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VENKATESH NARAYANAMURTI

# On Soloists, Symphonies, and Transdisciplinary Research

There is little dispute about the benefits and importance of scientific research to the prosperity and competitiveness of the United States. It may be less apparent, however, that some of the greatest scientific achievements, such as magnetic resonance imaging and the sequencing of the human genome, were born out of the integration of new knowledge, methodologies, and technologies from multiple disciplines. They thrived because of productive collaboration between federal agencies, universities and the commercial sector. A new report from the American Academy of Arts and Sciences, *ARISE 2: Unleashing America's Research & Innovation Enterprise*, proposes that addressing the complex problems facing today's societies will require even greater integration of scientific and technologic disciplines and better alignment of resources from government, academia, and industry. The success of the U.S. scientific research enterprise has created unprecedented opportunities to foster such integration, yet cultural and organizational barriers obstruct deeper collaboration and stifle American innovation.

Since World War II, the physical sciences and engineering (PSE) and the life sciences and medicine (LSM) have evolved in separate and distinct ways. PSE and LSM are similar in that both include basic (such as physics and biochemistry) and applied (such as engineering and clinical research) approaches, but they are quite different in how scientific discovery and application occur. Although PSE and LSM might be naturally linked by common goals, their traditions now stand in the way. The Academy's *ARISE 2* report contends that current constructs are not serving us optimally, and it seeks to identify both best-practice models and opportunities for transdisciplinary cooperation across fields and among academia, government, and the private sector.

The term "transdisciplinary" refers to deep scientific integration across disciplines—biology, medicine, physics, chemistry, engineering, mathematics, and computer science—that have grown increasingly isolated from one another. It differs from "interdisciplinary," which refers to endeavors that sit between two or more disciplines, and "multidisciplinary," which describes multiple disciplines operating alongside one another. Transdisciplinary efforts bypass the trappings of conventional thinking by first focusing on a broad or multifaceted challenge, then leveraging all available tools (methodologies, knowledge, concepts, and approaches) from multiple disciplines to tackle the problem. In so doing, transdisciplinarity also promotes an integration-driven emergence of new approaches, disciplines, and schools of thought. Continuous communication and information sharing are critical, and are leveraged by the creation of collaborative hubs such as shared core research facilities and cross-disciplinary training programs.

Powerful in theory, these concepts are more difficult to reduce to practice. Government agencies that support science and engineering have differing oversight structures, priorities, and rules of engagement, precluding facile collaboration or even common standards among them. Companies must focus on their profits and bottom line, making them less

likely to invest in risky efforts that will take a long time to come to fruition.

University departments hire and promote faculty to meet discipline-specific teaching or research needs, adhering to a decades-old model that can, inadvertently, disadvantage individuals who contribute as part of a large research team, or direct a shared research core facility, or collaborate outside the department's field. In some departments, particularly in LSM, a researcher's contribution to a collaborative work, no matter how significant, may be unduly discounted if the researcher is not the senior or primary author or if the work is published in a specialized journal outside of the researcher's discipline. Likewise, reference letters from experts in a researcher's field carry considerable weight in the evaluation of candidates for appointments, promotions, and tenure but may fall flat if the referee is from another discipline and his or her accomplishments and accolades are unfamiliar. Discipline-specific jargon and discipline-focused journals have created siloes and continue to present high communication barriers to sharing knowledge and approaches across diverse fields.

For all of these reasons, as powerful as the transdisciplinary research approach is, the scientific research community has been slow to take advantage of it. *ARISE 2* posits that, much like an orchestra in which every musician brings a different range and timbre, the scientific community can attack a challenging problem through the formation of a transdisciplinary ensemble that is greater than the sum of its parts. It offers recommendations to begin to take down barriers that have resulted from cultural norms, misaligned incentives, and impenetrable technical jargon and that continue to stand in the way of this synergistic fusion. The conductors of the science and technology orchestra—deans and provosts at universities, policymakers and program managers at federal funding agencies, and corporate research executives—have key roles to play in shaping the symphony by making traditional boundaries permeable to collaboration.

