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IN SCIENCE AND TECHNOLOGY

WINTER 2023

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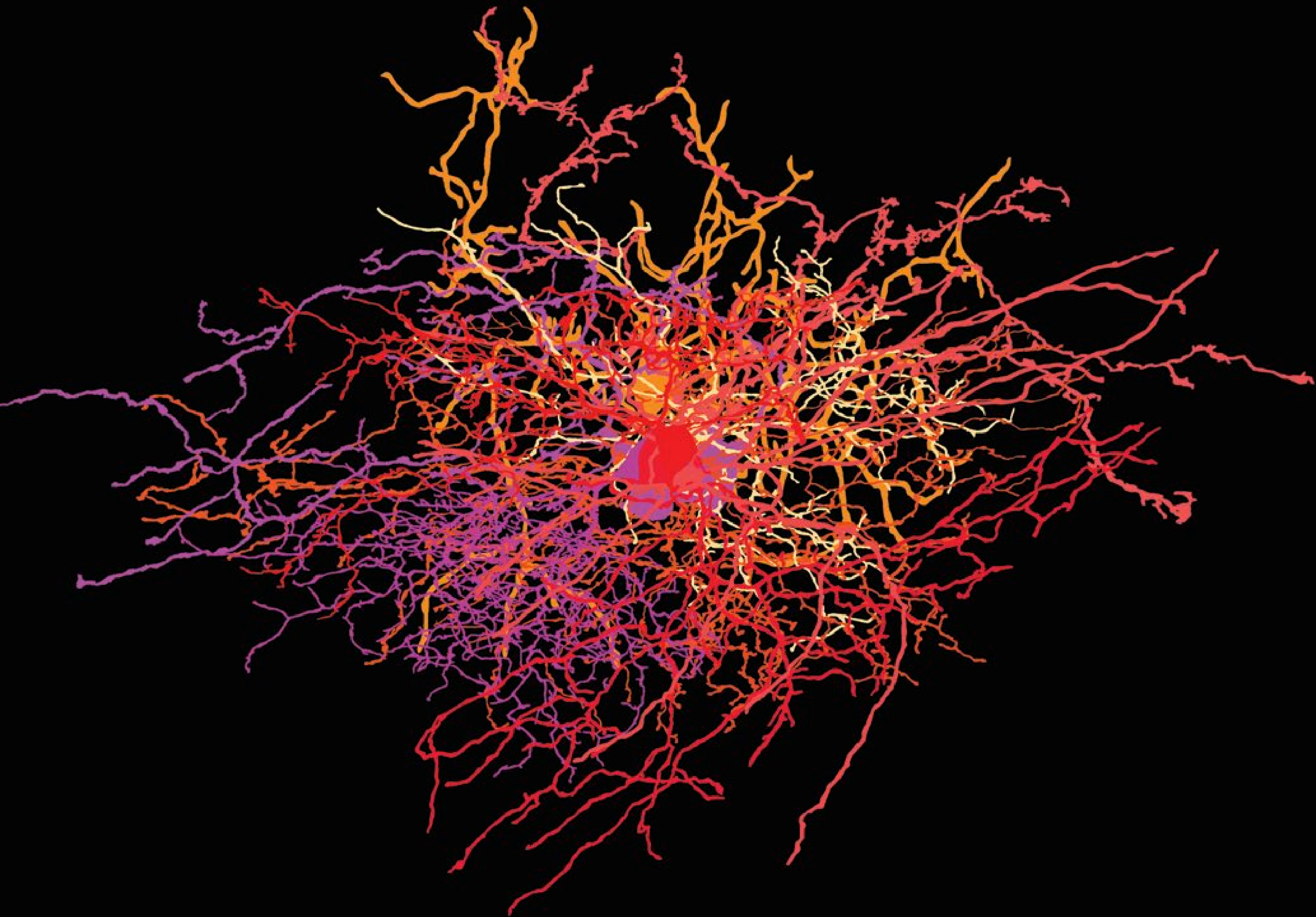

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talks politics, chips, and inclusive science

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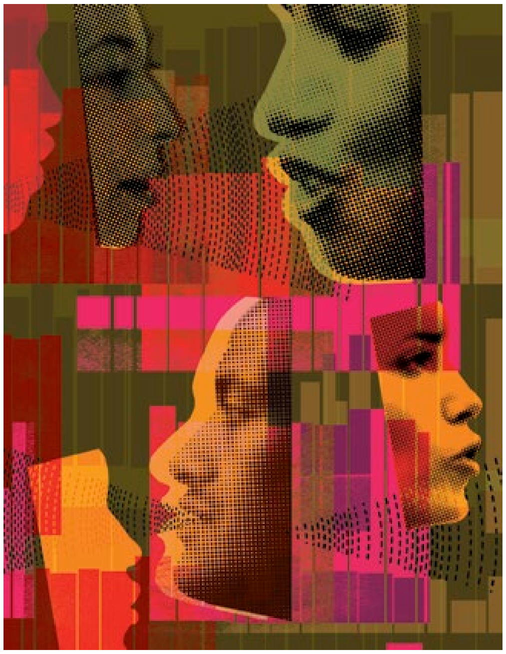
5

DEPARTMENTS

ON THE COVER: JULIA BUNTAINE HOEL, *Thoughts 10*, 2016–2017, digital print on aluminum, 20 x 16 inches. Neuron data acquired from neuroimaging software developed by EyeWire.

FEATURES



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DUKE RILEY, *Nos. 50-P, 74-P, 10, 70, 112, and 106 of The Poly S. Tyrene Memorial Maritime Museum*, 2020. Salvaged, painted plastic. Courtesy of the artist. © Duke Riley. (Photo: Robert Bredvad.)

GENE THERAPY FOR ALL

In "Making Gene Therapy Accessible" (*Issues*, Fall 2022), Kevin Doxzen and Amy Lockwood highlight contentious issues around gene therapy, even as the treatment shows good results and has raised hopes for many people with incurable diseases. The authors rightly point out that unless leaders carve out appropriate policies to develop gene therapy through a collaborative process, this novel therapy will be accessed by less than 1% of the world's population.

Treatment that is unavailable to patients in need has no value at all. Policies will need to focus on research promotion, clinical and regulatory infrastructural development, capacity-building, training, and development of an approval pathway and community adoption for success and sustainable affordability. And as the authors suggest, rather than concentrating on single diseases, efforts should be focused on establishing a platform that would be applicable to multiple diseases. This approach could help researchers working to develop therapies not only for infectious diseases such as HIV and hemoglobinopathies such as sickle cell disease and thalassemia, but also for "rare" diseases that may in fact be common in low- and middle-income countries (LMICs).

In our opinion, one of the biggest roadblocks in this regard is intellectual property rights. The successful application of patent pools in the development of antiretroviral drugs in LMICs provides a tried and tested strategy for bringing down the cost of gene therapy by sharing these rights. Moreover, lack of competition affects the cost of gene therapies, as only a very small number of companies are developing such therapies. Bringing in more players may bring down the costs markedly.

Apart from encouraging research and development, the authors also rightly underline the significance of regulatory guidelines and laws to ensure execution of safe and ethical research. To begin, global clinical trials need to be encouraged and facilitated with the participation of various patient populations from countries associated with high disease burdens. There needs to be proper guidance documents for development of indigenous platforms—utilizing the current capabilities and intellectual property of researchers and clinicians of various countries—to establish self-reliant assets for LMICs. This is also necessary for local gene therapy methods and products developed through technology transfer. To encourage the best practices globally, there should be twinning programs to provide appropriate hands-on training on the platforms established elsewhere and to generate a well-trained workforce for these resource-intensive and innovative technologies. Data sharing across the globe for drafting evidence-based recommendations for treating diseases with these modalities should also be encouraged so that stakeholders may learn from each other's experiences.

Also important are organizations such as the Global Gene Therapy Initiative, which, as the authors highlight, play a pivotal role in the development of gene therapies in LMICs. With the participation of multidisciplinary experts, such initiatives can go a long way toward preparing LMICs to maximize the impact of gene therapy.

Finally, policymakers and other authorities in government need to develop funding mechanisms and policies to prioritize long-term success and stronger health systems with respect to gene therapy, realizing the transformative potential of these technologies in improving millions of lives. Also, as emphasized above, regulatory convergence needs to be aimed for, to solve the existing bottlenecks and build the ecosystem for gene therapy methods and products in LMICs.

Geeta Jotwani
Varsha Dalal
Indian Council of Medical Research Headquarters
New Delhi, India

Duke Riley: Mischievous Maritime Art

In *DEATH TO THE LIVING, Long Live Trash*, Brooklyn-based artist Duke Riley uses plastic collected from beaches and waterways of the northeastern United States to tell a story of local pollution and global marine devastation. Riley's contemporary interpretations of historical maritime crafts—including scrimshaw, sailors' valentines, and fishing lures—confront the catastrophic effect that single-use plastics have had on the environment. On view at the Brooklyn Museum in New York City, the works are presented alongside a selection of historical scrimshaw in the museum's seventeenth- and eighteenth-century Dutch settler period rooms, directly connecting environmental injustices past and present.

Riley replaces scrimshaw's traditional medium—whalebone and walrus tusks—with discarded plastic containers and other found objects collected from waterways. The works incorporate the maritime imagery traditional to scrimshaw and expand it by replacing portraits of sea captains with depictions of international business executives that the artist identifies as responsible for the perpetuation of single-use plastics.

Also on view are Riley's fishing lures and sailors' valentines—originally a nineteenth-century nautical souvenir made of shells—created with cigarette butts, flossers, tampon applicators, bottle caps, and other detritus found on New York streets and waterfronts. The exhibition juxtaposes Riley's art made from corporation-driven pollution with several of his new short films that highlight New York community members working to remediate plastic damage and restore waterways.

Born in Boston, Riley is fascinated by maritime history and life around urban waterways. Known for his mischievous streak, Riley works in a wide variety of media—mosaic, illustration, sculpture, film, and performance—to address tensions between individual and collective behavior and draw attention to sociopolitical and environmental issues.

The exhibition is on view at the Brooklyn Museum through April 23, 2023.

DUKE RILEY, *No. 265 of The Poly S. Tyrene Memorial Maritime Museum*, 2020. Salvaged, painted plastic. Courtesy of the artist. © Duke Riley. (Photo: Duke Riley Studio.)

DUKE RILEY,
If It Feels Good Do It,
2020. Found plastic trash, mahogany. Courtesy of the artist. © Duke Riley. (Photo: Robert Bredvad.)

Development, acceptance, and sustainability of successful health interventions require both good planning and sound policies, as well as partnerships among many stakeholders. This is particularly the case when dealing with complex and sensitive interventions such as the introduction of and equitable access to gene therapy in low- and middle-income countries (LMICs), as Kevin Doxzen and Amy Lockwood highlight. The authors point out the familiar long delays between the time that new interventions become routine in high-income countries and their accessibility in LMICs. This must change.

To accelerate this change, Doxzen and Lockwood advocate for intersectoral, cross-cutting programs rather than single-disease vertical programs. Besides the examples the authors cite, this approach has proven to be very effective by other programs such as the European and Developing Countries Clinical Trials Partnership (EDCTP) and World Health Organization-TDR, which support interventions against diseases of the poor, especially in LMICs, and have broader mandates that include capacity development, networking, and fostering co-ownership of their programs.

Capacity development, including building environments for conducting quality health research and health service delivery, has far-reaching outcomes beyond the intended primary focus, as the authors cite in the case of the President's Emergency Plan for AIDS Relief, or PEPFAR, and its contribution to the COVID-19 response. The same can be said about the EDCTP and the World Health Organization-TDR programs, which have shown that it is most cost-effective to support cross-cutting issues that can be used generally in different settings.

However, as Doxzen and Lockwood point out, for ambitious programs such as equitable global accessibility of gene therapy, it is paramount to have in place good policies, sound strategic delivery plans, and coordination of activities. The strategy should consider inputs from all major stakeholders, including health authorities, regulatory agencies, civil society, international health organizations, the scientific community, development partners, industry, and the affected communities.

Of particular importance should be the involvement of health authorities in LMICs right from the start to inculcate a sense of co-ownership of the program. This will foster acceptance, active participation, self-determination, and program sustainability. Failure to do so may lead to public resistance, as evidenced in, for example, the vaccination campaign to irradicate polio in Africa and vaccinations efforts against COVID-19 and Ebola. Polio vaccination programs were falsely accused of imposing birth control in Nigeria, and COVID-19 immunization programs using mRNA vaccines were widely associated with negative misinformation about interference with human genes. Such involvement is particularly important in dealing with a sensitive issue such as gene therapy, which is prone to misinterpretation and misinformation. The involvement of local authorities and communities will also point out areas of weakness and capacity that need strengthening, including regulatory, laboratory, and clinical services.

Since it requires many years for such services to be readily available and accessible, this planning should take place now. There is no time to waste.

Charles Stephen Mgone
Retired Vice Chancellor
Hubert Kairuki Memorial University
Dar es Salaam, Tanzania

A NEW ROLE FOR POLICY ANALYSTS

In "Government and the Evolving Research Profession" (*Issues*, Fall 2022), Candice Wright highlights the increasing pressure on researchers to make fundamental advancements in their fields, enable technology transfer to help solve pressing problems, contribute insights to policy, and appropriately manage national security risks and research security. Navigating such challenges requires a mix of skills that are hard to find in any single person. Instead, these challenges call for collaboratively produced technical and policy-relevant analysis that can then be applied in both public and private spheres.

UNKNOWN ARTIST, Scrimshaw, circa 1825–1835. Whale tooth, 5 1/8 × 2 1/8 in. Brooklyn Museum; Brooklyn Museum Collection, X613.1. (Photo: Brooklyn Museum.)

It is imperative to consider how scientific and technical experts can best contribute to a productive, evidence-based scientific and policymaking process. How researchers answer this call can have a profound impact on their career, their professional standing, and occasionally their public reputation. The problem is that for professional academics and researchers with an educational and knowledge-generating mission, such policy, tech transfer, and national security work is difficult and often require time and resources that can be hard to justify within existing incentive systems. How do you best retain your honest-broker status amid the risk of entering the political fray or distracting from your research agenda with a multitude of nonresearch engagements and travel? Policy analysts who are well-trained and make a career at the intersection of policy, national security, and emerging technologies can help fill this gap with specialized skills that augment those of researchers.

Policy analysts (including those at the Government Accountability Office) can help translate the scientific and technical content for nontechnical decisionmakers. This is a viable career for both technically and policy-trained individuals. Working with good analysts who have a strong contextual understanding of policy and enough scientific technical expertise to understand the core issues in play is transformative. Their ability to communicate and translate information from technical experts will help bench scientists increasingly understand the analysts' value and will open up new ways to work together.

Finding people who can work both sides of the technical and policy equation is difficult. There's a history of training policy fellows (e.g., at the American Association for the Advancement of Science and the National Academies) and now some new fellowships are increasing attention on this role (TechCongress, Open Philanthropy, Federation of American Scientists). This is heartening, but the total number of highly skilled emerging-technology policy analysts is still relatively small, and their long-term career viability is still uncertain. The scientific research and academic communities need to create ramps and pathways from traditional fields to policy analysis roles with formal training options in these hybrid areas. Technical experts need to be encouraged to take these paths and find home organizations where they can develop and excel.

Those who choose to stay within research careers can cultivate alliances with colleagues at policy analysis institutions, and I offer the one I lead, the Center for Security and Emerging Technology, as an example. As this becomes more common, universities may choose to create more independent centers devoted to policy analysis or incentivize sabbaticals for those who can coproduce relevant policy analysis. Scientists and policy analysts are natural partners and have a vested interest in each operating at the top of their game, which can help fill the gap that Wright keenly observed.

Dewey Murdick
Director
Center for Security and Emerging Technology
Georgetown University

TIME TO REFORM ACADEMIC PUBLISHING

In "Public Access to Advance Equity" (*Issues*, Fall 2022), Alondra Nelson, Christopher Marcum, and Jedidah Isler touch on the many reasons why open access to federal research is critical and highlight some of the challenges to come. We wholeheartedly agree with their sentiment—"A research ecosystem where everyone can participate and contribute their skills and expertise must be built"—and we applaud both the Biden administration and the White House Office of Science and Technology Policy (OSTP), where the authors work, in their commitment to make federally funded research open to the public.

In particular, as graduate, professional, and medical students, we have been shaped by the relics of an inequitable publishing model that was created before the age of the internet. Our everyday work—from designing and running experiments to diagnosing and treating patients—relies on the results of taxpayer-funded research. Having these resources freely available will help to accelerate innovation and level the playing field for smaller and less well-funded research groups and institutions. With this goal of creating an equitable research ecosystem in mind, we want to highlight the importance of creating one that is equitable *in whole*.

In the same way that open access to reading publications is important to keep the public and institutions informed, open access to publishing is equally important, as it allows institutions to make their work known. With free access to federally funded research, this effect will be even greater. It is critical that access to publishing is open to promote *learning from* the public knowledge as well as *contributing to* it.

But today, the incentives *for* institutions do not align with goals of equity, and change will be necessary to help support a more equitable system. Nor do incentives *within* institutions always align with these goals. This is especially true for early-career researchers, who might struggle to comply with new open-access guidelines if they need to pay a high article publishing fee to make their research open in a journal that is valued by their institutions' promotion and tenure guidelines.

To these ends, it is imperative that the process for communicating research results to the public and other researchers does not shift from a "pay-to-read" model to a "pay-to-publish" model. That is, we should not use taxpayer dollars to pay publishers to make research available, nor should we simply pass these costs on to researchers. This approach would be unsustainable long-term and would go against the equity goals of the new OSTP policy. Instead, we hope that funders, professional societies, and institutions will come along with us in imagining and supporting innovative ways for communicating science that are more equitable and better for research.

As the research community works to implement the new OSTP policy intended to make scientific results publicly accessible, it will be critical for the next generation of researchers that the federally funded research system be made open in a way that is equitable and inclusive of those early in their careers.

Thaddeus Potter
President, National Association of Graduate-Professional Students
Michael Walls
National President, American Medical Student Association

THE PROBLEM WITH SUBSIDIES

The United States government is waging a "chip" war with China. The war is fought on two fronts: one is preventing China from accessing the latest artificial intelligence chips and manufacturing tools, and the other is subsidizing large firms to bring manufacturing back to the United States. But as Yu Zhou points out in "Competing with China" (*Issues*, Fall 2022), "whether [the CHIPS and Science Act] will improve US global competitiveness and prevent the rise of China is uncertain."

A race to subsidies as America's solution is uncertain and problematic because it is based on a misunderstanding of how innovative Chinese firms advanced their technologies. Contrary to the popular belief that China built its technology industry through massive subsidies, China's records of state-sponsored technology investments are often spotty. The prime example is the semiconductor industry, with billions of dollars invested by the state over the last three decades; the industry's advancement consistently fell short of government targets. The real secret of the Chinese high-tech industry is indigenous innovation—that is, innovative Chinese firms sense unfulfilled domestic demands, innovate to generate localized products at a lower cost, build on access to the vast Chinese market to scale up, and eventually accumulate problem-solving capabilities to approach the technological frontier. Ironically, the US government's chip war is creating a space for indigenous innovation for Chinese semiconductor companies, which was previously absent when China relied on American chips.

Taking the wrong lessons from China could have unintended consequences for the US industry. Since leading American high-tech firms have spent some $633 billion on stock buybacks over the past decade, it can hardly be assumed that their lack of enthusiasm for investing in semiconductor manufacturing is because of a lack of cash. But showering money on business, as China's experience showed, would certainly lead to unhealthy state-business relations. Already, the CHIPS and Science Act has created perverse incentives for lobbying for more and more subsidies.

Instead of competing on subsidies, the United States should compete with China in areas where it excels, namely innovation in emerging technologies. Historically, the United States has had few successes in reviving mature industries through subsidies, whether it was steel, automobiles, or memory chips. But it has consistently led the world in new technological revolutions over the past century. In a world facing a climate crisis, the United States should compete with China to bring innovations to solve the nation's existential problems and win the ultimate prize of technological leadership that benefits all humankind. After all, the subsidy war benefits few but corporate bottom lines.

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Author of *China's Drive to the Technological Frontier* (Routledge, 2022)

R&D FOR LOCAL NEEDS

In "Place-Based Economic Development" (*Issues*, Fall 2022), Maryann Feldman observes that the CHIPS and Science Act marks "an abrupt pivot in the nation's innovation policy" away from the laissez-faire system of the past and toward a policy focused on addressing regional economic development. Central to this new course is the act's directive for the National Science Foundation (NSF) to "support use-inspired and translational research" through its new Technology, Innovation, and Partnerships (TIP) directorate.

Yet nowhere within the statute are these terms defined or described. The phrase "use-inspired research" was coined in 1997 by the political scientist Donald Stokes in his seminal work, *Pasteur's Quadrant*, in which he sought to break down the artificial distinctions between scientific understanding and wider use while rejecting overly limiting terms such as basic and applied research. For Stokes, research focused on real-world societal problems—such as French chemist Louis Pasteur's work on anthrax, cholera, and rabies—can spark both new fundamental knowledge and applied breakthroughs.

But what potential uses will inspire the next generation of innovators? If we look to the text of the CHIPS and Science Act, the legislation outlines 10 technology focus areas and five areas of societal need to guide use-inspired research overseen by the TIP directorate. Beyond these lists however, there is another source of inspiration that is strongly implied by the legislative language: regional societal and economic needs—specifically, the needs of places where scientists live and work.

While this observation may sound simple, implementation is not. Indeed, researchers at the University of Maine previously described in *Issues* the intricate challenges of crafting a regional use-inspired research agenda, creating community partnerships, engaging stakeholders, and breaking through institutional and cultural barriers that transcend publish-or-perish incentives to help produce real-world solutions.

The CHIPS and Science Act has launched such an endeavor on a national scale with NSF as the driver. It is a new place-based research enterprise that finds inspiration from the needs of diverse geographic regions across the United States. The statute is an important step, though many bumps in the road lie ahead, including securing the necessary appropriations. However, by focusing more on the needs of geographic regions through use-inspired research, NSF can better meet the mandate of CHIPS and Science to address societal, national, and geostrategic challenges for the benefit of all Americans.

Tim Clancy
President, Arch Street
Former professional staff member, US House Committee on Science, Space, and Technology

TECHNOLOGY-BASED ECONOMIC DEVELOPMENT

In "Manufacturing and Workforce" (*Issues*, Fall 2022), Sujai Shivakumar provides a timely and important review of the CHIPS and Science Act. This landmark legislation aims at strengthening domestic semiconductor research, development, design, and manufacturing, and advancing technology transfer in such fields as quantum computing, artificial intelligence, clean energy, and nanotechnology. It also establishes new regional high-tech hubs and looks to foster a larger and more inclusive workforce in science, technology, engineering, and mathematics—the STEM fields. In a recent article in *Annals of Science and Technology Policy*, I noted that the act focuses tightly on general-purpose technologies,

DUKE RILEY, *Monument to Five Thousand Years of Temptation and Deception (I)*, 2020. Salvaged, painted plastic and mahogany. Courtesy of the artist and Praise Shadows Art Gallery, MA. © Duke Riley. (Photo: Will Howcroft for Praise Shadows Art Gallery.)

emanating from technology transfer at universities and federal laboratories. Shivakumar correctly notes that public/private investment in technology-based economic development (TBED) in manufacturing must be accompanied by workforce development to match the human capital needs of producers and suppliers.

I have two recommendations relating to workforce development, in the context of technology transfer. The first is based on evidence presented in a 2021 report by the National Academies of Sciences, Engineering, and Medicine titled *Advancing Commercialization of Digital Products from Federal Laboratories*. (In full disclosure, I cochaired that committee with Ruth Okediji of Harvard University.) The report concluded that accelerating commercialization of research requires that we achieve a better understanding of workplace and managerial practices relating to technology transfer, including individual and organizational factors that may inhibit or enhance the ability of scientists to engage in commercialization of their research. These factors include the role of pecuniary and nonpecuniary incentives, organizational justice (i.e., workplace fairness and equity), championing, leadership, work-life balance, equity, diversity and inclusion, and organizational culture. Understanding such issues will help identify and eliminate roadblocks encountered by scientists at federal labs as well as universities who wish to pursue technology transfer. It would also allow us to assess how "better performance" in technology transfer is achieved.

A second recommendation concerns a major gap that needs to be filled, in terms of developing a more inclusive STEM workforce to implement these technologies. This gap centers on tribal communities, which are largely ignored in TBED initiatives and technology transfer. Unfortunately, economic development efforts for tribal communities have predominantly focused on building and managing casinos and developing tourism. Results have been mixed, with limited prospects for steady employment and career advancement.

Opportunities for TBED strategies to aid tribal communities might include the development of new investment instruments, the strategic use of incentives to attract production facilities in such locations, and the promotion of entrepreneurship to build out supply chains. This would require adapting tools for TBED to be better suited to the needs and values of the communities. That means developing a TBED/technology transfer strategy that simultaneously protects unique, Indigenous cultures and is responsive to community needs.

In sum, I agree with Shivakumar that workforce development is key to the success of the CHIPS and Science Act. Two complementary factors that will help achieve its laudable goals are improving our understanding of how to better manage technology transfer at universities, federal labs, and corporations, and involving tribal communities in technology-based economic development initiatives and technology transfer.

Donald Siegel
Foundation Professor of Public Policy and Management
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THE VITAL HUMANITIES

The humanities bring a range of important perspectives to bear on the scientific and technological issues with which institutions such as Georgia Tech wrestle, as Kaye Husbands Fealing, Aubrey Deveny Incorvaia, and Richard Utz note in "Humanizing Science and Engineering for the Twenty-First Century" (*Issues*, Fall 2022). I want to start from that general argument in favor of interdisciplinarity and make a slightly different case, however.

First, it's important to note that the humanities are not the arts. Humanists are trained in analysis and interpretation; they are not trained in aesthetic production. Thus, when the article cites case studies from a Georgia Tech publication called *Humanistic Perspectives in a Technological World* that turn out to be about technical writing, music composition, and theater production, I worry. None of those fields center analysis—they all focus on production.

Collapsing the arts into the heading "humanities" is not uncommon. When I went to the Washington, DC, launch of the report cited in this article, *The Integration of the Humanities and Arts with Sciences, Engineering, and Medicine in Higher Education: Branches from the Same Tree*, I was struck by the poster presentations, which included projects that featured dance, music, art, and poetry. But not a single one of them included the humanities. Nothing analytical, critical, or interpretive. When "arts and humanities" is the framework being used, the humanities tend to disappear. It's easier to talk about the arts: everyone knows what music or poetry is. It's harder to be concrete in talking about philosophy or literary criticism. But what philosophers and literary critics do is just as essential as what musicians or poets do: they enable us to interpret the world around us and to posit a better one.

So what I want to point out is the specific value of integrating humanities into science and engineering by recognizing the expertise of humanities practitioners. That expertise is in visual analysis (art history), ethics and problem-solving (philosophy), close reading and analysis (literary criticism), and interpretation of the past (history). The doctor who likes reading novels is probably not the right person to be teaching the narrative medicine course when you have experts in narrative theory on your campus. The article notes that Florida International University's Herbert Wertheim College of Medicine "uses art analysis during museum tours as a practice analogous to detailed patient diagnosis." I hope the art analysis is done by trained art historians.

Interpretation and analysis are important skills for practitioners in science, technology, engineering, and mathematics (STEM) to learn, certainly. But the humanities are valuable for more than "equipping STEM practitioners with a humanistic lens." STEM researchers achieve the best interdisciplinary work not when they apply a humanistic lens themselves but when they partner with those trained in humanities disciplines. I think of Jay Clayton, for example, whose team of humanists at Vanderbilt University's Center for Genetic Privacy and Identity in Community Settings, or GetPreCiSe, analyzes cultural treatments of the topic of genetics. How do novels, films, stories, and other cultural expressions address the moral and ethical consequences of developments in genetics, and what do those cultural texts tell us about our society's changing sense of itself? How do such texts shape social attitudes? These are humanities questions calling for humanities methodologies and humanities expertise.

