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# Convergence Research Paradigm: Role in Science and Technology Centers

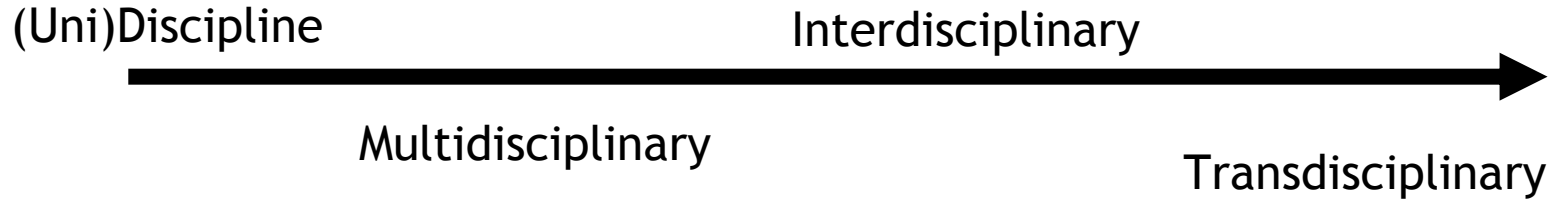
NSF STC STEPS  
Inaugural Visiting Seminar  
November 4, 2021

Pramod P. Khargonekar  
University of California, Irvine

# Outline

- Convergence
- Team Science
- Inclusion and Diversity
- Role in Science and Technology Centers
- Conclusions

# What is Convergence?



# Disciplines and Multidisciplinary

**Discipline:** particular branch of learning or body of knowledge

**Multidisciplinarity:** juxtaposition of two or more disciplines on a question, problem, topic, or theme.

- Juxtaposition of disciplines that remain separate
- Individuals work separately, results typically published separately or compiled, but not synthesized



# Interdisciplinary

**Interdisciplinary:** integration of information, data, methods, tools, concepts, and/or theories from two or more disciplines

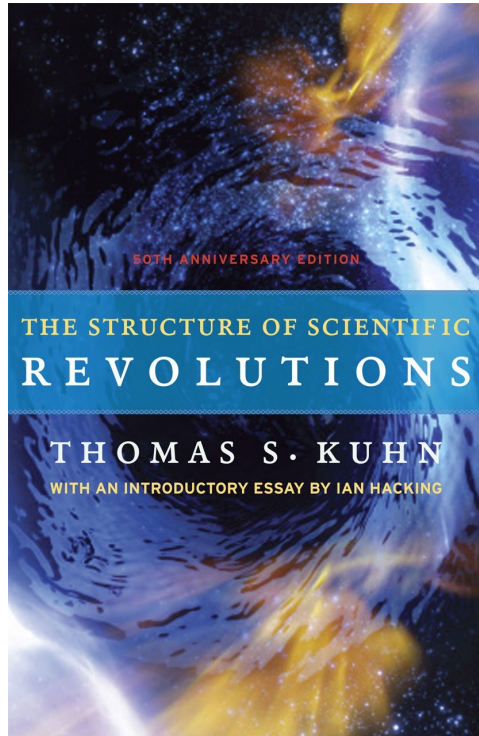
- Key defining concept: **integration**
- Individuals may work alone, but increasingly research is team-based.
- Collaboration introduces social integration, project management and communication.

# Transdisciplinary

**Transdisciplinary:** transcend disciplinary approaches through comprehensive frameworks and paradigms

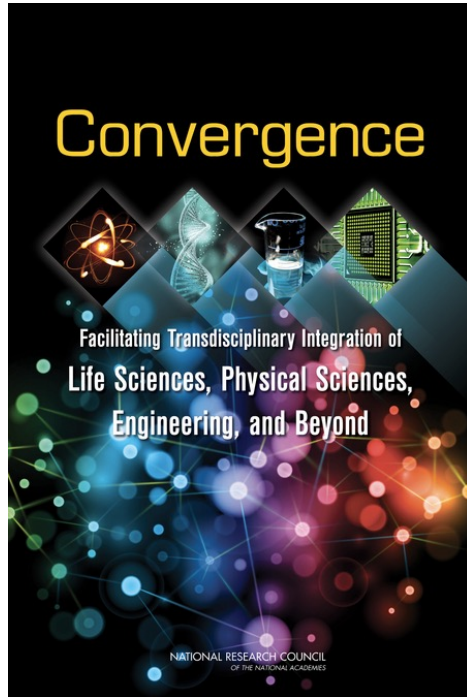
- **Problem-oriented research** that crosses the boundaries of both academic and public and private spheres.
- Mutual learning, joint work, and **knowledge integration** are key to solving “real-world” problems.
- Beyond interdisciplinary combinations to foster **new worldviews or domains**.

