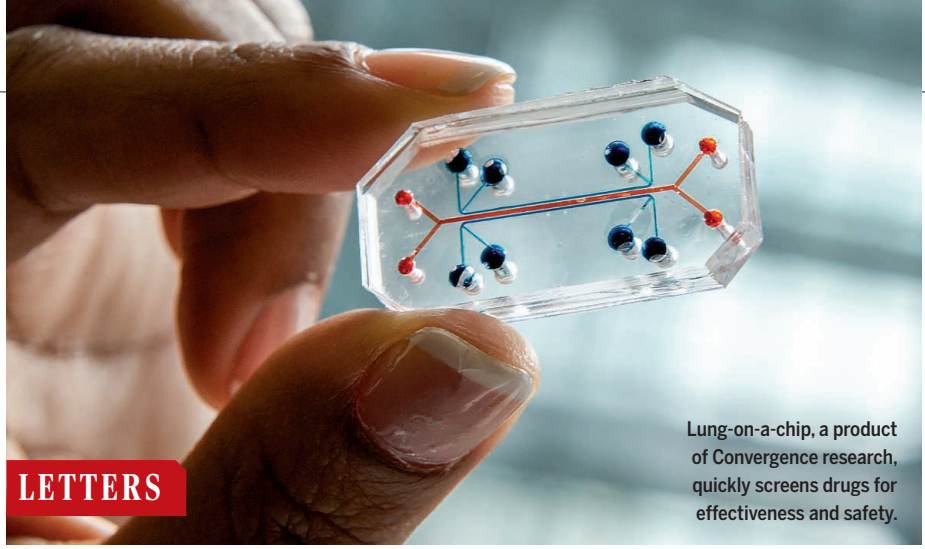

Lung-on-a-chip, a product of Convergence research, quickly screens drugs for effectiveness and safety.

PHOTO: DARPA

LETTERS

Edited by **Jennifer Sills**

Convergence: The future of health

THE INTEGRATION OF the life sciences, physical sciences, mathematics, engineering, and information technology—often referred to as Convergence—has emerged in recent years as a powerful approach to research with the potential to lead to medical and technological breakthroughs. As emphasized in the report, "Convergence: The future of health" (*1*), research funding is central to realizing the promise of Convergence.

As the new administration prepares to appoint its science leadership and to set research budgets, we urge them to recognize that science and technology are part of the infrastructure of the country. These fields are the source of both new jobs and the capacity to meet future challenges. Investing in the infrastructure of education and science is investing in the future economic health of the country.

Given that the National Institutes of Health (NIH) fund the majority of the biomedical research performed in the United States, the new administration should request sustained increases to the NIH budget, with funding targeted for Convergence research specifically. Beyond the NIH, support for Convergence at the National Science Foundation (NSF), the Defense Advanced Research Projects Agency, and the Department of Energy (DOE) is critical to enhance the impact of nonbiomedical disciplines necessary to foster Convergence.

The White House Office of Science and Technology Policy should coordinate partnerships across science agencies with relevant expertise. Convergence needs a coordinated strategic and funding plan across the science agencies to achieve its full potential to supply the innovations that will give physicians and patients the diagnostics, therapies, information, and tools to live healthier lives. The United States can be a leader in this research revolution, but only if we invest in it now.

Several federal agencies, including NIH, NSF, the Department of Defense (DOD), and DOE, are now involved in some aspect of Convergence research. However, the level of support is small, with only about 3% of NIH funding going to principal investigators in the physical sciences, engineering, or mathematics/statistics (*2*). Without greater inclusion of these perspectives, we will miss critical insights into health technologies and therapies of the future. The NSF has announced Convergence as one of its priorities, and we hope this will manifest as a substantial increase in funding. Numerous opportunities for greater collaboration exist between NIH and other agencies, such as DOE, DOD, the National Institute of Standards and Technology, and the Department of Agriculture, for expanding convergence to meet our pressing health care challenges.

Investing in Convergence, from early research through clinical applications, will transform health and provide health care cost savings. For example, Convergence can enhance early diagnosis. Catching problems at their outset can save on costly later-stage or last-minute treatment. Wearable smart devices that monitor health and wellness will alert patients and doctors to incipient health issues. Paired with advances in health information technologies that integrate molecular and genomic data, wearable monitors can help prevent disease progression. Meanwhile, algorithms to enable data-driven medical decision can help doctors use the best available evidence quickly.

Convergence can also increase the effectiveness of treatments. New immunotherapies and vaccines will enable our own bodies to better fight disease. Minimally invasive medical devices, including those that deploy nanotechnologies, will provide steady, regulated drug release, along with powerful tools for investigating subcellular processes. New regenerative and cell-engineering strategies for tissue and organ repair will reduce the need for organ transplants and heal wounds faster. And new smart prosthetics, like robotic arms and hands, will connect to the nervous system, so wearers can sense the world and control their movements.

