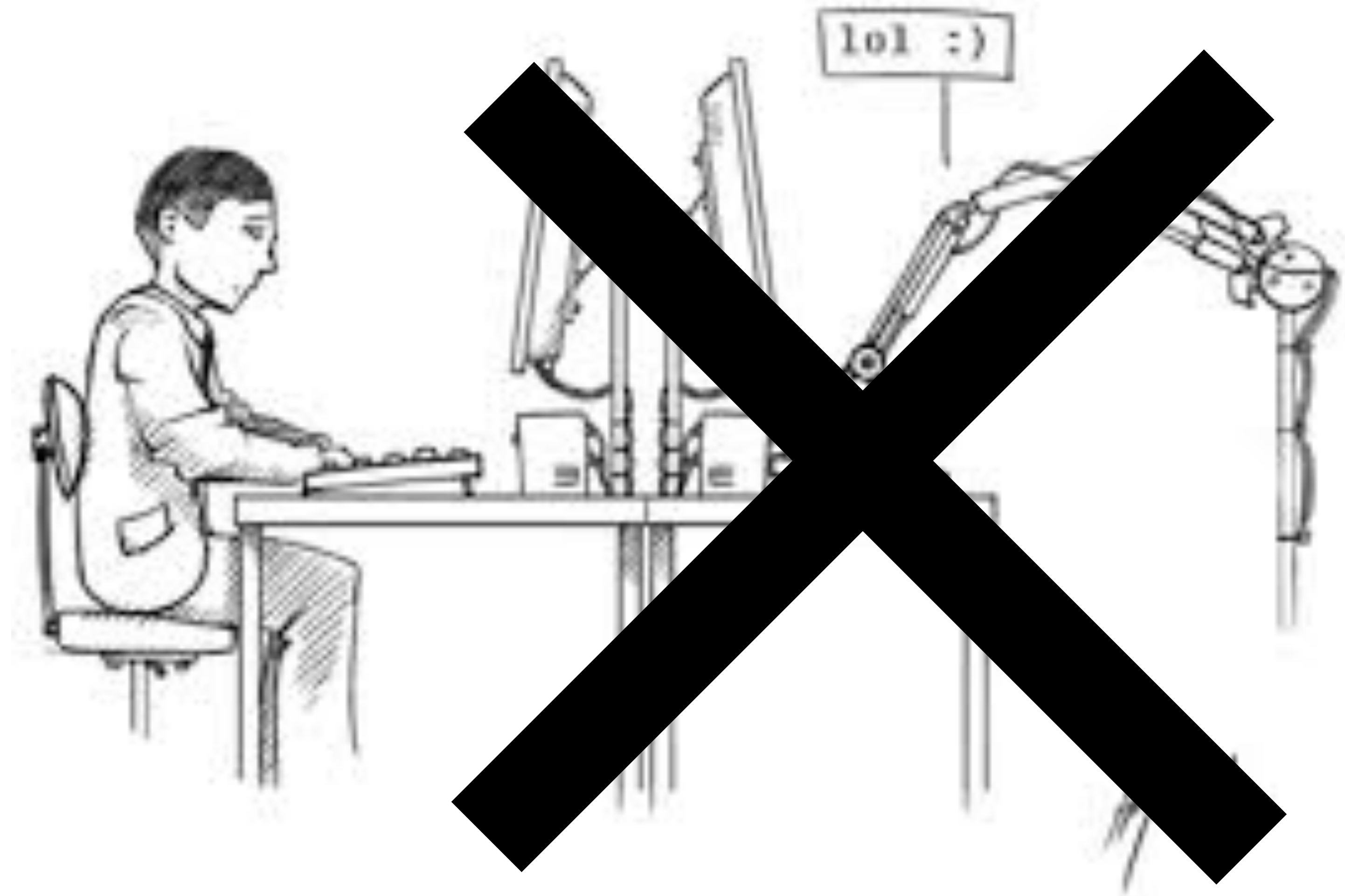
Jamshid Sourati
Postdoc

Alan Turing's 'Immitation Game'



in *"Computing Machinery & Intelligence"*

Alan Turing's 'Immitation Game'



in *“Computing Machinery & Intelligence”*






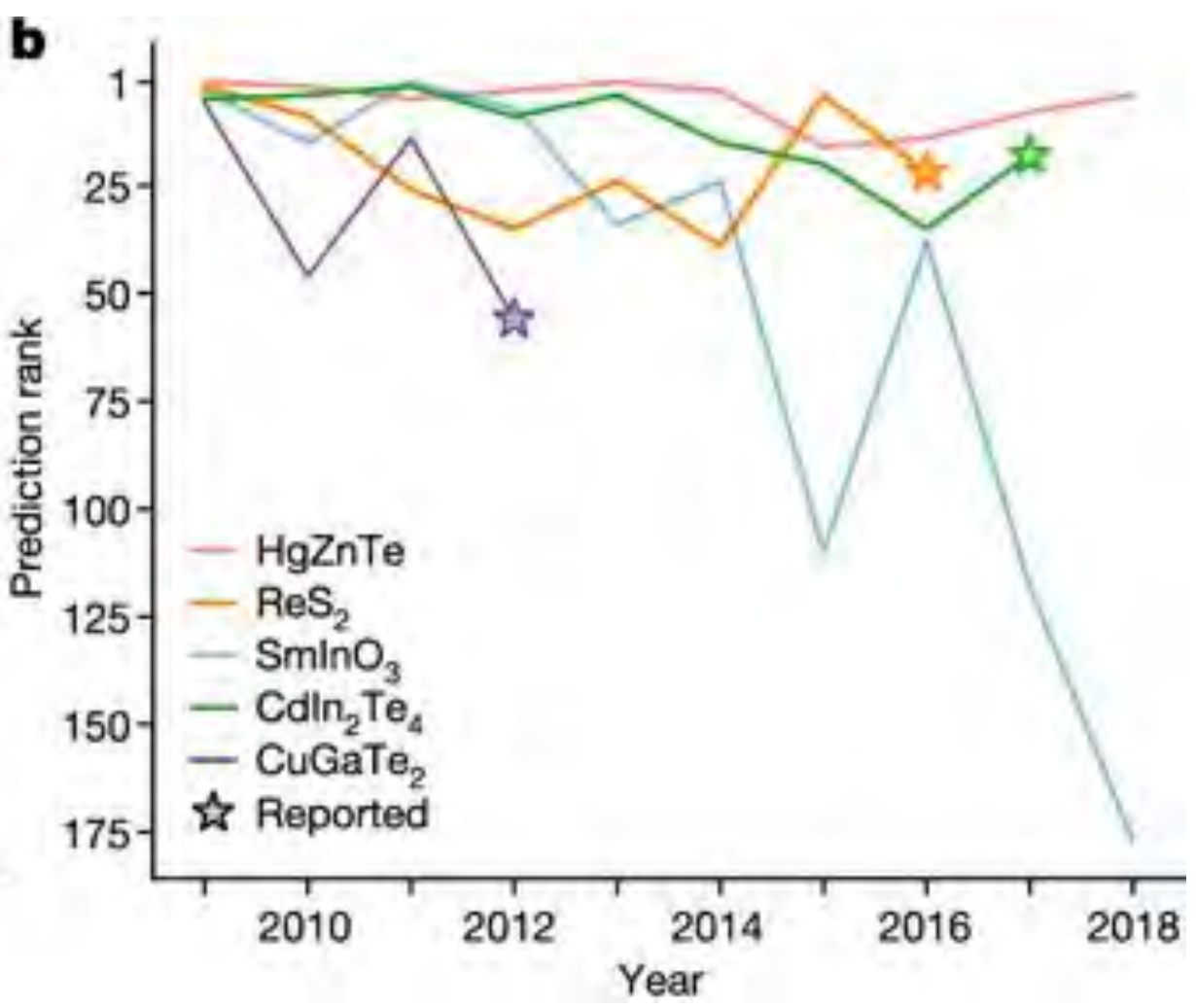
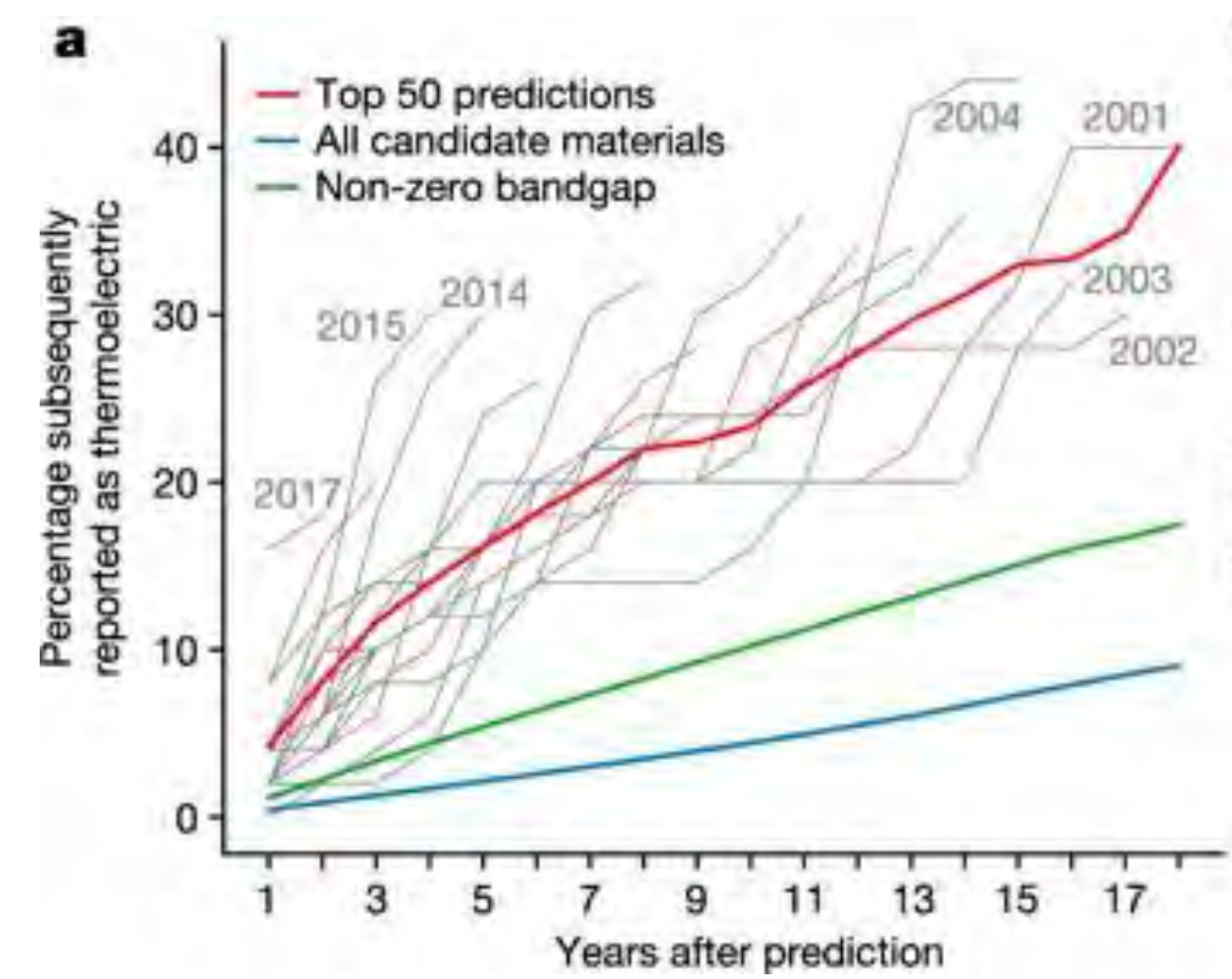
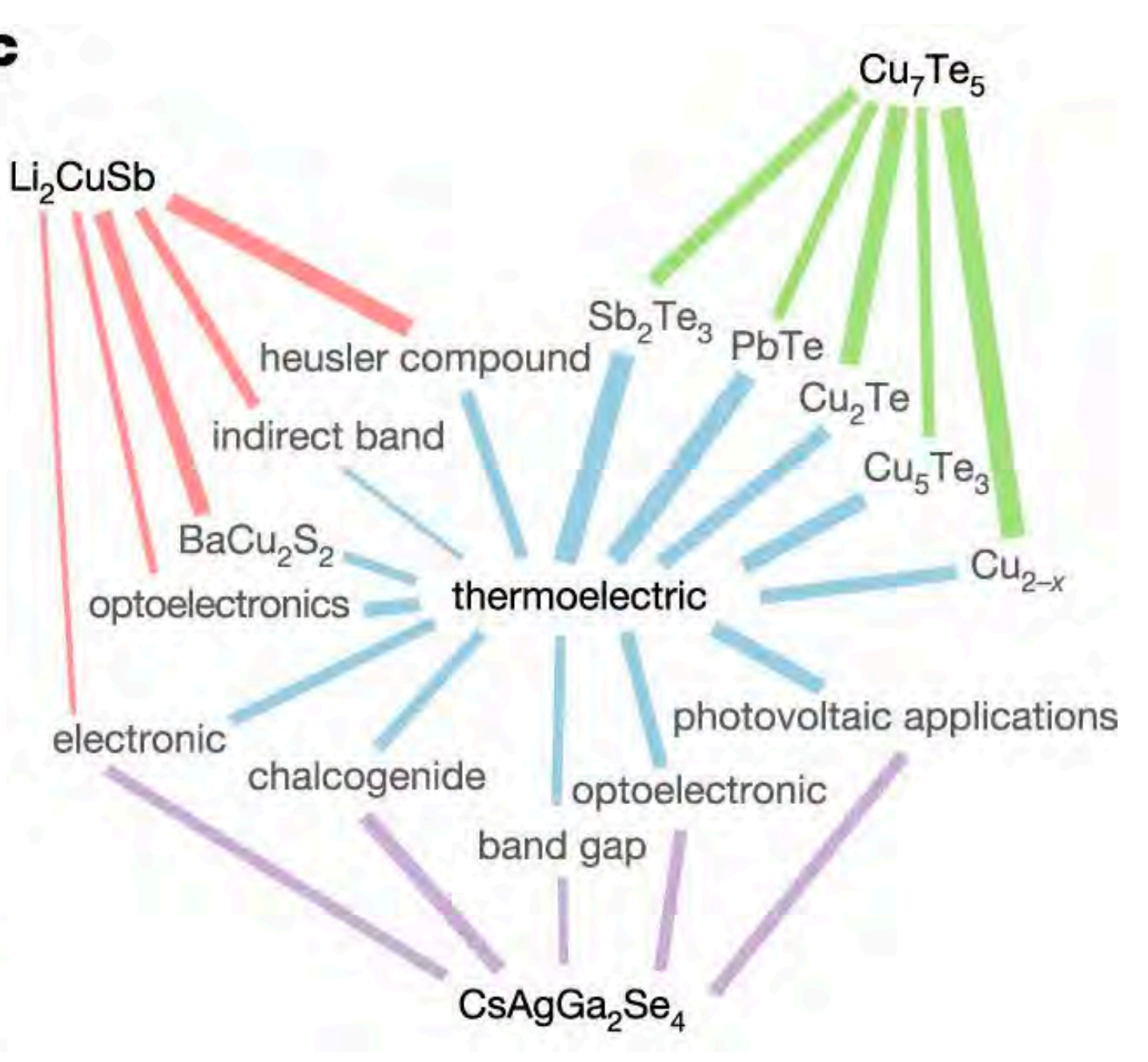
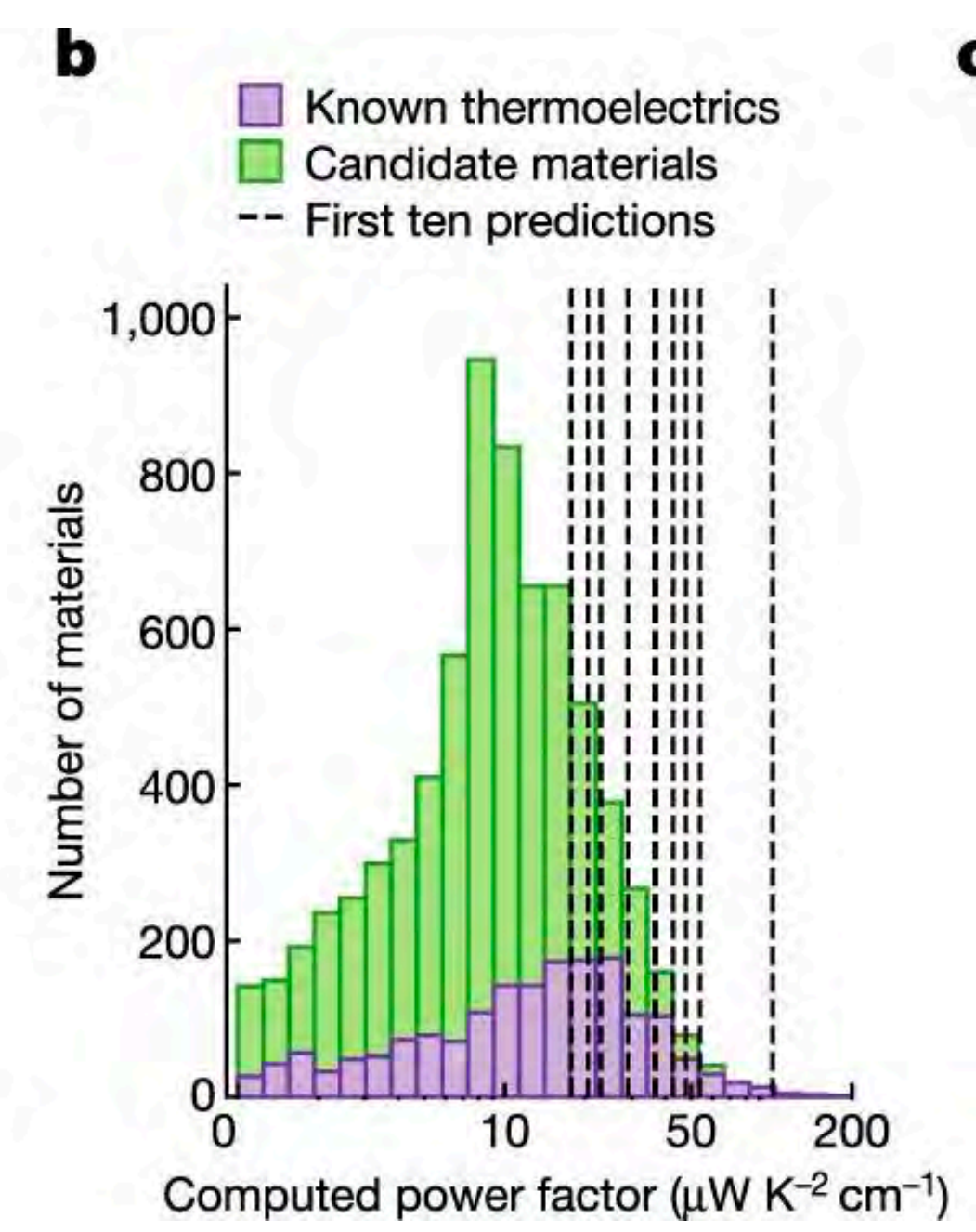
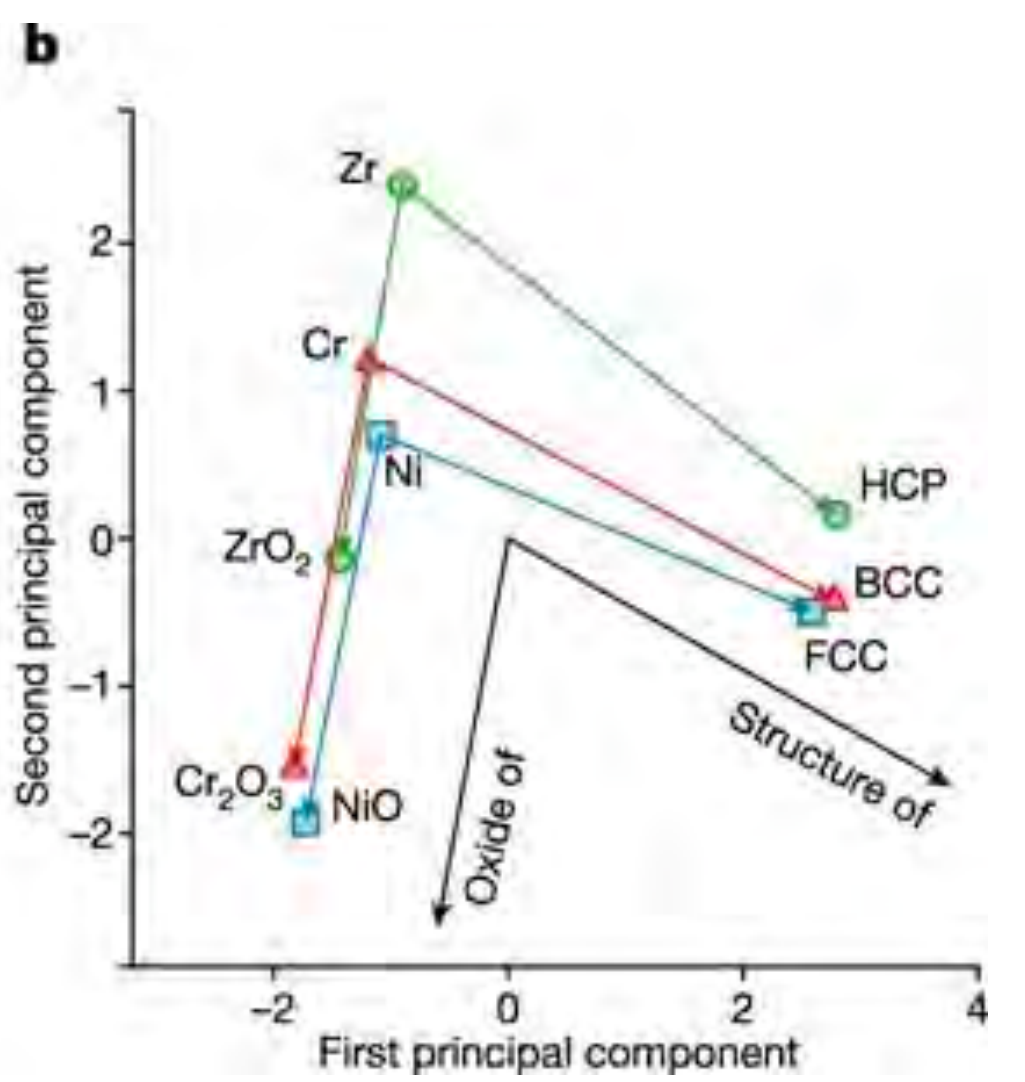
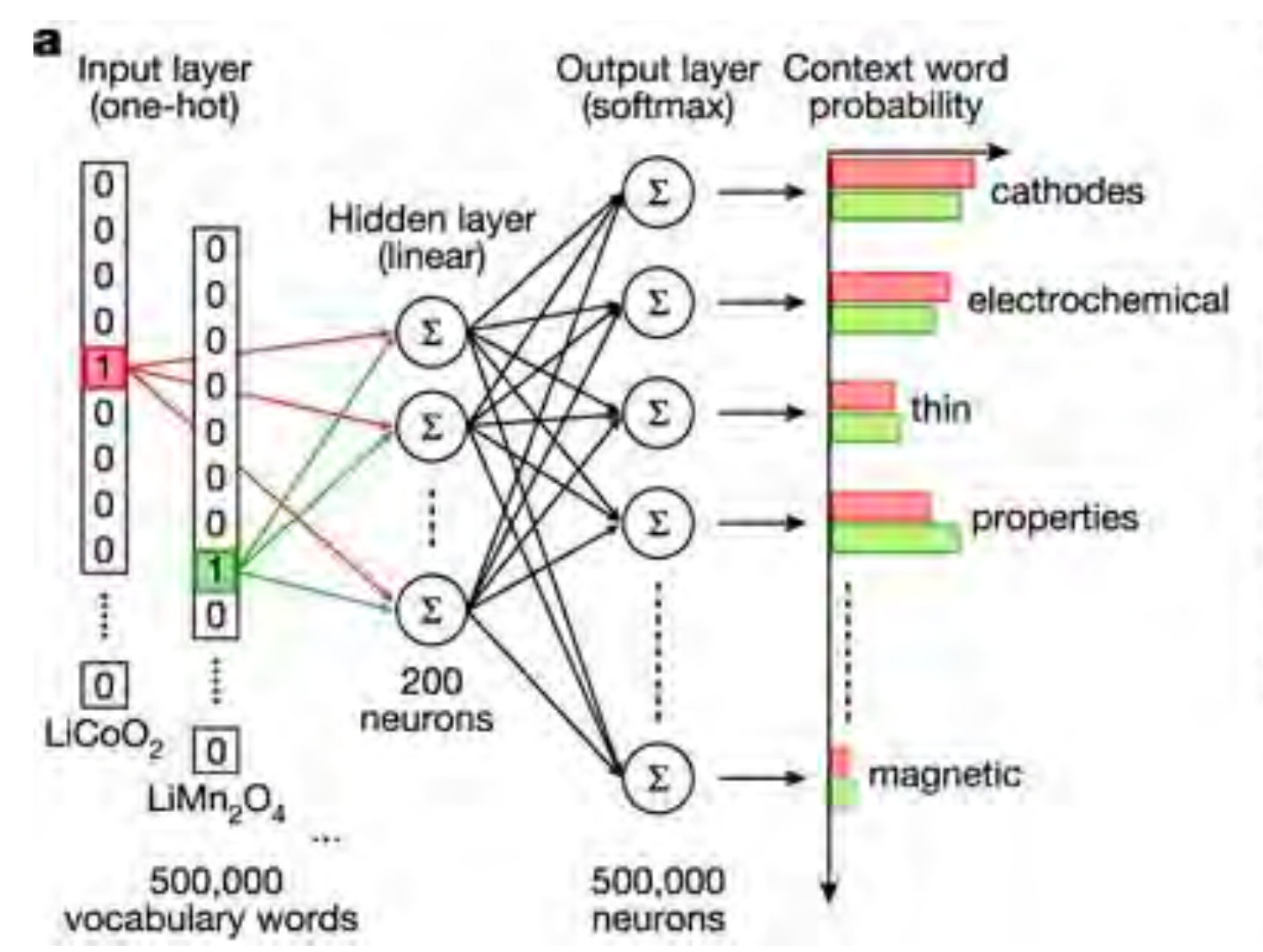
Alien Intelligences