# Thomas Kuhn and Paradigms in Science



“universally recognized scientific achievements that, for a time, provide model problems and solutions for a community of practitioners”

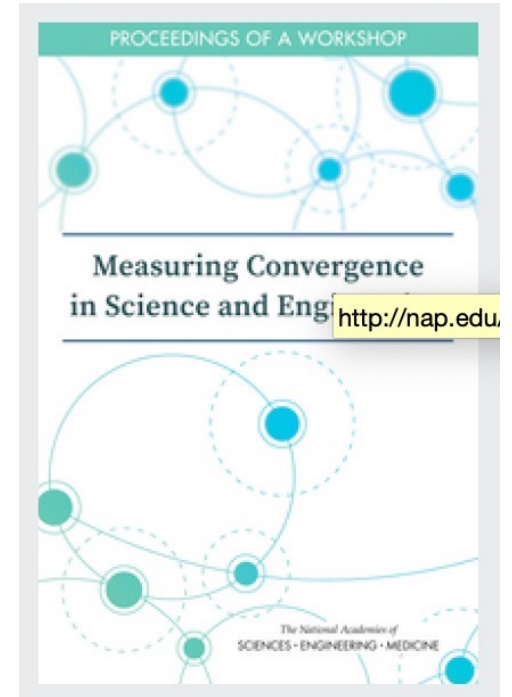
# Convergence Paradigm



[NRC 2014](#)



[MIT 2016](#)



[NASEM 2021](#)

# NRC Report on Convergence

Convergence is an approach to problem solving ... integrates knowledge, tools, and ways of thinking .. a comprehensive synthetic framework for tackling scientific and societal challenges ...

Two closely related but distinct properties:

- convergence of expertise
- formation of the web of partnerships.

# NSF Big Idea: Growing Convergence Research

Convergence Research has two primary characteristics:

**A. Research driven by a specific and compelling problem:**

Need to address a specific challenge or opportunity,  
From deep scientific questions or pressing societal needs.

**B. Deep integration across disciplines:**

Knowledge, theories, methods, data, research  
communities and languages intermingled or integrated.  
New frameworks, paradigms or disciplines from sustained  
interactions ...

# Four Key Pillars

- People
- Organization
- Culture
- Ecosystem

# People

- Students, faculty and staff
- Department chairs
- Deans
- Senate
- Center Leadership
- Others ...



# Organization

- Goal-oriented vision
- Program management
- Support for core facilities
- Catalytic/seed funding
- Reward risk-taking
- Governance systems

# Culture

- Mutual respect
- Opportunities to share knowledge
- Diversity of perspectives
- Inclusive
- Risk taking

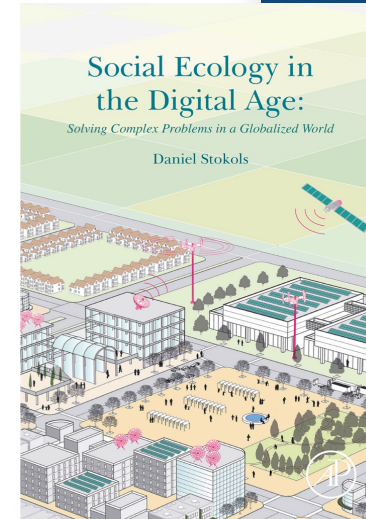
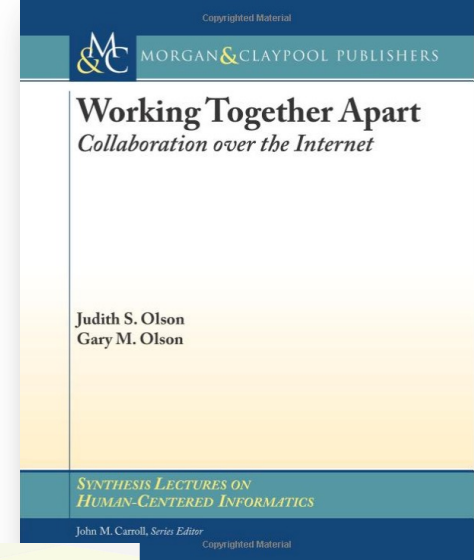
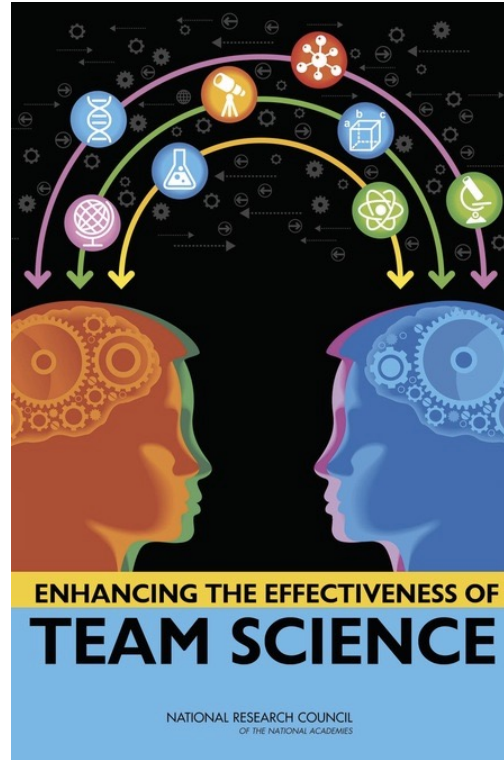
# Ecosystem

