National Research Council Reports: Innovations in Scientific Research

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

National Academy of Sciences
National Academy of Engineering
Institute of Medicine
National Research Council

NRC Reports: Innovations in Scientific Research

- Perspectives on the National Research Council and 3 Related Reports

  Margaret Hilton, National Research Council
- Convergence: Facilitating Transdisciplinary Intergration of the Life Sciences, Physical Sciences, and Beyond
  James Gentile, Hope College
- Enhancing the Effectiveness of Team Science
  Kara Hall, National Cancer Institute
- Questions and Discussion

Perspectives on the National Research Council

What is the National Research Council?

U.S. National Academy of Sciences Charter (1863)

"The academy shall, whenever called upon by any department of the government, investigate, examine… and report upon any subject of science or art ,… but the Academy shall receive no compensation whatsoever for any services to the government of the United States".

What does the National Research Council offer?

Independent, objective, & nonpartisan advice

6,000 expert volunteers annually

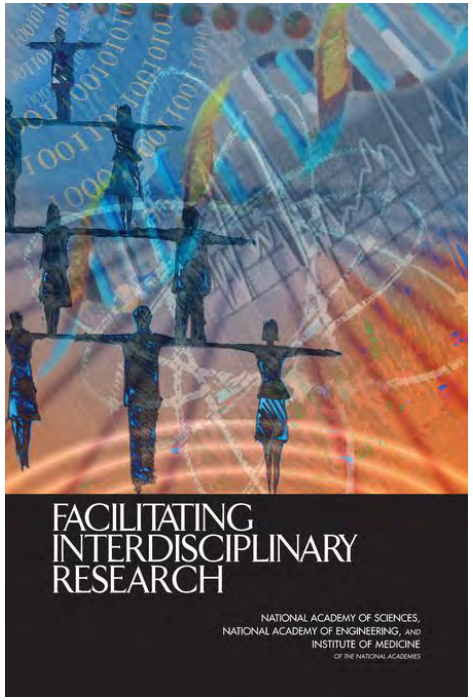
Nominees for committee membership from many sources (typically 100 or more names received for each activity)

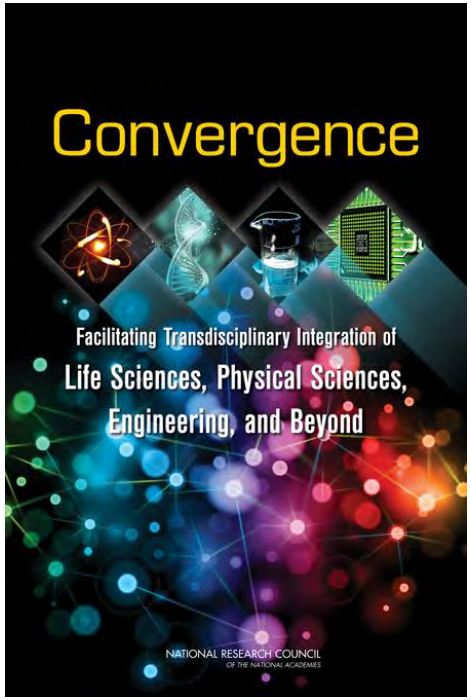
Study process: public data gathering; closed deliberations; rigorous report review

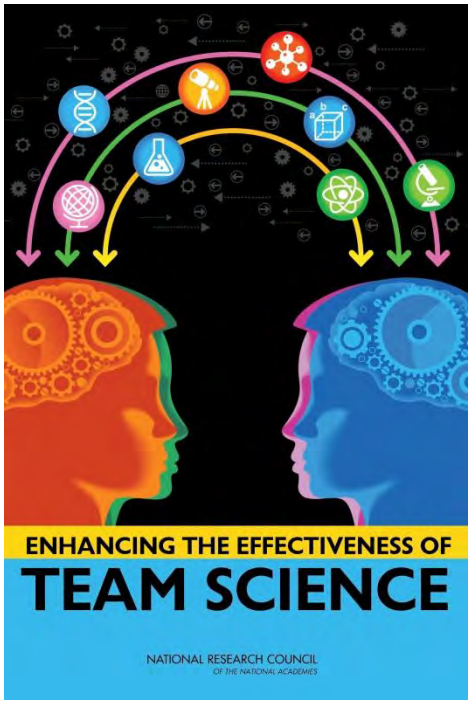
Consensus reports offer recommendations agreed to by the entire volunteer committee

Attention of Congress, government agencies, and the public

Three Reports on Innovations in Scientific Research







Definitions

- *Interdisciplinary research* by teams or individuals integrates information, data, techniques, tools, perspectives concepts and/or theories from two or more disciplines to advance fundamental understanding or to solve problems (NRC, 2005)
- *Transdisciplinary research* not only integrates research approaches but also extends beyond them to transcend disciplinary boundaries (Stokols, Hall and Vogel, 2013). It includes problem-oriented research that crosses academic-industry boundaries (NRC, 2014).

Definitions (cont.)

