The Role of Universities: How to succeed with research, education and innovation

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AMERICAN ACADEMY
OF ARTS & SCIENCES

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1780

CHERISHING KNOWLEDGE
SHAPING THE FUTURE
2008:

Thomas R. Cech, Chair

David Baltimore; Steven Chu; France Córdova; Thomas E. Everhart; Richard B. Freeman; David Goldston; Susan L. Graham; Robert Horvitz; Linda P. B. Katehi; Peter S. Kim; C. D. (Dan) Mote, Jr.; Daphne Preuss; David D. Sabatini; Randy Schekman; Richard H. Scheller; Albert Teich; Mark S. Wrighton; Keith R. Yamamoto; Huda Y. Zoghbi
Venkatesh Narayanamurti, Harvard University, Co-chair
Keith R. Yamamoto, University of California, San Francisco, Co-chair
Nancy C. Andrews, Duke University School of Medicine
Dennis Ausiello, Harvard Medical School
Lawrence Bacow, Tufts University
Malcolm R. Beasley, Stanford University
Edward J. Benz, Jr., Dana-Farber Cancer Institute
David Botstein, Princeton University
H. Kim Bottomly, Wellesley College
Robert Brown, Boston University
Claude Canizares, Massachusetts Institute of Technology
Uma Chowdhry, DuPont
Mary Sue Coleman, University of Michigan
Alan Ezekowitz, Abide Therapeutics
Harvey V. Fineberg, Institute of Medicine
Mary L. Good, University of Arkansas
Leah Jamieson, Purdue University
Linda Katehi, University of California, Davis
Neal Lane, Rice University
Eugene H. Levy, Rice University
Joseph B. Martin, Harvard Medical School
Cherry A. Murray, Harvard School of Engineering and Applied Sciences
Gilbert Omenn, University of Michigan
Thomas D. Pollard, Yale University
Robert C. Richardson, Cornell University
David D. Sabatini, New York University School of Medicine
Randy Schekman, University of California, Berkeley
Richard H. Scheller, Genentech, Inc.
Henri A. Termeer, Genzyme Corporation, ret.
Samuel Thier, Harvard Medical School
Leslie C. Berlowitz, ex officio, American Academy of Arts and Sciences.
Research at an inflection point?

“all-hands” approaches, systems problems and beyond

ultra-specialization, defined problems

Reassess and revise practices and policies
Distinct historical setpoints

Physical sciences and engineering (PSE)
Continuum of discovery and application

Life sciences and medicine (LSM)
Disconnect of discovery and application

Common drivers of change

Scientific progress illuminates new opportunities
Dependent on communication and cooperation

Political and economic forces
Uncoupling disciplines; uncoupling basic and applied research
Overarching objective: Integrate practices and policies across two planes

Stakeholder synergy: Cooperate across academia, industry, government sectors

Trans-disciplinary science: Merge physical and life sciences theory, concepts, applications
Goal 1: Move from interdisciplinary to transdisciplinary

Goal 2: Promote cooperative, synergistic interactions among the academic, government, and private sectors throughout the discovery and development process
**Goal 1:**
**Move from interdisciplinary to transdisciplinary**

**Recommendation 1.1**
Develop and foster a massive “knowledge network” that enables investigators from different disciplines to identify opportunities, establish collaborative efforts, and focus disparate expertise and approaches on problems of common interest.

**Recommendation 1.2**
Expand education paradigms to model transdisciplinary approaches: Develop new and support existing graduate and postdoctoral training programs that integrate concepts and technologies across PSE and LSM.

**Recommendation 1.3**
Expand support for shared core research facilities (especially those that span multiple PSE and LSM approaches), including funding for stable appointments of professional staff to direct them.

**Recommendation 1.4**
Ensure that appointments and promotion policies recognize, support, and reward contributions to collaborative and transdisciplinary research and education endeavors.

**Recommendation 1.5**
Better enable transdisciplinary research by scrutinizing current administrative policies, revising them to optimize efficiency and effectiveness, aligning incentives appropriately, and incorporating dynamic evaluation into future policies.
Goal 2:  
Promote cooperative, synergistic interactions among the academic, government, and private sectors throughout the discovery and development process

Recommendation 2.1  
Establish one or more “grand challenges” that will motivate alignment, cooperation, and integration of efforts and approaches across academia, industry, and government.

Recommendation 2.2  
Develop and implement new models for research alliances between academia and industry.

Recommendation 2.3  
Enhance permeability between industry and academia at all career stages.

Recommendation 2.4  
Set new priorities for the technology transfer function between academia and industry with the explicit goal of maximizing exchanges of knowledge, resources, and people.

Recommendation 2.5  
Develop policies that focus on common interests between academia and industry, while acknowledging and managing intrinsic and avoidable conflicts.