- Dynamic interactions at various levels
- Multiple partners
- Within institution
- Across institutions
- Academic-industry-foundations-government

# Convergence and Team Research

## Collaboration & Team Science:

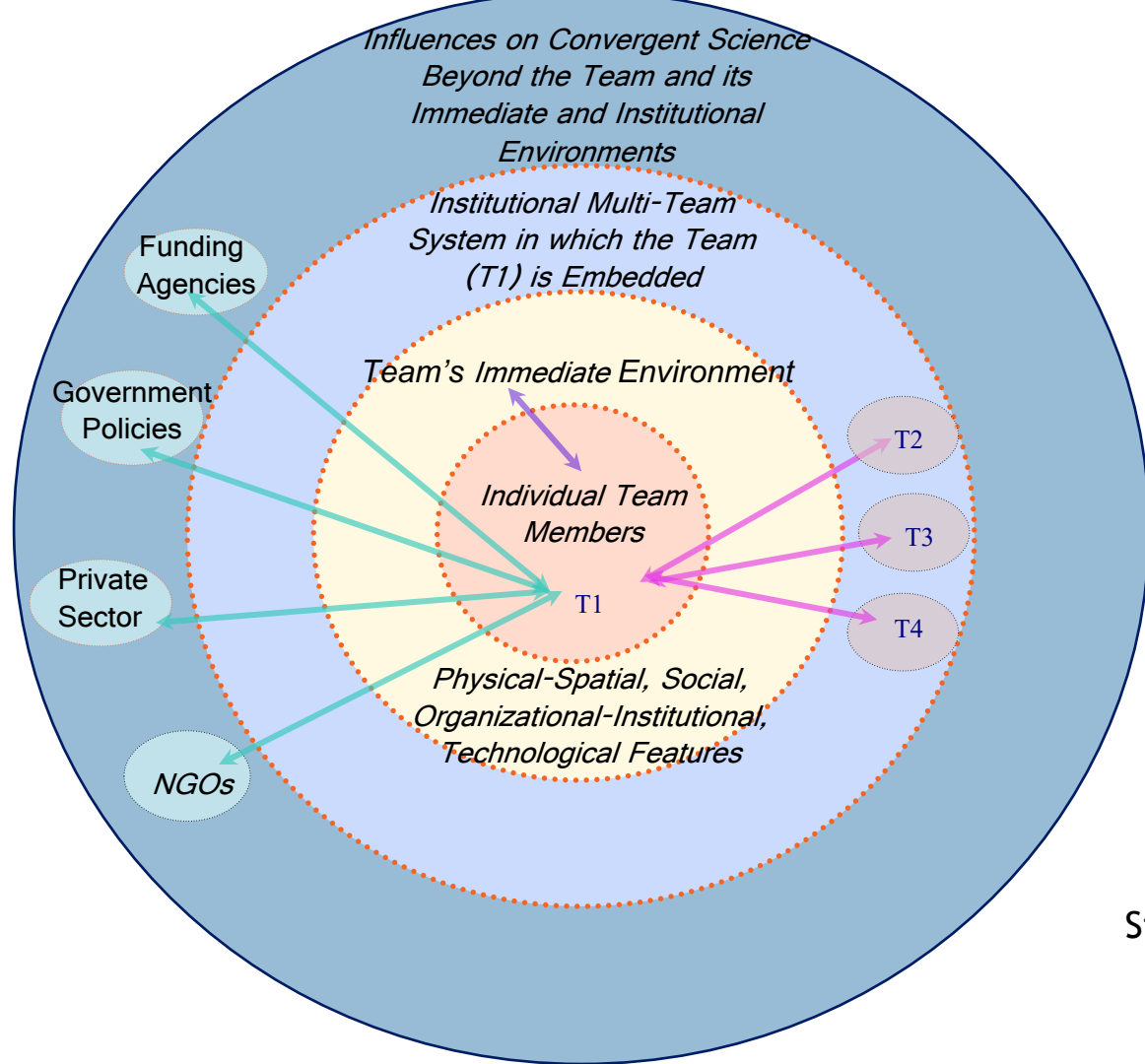
*A Field Guide*



# Dimensions of Team Science

- Diversity of team members
- Disciplinary integration
- Team size
- Goal alignment
- Permeable boundaries
- Geographic proximity
- Task interdependence

*“a new interdisciplinary field ... aims to better understand ... team-based research and practice and to identify the unique outcomes of these approaches ...” (Stokols et al. 2018)*



Stokols, 2018

# Improving Team Effectiveness

- Team processes
- Team composition
- Team professional development
- Leadership for team science
- Support for virtual collaboration
- Organizational support for team research

# Team Scholarship Accelerator Lab



TEAM SCHOLARSHIP ACCELERATION LAB

About

Team Resources



## Team Scholarship at UCI

<https://tsal.uci.edu/>



# Inclusion and Diversity in Convergence

“A central hypothesis of convergence is that diverse teams are able to generate innovative solutions ...