- *Convergence* refers to both the convergence of expertise across disciplines and the convergence of academic, government, and industry stakeholders to support scientific investigations and enable rapid translation of the resulting advances(NRC, 2014)
- *Team science* is collaborative research conducted interdependently by more than one individual (NRC, 2015)

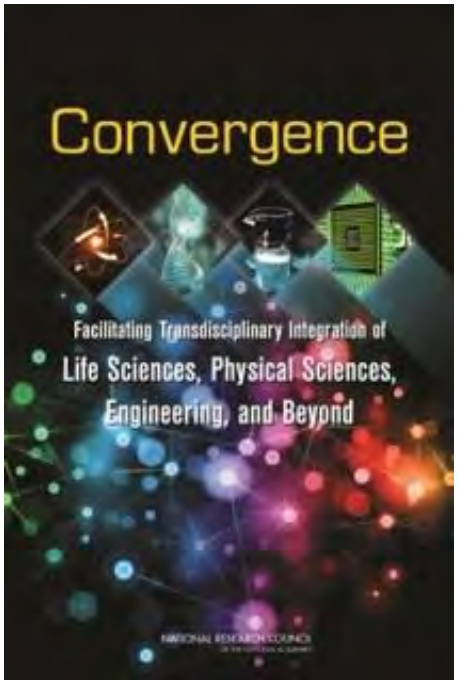
Common Recommendations

- Universities: Revise promotion and tenure policies to recognize and reward interdisciplinary research (IDR)/convergence/team science
- Funders: Expand funding mechanisms and revise review criteria to support IDR/convergence/team science
- Conduct further research/evaluation to understand and guide improvement in IDR/convergence/team science

Convergence

Facilitating Transdisciplinary Integration of Life Sciences, Physical Sciences, Engineering, and Beyond

Committee on Key Challenge Areas for Convergence and Health



The full report, "report in brief," and short video are available at
http://www.nap.edu/catalog.php?record_id=18722
(or search convergence at www.nap.edu)

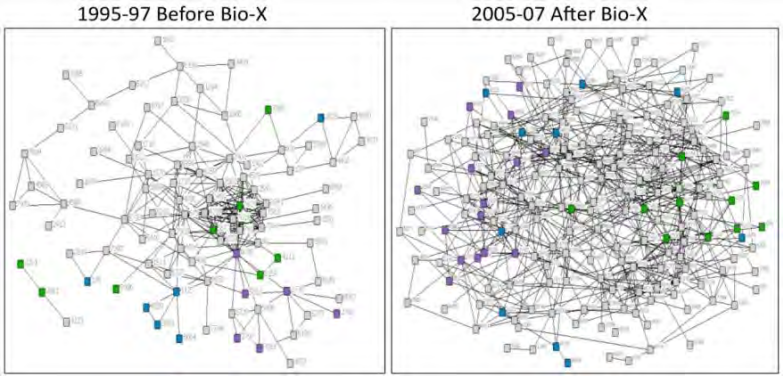
Convergence

An approach to problem solving that…integrates knowledge, tools, and ways of thinking from life and health sciences, physical, mathematical, and computational sciences, engineering disciplines, and beyond to form a comprehensive synthetic framework for tackling scientific and societal challenges that exist at the interfaces of multiple fields.

- goal of “merging” expertise is not new - type of approach has been feature of industrial research laboratories and academic institutions already have set up programs to support convergence
- Without a systematic focus, however, convergence will continue to be a patchwork of isolated efforts

Study Goals:

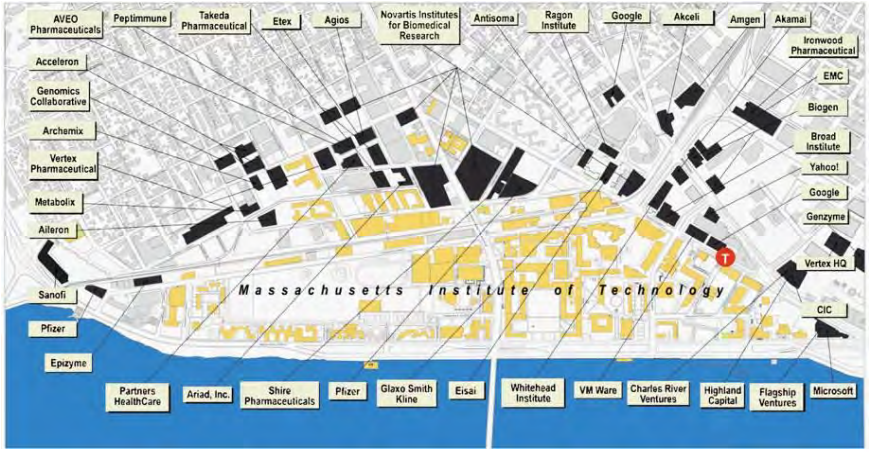
- Explore barriers encountered in facilitating convergence
- Provide practical guidance on strategies to structure and sustain a convergence program



A web of faculty interactions has been created by Bio-X, Stanford University. Courtesy of Daniel McFarland.

Selected Conclusions

- The interconnected network of partners, from academic leaders and practitioners to industry researchers, clinicians, and funders, form an ecosystem for convergence
- Convergence can lead to advances in fundamental knowledge, the creation of new, problem-driven solutions, and strategies for educating the next generation of STEM professionals
- A “one-size-fits-all” approach is not possible although essential characteristics of environments supporting convergence can be identified
- Social sciences and humanities scholarship can inform theory, best practices, and organizational structures employed in convergence programs



Multiple companies surrounding MIT form part of an ecosystem created and sustained by convergence. Courtesy of Phillip A. Sharp, MIT

Recommendations

1. Identify key problems whose solution requires convergence in order to catalyze new research directions and guide research priorities

2. Address barriers to effective convergence, including:
   - expand mechanisms for funding convergence efforts
   - support collaborative proposal review across funding partners
   - implement or expand institutional seed funding to catalyze collaborations

3. Review administrative structures, faculty recruitment and promotion practices, cost recovery models, and research support policies to identify and reduce roadblocks

4. Include explicit guidelines in hiring and promotion policies to recognize the importance of both convergent and disciplinary scholarship and criteria to fairly evaluate them

Recommendations

5. Identify evidence-based practices that have facilitated convergence by drawing on the expertise of economic, social, and behavioral sciences, program management, and strategic planning

6. Develop partnerships with colleagues in other organizations, especially in small universities and institutions that serve traditionally underrepresented groups

7. Collect, establish, and disseminate best practices on the effective transfer of technologies from research organizations into the private sector.