Paula M. Krebs
Executive Director
Modern Language Association

As an educator and researcher concerned with equity, I'm tasked with looking for and identifying useful connections between science, technology, engineering, and mathematics (the STEM fields) and the arts, a collective span otherwise known as STEAM. My work amplifies the contributions of artists and cultural practitioners who are often left out of the discourse in STEM areas. For example, popular comics and movies give us Shuri in *Black Panther*, who uses her knowledge of science, culture, and the natural resources around her to design and build things. As an artist who uses artificial intelligence, I combine my knowledge of color theory, culture, literature, creative writing, and image editing to create unique art that captures the spirit of the present moment.

While reading the essay by Kaye Husbands Fealing, Aubrey Deveny Incorvaia, and Richard Utz, I thought about Albert Einstein, who used thought experiments as a way to understand and illustrate physics concepts. Einstein considered creative practice as essential to problem-solving. He took music breaks and engaged in combinatory play, which involved taking seemingly unrelated things outside the realms of science (e.g., music and art) and combining them to come up with new ideas. These interludes helped him "connect the dots" of his experiments at opportune moments when he played the violin. Einstein's ideas influenced musicians such as John Coltrane, who used theoretical physics to inform his understanding of jazz composition.

Scientists who embrace the arts use cognitive tools that the biologist and historian of science Robert Root-Bernstein identifies as observing, imaging, recognizing patterns, modeling, playing, and more to provide "a clever, detailed and demanding fitness program for the creative mind" across scientific and artistic disciplines. A study led by Root-Bernstein considered the value of the arts for scientists. He and his collaborators found that scientists often commented on the usefulness of artistic practices in their work. They suggested that their findings could have important implications in public policy and education. Conducted over a decade ago, this research has not yet led to a marked shift in science policies and the development of STEM and STEAM curricula. Science, the arts, and the humanities are still siloed in most US institutions.

Many scientists and musicians never realize the links between physics and the polyrhythmic structures in music. K–12+ physics teachers don't teach their students about the connections between theoretical physics and jazz. Music students never consider physics when learning to play Coltrane's "Giant Steps," and I think this is a missed opportunity for interdisciplinary learning. Scholars such as the multidisciplinary Ethan Zuckerman argue for the combining of technical and creative innovation through the use of artificial intelligence, which has a potential for composing music, visualizing ideas, and understanding literature. The gaps or frictions in the sciences, the arts, and the humanities belie the fact that all these disciplines or fields are charged with investigating what it means to be human and how we might improve our states of wellness and well-being. To create a more inclusive future inside and across disciplines, it's up to all of us to make these connections more apparent, and our engagements with inclusion more intentional.

Nettrice Gaskins
Assistant Director, Lesley STEAM Learning Lab
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MISSOURI LAWMAKERS AND SCIENCE

In "How Missouri's Legislators Got Their 'Science Notes'" (*Issues*, Fall 2022), Brittany N. Whitley and Rachel K. Owen examine the value and challenges of bringing scientific information into the vast array of decisions that state legislators must make each year. With over 2,000 bills considered by the Missouri General Assembly annually, so many of them impact the daily lives of people across the state, changing how they connect, work, learn, and live. And eventually, many of these seemingly "local" decisions add up to national impacts.

We often hear concerns that people do not care about science or do not trust experts. However, experts often do not show up in ways that center the user's actual problem, respect the context and complexity of the decision being made, and provide the scientific information in a way that can be valued and understood across backgrounds and party lines. Whitley and Owen provide a compelling approach for addressing these challenges.

There is an additional underlying challenge I would like to bring to this discussion, one that funders do not like to support or sustain. Few groups have the breadth of expertise to understand the landscape of emerging scientific information, aggregate that learning into knowledge, and translate that knowledge into useful inputs for decisions.

There is the fundamental need for trusted translators in our society.

If we want the funding the United States pours into science—over $40 billion of federal funding for basic research annually—to lead to real-world solutions and to impact how policy leaders make decisions, it will be necessary to provide those leaders with information in ways they can hear, understand, and trust.

The scale of the challenge is often glossed over. Looking at just the Scopus database, curated by independent subject matter experts, we see that the overall scientific literature as characterized by the National Science Foundation is growing at almost 4% each year, with approximately 1.8 million publications in 2008 and growing to 2.6 million in 2018. This gives us roughly 20 million articles in just a 10-year period from Scopus alone, providing new information that is supposed to be building on itself. But the articles are often laden with jargon, highly academic, and focused on other experts in the field. They also tend to highlight novelty instead of a road map for how to actually use the information and aggregate it into knowledge.

Who is supposed to aggregate knowledge from those tens of millions of papers over time? This is a daunting task for an expert; it is an unreasonable if not impossible expectation for legislative staff with little support. That funders of all types—federal, state, philanthropic, and industrial—will pour billions of dollars into science, but far fewer dollars into sustained efforts to make science results useful, is a fundamental flaw in our system.

I applaud the progress being made by the Missouri Science & Technology (MOST) Policy Initiative, as the authors document, along with the achievements of other state-level science programs in New Jersey, California, and Idaho, among others. But if we believe that evidence-based decisions are critical to solving society's most pressing problems, we must rethink how we support and sustain those organizations actually doing the work.

Melissa Flagg
Flagg Consulting
Former Deputy Assistant Secretary of Defense for Research

As a Missourian, I applaud the efforts of the visionary founders and the savvy of the current leadership of the Missouri Science & Technology (MOST) Policy Initiative and their contributions to sound science-based policy and legislation in the state. As Brittany N. Whitley and Rachel K. Owen describe, in a truly short time and in the context of a part-time legislature (never mind the restrictions of a global pandemic), the MOST fellows have already demonstrated remarkable effectiveness and have garnered the respect and appreciative of our state lawmakers.

I have always hoped that the highly successful model of the American Association for the Advancement of Science's Science and Technology Fellows program, which has so successfully helped integrate scientific knowledge into the work of the federal government, would be, in the true spirit of federalism, translated into state houses and local governments. MOST is among a small number of state-based programs demonstrating the effectiveness of such translation. Whitley and Owen provide an excellent historical record of the importance of having sources of solid, nonpartisan scientific knowledge informing the many decisions state governments make that can impact, for example, the health of their citizens, the future of their environmental resources, the strength of their economies, and the quality of their educational systems.

The piloting of state initiatives would not have been possible without the support of private funders. Investment by the Gordon and Betty Moore Foundation was integral to the launching of several state programs, and in Missouri, the James S. McDonnell Foundation contributed significantly to launching MOST and has recently renewed its support. So, in what is otherwise a positive article, I was surprised to read the negative slant of the discussion concerning the role of private funders.

I am sympathetic to the plight of programs, such as MOST, whose fellows are engaging in novel undertakings requiring both the building of trust relationships and the time to develop a record of accomplishment. However, it is well known that private funders typically see themselves as the source of "start-up" funding and not a source of long-term sustaining support. Philanthropy is a source of social venture capital—with the return on investment measured in terms of contribution to the common good. For philanthropy to continue as a source of venture funds, it has to carefully evaluate the duration of the commitment it can make to any one beneficiary. While I am certain MOST will continually garner support from private funders, it is likely that the identities of the donors will change as the organization's maturation changes its needs. It is also likely that the leadership of MOST will continue to grow more skilled at communicating its accomplishments and requesting the necessary resources to continue its essential work.

I fervently hope that MOST will garner long-term and sustainable support from the constituency it serves so well, and that the state of Missouri and its citizens will recognize the value that MOST fellows provide to informed governance by appropriating funds to the program.

Susan M. Fitzpatrick
President (retired)
James S. McDonnell Foundation

PUBLIC SERVICE DATA

In my job, I witness firsthand how the tools of data science and artificial intelligence can transform social approaches to human challenges. And I agree with Julia Lane's vision, eloquently presented in "A Vision for Democratizing Government Data" (*Issues*, Fall 2022), that unlocking data access for policymakers will open multitiered opportunity—first, to create enabling environments to access, sift, and analyze information; and second, to ensure that the appropriate consumers are equipped with the policy and experiential frames to responsibly use that data for social import.

As one example of the potentials, the Invisible Institute in Chicago applies data at scale to identify racial disparities in nationwide eviction patterns. With a long history of research in urban policy, socioeconomic effects of discriminatory policies, and new access to national macro data sets, the institute advocates for a new policy framework for regulators and city officials to improve racial equity in housing. This organization and others with similar missions continue to generate tangible change by identifying a problem and scouring government data to influence policy.

To build a data marketplace that serves the needs of society, I suggest considering the following:

Build solutions that address short-term problems while unlocking long-term opportunity. A data marketplace is foundational infrastructure, but cannot stand alone. Actively engaging stakeholders to contribute to solutions requires us to first define our hypotheses through a human-centered lens. Developing evidence-based policy solutions can address short-term harms—and build long-term equity.

Civil society can help turn data into insight. Civil society organizations intimately understand societal challenges—and serve as long-term informal data stewards. By creating open access to government data for civil society, we can generate new insights on labor mobilization, humane policing, and several other issues from organizations with deep historical context and community knowledge.

Citizen participation is essential for effective policy development. We need new structures for data agency that empower individuals to both contribute to and benefit from these shared data marketplaces. Through new mechanisms of data governance, fiduciaries, or consumer protection, citizens can access transparent pathways to understand how their data are used.

Unlocking insights at the intersection of government, private-sector, and civil society data remains underexplored territory at all levels. We have the opportunity to create a new dynamic that empowers individuals to safely and confidently share their data, equips civil society organizations to best represent their interests, and accelerates more effective and targeted policy decisions for a better future. Lane's vision of a data-enabled world is within reach—one that leverages data for effective public policy in tireless pursuit of equity, human welfare, and a thriving future for humanity.

Vilas Dhar
President
Patrick J. McGovern Foundation

Editor's Journal

The Obligations of Knowledge

LISA MARGONELLI

In his profound essay on the life and death of Terry Wallis, physician and neuroethicist Joseph J. Fins writes that as science advances, so do humanity's obligations. Wallis, who suffered a severe brain injury in an Arkansas car wreck, seemed to be unconscious for 19 years before greeting his mom—who had visited him regularly—and saying the word "Pepsi," his favorite drink.

Wallis's awakening set off a revolution in neuroscience. "Terry's narrative helped to rewrite expectations about time and the brain, revealing both biological processes of recovery and the contingent construction of knowledge in this field," writes Fins. He argues that this new knowledge of the brain—both its extended timetable of repair and the possibilities for treatment—gives society new moral responsibilities.

Early in his own career, Fins relates, severe brain injury was considered hopeless for patients, but new medical insights make the need to provide rehabilitative care for disorders of consciousness increasingly urgent. Because the US health care system reflects social inequalities and geographic disparities, many patients still miss out on neuroscience's gains. And as neuroscience progresses, these gaps in care may increase. Without deliberate action, society risks ignoring its moral obligations, Fins warns. "Now that scientists are on the cusp of having the technological means to provide imaging, stimulation, and drugs that may allow for more human flourishing, the nation must begin to grapple more meaningfully with the care and regard of marginalized people with disorders of consciousness."

Fins's recognition of the obligations brought by new knowledge are at odds with the American public's dialogue around science and technology, which is often framed individualistically, in terms of increasing personal choice and convenience. In 2012, shortly after the debut of Siri, Apple's sophisticated voice assistant, TV ads featured celebrities such as director Martin Scorsese cancelling his appointments from the back of a taxi, and actor Samuel L. Jackson making risotto alone while talking to Siri in a commercial called "Date Night." Of course, even a decade ago it was clear that whatever untethered freedom a mobile phone offered was offset by its "always on" availability to family, bosses, and advertisers. But in a culture that so highly values both science and independence, the first is often portrayed as a route to the second, even when the promised independence is an illusion.

And that reasoning—that scientific advances are for personal gain—obscures deeper ethical obligations. Vaccines, for example, are often promoted as a means of self-protection. But their effectiveness is partly rooted in their implications for public health.

In the United States, the idea that science is a path to greater moral connection to one another remains relatively unexplored. But as the pandemic enters its fourth year, it is worth considering whether deliberately excavating these manifold areas of mutual obligation could lead to better science.

The interrelationship of technological and social change is something Eddie Bernice Johnson, the

In the United States, the idea that science is a path to greater moral connection to one another remains relatively unexplored.

Terry Wallis (1964–2022) out with his family on a mountain in Arkansas. His brother George pushes his chair with his brother Perry behind. Terry's sister, Tammy Baze, is reflected in his glasses. (Photo courtesy of Tammy Baze.)

outgoing chairwoman of the House Science, Space, and Technology Committee, has thought about deeply during her half-century in public service. Johnson has seen—and led—historic efforts that combine advances in both. As a schoolchild in Texas in the 1940s, teachers discouraged her from being a doctor and segregation forced her to go out of state to attend an accredited nursing school. She later got involved in civil rights activism, entered politics, and in 1993 became the first registered nurse in Congress, where she joined the House Science Committee. After nearly 30 years of influencing US science policy, Johnson recently steered the landmark CHIPS and Science Act to passage. She now leaves a legacy that may last for generations.

In her interview with *Issues* editor Molly Galvin, Johnson talks about watching Texas Instruments and the chips it made transform her district and then the world. To deliver on the promises of the US research and innovation system, she has long argued—and reinforced in legislation—that science has an obligation to be more inclusive. “Our society has gotten into a rut of doing it the way we’ve been doing it,” she says. “Not much imagination has gone into how to expand opportunities and expand outcomes.”

Another of science’s obligations is to nurture the students, staff, and junior researchers who embody both its workforce and its future. This edition of *Issues* features new thinking on ways to change the culture around sexual harassment, which was first named as a problem in academia in the 1970s and was the subject of an influential National Academies report in 2018. Karen Stubaus, vice president of academic affairs at Rutgers University, shares that the report sparked a “sea change” in thinking about sexual harassment that continues today in committees at both the national and collegiate level. “And it has sparked a truly national conversation about the need to move beyond mere compliance to a focus on prevention and culture change,” she writes. Stubaus and early-career neuroscientist Vassiki Chauhan describe different ways to shift the dynamic away from its current focus on enforcement and toward creating more productive and accountable research environments.

Scientific progress is conventionally framed as advancing frontiers of knowledge, but as these articles show, progress on social frontiers can be productive for both society and science. In a randomized controlled trial that provided some congressional offices with structured scientific advice but not others, Penn State University researchers Max Crowley and Taylor Scott found that offices that received the advice were more likely to include research-related terms in legislation they proposed. Less expectedly, the researchers who engaged with congressional offices became significantly more likely to say that their research had benefited from the interaction than those in a control group.

Similarly, there were unanticipated benefits for science when NASA participated in two-way dialogue with the public about defending Earth from asteroids. In an oral history of the project, Mahmood Farooque and Jason L. Kessler explain how the results of citizens’ deliberations on technical tradeoffs in space missions enriched the work of agency experts. Their story suggests that shared decisionmaking could bolster agencies that conduct science in the public interest—and might even provide creative solutions to seemingly intractable problems. The authors argue that to make the most of this new knowledge, agencies need to develop the capacity for regular public engagement.

And decision researchers Kara Morgan and Baruch Fischhoff describe how federal agencies can communicate more successfully with the public about risk by using a structured approach called mental models. “Risk communication seeks to inform decisions, not manipulate them,” they write. “Thus, it protects agencies and the scientists who work within them from the charge that they are spinning the facts to achieve policy goals, or that they are acting as advocates rather than resources.”

Today, these important relationships among researchers, citizens, and policymakers are largely the result of serendipity—a single study, or a grant that results when an intern happens to write a blog post at the right moment. The United States has much to gain by institutionalizing the capacity for this three-way dialog. And the scientific enterprise could benefit by defining problems and solutions more inclusively, making research more meaningful, and increasing the usefulness of science for society.

In this magazine and through our website, podcast, and events, *Issues* aspires to fulfill its mission to be a space for ongoing conversations “to enhance the contribution of science and technology to the creation of a better world.” As you read through the articles in this issue, you’ll see again and again the intertwining impacts and obligations of expanding scientific knowledge. Reaching that “better world” requires, crucially, more deeply exploring our moral obligations.

ZEESHAN HABEEB

Fixing Academia's Childcare Problem

Academia in the United States has a childcare problem. Getting established in an academic career as an independent investigator takes a lot of time, beginning with attending graduate school. In 2021 the average age of PhD recipients in science and engineering fields was 31. Most academics pursue further training through postdoctoral studies before applying to faculty or research positions. Even then, it takes time to establish a productive research group and attract grant funding. For those in biomedical fields, for example, the mean age at which PhD scientists received their first National Institutes of Health Research Project, or R01, grant was 43 in 2020, and only 10% of such awardees are 35 years old or younger. This lengthy training interval coincides with the time most people consider having children and starting a family. But because of a lack of support for new parents during this period of intense training, many of them are leaving academia. In 2022 there were reports of a shortage of postdoctoral candidates, with PhD graduates choosing to directly enter the private sector, which offers better compensation and benefits. This will severely affect the US science and technology workforce and the country's competitiveness globally.

This lengthy training period to become an independent investigator is characterized by long hours, low salaries, and a lack of job security. Graduate students and postdocs are supported by stipends or grant-provided salaries that are often well below standard costs of living—in 2020 more than a quarter of graduate students in the United States reported food or housing insecurity. Resources for caregivers are scarce in the US system as a whole: the United States spends only half of what other wealthy countries spend on early childhood education. The result, as shown in a 2019 study, is that nearly a quarter of new fathers and almost half of new mothers in the US science, technology, engineering, and mathematics (STEM) workforce were reported to leave full-time employment after the birth of their first child. In academia, women with children are less productive and more dissatisfied with their jobs than their male peers due to a lack of family-friendly policies, including accessible childcare.

Lack of childcare support options for early-career academic researchers is holding back America's economy, competitiveness, and equitable improvements to standards of living by pushing skilled talent out of the STEM workforce. Leaders in the scientific community have made the case that the United States must bolster its STEM workforce by being more inclusive of women, underrepresented groups, socioeconomically disadvantaged people, and others. Supporting parents should be seen as a key aspect of this inclusiveness. Research shows that supporting new parents aids in employee retention across sectors and industries. To truly support a robust, inclusive academic STEM workforce, the federal government and other funders, as well as institutions themselves, must do more to support graduate students, postdocs, and early-career faculty who are also parents. Taking steps to provide or support affordable and accessible childcare options is critical.

Providing childcare bolsters workforce productivity and retention

To be viable for early-career researchers, childcare options must be both accessible and affordable, and there are challenges with both. While access to childcare may depend in part on geographic location, data from the National Center for Education Statistics show that the share of four-year public institutions with childcare centers declined from 55% in 2005 to 49% 2015; the share is around the same in 2021. According to a national study by the Center for American Progress, the average yearly cost of care for an infant was about $16,000 in 2021. Many graduate students have yearly stipends of less than $30,000.

When coupled with the intense work culture of academia that rewards productivity at the expense of a work-life balance, these data help explain the longer-term trend that female faculty tend to have fewer children, are more likely to be unmarried, and have higher divorce rates than their male peers. The lack of accessible childcare is a crisis that has long been ignored. It took the shock of the public health restrictions brought on by the COVID-19 pandemic, which suddenly closed schools and daycare centers, to reveal the fragility of support for childcare systems in US academia. The pandemic directly impacted productivity: the number of scientific papers published decreased during the public health measures—especially for mothers (even if both parents were home), and even more so if children were five years old or younger.

Other sectors have recognized these ongoing problems and taken steps to alleviate them, with promising results. Case studies of private companies suggest that providing subsidized on-site childcare as a benefit to employees positively affects employee attitudes and retention while also improving productivity and mental health and reducing absences. And in the public sector, Congress spent $12 million in taxpayer funds to create a subsidized childcare facility at Capitol Hill. Members of Congress recognized that on-site childcare is essential to retaining talented staffers. Beyond that, the Federal Election Commission allowed candidates running for federal office to use campaign funds to pay for childcare.

Providing access to affordable, on-site childcare could lead to similar gains in academia, including improving outcomes for children enrolled in such programs and increasing women's participation in the STEM workforce. Supporting on-campus childcare centers could improve retention of graduate students, postdocs, and early-career faculty. In England, institutions with more generous parental leave policies were able to retain more female professors. But translating this support into academia and making it the norm will require action by the federal government and other research funders, as well as by academic institutions themselves.

Fixing the childcare problem on campus

On many campuses, an on-site childcare facility is economically unfeasible due to high operational costs and strict regulations. The childcare industry includes caps on the ratio of care providers to children and requires extensive training and certification for providers. According to the National Coalition for Campus Children's Centers, most funding for campus centers comes from parent fees, along with a mix of contributions from institutional funds, donations, and student and faculty associations.

The use of internal institutional funds for childcare depends heavily on the resources of the institution and the strength of shared governance to lobby for allocations, both of which vary greatly. Even top private research universities have dropped the ball: at Columbia University, for example, a 2018 survey found that a large portion of graduate student parents reported dissatisfaction with support for families, with nearly half reporting having missed classes or exams and 90% missing meetings and professional networking events for childcare-related needs. Some universities utilize their large endowments to provide childcare scholarships to tenure-track faculty, but since not all institutions can do this, a more equitable solution is needed.

The federal government and other funders, as well as institutions themselves, must do more to support graduate students, postdocs, and early-career faculty who are also parents.

One step the federal government should take is to build on the existing Child Care Access Means Parents in School (CCAMPIS) program, which provides funding to support institutions and their students who have significant enrollments of low-income undergraduate students. In 2016–17, according to the Government Accountability Office, this program helped around 3,300 student-parents pay childcare costs for about 4,000 children. The majority of eligible institutions also used the funds to provide both childcare and support services for parents, such as parenting classes and access to food banks. However, the program remains underfunded as evidenced by the long waiting lists: about 51% of all CCAMPIS-eligible children were on waiting lists for facilities, and of these, 65% were infants and toddlers. This program should be adequately funded and, moreover, should be extended so that enrolled graduate students are eligible.

Beyond its role in making higher education more affordable generally, the federal government is the largest funder of academic research at US universities and could build additional ways to subsidize childcare into grants, either through the indirect or direct portions of grant funding. For example, institutions could receive higher indirect cost reimbursement rates in exchange for providing evidence they have used funds to subsidize off-campus childcare or an on-campus childcare facility. While including human infrastructure as an allowable cost would require changes to the Office of Management and Budget's rules for federal awards, it would have benefits for both the government and institutions. Such a change could help federal agencies achieve priorities such as improving educational outcomes and building and diversifying the STEM workforce while making it easier for institutions to improve engagement and retention. However, a focus on indirect cost reimbursement would be less helpful for institutions that do not apply for many federal research grants.

Agencies could also consider allowing adequate childcare expenses to be built into the direct costs of grant proposals, just as salaries, other benefits, and tuition waivers are. The National Science Foundation and National Institutes of Health have already taken some steps in this direction, but the allowed dollar amounts fall far short of childcare fees. Beyond raising the dollar amounts to account for actual costs, agencies should do more to make principal investigators aware of these options and to make it clear that proposals will not be penalized for taking advantage of them. One possible downside of the direct cost approach is that tying childcare costs to grant funding may leave students and postdocs whose funding lapses, or who receive funding from other sources—e.g., from their institution in exchange for teaching responsibilities—without the subsidy.

A third option is to create a special class of institutional federal grants focused on supporting the childcare needs of graduate students, postdocs, and faculty. To be a long-term solution, such grants must be large enough to potentially build new childcare facilities. These types of grants already exist for research facilities, usually utilizing shared costs between institutions and federal, state, and local governments. But such grants would support human rather than research infrastructure.

Given how US academic institutions vary in size, location, resources, and culture, there is no one-size-fits-all solution, which makes it essential that agencies provide as much flexibility as possible. But to sort through these options, it would be helpful for agencies to gather public input from the research community, including early-career researchers as well as established faculty and administrators. These agencies can then advocate on behalf of the research community to the federal government and Congress to create funding mechanisms to support new parents.

Institutions also have an enhanced role to play here. They can begin by evaluating their own suite of internal policies, such as parental leave policies and those surrounding allowable costs on grants, to be sure they are as friendly to parents as possible. Institutional associations such as the Association of American Universities, Association of Public and Land-grant Universities, and National Association of Independent Colleges and Universities can provide forums for developing and sharing best practices. Most federally funded graduate students and postdocs receive their funding from a small number of federal agencies. Dialogue among these agencies and institutions could help to break roadblocks and chart a course forward.

If the United States is serious about building a more inclusive STEM workforce and embracing the talents and expertise of the nation's diverse population, solving academia's childcare problem is an essential step. Beyond hindering achievement of these societal goals, lack of childcare is also affecting the country's competitive edge in STEM. During World War II, when faced with threats overseas, the federal government funded universal childcare to enable women to make up the shortage in labor while many men were fighting. Today society faces a different set of global challenges, and failing to address the lack of childcare in academia squanders potential and puts the United States at a disadvantage.

If the United States is serious about building a more inclusive STEM workforce and embracing the talents and expertise of the nation's diverse population, solving academia's childcare problem is an essential step.

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KEONYEONG JEONG, YONGSEOK SEO, AND KYUNGMOO HEO

What the Ukraine-Russia War Means for South Korea's Defense R&D

South Koreans are watching the war between Russia and Ukraine not as a far-off conflict, but as a possible model for future power struggles in East Asia—especially in the context of increasing rivalry between the United States and China. Many experts have been struck by the role technologies developed without explicit military applications in mind—nondefense technologies such as drones, information technology (e.g., through cyberattacks), and space communications—have come to play in the conflict alongside conventional weaponry such as missiles, tanks, artillery, and soldiers. Although nondefense technologies can escalate tensions, and sometimes even win battles, they may also serve as deterrents to conflict. For this reason, South Korean government officials and defense researchers are taking notes on the new ways science and technology are changing warfare and defense capability.

We would like to call out two aspects of the Ukrainian armed forces' robust defense against Russia's aggression to which South Korea should pay special attention. First, the Ukrainian defense has adopted high-tech weaponry that was developed for both military and civilian use. In the wake of the Russian surprise assault, Ukrainian forces responded with new applications of high-tech systems, including using 3D printers to add tail fins to drone bombs; employing artificial intelligence-based voice recognition and translation software to highlight information relevant to the Ukrainian forces from unencrypted Russian voice communications; deploying space remote sensing; and enabling satellite communication. Although more technology is no guarantee against low-tech attacks, these nondefense technologies have played important roles in the conflict so far.

Second, unlike other wars, this conflict includes a high degree of engagement by people outside the military. For example, Ukraine's Military Intelligence Team and Aerorozvidka (a special drone unit) consist of professionals from the private sector who are now engaged in civilian-military cooperation. In particular, the Ukrainian information technology unit widely known as the "IT Army" is operated mainly by private professionals supported by volunteer hackers from all around the world, and is not included in the formal organization of the Ukrainian armed forces. In addition, SpaceX, the American aerospace company owned by Elon Musk, supports Ukraine by providing seamless communication capabilities to both military command and the public.

In short, these technologies are not only changing the course of the conflict, but also blurring traditional demarcations between the military, nondefense ministries, and the private sector. As a harbinger of future conflict, the use of convergent and transboundary technology provides important lessons for South Korea's research and development system. To be ready for unpredictable future conflicts and technology-driven uncertainty, South Korea needs to examine and change the way it structures defense R&D. For many decades, the country has fundamentally separated defense R&D from the government's wider R&D processes. Adopting a more inclusive R&D structure, while shifting the system's focus toward future science and technology needs, can advance national security objectives. Making these changes will help ensure that South Korea remains prepared for future threats.