... an environment where opinions—especially dissenting opinions—are openly expressed, where diversity is valued, and opposing ideas are respectfully communicated may be vital to the success ....”

# Types of Diversity and Implications

## Diversity

- Problem-solving approaches (functional)

- Demographic, cultural, and ethnic backgrounds (identity)

## Relationship with team performance:

- Challenges in social integration and communication

- Perspective can mitigate and ... reverse these effects

- Greater creativity and satisfaction

- Environment with diverse views and perspectives can be uncomfortable

- Inclusive attitudes, management strategies critical

**Convergence and Pressing Societal Needs**  
**=**  
**Grand Challenges?**

# Grand Challenges: NAE and UN SDG

## GRAND CHALLENGES FOR ENGINEERING



Make solar energy economical



Provide energy from fusion



Develop carbon sequestration methods



Manage the nitrogen cycle



Provide access to clean water



Restore and improve urban infrastructure



Advance health informatics



Engineer better medicines



Reverse-engineer the brain



Prevent nuclear terror



Secure cyberspace



Enhance virtual reality



Advance personalized learning



Engineer the tools of scientific discovery



# Grand Challenges are often Wicked Problems

Wicked problems ... there is no clear stopping rule ... working on it more ... better solution ... no single right answer ... every attempt can matter because it affects the things people depend upon.

[Horst and Rittel, 1973](#)

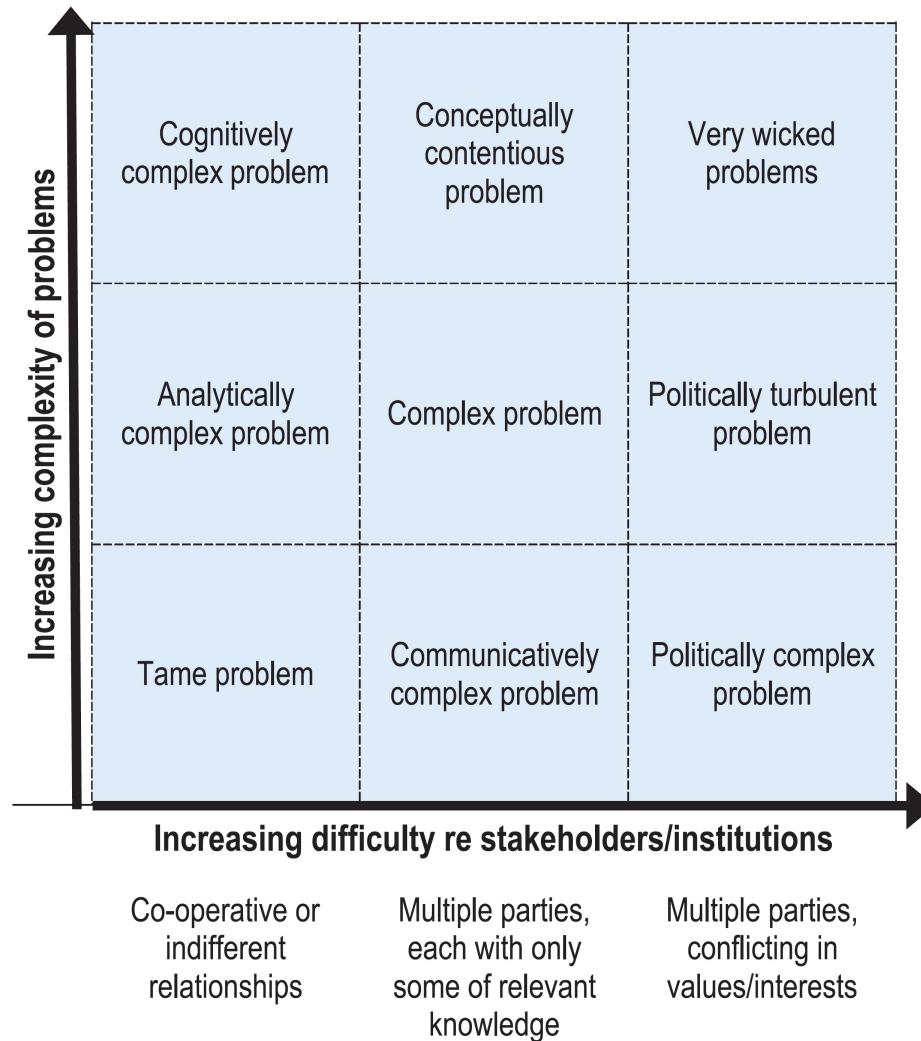
# Characteristics of Wicked Problems

- No definite formulation of a wicked problem.
- No stopping rules.
- Solutions are not true-or-false, but better or worse.
- No immediate and no ultimate test of a solution to a wicked problem.
- Do not have an enumerable (or an exhaustively describable) set of potential solutions
- Every wicked problem is essentially unique.
- Causes can be explained in numerous ways.