8. National coordination on convergence is needed to support the infrastructure to solve emerging problems that transcend traditional boundaries.

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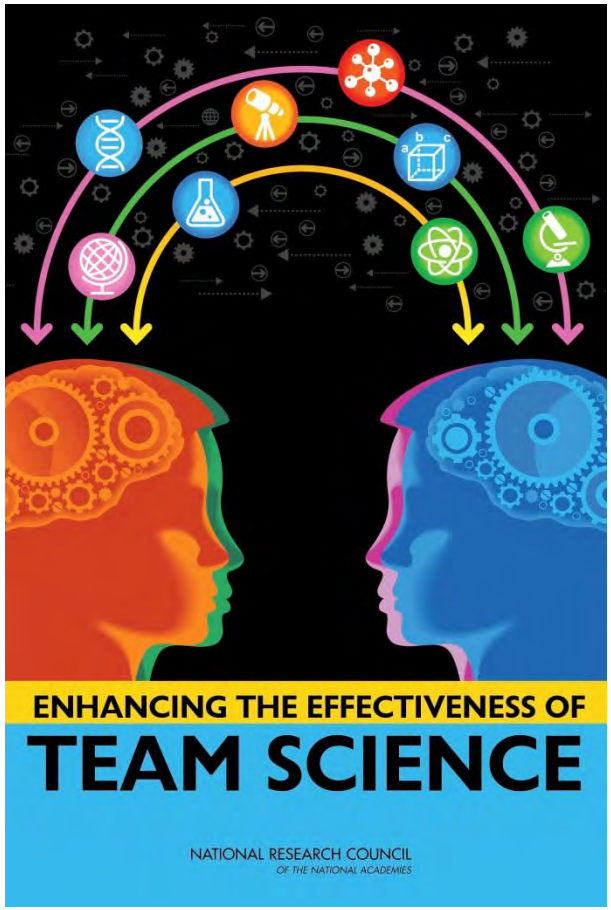
Enhancing the Effectiveness of Team Science

(National Research Council, 2015)



Study sponsored by the National Science Foundation and Elsevier

Committee Charge

Conduct a **consensus study** on the science of team science to recommend opportunities to enhance the effectiveness of collaborative research in science teams, research centers, and institutes… Explore:

- How **individual factors** influence team dynamics, effectiveness and productivity
- Factors at **team/center/institute** level influencing effectiveness
- Different **management approaches and leadership styles** that influence effectiveness
- How **tenure and promotion policies** acknowledge academic researchers who join teams
- **Organizational** factors that influence effectiveness of science teams (e.g., human resource policies, cyberinfrastructure)
- **Organizational structures, policies and practices** to promote effective teams

Study Committee

- **NANCY J. COOKE (Chair),** Arizona State University
- **ROGER D. BLANDFORD (NAS),** Stanford University
- **JONATHON N. CUMMINGS,** Duke University
- **STEPHEN M. FIORE,** University of Central Florida
- **KARA L. HALL,** National Cancer Institute
- **JAMES S. JACKSON (IOM),** University of Michigan
- **JOHN L. KING,** University of Michigan
- **STEVEN W. J. KOZLOWSKI,** Michigan State University
- **JUDITH S. OLSON,** University of California, Irvine
- **JEREMY A. SABLOFF (NAS),** Santa Fe Institute
- **DANIEL S. STOKOLS,** University of California, Irvine
- **BRIAN UZZI,** Northwestern University
- **HANNAH VALANTINE,** National Institutes of Health

- **MARGARET L. HILTON,** *Study Director*
- **TINA WINTERS,** *Associate Program Officer*

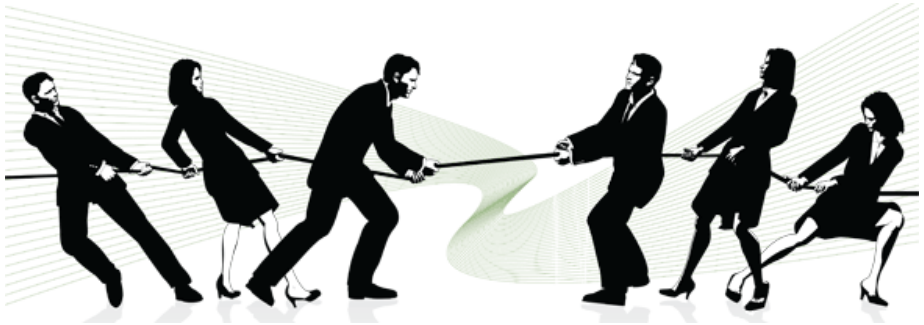
Why Team Science?

- Complexity of modern problem solving require a team
- Team Science has been documented to
  - Have large impact (Wuchty, et al., 2007; Uzzi, et al., 2013)
  - Demonstrate high levels of innovation (Uzzi, 2013)
  - Increase productivity (Hall, et al., 2012)
  - Have a broad reach/uptake (Stipelman, et al, 2014)

Defining Key Terms

- ***Team science*** – collaborative, interdependent research by more than one individual
- ***Science team*** - Two to 10 individuals who conduct team science
- ***Larger group*** - More than 10 individuals who conduct team science
- ***Team effectiveness*** – A team's capacity to achieve its goals and objectives

Key Features that Create Challenges for Team Science



- Large membership diversity
- Deep knowledge integration
- Sometimes large size
- Goal misalignment with other teams
- Permeable boundaries
- Geographic dispersion
- High task interdependence

Improving Team Effectiveness

Conclusion: *Strong body of research conducted over decades demonstrates* ***team processes related to team effectiveness****. Interventions that foster positive team processes offer most* ***promising route to enhance team effectiveness****.*