South Korea's defense R&D capability is limited by its history

The two Koreas—North and South—have been in a standoff since the 1953 armistice treaty, with periodic military collisions including the battles of the Korean West Sea in 1999 and 2002 and the Cheonan ship sinking in 2010. This nearly seven-decade standoff, against the backdrop of North Korea's many nuclear missile tests and development of intercontinental ballistic missiles, has meant that South Korea's military remains ever-vigilant. To maintain the same level of military strength as North Korea—especially given its relatively low birth rate and decreasing number of enlisted soldiers—the South has long invested a large amount of its government budget in military R&D.

A key strategy for enhancing South Korea's military power has been a separation of defense R&D from the government's wider R&D processes and plans. By taking this approach, the Ministry of National Defense maximizes the use of defense resources for internal production of high-tech weaponry, rather than purchasing weapons and equipment from other countries with advanced militaries. As a result of this strategy, South Korea had the world's ninth-largest defense R&D spending in 2015. But even though this strategy protects South Korea from dependence on foreign weapons or parts, the Ukraine-Russia conflict has revealed its limitations. Rather than fostering integration between defense and civilian technological development, the South Korean system is siloed, with defense R&D centralized in a few institutions. Furthermore, the process itself is narrowly focused on current rather than future needs.

While centralization helps defense R&D to respond quickly to urgent security and defense issues, it may hinder flexible utilization of some technologies mostly led by the nondefense private sector, such as artificial intelligence and big data. South Korea's defense R&D is centered in two government agencies, the Agency for Defense Development (ADD) and the Defense Agency for Technology and Quality, both of which are administered under the auspices of the Defense Acquisition Program Administration (DAPA). The ADD plays an especially important role in the defense R&D system: nurturing defense industries, cooperating with private companies, running R&D programs, and even facilitating industry-academic partnerships. Together, these agencies receive around 98% of the defense R&D budget.

This level of centralization simply cannot meet the demands of an open and collaborative R&D stream, which requires private-public partnership and civil-military cooperation. In addition, such centralized public services make corruption or other malfeasance more likely. For example, according to the annual Index of Public Integrity survey by the Korean Anti-Corruption and Civil Rights Commission, DAPA scored as one of the lowest-ranked public institutions in 2021.

As a result of this centralization, defense R&D in South Korea has a unique governance that may no longer serve its original intention. Nondefense government R&D programs and projects must go through a lengthy set of administrative steps for budget transparency and legislative consensus. By contrast, defense R&D is exempted from the Framework Act on Science and Technology, South Korea's highest science and technology law. This relative freedom of operation is designed to foster need-driven planning in service of the Korean armed forces, with the Korean government and military as the end consumers of defense R&D.

Within this scheme, defense R&D funding in South Korea tends to be seen as expenditures focused on current needs, rather than as investments that reflect careful calculations of risks and opportunities to meet future national security demands. As one example, the portion of the overall defense budget devoted to defense R&D is still small (around 8% in 2021); by contrast, the percentage of the budget devoted to maintaining key military strengths, like the response to weapons of mass destruction, stands at around 32%. In addition, within the defense R&D budget, the portion devoted to developing weapons systems such as tanks, ships, and airplanes (around 49%) remains larger than that for technology development (around 35%). Indeed, a recent analysis revealed that needs-based defense R&D, with those needs being solely those of the military, accounts for 88% of the total South Korean defense R&D expenditure, despite the changing nature of modern warfare. As technologies with dual uses among the military and civilians become increasingly common on battlefields, the South Korean system remains tightly focused on the practices of the past.

The upshot is that in South Korea, defense R&D is organized, governed, and focused independently from nondefense and private R&D. Needs-driven defense R&D under the auspices of the ADD and DAPA is done on a budget that is kept separate from the government's broader R&D investment plan. In addition, initiation of civil-military science and technology cooperation for small and medium-sized enterprises is still conducted by the ADD alone for the sake of efficient national security. But as the Ukraine-Russia conflict has revealed, this separation no longer reflects the nature of modern warfare. To be prepared for future conflicts, South Korea must revamp its R&D structure and reduce this separation.

Preparing for future conflict by enhancing defense R&D

If future wars follow the pattern of the Ukraine-Russia conflict, then armed forces and weaponry driven exclusively by traditional defense R&D will not be enough to deter or prevail in confrontations. In fact, nondefense technology and nonmilitary actors' engagement could be determining factors in the outcome of future conflicts. To be ready, South Korea's defense R&D system must become better integrated with nondefense and private-sector R&D. We propose three steps to move in this direction: first, develop a more inclusive R&D structure; second, focus R&D on long-term challenges rather than immediate needs; and finally, diversify the defense R&D portfolio and use new conflict scenarios for dynamic planning.

Establishing inclusiveness within South Korea's defense R&D system means changing organizational culture and attitudes. This goes beyond structural changes such as decentralization or increasing communication between actors. It requires enhancing openness, participation, and diversity in the system. It also involves using practice exercises to stimulate open thought, adaptive attitudes, and agile behaviors. This will allow actors within the system to more readily accept different frames of belief, embrace multiple pathways for innovation, and establish expandable and flexible mechanisms for cooperation. In short, inclusive R&D is a collective intelligence process that makes tacit knowledge explicit through mutual and organizational learning.

A good starting point would be to integrate nondefense and private R&D into defense R&D by using new communication technologies. For example, for security reasons, sharing classified information on defense R&D with others is currently highly inconvenient. Using more current information security technologies such as digital rights management and nonfungible tokens on blockchain technology, however, could make sharing information in a secure environment easier. Blockchain technology can store data and transactions in each cryptographic block. This information block can only be updated or changed with the consensus of all participating actors, so data and information cannot be arbitrarily opened, modified, or deleted.

Second, defense R&D should be designed to implement programs focused on long-term challenges and future science and technology needs. South Korea's nondefense government R&D often skews toward such an approach, but sometimes fails to initiate such programs due to prevailing uncertainty and systemic disincentives, such as performance-based R&D budgeting. In this regard, the defense R&D system actually has distinctive merits. Despite being controlled or swayed by needs-based R&D, the defense sector operates on a relatively long time span and with a fairly secure market. Defense procurement contracts that are agreed to before R&D commences often oblige the armed forces to purchase the end products, which sometimes leads to even more funding to meet military requirements.

When it comes to encouraging risky R&D, nondefense R&D agencies could productively work with the armed forces and military contractors while using a longer R&D window. Operating this way could guarantee continued investment in and future consumption of the end products of R&D, such as high-tech prototypes. Therefore, the distinctive characteristics of defense R&D can help to hedge future risk and uncertainty by providing a test bed for new science and early technology—especially when the government is collaborating in a joint R&D project with private actors.

Third, South Korea's defense R&D planning should become more agile, dynamic, and resilient by diversifying the portfolio to encompass a wider range of conflict scenarios with different actors and technologies. Defense R&D should not adhere rigidly to one definitive concept of R&D, nor should it be inclined toward one specific probable future, such as a simple future extrapolation of ongoing social and technological trends. Rather, it must take an anticipatory and dynamic perspective to plan for multiple possible futures while remaining flexible enough to accommodate sudden changes.

In an era characterized by uncertainty and complexity, a fundamental discussion among government officials, military officials, researchers, defense industries, and the public is needed to reestablish and diversify defense R&D investment portfolios to be more future-oriented. Foresight activities such as technology forecasting and horizon scanning can serve as a good starting point to build such dynamic frameworks, including anticipation of multiple possible future conflict scenarios on uncertain battlefields and in complex future combat environments.

As the unorthodox progress of the Ukraine-Russia War demonstrates, military systems and equipment can now make use of advanced technologies in unprecedented and unforeseen ways. The days when the military was always at the cutting edge of technology are coming to an end, and battlefields on land, sea, air, space, and cyberspace are increasingly dominated by new technology that first appeared in nondefense government and private-sector R&D. The convergent and transboundary nature of technology, a feature of what is sometimes called the fourth industrial revolution, has blurred the lines between military and nondefense R&D. For South Korea, the challenge of integrating defense, nondefense government and private-sector R&D is urgent. Such integration, and the innovation that it sparks, will be a key factor in winning future conflicts, while also contributing to national competitiveness and political, economic, and social development.

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JOHN KRIGE AND MARIO DANIELS

Change and Continuity in US Export Control Policy

The question of instituting new export controls, usually only of interest to specialists, has taken center stage in the current tensions between the United States and China. The Biden administration's new high-technology export controls deliberately blur the boundaries between concerns over military confrontation and economic competition. These rules restrict China's ability to obtain advanced computer chips to promote the dual objectives of securing or enhancing US technological leadership while also making it more difficult for China to use artificial intelligence (AI) and high-performance computers for military purposes.

The administration's technology denial strategy is complemented by the CHIPS and Science Act, which aims to strengthen the US semiconductor industry and build a domestic science and technology base capable of translating federally funded research into commercial applications. The Biden administration's technological protectionism of the semiconductor industry exemplifies a strategy of "economic security": a dual-use industrial policy, first embraced in the Clinton era, that understands domination in the civilian market and global military leadership as two sides of the same coin. Although China has been accused of following a course of "civil-military fusion" by deliberately shifting chip technology between the military and the civilian spheres, clearly this strategy of technological integration is a mirror image of established US industrial policy.

Biden has introduced a suite of export controls in strategic industries in a serious and likely far-reaching attempt to affirm and secure US leadership in the face of the rise of China and other authoritarian regimes. Viewing these recent developments within the long history of export controls offers crucial tools for better understanding the context, effects, prospects, and challenges of the administration's policies. Past export control policies have faced serious obstacles, which hold lessons for today. In particular, there have been long-standing debates about the efficiency of export controls in slowing down the development of adversaries and their putative negative impact on US national competitiveness. This is not the only issue to consider. History reveals that focusing narrowly on the question of whether export controls work or not oversimplifies the historical functions and effects that these regulations have had on both foreign and domestic politics.

Although much of the response to the Biden initiative rightly stresses that it constitutes a major shift in policy, the underlying strategic attitudes are not really new. In this regard, there are strong continuities from the Trump to the Biden administration. In the White House National Security Strategy of December 2017, President Trump is quoted as saying that "economic security is national security." But the precedents go further back than just a few years. Indeed, the United States has long sought to sustain technological leadership by regulating trade with political rivals—and allies—in the name of national security.

Examining history through the lens of export controls reveals how economic and national security have become so entwined. Many of the features of the current export control system were first articulated in the 1940s. As early as the 1970s, the system's main goal became maintaining at least a one-generation technological gap between the United States and its competitors and enemies for the production, manufacture, and development of militarily significant commodities, technology, and know-how. In the 1980s, the rapid advancement of the Japanese semiconductor industry was a wake-up call: military strength alone could not secure global leadership. To be effective, military capability needed to be coupled with economic power, and the concept of national security was expanded to embrace economic security in its current meaning.

To compete with Japan, economic security advocates pushed for the integration of the military with the civilian techno-industrial base. If defense contractors had previously prioritized performance over cost, now they had to deliberately lower costs to penetrate global markets, reinvesting profits in advanced research and development to improve performance. As Anita Jones, the Department of Defense's director of research and engineering, put it to a congressional subcommittee in 1994, defense contractors would have to learn to serve "multiple customers, not just one, to market products rather than respond to specifications, and to regard cost" as being "as important as performance." William Reinsch, a senior official in the Department of Commerce, further described the stakes in 1999: "As the line between military and civilian technology becomes increasingly blurred, a second-class commercial satellite industry means a second-class military satellite industry." Market domination in dual-use items became essential for military strength. And this remains true today.

The Biden initiative pushes this philosophy to its limits. The initiative attempts to leverage export controls to exploit technological dependencies and open the technological gap as wide as possible. However, despite these actions, China will still be able to produce and use chips—and not simply for washing machines. China is already a leader in the use of AI and high-performance computing for applications such as smart cities and self-driving vehicles. The country uses facial recognition technology for everything from grocery shopping and pedestrian control to surveillance of the ethnic minority Uighur population. Even though denying the most sophisticated chips to China will probably open a wide gap between Chinese and US military technological capabilities, no one can predict how important that advantage will be to the development of civilian applications of AI and high-performance computing in China. Equally unclear are the economic consequences for US and other international firms, given that China is the biggest semiconductor market in the world.

The role of nations other than the United States and China further complicates the picture. While the United States is essentially acting unilaterally, the effectiveness of these efforts requires negotiations with allies. If the Biden administration wishes to keep the playing field level for US firms, it cannot stop them exporting to lucrative markets like China without also impeding foreign competitors from doing so. Controls are only effective if all producers of technology comply with them. And the export control system can only serve US purposes if its allies accept US limitations on the trading practices of their corporations.

Historically, this has been a major source of friction. During the Cold War, Washington's ideas about what was needed to protect national security did not always coincide with the perceptions of the communist threat in London, Bonn, or Paris. In particular, during the Reagan years, resentment grew over the extraterritorial application of US export controls on trade between other allied countries. A 1984 internal memo by the British computer manufacturer ICL spoke of a growing "technological imperialism" in the United States, and suggested that controls invoked in the name of national security were being instrumentalized to maintain the technological lead time of American firms over their Western competitors.

The United States has long sought to sustain technological leadership by regulating trade with political rivals—and allies—in the name of national security.

During the Cold War, such conflicts were managed, although not always successfully, by seeking to align European with American export controls through the Coordinating Committee on Multinational Export Controls (CoCom). CoCom was established in 1949 as an organization of the NATO allies (and later, Japan). It coordinated national policies of economic containment against communist countries and played an important role in the multilateral implementation of the day-to-day licensing of technology exports crossing the Iron Curtain. Yet, in its more than four decades of existence, CoCom was far from being free from conflicts. The low point was an acrimonious fight over the export of Western gas pipeline technology to the Soviet Union in the early 1980s. The Reagan administration implemented unilateral export controls against British, French, and West German firms to force them to break their contracts with the Soviets. The European governments, however, dug in their heels and fought back, and the United States eventually backed down.

By the early 1990s, CoCom was increasingly seen as a relic of the Cold War whose mission had been overtaken by ambitious Western visions of a new historical phase of neoliberal globalization. The organization was disbanded in 1994 and replaced by the Wassenaar Arrangement. This agreement engaged far more governments (they now number 42, including Russia) whose diverse political and ideological agendas severely limit its powers over national trading policies in conventional arms and dual-use technologies. This poses a problem for US policies vis-à-vis China. Without a strong multilateral agreement, the Biden initiative is heavily reliant on unilateral threats of technological denial to foreign firms that trade with China in defiance of its new export control regime. Thus, foreign firms and states are being forced to comply with US export control regulations intended to secure US market dominance and global military power, and even close allies may again accuse the United States of "technological imperialism."

Biden's invocation of the Foreign Direct Product Rule is another reminder of the reach of US power beyond its borders. Crucially, this initiative also applies "controls on US persons providing support to [Chinese] fabrication facilities operating at a more advanced level than the thresholds we identify." The emphasis on "persons" recognizes the important role played by the transfer not only of technological artifacts but also of technical data, tacit knowledge, and know-how by highly trained scientists and engineers in enhancing the performance of complex manufacturing processes. As we have written, attempts to control this often-intangible knowledge also began as early as the 1940s and became a central tenet of US policy beginning in the 1970s. The extraterritorial effects of these controls are clear: not only Chinese citizens in the United States but also American citizens and permanent residents working in semiconductor firms on Chinese soil are subject to the jurisdiction of the US government. This potentially cuts off the Chinese chip industry's access to many forms of scientific-technological exchanges, including access to universities and foreign talent. The extension of export controls over knowledge also puts pressure on the principles of academic freedom and raises thorny questions about the First Amendment rights of researchers in the United States—harkening back to similar debates in the early 1980s.

This relates to the parts of the US strategy that complement such technological denial, such as the "science" part of CHIPS and Science. If the United States wishes to benefit fully from its new export controls in semiconductor and high-performance computing manufacturing and development, it must nurture its own innovation and manufacturing capacities. Along with this growth, there are personnel issues to resolve. The United States must increase the number of US nationals graduating in scientific and technical fields and find new sources of foreign talent. Export controls have long been used by the United States to maintain technological superiority in dual-use items that bolster both competitiveness and national security. While controls are an important tool, they are but one piece of a larger, long-term, and highly complex strategy.

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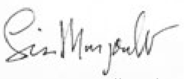


Lisa Margonelli, *Editor and Publisher*

Interview

"The more inclusion we have in science, the better outcomes we'll get."

Illustration by Shonagh Rae

Congresswoman Eddie Bernice Johnson spent five decades in public service, during which she ushered through landmark science and technology legislation and helped to advance opportunities for all Americans.

It's hard to name a single person who has had a greater impact on US science legislation in the twenty-first century than US Representative Eddie Bernice Johnson, who recently retired after more than 50 years in public service. A Democrat who represented Texas's 30th congressional district for 15 terms, Johnson is the outgoing chair of the House Committee on Science, Space, and Technology. Under her leadership, the committee helped enact several historic pieces of science policy legislation including, most recently, the CHIPS and Science Act and the Inflation Reduction Act. Over her career, Johnson was involved with thousands of pieces of legislation and is credited with authoring and coauthoring more than 170 bills that became law.

Underlying the magnitude of Johnson's contributions to US science is a clear and consistent focus on the future, combined with her enduring view that science should serve everyone. In her leadership roles in crafting not just the recent CHIPS and Science Act but many other pieces of legislation, big and small—such as the America COMPETES Act of 2010—she has worked to make science more inclusive, expanding opportunities for women, people of color, and Americans from every part of the country. As a member of the Science Committee since 1993, Johnson is often praised for her bipartisanship and reputation for valuing all perspectives. This skill made her an effective legislator, even as technology, society, and the environment in Congress changed over time.

Growing up in Waco, Texas, Johnson wanted to be a doctor from a young age, but was discouraged by teachers who said girls could only be nurses. Nursing schools in Texas were segregated, however, so she traveled to Indiana to attend a nationally accredited program. After becoming chief psychiatric nurse at the Veterans Administration hospital in Dallas, she became involved in civil rights activism and then ran for the Texas legislature. With that election, she became a "first" everywhere she went: she was the first registered nurse in the Texas State House (1972), the Texas Senate (1986), and the US House (1992). She was also the first woman and the first Black legislator on the House Science Committee. Johnson recently sat down with *Issues* editor Molly Galvin to discuss the 15 minutes that determined her career in politics, how the semiconductor chip transformed Dallas, and her hopes for the future of the scientific enterprise.

You were a nurse for 16 years and had risen to the position of chief psychiatric nurse at the Veterans Administration hospital in Dallas before you decided to run for statewide office. How did you get involved in politics, and what was that leap like for you?

Johnson: After work and on weekends, I did a lot of volunteering with different neighborhood and community organizations doing medical screenings—for glaucoma, polio, and tuberculosis. It was really that volunteer work that got me involved with people who were active in the community and led me to join a group that was trying to expand opportunities for office. I was also involved with attempting to open opportunities for women. [She was active in a local YWCA chapter that formed a group called "50 Sensitive Black Women" to boycott Dallas department stores that put race-based restrictions on customers.]

We were meeting at homes to discuss how we could open accommodations and equal opportunity. In the midst of that came a lawsuit to make the Dallas City Council represent the diversity of the city's residents. I participated by going door to door to help collect some money to fund that lawsuit. That really gave me the opportunity to join others to discuss how we could create a better environment and more representation, and it just took off from there.

I had some reservations. The year before I ran, I had ended a 14-year marriage. I was really concerned about how I would provide for myself and my son. I finally decided at the very last minute to file for office. As a matter of fact, I was sitting at home 15 minutes before the filing deadline when I got a call to remind me to go. I didn't have the filing fee, which I think was $50 at the time. But they gave me 30 days, and I was able to file, and I was off and running.

It was very new and very different, especially for this community, which was predominantly non-African American. They had never seen a woman, let alone an African American woman, do a "man's job." I did have four or five very loyal volunteers. We had to plan day by day and hour by hour.

My campaign manager developed a plan to knock on 40 doors every day as a minimum. I would leave work and go knock on those doors. When I reached 40, I was ready to stop, but if it was still light outside, the campaign manager said, "You can get 10 more in." I was working with a statistician who had identified the registered voters. I had three male opponents. We went into a runoff, and I won.

We had the largest number of women ever elected to the Texas House that year—a total of six women in the Texas House. That included Sarah Weddington [the attorney who represented "Jane Roe" in *Roe v. Wade* before the US Supreme Court]; we got the ruling on *Roe V. Wade* a few days after we started the session that year. It also included Kay Bailey, now Kay Bailey Hutchison, who became a US senator and ambassador to NATO. It was a very engaging, very energetic, and very supportive community.

You have served on the House Science Committee since you were first elected to Congress. You became ranking member in 2011, and of course, you left as outgoing chairwoman. Why has science been such a high priority for you throughout your career?

Johnson: Firstly, I was in a science field, in a health field, as a nurse. But secondly, I was living in Dallas, and Texas Instruments was based there. I knew all the founders and worked closely with them throughout their careers. When that first semiconductor chip was developed, it really changed things so dramatically and so quickly. All of a sudden, we went from calculators to computers to portable phones—even though those early phones looked like briefcases, they were still portable telephones. You could just see the differences happening before your eyes. In the healthcare profession, for example, there were computers to collect notes, when before we had to write it all down. Now, there are more extensive health records.

We've been able to see how this technology has dominated the world. But from the beginning, I said, "We've got to make sure that women and minorities are involved in all this excitement." Once semiconductors became a part of practically everything, you could see the potential for the elimination of human talent, as well as many opportunities for the growth and addition of human talent.

And this has come full circle for you. You're ending your legislative career on a high note by helping to steward the CHIPS and Science Act into law. Your committee contributed several important pieces to help shape that act. How do you see CHIPS and Science influencing the future of science?

Johnson: Well, I think that it makes it much more inclusive and opens up many more opportunities for a broader group of people. It is absolutely captivating to see the possibilities. But we can also see that unless we broaden this to be inclusive for every mind, every way of thought, every location in our country, we'll miss many opportunities.

You can't even calculate the impact of technology. It brings people together. We just got through this pandemic with us all working from different locations with the aid of those chips. It is exciting and fascinating to imagine, where will this take us? We don't know yet.

For example, in rural areas, people can visit remotely with their physicians. That has improved health care delivery tremendously for so many people. Eventually, I think technology will make things much more inclusive and provide many more opportunities for a broader group of people. And we do know that it's going to be the human beings that got us there.

Already we can see that we need talent. We're trying to reach out and look for that brain power. For example, one of the scientists who helped develop Moderna's COVID-19 vaccine, Kizzmekia Corbett, came from a small town in North Carolina and then went to the University of Maryland, Baltimore County. It just goes to show you that talent can be found anywhere, and we don't want to miss that talent. We want to broaden opportunities, decentralize, so that inclusiveness can be felt in every part of the country. The more inclusion we have in science, the better outcomes we'll get.

We will never be able to be the best until we involve people who have actually experienced some challenges in coming up with brilliant ideas. If they're not at Harvard or Yale or some other large school, they might get overlooked. We don't want that to happen. It's nothing against Ivy League universities, but it is about being inclusive to include more brain power. The more brain power we have, the better progress we make.

> "We've got to use our knowledge and try to come up with the best solutions. We owe that to our nation and to the world."

You have had quite a track record of success in the legislative arena even as the political environment has become increasingly polarized. How did you personally, and as the leader of the committee, manage to work in such a bipartisan way?

Johnson: I tried to focus on the science, on solutions, and on progress. I try to give the respect to the other members that I want to get from them. I try hard not to condemn anyone before I know them. On our committee, I've tried to reach out and be inclusive and listen to ideas, and just emphasize that our work is based on science. Let's work toward getting the scientific outcomes. Everybody's important. We need all your thinking. We cannot decide one side knows it all. We've got to use our knowledge and try to come up with the best solutions. We owe that to our nation and to the world. As a leading nation on science, we cannot do anything less.

During your political career, have you seen a difference in how the research community engages with policymakers to advance their goals?

Johnson: The science community stands ready to join us with ideas and innovations. They just need to know that they are appreciated, and there are opportunities for them today, and that we need them. We can't sit in the halls of Congress and think about all the ideas that are being tried and tested in the same way they can. We've got to embrace the science community, and they must educate us. That's how we moved to where we are now with the CHIPS and Science bill. We're there to help them try to see that the opportunities are there, but we don't claim the brain power.

You have been advancing the cause of increasing diversity, equity, and inclusion in science, technology, engineering, and mathematics (STEM) for your entire career—in fact, you sparked many National Academies studies and activities, including a major study on anti-racism in STEM that will be released in the coming weeks. If you had to give a grade to the STEM community on their progress, what would it be?

Johnson: I think this is a work in progress. We had to do a lot of background research to convince even our committee members in the House that this needed to be done. Our society has gotten into a rut of doing it the way we've been doing it. Not much imagination has gone into how to expand opportunities and expand outcomes.

If we make science more decentralized, you will get, for example, NOAA [the National Oceanic and Atmospheric Administration]—a unique agency that performs cutting edge science but is also rooted in providing critical environmental service and stewardship. And NOAA's work on predicting the weather is incredibly useful to everyone in every part of the country, because now they have time to prepare for storms. But you can't get that kind of transformation and such useful science if you do all of it in California. You can't do all of that in Massachusetts. You can't do all of that in Mississippi. You have to look at it where innovation is happening and bring these minds together. This involves much more inclusion, which will include race and include gender, but it should also include lived experiences.

What can be done to accelerate change on these fronts?

Johnson: We have so much more communication now with new technology. When you think about the past, a big inspiration was space exploration. It has become a worldwide endeavor and has really expanded our knowledge base, and experience base, and diversity base. And I think that space exploration has stimulated the minds of many of our young people who never gave much thought to the universe except the block where they live, or the downtown where they live.

All of that is important. When you think about history, most of the real inventions that helped farmers, for example, came from farmers who were doing the work, including African Americans. To bring that knowledge to the table to advance technology—that can still happen today.

That's how we get improvements. People who are on the job, doing a job, can find a way to do it better and more efficiently. We've got to be inclusive. We've got to include geographic diversity and we've got to include many types of backgrounds. We have had some of the greatest scientists who come from other countries. When we mix that talent with American brains, there's no stopping us.

You have seen a great deal of technological change throughout your lifetime, and at the same time, so much social progress and change. Do you think that those two things are interrelated?

Johnson: They have to be. It's very difficult to bring about change without people feeling it and sharing it, without people being able to talk with each other and getting to know each other—crossing cultures, crossing races. It has to make things better. We're in a position to make the best of our democracy and make the best of all our talent, to include and encourage it. That's why I'm so concerned about getting this message out to our young girls. We have proven through our research that they have not been greatly welcomed in some of these STEM areas, but it does not mean they should walk away from those fields. We're trying to make sure to broaden those opportunities for them.

Given your experience and everything that you've been through in your career and in your life, what would you say to encourage a young person who is interested in getting involved in politics or policymaking or science?

Johnson: This is your day. You own as much of this world as everyone else. You have the freedom to think, to study, to research, to learn, and to do. Don't let anyone take that away from you because the world is waiting for your talent. We need it.

