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Grand Theories: How Far Have We Come and Where Will We Go?

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President Obama's call for science to be "restored to its proper place" excites science policy advocates. Science, it appears, may play an important role in informing societal decisions and restarting the country's economic engines. Lawmakers heeded his call during the construction of the American Recovery and Reinvestment Act of 2009: upon passage, the act included more than $17 billion for scientific research and infrastructure, intended in part to "secure America's role as a world leader in a competitive global economy...[by] renewing America's investments in basic research and development."

But can these investments spur the innovations necessary for the country to find good alternatives to fossil fuels, help stem climate change, and lead the world in finding solutions to other catastrophic problems? It depends. Innovation comes from transformative, integrative, and often risky research, say influential reports from the National Science Foundation (NSF) and the National Research Council (NRC), among others. The question is, then, has such transformative, integrative, and risky research become part of the culture and practice of biologists?

Over the course of most of the 20th century, biology research became increasingly reductionist and compartmentalized, with little exchange of ideas and information between the field's subdisciplines. In the 1990s, however, the growth of interdisciplinary collaborations and advances in technology led to the concept of integrative biology, an approach to studying biological systems by integrating perspectives and insights from various disciplines. As the concept caught on, more than a few departments of biology across the country renamed themselves departments of *integrative* biology. Despite the buzz, science commentators note, relatively few researchers employ a truly integrative approach. Marvalee Wake, professor of integrative biology at the University of California, Berkeley, attributes the problem to inadequate definition: "The term means different things to different scientists." To make further progress will require "changing the paradigm of graduate student training, development of shared facilities, and changing attitudes about the nature of expertise," Wake says. Nevertheless, she adds, "the general concept is taking hold as it becomes ever clearer that complex questions require not just diverse expertise, but new approaches."

In an effort to stimulate those new integrative approaches, the NRC published *The Role of Theory in Advancing 21st-Century Biology: Catalyzing Transformative Research.* The study points out that many principles in the theory-rich discipline of biology—such as evolution—blur disciplinary boundaries, and it encourages biologists in all subdisciplines to "examine the theoretical and conceptual framework that underlies their work and identify areas where theoretical advances would most likely lead to breakthroughs in our understanding of life." After the report's publication in 2008, the NSF launched "Advancing Theory in Biology" (ATB), an initiative to develop new theoretical approaches to "improve our understanding of fundamental biological principles that integrate phenomena across levels of biological organization."

A year into the ATB program, it is fair to ask whether the initiative has yielded any grand biological theories. Judging from the number of grant proposals, it would appear that the idea of grand biological theories has not yet fully caught on, according to Saran Twombly, an ATB program director. Sixty-eight grant proposals were received in 2008, many of them from chemists and physicists who wanted to use theories from their fields to transform biology; fewer proposals came from biologists. Many applicants apparently failed to understand that the mission was to develop grand theories from studies that cut across disparate fields of biological inquiry, not from studies across biology and other physical sciences. "We've made a generation of biologists [who] think that the answer is to collect facts, but...the power of theory is that is can tell us much more than facts can tell us," Twombly said.

The research funded by ATB is necessarily innovative and therefore risky, which may be another reason for biologists' slow response to the program. Researchers have long believed that mainstream projects—the ones promising results rather than risk—are the ones that get funded. And because funding for NSF's Biological Sciences Directorate has been stagnant, Twombly suggests, "program officers have been extremely conservative in who they fund," thereby trying to ensure the most bang per buck of funding.

The ATB program accepted its last round of applicants in February 2009, which Twombly finds "unfortunate, because it seems that momentum is finally gaining for integrative approaches to studying biology and the biological science." However, NSF officials hope that the federal stimulus package may provide resources to fund more worthy proposals, and thus help biology transform itself and the economy.

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