Interventions in 3 Areas:

- Team Composition
- Team Development
- Team Leadership

Team Effectiveness

Composing the Team

Conclusion: *Research in non-science contexts finds that* ***team composition influences team effectiveness****; relationship depends on* ***complexity*** *of the task, degree of* ***interdependence****, and* ***team familiarity****.* ***Task-relevant diversity*** *is critical and has a positive influence on team effectiveness.*

Conclusion: ***Task analytic methods*** *developed in non-science contexts and* ***research networking tools*** *developed in science contexts allow practitioners to* ***consider team composition systematically****.*

Team Composition: Recommendation

Team science leaders and others involved in assembling science teams and larger groups should:

- **Consider using** task analytic methods that identify necessary **knowledge, skills, and attitudes**
  - *Use methods to match task-related diversity among team or group members with project needs*
- **Consider applying** tools such as **research networking systems** designed to **facilitate assembly** of science teams
- **Partner** with researchers **to evaluate and refine** these tools and task analytic methods

Team Professional Development

Conclusion: *Research in contexts outside of science has demonstrated that several types of **team professional development interventions improve** team processes and outcomes.*

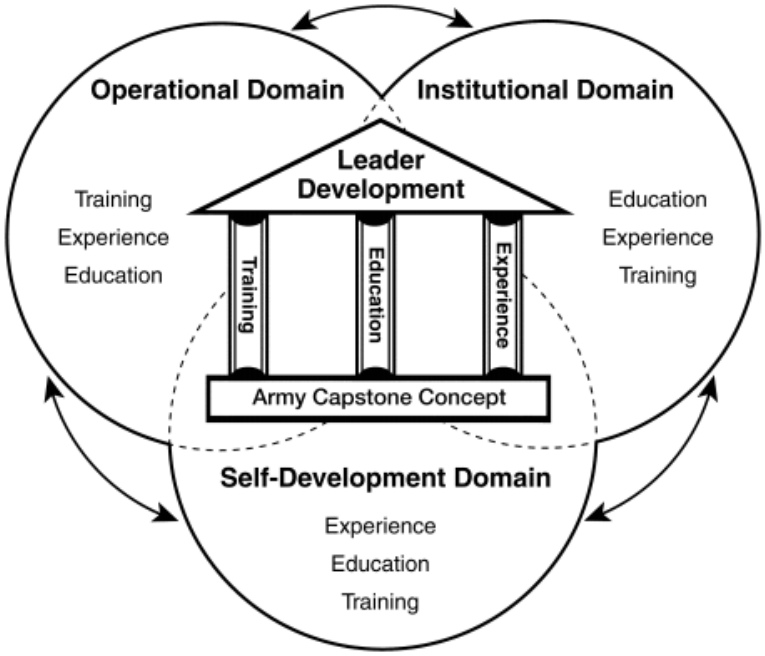
Team Professional Dev: Recommendation

Team-training researchers, universities, and science team leaders should **partner to translate, extend, and evaluate the promising training strategies**, shown to improve the effectiveness of teams in other contexts, to **create professional development opportunities for science teams**.

Leadership

Conclusion: *Fifty years of research on team and* ***organizational leadership in contexts*** *other than science provides a* ***robust foundation of evidence to guide*** *professional development for leaders of science teams and larger groups.*

Leadership: Recommendation



Researchers, universities, and team science leaders should **partner to translate and extend the leadership literature** to create and evaluate science leadership development opportunities for team science leaders and funding agency program officers.

Challenges of Virtual Collaboration

Conclusion: *Research on* ***geographically dispersed science teams*** *and groups has found that* ***communicating*** *and* ***developing trust*** *are* ***more challenging*** *relative to face-to-face teams and groups.*

- ***Limitations*** *of virtual collaboration* ***may not be obvious*** *to members and leaders of the team or group.*

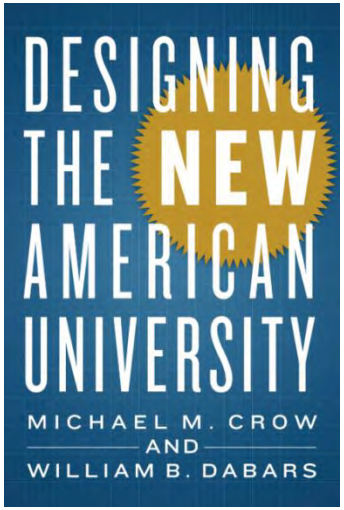
Virtual Collaboration: Recommendation

Leaders of geographically dispersed science teams should:

- **Utilize activities** validated to help participants **develop shared knowledge** (e.g., common vocabulary)
- Consider task assignments within semi-independent units at each location to **reduce the burden of constant electronic communication**.

Research Universities

Conclusion: *Universities have launched* ***new efforts to promote interdisciplinary team science*** *(e.g., creating research centers and institutes), but* ***the impact*** *of these initiatives on the amount and quality of team science* ***has not been systematically evaluated.***



Reward Structures

Conclusion: *University promotion and tenure review policies typically do not provide* ***comprehensive, clearly articulated criteria*** *for evaluating* ***individual contributions to team-based research.***

The extent to which researchers are rewarded for team-based research ***varies widely*** *across and within universities.*

Where team-based research is not rewarded, ***young faculty may be discouraged*** *from joining those projects.*

Funding Agencies

Conclusion: *Public and private* ***funders are in the position to foster a culture*** *within the scientific community that supports those who want to undertake team science through:*

- funding, white papers, training workshops, and other approaches.

NIH National Institutes of Health

Funders: Recommendation

Funders should work with the scientific community to:

- **Encourage the development and implementation of new collaborative models** (e.g., research networks, consortia)
- **Develop incentives** for team science (e.g., new p&t policies)
- **Provide resources** (e.g., information repositories, training modules).