To Support Evidence-Based Policymaking, Bring Researchers and Policymakers Together

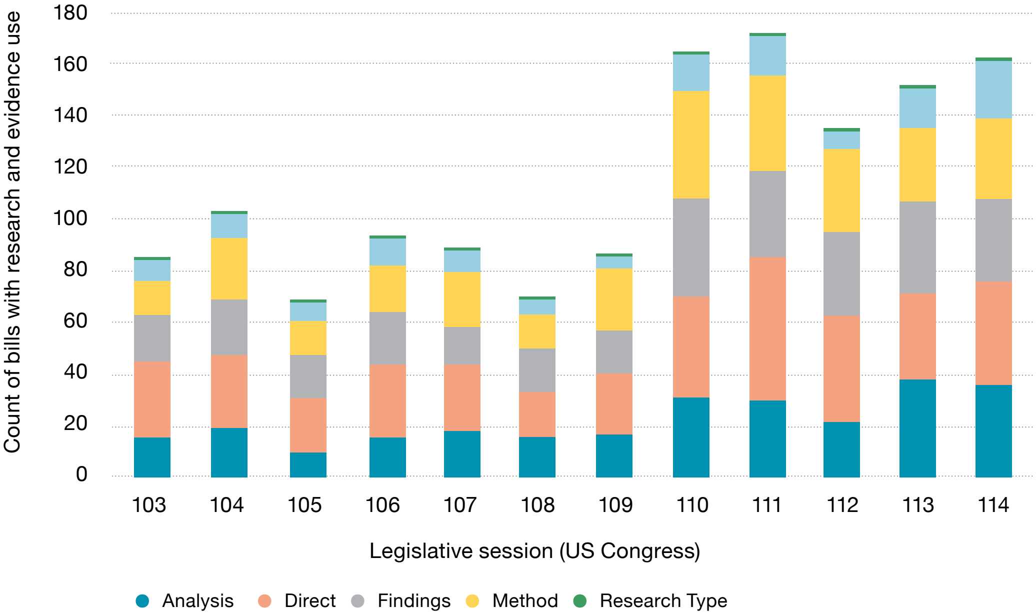
D. MAX CROWLEY AND J. TAYLOR SCOTT

Scientists frequently bemoan the gap between science and policy, seeing the slow adoption of scientific and technological solutions through research-informed policy as missed opportunities to help people and benefit society. Yet if researchers want leaders to make evidence-based policies, they must develop ways to support the use of research in policymaking that are themselves based on evidence. This sentiment has been a driving force for our work over the past decade, developing and testing strategies to support evidence-informed decisionmaking through the Evidence-to-Impact Collaborative, a Penn State University research center.

We found early on in an experimental study of over 400 community leaders that when different types of people work together on shared policy problems, knowledge about evidence-based practices improves. We brought together leaders working to reduce youth substance abuse from schools, law enforcement, cooperative extensions, and parent organizations. Using a model called PROSPER (PROmoting School-community-university Partnerships to Enhance Resilience), we engaged with participanting leaders and tracked their knowledge and use of evidence-based practices over half a decade. The type of structured, trust-building engagement embodied in PROSPER led leaders to be twice as likely to identify an evidence-based intervention as those in the control group, and nearly three times as likely to understand how to implement such interventions properly. Subsequent work found that, by bringing together community leaders, the PROSPER model could in turn prevent youth misuse of opioids, cannabis, alcohol, and other drugs.

In the state and federal policy spheres, referencing research and evidence has become more common over time (Figure 1), although the proportion of total bills using evidence language has increased only slightly, from 59% to 70% between 1993 and 2017. This small change reflects missed opportunities to bring more evidence into policymaking. It is all the more surprising because studies show that bills using such terms are more likely to be successful. For instance, a review of federal behavioral health legislation over the last 30 years found that bills that explicitly referenced scientific evidence were over three times more likely to be enacted into law than bills that did not. We found similar results in other federal policy areas, such as substance abuse and human trafficking, and we replicated and expanded on this finding in studies of state-level legislation as well.

Figure 1: **NUMBERS OF BILLS RELATED TO JUVENILE JUSTICE CONTAINING RESEARCH AND EVIDENCE KEYWORDS IN THE US CONGRESS BY SESSION**



Keywords were classified as:
***Analysis**: referring to statistical processes or interpretations*
***Direct**: referring to processes of dissemination and related terms such as "evidence-based" or "best practice"*
***Findings**: referring to scientific literature or study results*
***Method**: referring to the process of obtaining, collecting, or managing data or conducting studies*
***Research Type**: referring to different kinds of studies or research without necessarily referencing findings*

But it goes beyond the mere presence of evidence or research terms in legislative text—our findings show that the quality of these terms matters. As shown in Figures 1 and 2, the frequency with which different research terms are used in juvenile justice legislation varies, but bills that directly reference scientific study designs (research type: e.g., "randomized trial" or "longitudinal study") were 65% more likely to pass out of committee. Bills that directly reference the process of conducting studies (method: e.g., "data collection" or "data mining") were also more likely to be enacted into law.

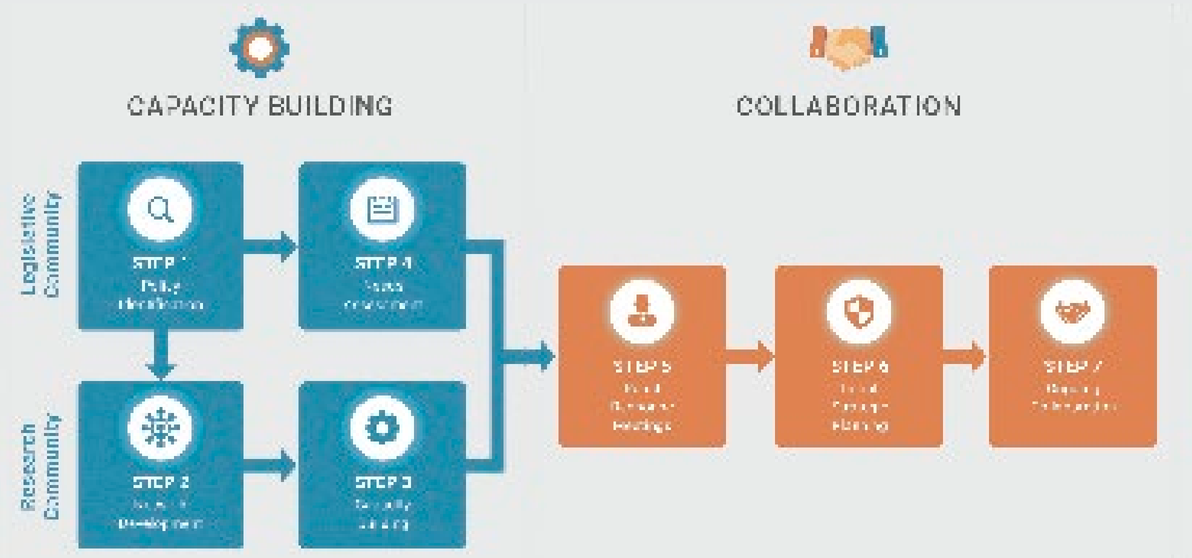
Bringing together all these findings, we recognized the need to facilitate diverse scientific engagement with policymakers that would systematically improve not just the quantity, but also the quality of evidence used in legislation. This is not a new challenge. A long history of efforts to increase the use of science in policymaking has highlighted the limitations of expecting policymakers to go out and find the relevant science, and even the limitations of more recent models that simply push science onto the policy community. Research shows that success requires strategies that cultivate trusting relationships directly between scientists and policymakers who desire quality information. Federally focused programs such as Science & Technology Policy Fellowships from the

Figure 2: **FREQUENCY OF SPECIFIC RESEARCH AND EVIDENCE KEYWORDS IN JUVENILE JUSTICE LEGISLATION INTRODUCED IN THE US CONGRESS**

A word cloud from evidence phrases seen in bills to illustrate frequently used language in legislation from the 103rd (1993–1995) to 114th (2015–2017) congressional sessions.

THE RESEARCH-TO-POLICY COLLABORATION MODEL

The Research-to-Policy Collaboration (RPC) model uses seven steps to build capacity in the research and legislative communities, and then to facilitate collaboration between the two to achieve short-term policy objectives as well as longer-term development of relationships and mutual trust.



STEP 1: *Policy Identification* involves initial outreach to legislative staff and assesses policymakers' overarching policy goals for the legislative session.

STEP 2: *Rapid Response Network Development* involves identifying researchers who have expertise relevant to policymakers' goals and are willing to contribute to research translation efforts. Their areas of expertise are cataloged in a strategic resource mapping process that builds capacity for matching researchers with policymakers.

STEP 3: *Network Capacity Building* occurs through training that aims to increase researchers' policy skills and engagement. This includes training on adapting to legislative norms without violating lobbying regulations, as well as opportunities to respond to lawmakers' interests.

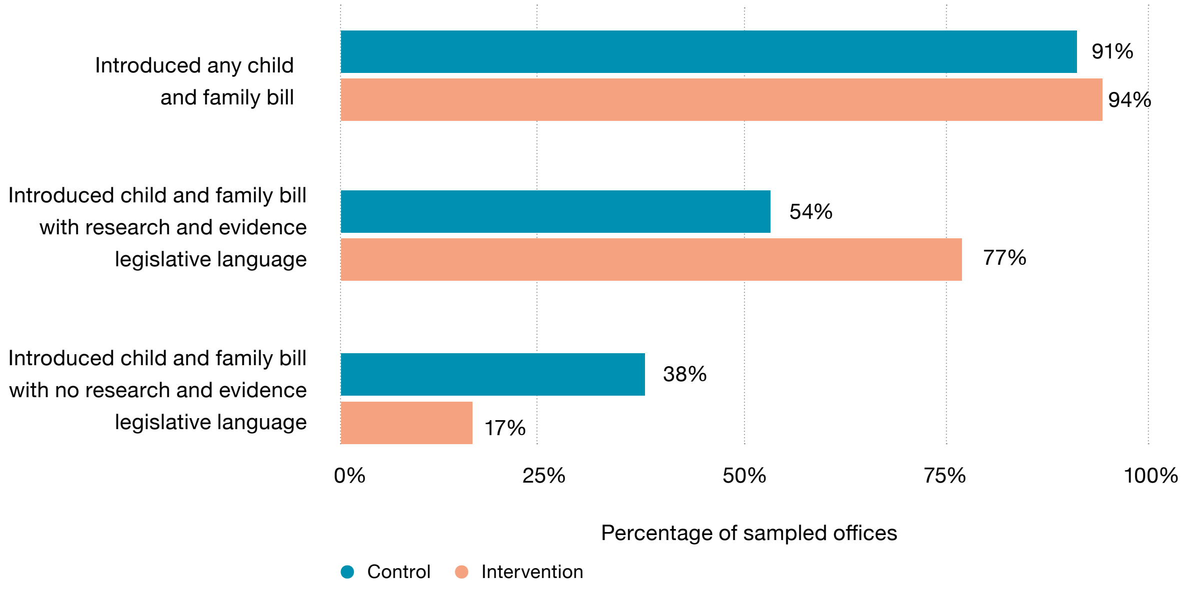
STEP 4: *Legislative Needs Assessment* identifies short-term priorities and needs in anticipation of matching policymakers with researchers who have corresponding experiences and scholarly interests. This assessment is action oriented to identify ways that researchers might support legislative efforts.

STEP 5: *Rapid Response Meetings* engage legislative staff and researchers in direct interactions to discuss research and facilitate relationship development. Meetings aim to support the co-development of science implications, since research interpretation is a formative and iterative process. Researchers respond to initial legislative requests and plan next steps for ongoing collaboration. Researchers are invited for these meetings based on prior RPC participation, time availability, relevant scholarly interests, and geographic similarities (e.g., researchers having done work in the state the congressional member represents).

STEP 6: *Initial Strategic Planning* for rapid responses follows immediately after meetings to summarize goals, determine next steps, prioritize and create a timeline, and identify point person(s) for follow-up.

STEP 7: *Ongoing Collaboration* includes rapid responses to legislative requests. As an example, this could include collecting and summarizing research resources, planning briefing events or testimony, or publishing written products for dissemination (e.g., briefs, op-eds).

Figure 3: **INTRODUCTION OF CHILD AND FAMILY BILLS THAT USE RESEARCH AND EVIDENCE TERMS IN LEGISLATIVE LANGUAGE INTRODUCED BY CONGRESSIONAL OFFICES**



American Association for the Advancement of Science and state-focused programs such as the Missouri Science & Technology (MOST) Policy Initiative utilize these strategies, but they require immersive and embedded full-time fellowships for a handful of scientists per year. For the typical scientist facing existing institutional constraints, such engagement remains difficult.

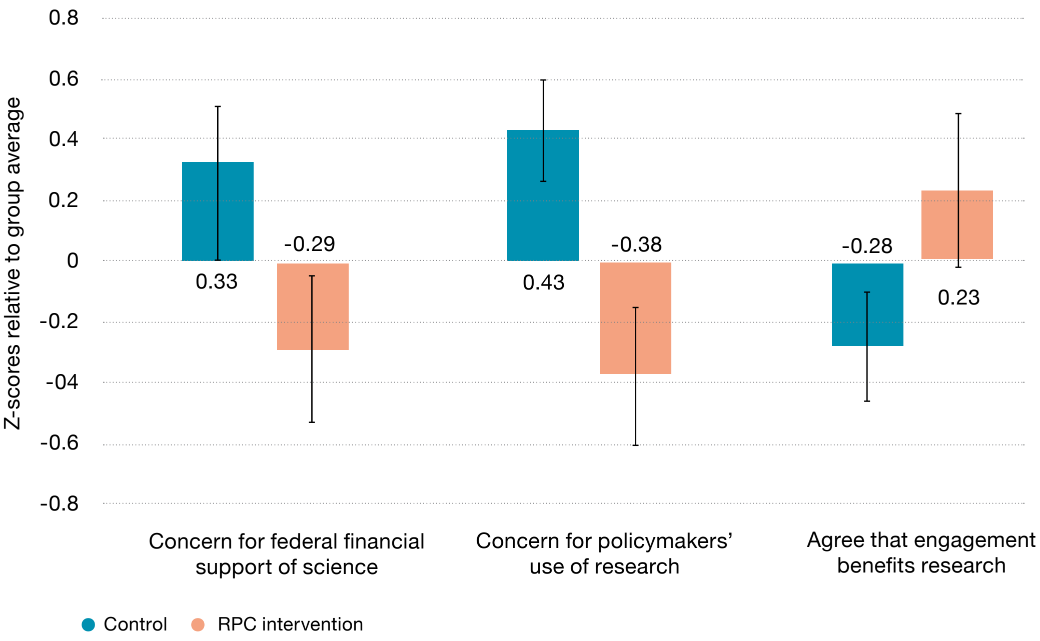
Recognizing this gap, we developed a replicable model to facilitate engagement between policymakers and the scientific community: the Research-to-Policy Collaboration (RPC) model. The RPC is a behavioral and structural intervention that involves both policy and research communities through seven steps.

A pilot study of the RPC model with a focus on prevention science (the study of practices that mitigate and reduce the occurrence of social problems) demonstrated promising results in improving scientists' legislative engagement, fostering legislator-researcher connections, and eliciting requests for evidence from legislative offices. This work emphasized a dual-community strategy that increased researchers' capacity for engagement while conducting strategic assessments of policymakers' need for scientific evidence.

Although promising, the pilot did not provide sufficient evidence that RPC actually improved use of research and methods in the legislative process. This led us to conduct a follow-up study that we believe was the first randomized controlled trial of the US Congress to improve the use of research. We randomized 96 congressional offices to either receive the support of the RPC or be assigned to a control condition where they did not. We found that though offices that participated in the RPC intervention were not more likely to introduce child and family bills, the use of research and evidence terms in bills that were introduced varied significantly between the intervention and control offices (Figure 3). Those participating in RPC were more than 20% more likely to write bills with research and evidence language compared to the control group, a statistically significant difference. They were also much less likely to introduce bills that did not include such terms. Longitudinal surveys revealed other changes in congressional offices assigned to receive the RPC—including a 7% increase in the value offices placed on using scientific evidence to understand how to think about or conceptualize problems.

Besides its effects on legislative offices, RPC participation also had impacts on the scientific community, with benefits for researchers who participated. We conducted a parallel

Figure 4: **EFFECTS OF RESEARCH-TO-POLICY COLLABORATION ON RESEARCHER ATTITUDES**



Z-scores depict trends relative to the group average (M = 0, SD = 1). Negative scores indicate a lower rating relative to the group mean. All differences shown here are statistically significant at p ≤ .05.

randomized controlled trial of over 200 researchers who either received the RPC or received traditional, static policy engagement materials instead. Compared to the control group, researchers who received the RPC were more likely to engage with policymakers, report fewer concerns about funding for science and about policymakers' use of research and evidence, and report that their policy engagement improved their own research program (Figure 4). Moreover, researchers who identified as members of racially or ethnically marginalized groups were, before the trial, significantly less likely to engage with policy communities—but those who did engage as part of the trial reported the greatest benefits.

Although this work demonstrates the potential of experimentally validating strategies to improve the use of research, it also highlights how far both the scientific and policy communities still have to go to successfully engage at all levels of government. While designing new strategies, the scientific community must be mindful of who and how they engage, considering issues of burden—time, effort, and financial resources—on both scientists and policymakers. These strategies also need to ensure that scientists with a diverse mix of perspectives and backgrounds are included. And the scientific community must also prepare for inevitable disagreement and controversy, ensuring policymakers and scientists can effectively engage in an appropriate manner and without loss of trust when they may be at odds with each other.

Beyond strategy development, scientific and policy institutions must become more amenable to sustained, meaningful engagement around the use of evidence. Perhaps one of the greatest challenges will be culture change: finding ways to align organizational incentives that influence the behaviors of scientists, policymakers, and their staffs. Our experimental studies show that bringing scientists and policymakers together provides mutual benefits for the individuals and offices involved, as well as the larger societal benefit of improved use of evidence in policy.

Looking to the future, and the many challenges that humanity is likely to face in the coming decades, such collaboration will only become more necessary if scientists and policymakers hope to best serve all members of society.

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SUEYEUN JULIETTE LEE

How much chemical disorder…

How much chemical disorder
can be survived depends   on medical technology.
A hundred years ago, cardiac arrest was irreversible.
People were called dead
when their heart   stopped beating.
Today death is   believed to occur 4
to 6 minutes after   the heart stops beating
because after   several minutes it is difficult
to resuscitate the brain.
However, with new experimental
treatments, more than   10 minutes of warm cardiac
arrest can   now be survived without
brain injury.   Future technologies
for molecular repair may extend the

frontiers of resuscitation beyond
60 minutes or more,
making today's   beliefs about
when death   occurs
obsolete

merely transitory evidence   a stray boundary between
a much longer-lasting   (*invisible*   opposite polarities
feature   the fields annihilate
the field tries to   one another
repel the intruder   rapidly

velocities   directly   shine in emission
visible   shortly

in terms of   before
brightness   totality

Illustration by Shonagh Rae

TOMMY SHIH

Navigating the Gray Zones of International Research

Science funders can enable responsible international collaboration by developing global norms for ethical research that appropriately respond to today's geopolitical tensions.

The past two decades have seen rapid global growth in investments in research and development with a concomitant volume of publications. Much of this growth is associated with countries, such as Brazil, Russia, Iran, India, and especially China, that have not historically been considered global leaders in investing in science. China in particular has become a significant part of the global science enterprise. Since 2016, China has been the largest producer of scientific publications in the world, and in 2020 produced nearly 23% of the world total. Moreover, papers from China overall are cited at a higher rate than the average rate for the world total, indicating rising quality.

Accompanying this globally distributed growth, international scientific collaboration is also on the rise. Between 2009 and 2018, for example, the growth in scientific articles in major European research nations was almost entirely due to international coauthored papers, including with countries whose scientific enterprises are growing swiftly. In the last five years, researchers have collaborated internationally to sequence and monitor SARS-CoV2, develop and deliver vaccines, preserve habitat, mitigate climate change, and more. But though global problems have never been more pressing, geopolitical tensions and politicization of research are raising barriers for transnational scientific cooperation. For example, in the United States, the FBI warned in July 2020 that "China pays scientists at American universities to secretly bring our knowledge and innovation back to China," with interests including crops, energy, and military equipment. With the exception of COVID-related research, China-United States collaborations declined during 2020. Australia, Germany, India, Japan, and the United Kingdom are also reported to be increasing scrutiny of international research relationships.

Meanwhile, there are concerns about the integrity of research coming from emerging countries. From 2011 to 2020, the number of grant applicants to China's main basic research funding agency grew about 9% a year, an unprecedented rate of growth. Yet stringent structures to ensure ethical, rigorous research take time to form and can be thwarted by hypercompetitive environments. The research community, including Chinese funders, has tried to quell a rise of research fraud, including faked peer reviews and fraudulent research articles produced by paper mills. What's more, research performed under an authoritarian government brings other challenges, such as the lack of institutional autonomy for research organizations and academic freedom for researchers. And of course China is not the only country where researchers must deal with autocracy and hypercompetitive pressures to publish.

While more research and inclusion of more countries in global science are needed, the challenges of emerging science systems and the greater institutional differences encountered by researchers today negatively impact research quality and accountability. This makes it difficult to foster high standards of integrity in international collaborations. A deep global dialogue is necessary to set out what is needed to uphold research standards and how to enforce them, but national governments have not initiated such multilateral dialogue. And researchers, while vital to any such discussion, do not themselves have authority to set international norms.

I study international research collaborations amid geopolitical tensions, with a focus on China. In my view, national and global science funders are best positioned to launch dialogue that can harmonize research norms and build trust. Funding mechanisms offer a way to induce behavioral changes. Moreover, coordination between funding organizations can be done flexibly and iteratively via the development of a common code of conduct that funding recipients must adhere to.

Some dialogue has already begun. For example, a network of international research funders—including the Swedish Foundation for International Cooperation in Research and Higher Education (STINT, to which I am an advisor), Swedish Research Council, Vinnova (the Swedish Innovation Agency), Research Council of Norway, Academy of Finland, Japan Science and Technology Agency, and US National Science Foundation—began discussing responsible practices in international research collaboration amid geopolitical tensions in 2022. Since 2019, the Nordic funders have also held discussions with the National Natural Science Foundation of China (NSFC) on the topic of global research norms.

But more than funder-to-funder discussion is needed to recalibrate codes of conduct. In today's scientific world, no set of international norms will be broadly adopted unless their development includes a broad base of players: advanced as well as emerging science nations, funders, and researchers. Actors in places like the United States, Europe, and Japan need to include China in discussions and dialogues about norms. In China, there must be an increased willingness to take greater responsibility for deteriorating global political conditions, as well as to see research more broadly than as an instrument primarily used for the rejuvenation of the Chinese nation.

Done inclusively, the global research community can support the vital work of forming an open science system that, while not independent of geopolitical frictions, can better withstand them and push on to solutions addressing climate change, epidemics, and other global challenges.

Steering toward responsible collaboration

Older guidelines seeking to harmonize scientific integrity in an international context are often not easy to apply in researchers' current reality. These efforts and the resulting brief statements (e.g., the 2010 Singapore Statement on Research Integrity, the 2013 Global Research Council Statement on Principles for Research Integrity, or the European-focused ALLEA code of conduct in 2017) were formulated primarily based on norms set by Western countries, and they reflect high-level principles rather than concrete practices. Nor do these declarations anticipate how to navigate geopolitical tensions.

To address this need, the European Commission and governments in Japan, Australia, the United Kingdom, and the United States have taken actions to protect national research institutions from foreign interference. The Organisation for Economic Co-operation and Development (OECD) released a report in June 2022 that elaborated ways to strike the proper balance between research security and research integrity on one hand and the need for international research collaboration to solve global challenges on the other. The report includes recommendations for good practices in research security and research integrity, such as developing clear guidelines for handling specific research security and research integrity issues and developing capabilities across institutions by sharing information, guidelines, or databases.

In conjunction with the OECD report, the Group of Seven intergovernmental forum released a document on common values and principles regarding research security and research integrity. These principles are designed to safeguard the research and innovation ecosystem from risks to open and reciprocal research collaboration, such as foreign interference or unauthorized information transfer. Guidelines by international organizations and forums could be valuable in building global norms, but they will need to be put into practice. Funders are uniquely positioned to translate these principles into practice by creating guidelines for researchers across nations and scientific fields and to ensure that the guidelines foster international collaboration rather than stifle it.

Crucially, funders can also help to build appropriately nuanced frameworks for future collaboration. Although much of the debate on international research has focused on red lines and extreme examples such as espionage, direct dual use, or human rights violations, such flagrant threats will not be germane to what many scientists may face in their research collaborations. A study of the STINT-NSFC Joint China-Sweden Mobility Program (for 2015–2021) found that "the percentage of considerable ethical challenges identified by the evaluators in the program applications received was in the low single digits."

Of course, research collaborations that encroach on human and individual rights, violate laws, or directly help develop weapons must be handled in a resolute and clear manner by both government authorities and research organizations. But responses crafted to control rare, extreme, and even hypothetical risks could set restrictions that limit international cooperation, including cooperation that would ensure research integrity. That's especially true for funders and researchers in a repressive setting.

Funders should work on what's really important for maintaining integrity in international scientific collaborations, which includes helping researchers navigate the gray zones they are more likely to encounter as their colleagues become increasingly international. For most researchers, for example, conversations about guest authorship and informed consent are more relevant than safeguarding military secrets.

Research collaborations can fall into gray zones because of differences in national laws or varying levels of implementation of ethical codes. And when scientists or scientific organizations exploit gray zones, it can lead to what is referred to as "ethics dumping": conducting unethical research in another country because of lower requirements, or testing technologies that are not approved or certified for use in the inventor's country in places with less rigorous oversight. Ethics dumping can be a particular problem for clinical trials in developing countries, with populations vulnerable to exploitation. While not necessarily illegal, ethics dumping practices are highly inappropriate, and funders are often well positioned to identify, recognize, and regulate such practices.

Identifying gray zones and developing ways to deal with them will help pinpoint where responsibilities lie for scientists and their communities and organizations. Discussions around specific gray zones, such as conducting clinical trials in developing countries or performing research with nonhuman primates, can illuminate how to view reciprocal exchanges of data, financial resources, or personnel; pinpoint shared boundaries for transnational exchanges; and identify opportunities for training and education. Discussion of reciprocity can also help clarify the reasons why specific projects should be undertaken in an international context.

Better collaborations, stronger science

In addition, deliberately discussing gray zones may strengthen scientific collaborations more broadly: researchers can develop more nuanced skills in balancing due diligence with relationship-building. Currently, researchers based in Europe, Australia, and the United States are asked to be vigilant of foreign interference when collaborating with researchers in authoritarian countries by conducting due diligence to avoid transgressing legal requirements. This could occur, for example, if a researcher accepts a secondary position through one of China's talent plans, which seek to incentivize scientists to bring their work to China. But starting relationships with due diligence is a challenge. Collecting information about individuals and institutions in foreign countries can be difficult. For instance, the Australian Strategic Policy Institute's China Defence Universities Tracker identifies universities in China with military ties, but the categories are so blunt that they might cause researchers to refrain from undertaking what may be fruitful, low-risk collaborations.

For productivity and longevity, collaborations require reciprocity and mutual benefits. Establishing such reciprocity is challenging in the current research landscape due to unequal conditions and systemic differences. This is not only because of variances between the Global North and Global South or among national government policies, but also due to mobility differences. Creating more equity in the relationships within and between research groups requires mobility, so that people can get to know each other in person and become familiar with each other's research cultures. Western researchers and students seldom seek opportunities in new or emerging science countries compared to the reverse. For instance, recent data show that in 2018–2019, just prior to the COVID-19 pandemic, the United States hosted more than 136,000 international scholars, of which around 80,000 (59%) came from Asia. That same year, the United States hosted more than 1 million international students, of which around 768,000 (70%) came from Asia. While data on international scholar mobility globally is limited, the United States had around 347,000 study abroad students in 2018–2019, of which only around 40,000 (12%) went to Asian countries.

Funders can improve equity by encouraging North Americans and Europeans to travel and, within collaborations, incentivizing frequent meetings between research teams. Granted, it will be an uphill battle in the current environment to incentivize Western researchers or students to conduct research or study in countries such as China or India. Increased suspicion by institutions and governments does not help. Nevertheless, exchange is important, be it through online video conferencing, at international branch campuses, or in international conferences. A more equal exchange with the West could help build relationships and co-develop norms in nations that are still developing scientifically.