Neither problem nor  
solution is clear

Problem clear, solution  
not clear

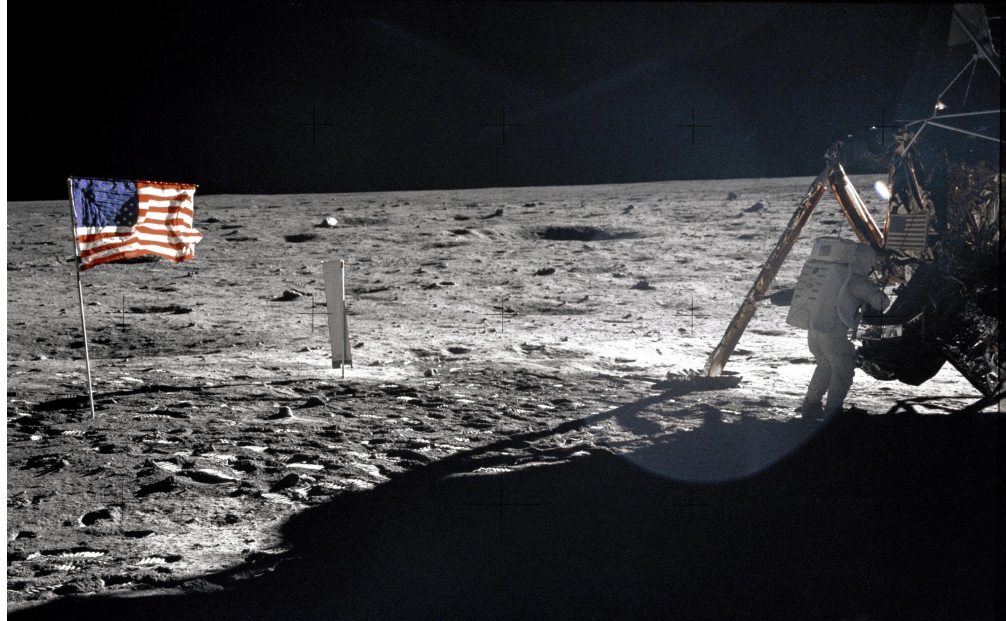
Both problem and  
solution clear



# Model Grand Challenge



President John F.  
Kennedy speaks before a  
joint session of Congress,  
May 25, 1961



Apollo 11, July 20, 1969  
Neil Armstrong: One Giant Leap For Mankind



# Grand Challenge: Small Pox Eradication



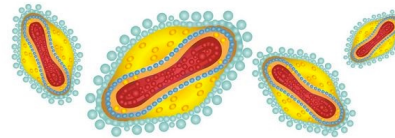
Edward Jenner

“On the Origin of the Vaccine Inoculator  
1801

“the annihilation of the smallpox, the  
most dreadful scourge of the human  
species, must be the final result of this  
practice.”

**VACCINATION** — prevention is better than a cure!

## smallpox ERADICATED



**1796**

Edward Jenner creates  
first smallpox vaccination

**1967**

World Health Organization  
pushes eradication efforts

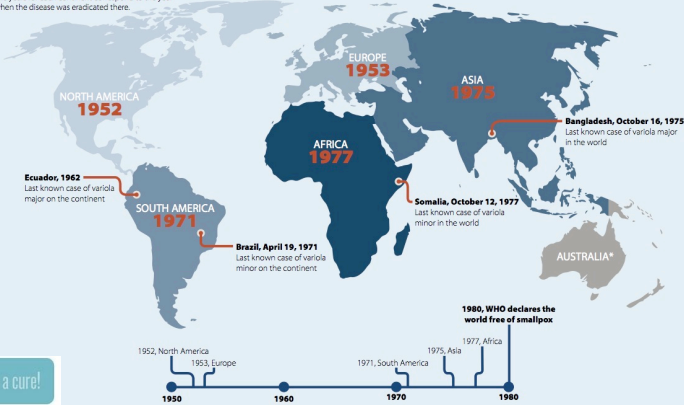
**1980**

World Health Organization  
declares smallpox eradicated!

Source: [www.historyofvaccines.org/content/timeline/smallpox](http://www.historyofvaccines.org/content/timeline/smallpox)

## GLOBAL SMALLPOX ERADICATION

The historically important dates highlighted in the map show countries in which the last naturally acquired cases of smallpox occurred.  
The years for each continent correspond to the year when the disease was eradicated there.



\* Smallpox was never endemic (widespread) in Australia (C3265471) A



1881



1911



1930's



1953



**The most anticipated transit projects opening in time for the 2028 LA Olympics**

From the subway extension to the Westside to a people mover at LAX

1990

# Next Green Revolution

OP-ED CONTRIBUTORS

## We Need a New Green Revolution

By Phillip A. Sharp and Alan Leshner

Jan. 4, 2016

...one that goes beyond advancing production to focus on reducing exorbitant rates of food loss

Zia Khan  
Rockefeller Foundation

Small-scale farmers still feed a majority of the world and must therefore be at the center of any future agricultural research agenda.