Advancing the Research

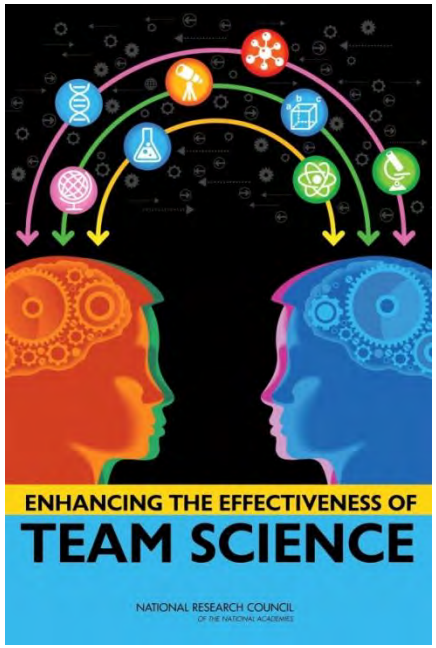
- ***Conclusion: Targeted research is needed*** *to evaluate and refine the tools, interventions, and policies recommended in this report,* ***along with more basic research*** *on team science to guide continued improvement in the effectiveness of team science.*
- ***Few, if any, funding programs support research*** *on the effectiveness of science teams and larger groups.*

Research: Recommendation

- Public and private **funders should support research** on team science effectiveness through funding.
- **Support ongoing evaluation and refinement of the interventions and policies** recommended above
- Support **research on the role of scientific organizations** (e.g., research centers, networks, consortia) in supporting science teams and larger groups.
- Collaborate with universities and the scientific community to facilitate researchers' **access to key team science personnel and data sets**.

Conclusions

- There is a rich and robust science of teams that can be extended to improve team science effectiveness
- The science points to interventions through:
  - Assembling teams
  - Providing professional development and education opportunities and
  - Leadership development opportunities
- Other interventions can improve:
  - Virtual collaboration
  - Promotion and tenure credit for team-based work
  - Support from funding agencies for team science



NIH National Institutes of Health
Turning Discovery Into Health

SciTS 2015

Building the knowledge base for effective team science

SciTS 2015 Conference | June 2-5, 2015 | Bethesda, Maryland

The conference will bring together thought leaders in the SciTS field, researchers engaged in team-based science, and institutional leaders, policy makers, and federal agency representatives who support collaborative research. Central themes include **effective practices and policies** for enhancing team science as well as hot topics and emerging trends such as **team diversity**, **big data**, **citizen science**, **open data**, and **research networking**.

To learn more, go to: www.scitsconference.org

Making Science A Priority

- **SOLVING COMPLEX QUESTIONS IN SCIENCE THROUGH INNOVATION & INTERDISCIPLINARY COLLABORATION**

Where is Science Going?

- **Problem centered on issues that transcend disciplinary boundaries**
- **Mother nature is winning (i.e., she does not have academic departmental structural constraints to what she offers the world)**
- **Tools of science transcend disciplines**
- **Even more information will accrue within traditional areas of study**
- **Moral and ethical issues will abound**
- **The Era of Life science is exploding**

CONTEXT MAP: 2022 Science Landscape

Science Foundation Roundtable

SCIENCE TRENDS

- Declining scientific judgment and expertise
- Increasing "citizen science"/patient advocacy
- US leading in science, but for how long?

POLITICAL FACTORS

- Conservative, risk-averse bias
- Deregulation likely continue
- "So what?" factor in government towards science
- Anti-science mentality
- Bio-ethical debates/ideology
- Metrics/testing-driven education philosophy

ECONOMIC CLIMATE

- Declining Federal and research institution budgets
- European economic collapse leads threatens world science progress
- Rise of Asia
- Public university access to $$ declining
- Student debt rising
- Private sector growth?

FUNDING TRENDS

- Applied Sci. vs Basic Sci.
- Safe funding "wins"
- Venture Philanthropy
- Pharma fuels R&D through start-up acquisition
- Industry leaders carry research flag
- Reduced industry research in less profitable sectors
- Small % total US foundation funding is for science
- Who are next gen. funders for science?

Public assumes higher levels of science funding than actual

DEMOGRAPHIC TRENDS

- Worldwide population growth
- Increasing urbanization
- Increasing middle class

TECHNOLOGY FACTORS

- Volume/complexity of data
- Internet expansion: communications, collaboration, learning
- IP tied up/ restricting science
- Global sharing of scientific exploration

RESEARCH FIELD NEEDS

- Make the "Both/And" case for Science
- Increase public understanding and support for science
- Strengthen science career potential to encourage student pipeline growth
- Growing divide between academic "Haves"//"Have Nots" (lack of access to funding and lack of viable career prospects)
- A compelling new narrative for science

"Tell the Story"

Role of BIG Philanthropy?