Think Differently

Letter | Published: 03 July 2019

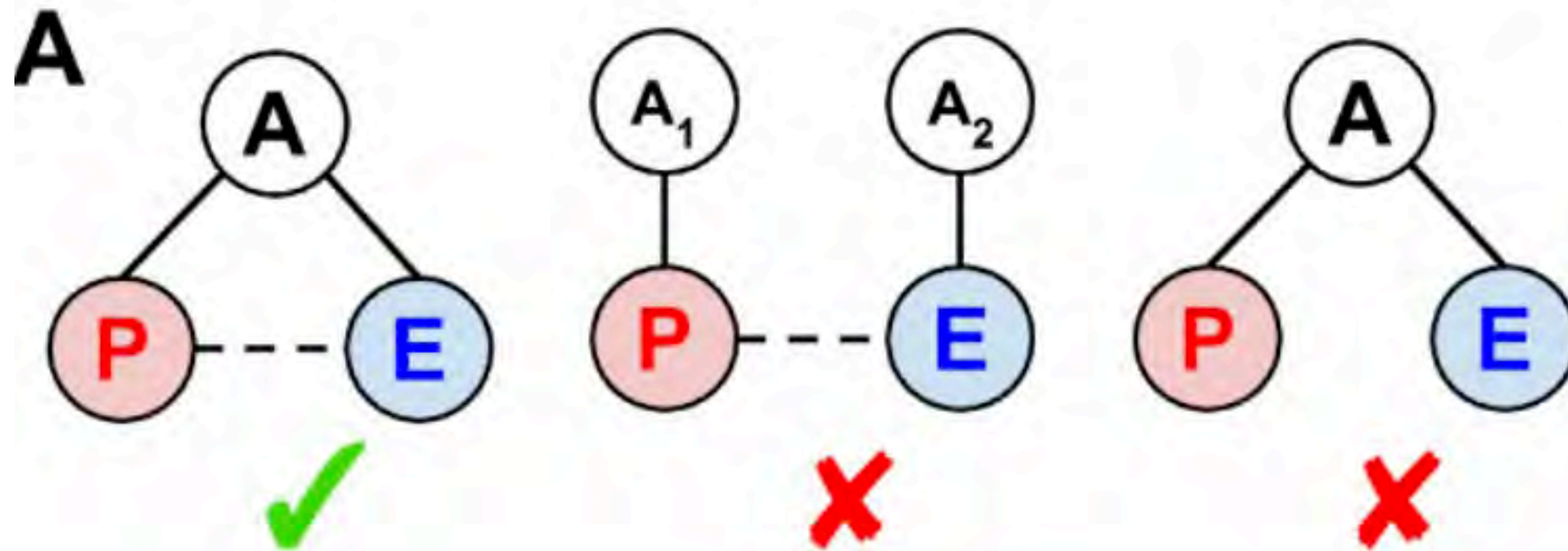
Unsupervised word embeddings capture latent knowledge from materials science literature

Vahe Tshitoyan , John Dagdelen, Leigh Weston, Alexander Dunn, Ziqin Rong, Olga Kononova, Kristin A. Persson, Gerbrand Ceder  & Anubhav Jain 