R. Offenheiser  
President, Oxfam America

# **Role in Science and Technology Centers**

# It is Getting Harder to Innovate

Figure 1: Aggregate Data on Growth and Research Effort

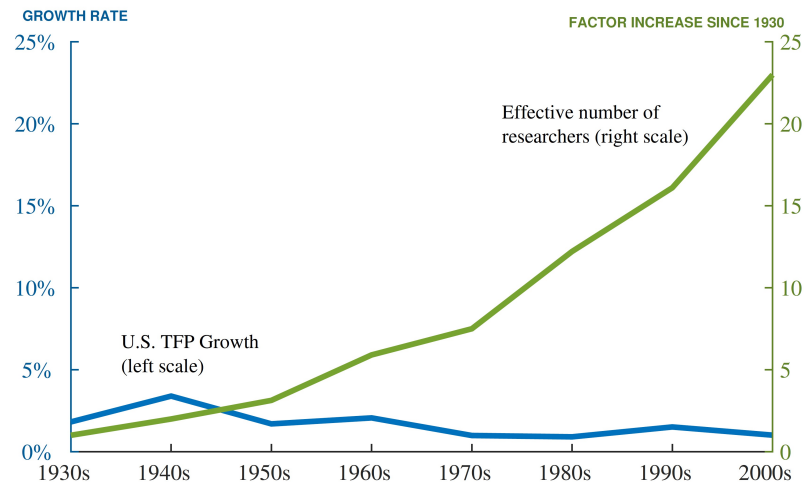
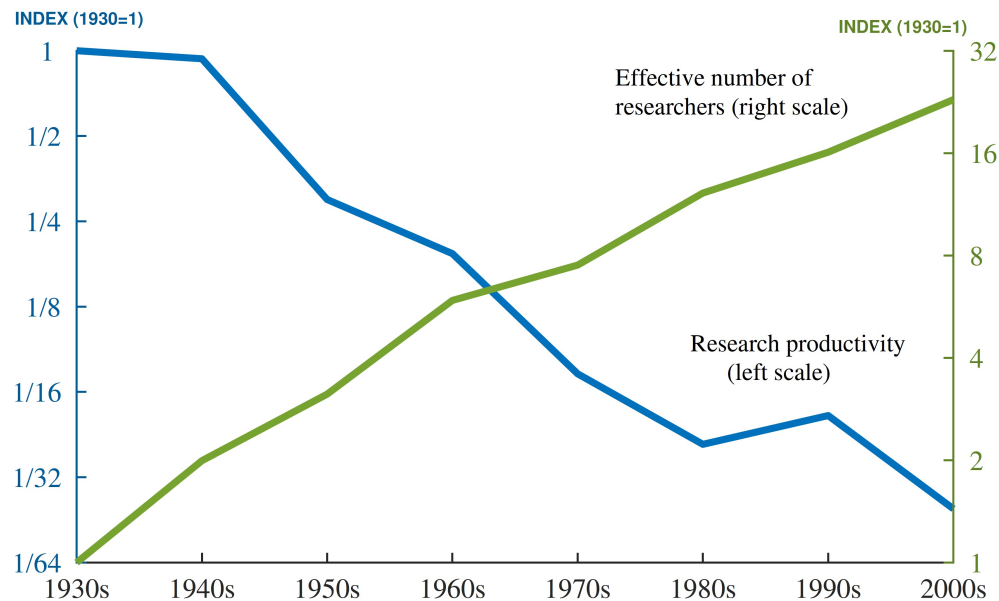


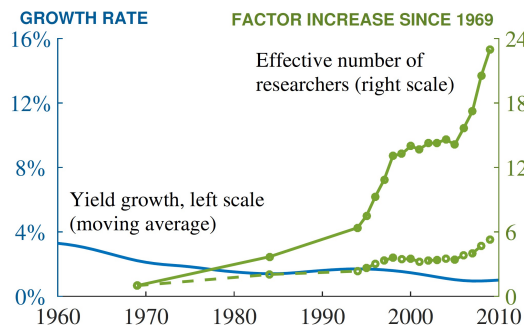
Figure 2: Aggregate Evidence on Research Productivity



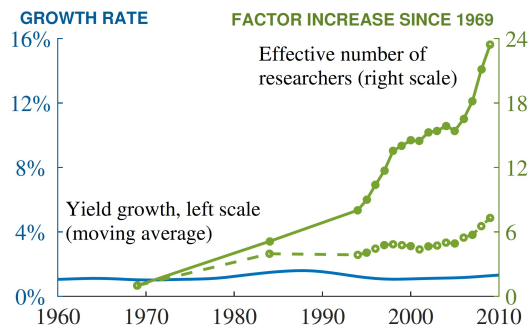
Note: Research productivity is the ratio of idea output, measured as TFP growth, to research effort. See notes to Figure 1 and the online data appendix. Both research productivity and research effort are normalized to the value of 1 in the 1930s.

