RESEARCH AGENDA

Promoting Convergence in Biomedical Science

Multidisciplinary thinking and analysis will permit the emergence of new scientific principles and opportunities.

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The next challenge for biomedical research will be to solve problems of highly complex and integrated biological systems within the human body. Predictive models of these systems in either normal or disease states are beyond the capability of current knowledge and technology.

These problems have been attacked via interdisciplinary research approaches, where, for example, biologists called on engineers and computational experts and their tools. However, rather than bringing together practitioners from separate silos to provide skills, there is an increasing need to merge expertise that goes beyond the interdisciplinary intersection of fields to the emergence of new disciplines. In recent decades there have been two biomedical revolutions: molecular biology and genomics. We believe the convergence of fields represents a third revolution (*1*, *2*), where multidisciplinary thinking and analysis will permit the emergence of new scientific principles and where engineers and physical scientists are equal partners with biologists and clinicians in addressing many of the new medical challenges.

Convergence is already emerging. For example, the tissue-engineering field combines advances in developmental biology with engineering and materials methods to replace or improve tissue, organs, and other biological functions. This is not a typical interdisciplinary situation where a cell type can be given over to an engineer or an engineer can guess what kind of scaffold will work in a biological system. Rather, there must be multidisciplinary collaboration from the start, with all participants having common reference points and language. This field simply would not exist without the convergence approach (*3*).

Similarly, convergence will be key to advances in many crucial areas, such as using microfabrication to analyze single cells, the development of targeted nanoparticle therapeutics, the integration of large data sets to create personalized medicine at the bedside and microsensors that can detect the onset of disease.

Although a deep disciplinary background remains vital, a robust cross-disciplinary education is essential, too. Researchers need to learn a kind of "convergence creole" to help them communicate across disciplinary lines and then to become fully "multilingual."

One example of convergence in education is the Princeton Quantitative and Computational Biology program, described as "a collaboration in multidisciplinary graduate education among faculty in the Institute and the Departments of Chemistry, Computer Science, Ecology and Evolutionary Biology, Molecular Biology, and Physics" (*4*). At a national level, research training grants are needed to encourage more institutions to develop courses and programs that prepare students, postdoctoral researchers, and fellows for convergence-driven research. Research centers built around convergence are emerging (*5*) and will require concentrated federal backing.

The National Institutes of Health (NIH) should consciously adopt this approach for funding considerations. The NIH Common Fund was organized as a way to avoid "the traditional divisions within health research" (*6*). Common Fund dollars offer a flexible way to support higher-risk extramural research through cutting-edge, multidisciplinary, multi-investigator research projects. In addition, a more multidisciplinary peer-review process for NIH-funded projects is needed to evaluate merged capabilities evolving from the intersection of disciplines. For example, a college of scientific reviewers working at the intersections of disciplines not traditionally funded by NIH should be made accessible for more study sections.

The NIH does currently fund projects that blend disciplines; The National Cancer Institute (NCI) (creating initiatives for nanobiology, systems biology, and physical science applications to cancer) and The National Institute of Biomedical Imaging and Bioengineering (promoting emerging areas such as biophotonics and image-guided interventions) are only two of many examples. This is important, but it is only a start. We need to build on this systematically across institutes so that NIH is consciously breaking down silos. For instance, the proposed National Center for Advancing Translational Sciences, NCATS, will need to embody convergence. If translation is isolated into one new center it will not evolve; by making convergence a guiding model, NCATS could help break silos across NIH and evolve partnerships outside it with industry and other agencies.

Our national scientific research has historically been funded in separate stovepipes by science-mission agencies. In areas where collaboration can be productive, our funding agencies, not just our scientists, should become collaborators. That means jointly identifying areas of opportunity and collaborative efforts. The NIH Challenge Grants, which are available to investigators from outside NIH, are one step. Another might include opportunities for experienced federal agency researchers and program directors to take on short-term, multidisciplinary assignments in other research agencies, forming new think-tank environments. Such a program might be coordinated by the National Science and Technology Council. We will need an ongoing evaluation effort for progress in research and education, perhaps through the expertise of the Office of Science and Technology Policy.

In a period of challenges to research funding, convergence offers a path toward innovation that makes a strong case for growth of federal support.

References and Notes

1. P. A. Sharp *et al.*, *The Third Revolution: The Convergence of the Life Sciences, Physical Sciences, and Engineering* [White paper on convergence, Massachusetts Institute of Technology (MIT), Washington, DC, 2011]; web.mit.edu/dc/Policy/MIT%20White%20Paper%20on%20Convergence.pdf.
2. The MIT-AAAS Forum on Convergence, Washington, DC, 4 January 2011; http://techtv.mit.edu/.
3. T. Dvir *et al.*, *Nat. Nanotechnol.* **6**, 13 (2011).
4. QCB@Princeton, www.princeton.edu/qcbgrad/.
5. Examples include the Clark Center, which houses the Bio-X program at Stanford University, the Koch Institute at MIT, the Wyss Institute at Harvard University, the Petit Institute for Bioengineering and Bioscience at Georgia Tech, the Molecular Engineering Institute at the University of Chicago, and the North Campus Research Complex at the University of Michigan.
6. NIH Common Fund, http://commonfund.nih.gov/interdisciplinary/overview.aspx.

7. The authors thank W. B. Bonvillian and A. J. Arnold for help and advice.

10.1126/science.1205008

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