ARISE 2

Report Brief

Advancing Research In Science and Engineering: **Unleashing America's Research & Innovation Enterprise**

Over the last fifty years, scientific and technological advances have transformed how long and how well we live, and they have been a vital ingredient in U.S. economic prosperity and security. These advances have brought us to a point of great opportunity, where unprecedented collaboration between disciplines can lead to the adoption of novel approaches to complex problems. Biologists, clinicians, physicists, computer and computational scientists, and engineers are finding broader and deeper collaboration to be increasingly rewarding. For example, interdisciplinary collaboration led to the determination of the human genome sequence just five decades after the structure of DNA was elucidated. In addition, there is enormous potential for such scientific advances to contribute to new technologies, commercialized by an innovative and internationally competitive private sector.

Efforts to take advantage of these opportunities, however, have met significant barriers. The current organization of the research sector complicates communication and collaboration across disciplines. Furthermore, fundamental advances are not being translated efficiently into new products and services. Both of these problems have historical roots. This report considers two broad sectors: the physical sciences and a primary venue for their application, engineering (PSE); and the life sciences and one of their major application areas, medicine (LSM). Throughout the last half of the twentieth century, advances in PSE were rapidly translated into a flood of innovative products. In turn, the quest for innovative technologies drove further advances in fundamental understanding. That is, in PSE, basic and applied research existed as an interwoven continuum. In contrast, the basic and applied life sciences were traditionally pursued as distinct and separate activities: life scientists focused on achieving a fundamental understanding of basic biological processes and until the dawning of biotechnology did not extend those discoveries into practical applications, for example, in medicine.

Despite these distinct historical set points, PSE and LSM now find themselves presented with a number of common challenges and opportunities. If these two sectors are to advance together, as they should, each must be mindful of the impact of their different histories on how challenges and opportunities are perceived and addressed. What are some of these common challenges and opportunities?

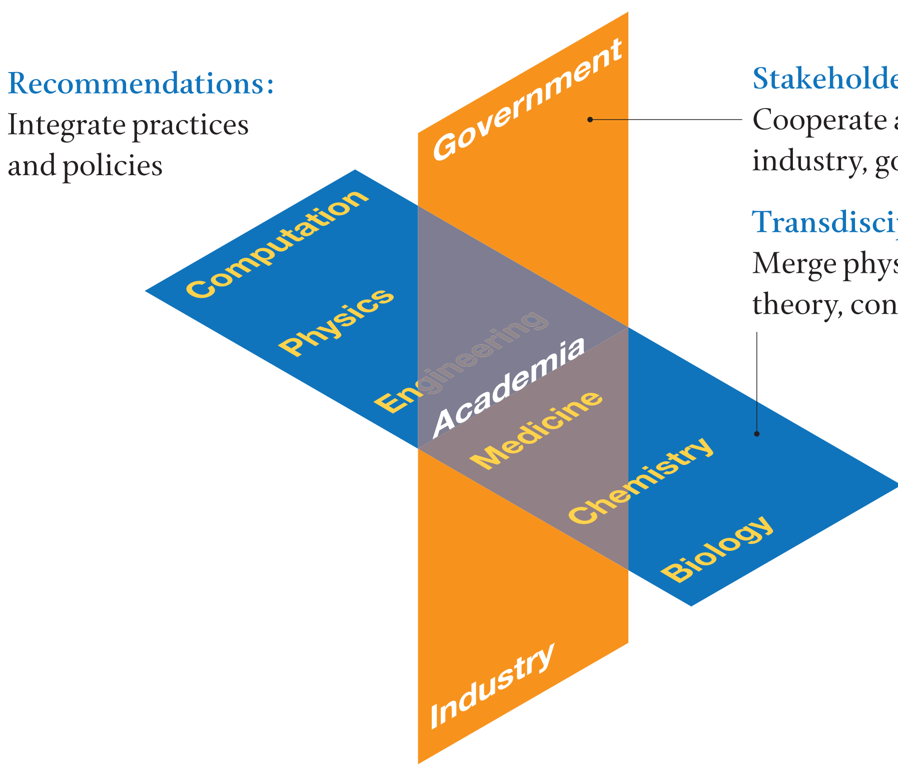
- *Dynamic and global economic challenges:*
  U.S. corporations face economic challenges that severely constrain their willingness to invest in fundamental science and technology research. Each generation of technology has a shorter competitive life span than the preceding one, and capital markets have little tolerance for long-term risk. Increasingly, if the most creative U.S. companies are to