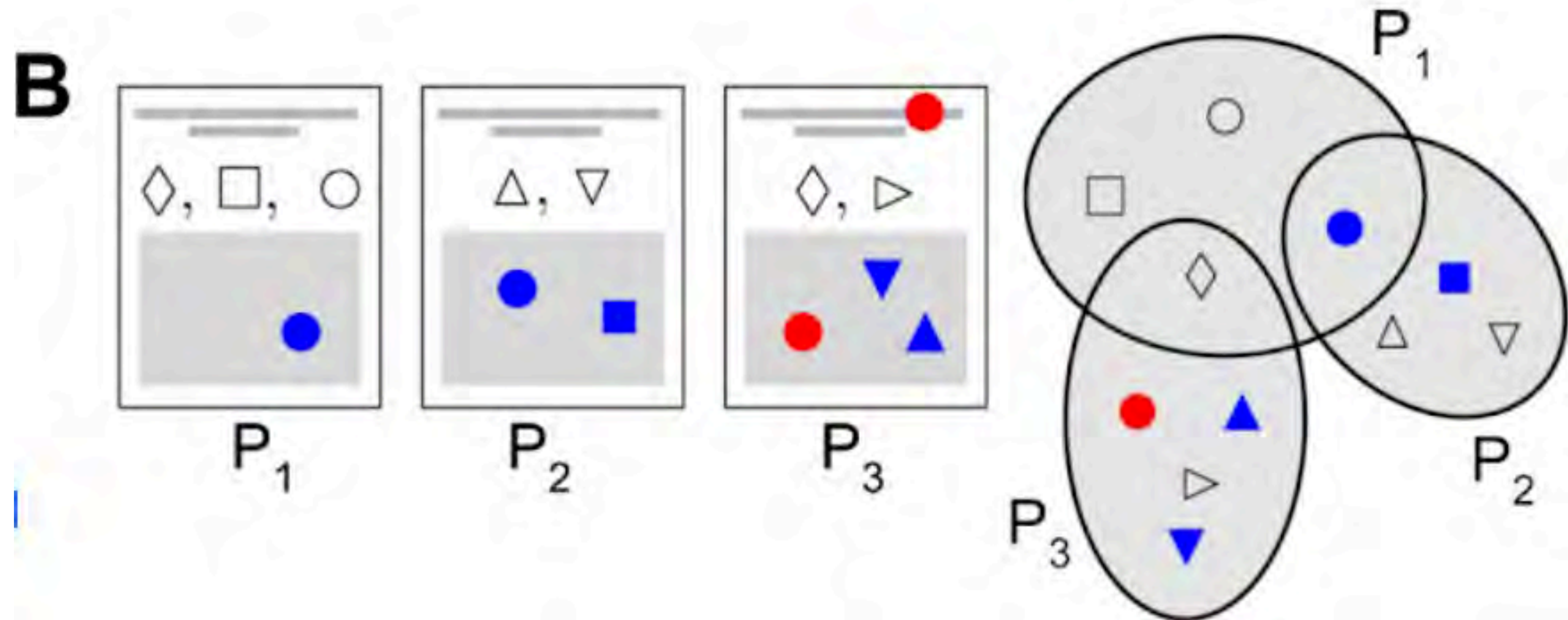


40% Precision

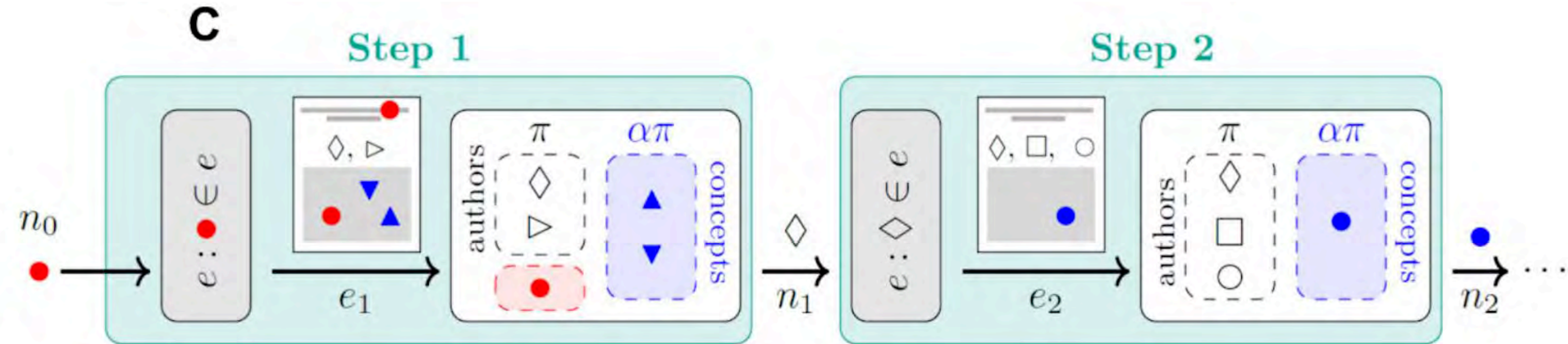
What Inferences are Most Likely Cognitively?



What Inferences are Most Likely Cognitively?



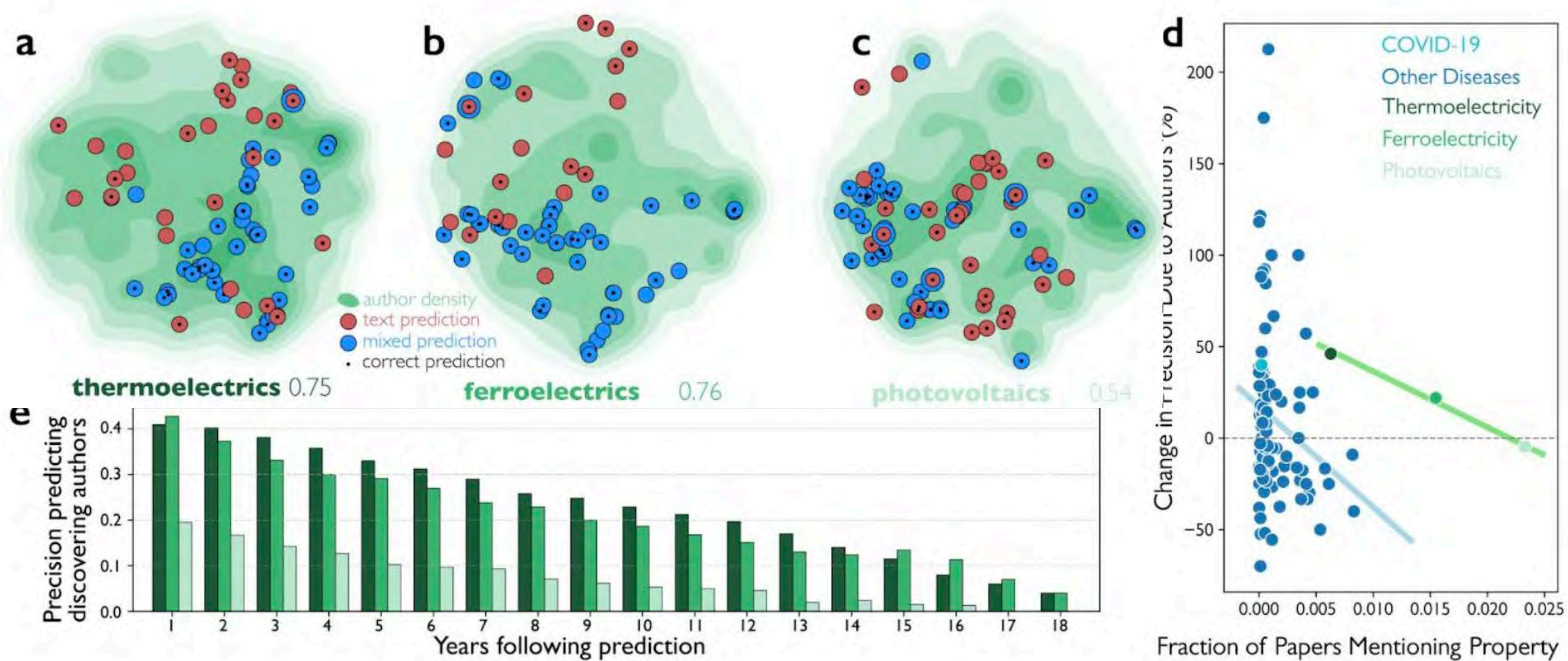
What Inferences are Most Likely Cognitively?



$$n_i \sim \pi \mathcal{U} \left(e_i \text{ authors} \cup \{\bullet\} \right) + \alpha \pi \mathcal{U} \left(e_i \text{ entities} \right)$$

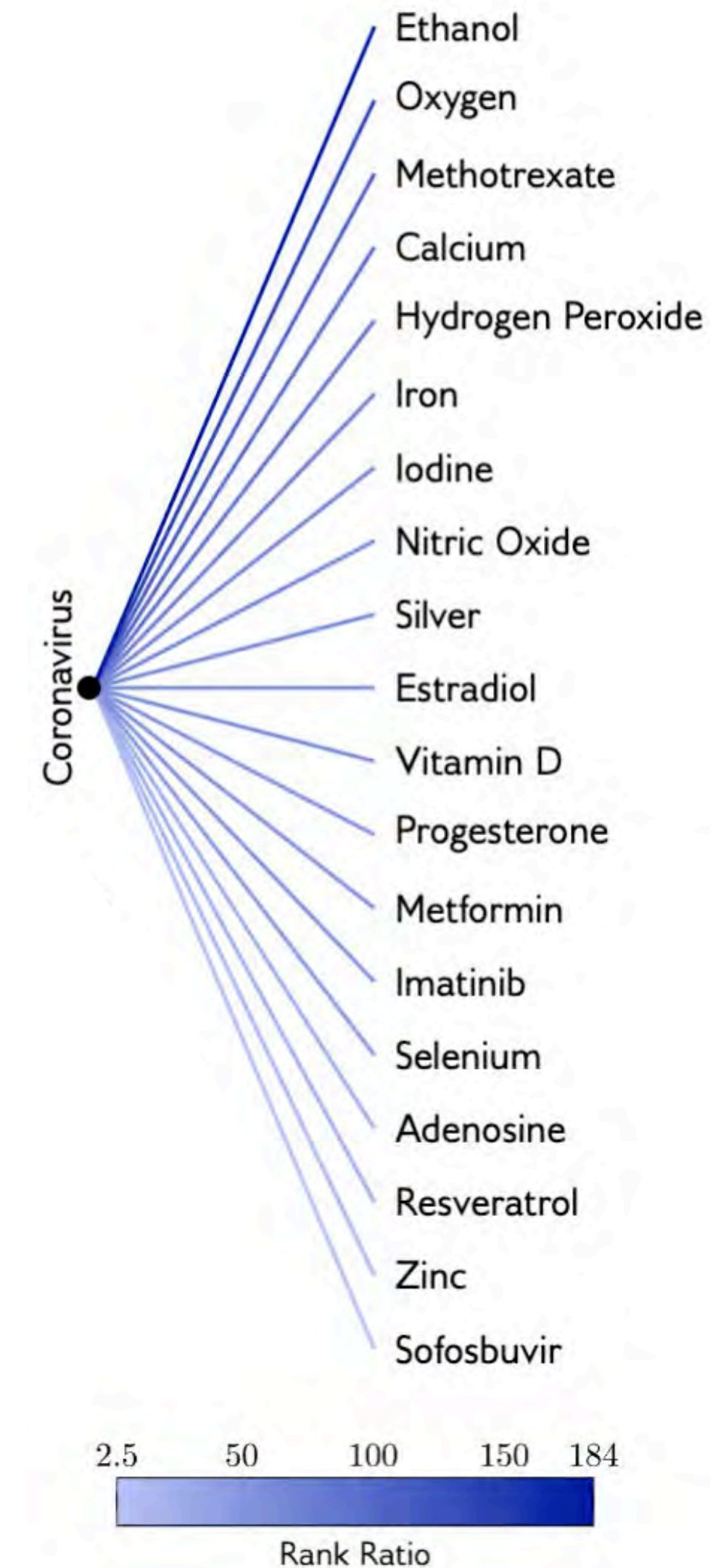
\mathcal{U} : uniform distribution

Why/When?