Source: [Are Ideas Getting Harder to Come by, Bloom et al, 2020](#)

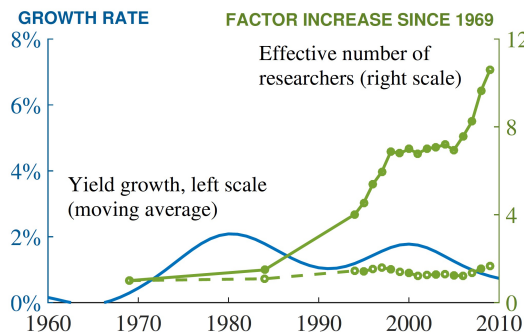
# Case of Agriculture Crops



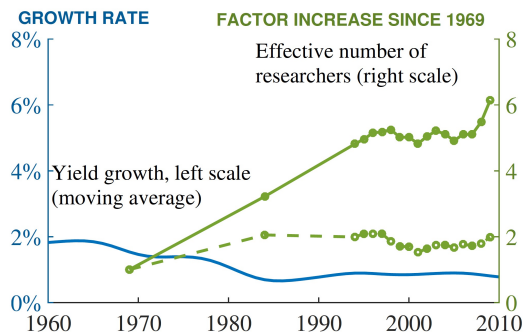
(a) Corn



(b) Soybeans



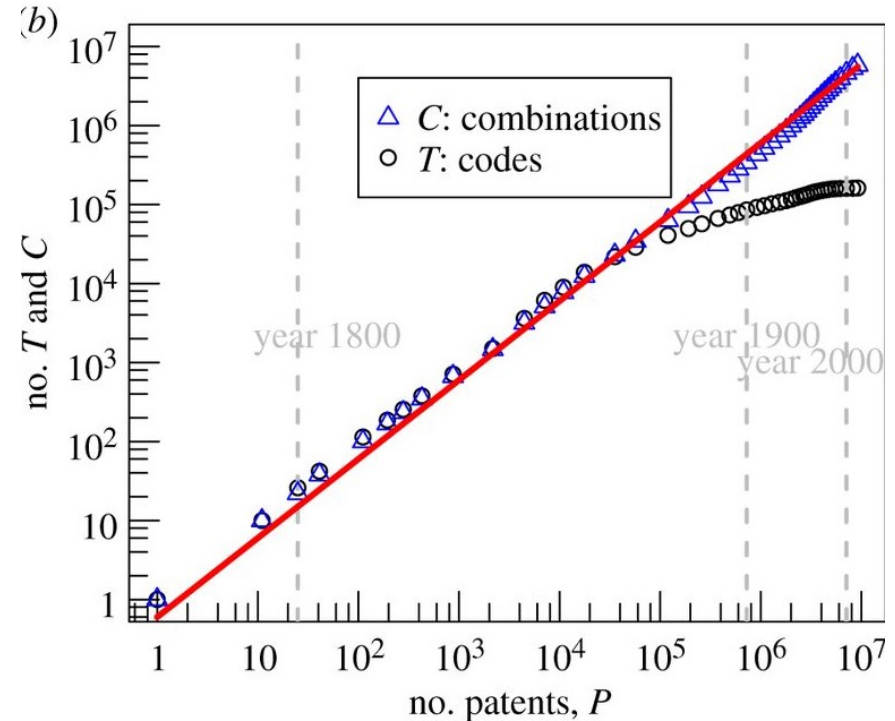
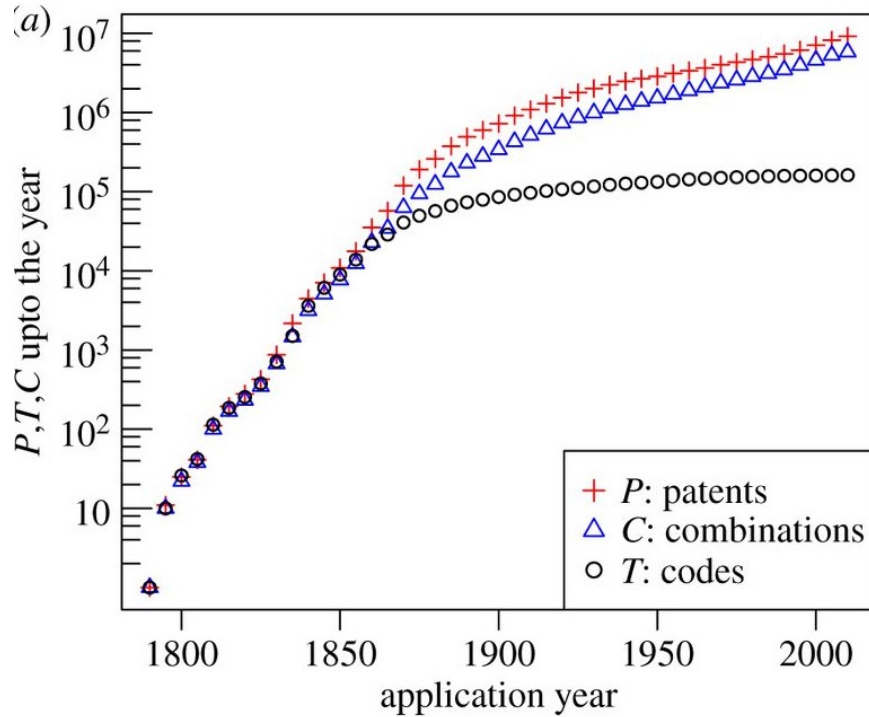
(c) Cotton