Finally, any effort by funders to establish new norms for international research collaborations must include a component of educating and socializing these norms within the research community. An example is an educational initiative launched by STINT and developed with three Swedish research universities—Karolinska Institutet, KTH Royal Institute of Technology, and Lund University—to address responsibility in international research collaborations. Working together, these institutions provide a forum to manage gray zones, highlight opportunities in international research, and better understand trade-offs like the conflicts between individual and institutional goals or the risks and benefits of openness versus securitization. The target groups for the initiative have been university leadership, department chairs, and other administrators. But it is at least as important that active researchers receive this education and training. STINT has also since 2020 asked applicants to reflect on responsible internationalization in their applications. Applicants must describe the benefits of their research in a transnational context as well as detailing potential challenges or risks. For example, studying women's rights in a setting where they are severely encroached upon might pose risks to the study population as well as the researchers. By working with the universities where funded researchers work, STINT hopes to target the broader research community.

Research funders have a leadership role to play in developing a more inclusive global dialogue to first spell out who has the responsibility and authority to uphold academic principles and then to implement necessary changes. But the norms must focus on the gray zones collaborators are more likely to encounter, and emphasize the balance between due diligence and reciprocity. Such norms, properly developed and socialized, can enhance relationship-building and global scientific collaboration at a time when it is more needed than ever.

Tommy Shih *is an associate professor at Lund University and is an advisor to the Swedish Foundation for International Cooperation in Research and Higher Education and other international funding agencies.*

JOSEPH J. FINS

The Complicated Legacy of Terry Wallis and His Brain Injury

An Arkansas man's unprecedented recovery of consciousness, and his recent death, demonstrate why progress in neuroscience must be matched by new standards of care for patients that protect their civil rights.

In the eight years that I have been teaching a seminar on disability rights and brain injury at Yale Law School, I have never come close to tears. But I choked up when I told my students about the death of Terry Wallis, at age 57, on March 29, 2022. Wallis, who came to international attention when he awakened from what was thought to be a permanent vegetative state after 19 years of being unresponsive, was well-known by my students—his astonishing experience anchors what I hope will become legal frameworks that enable disability law to better meet the needs of patients with severe brain injury.

After an accident in 1984, Terry was considered by his care team to be in a state of permanent unconsciousness, until 2003—when he said "Mom" and then "Pepsi," his favorite drink. It's not an exaggeration to say that Terry's awakening set off a "golden age" of brain science, profoundly changing the scientific, moral, ethical, and legal understandings of consciousness. Although Terry was exceptional—he became a brain injury rock star—his death was all too ordinary and, arguably, avoidable: a consequence of therapeutic nihilism about severe brain injury, widespread discrimination against people with disabilities, and inadequate rehabilitation facilities in the rural area where he lived.

The irony and injustice of the way he died affected me deeply. Despite the fact that neuroscience has learned so much from Terry's remarkable journey, the United States' depersonalized health care system neglected him, like so many others with severe brain injury. His death was a harsh reminder that the revolution in brain science that Terry helped launch will remain incomplete until scientific progress is matched by an obligation to bring these advances into clinical practice in ways that are meaningful and just.

In the months since his passing, I have come to think that Terry's death may be as important as his emergence for the way it encapsulates both the progress and peril of how society is coming to understand severe brain injury and frame its obligations to care for people who have experienced them.

Launching a golden age

I first met Terry and his parents, Angilee and Jerry, when they came to the Consortium for the Advanced Study of Brain Injury at Weill Cornell Medicine and Rockefeller University in 2004 to see if our team, which I codirect with neurologist Nicholas D. Schiff, could explain his emergence. I interviewed Angilee and Jerry as part of research for my book on the rights of those with severe brain injury, *Rights Come to Mind,* shortly after they arrived in New York from rural Arkansas. I gathered they felt out of place in Manhattan, but we immediately struck a connection when they realized that their concern for Terry was matched by our research group's interest in his experience.

The Wallis family was *familio-centric*: nothing was more important than Terry, whose medical course Angilee had tracked carefully since his car accident. She told me that the family thought they had seen glimmers of awareness over the years and had asked for a neurologist to reassess Terry's condition, only to be told it was too expensive and wouldn't matter.

Terry's remarkable story had garnered international headlines and been hailed as a miracle, but my colleagues and I were not surprised by his recovery. Although he had been described as being in the vegetative state—that is, permanently unconscious—we suspected he had actually been in the minimally conscious state (MCS), a condition that was only formalized a year before Terry started to talk again.

MCS resembles the vegetative state but is distinct because MCS patients are *conscious,* albeit liminally so. They have awareness of self, others, and the environment. The challenge is that they don't always manifest these behaviors and can appear vegetative when these signs are absent. But biologically, these patients are distinct from those in the vegetative state. The minimally conscious brain is functionally integrated and capable of communicating across widely distributed neural networks necessary to sustain consciousness. This contrasts with the functionally disintegrated vegetative state, which cannot work as a consolidated unit and thus cannot sustain consciousness. In contrast, MCS patients exhibit behaviors reflective of awareness and consciousness: they may say a word, reach for a cup, or look up when you enter the room. However, these behaviors are usually episodic and intermittent, and such signs of covert consciousness are easy to miss. One study found that up to 43% of nursing home patients diagnosed as vegetative following traumatic brain injury were in fact in MCS.

Before we even met Terry, we guessed that he had been in MCS, which meant that during the many years that he was lying in his nursing home bed, his brain had recovered. Imaging studies of Terry's brain done by Schiff and our team found dynamic changes that might explain the improvement in his brain state. These included possible axonal regrowth of the white matter fibers that connect nerve cells—a phenomenon normally seen in children's brains as they develop. This suggested that his neurobiology was adaptive: a developmental process was being reharnessed in service of repair and regeneration. This hypothesis was later confirmed in a longitudinal study published in 2016 that tracked another patient as she regained an ability to communicate over the course of 54 months.

Terry's scans were stunning, revealing the potential of the injured brain to heal itself and carrying implications for how physicians view the depth and length of rehabilitation. If brain recovery recapitulates brain development, which takes years, maybe the duration of rehabilitation should resemble that of childhood education, which is tailored to the developing brain. If rehabilitation is viewed as analogous to the educational process, then payments for its provision should be guided by the underlying recovery. Instead, they are often guided by the traditional reimbursement criteria of insurance companies, which presume stasis—often resulting in patients having to forgo rehabilitation efforts altogether. Brains recover by biological mechanisms, not reimbursement criteria.

In the two decades since Terry regained his voice, the science of disorders of consciousness—and the possibility of treatment—has radically shifted. Researchers have learned how to identify covert consciousness with functional neuroimaging, begun to develop drugs and devices that can accelerate the return of consciousness, and now even consider the ethical implications of these advances. This progress culminated in 2018, when a new standard of care for patients with disorders of consciousness was issued by the American Academy of Neurology, the American College of Rehabilitation Medicine, and the National Institute on Disability, Independent Living, and Rehabilitation Research. In addition to the use of emerging technology and drugs to assess and treat patients, the new standard importantly called for the amelioration and prevention of confounding conditions that effect the morbidity and mortality of these patients, such as bedsores, urinary tract infections, and pneumonia. If a patient succumbed to these conditions because of inadequate care, any progress in the diagnosis and treatment of their underlying brain injury would be for naught.

It was clear that Terry's awakening had helped catalyze a promising era of neuroscience and prompted a moral consideration of what society's responsibilities should be toward people with severe brain injury. Indeed, as the personification of MCS and example of what neuroscience was learning about severe brain injury, Terry's passing was a major news event: the *New York Times* carried a full obituary with a photo, and I saw him featured as a "notable death" on a national TV news show.

An unworthy death

These cultural markers, however, only tell part of Terry's story—celebrating his emergence. They don't acknowledge *how* he died. That Terry was so well known makes the circumstances of his death all the more disquieting. With access to adequate care, I believe the complications that led to his death might have been prevented and treated. But for patients with brain injuries, who are often subject to what is euphemistically called "custodial care," such deaths are all too common. These gaps in care are the bleak companion to an emerging golden age of brain science. A systematic review published in 2018 revealed that the number of patients with prolonged disorders of consciousness admitted to inpatient rehabilitation had "progressively declined" over the previous 15 years. Access to high-quality rehabilitation is limited by

Illustration by Shonagh Rae

geographic availability and insurance preauthorization requirements that tend to send such patients to nursing facilities rather than rehab. Thus there is a paradox: scientific progress over the past two decades has not been matched by greater access to the latest standards of care. Without adequate rehabilitation, patients cannot benefit from advances in neuroscience.

In January 2022, Terry developed pneumonia. Before participating in a decision to place him on a ventilator, his sister, Tammy Baze, called Schiff and me for advice. Tammy said that his doctors advised against the procedure because they couldn't imagine that the life he led was worth living. But Terry had treatable pneumonia, and his family insisted he be treated like anyone else.

Later the family told us that doctors asked to remove the ventilator, saying that Terry seemed withdrawn—which they ascribed to the hopelessness of his brain injury. However, his family felt that his interactions with them hadn't changed, but rather that he was still grieving his mother Angilee, who had died two years earlier. Furthermore, he couldn't fully articulate his feelings with a tracheostomy in his airway. The family felt that because they couldn't clearly understand his wishes, it would be wrong to withdraw life support.

Based on what the family told us, Schiff and I said that Terry needed access to pulmonary rehabilitation to regain lung function. A new doctor agreed, but there were no facilities nearby that had availability and were capable of providing the kind of rehabilitation he needed. There seemed to be a place out of state, but Terry was too frail for a long ambulance ride. He was transferred to a skilled nursing facility that could provide pulmonary support until he was strong enough to make the trip. Despite the best efforts of his family and care team, he died of pulmonary complications.

It would be a shame if the public only remembered Terry's awakening and failed to acknowledge the policy implications of his death. Even though Tammy advocated for Terry and rallied support from his care team, without access to rehabilitation locally, his treatment was predicated on him becoming well enough to travel out of state. All of this speaks to the *intersectionality*—and compounding vulnerability—felt by people with severe disabilities. These challenges are amplified by poverty, limited access to health care in rural America, and historic crosscurrents about vulnerable people's right to die and right to care. Safeguarding the rights of people with disabilities is especially critical when their lives are marginalized by so many complicating factors.

I didn't get the chance to go to Terry's funeral, which was near his home in Big Flat, Arkansas. He was buried next to his mother and—reflecting his sense of humor and his favorite soft drink—he wore a Pepsi shirt and his casket was decorated with red, white, and blue flowers. Tammy wishes Terry were still alive but is consoled, knowing that he could give Angilee a "hug for the first time in 38 years."

Time and the brain

To eulogize Terry and recall his remarkable life, emergence, and death, I want to consider the scientific legacy he left behind and what it implies for the future of disability rights for people with brain injury.

Over the past several decades, neuroscience has grappled with temporal questions about how long recovery from brain injury takes and how its pace varies. This question is linked with mechanisms of recovery and therapeutics and thus is central to neuroscientists' framing of the underlying science. To that end, Terry's narrative helped to rewrite expectations about time and the brain, revealing both biological processes of recovery and the contingent construction of knowledge in this field. Previously in these pages, I wrote about how a lack of temporal knowledge about COVID-19 complicated clinical practice and moral judgement during the early phases of the pandemic; a similarly shifting conundrum—the trajectory of brain injury—has plagued neuroscience for most of my career.

> Terry's awakening had helped catalyze a promising era of neuroscience and prompted a moral consideration of what society's responsibilities should be toward people with severe brain injury.

In 2003 the possibility of a late recovery from the vegetative state was unthinkable, indeed heretical. Terry's awakening exposed the provisional nature of neuroscience's knowledge about the trajectory of severe brain injuries and recovery—a conversation that began in 1972 when the vegetative state was first described by British neurosurgeon Bryan Jennett and American neurologist Fred Plum in a now-classic *Lancet* article. Half a century later, the article is as prescient for what it says as it is for what it doesn't say when describing these brain states.

Jennett and Plum's essay remains a study in interdisciplinary collaboration between two cross-Atlantic enantiomers whose talents came together to describe and name the vegetative state. Luminaries in mid-century neurology—Jennett developed the Glasgow Coma Scale, and Plum first described the locked-in state and was the court-appointed neurologist in the 1975 right-to-die case of

Scientific progress over the past two decades has not been matched by greater access to the latest standards of care. Without adequate rehabilitation, patients cannot benefit from advances in neuroscience.

Karen Ann Quinlan—each man held a piece of the puzzle to characterize the paradoxical clinical condition in which a patient can open her eyes, yet exhibits no apparent evidence of awareness of self, others, or the environment.

Jennett and Plum sought to make sense of this "syndrome without a name" by explaining the physiology and clinical characteristics of the isolated functioning of the brain stem without higher cortical functions. Although the name they chose has been interpreted by some to mean that individuals in that state were "vegetables," the etymological and historical origins of the term "vegetative state" reveal the rich intellectual history of the way science understands consciousness.

The use of the term vegetative originated with Aristotle's *De Anima* (*On the Soul*), which distinguished plant-like functions from higher animalic ones. Borrowing from this typology, Jennett and Plum named the autonomic brain stem tasks that control breathing and heartbeat as vegetative in order to differentiate them from higher cortical ones that control thought and emotion. Their naming of the vegetative state is an elegant invocation of the history of science that contextualizes new discovery against an ancient text.

Equally noteworthy is how Jennett and Plum decided on the *temporal* description of the vegetative state. Reading the text 50 years after they wrote it, I can almost hear their debate. (I met Jennett late in his life and Plum was my teacher and later colleague at Weill Cornell Medical College.) Should the vegetative state be called persistent, permanent, or prolonged? After deciding on *persistent* vegetative state, they thought it critical to explain their reasoning and justify their choice, using the first person plural. "Certainly we are concerned to identify an irrecoverable state, although the criteria needed to establish that prediction reliably have still to be confirmed. Until then 'persistent' is safer than '*permanent*' or '*irreversible*'; but *prolonged* is not strong enough, and unless it is quantified, it is meaningless."

Jennett and Plum's logic is what makes the essay so very prescient. Absent long-term epidemiological data about the time course of these brain states, they couldn't be declarative in predicting when the vegetative state would become permanent. *They knew what they didn't know* and so were cautious. By 1994, things had seemed to evolve. A *New England Journal of Medicine* multi-society task force report on the vegetative state concluded that a persistent vegetative state became permanent if it lasted three months after anoxic injury (inadequate oxygen getting to the brain in the setting of cardiac arrest or profound drops in blood pressure) and 12 months after a traumatic brain injury. That framework informed clinical thinking for over two decades, bringing with it notions of futility once "permanence" had set in.

That designation was reversed in 2018 when new data revealed that upward of 20% of those thought to be permanently vegetative—patients like Terry Wallis—could evolve into higher brain states. With this in mind, patients who remained in the vegetative state three months after anoxic injury and a year after traumatic injury were redesignated as being in the *chronic* vegetative state. The term chronic vindicated the foresight of Jennett and Plum in 1972 when they opted for "persistent" instead of "permanent" to designate the condition.

If the renaming of the permanent vegetative state as chronic is scientific confirmation of Jennett and Plum's prudence, it is also part of Terry Wallis's legacy. The protracted nature of his recovery defied temporal expectations about the return of consciousness long before experts thought this possible. If nothing else, it reminds would-be classifiers of illness to have nosological humility when working at the edge of knowledge.

Covert consciousness

Questions of humility and uncertainty become even more salient in another part of Terry's legacy—his narrative revealed the clinical paradox that what one sees at the bedside might be deceptive. What doctors observe in clinical practice may not reflect the true capacities hidden within an injured brain, which has important implications for the care of those with brain injuries who may be covertly conscious.

When I interviewed Terry's mother, Angilee, a few years after he began speaking, she told me a story that suggested her son may have been aware as early as 1993. As I recounted in my book *Rights Come to Mind*, one morning she received a call from an aide at the nursing home where Terry lived, urging her to come to the facility to comfort her son. Angilee told me that the aide said Terry's elderly roommate with advanced dementia had died overnight from suffocation after becoming entangled in his bedsheets. The aide thought that Terry seemed "bothered" and urged Angilee, "I [Angilee] needed to be down there." The aide—who hadn't been schooled in the characteristics of the vegetative state—didn't know that doctors considered it technically impossible for a person in the vegetative state to respond to their environment or to be upset. As she told Angilee, both observation and her intuition told her that Terry needed his mother.

Angilee explained that when she arrived, Terry wouldn't go to sleep and he "was laying there with his eyes wide open." She stayed there all day until he finally was able to sleep. Haunted by his response, especially in light of the fact that he had since recovered consciousness, Angilee worried that he might have been aware of his roommate dying or suffering. When I interviewed her years later, after Terry had begun to talk, she said, "So I don't know what he saw, but I know he saw something. And … I knew then it had to be something that was really bad." In the years after Terry recovered speech, Angilee's feelings of unease that day had become even more terrifying to her. She had become convinced that his aberrant behavior after his roommate's death indicated that he had been aware at some level.

I sensed that she wished she had better understood that Terry could have been in a liminal state of consciousness that night, so she might have been better able to console him. In retrospect, I wish I had consoled her when she told me about this. I would have wanted her to know that she did the best she could given what she knew at the time. Her experience is a vivid reminder that as science expands knowledge, it sometimes creates and exposes moral quandaries in its wake.

Although it is impossible to know precisely what Terry experienced that night, in the ensuing years functional magnetic resonance neuroimaging has demonstrated that patients who appear unconscious may in fact have a nonbehavioral response on brain scans. While in a scanner, a patient thought to be in the vegetative state was asked to follow a volitional prompt such as imagining playing tennis and navigating around the patient's house. The prompts resulted in the activation of the motor cortex or parietal lobe—areas associated with these tasks—indicating that the patient was not unconscious but in a nonbehavioral, minimally conscious state. Schiff would later write of "cognitive motor dissociation" to describe the mismatch between brain activity and observable behaviors at the bedside.

Just as Terry's story foretold the discovery of covert consciousness before neuroimaging confirmed it, Jennett and Plum's literary precision also anticipated the possibility that what was seen at the bedside might tell only part of the story. In their initial description of the vegetative state, they observe, "It seems that there is wakefulness without awareness." Here again, Jennett and Plum were prescient when they wrote that the vegetative state seems to be one of wakeful unresponsiveness. Based on the presence of a functioning brain stem and the absence of higher cortical function, on clinical examination they believed that the vegetative state was devoid of consciousness. But absent functional neuroimaging, which would only begin to probe the workings of the hidden brain in the 1990s, they could not know for sure. So they hedged and wrote that the vegetative state seems to be one of wakefulness without awareness. While Jennett and Plum did not explicitly suggest the possibility of covert consciousness, the logical implication of their cautionary wording suggests that it might have been possible. Their deep commitment to prudential wording—their nosological humility—reminds physicians and researchers today of the need to respect the limits of our knowledge and leave open the possibility that technological advance will provide additional insights in the future.

From diagnosis to therapy

In his 1894 essay entitled "The Leaven of Science," renowned physician Sir William Osler said, "The determination of structure with a view to the discovery of function has been the foundation of progress." Over the past two decades, neuroscience's growing knowledge of the physiology of consciousness and mechanisms of recovery have underpinned the advance of nascent drug- and device-based therapies. The promise of these therapies, coupled with the rapid evolution of knowledge about consciousness, raises questions that society has barely begun to explore.

Central to today's therapeutic approaches is the work done to elucidate the mesocircuit by Schiff, whose images in 2004 revealed hints of the physiology behind Terry's brain recovery. The mesocircuit, demonstrated via studies of cerebral dysfunction in severe brain injury, highlights the key role that the central thalamus plays in linking the cortex, basal ganglia, and the brain stem in the support of consciousness. In this model, the thalamus functions much like an airline hub—analogous to the role Atlanta's Hartsfield-Jackson Airport plays for Delta Airlines. All connections lead through Atlanta, and if there is a storm there, a traveler's passage will be disrupted. The thalamus, similarly, acts as a way station for wide thalamo-cortical connections, which splay out into the cortex, with projections up from the brain stem arousal system. The former helps to integrate cortical function, and the latter provides arousal input necessary to sustain consciousness.

Even an isolated thalamic injury can be devastating. Knowledge of the mesocircuit has informed a number of promising therapeutic approaches using deep brain stimulation (DBS) to activate dormant connections in the mesocircuit and restore the brain's functional integration. In 2007, my colleagues and I reported on our experience using DBS in a 38-year-old man who had been in the minimally conscious state for six years following an assault. He initially had a low score for responsiveness, but he later evolved into the vegetative and then minimally conscious state with little more than an inconsistent ability to follow commands with eye movements. With stimulation, he recovered fluent language, improved limb control, and was able to eat by mouth for the first time since his injury. He was able to say six- or seven-word sentences, tell his mother he loved her, and voice a preference about clothing when she took him shopping at Old Navy. These improvements were directly associated with stimulation and constituted the first evidence that DBS could promote late recovery in severe traumatic brain injury.

Our research has continued with other people with moderate to severe brain injury, as reported in the *New York Times*. While much more needs to be done to turn this type of investigative work into established therapies, some trials have been encouraging and suggest the possibility of an emerging new intervention for a population currently looking for effective treatments.

A right to consciousness

When I started medical school, these vast questions around consciousness, treatment, time, rights, and responsibilities were not discussed or even considered. At the time, neuroscientists saw the vegetative state as one of futility, and so the dominant societal conversation was about the right to die.

The origin of the legal right to die in America was predicated upon the vegetative state that had been documented in the 1970s with Karen Ann Quinlan, and later with Nancy Cruzan and Terri Schiavo. Establishing this right for patients and families was vitally important, but the early association of the vegetative state with the establishment of the right to die has left an enduring presumption that severe brain injury is without hope. This historic legacy can lead to implicit bias and premature discussions about end-of-life care, even as neuroscientists have developed increasing hope for treating disorders of consciousness. Nearly a half-century after Quinlan's death, Terry Wallis's experience reflects these tragic, embedded assumptions.

Nonetheless, evolving knowledge has opened new clinical and normative horizons for brain injuries. With a better sense of the prevalence of covert consciousness, the temporal frame for brain recovery, and an expanding set of therapeutic possibilities, the widespread neglect of brain-injured patients has become a societal challenge demanding a comprehensive, humane approach. Learning to identify covert consciousness and predicting its course are projects for the future of the field. But now that these possibilities have been proven to exist, it is no longer acceptable to look away and presume the worst.

As the neuroscience about disorders of consciousness has evolved, it has become clear that society has a pressing ethical and legal obligation to view consciousness as a civil right: if it is present, it must be recognized; if insecure, it must be supported. As researchers develop the technological means to identify covert consciousness and then to restore and sustain people with disorders of consciousness, society must begin to see this as a responsibility concordant with disability law and the Americans with Disabilities Act (ADA).

The ADA compels society to hear the voices of people with disabilities, respect their lives, and integrate them into the nexus of their families and communities. The law, and its aspirations, gives sobering context to the narrative of Terry's life and death. And his death demonstrates that rights are necessary but not sufficient—they must be backed up by appropriate, accessible care, in every part of the country. Terry deserved better, and so do others who struggle under the burden of severe brain injury and are left isolated and away from the larger community.

Now that scientists are on the cusp of having the technological means to provide imaging, stimulation, and drugs that may allow for more human flourishing, the nation must begin to grapple more meaningfully with the care and regard of marginalized people with disorders of consciousness. Their plight is the civil right that we don't often think about, but we must.

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RECOMMENDED READING

J. J. Fins, *Rights Come to Mind: Brain Injury, Ethics, and the Struggle for Consciousness* (New York, NY: Cambridge University Press, 2015.)

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LUCILLE NALBACH TOURNAS AND WALTER G. JOHNSON

Ambiguities in Neurotech Regulation

Breakthrough neurotechnologies have the potential to help patients suffering from a range of diseases—if regulators can ensure these devices serve those who need them most.

Emerging technologies for health care, such as brain-computer interfaces (BCIs), offer hope to people suffering from myriad neurological diseases and disorders, including depression, Parkinson's disease, and Alzheimer's. These conditions have been uniquely difficult to treat because of complexities that include the blood-brain barrier (which helps protect the brain from harmful toxins and pathogens in the bloodstream), the intricacy of the nervous system, and the obscure nature of the human mind. Further, mental health conditions often lack easily measured biomarkers like heart rate or blood glucose levels that can be used to assess treatments for other diseases. Neurological maladies cost the United States an estimated $800 billion per year and place incalculable emotional and financial burdens on patients, caregivers, and loved ones; the possibility of new, effective treatments is more than welcome.

Despite their promise, the breakthrough neurotechnologies that are in development face a critical barrier: the growing gap between innovations and the current policy for regulating and managing medical devices. If this gap is not bridged, misguided use could cause harm and even spur public backlash against BCIs and similar technologies. Before more BCIs enter the market, policymakers must find ways to close this rift.

A recent legal battle illustrates the gray area in medical device regulation, which could foreshadow issues with neurotechnologies. In 2021, the US Court of Appeals for the District of Columbia Circuit overturned a ban the US Food and Drug Administration (FDA) had put on the use of wearable devices that deliver painful electric shocks intended to modify self-harming or aggressive behaviors. The FDA issued the ban in 2020, after six years of deliberation, against a specific use of electric shock devices by a school in Massachusetts. For years, disability rights activists had protested the Judge Rotenberg Educational Center, a residential school that reportedly used these devices frequently to deter behavior by students with autism and other conditions. After a court case used a 2012 treatment video from the facility showing a child crying and begging to not be shocked, only to be shocked into a catatonic state, the video went viral. In 2013, the United Nations Human Rights Council issued a report declaring the practice violated rights on freedom from torture.

In its 2020 ban, the FDA argued that using "electrical stimulation devices for self-injurious or aggressive behavior" presented an "unreasonable and substantial risk of illness or injury." Relying on its federal authority to keep dangerous devices from the market, it banned this application, citing physical and psychological risks "including worsening of underlying symptoms, depression, anxiety, post-traumatic stress disorder, pain, burns and tissue damage." The school insisted that the benefits to its patients far exceeded the risks and filed suit, arguing that the school's doctors should be allowed to select the treatment option they felt was best.

Subsequently in 2021, the DC Circuit Court, in a two-to-one ruling, held that the FDA's "use-specific" ban "interferes with a [medical] practitioner's authority by restricting the available range of devices through regulatory action." According to this argument, the school's use represented the "practice of medicine" and so was outside the FDA's authority.

Before this ruling, so-called off-label use—when health care providers prescribe pharmaceuticals or medical devices for something other than what the FDA's authorization covers—had not been particularly controversial. After the FDA has determined the basic safety of treatments, allowing physicians to manage off-label use under their authority to practice medicine can help bring treatments to patients. And for patients with complex conditions that cannot be tested directly in clinical trials, the practice has been beneficial. However, as the opinion written by Sri Srinivasan, the dissenting judge from the DC Circuit Court, suggests, an extreme interpretation of this approach—where the FDA cannot step in to prevent specific, harmful off-label uses—lacks crucial flexibility. Given that the FDA could ban the device outright for all uses, Srinivasan argued, it was "hard to perceive why Congress could want to deny the agency that middle-ground option."

Going forward, this lack of a middle ground could hinder the government's ability to properly regulate medical devices. Besides the option of banning devices, it leaves decisions about safety, risk, and clinical utility to individual health care practitioners or their organizations. The more complex and powerful the medical device, the more concerning this is.

In this regard, BCIs are of particular concern. These devices connect the user's brain to a computer—and some could require invasive surgery—to interpret, respond to, or change brain activity. Current devices target conditions such as paralysis, epilepsy, and depression. But rulings like the recent DC Circuit Court's leave the door open for a BCI device to gain FDA approval for a narrow indication, like a severe physical impairment, only to be applied more broadly, such as for behavioral modifications or even cognitive enhancement—without any formal assessment of risks and benefits.