UNCERTAINTIES

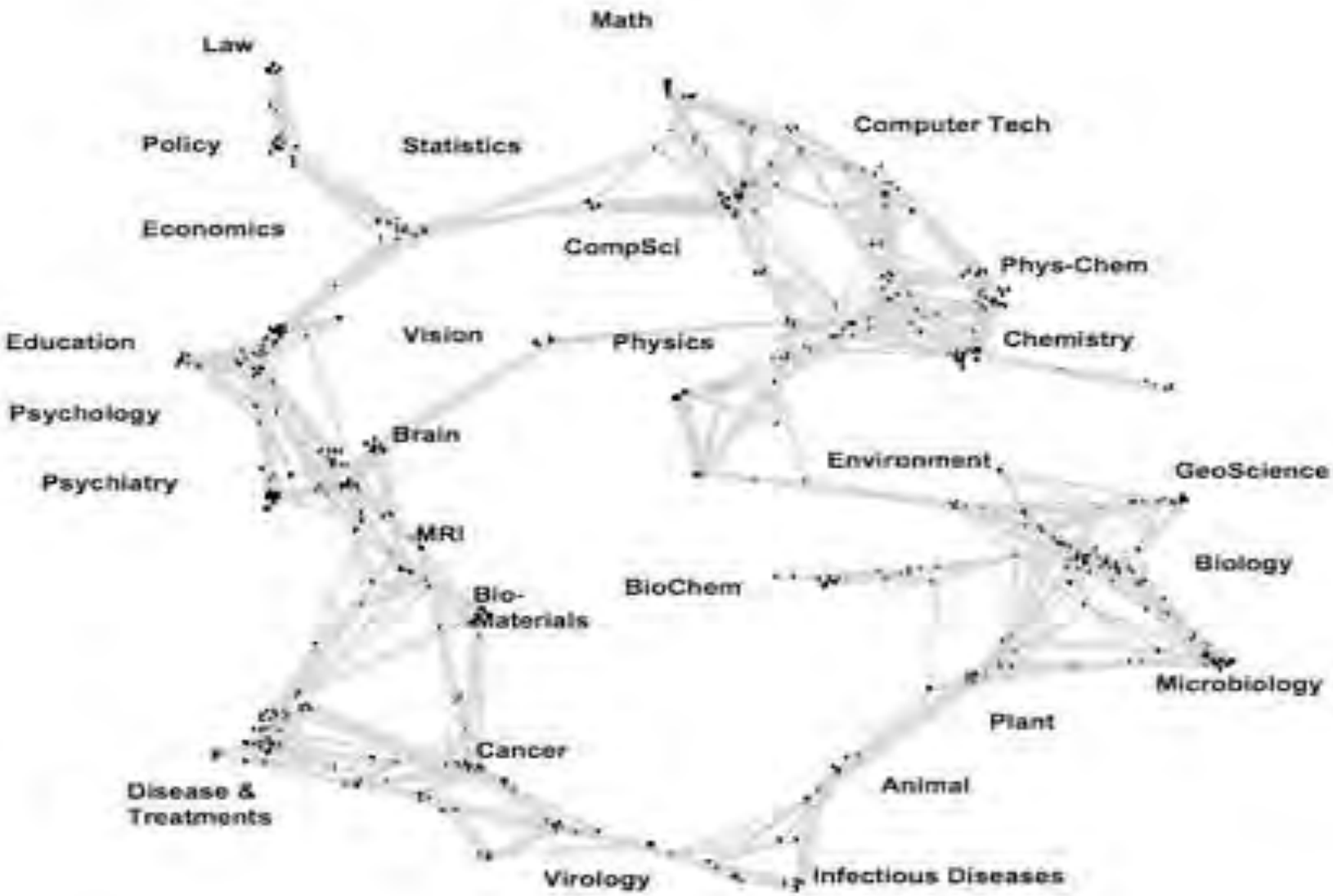
- Deregulation vs. Re-regulation
- Threat of bio-ethics "event"
- Venture capital support for science
- Future level of industry investment

5/15/12

Some 'Grand Challenges'

1. Capture/create competitive green energy sources
2. Understand the chemistry/physics of living systems
3. Harness the synthetic capacity of life
4. Use '-omics' to uncover new approaches to disease cure and environmental well-being
5. Develop 'molecular' self-assembly for the synthesis of complex systems and materials
6. Understand/manage dwindling environmental resources & systems
7. Attract the best and the brightest young minds into science
8. Communicate science effectively to the general public