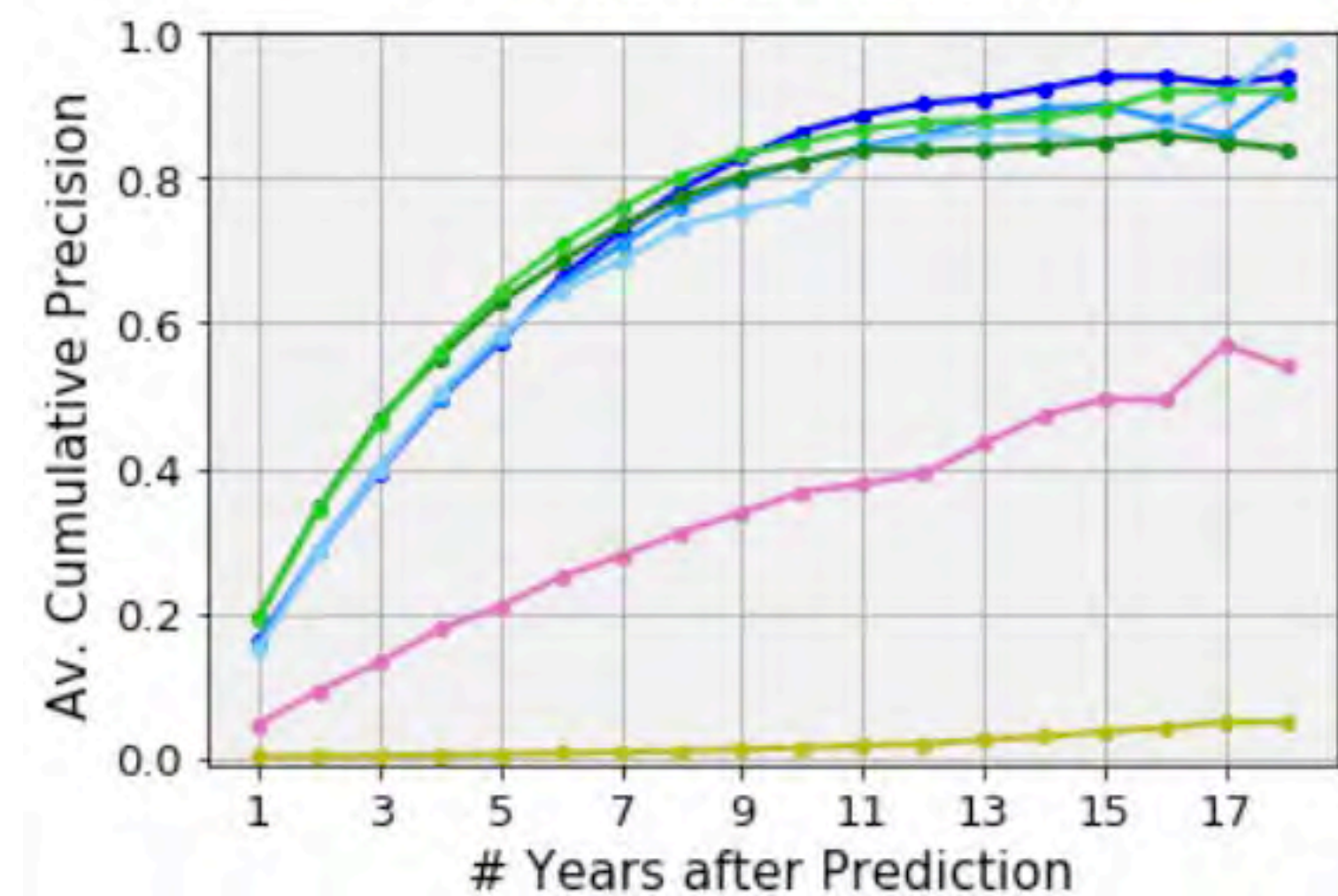
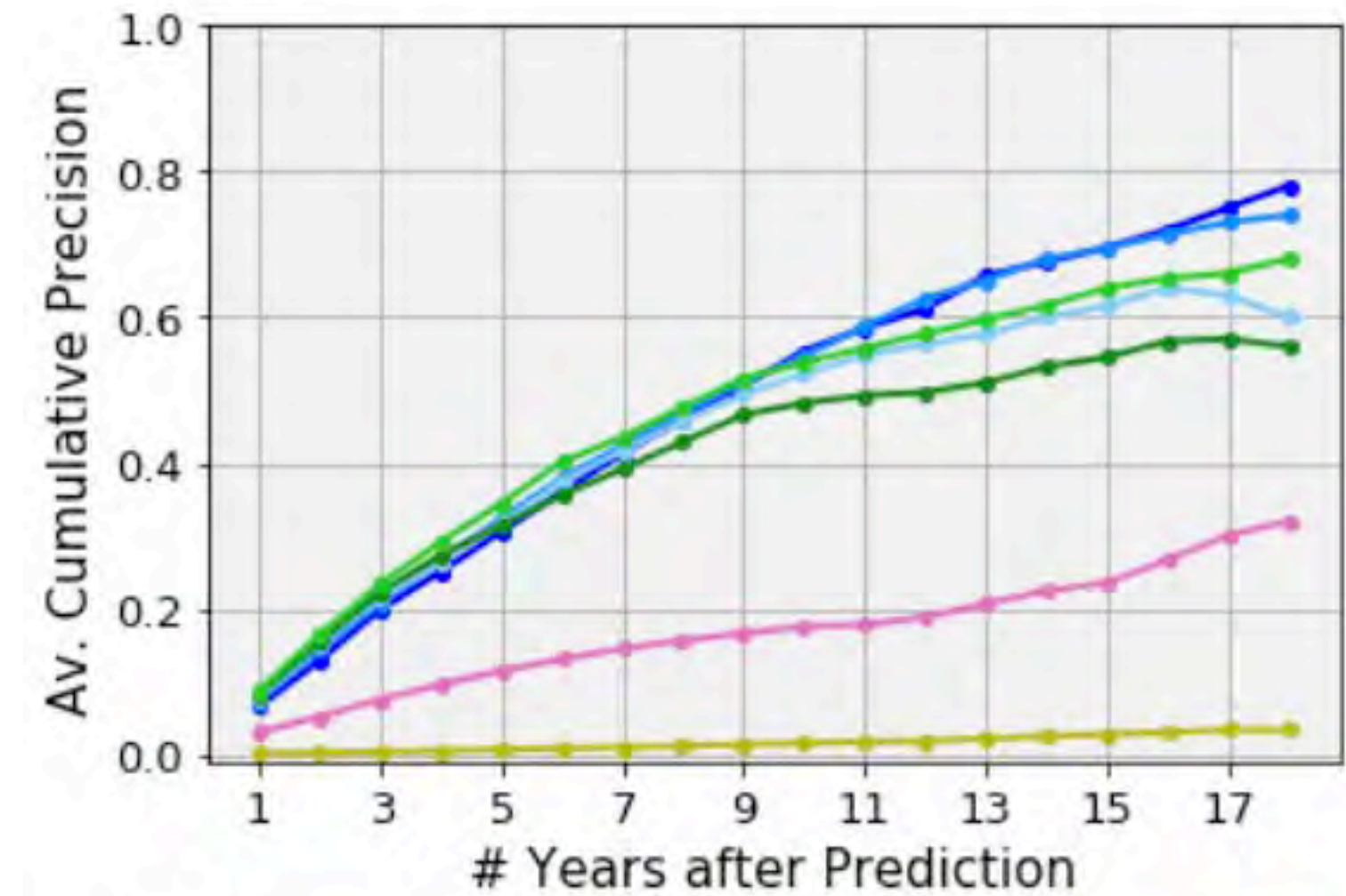
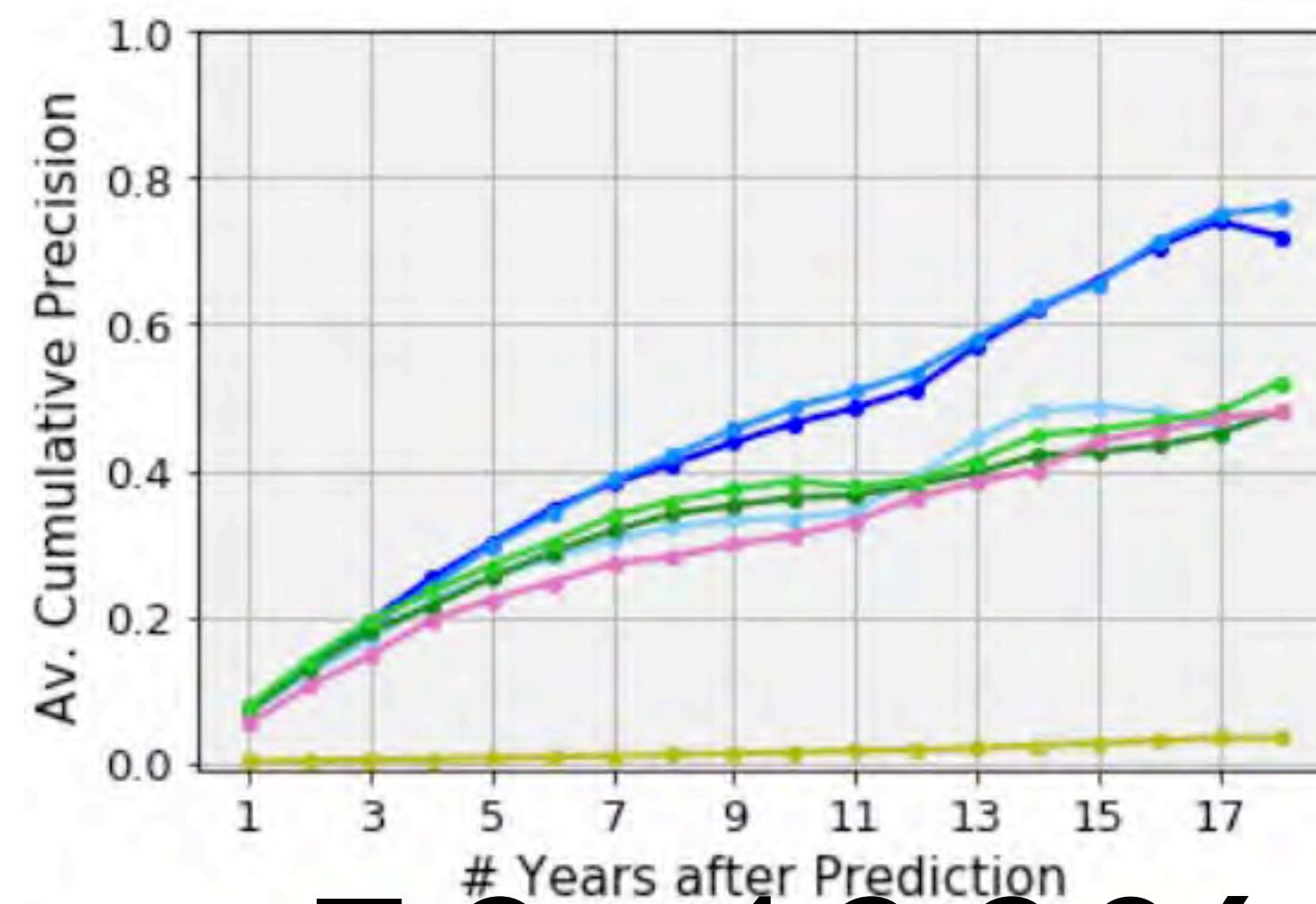
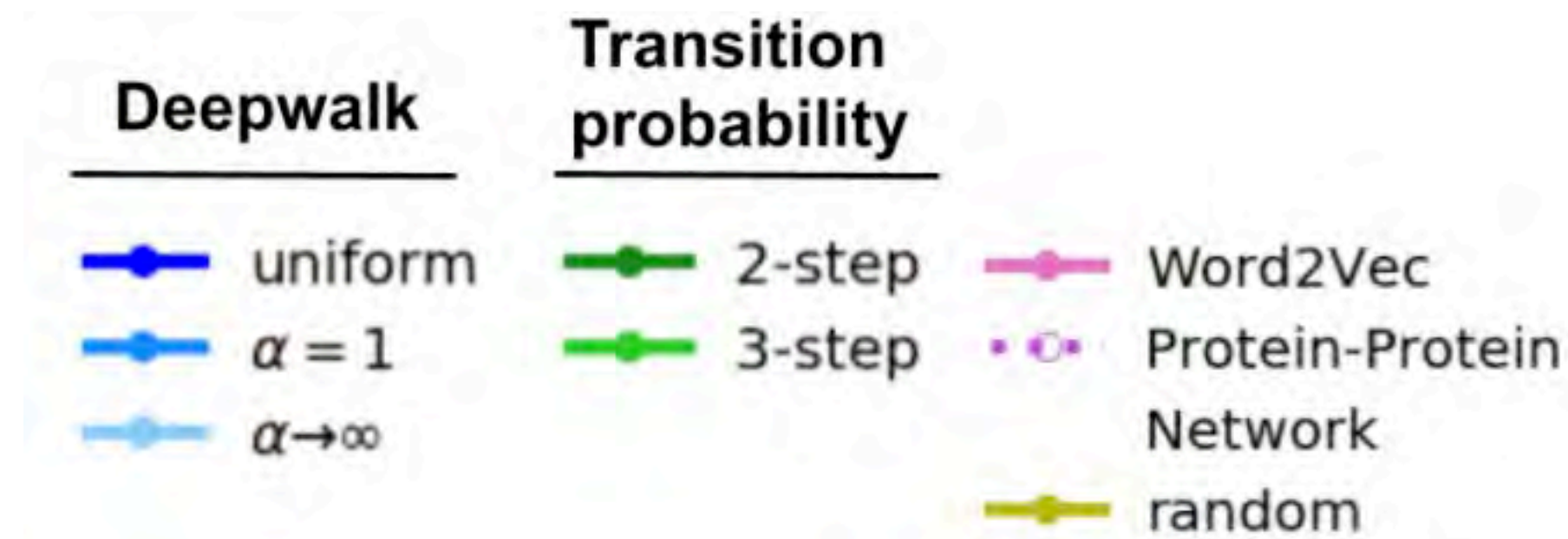
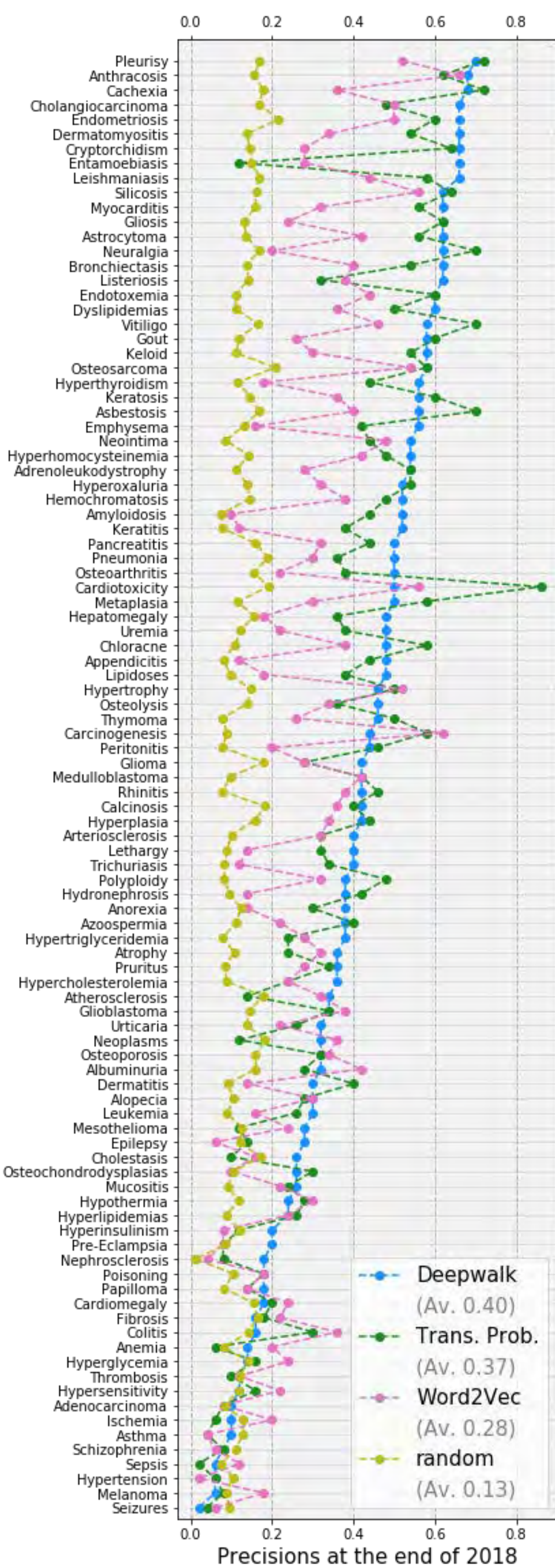