Although BCI treatments for mental illness could potentially help patients, poorly regulated off-label uses may also unveil potential harms and controversies. Disability rights groups argue that electroshock interventions to "treat" behaviors perceived as socially problematic are abusive and violate human rights. Neurodiversity poses another conundrum: parents, physicians, and societies continue to debate whether autism spectrum and attention-deficit/hyperactivity disorders are diseases requiring treatment or neuroprocessing differences that demand respect. After all, nonheteronormative sexual orientations and gender identities were long considered mental illnesses. And in some cases, gay men were enrolled in studies that used electroshock treatments designed to cause pain in what was called "aversive conditioning."

BCIs could soon offer unprecedented access to the human mind, and policies surrounding them require immediate attention. First, Congress should enact legislation to give the FDA clear authority to regulate and even ban "single-use" applications of BCIs, given the unique challenges of off-label use. This would give the FDA tools to erect safeguards around potentially harmful or marginalizing uses of powerful devices without drastically expanding the agency's authority.

For particularly vulnerable people, including children and those with intellectual disabilities, policymakers could require some level of informed consent to BCI use, both directly and from caretakers. Colorado has already lowered the age to consent to psychotherapy without a parent or guardian, for example, reflecting a desire to empower young people to make their own decisions about treatments. Federal and state legislatures should also consider policies to regulate the use of BCI devices within schools and other contexts involving children.

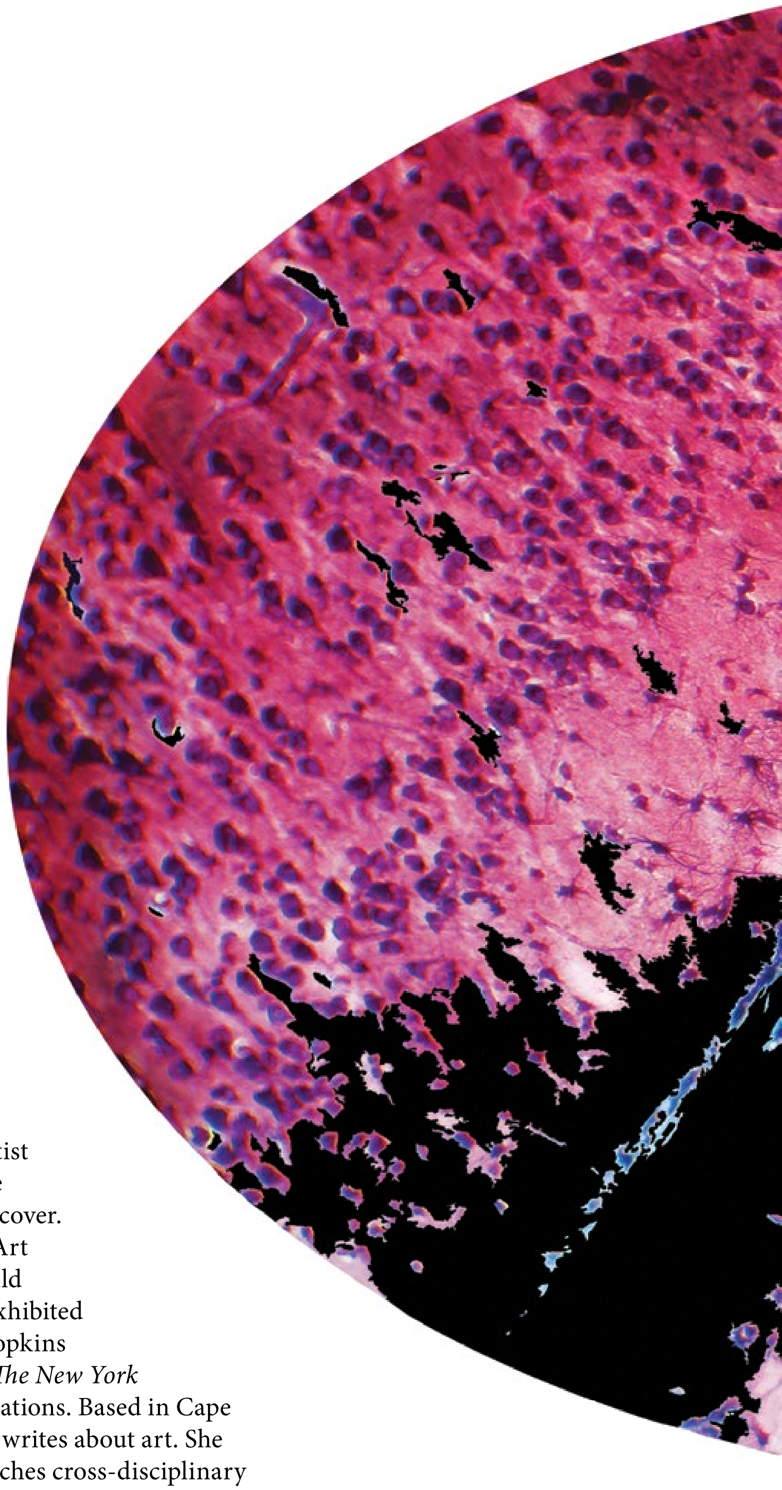
> **Allowing physicians to manage off-label use under their authority to practice medicine can help bring treatments to patients. And for patients with complex conditions that cannot be tested directly in clinical trials, the practice has been beneficial.**

Lastly, health care professional societies and state licensing boards should set standards of care and codes of conduct that guide medical practice and inform malpractice claims.

Ultimately, realizing the vast potential of BCIs to alleviate suffering from neurological disease and mental illness may depend on careful policies to ensure these devices best serve those who need them most. Safe and responsible development of BCIs should include honest discussions about the gaps in regulatory authority over specific uses and particularly vulnerable patients, especially when treatments are to curb behaviors perceived as socially unacceptable rather than to reduce individual suffering.

Lucille Nalbach Tournas *has a law degree and is a PhD candidate at Arizona State University's School of Life Sciences and board member at the Institute of Neuroethics (IoNx).* ***Walter G. Johnson*** *has a law degree and is currently a PhD candidate at the School of Regulation and Global Governance at the Australian National University.*

THE MOST COMPLEX PUZZLE



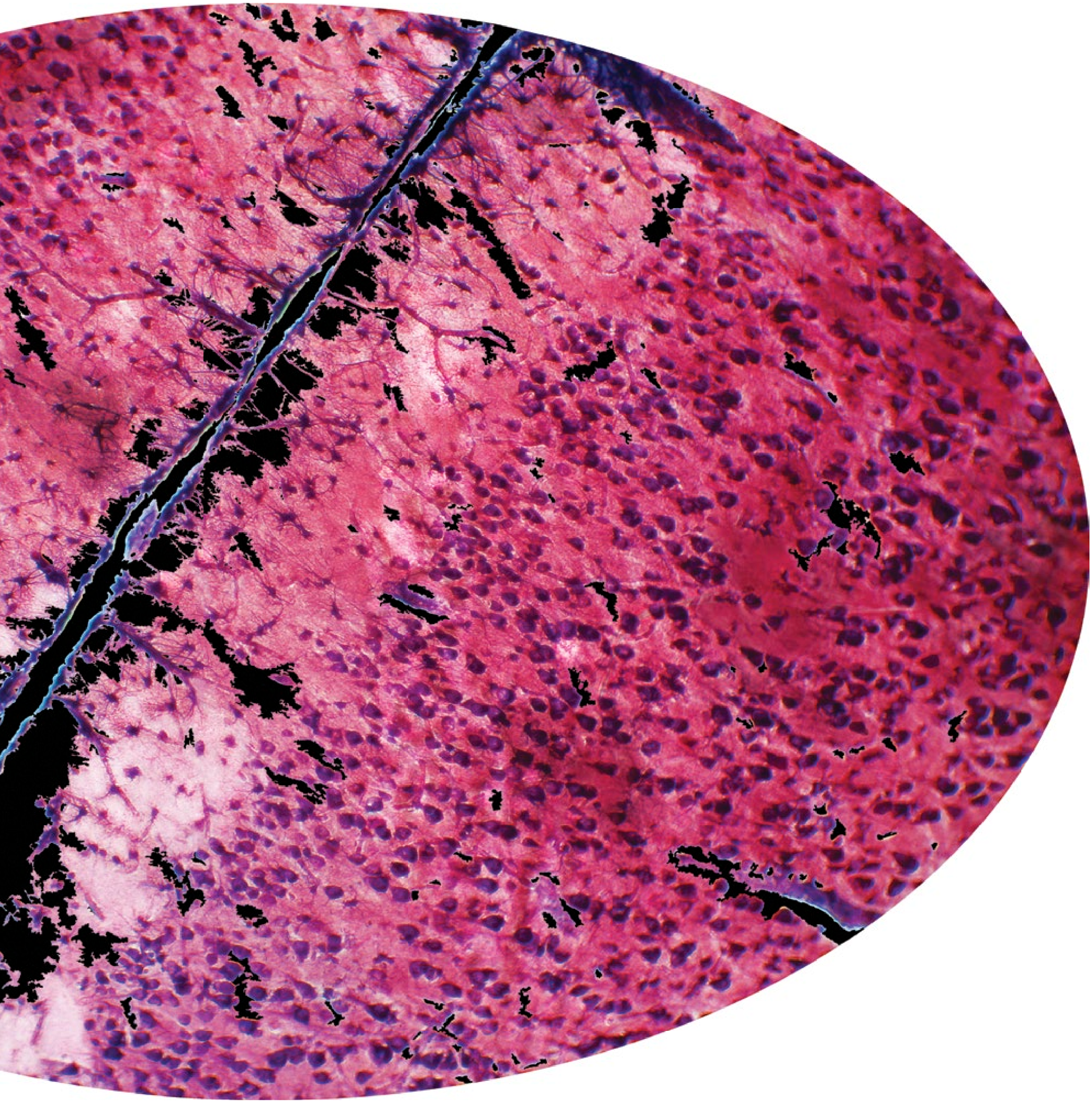
Julia Buntaine Hoel

Artist Julia Buntaine Hoel is fascinated by the intricate workings of the brain, describing it as "the most complex puzzle … our sciences have examined." Beginning with biological forms and data culled from neuroscience, her work moves into the world of aesthetics as she manipulates ideas and imagery through the use of scale, metaphor, material, and form. With sculptures, prints, and animation, she explores essential questions: How does the brain change from day to day? What would brain frequencies look like in three dimensions? What is the shape of a thought?

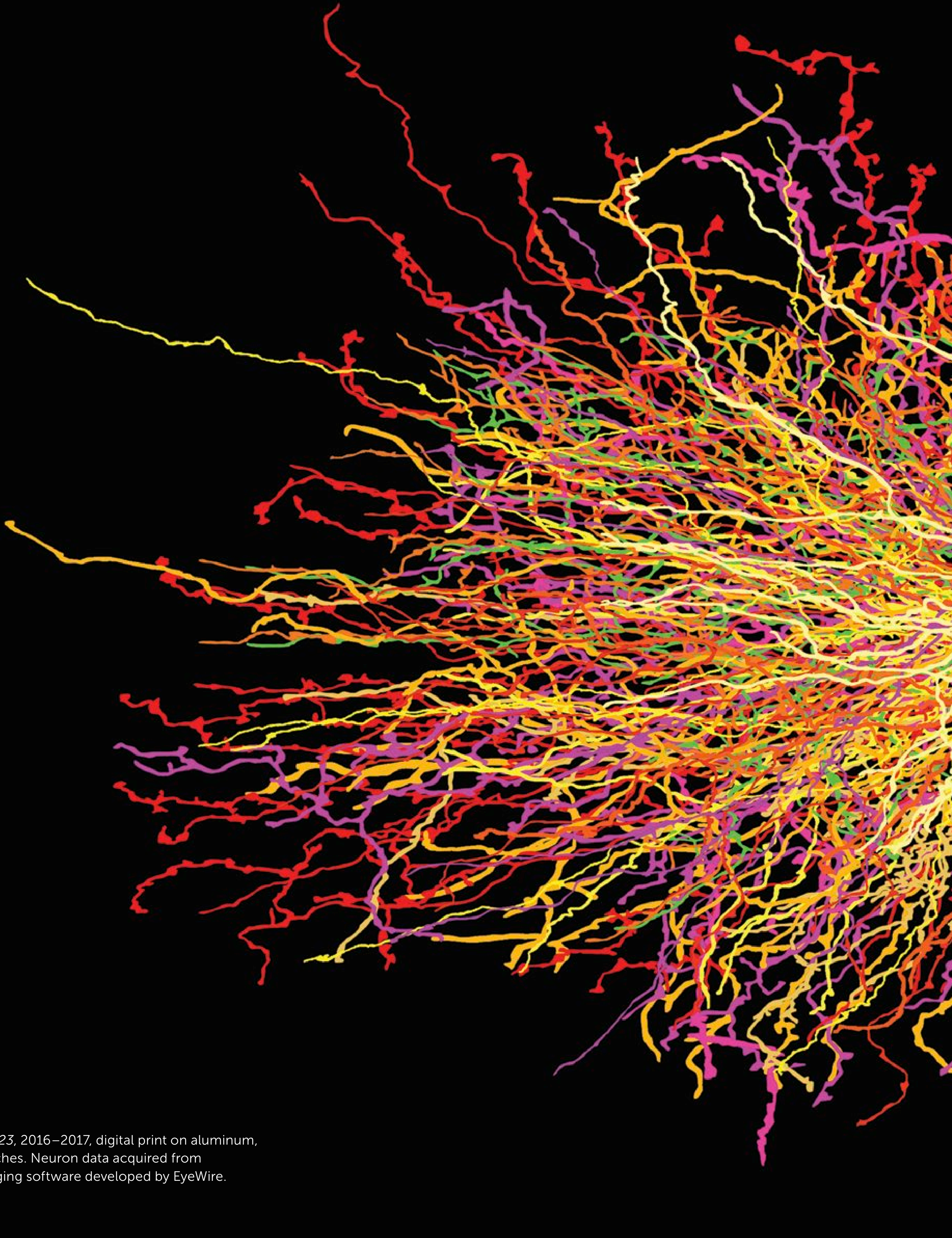
Scientific knowledge often emerges from analyzing raw empirical data and is presented in journal articles as the objective result of this analysis. In contrast, scientific ideas presented in the form of art inherently demand subjective judgment and interpretation. Hoel's goal as a science-based artist is to provide viewers with an alternative way to understand the wonders of human biology that scientists are continuing to discover.

Hoel is the founding director and editor-in-chief of the SciArt Initiative, a cross-disciplinary organization that uses art to build connections and envision a better future. Her work has been exhibited internationally and can be found in the collections of Johns Hopkins University and New York University. She has been profiled in *The New York Times*, *Forbes*, and *Smithsonian Magazine*, among other publications. Based in Cape Cod, Massachusetts, Hoel frequently consults on, curates, and writes about art. She holds positions at multiple academic institutions where she teaches cross-disciplinary practice, science-art, art history, and arts entrepreneurship and management.

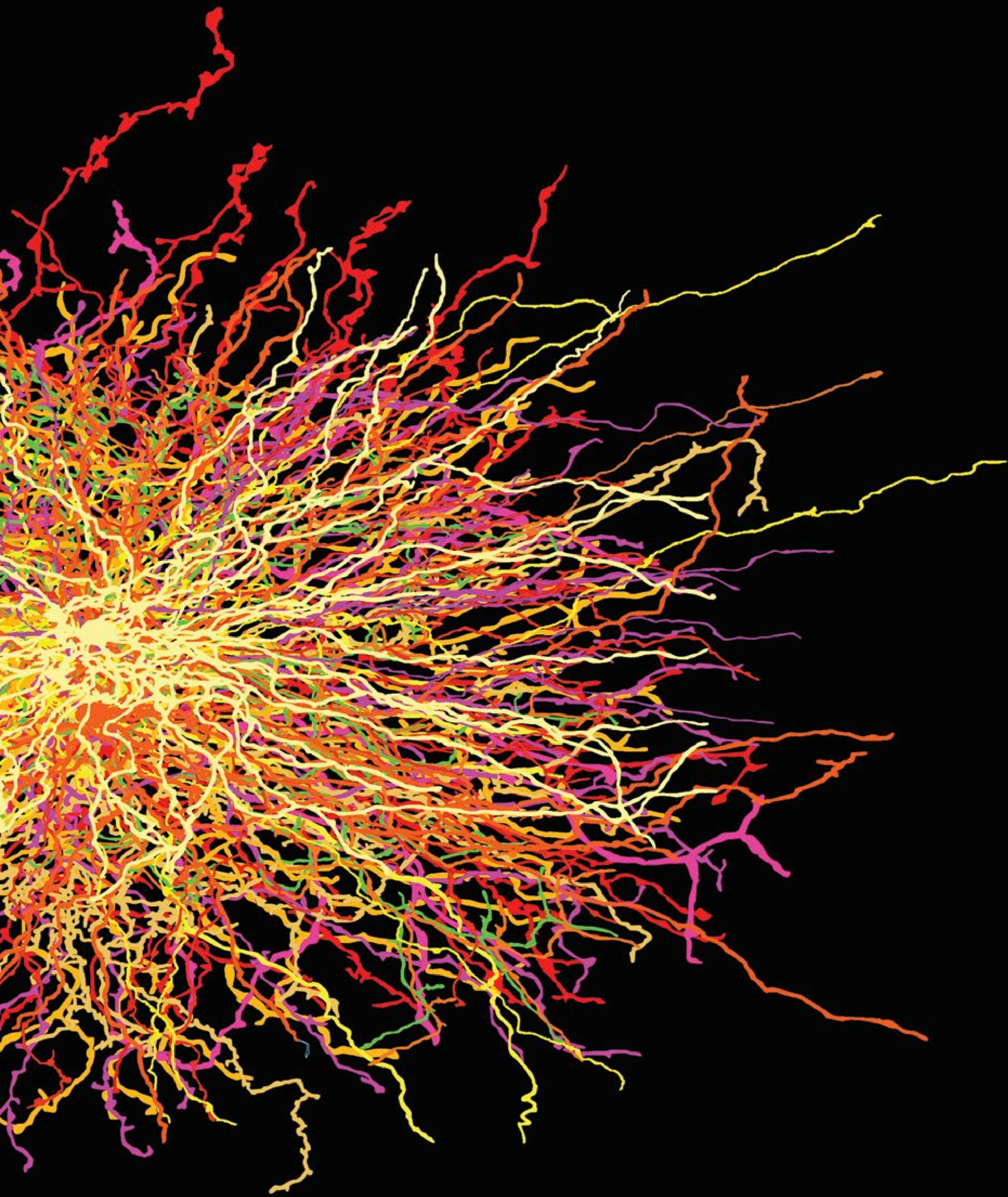
All images courtesy of the artist.

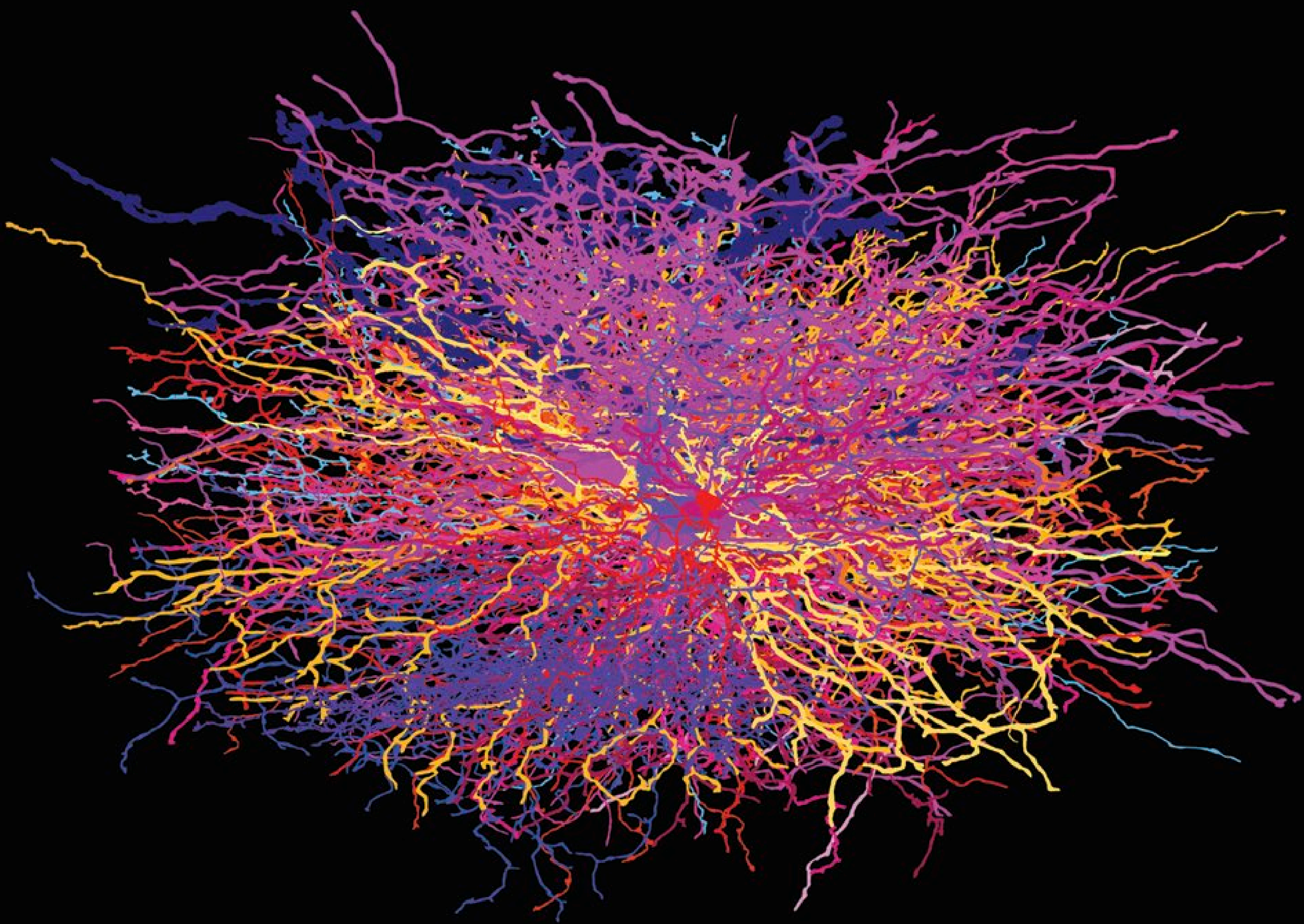


Territory 1, 2017, digital print on aluminum, 16 x 24 inches. Created from microscopy photographs taken by the artist of rhesus macaque brain slides.

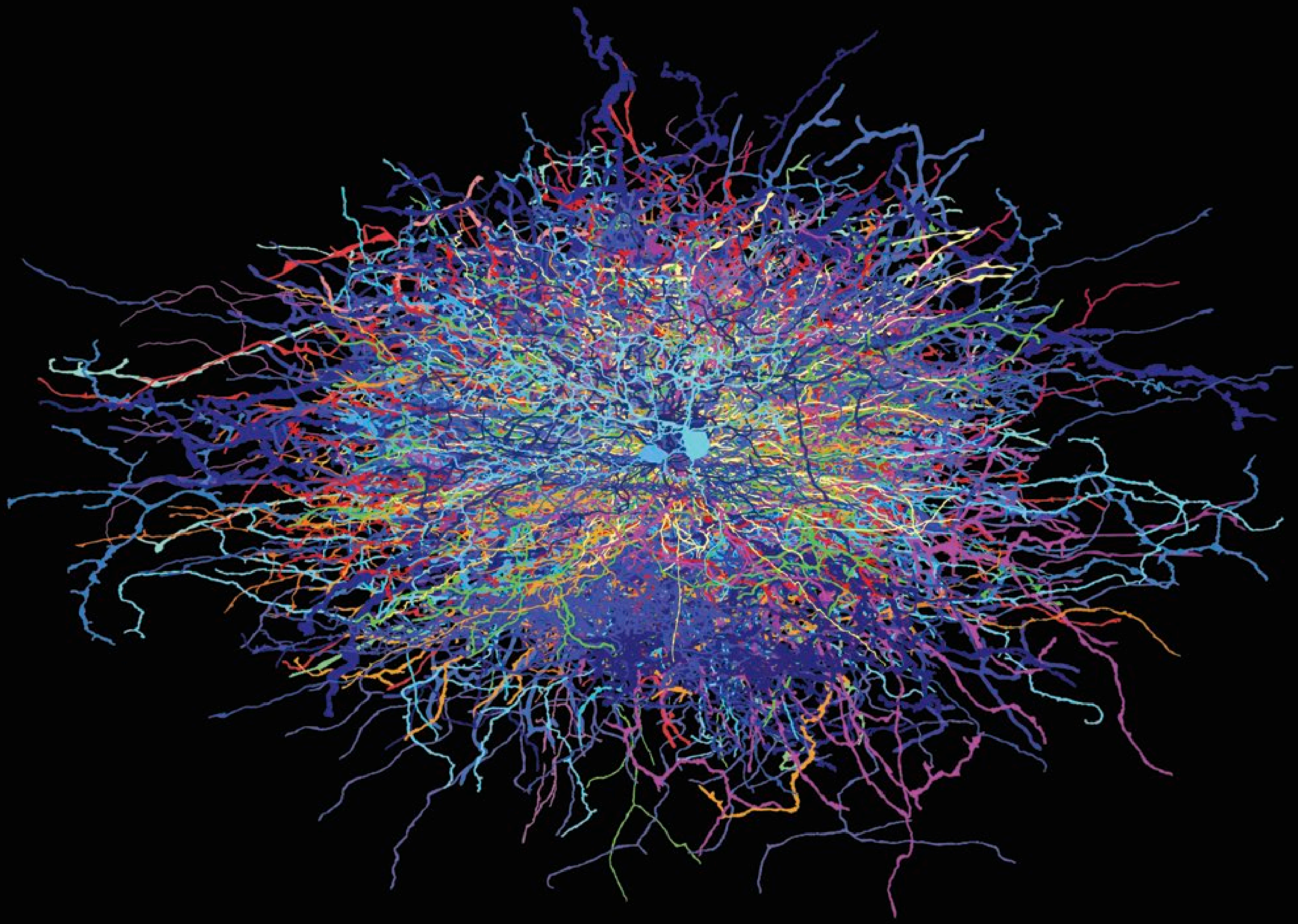


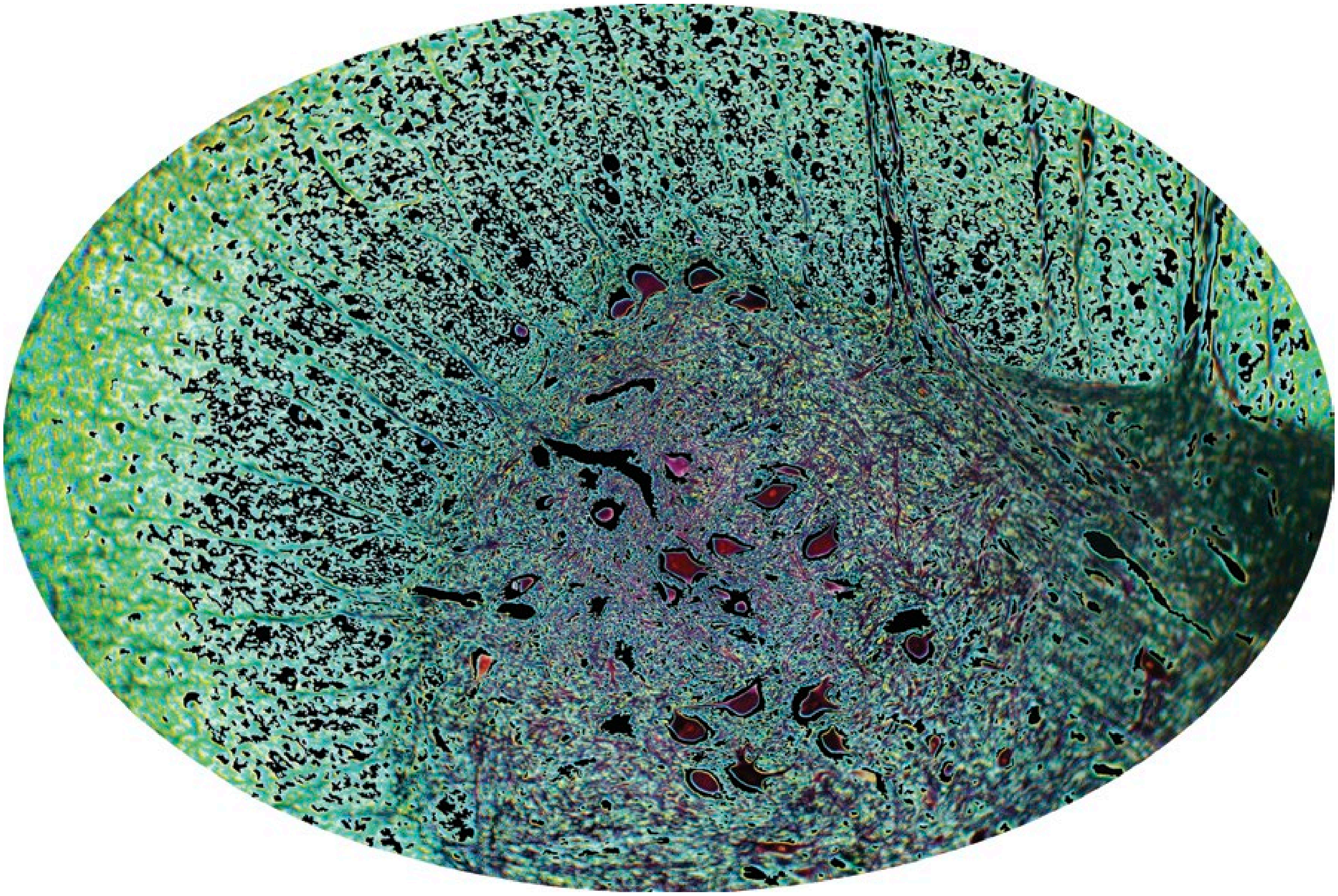
Thoughts 23, 2016–2017, digital print on aluminum, 20 x 16 inches. Neuron data acquired from neuroimaging software developed by EyeWire.