Science Questions are Getting More Complex




CONVERGENCE

Timeline: The Three Revolutions

1953: Discovery of DNA

1976: Biotech sector emerges with founding of Genentech

mid-2000s: Academic sectors start exploring convergence

2009: NAS releases *A New Biology* report

Molecular Biology Revolution

Genomics Revolution

Convergence Revolution

1950 1960 1970 1980 1990 2000 2010

1969: Salvador Luria, theorist of molecular biology, awarded Nobel Prize

2001: Human Genome Project, Celera publish working draft of human genome

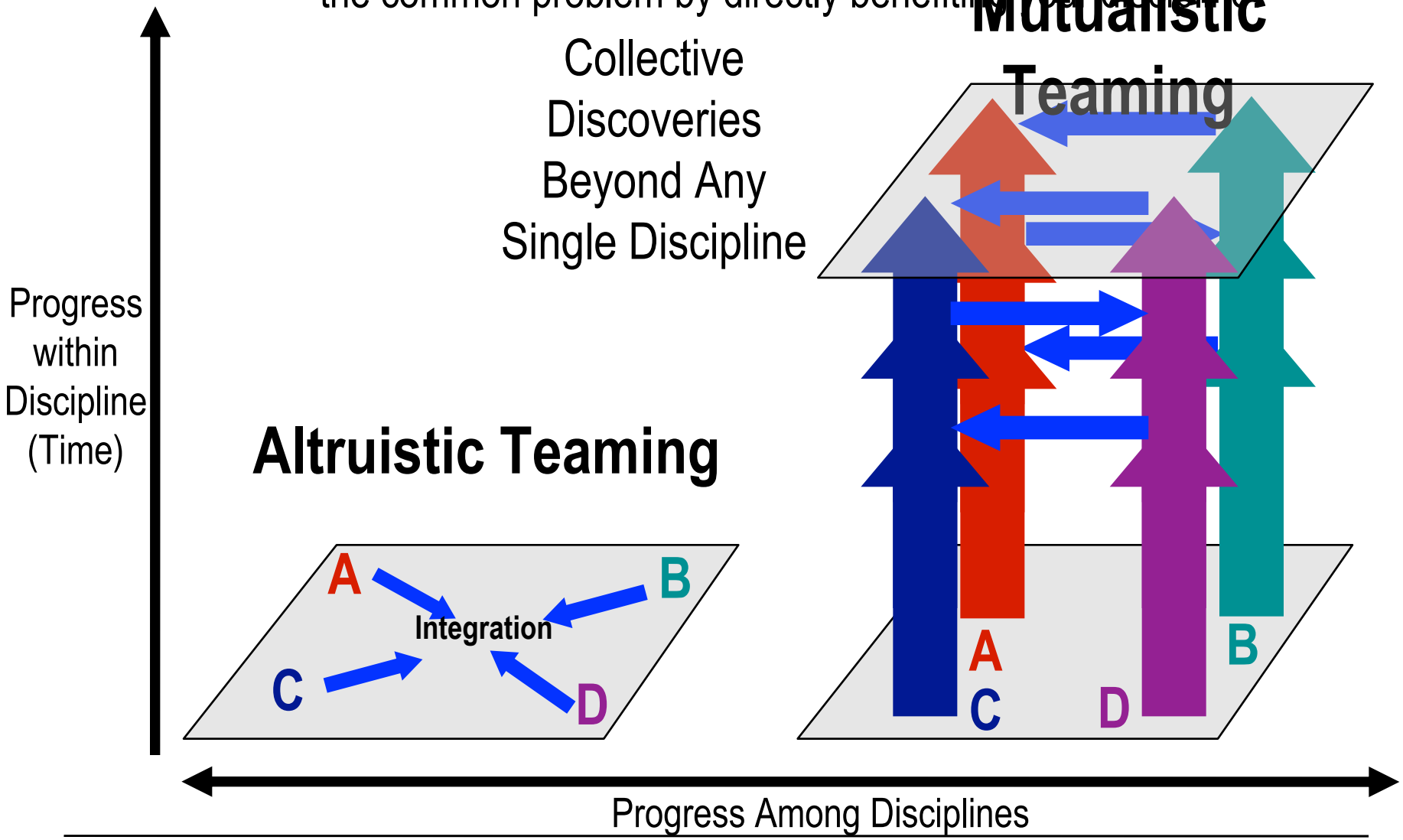
Image and info credits (clockwise from top-left): DNAmazing.com, Gene.com, BioX.stanford.edu, qb3.org, mit.edu/ki, nap.edu, sciencemag.org, nature.com, nlm.nih.gov

Brain Mapping

Interdisciplinary Research

Engagement remains high because the collaboration solves the common problem by directly benefiting your discipline

Collective Discoveries Beyond Any Single Discipline

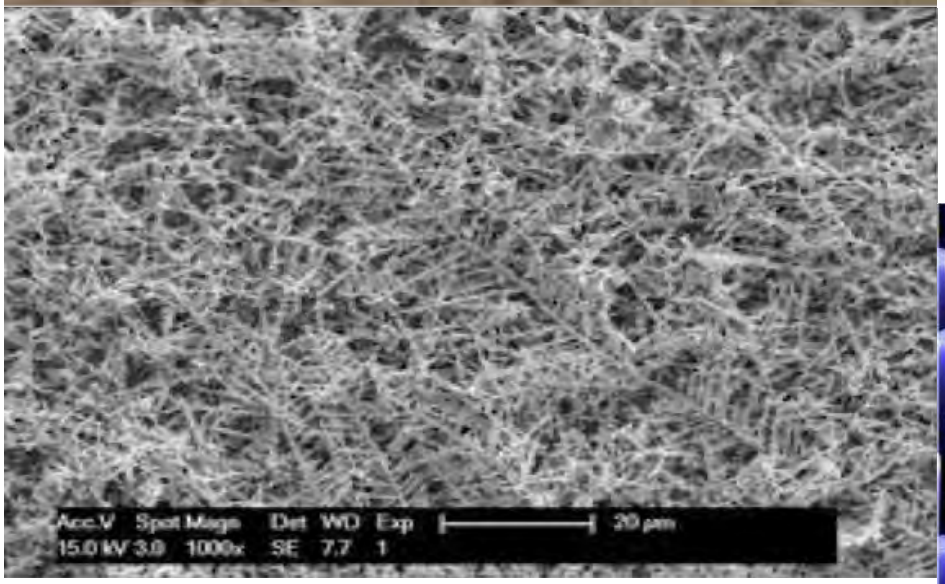


SCIalog

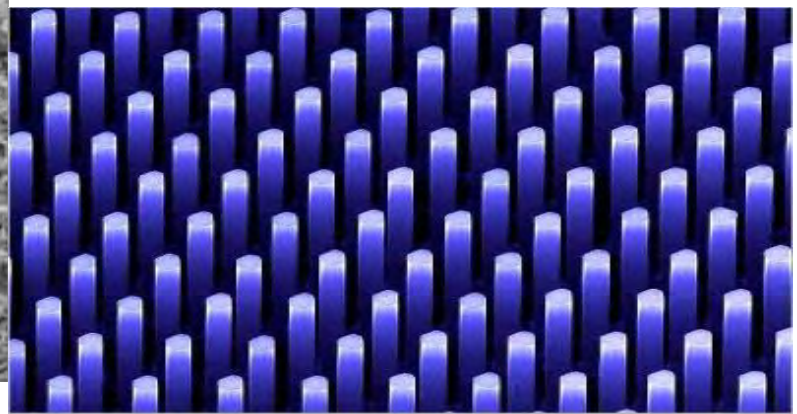
Research Corporation for Science Advancement

An initiative in Funding, Dialog, and Collaboration


www.shutterstock.com · 2125298



Bio-inspired electro-optic silicon photovoltaics. A collaboration between University of California-Irvine, Western Washington University, Penn State, and Arizona to study artificial nanoscale enzymes for carbon dioxide reduction catalysis.