Predicting Cognitively Available Inference

Tracing Discovery In Science

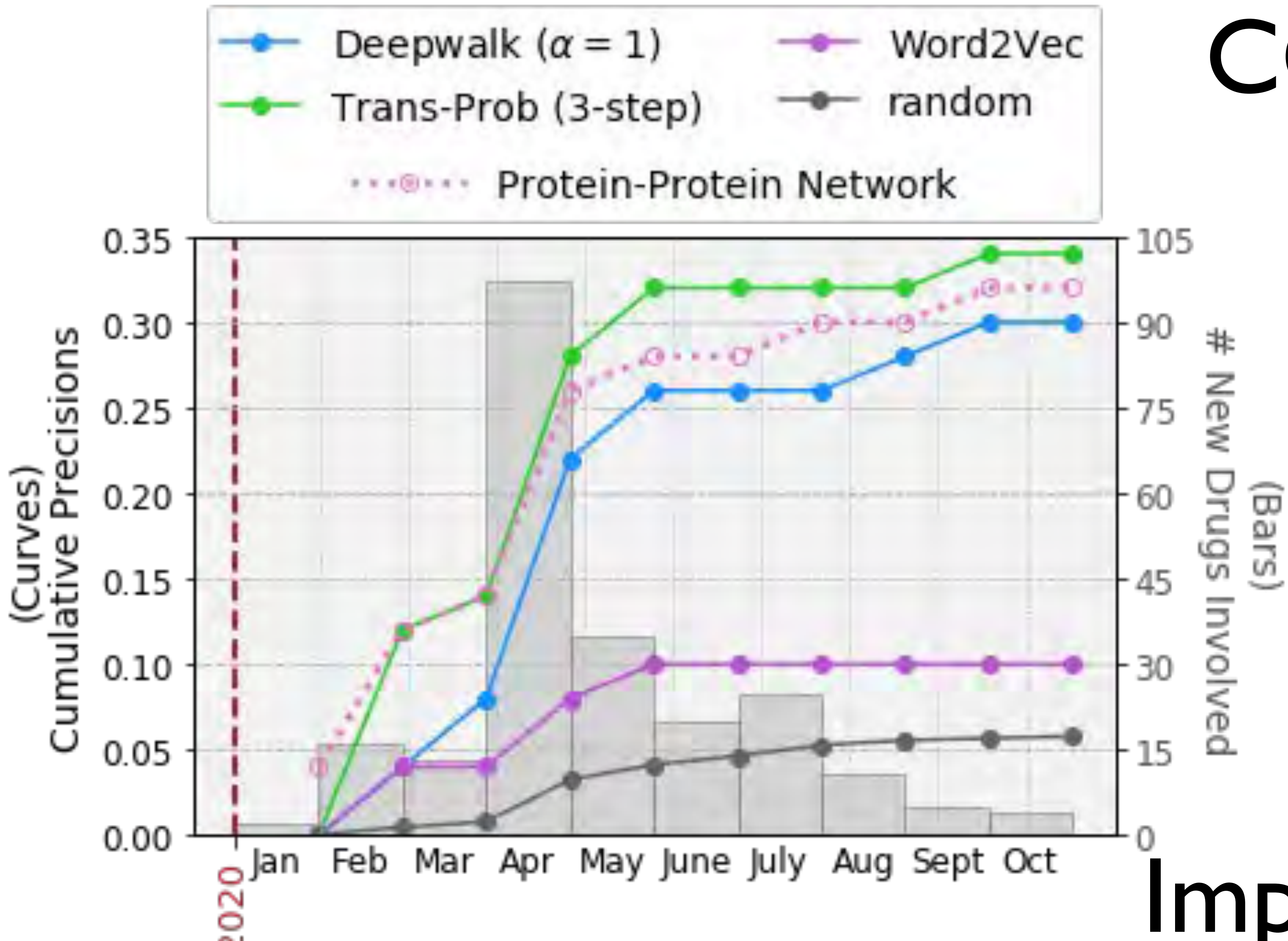


100 Drugs; 450 Diseases



50-400% Improvement

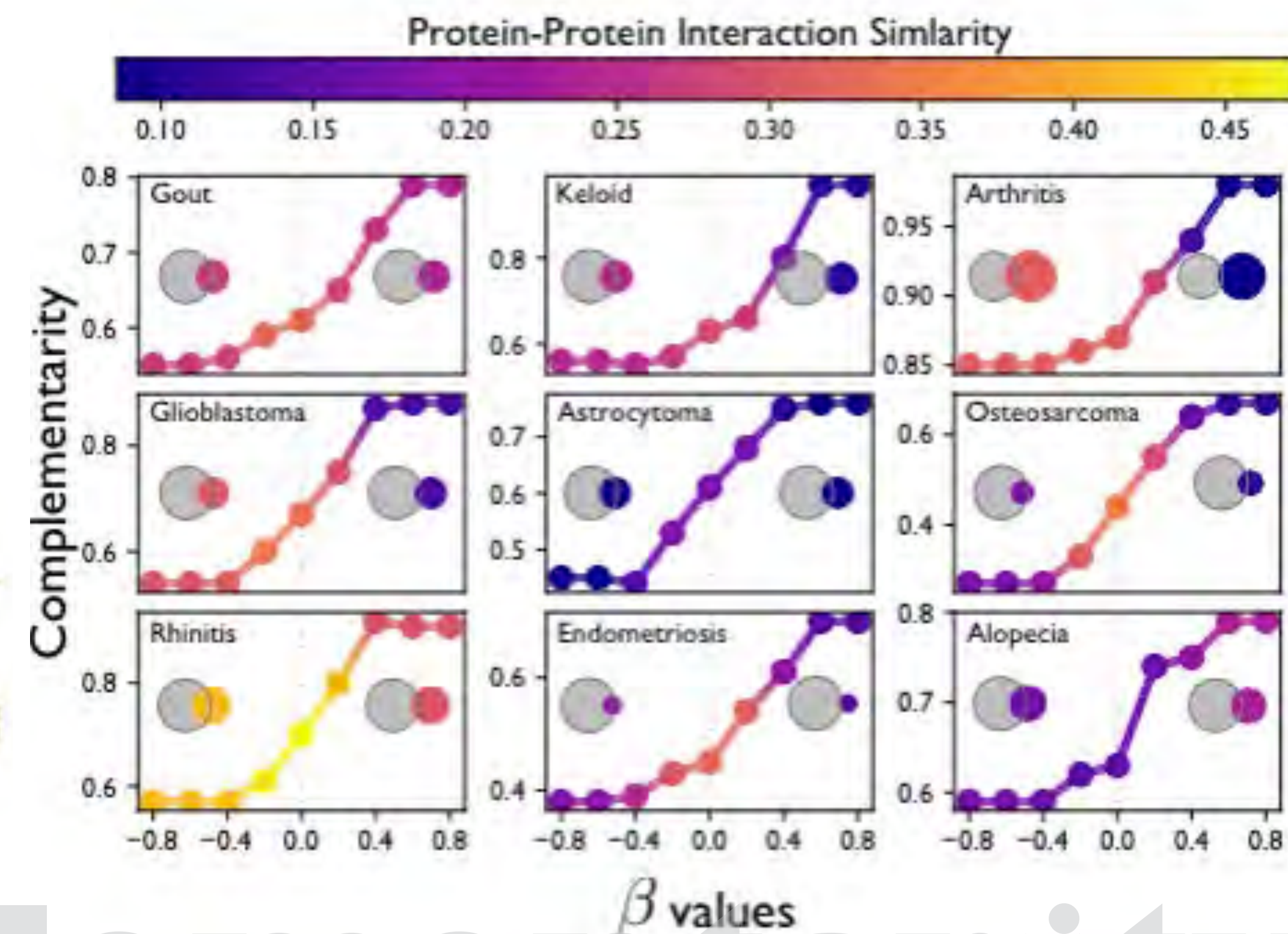
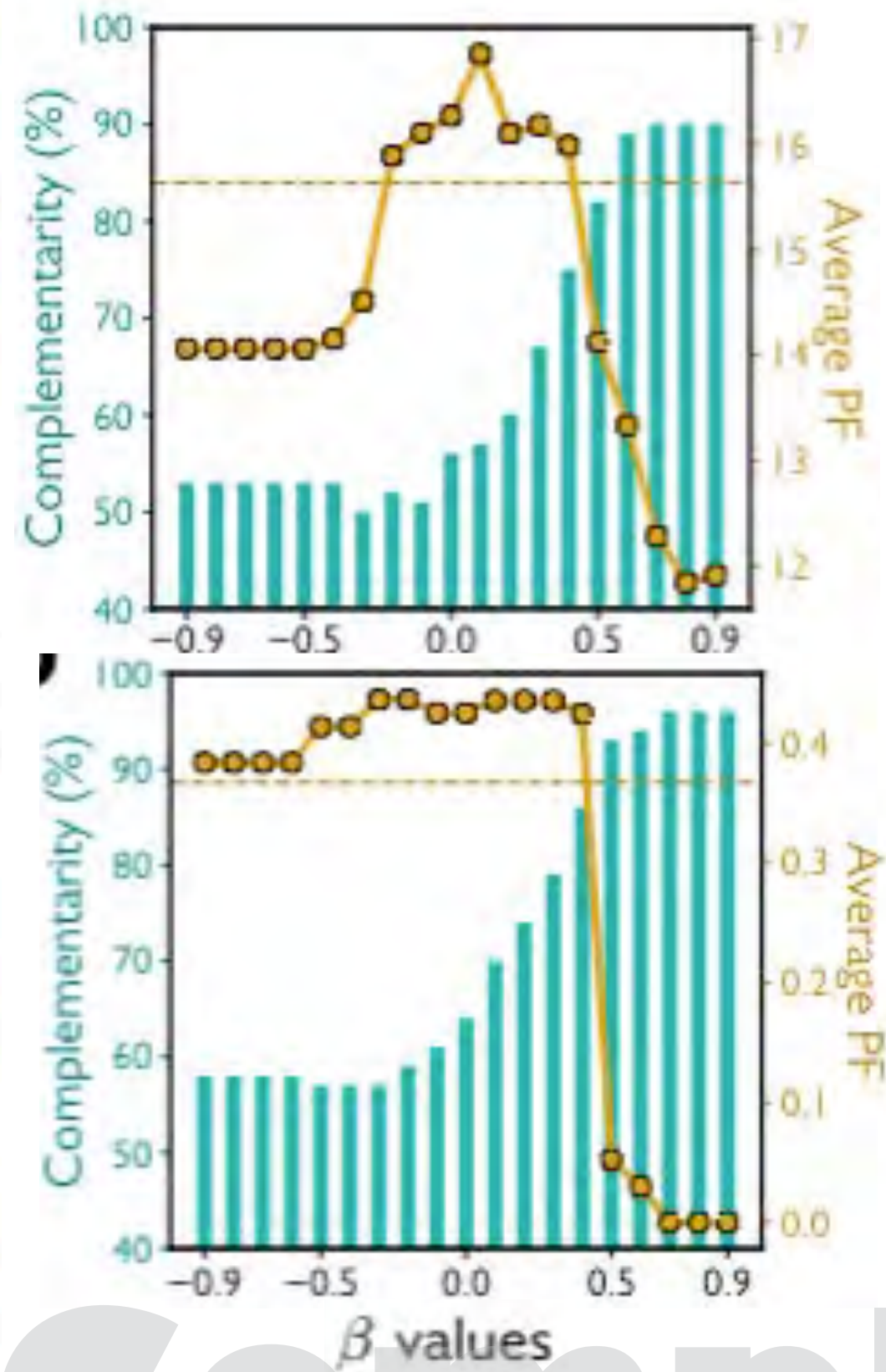
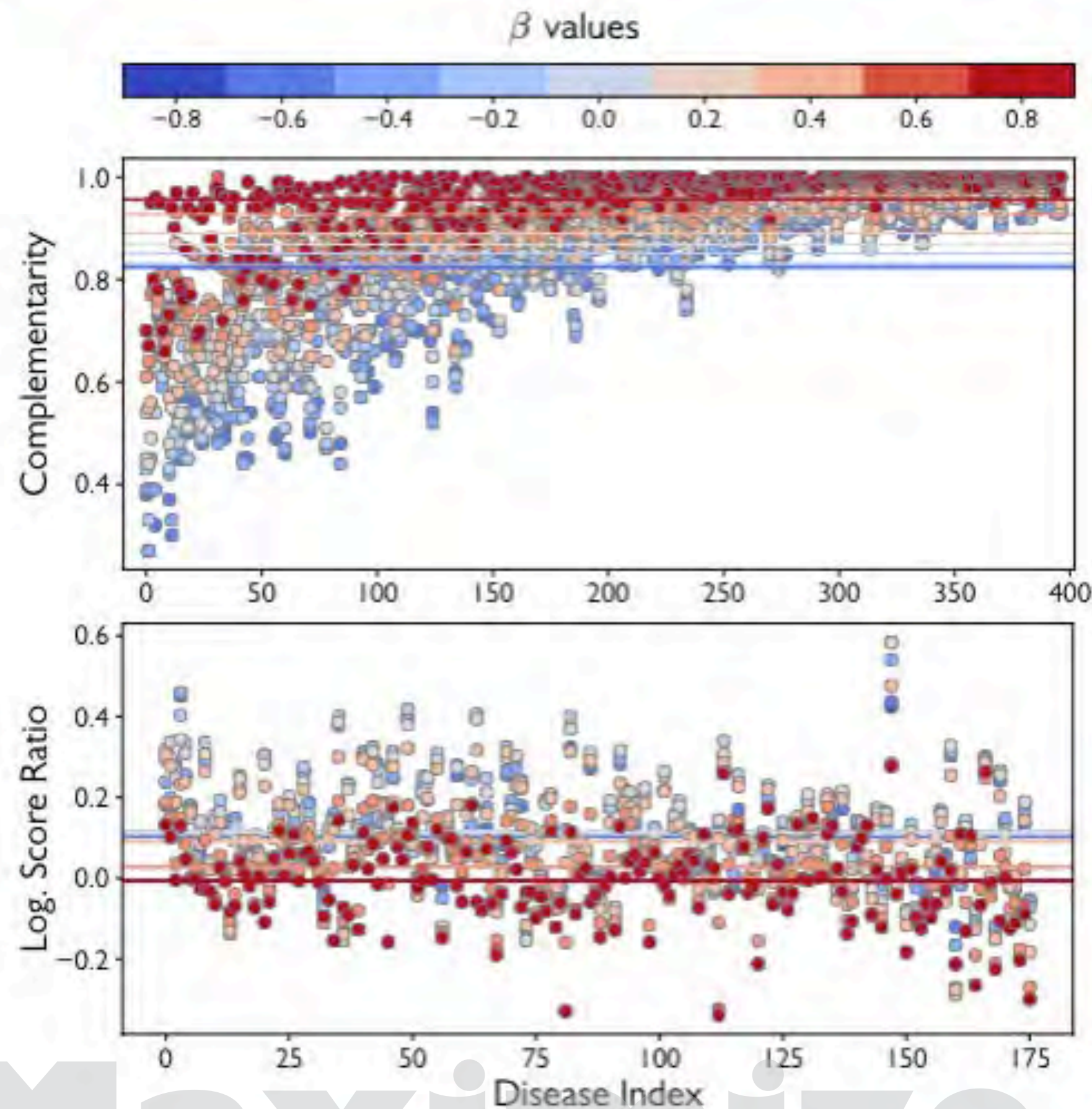
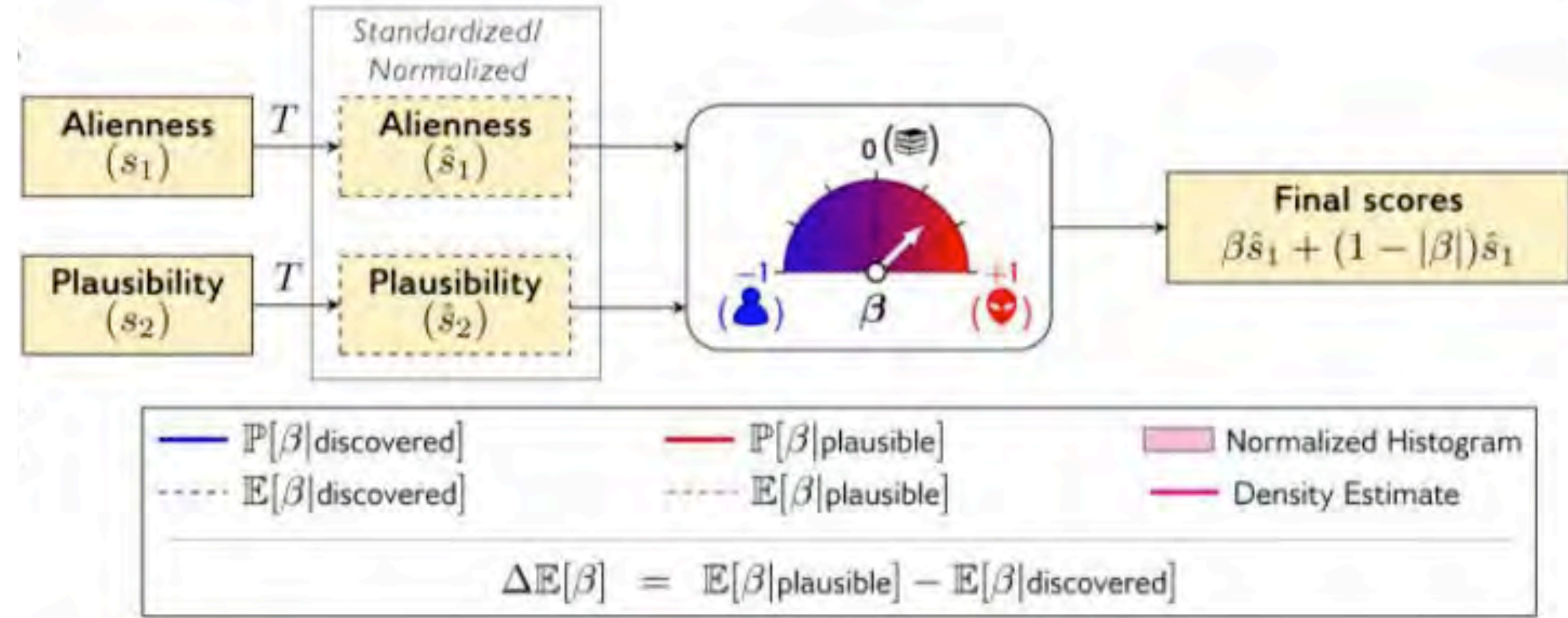
COVID-19 Search