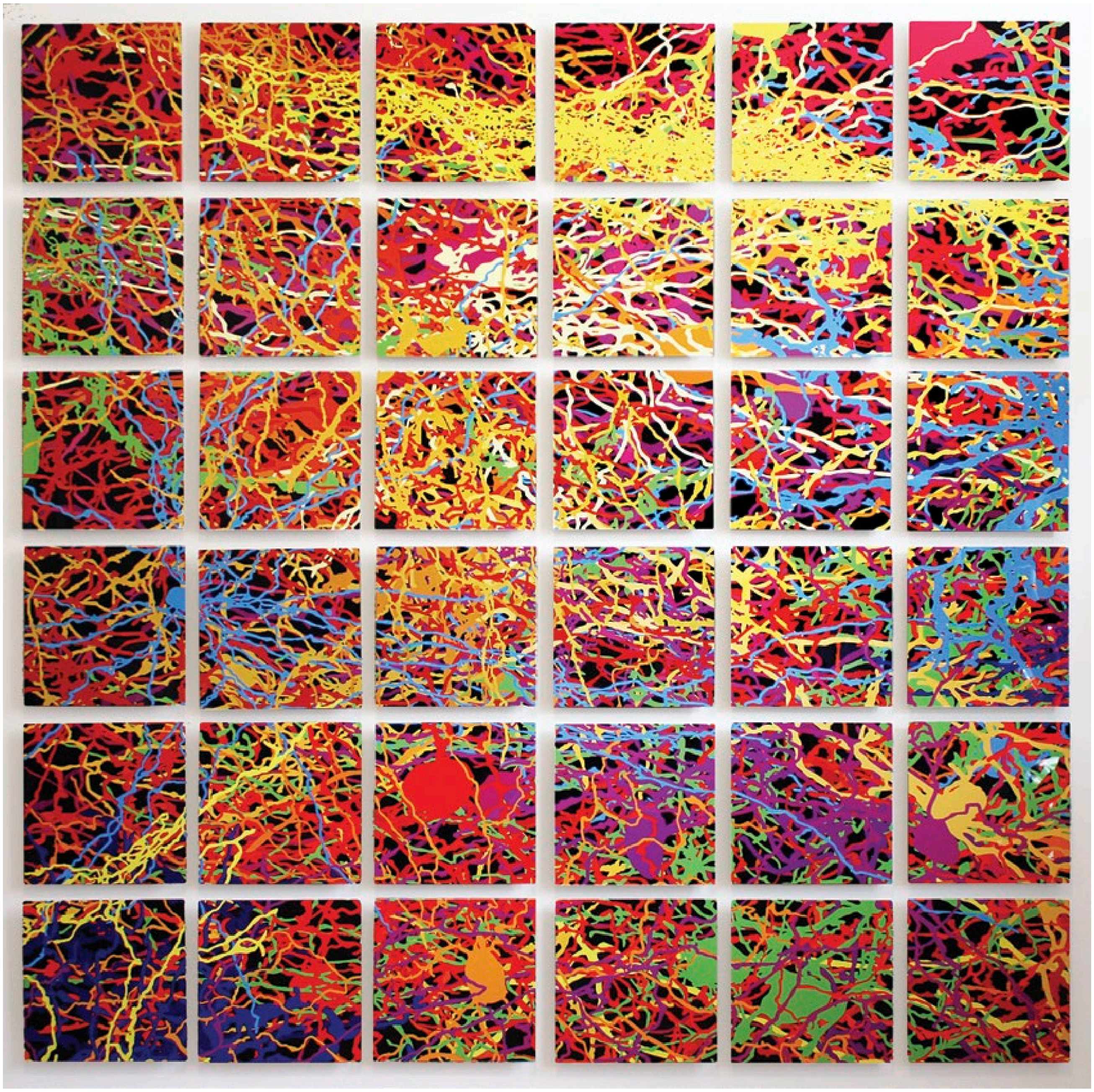


Left to right: *Thoughts 35* and *Thoughts 86,* 2016–2017, digital prints on aluminum, 20 x 16 inches. Neuron data acquired from neuroimaging software developed by EyeWire.





Territory 4, 2017, digital print on aluminum, 16 x 24 inches. Created from microscopy photographs taken by the artist of rhesus macaque brain slides.



For Pollock, 2017, digital collage printed on aluminum, 65 x 65 inches. Neuron data from EyeWire.

KARA MORGAN AND BARUCH FISCHHOFF

Mental Models for Scientists Communicating With the Public

To make research more valuable and enhance trust in science, scientists and institutions must build greater capacity for risk communication.

Over the past few decades, scientists have delivered stunning achievements—from improving crop yields to exploring Mars to identifying the COVID-19 virus. Despite such successes, many scientists feel unappreciated and even dismissed by policymakers and the public. A February 2022 study by Pew Research Center found that trust in scientists had declined significantly over the preceding year in the United States. Scientists fret about misinformation and disinformation and bemoan public innumeracy and scientific illiteracy. Some scientists try to set the record straight through social media, blogs, conferences, and op-eds, often with disappointing results. In frustration, scientists may become eager consumers of the "deficit model," which emphasizes the public's lack of knowledge and biased judgments, a narrative that allows scientists to relish being experts—smarter and more knowledgeable, yet underappreciated.

But blaming the public for such a disconnect absolves scientists of their responsibility to provide people with the information they need. Over the past few decades, social science has shifted away from the deficit model to embrace a "dialogue model," but this shift has not carried over into the natural sciences. We believe that scientists and their institutions (e.g., universities and government agencies), should embrace evidence-based models of communication with the public. One well-tested model is risk communication, which is the exchange of information for the purpose of making a good decision about a potential harm.

Risk communication can make scientific information useful for a specific decision by building on the general understanding that people acquire in formal science education in schools and informal science education in documentaries, popular nonfiction books, science museums, nature centers, and elsewhere. After identifying the scientific information that is relevant for decisionmakers, risk communication employs evidence-based methods for translating that science into a comprehensible, relatable message, conveying estimates of the expected costs, risks, and benefits of specific choices.

Unlike traditional science communication, risk communication requires dialogue, because there is no way of knowing what information people need without talking to them. Nor is there any way of knowing how well messages work without assessing how people interpret them. And by focusing on what scientists say, rather than how they say it, risk communication has substantially different goals than training in communication and media skills. The right content, not just the right delivery, is essential for building and maintaining public trust in science. Although many scientific organizations provide skills training about message delivery, few support evidence-based content development and testing. We believe that just as legal, financial, and data management capacity are essential for science-based organizations, so is risk communication.

Why so many scientists struggle with communication

Many scientists want and need to get better at communicating their research with the public, but the nature of science, beginning with training, stacks the deck against them. We see three structural barriers that hamper effective communication.

The first barrier is that scientists are trained to communicate with other scientists, not with non-scientists or even with scientists outside their own specialty. Scientists begin their papers by bounding a problem, and then write for peers who understand and accept these bounds. Scientists identify limits to their research in ways that make sense to peers who know the strength of its theories and methods. As a result, scientists may leave out information of relevance to other people, which creates opportunities for misunderstanding and distrust. For example, when public health and medical scientists discuss the benefits of vaccines and medicines, they understand there are also risks, but that these are outweighed by the benefits to the population. However, members of the public, who must make decisions for themselves based on their own personal circumstances, likely do not have the same understanding and may feel betrayed when they learn about potential risks.

The second barrier to effective risk communication is that teaching, a vital part of many scientists' responsibilities, is not necessarily good preparation for communicating what the public needs to know about scientific findings. Classrooms provide clear, prompt feedback through blank faces in lectures and wrong answers on tests. There is rarely such direct feedback from the general public, leaving scientists with no way of knowing if they are communicating effectively, and no idea about how to do better. Moreover, in the classroom, teachers decide what topics matter. In risk communication, it is the audience whose decisionmaking needs determine the topics.

The third structural barrier is that science tends to be disciplinary, whereas risk communication is necessarily multidisciplinary, integrating knowledge from the multiple sciences needed to inform decisions. When individual scientists know only some of the science that decisionmakers need, they can wind up on shaky ground if they offer opinions outside their specialty. However, scientists who acknowledge their ignorance may leave a vacuum that can be filled by confusion, distrust, or (at worst) people peddling misinformation or disinformation. Risk communication brings scientists together with the knowledge necessary to provide a comprehensive perspective.

> Unlike traditional science communication, risk communication requires dialogue, because there is no way of knowing what information people need without talking to them.

A robust psychological finding is that people overestimate how well they understand one another. That gap grows with the difference in people's backgrounds, experiences, and decisions. Scientists, though vaunted as experts, are not immune to this bias. The mental models approach to risk communication provides a scientifically grounded, practical way to overcome these three structural barriers.

The mental models approach

The mental models approach addresses the gap between scientists' mental models of a domain and the mental models of the public that scientists aim to inform. To communicate effectively, scientists must understand the mental models that people use to understand the world around them. Unless these intuitive perspectives align with scientists' claims, the public cannot fully absorb the information that scientists offer and may distrust it.

The mental models approach to risk communication integrates psychological studies, which describe how people think about how things work, with risk analysis, which develops information on the severity and likelihood of harm that is relevant for a specific decision. Thus, the mental models approach helps identify the

The right content, not just the right delivery, is essential for building and maintaining public trust in science. Although many scientific organizations provide skills training about message delivery, few support evidence-based content development and testing.

most meaningful ways to communicate the science that people need. It structures the two-way dialogue with the public that scientists need to identify the information needs, assemble the relevant science, and convey it clearly. Perhaps most importantly, it respects the public's right to understand the science relevant to their decisions, and does so in terms that align with their current thinking. In this manner, it seeks to build trust by helping science serve the public.

Since the mental models approach was developed in Carnegie Mellon University's Department of Engineering and Public Policy about 30 years ago, it has been applied to dozens of wildly varied problems, including soil management, ionizing radiation, illegal drug management, vaccines, pandemic disease, breast cancer, breast implants, industrial accidents, Plan B contraceptives, trauma triage, riverine flooding, storm surges, and others. For example, the Dartmouth Toxic Metals Superfund Research Program used mental models to understand why the public showed little concern regarding the risks of naturally occurring arsenic. In British Columbia, authorities used mental models to facilitate collaborative planning between foresters and residents over prescribed burns. A study in Kenya used the approach to understand why farmers rejected a chemical disinfection dip for poultry carcasses that could reduce foodborne illnesses.

The mental models approach to developing effective risk communication follows five steps. The first step identifies the science most relevant to the decisionmakers' needs. That involves an iterative process: consulting with members of the intended audience about their goals and options, then with scientists about their relevant knowledge. That science is then organized, typically in the form of an influence diagram. These graphic models show the factors affecting decision outcomes, represented as nodes linked by arrows indicating when knowing one factor (e.g., age) should influence predictions of another (e.g., severe COVID-19). The influence diagram, which pools and synthesizes relevant science, is the "expert mental model."

The second step involves open-ended interviews with members of the intended audience, structured around the expert mental model. These interviews seek to capture what people know and how they think about issues in the expert mental model in their own natural terms. Knowing how people frame and talk about the issue is essential to communicating in meaningful terms. These conversations almost always reveal surprises regarding what people believe, what matters to them, and how they express themselves—all critical inputs to effective risk communication. For example, our study of domestic radon found that people assumed that radon in their homes was a long-lasting contaminant, like the toxic materials in Superfund sites, rather than a problem that was readily remediated. The Kenyan food safety study found that the experts were not aware that consumers did not want to buy disinfected carcasses because they feared exposure to the disinfection chemicals.

The fourth step in the mental models approach compares the mental models revealed in the interviews with the expert mental model. Gaps in the expert model are addressed by adding factors mentioned in the interviews and, if needed, adding scientists with the missing expertise to join the communication team. Gaps in audience members' thinking are addressed by developing materials that connect scientific concepts to their existing mental models.

The final step is developing communications that strengthen people's mental models by reinforcing what they already know, filling gaps in their knowledge, and addressing misperceptions. Before being deployed, these communications must be tested. The simplest test of a draft communication is the think-aloud protocol, asking people from the target audience to say whatever comes into their minds as they read. That test may reveal content that readers found unclear, interpreted differently than the experts intended, sought but didn't find, or that struck the wrong tone. This step is iterative: each round of testing improves communications.

Though any scientist could use the mental models approach to improve their communication related to decisions they aim to inform, applying the method well is outside most scientists' skill set. For this reason, scientists need deliberate risk communication capacity building and support from their institutions.

Building risk communication capacity

Just as scientific agencies and organizations have legal, financial, and IT departments, they need departments supporting risk communications. In addition to conventional communication training, such departments should work with scientists to create meaningful content and to test risk communications, drawing on the decades of peer-reviewed social science research on framing messages and conveying potentially difficulty constructs (e.g., uncertainty, exponential processes).

Some institutions have developed such high-level teams, suggesting models and revealing pitfalls. The US Food and Drug Administration (FDA) was an early adopter of risk communication, creating initial infrastructure in 2003, followed by a strategic plan for risk communication, a Risk Communication Advisory Committee with a rotating membership of researchers and practitioners, and a practical guide for risk communication. However, the social science support staff was disbanded and the advisory committee has not met since 2018, leaving no coordinating mechanism for the social scientists scattered throughout the agency. FDA's communications during the COVID-19 pandemic might have been more effective had it strengthened, rather than depleted, its risk communications capabilities. Behavioral research units have also been established, to one degree or another, in agencies such as the Consumer Financial Protection Bureau, General Services Administration, Security and Exchange Commission, and the Federal Reserve.

Such units, where they exist, would be logical homes for adding risk communication capacity, as well as bases for coordinating, sharing, and leveraging expertise across agencies. Other agencies still need to shift toward adding risk communication expertise to their resources. The National Science and Technology Council in the White House Office of Science and Technology Policy recently re-chartered its Subcommittee on Social and Behavioral Sciences (SBS), an interagency working group. Given the importance of public trust in government risk management, risk communication should be a focus of SBS's mission, supporting agencies in creating and sustaining risk communication capacity. Ideally, agencies would establish their own chief risk communication officers to guide two-way dialogue between agencies and their stakeholders.

Scientifically sound risk communication as part of agency functions would benefit both the public and the agencies. Underlying the process of risk communication is a recognition that even world-class science will have limited value unless it is translated into trusted, useful terms. Additionally, risk communication facilitates proactive engagement with the public—understanding, respecting, and addressing its concerns. And because risk communication is a disciplined, transparent, and evidence-based process, it also provides a benefit by enabling scientists to overcome their sometimes mistaken intuitions about the public. A final benefit of embedding risk communication within agencies is enhancing trust. Risk communication seeks to inform decisions, not manipulate them. Thus, it protects agencies and the scientists who work within them from the charge that they are spinning the facts to achieve policy goals, or that they are acting as advocates rather than resources. Instead, it helps scientists and agencies be seen as providers of clear, unbiased, and relevant information, making them more trustworthy.

Risk communication empowers scientists by training them to engage the public in respectful dialogue, with the goal of enabling good decisionmaking. The mental models approach aligns naturally with the scientific process: investigate the issue, assess the science candidly, update messages as the evidence changes, evaluate their success, and repeat as necessary.

There clearly are disconnects between scientists and the public. However, their source is often not the public's failure to understand science, as the deficit model supposes. Rather, it is science that has failed to understand the public, in terms of what and how to communicate. Risk communication research and practice can help to fill those gaps if the scientific enterprise creates the capacity and resources for using them. Science depends on the public's goodwill. The public depends on scientists' knowledge. Risk communication can structure the dialogue needed for science and the public to work together more effectively.

Underlying the process of risk communication is a recognition that even world-class science will have limited value unless it is translated into trusted, useful terms.

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HOW TO CHANGE THE CULTURE AROUND SEXUAL HARASSMENT IN ACADEMIA

Illustration by Shonagh Rae

KAREN STUBAUS

Stop Hugging Your Postdocs—and Learn to Start Conversations That Prevent Harassment

The long fight against sexual harassment is shifting from compliance to culture.

After a whirlwind of committee meetings on preventing sexual harassment, I thought I had some good news for the faculty at Rutgers University, where I am vice president for academic affairs. Promotion and tenure committees could now officially consider conduct—and therefore misconduct—alongside metrics on teaching, research, and service. This radical change was possible thanks to previously overlooked language included in a "Statement on Professional Ethics" embedded within the university's policy on academic freedom. The statement specified that professors should "avoid any exploitation, harassment, or discriminatory treatment of students," and that "professors do not discriminate against or harass colleagues." This was readily incorporated into formal evaluation guidelines, and thus, faculty who had harassed or bullied students, postdoctoral researchers, or colleagues could, starting with the 2019–20 academic year, face repercussions in tenure and promotion decisions.

To my great surprise, this news was not greeted with universal enthusiasm. Many faculty commented that they did not feel comfortable assessing their colleagues' behavior. One chair, not in the habit of shying away from difficult issues, told me, "I know how to evaluate a research profile in my field. I have no idea how to evaluate a colleague's conduct, or how bad the conduct has to be in order to deny someone promotion or tenure."

According to behavioral surveys, academia is second only to the military in its prevalence of sexual harassment against women. Alongside violent sexual assault and offers of professional opportunities in exchange for sexual favors, the term "sexual harassment" covers sexually suggestive comments and unwanted sexual attention as well as language and behaviors that denigrate women as a group. According to a 2018 report from the National Academies of Sciences, Engineering, and Medicine (NASEM) entitled *Sexual Harassment of Women*, all these behaviors—even "mild" comments—undermine targets' health, work satisfaction, advancement, and productivity. And too many women are harassed out of science altogether, which, in addition to hurting the women themselves, also deprives science of the benefits of their talent and training.

A narrative legal history by Fred Strebeigh describes how the term "sexual harassment" itself can be traced to academia. In the 1970s, the head of a nuclear physics lab at Cornell University repeatedly, and sometimes publicly, groped, leered at, and propositioned an employee, Carmita Wood. After both university and government officials trivialized her experience, she connected with Lin Farley, a university lecturer collecting stories of women in the workplace. Farley and two colleagues recognized Wood's experience as pervasive and described it in a large mailing calling for help to build a legal case for sexual harassment as a violation of civil rights. This effort, and "sexual harassment" as a phrase, was reported by *The New York Times* and subsequently entered the public lexicon.

A half-century later, every academic campus in the United States that accepts federal funds must have an official process to handle sexual harassment complaints in order to comply with Title IX, the federal civil rights law that prohibits discrimination based on sex in education. And yet, according to the NASEM report, "Studies on sexual harassment from the 1980s through today continue to show that sexual harassment of women is widespread in workplaces and that the rates of sexual harassment have not significantly decreased."

This may seem like reason to despair, but academia changes slowly, and the conversation has recently begun to shift. Now instead of simply asking, "What sanctions do you impose?" many of us working on this problem are asking, "How do you create a climate where faculty understand what behaviors are unacceptable?" as well as "How can an academic community *effectively* hold its members accountable for sexual harassment?"

Cultural shift

Back in the 1980s, early in my career handling sexual harassment issues, I was alerted to a faculty member who was in the habit of congratulating his postdocs with hugs. After a postdoc spoke up, we soon had accounts of unwanted embraces from multiple current and former postdocs. It fell to me to tell the faculty member to stop hugging his postdocs. I remember he seemed genuinely surprised that his "fatherly" gesture of support was being negatively received. It struck me even then that academia lacked effective ways to set and transmit expectations of inappropriate behavior.

By the time the NASEM report came out in 2018, I'd been dealing professionally with sexual harassment in the academy for over 25 years. Most of the cases I became familiar with involved sexual harassment of graduate students and postdocs by tenured faculty. Enough time has passed that those graduate students and postdocs may now themselves be tenured faculty, yet harassment persists. It is clear that this problem is not a generational one that time will resolve.

The NASEM report had a particular resonance for those of us working in higher education. It was clear the report's authors knew their way around the inner workings of academia, recognizing both the "star culture" that sometimes accommodates egregious behavior as well as the need to move away from relying solely on academic output in faculty evaluations. The NASEM report also acknowledged that transparency around (admittedly sensitive) personnel matters had to improve in order to convince the community that harassers would be held accountable.

To me, the NASEM report represented a sea change in how to think about sexual harassment. And it has sparked a truly national conversation about the need to move beyond mere compliance to a focus on prevention and culture change. Within a year of releasing the report, NASEM invited academic institutions and professional associations to join its Action Collaborative on Preventing Sexual Harassment in Higher Education and so commit to exploring and supporting ways to put a stop to sexual harassment. Members include national labs and many research-intensive public and private universities, such as Caltech, Harvard University, Michigan State University, and the University of Michigan, along with Rutgers University, where I am the university's current representative to the collaborative.

For two years, I cochaired a subgroup of the collaborative that considered how to respond to sexual harassment and misconduct. We knew that the sanctioning issue was only one part of the problem. Sanctions result only after a formal complaint, a thorough process of investigation, and a finding of a policy violation. But the vast majority of targets of sexual harassment do *not* file a formal complaint. Inappropriate behaviors may thus continue, bringing harm to other targets and creating a toxic environment in a department or lab. For that reason, it was important to explore effective early interventions—responses and actions designed to correct harmful behaviors before they escalate and result in a formal finding of a policy violation.

We knew we were taking on a big task. Many academics consider themselves to be independent entrepreneurs or contractors, with their primary loyalties to their disciplines or labs rather than their departments or institutions. Often this translates into a reluctance to intervene in a colleague's (or friend's) business. It's essential to remind faculty about what constitutes inappropriate behavior and to give them the tools to talk to their colleagues when they witness it.

In the meantime, I had been pursuing change at Rutgers. After the NASEM report came out, Rutgers' senior vice president for academic affairs and I, encouraged by several members of the faculty, wanted to explore how we could implement the report's recommendations at our institution. Concerned that the usual route of creating a large task force would lead to years of talking about the problem with little action, we decided instead to create a small, nimble committee of no more than a dozen people. But word got out and—to our surprise—people clamored for spots: faculty who'd studied harassment, Title IX staff who dealt with student sexual assault, graduate directors who faced problems in their own programs, and diversity leaders who were working to create more inclusive cultures. We had tapped into a wellspring of people eager to make positive change, and quickly brought in nearly 50 people, organized into six smaller subcommittees.

The Rutgers Committee to Prevent Sexual Harassment moved at the speed of light, at least for academia, and produced a report with recommendations in about six months. I was happily surprised at both the efficiency of the effort and the magnitude of what the committee recommended—for instance, Now instead of simply asking, "What sanctions do you impose?" many of us working on this problem are asking, "How do you create a climate where faculty understand what behaviors are unacceptable?"

changing policy so that treatment of colleagues could be included in faculty promotion and tenure decisions. But I soon learned, or rather was reminded, that it's much easier to change policy than culture.

Learning to talk

Along with their general discomfort with discussing their colleagues' behavior, some faculty have expressed more specific concerns. What if they criticized a colleague for misbehavior and he filed a grievance against them? Couldn't including criteria of "professionalism" or "civility" turn personnel decisions into a sort of popularity contest, or penalize women or underrepresented groups if colleagues feel they don't "fit in" with the dominant culture? We are still working through these and other concerns, but I firmly believe that the decision to include conduct in promotion and tenure evaluations was absolutely the right one.

Socializing the changes has been challenging, especially given the COVID-19 pandemic. Usually the most productive conversations that occur when I work to introduce new programs are not part of the public discussion, but instead happen when faculty buttonhole me after the meeting to share their concerns and experiences. These essential scaffolding conversations are hard to bring into virtual spaces.

But in the quiet conversations I've been able to have, one message has come through: while faculty want to create a welcoming and productive climate in their departments and labs, most simply don't know how to do it. Universities must give them the tools, and the scripts, to enable them to make it happen. And a welcoming culture should boost academic excellence as well; promising new faculty members, postdocs, and graduate students will think twice about joining a department or lab with a reputation for having a toxic environment.

This will be a much broader effort than changing promotion and tenure criteria. One pilot underway is to ask departments to develop a "Statement of Shared Values" customized to their own circumstances and culture. Department-specific statements would allow for addressing particular situations that occur in some academic fields, such as international field work, community internships, and clinical placements. But to be most effective, these documents must be developed through an inclusive process that fosters community among and between faculty, students, and staff, while at the same time producing a tool for intervention when inappropriate behavior occurs.

Along similar lines, we're making plans at Rutgers to translate strategies for "bystander intervention" developed by student affairs professionals into tools that can be used by faculty who observe colleagues acting inappropriately. Promising models already exist at several other institutions. Florida International University has a five-step process to teach individuals to recognize inappropriate conduct and assess how to intervene. Perhaps best known are the "coffee conversations" going on at Duke Health Systems in North Carolina, patterned after efforts at Vanderbilt University in Tennessee. This method focuses on stopping inappropriate behavior before it reaches the level of a serious event and relies on trained volunteer "peer messengers" who hold brief, informal conversations with individuals whose behavior was reported as unprofessional. From 2015 to 2018, 60 faculty trained to deliver messages had over 300 initial conversations at Duke University Health Systems; repeat behaviors were reported for only 1.5% of faculty. NASEM reports that of 85 individuals who have had coffee conversations at Duke, follow-on discussions—"espresso conversations"—were necessary for only three.

But all these programs are relatively new, and there is much work to be done to assess how well they work and under what circumstances. More research is needed on whether formal sanctions are effective in preventing repeat harassment, and if they are, which sanctions are most effective; on which early interventions seem to be most effective in correcting so-called low-level harassment and why; and on which approaches are most effective in creating inclusive, welcoming academic climates. Additionally, more research is needed to explore links between a positive culture and academic excellence.