Recommendation 2.6  
Create mechanisms that increase coordination and cooperation among government agencies that support PSE and LSM.
Outline

- The Discovery-Invention Cycle Case studies of Nobel and Draper Prizes
- The role/culture of the Great Industrial Laboratories
- The need for bridging the “Basic”-“Applied” Dichotomy and rethinking of National S&T Policies and for Bell Labs 2.0 to address Societal Grand Challenges
- The particular case of U.S. Department of Energy
Why did we write this book?
Some Reflections and Contrasting themes

- “Pure” science vs “Applied” science
- Directions of causality
- Implications for S&T Policy and design of R&D institutions
What is the core argument of the book?
Overview of Department of Energy Budget Proposal for fiscal year 2016

Wednesday Feb. 25, 2015

Chairman Lamar Smith
Texas (R)

Secretary Ernest Moniz
Department of Energy

Brian Babin
Texas (R)

Audience Question: What knowledge frameworks (mental models) inform this exchange?
Overview of Department of Energy Budget Proposal for fiscal year 2016

Wednesday Feb. 25, 2015

Randy Hultgreen
Illinois (R)
Basic (or "pure") Research vs. Applied Research

Congressional Mental Model

Practitioner Mental Model

Example: EFRCs

Entire Innovation Chain

Where does this model come from?
The Standard View – 1940s

- Basic Research = Research without thought of practical ends
- Basic research must be cordoned off from Applied Research
- Basic Research = Pacemaker of Technological Progress
- Applied Research = Focused on solving practical problems

Science the Endless Frontier - StEF

Vannevar Bush
Electrical Engineer & Dean of Engineering at MIT
The Bush Effect
The core argument of the book is...

Need for a new paradigm!

Where can we find one?
The world’s first transistor, developed in 1947. It was a point-contact device roughly one centimeter across.
### Articulating a New Model

<table>
<thead>
<tr>
<th>Standard Model</th>
<th>New Model</th>
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<tr>
<td><strong>Basic Research:</strong>&lt;br&gt;Basic research is performed without thought of practical ends. It results in general knowledge and an understanding of nature and its laws. – Bush <em>(StEF)</em></td>
<td></td>
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<tr>
<td><strong>Applied Research:</strong>&lt;br&gt;Provides answers to important practical problems. – Bush <em>(StEF)</em></td>
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**Invention**, is the accumulation and creation of knowledge that results in a new tool, device or process that accomplishes a particular, specific purpose and **Discovery**, is the creation of new knowledge and facts about the world.
Recent “Mini Bell Labs” attempts

- Janelia Research Campus
- ARPA-E
- Energy Innovation Hubs
- Energy Biosciences Institute
- National Laboratories?
- Research Universities / Case of UCSB

Logar, Narayanamurti, Anadon, CUP, 2014
Narayanamurti & Odumosu, HUP, 2016
Energy Innovation
and
U.S. Department of Energy
Importance of Integrated View of Energy Innovation
Comparison of Electricity & Telecommunications

- Analogy between electricity sector and the telecommunications industry in the era of Bell Labs and AT&T
  - The telecommunications industry was made of regulated utilities
  - They required large capital investments

- Electric utilities lack important aspects of telecoms industry
  - Telecommunications utilities were both technology developers and adopters through vertical integration
  - Manufacturing in telecommunications was not isolated from R&D or customers
  - During the golden era of AT&T the market for telecoms was increasing, as were the range of services being provided (e.g., undersea cable systems, fiber optic communications, wireless communications)
  - Excellent technical leadership
Innovation in Energy is more Difficult than in Other Sectors

- Limited and uncertain market signals for energy research, development, and demonstration (RD&D) and for deployment.
  - The public good value of technologies that address the externalities of GHG emissions and energy security, for instance, are not appropriately represented in the market.

- The energy sector is large and technologies are developed over long timeframes.
  - This hinders the participation of the private sector in the development of such technologies.

- Energy technologies are very heterogeneous within each stage.
  - There are several different challenges, with early deployment and subsequent expansion issues being particularly important.

- Energy technologies have to compete in the market place with incumbent technologies and integrate into a larger technological system, where network and infrastructure effects lead to “lock-in.”