400%

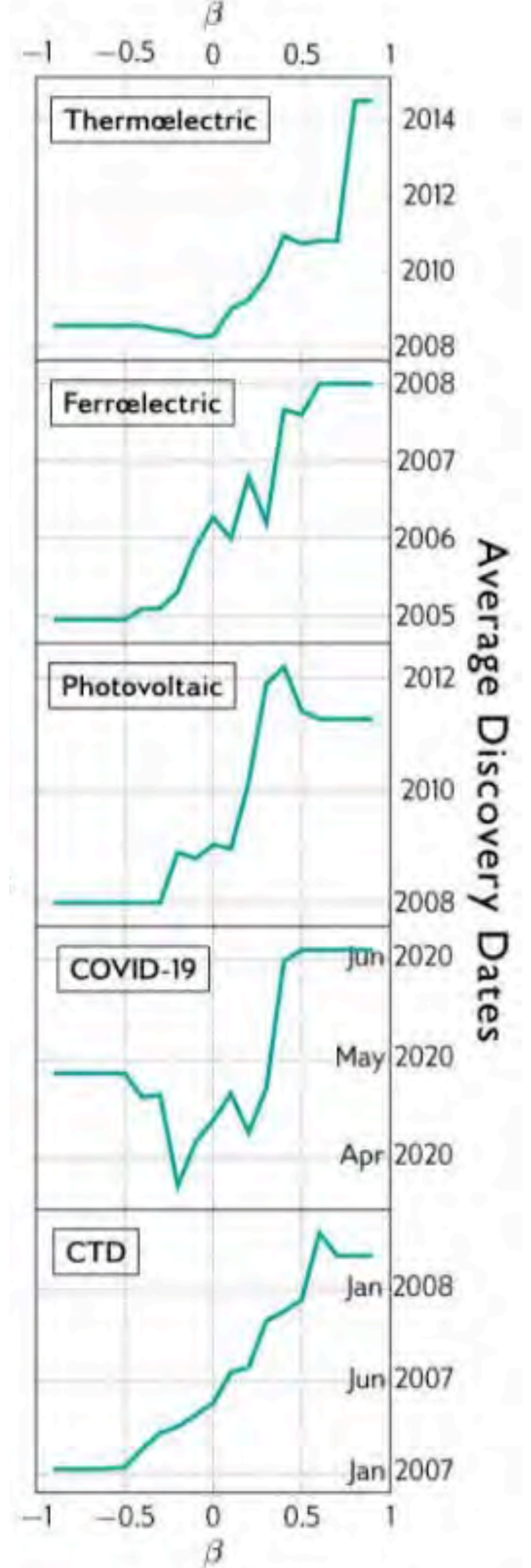
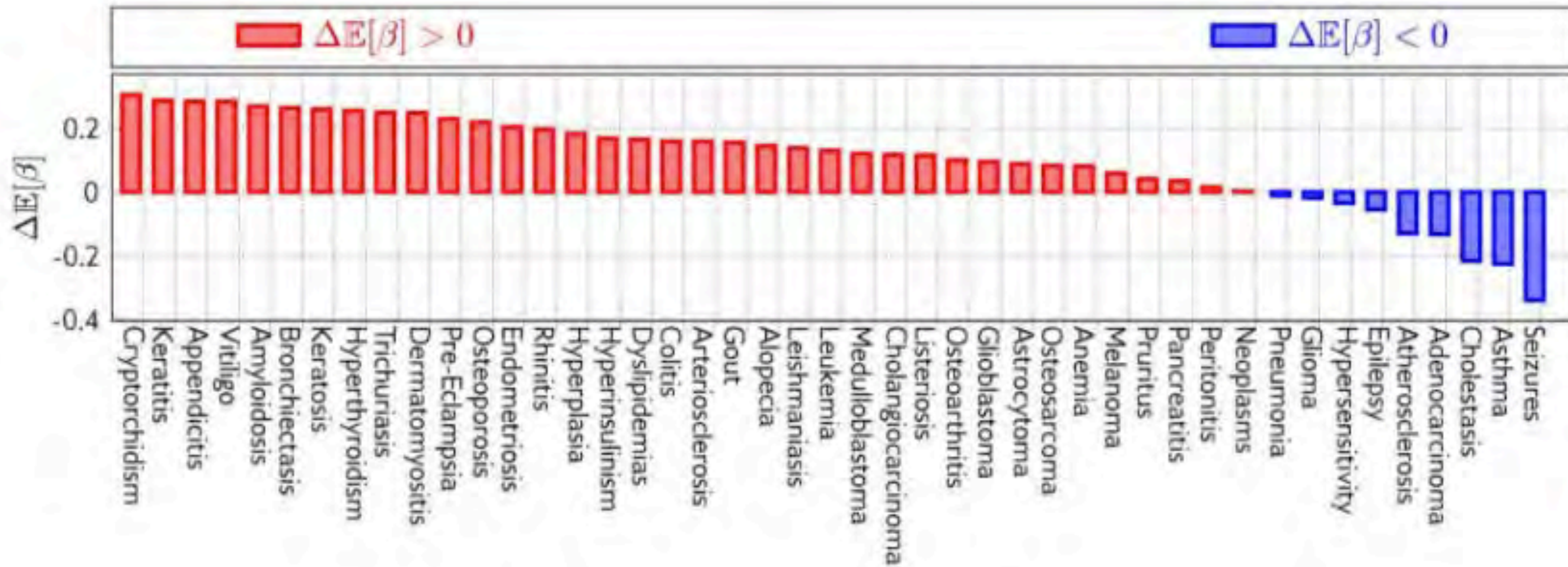
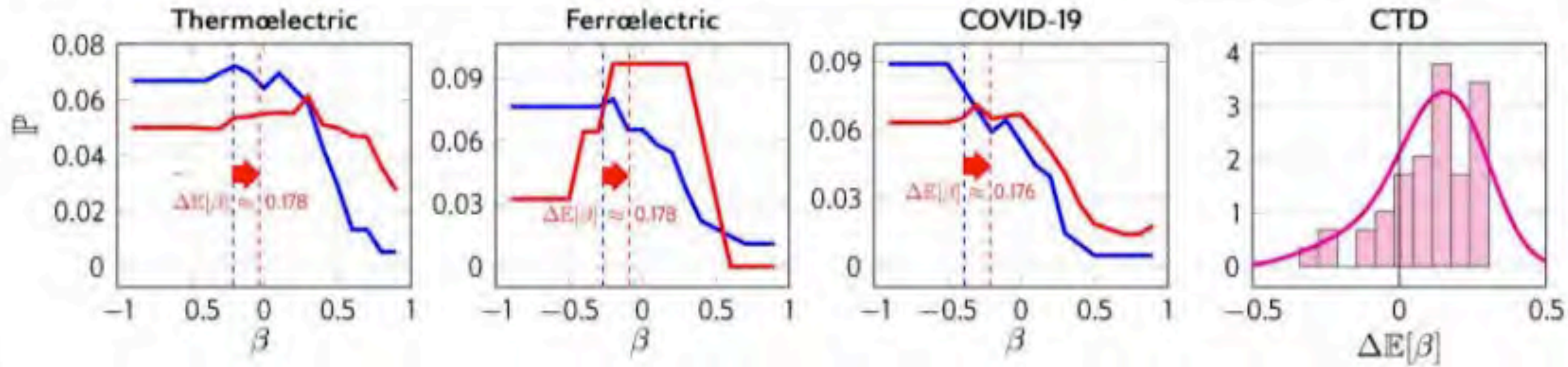
Improvement

By Avoiding Scientists
we can **Predict** what
they *won't* **Discover**



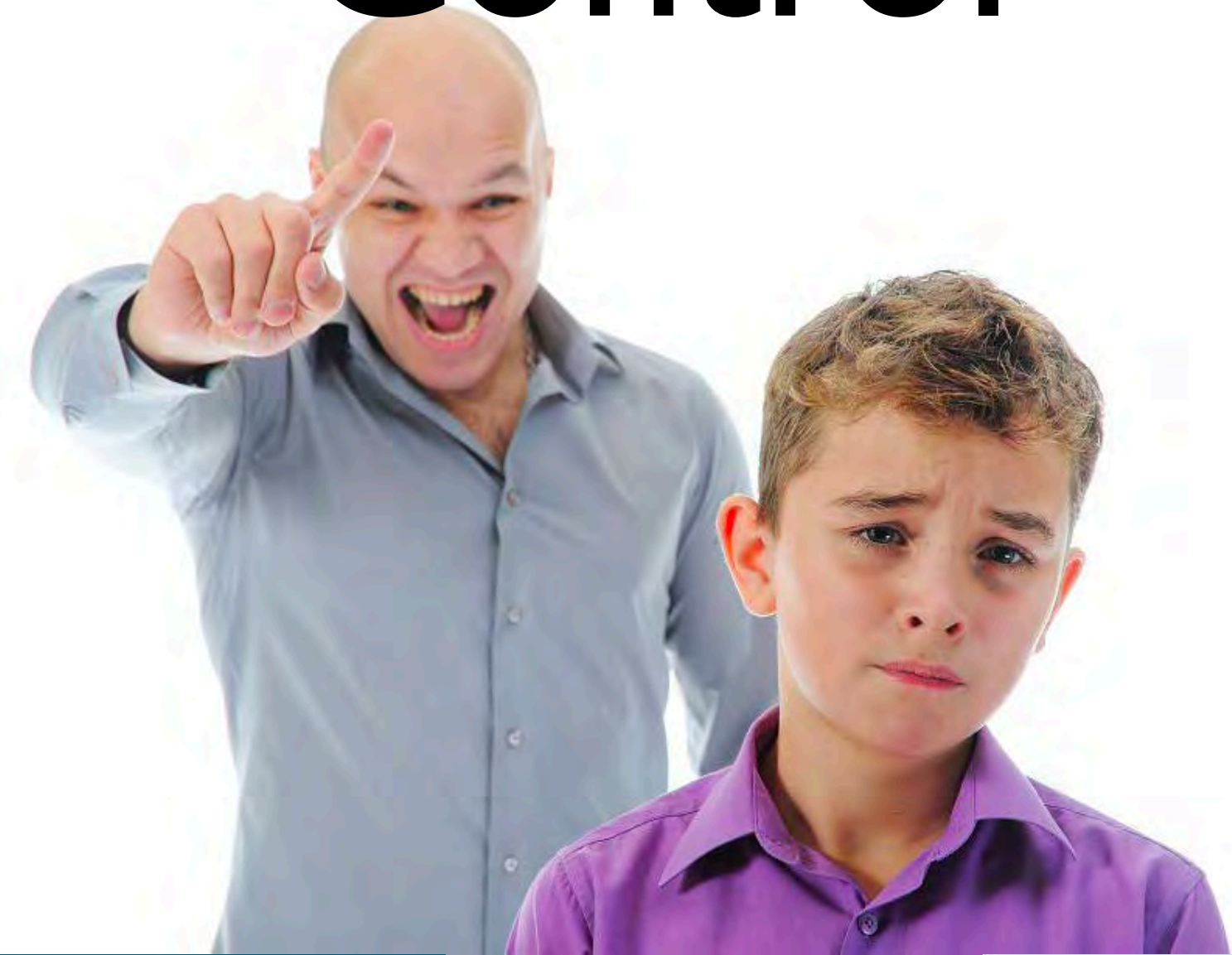
Maximize Complementarity

(and its better)