More broadly, Convergence can advance fundamental knowledge. New computational models of complex systems, advanced imaging at every scale (from subcellular processes to the whole body), and detailed characterization of protein, RNA, and DNA of single cells will expand our understanding of what makes us healthy or sick. And synthetic biology will permit the design of tomorrow's health-enhancing microbes.

We urge the next administration to embrace the potential of Convergence to develop new therapies, advance science, and foster health innovations. It is the key to increasing the quality of health care at a sustainable cost. Let's invest in our future, now.

Phil Sharp*[1,2] *and Susan Hockfield*[3,4]*†

*These authors sign on behalf of more than 100 scientists and leaders who participated directly in the report "Convergence: The future of health" or who became aware of the Report and asked to sign. A full list of signatures can be found at www.convergencerevolution.net/blog/letter

[1]Institute Professor, Massachusetts Institute of Technology, Cambridge, MA 02139, USA. [2]President of AAAS, 2014–2015. [3]President Emerita, Massachusetts Institute of Technology, Cambridge, MA 02139, USA. [4]AAAS President.

†Corresponding author. Email: hockfield@mit.edu

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Precaution: Open gene drive research

IN THEIR POLICY Forum "Precaution and governance of emerging technologies" (11 November 2016, p. 710), G. E. Kaebnick and colleagues convincingly assert that precaution is consistent with support for science. However, they overlook one way to improve safety while hastening discovery: Make research open.

The National Academies of Sciences, Engineering, and Medicine (NASEM) report on gene drives states that "Experts acting alone will not be able to identify or weigh the true costs and benefits of gene drives" (*1*). The same is true for many other technologies. Yet most research is conducted

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in isolation by small groups of specialists. This system not only mandates inefficient blind searches, but also ensures that many new technologies will be discovered by scientists who cannot reliably anticipate the consequences.

Enabling other scientists and interested citizens to view proposals in advance of experiments could identify inadequate safeguards and address concerns early. Ideally, researchers would formally preregister new projects by publishing a preprint describing their rationale and planned experimental approach. This "living document," which could readily become a grant proposal, would be updated with new figures as the authors gather and analyze data until it becomes a peer-reviewed publication. In addition to enhancing safety, early-stage openness should reduce wasteful duplication and accelerate progress by allowing scientists to collaborate or compete intelligently. Many scientists may be rightly concerned by the prospect of endless risk assessments and controversy, but in fields not already politicized, opening research and inviting informal oversight will reduce suspicion and the need for intrusive and adversarial bureaucratic regulation.

Changing such a fundamental characteristic of the scientific ecosystem will be difficult, and itself warrants caution. One approach is to test the effects in a single, uniquely suitable field: gene drive research. Because gene drive systems are intended to alter the shared environment, building them in secret denies people a voice in decisions that could affect them. For example, New Zealand seeks to locally eradicate rats by 2050 (*2*), but any lab that builds a global CRISPR-based suppression drive system to aid conservation risks accidental release and unauthorized international spread (*3*), possibly precipitating a loss of public confidence in science and governance that would impact other scientists' ability to perform their own research and deploy biotechnologies. This social risk greatly outweighs potential ecological or biosecurity hazards.

Openness and collective oversight would reduce the risk of an accident involving gene drive, and may mitigate the backlash from such a disaster, while accelerating—not impeding—discovery. Journals, funders, policy-makers, and holders of intellectual property should work to ensure that all gene drive research is open from the proposal stage onward.

Kevin M. Esvelt

MIT Media Lab, Massachusetts Institute of Technology, Cambridge, MA 02139, USA. Email: esvelt@mit.edu

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Precaution: Risks of public participation

IN THEIR POLICY Forum "Precaution and governance of emerging technologies" (11 November 2016, p. 710) about the 2016 report from the U.S. National Academies of Science, Engineering, and Medicine (NASEM) on gene drive research (*1*), G. E. Kaebnick *et al.* seem to agree with the NASEM report that scientists should engage with the public early and often when exploring new technologies, in an effort to avoid public pushback later in the process. However, although this has become mainstream thinking, there is simply no proof that engaging the public early in the research, and "as equals," benefits either scientists or society.

Including "a wide range of stakeholders" means inviting to the debate those with uncompromising views, such as anti-technology activists. Such stakeholders are quite skillful at deploying values such as justice and democracy to further their own goals. Meanwhile, early in the process, scientists will not yet be equipped with data to bring to the debate. As a result, discussions may be dominated by opinions and entrenched economic and political interests. This would not prevent decision-makers from adopting policies that rely on public misperceptions and fears rather than on evidence. As the ever-recurring genetically modified organism (GMO) dispute has made clear (*2*), the participative approach and its benefit for science, for risk assessment, or for the general public understanding of these processes need critical analyses (*3*, *4*).

Marcel Kuntz

Laboratoire de Physiologie Cellulaire & Végétale, CNRS, CEA, INRA, University Grenoble-Alpes, Grenoble, France. Email: marcel.kuntz@cea.fr

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Editor's Summary

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