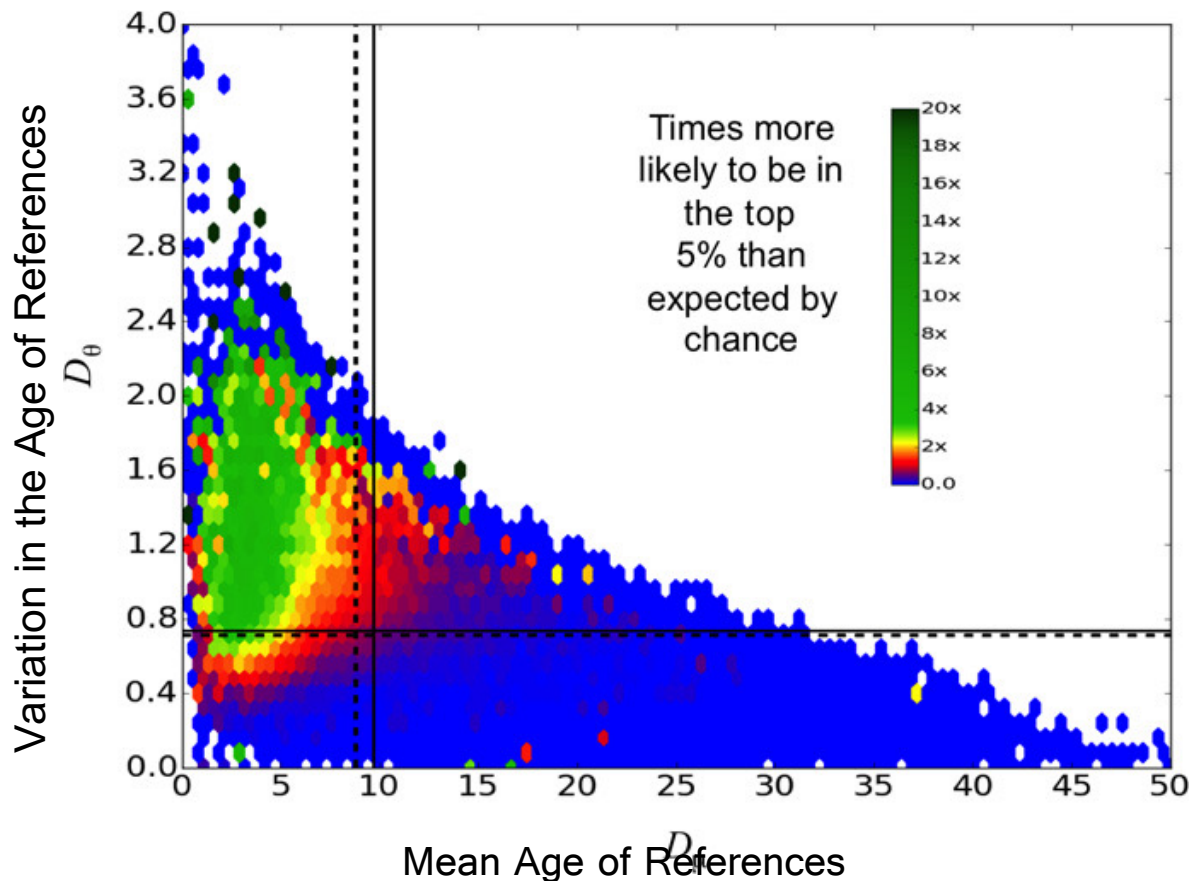
(d) Wheat



# Technology Innovations Increasingly have a Combinatorial Nature



# Combining Old and New for Science Impact



Our analysis parameterizes the age distribution of a work's references and revealed three links between the age of prior knowledge and hit papers and patents. First, works that cite literature with a low mean age and high age variance are in a citation "hotspot"; .... Second, the hotspot is nearly universal in all branches of science and technology .... Third, a scientist or inventor is significantly more likely to write a paper in the hotspot when they are coauthoring than when they are working alone.

**The nearly universal link between the age of past knowledge and tomorrow's breakthroughs in science and technology: The hotspot**

SATYAM MUKHERJEE, DANIEL M. ROMERO, BEN JONES, AND BRIAN UZZI [Authors Info & Affiliations](#)

[Mukherjee et al \(2017\)](#)



# Working Hypothesis

Inclusive and diverse teams in the convergence research paradigm will innovate more effectively to generate high impact breakthrough scientific advances and transformative new technologies, thereby adding value to society.

**Comments**

**Ideas**

**Questions?**

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