Training Logic

Control

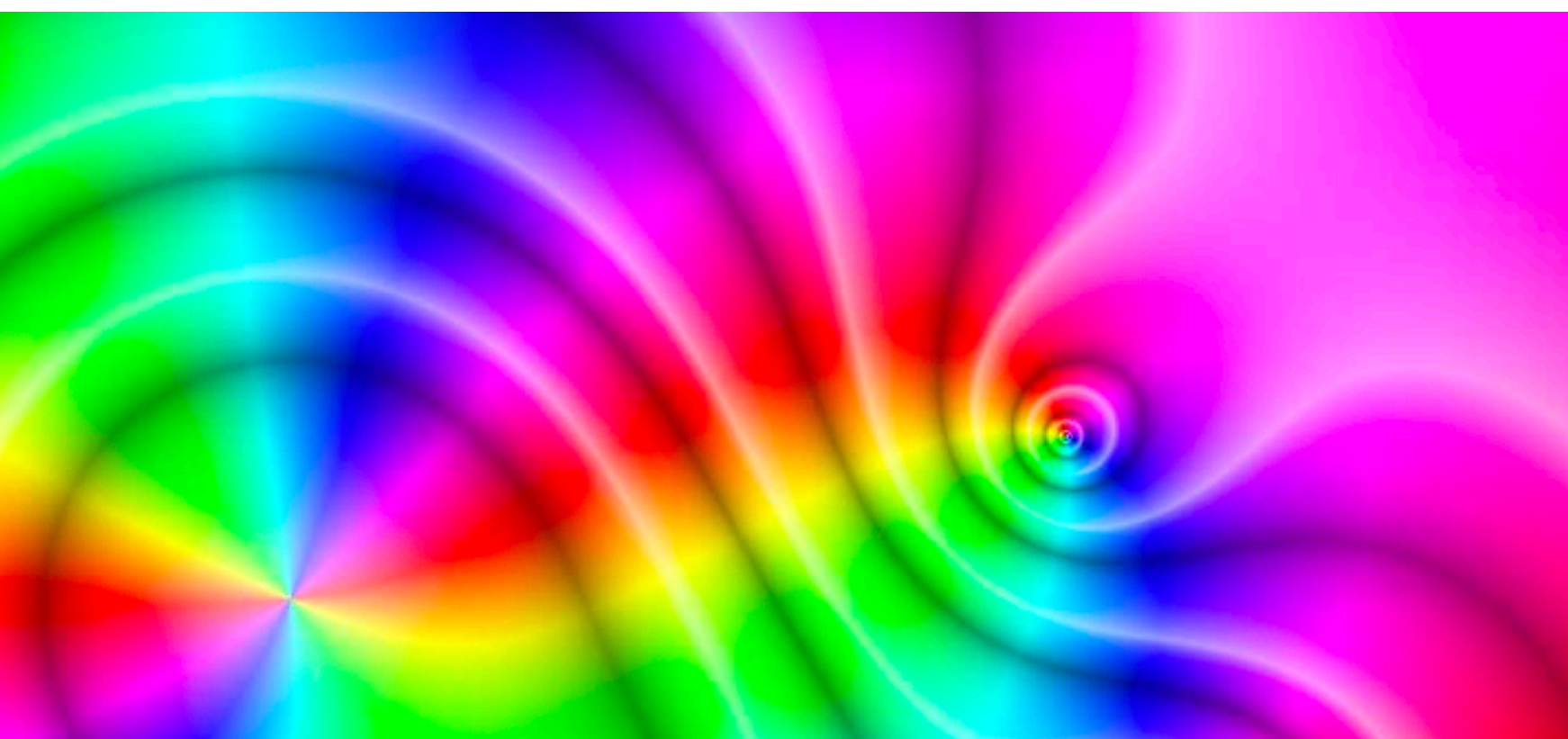


Caregiving

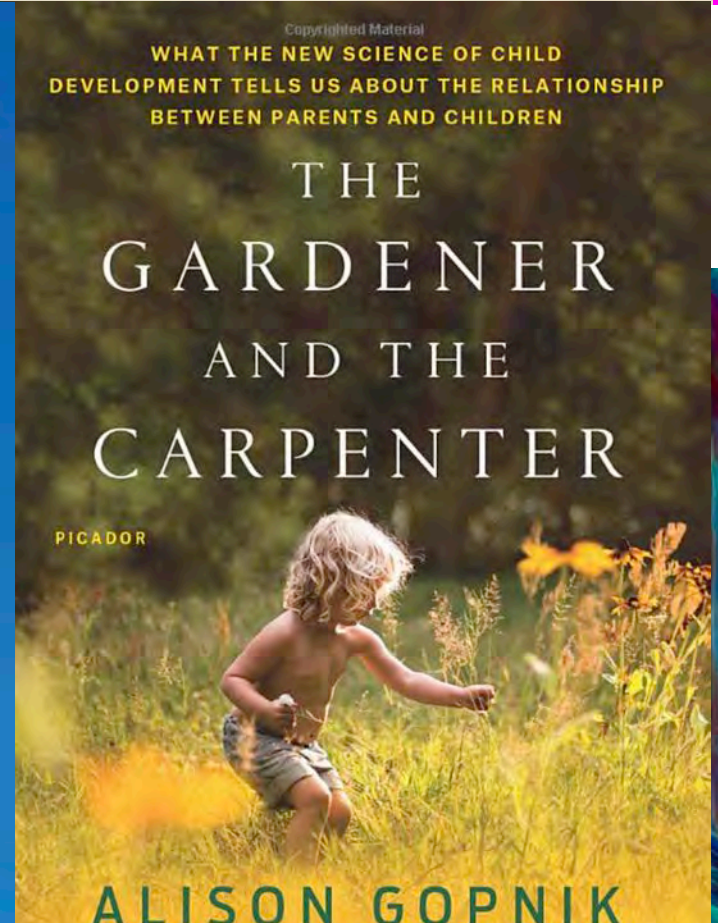
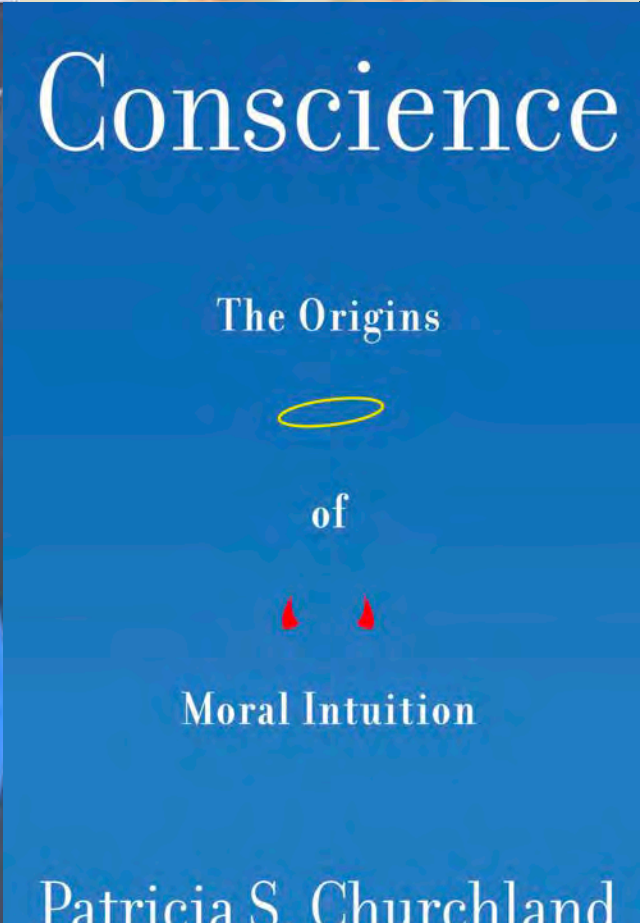
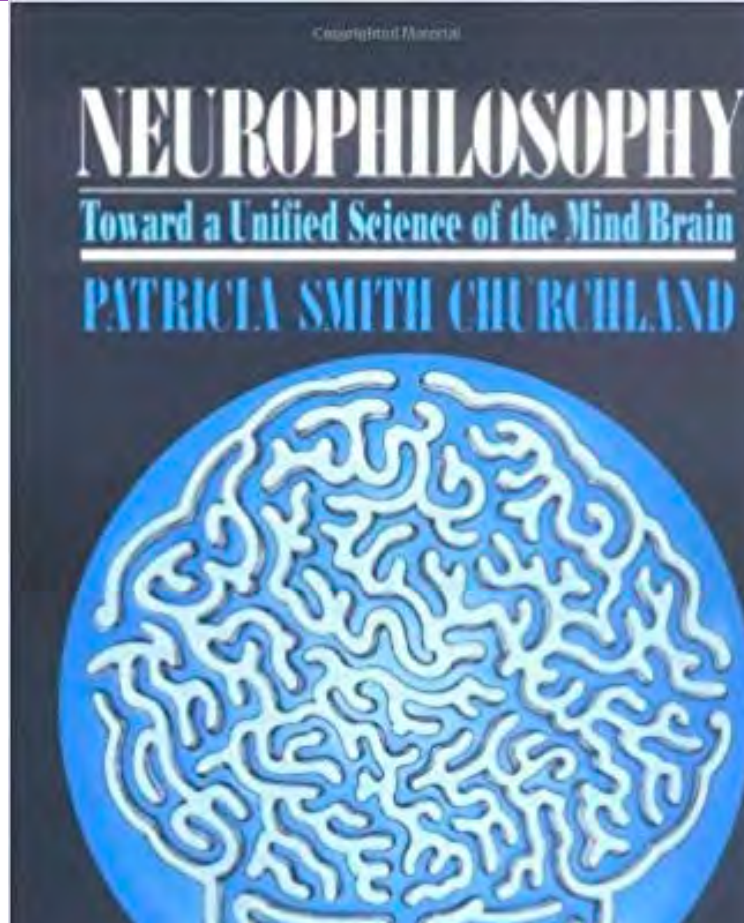
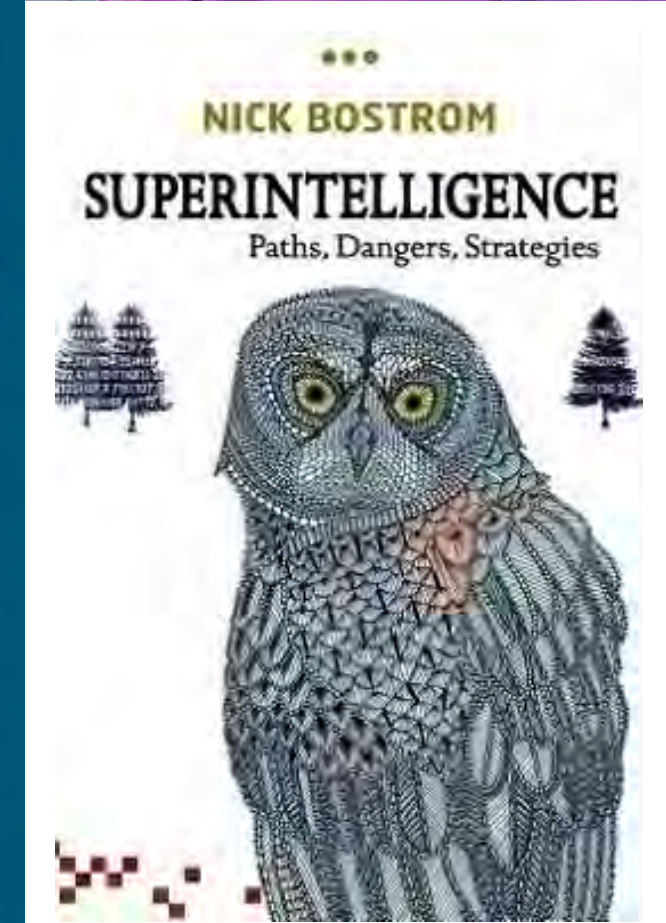
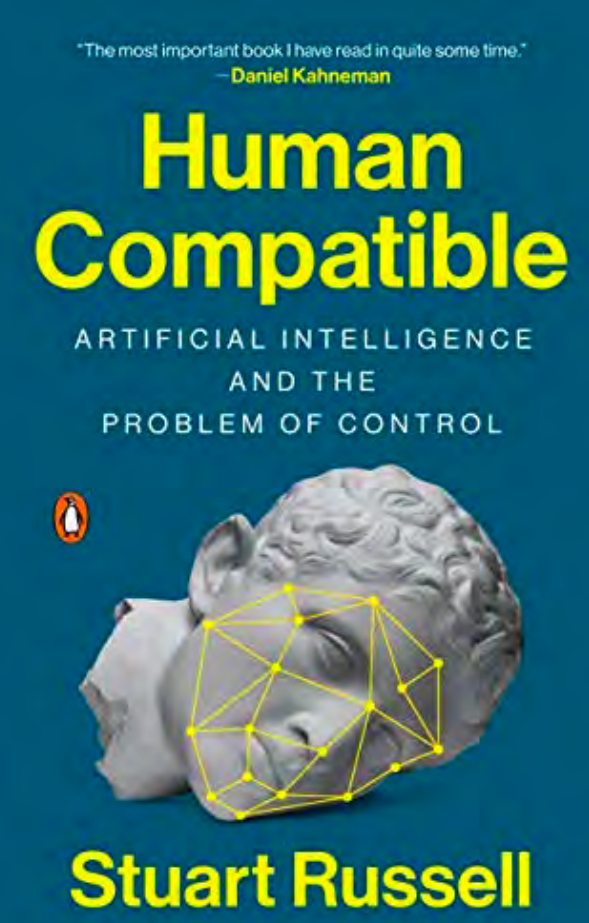
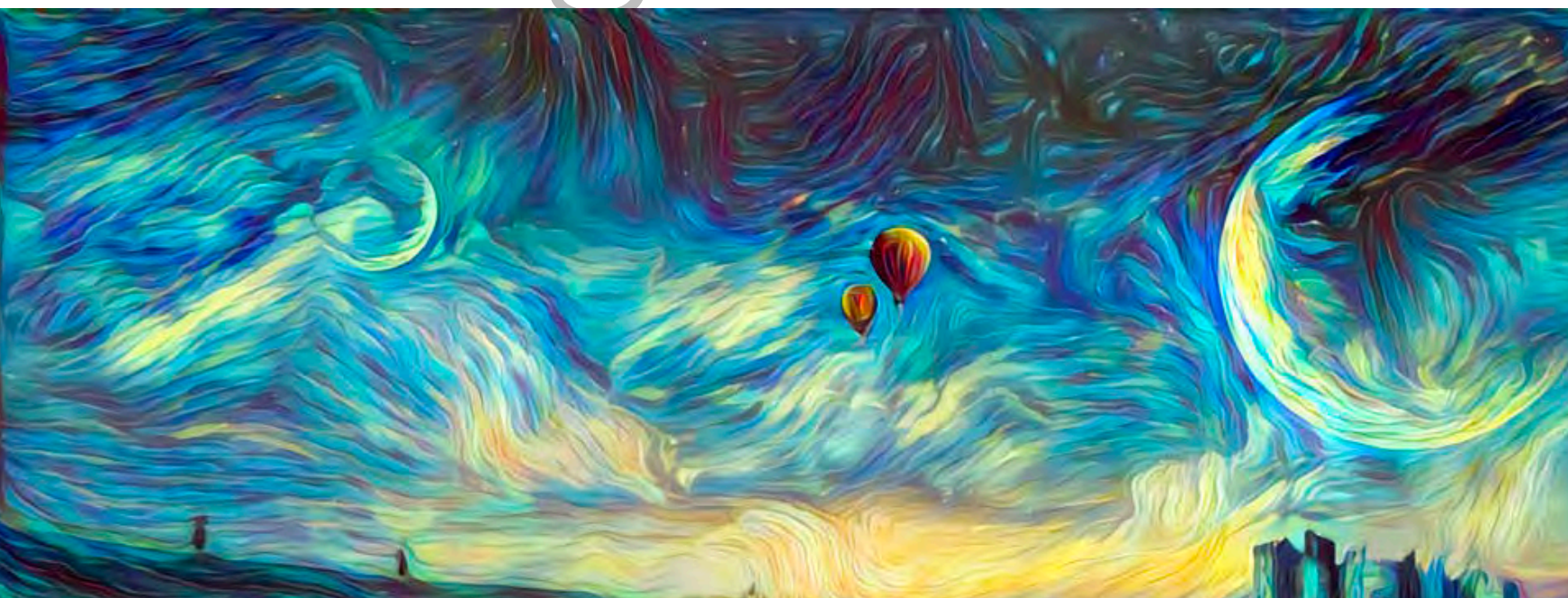
Alien Capacities



Objectives



Imagination



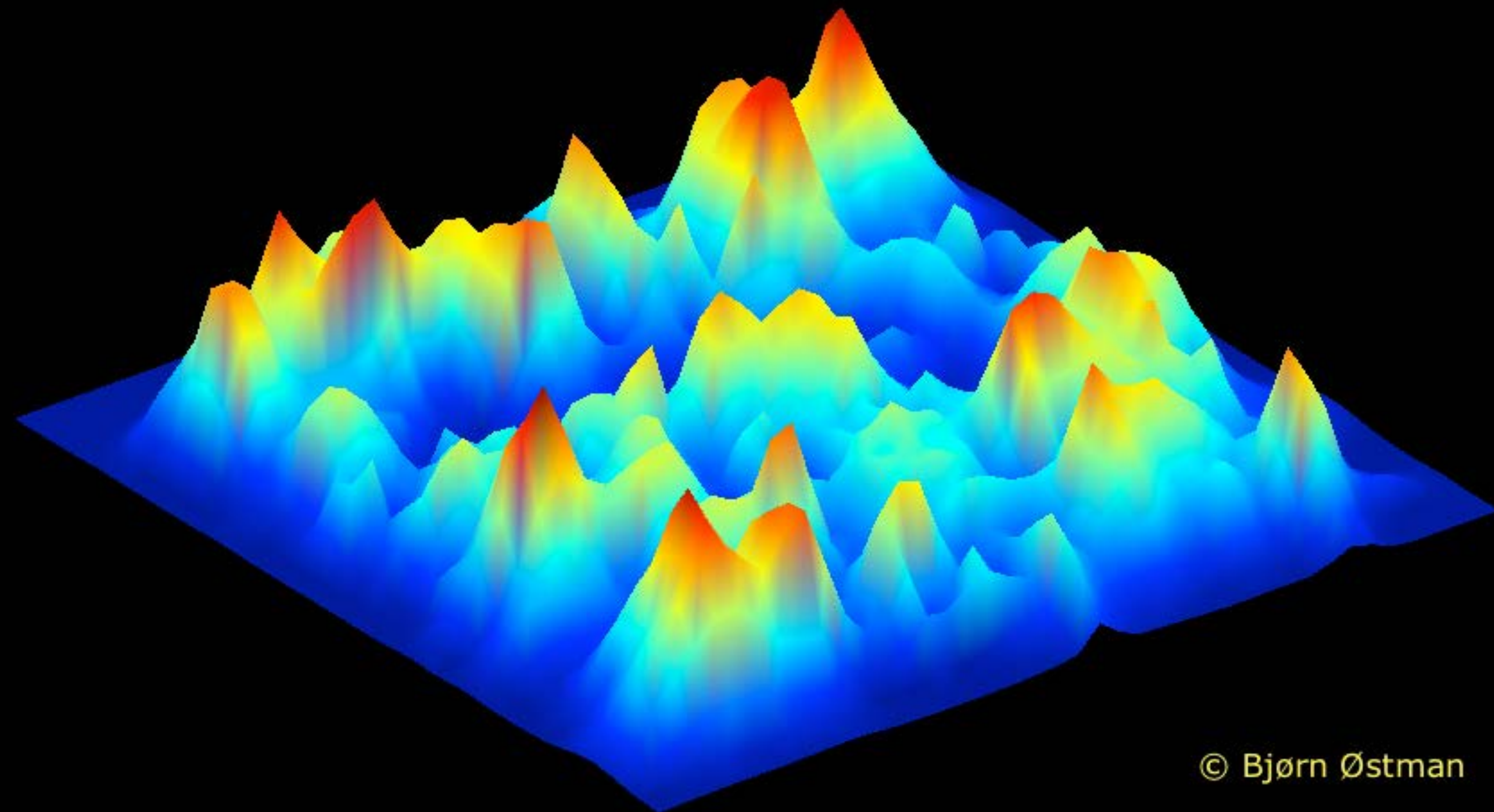
Build Ensembles of Diverse Intelligences through **AI** Coaching, Coordinating, Collaborating