**Conducting the symphony**

It is within the power of these "conductors," who have a detailed understanding of the many intricate pieces (both technical and cultural), the ability to see the bigger picture, and access to resources (facilities, funding, and a platform for sharing knowledge), to build bridges across disciplines. They should work together to encourage an environment where transdisciplinary research is a priority, while also creating a robust series of safety nets that protect individual investigators during a time of transition to a more integrative research enterprise.

Researchers also have fears about the implications of such a broad change. Upon shifting to a transdisciplinary approach, will large projects consume a disproportionate amount of the grant money pool? Will scientists still be able to pursue their independent research interests, or will the direction of their research be dictated by individuals outside of their scientific community? What does all of this mean for the progress and success of their individual careers? Understandably, at a time when federal grant funding—the lifeblood of academic research and a large source of many researchers' salaries—is tight, few people may want to rock the boat when their careers are on the line.

*ARISE 2* specifically recommends that deans, provosts, policymakers, and program officers develop guidelines to give due credit to the contributions of collaborators in transdisciplinary research efforts, and that they reserve a subset of faculty appointments for researchers who bridge disciplines, departments, or schools. But weaving these guidelines into the current framework of rules and regulations is challenging and requires universities and funding agencies to work closely together, and they too must overcome their own barriers to collaboration.

Academia must find ways to both decrease friction and increase collaboration across departments or schools. They can build bridges across disciplines to promote transformative changes that move away from the traditional university model, which relies on distinct disciplines. On the federal side, each funding agency has its own mission, culture, and selection criteria for grant proposals that can get in the way of productive collaboration across multiple funding agencies to support transdisciplinary research. The federal government can be more deliberate in finding ways to harmonize the various agencies that support science and technology. This may be particularly difficult now, when competition for shrinking federally allocated funds is vicious and requires agencies to distinguish themselves from the pack, further cementing the divides between agencies. Overcoming this will require the development of new mechanisms for interagency coordination and securing a fraction of the federal research budget for interagency projects. *ARISE 2* suggests that agencies such as the National Institutes of Health (NIH) might experiment in the Defense Advanced Research Projects Agency (DARPA) tradition and adopt approaches in which excellent program managers have more say in funding decisions and project execution, or perhaps work more closely with DARPA toward common objectives.

Windows of opportunity to embark on these transformative changes have recently presented themselves. The Brain Research through Advancing Innovative Neurotech-

nologies (BRAIN) Initiative, announced by President Obama last spring, calls for deep integration across disciplines and has the potential to be an outstanding example of an opportunity for both transdisciplinary research and interagency cooperation. The initiative is expected to involve investigators with expertise in neuroscience, physics, computer science, and engineering; engage with both academia and the private sector; and be collectively led by NIH, DARPA, and the National Science Foundation. As a "grand challenge," very much in the mold of what has been proposed in *ARISE 2*, we hope the BRAIN initiative will succeed as a new model.

**Time to change the music**

The current system of specialized academic disciplines and mission-focused federal funding agencies has led to tremendous advancement in scientific research and innovation. But the status quo cannot keep up with 21st-century grand challenges. Much of the truly transformative research of today grows out of transdisciplinary efforts that fuse knowledge and technologies across multiple disciplines. To engender a transdisciplinary research community requires cultural changes across both academia and federal funding agencies that dissolve the barriers standing in the way of communication and collaboration. But, as with an orchestra in which all sections must change tempo simultaneously, the entire research ecosystem must engage in this cultural shift together.

*Nancy C. Andrews (Nancy.Andrews@duke.edu) is dean of the Duke University School of Medicine and Vice Chancellor for Academic Affairs; Venkatesh Narayanamurti (venky@seas.harvard.edu) is a professor of technology and public policy and professor of physics at Harvard University and director of the Science, Technology and Public Policy Program in the Belfer Center for Science and International Affairs at the Harvard Kennedy School. They are a member and cochair, respectively, of the American Academy of Arts and Sciences' committee that produced* ARISE 2: Unleashing America's Research & Innovation Enterprise.