continue to derive new ideas from within the United States, the government must fund, and academia must generate, the discoveries that will drive the next round of innovative products. Yet establishing productive and sustainable collaborations between academia and industry has proven to be difficult. Parallel challenges exist in PSE and LSM education. Both sets of disciplines face increasing global competition to attract the best trainees and then to retain them to populate all sectors of the U.S. research enterprise.

- *Transdisciplinary opportunities:*
The promise of interdisciplinary approaches has been noted for many years, and both universities and funding agencies have invested considerable effort into fostering such collaborations. However, both universities and funding agencies continue to be characterized by inflexible disciplinary and mission boundaries. Even the term *interdisciplinary*, which implies a space *between* disciplines, fails to convey the potential for integration across PSE and LSM. Perhaps *transdisciplinary* better captures the extent of integration required: it is the dismantling of disciplinary boundaries, rather than ad hoc collaborations, that could transform the scientific enterprise and deliver the potential to address previously intractable problems.

- *Urgent and formidable societal challenges:*
The challenges facing society—from climate change to fossil fuel dependency to providing adequate food for a growing population—are immense, urgent, and intimately connected. With proper coordination, science and technology are poised to help solve problems at this level of complexity and importance. Larger-scale projects and collaborations need not—and should not—replace the more focused projects initiated and sustained by individual scientists. Indeed, *transdisciplinary* approaches to complex challenges will rely on the expertise and tools developed by many individual researchers. However, the collaborative pursuit of grand challenges can allow progress to accelerate beyond what individuals can accomplish alone.

- *Dated and inflexible policies and organizational structures:*
Renovating dated organizational structures and cultural attitudes within and across the sectors could dramatically increase the availability of resources to enable transdisciplinary efforts. Some entrenched traditions, policies, and regulatory structures, while they made sense when implemented, have become counterproductive over time. Indeed, some policies now hamper progress.



The recommendations in the *ARISE II* report promote synergy among the stakeholders in the U.S. research enterprise and the integration of theory, concepts, and applications from the physical and life sciences.

Rapid progress is now within reach. A new model for cooperation and coordination among the stakeholders—the various disciplines within academia, many different government agencies, and a diverse set of for-profit and nonprofit private-sector entities—has been slow to emerge, possibly because no one part of the system can change in isolation. A coordinated effort will be required to reduce risks sufficiently for a critical mass in academia, government, and the private sector to try new approaches. This report from the American Academy of Arts and Sciences identifies two overarching goals and eleven recommendations that reach toward a new and powerful integration of the physical sciences and engineering (PSE) and the life sciences and medicine (LSM):

Goal 1:

Move from interdisciplinary to transdisciplinary

Moving toward transdisciplinary research will require more than encouraging researchers from different disciplines to work together. A critical next step is to provide incentives and remove barriers so that the tools and expertise developed within discrete disciplines are shared and combined to enable a deep conceptual and functional integration across the disciplines.

- *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

Creating an interdependent ecosystem requires incentives for basic and applied research, development, and deployment. Novel discoveries can emerge during the development process, and new technologies can arise out of basic research labs. The academic, government, and private sectors must develop an inclusive and adaptive environment that ensures that the unique objectives, skills, and points of view of the different sectors are integrated and optimally utilized.

- *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.

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