To Advance Science, Technology, Enterprise,
& **the regulation of other AI**s

Conserving Human Diversity Cultivating Algorithmic Diversity Designing Collective Diversity for Sustainable Innovation

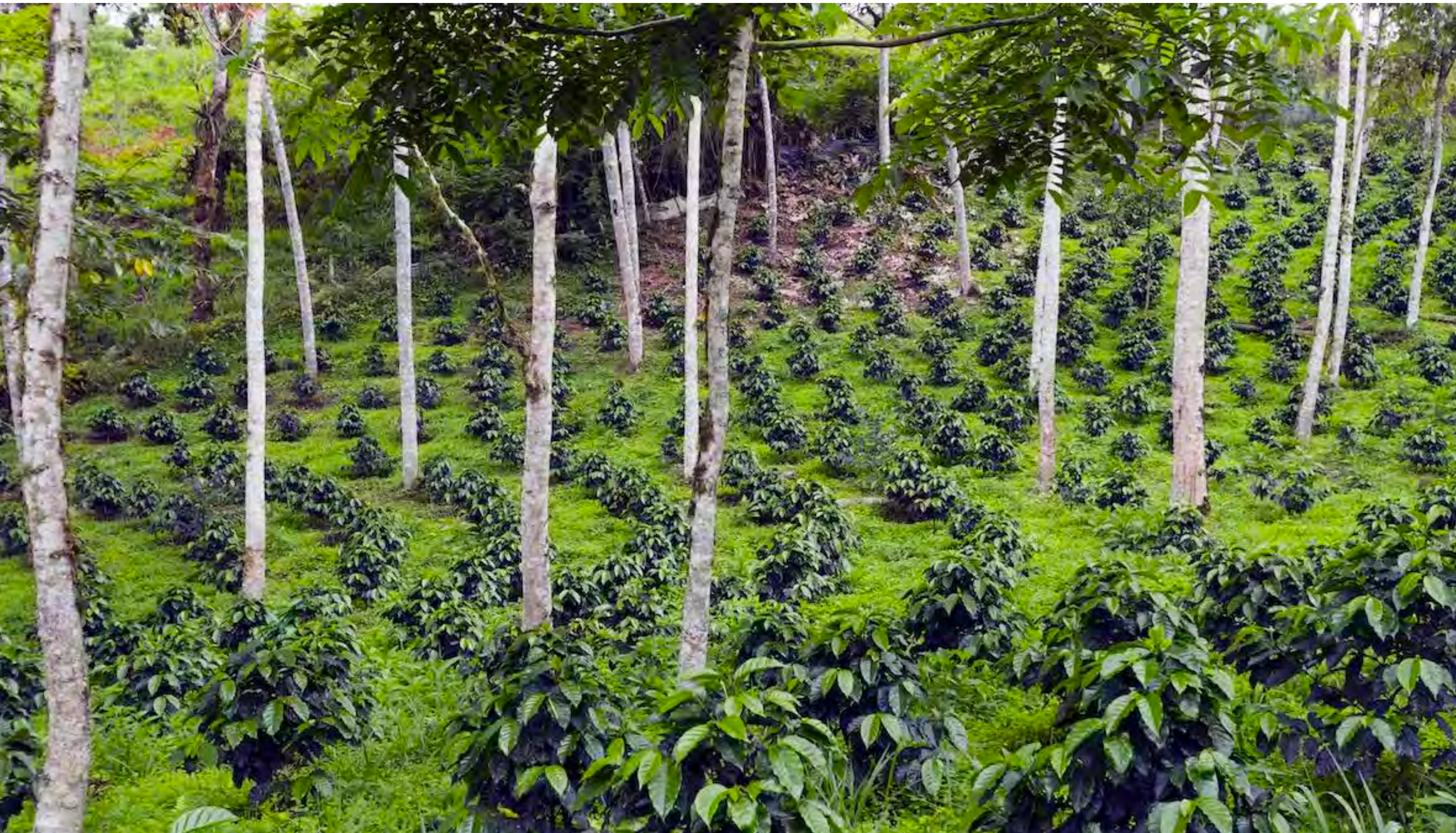
- Innovation in Science, Tech, Enterprise & Culture are **High-Dimensional & Rugged** requiring
- Social, Cultural, Institutional, & Methodological **Disconnection**





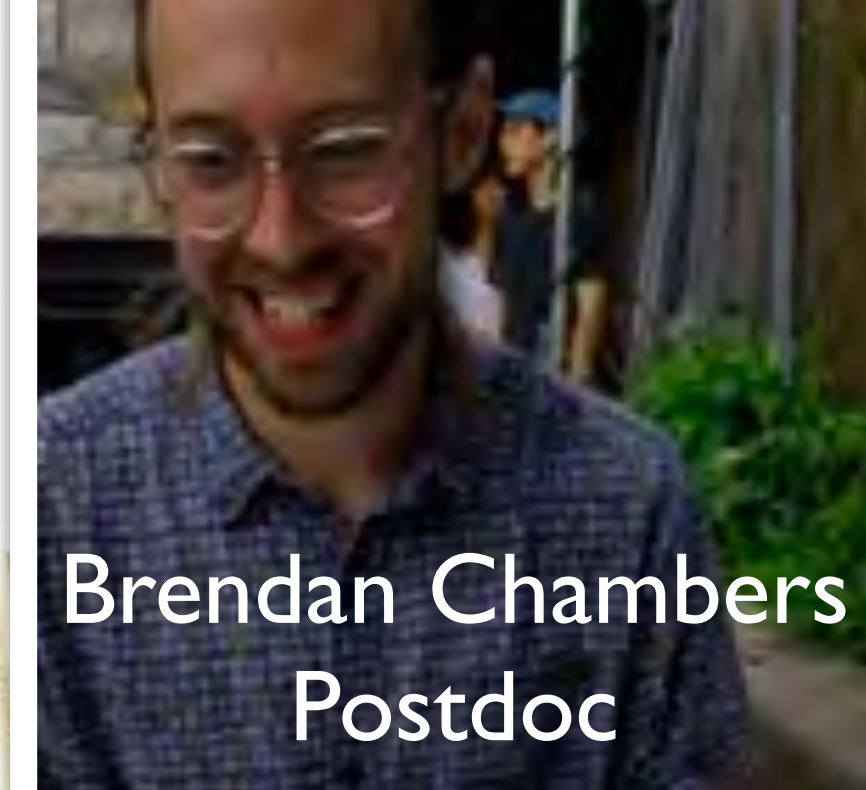
SANTA FE
INSTITUTE

Sustainable Bridging





Jamshid Sourati
Postdoc



Brendan Chambers
Postdoc



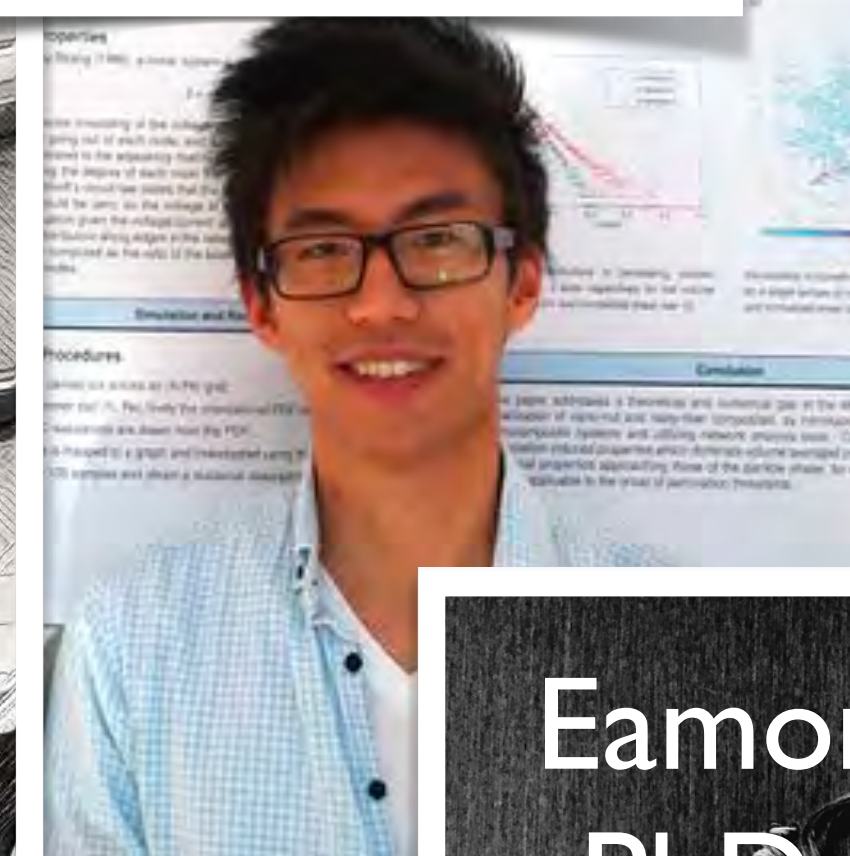
Haizi Yu
Postdoc



Fengli Xu
Postdoc



Sasha Belikov
Postdoc



Caroline Lewis
Assist. Director



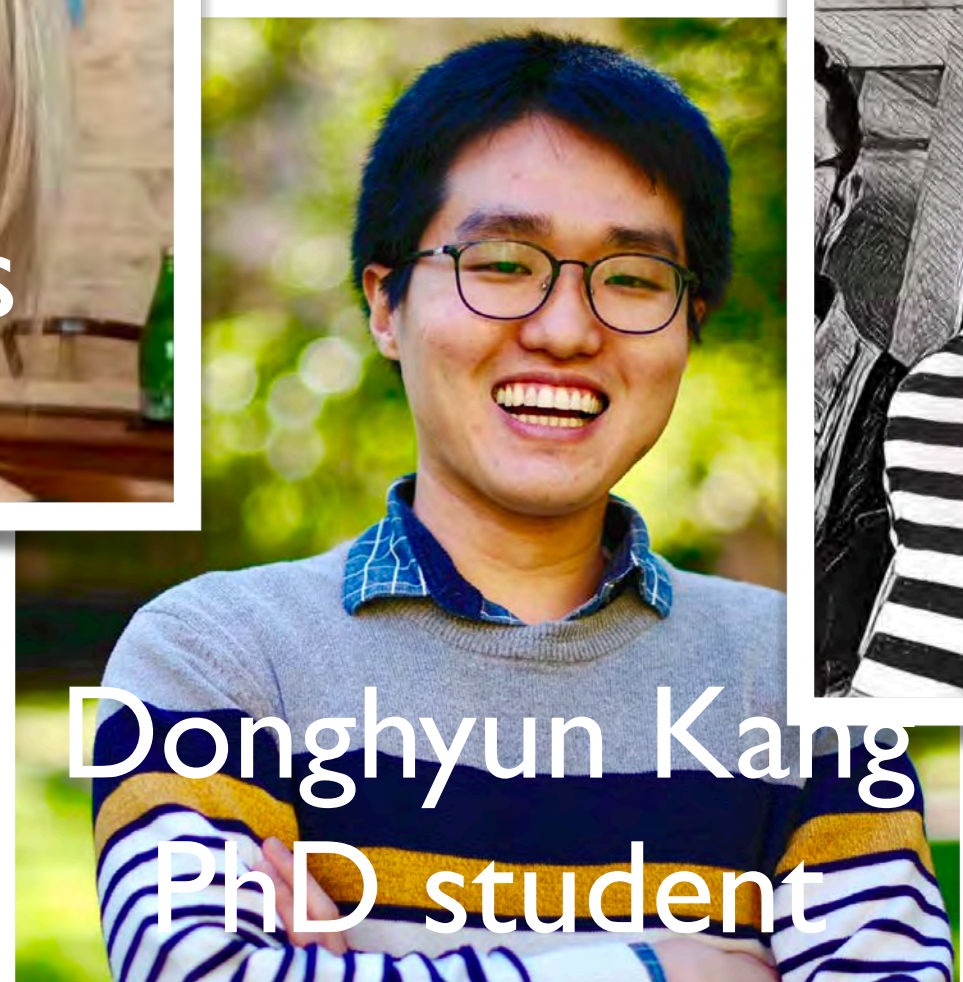
Eamon Duede
PhD student



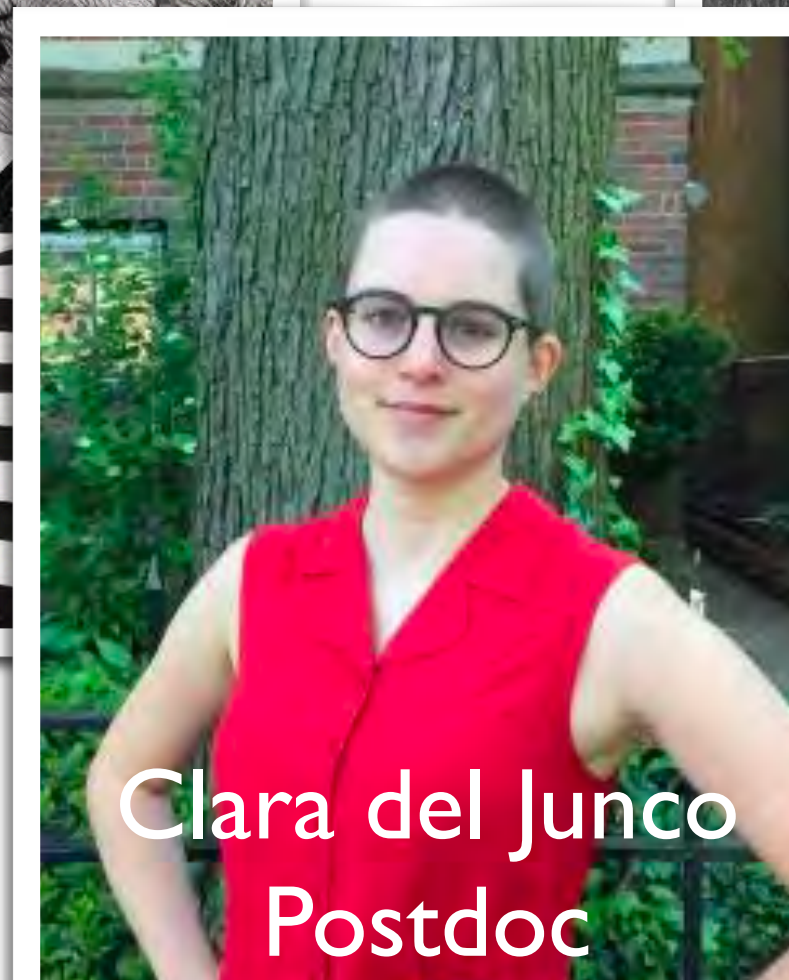
Bhargav Desikan
Masters student



Molly Lewis
Postdoc



Donghyun Kang
PhD student



Clara del Junco
Postdoc