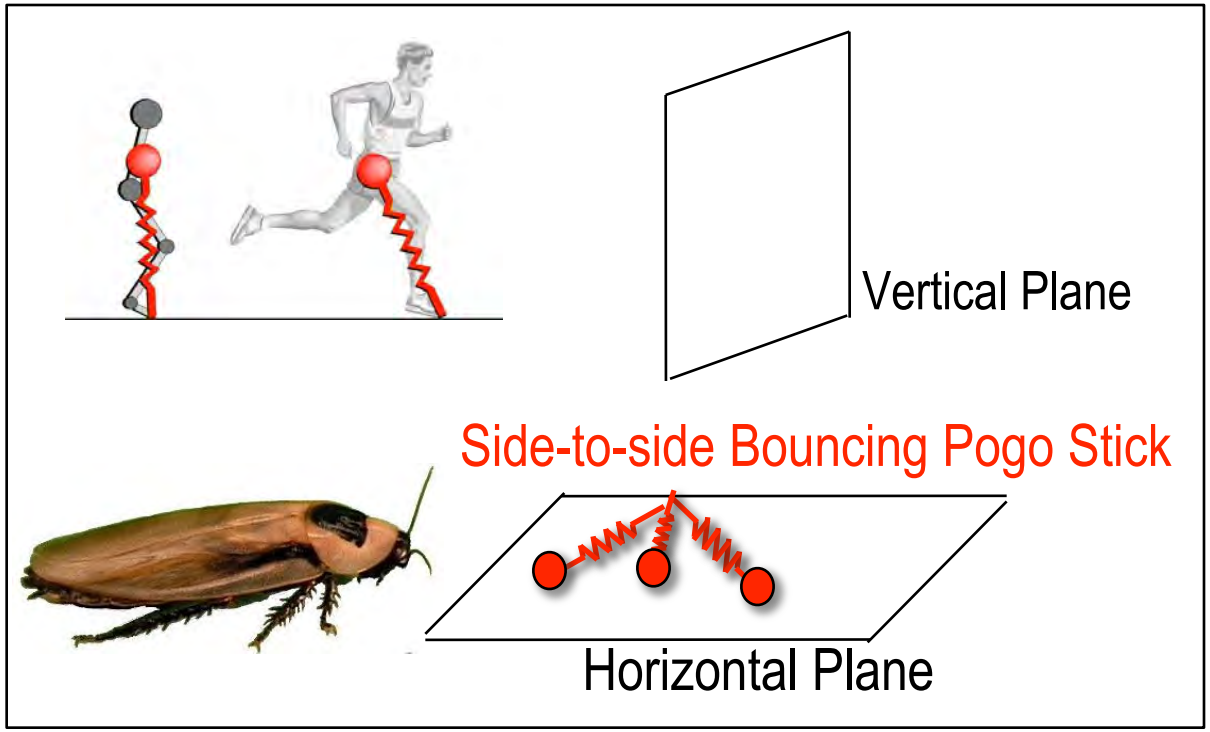
Extraordinary Stability

Animals appear to be Self-Stabilizing using Springy Legs

Cockroach on Rough Terrain

Obstacles as great as 3 times hip height!

Art Inspires Science



Undergraduate Tim Kubow Creates Horizontal Plane Mathematical Model.

Kubow and Full, 1999

Mathematical Model Self-stabilizes!

Animals recover from perturbations without using their brain.

Control is built into the body and legs like a tuned passive suspension system.

Can be used for next generation of legged robots!

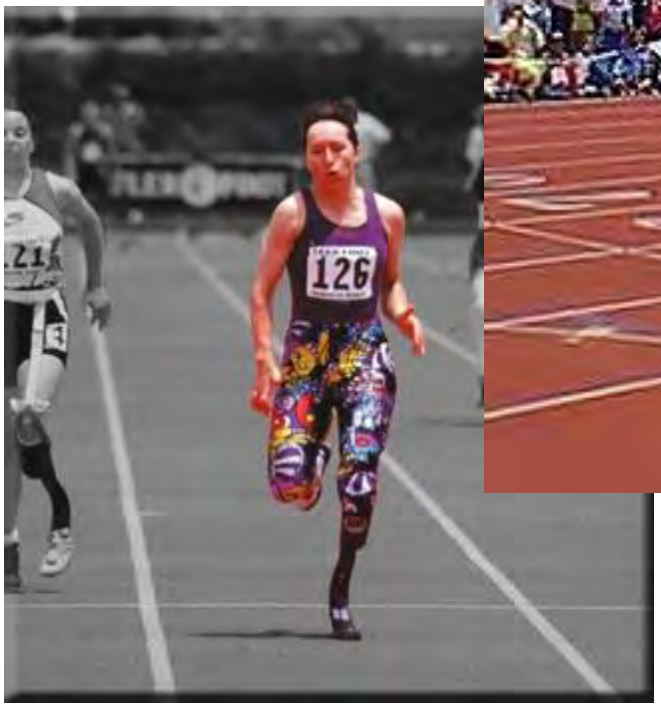
Altendorfer, Moore, Komsuoglu, Buehler, Brown, McMordie, Saranli, Full, Koditschek. 2000

Use General Principle of BioMotion

Set Stiffness of Prostheses

Flex Foot™

Ossur



BioMotion Explorers Awards

Most Diverse Teams Do Best!

Most Creative Design

Kids Do Not Fear Science

But we need teachers who also do not fear science

Future Science Research & Education success will be enhanced through the Formation of Unique Partnerships