Narayanamurti, Anadon and Sagar (2009)
Volatility in R&D Deters Innovation: Longer Time-scales are Needed

Year-to-year variation of U.S. government R&D on DOE renewables funding

Narayananumrti, Anadon, Sagar (2009)
<table>
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<tr>
<th>Basic Research</th>
<th>Applied Research</th>
<th>Technology Maturation and Deployment</th>
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<tr>
<td>Grand Challenge</td>
<td>Discovery</td>
<td>Use-Inspired</td>
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<tr>
<td>• Goal: New Knowledge and Understanding</td>
<td>• Goal: Practical Targets</td>
<td>• Goal: Performance</td>
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<tr>
<td>• Focus: Phenomena</td>
<td>• Focus: Performance</td>
<td>• Metric: Milestone Achievement</td>
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<tr>
<td>• Metric: Knowledge Generation</td>
<td>• Metric: Milestone Achievement</td>
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<tr>
<td>• Addresses fundamental limitations of current</td>
<td>• Establishes proof of new, higher-risk concepts.</td>
<td>• Scales up research.</td>
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<tr>
<td>theories and descriptions of matter in the energy</td>
<td>• Prototypes new technology concepts.</td>
<td>• Demonstrates small-scale and all-scale technology.</td>
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<tr>
<td>range important to most energy technologies.</td>
<td>• Explores the feasibility of scaling up demonstrated</td>
<td>• Reduces costs.</td>
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<td>technology concepts in a “quick hit” fashion.</td>
<td>• Involves manufacturing R&amp;D.</td>
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<td>• Pursues fundamental new understanding, usually</td>
<td>• Includes deployment and support activities leading to</td>
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<td>focused on scientific showstoppers, to advance</td>
<td>market adoption.</td>
</tr>
<tr>
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<td>energy technologies.</td>
<td>• Shares cost with industry partners.</td>
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Basic Energy Sciences

ARPA-E

Applied Programs

BES Core Research Areas

Energy Frontier Research Centers

BES Energy Innovation Hubs
Energy innovation institutions

- To be fully effective, U.S. energy innovation institutions need:
  - Clear mission
  - Stable funding
  - Broad, flexible authority – with accountability – for management
  - Culture of technical excellence and willingness to take risks on uncertain but potentially high-payoff ideas
  - ARPA-E appears to be achieving many of these goals – but achieving them elsewhere will require major changes in approaches to running the national laboratories

- An institution for implementing technology demonstrations is likely to be needed
  - Need to be implemented in a way the private sector sees as replicable – current DOE structures likely inadequate

The pressing energy innovation challenge of the US National Laboratories

Laura Diaz Anadon1,2,3*, Gabriel Chan4, Amitai Y. Bin-Nun1 and Venkatesh Narayanamurti1,5

Accelerating the development and deployment of energy technologies is a pressing challenge. Doing so will require policy reform that improves the efficacy of public research organizations and strengthens the links between public and private innovators. With their US$14 billion annual budget and unique mandates, the US National Laboratories have the potential to critically advance energy innovation, yet reviews of their performance find several areas of weak organizational design. Here, we discuss the challenges the National Laboratories face in engaging the private sector, increasing their contributions to transformative research, and developing culture and management practices to better support innovation. We also offer recommendations for how policymakers can address these challenges.
DOE and Lab directed technology transfer outcomes

![Graph a](chart_a.png)

Invention disclosures per dollar of R&D (million 2013 US$)

- DOE-directed R&D, inventions disclosed
- Lab-directed R&D, inventions disclosed

![Graph b](chart_b.png)

Patents granted/filed per dollar of R&D (million 2013 US$)

- DOE-directed R&D, patents granted
- DOE-directed R&D, patents filed
- Lab-directed R&D, patents granted/filed
Some Characteristics of Grand Challenges

- Compelling
- Large
- Relevant
- Feasible
- Timely
- Transdisciplinary

ARISE II: Advancing Research in Science and Engineering, American Academy of Arts and Sciences

Cycles of invention and discovery offers an in-depth look at the real-world practice of science and engineering. It shows how the standard categories of “basic” and “applied” have become a hindrance to the organization of the U.S. science and technology enterprise. Tracing the history of these problematic categories, Venkatesh Narayanamurti and Toluwalogo Odumosu document how historical views of policy makers and scientists have led to the construction of science as a pure ideal on the one hand and of engineering as a practical (and inherently less prestigious) activity on the other. Even today, this erroneous but still widespread distinction forces these two endeavors into separate silos, misdirects billions of dollars, and thwarts progress in science and engineering research.

The authors contrast this outmoded perspective with the lived experiences of researchers at major research laboratories. Using such Nobel Prize-winning examples as magnetic resonance imaging, the transistor, and the laser, they explore the daily micro-practices of research, showing how distinctions between the search for knowledge and creative problem-solving break down when one pays attention to the ways in which path-breaking research actually happens. By studying key contemporary research institutions, the authors highlight the importance of integrated research practices, contrasting these with models of research in the classic but still-influential report Science the Endless Frontier. Narayanamurti and Odumosu’s new model of the research ecosystem shows that discovery and invention are often two sides of the same coin that propels innovation forward.

Harvard University Press (2016)