Even as the evidence base accumulates, expanding bystander and other interventions may take an extra push. Perhaps we can learn some lessons from the way conversations about diversity, equity, and inclusion have infused many of our institutions. In my experience, those conversations have become increasingly frank and productive, but academia still has a long way to go before faculty are able to talk about sexual harassment as effectively. We have to flip the script and talk affirmatively about the climates we want, not focus solely on the behaviors we object to.

Sexual harassment is still pervasive in academia, but we know what work has to be done, and there are more and more of us eager to do it. For the first time in my long history working on these issues, I am cautiously optimistic.

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VASSIKI CHAUHAN

Make It Everyone's Problem

Sexual harassment in scientific and technical fields isolates survivors, and legal compliance practices alienate some even further. Collective bargaining could engage the whole academic community in creating a better workplace.

It doesn't take a visionary to imagine a world where scientists are not subjected to sexual harassment, but making that vision a reality remains a challenge. There is at last recognition that sexual harassment is prevalent in science, technology, engineering, math, and medicine, but acknowledgement has not removed the circumstances that allow it to persist. What is needed now are roles for survivors, as active agents, to change how harassment is redressed.

That is not to say that past efforts by survivors and activists have been in vain. They have propelled the discourse in important ways. For example, in 2013, anthropologist Kate Clancy and colleagues raised awareness with a survey of field scientists that found 60% had faced inappropriate sexual comments and 20% experienced sexual assault or touching. Subsequent surveys across academic science in Australia, the United Kingdom, and the United States found that roughly one third to half of respondents have experienced intrusive, demeaning, or suggestive comments, repeated propositions, leering, or worse. A sizable fraction of that included unwanted touching and assault. In 2017, two prominent polar scientists described their own experiences in an editorial in *Science* titled "Harassment in Science is Real." Five years later, such proclamations remain valuable and necessary, but now seem to state the obvious. Harms to health, happiness, productivity, and scientific careers are well documented.

Despite the attention the subject has gotten, the costs of reporting remain devastating and could prove to be career-ending for those few who feel capable of filing complaints. Scholars and even institutional compliance officers conclude that harassment is drastically underreported: survivors fear reprisal, blame, humiliation, and disbelief and do not trust the process. When I was a junior researcher at Dartmouth College, I feared that speaking up about my experience of sexual harassment would harm my department, university, and science in general; so did other survivors I have spoken with. At the same time, we felt it was up to us, alone and unsupported, to reform the system by preventing further harassment. What emboldened us was the belief that even if our actions appeared to harm the institution's reputation in the short term, they would yield improvements for academic workers in the long term.

Unfortunately, individuals with first-hand experience have too few avenues at their disposal to achieve the broad cultural change necessary to eliminate harassment from workplaces. In part, this is because sexual harassment and abuse are cast as special hazards with their own set of rules. But harassment functions alongside sexism, racism, ableism, casteism, and other systemic forms of discrimination and requires a systemic response. Efforts to quell harassment should be incorporated into broader demands for acceptable working conditions such as fair wages, access to health care, and appropriate safety equipment. Most of all, the academic research enterprise should view a workplace free of sexual harassment not as a visionary dream of targets and survivors, but as a goal for everyone.

How the current system fails students

In 2018, frustrated by Dartmouth's excuses that tenured faculty who were perpetrators of sexual violence might sue the college if it brought formal accusations against them, I joined a group of women who filed a class action lawsuit against the school. We presented evidence and testimony that three tenured professors in the school's Department of Psychological and Brain Sciences had engaged in far-ranging sexual misconduct, including assault. My own report was from 2017, but some allegations went back to

2002. In 2020, a federal judge approved a $14.4 million settlement along with a plan for programmatic reform. But one often overlooked mark of progress was that we settled the lawsuit as a class, which is not the norm and represented a collective challenge to the status quo. After many years of wrongdoing in the department, it was survivors taking power into our own hands that made change and accountability possible.

Although we were a group and standing for something greater than ourselves, the experience was grueling and alienating. In speaking with survivors within the United States and beyond, I have learned that they too find civil litigation to be insufficient. The process of reporting is profoundly isolating; it duplicates and intensifies the effects of being targeted. As a result, I have tried to envision better, more nuanced forms of justice—approaches that mitigate the shame and isolation that come with both experiencing and reporting harassment.

The dominant antiharassment system at US research institutes centers on legal compliance, particularly with the civil rights law Title IX, which requires universities to have designated processes to handle reports and investigations. While federal antidiscrimination legislation is important, this effectively siloes sexual harassment away from other kinds of discrimination and prioritizes investigations over redressing harm. Furthermore, this separation frames incidents of sexual harassment as one-off scandals, putting an extra burden on survivors without tackling what are clearly systematic issues.

My own and others' direct experiences with Title IX offices show that what is couched as a set of resources can discombobulate an already overwhelmed person. Although there are a range of harassment categories and response options, the actual fact-finding process is generally one-size-fits-all. Even in the best circumstances, Title IX cannot factor in complex individual situations or the potential for retaliation: international students rely on their advisors for their visas; lab members may need a dean's endorsement to build their career. The focus on investigating individuals and incidents also fails to acknowledge the humanity of the complainants by disregarding not only their trauma, but also what justice they hope reporting can achieve.

Power imbalances amplified

Today's reporting systems have the potential to reinforce the power structures that fuel abuse in the first place. Investigations often pit powerful individuals against a lab's most junior members. Survivors must choose between staying anonymous to try to avoid retaliation, or using their names, faces, and voices to try to make their claims less easy to dismiss. Complainants are forced to make critically important decisions in the immediate aftermath of an experience that is, by definition, a denial of personal agency. For example, junior researchers, who are at the most vulnerable stage in their careers, must decide whether to come forward immediately after an incident or whether to wait until they are in a more stable position. As the 2018 National Academies report *Sexual Harassment of Women* observed: "The general perception that institutions are unable or fail to prevent or respond supportively to wrongdoings by individuals (institutional betrayal) leads to a climate of distrust." In this atmosphere, those who are already disadvantaged are even more vulnerable, and young scientists who have been trained to accept a "shut up and calculate" dictum to achieve academic success find themselves tasked with making decisions far outside their skill set, often under the guise of confidentiality and due process.

As the 2018 Academies' report summary states, "An increased focus on symbolic compliance with Title IX and Title VII has resulted in policies and procedures that protect the liability of the institution but are not effective in preventing sexual harassment." From what I've seen, universities have a formal process to handle complaints—but no process to make things easier for complainants, to reduce incidents of harassment, to draw lessons for improvement, or to share better practices.

In my opinion, survivors who file reports are typically not seeking retribution but redress. The legal focus, and the climate it engenders, ignores what survivors hope to achieve by coming forward, which is to receive support and prevent abuse in the future. The reporting process requires complainants to examine their experiences in terms of what can be counted as evidence, but it provides no opportunity to engage with what they think is just or right, or what would improve the workplace going forward. Having struggled with the potential for retaliation, complainants soon realize that there are few avenues to translate their personal experience into lasting reform.

The path forward

Some of us who have come forward after sexual assault have been hailed as heroes, but I know I'm not alone in saying that I would gladly give up the accolade to have more people standing with us. In my own experience and what I know of other survivors' experiences, what's been helpful has been support—provided not from the administration down but from the rank-and-file up. I have come to believe that the most promising approach to achieving lasting change is to claim the power and solidarity that should belong to us as workers.

To end the culture of harassment, survivors and allies should emphasize collective bargaining between unions and employers, which has a long track record of improving workplace conditions. This approach can prevent future harms while also tacitly acknowledging the toll that harassment (and its aftermath) takes on an individual's well-being. Multiple academic workers I have spoken with told me that their experiences with sexual harassment and other forms of discrimination were what drove them or their colleagues to seek solidarity with peers in the labor movement. Situating harassment alongside other workplace issues, including safety, childcare, tuition waivers, and working hours, leaves survivors feeling more like members of a community and less like victims. It also encourages a holistic treatment of harassment. The entire community can engage in the imaginative process of reforming workplace culture. That would allow survivors to work together, side by side with others in the community, on interconnected reforms toward a better future.

Already, some graduate student unions have made a difference. In the United Kingdom, the 1752 Group, a lobby organization that aims to end sexual harassment in higher education, and the National Union of Students have carried out the United Kingdom's first national study to assess staff-on-student harassment and to focus calls for action. Among the demands of graduate students who are involved in collective bargaining are provision of support groups for survivors of sexual harassment and third-party independent investigations of complaints. The graduate student union at the University of Connecticut has provided alternate grievance and legal procedures that specify what interim measures and remedies should be made available and elect to have a union official act as a support person in an investigation. New York University's union for graduate employees has put forward a contract that eliminates standard timelines for filing grievances about discrimination and allows some grievances to be taken up by the union itself.

Lasting structural change requires a long-term group of allies—broader than individual early-career researchers or ombuds who may not be at an institution long enough to see changes through. Collective bargaining could elevate and stabilize demands to treat complaints of sexual harassment fairly and keep the topic on administrators' agendas after any one complainant or advocate has moved on.

Whereas the process of filing a sexual harassment complaint is extremely isolating, unions embody the idea that fighting for better workplace conditions for oneself is a necessary part of fighting for better treatment of all workers. Allies made through collective bargaining can transcend hierarchies within academia.

Of course, there will be difficulties with logistics and fairness. The fact that change will be challenging and imperfect is not a reason to dispense with the process. Collective bargaining should be enshrined in policy at the institutional level, and it should be fostered by major science funders such as the National Science Foundation and the National Institutes of Health. In parallel, graduate worker bargaining rights should be explicitly and consistently recognized by agencies like the National Labor Relations Board.

Ultimately, sexual harassment cannot be solved by institutional administrators alone because harassment inherently deals with the question of power—and institutions are uncomfortable sharing power. As influential, long-term members of a university community, administrators and faculty are represented in the adjudication of sexual harassment in a way that survivors are not. An entity like a union can bring survivors' concerns to the table and defend the interests of those on the lower rungs of the power structure. In just the last few years, some universities have expanded efforts against sexual harassment beyond mere compliance and into cultural change by updating hiring practices and implementing intense training. These efforts are laudable and could synergize well with unions' efforts if collective action on campus were to be appreciated and not merely tolerated.

Situating harassment alongside other workplace issues, including safety, childcare, tuition waivers, and working hours, leaves survivors feeling more like members of a community and less like victims.

Most difficult of all may be learning to share power fairly. Even unions run the risk of replicating historical imbalances that exist in other parts of society; indeed, unions may lack clear processes for handling complaints of harassment by one member against another. And it is both important and difficult to ensure investigations and disciplinary action treat respondents and complainants fairly.

The inclusion of sexual harassment into workplace demands would help expand understanding of the issue beyond the people directly involved. Survivors will no longer feel that they are the only ones stuck fighting harassment. Instead of being alienated and isolated, those researchers who dream of a workplace free of harassment can labor together to achieve that vision. It is with the validation of survivors' experiences, recognition of harassment's prevalence, and solidarity with others who have faced similar treatment that true restoration is possible.

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MATTHEW N. EISLER

Computers on Wheels?

In the early 2000s, a metaphor borrowed from consumer electronics helped electric vehicle enthusiasts, Silicon Valley engineers, and policymakers reinvent the automobile.

In the early 2000s, electric vehicles (EVs) fell victim to what some observers characterized as one of the most heinous and irresponsible acts of industrial vandalism in American history. After leasing several thousand EVs to customers, many of whom grew to love their cars, automakers recalled and destroyed or otherwise disposed of almost all of them. As documented by filmmaker Chris Paine in the 2006 film *Who Killed the Electric Car?*, General Motors' brazen cancellation of its popular EV1, then the world's most advanced automobile, became seared in the popular consciousness. Embittered by what they saw as a corporate conspiracy against common sense and environmental rectitude, EV proponents pushed back. Enthusiasts had long homebrewed their own EVs, and the death of the electric car sparked a fresh round of do-it-yourself activism.

This activism, informed in large part by the information technology (IT) revolution, played a major role in enabling the EV revival that began in the late 2000s and early 2010s. Guided by experience with materials, systems, and modes of organizing innovation from the world of IT, the movement spawned a powerful metaphor: the EV as a computer on wheels. This idea would cast the electric car in the glow of Silicon Valley's unparalleled success, breathing new life into the EV project and sustaining it until public policy intervened to secure its future in the mid-2000s.

While the analogy of the EV as a kind of large mobile device proved a fruitful thought experiment in sorting through the problems of developing new products, it was not easy to translate into industrial engineering practice. Ultimately, though, the consumer electronics industry and public policy accomplished an end run around the automaking establishment to reinvent the EV.

An off-the-shelf car

The origins of the EV revival are often traced to a pair of Silicon Valley engineers who founded Tesla, a company now widely regarded as a peer of tech giants such as Apple, Google, and Amazon. Around 2000, newly wealthy from developing one of the first electronic books, Martin Eberhard and Marc Tarpenning pondered the fate of the EV. Eberhard believed all-battery EV propulsion was the most efficient way to convert energy for automobile use and that automakers had, with the exception of the EV1, deliberately designed most EVs to fail by making them ugly and underpowered—and in the process had misinformed the public about the technology's potential. To change public attitudes, Eberhard and Tarpenning envisioned building and commercializing the electric supercars that mainstream automakers claimed could not be built and commercialized—initially for wealthy customers and then for average motorists once costs had been trimmed.

The pair professed little knowledge of battery or automobile engineering, but a trend in IT industrial management seemed to offer a solution. As Silicon Valley deindustrialized, starting in the early 1970s, developers of consumer electronics began to integrate off-the-shelf components into new products, a management model that emphasized marketing and logistics over research and development. Dell Technologies founder Michael Dell, who did much to commodify the computer, referred to this approach as virtual integration.

Eberhard saw that the auto sector was deindustrializing too, and believed that something like virtual integration could also work in that context. If a commercial EV could not easily be scratch-built, reasoned Eberhard, perhaps one could be assembled from components available on the open market. The technologies that most interested him were the induction motor (desirable because it induced a magnetic field to generate mechanical motion and dispensed with the need for a costly permanent magnet) and the rechargeable lithium-ion cells used to power laptop computers and other handheld devices. Eberhard and Tarpenning calculated that a pack of such cells would have sufficiently high energy density to give an induction motor-equipped EV unprecedented acceleration and range.

These ideas were not entirely new. Politicians had been intrigued by the possibility of applying the methods of the semiconductor and electronics sectors in other industries, including automaking, at least as far back as the Clinton administration, which introduced this concept in policy discourse in the early 1990s. Car companies had been experimenting with induction motors since the 1960s, and in the 1990s Toyota and Matsushita adapted commodity cells for use in the first-generation hybrid electric Prius. The novelty of what Eberhard and Tarpenning envisaged lay in combining these elements with lithium power in an all-battery EV.

Steering away from an anticipated crisis

Positioning the EV as a kind of IT product made sense to tech investors at the time. In the early 2000s, venture capitalists were ready to diversify. In part, this was a consequence of the dot-com bubble bursting in 2000 and 2001, which wiped out $5 trillion in paper wealth. In the ensuing recession, there was further apprehension about the direction of IT.

The efforts of Eberhard, Tarpenning, and others suggested that the next big thing could be transportation, and developments in the IT sector reinforced this thinking. Progress in computing technology and IT more generally is often linked with Moore's Law, the miniaturization trend named for Gordon Moore, the cofounder of Fairchild Semiconductor and Intel, who in 1965 observed a correlation between falling costs and increased transistor density in silicon chips. Moore and many other experts perceived this trend to be in a permanent state of crisis, which they understood in terms of the anticipated physical barriers to scaling. But long before this could happen, manufacturers faced the problem of overproduction. Integrated circuits were first used in military applications and entered civilian markets via cheap and relatively rudimentary devices such as electronic wristwatches and pocket calculators. By the late 1970s, Moore worried that scaling was outstripping the capacity of those markets to absorb commodity microchip production and predicted that the next major applications of chips lay in homes and automobiles.

Eberhard and Tarpenning did not explicitly frame the all-battery EV as a solution to fears about the oversupply of semiconductors. Instead, the pair led the way in suggesting that an important avenue of growth for IT lay in electric automobility. To realize this goal, the entrepreneurs drew on the communitarian energy of Silicon Valley start-up culture, engaging collaborators who contributed capital, expertise, and technology.

Cadging commodity cells

Virtually integrating EV production turned out to be a difficult task, largely because the borders separating programming, consumer electronics, and automaking proved less porous than Eberhard and Tarpenning had assumed. The lithium cells the pair sought to acquire were composed of highly combustible organic electrolytes and metal oxides that required safety controls to prevent them from overheating and triggering a very hot fire that could not easily be extinguished. Such cells had already been involved in fires in mobile devices, and by the early 2000s they were drawing increasing regulatory scrutiny. Very large battery packs of the sort Eberhard and Tarpenning were planning contained vastly more incendiary material than packs for mobile devices, and required even more sophisticated safety controls. The pair started sketching the architecture of such a system around 2001.

From the perspective of electronic and automotive parts suppliers, however, the benefits of participating in this new venture were unclear. Suppliers worried about the legal ramifications if their components were implicated in malfunctions. For that reason, Eberhard maintained, makers of lithium cells had hitherto refused to sell to EV enthusiasts. Auto parts suppliers were also reluctant to do business with Eberhard and Tarpenning because the volume of EVs they initially proposed to produce was far short of commercial scale.

Still another complicating factor was that virtually all cell manufacturing was then based abroad and rooted in a corporate culture largely closed to outsiders. By the turn of the millennium, decades of globalization had concentrated semiconductor and computer design in the United States, semiconductor production in Taiwan and South Korea, and much of the rest of the consumer electronics industry in Japan, whose semiconductor industry increasingly served domestic consumer goods manufacturers producing a wide array of applications and their subsystems, including lithium-ion cells. Eberhard learned that in Japan, sales decisions were made not by dedicated sales staff (as in the United States) but by plant managers, and the only way to engage them was to forge personal relations on the ground.

After many visits to Japan, Eberhard eventually managed to win over electronics company Sanyo with an argument that aligned the business plan he and Tarpenning were developing with the business model of cell manufacturers. In his pitch to a Sanyo factory manager, Eberhard reasoned that just one of the vehicles he was proposing required as many cells as 2,000 notebook computers, meaning that 1,000 such cars would require as many cells as two million notebooks. Intrigued, the manager allowed Eberhard to demonstrate his and Tarpenning's ideas for battery pack management and safety systems.

Integrating the powertrain

The other key component of Eberhard and Tarpenning's electric supercar was the powertrain. In the early 2000s, Eberhard discovered AC Propulsion (ACP), an engineering research company cofounded by Alan Cocconi and Wally Rippel, engineers who had made major contributions to the Impact, a concept car built by AeroVironment and GM in the late 1980s that served as the prototype of the EV1. Impact utilized induction motors and an onboard charger integrated into the powertrain. GM's decision to design the EV1 with an off-board charger caused Cocconi to quit the project and start ACP with the goal of developing integrated EV powertrain technology. The company sold this technology to established automakers who used it for demonstration purposes and in so-called compliance cars that the California Air Resources Board had compelled them to produce through the zero-emission vehicle mandate of 1990, which itself had been inspired by the original Impact concept car. This arrangement sustained ACP's research and development operations and allowed car companies to invest minimal resources in the all-battery EV format they despised

Eberhard and Tarpenning aimed to license ACP technology and integrate it, along with the battery pack they were conceptualizing, into the chassis and frame of a sports car adapted from the Lotus Elise. In July 2003, Eberhard and Tarpenning founded Tesla Motors, named for Nikola Tesla, the inventor of the induction motor. Jeffrey Brian (JB) Straubel, an electronics engineer who had also patronized ACP, was later hired to develop the battery pack. Having assembled the components for an EV prototype, Eberhard and Tarpenning sought the capital to build it. With major investors cautious in the wake of the collapse of the tech bubble, the EV entrepreneurs embraced Elon Musk, a programmer who, like them, had managed to make and keep a fortune in the tech boom and believed that the next big thing was transportation. He also had links to ACP through Straubel, a friend who later became Tesla's chief technology officer. In 2004, Musk committed $6.5 million, becoming chair of Tesla Motors and its single largest shareholder in one stroke. The new partnership was short-lived. By 2007, Musk had assumed sole control.

Public policy and the EV revival

In succeeding years, Musk sank much of his personal fortune into Tesla, keeping it afloat as the company struggled and earning Musk credibility in enthusiast circles. However, public policy played an important and under-recognized role in shaping the financial conditions for the EV revival. While the Bush administration had promoted hydrogen fuel cell electric propulsion at the expense of first-generation all-battery EVs, the success of the hybrid Prius, and variants modified by activists for plug-in capability, caused policymakers to reverse course. Support for large-battery plug-in EV technology came through the Energy Policy Act of 2005 and the Energy Independence Act of 2007.

By 2008, the stage was set for the rebirth of the EV. That year, the Roadster hit the market as Tesla's first semi-commercial offering. It was the first purpose-built, serially-produced, all-battery EV to take to US roads since the EV1, and was followed by Nissan's all-battery electric Leaf in 2010. These cars had the ill fortune of launching during the Great Recession, but both greatly benefitted from the Obama administration's stimulus initiative, a continuation of earlier efforts by the federal government to encourage US EV manufacturing. Clean car technology initiated by a vision of virtually integrated start-up innovation was now the darling of the federal government, which became intent on expanding EV adoption through national industrial-technological dirigisme.

Over the course of the 2000s and 2010s, under three presidential administrations, the federal government spent many billions of taxpayer dollars on advanced power source technoscience, incentives for consumers, networks of chargers, and a domestic cell manufacturing complex, stoking demand for EVs and helping Tesla become (for a time) the world's largest manufacturer of EVs and the most valuable car company by market capitalization.

Automobile as mobile device

How significant were IT analogies in shaping the contemporary electric vehicle? In the years following the demise of the EV1, initiative in US EV development came from actors outside the automaking establishment, for whom IT was the lodestar of advanced industrial innovation. For them, the idea of the EV as a mobile device served as a heuristic that facilitated engagement with new and unfamiliar technologies. It also helped them make common cause with policymakers who had long seen electronics, and semiconductors above all, as vital to US economic competitiveness and national security. In retrospect, it appears that IT metaphors helped marshal resources and keep the EV dream alive in the bleak post-EV1 years.

While the EV renaissance is savored with more than a little schadenfreude by those who nurse a grudge against Detroit, innovation maxims derived from IT may well have obscured the real complications of developing EV technology. For all their points of similarity, EVs and mobile electronic devices are significantly different in terms of scale, complexity, and, importantly, lifecycle. Repurposing commodity cells originally designed for consumer electronics applications was problematic because such cells were designed to last the lifetime of mobile devices—generally a few years at most. Cell chemistries had to be modified for EV applications, and later generations of cells were designed specifically for use in EVs.

Crucially, however, the useful lifetime of electric motors is potentially much longer than that of even the most robust batteries because electric motors do not physically degrade over time in the manner of electrochemical energy storage devices. Indeed, the temporal mismatch between the motor and the battery may have been the main reason the global automaking establishment (not just Detroit) was skeptical about the all-battery EV. Given that the battery is the single most valuable EV component, the temporal mismatch implied that battery-making would become the most lucrative aspect of any commercial-scale EV program. The auto industry perceived this scenario as threatening to its century-old business model, a key factor in the resistance of car companies to the zero-emission vehicle mandate.

Other assumptions about electric vehicles, influenced at least to some degree by IT metaphors, grew out of the fact that the all-battery EV utilizes fewer moving parts than vehicles powered by the internal combustion engine (ICE). It is widely believed that this quality enables such vehicles to convert energy more efficiently than ICE vehicles and hence have lower operating costs—at least if battery replacement is not factored into the equation. But it also gave rise to the fallacy that the all-battery EV is easier to build than ICE vehicles. The reality is that costly and sophisticated technologies are required to fabricate all types of high-performance EVs. One industrial engineer I interviewed held that ensuring quality control of EV cells involved hundreds of thousands of line items of failure mode and effects analysis and entailed manufacturing complexity he believed was greater than for the ICE. Cell defects can compromise the safety of the battery pack and vehicle.

Integrating battery packs into EV powertrains entails another layer of systems complexity. Of course, systems issues are by no means exclusive to EVs. Automakers have increasingly treated all cars, including ICE vehicles, as computers on wheels, stuffing them with ever-larger quantities of computer hardware and software designed to manage everything from energy conversion to entertainment to the act of driving itself. This results in systems dynamics—and occasional failures—that are not always well understood.

Conceptualizing EVs as computers on wheels may also have obscured the impact that a growing EV fleet could have on electrical infrastructure. As EVs proliferate, their collective recharging may create peak loads higher than the grid was designed to supply. Risk analyst Robert N. Charette notes that certain EV-dense municipalities may soon have to make major infrastructure investments as EV recharging ages local power transformers and shortens their service lives. Such problems trace back to public policies that were intended primarily to improve air quality by means of clean car technology and that failed to consider the network effects of utilizing the advanced propulsion automobile as a vehicle of environmental regulation.

The distributed industrial complex informed by the IT worldview that produces the EV and that concentrates research, development, and design in Western (primarily US) enterprises and manufacturing in Asian enterprises has proven surprisingly resistant to reform. An important goal of the American Recovery and Reinvestment Act of 2009 was the development of domestic EV manufacturing, an objective that implied some degree of decoupling from Asian EV supply chains. However, some stimulus money intended to build domestic cell capacity went to manufacturers owned by Asian companies, bolstering them and virtual integration as a business practice. In effect, stimulus accentuated rather than mitigated the geocultural division of labor and capital in the global consumer electronics industry. When establishment automakers grudgingly followed Tesla and Nissan's lead and began producing large-battery plug-in EVs, most chose to outsource cells that they integrated into battery packs of their own design. Some, such as Ford, have begun to outsource even battery packs.

Policy efforts to decouple US industry from dependence on Asian supply chains have continued under the Biden administration, this time targeting China, now the world's largest maker of EV batteries and EVs. This has thrown some planned US-China joint ventures into question, but the degree to which supply chains can be unwound, shortened, and localized remains unclear. Although some Chinese cell and battery enterprises may be prevented from doing business directly in the United States, most American EV cell manufacturing is performed by joint ventures involving US automakers and Japanese and South Korean suppliers with various ties to China of one kind or another. And it seems probable that globalization, and the trend in the global automaking establishment's loss of initiative to policymakers and the IT sector in dictating the technological agenda, will continue into the foreseeable future—if only because offshoring and outsourcing have hitherto enabled US capital to reap the lion's share of profits. For all the systems integration issues that can arise when automobiles are treated literally as computers on wheels, that metaphor and the modes of innovation and manufacturing it reflects and reinforces—above all, virtual integration—well suit the financial and industrial relationships the West and Asia have coproduced over the last 40 years.

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MAHMUD FAROOQUE AND JASON L. KESSLER

How Would *You* Defend the Planet From Asteroids?

When NASA collaborated with social scientists to engage the public in two-way conversations about the agency's Asteroid Initiative, the outcome surprised everyone.

Participants discuss Asteroid Redirect Mission options at the Arizona Science Center forum. (Photo by Marissa Huth.)

On September 26, 2022, NASA successfully smashed a spacecraft into a tiny asteroid named Dimorphos, altering its orbit. Although it was 6.8 million miles from Earth, the Double Asteroid Redirect Test (DART) was broadcast in real time, turning the impact into a rare pan-planetary moment accessible from smartphones around the world.

For most people, the DART mission was the first glimmer—outside of the movies—that NASA was seriously exploring how to protect Earth from asteroids. Rightly famous for its technological prowess, NASA is less recognized for its social innovations. But nearly a decade before DART, the agency had launched the Asteroid Grand Challenge. In a pioneering approach to public engagement, the challenge brought citizens together to weigh in on how the taxpayer-funded agency might approach some technical decisions involving asteroids.

The following account of how citizens came to engage with strategies for planetary defense—and the unexpected conclusions they reached—is based on the experiences of NASA employees, members of the Expert and Citizen Assessment of Science and Technology (ECAST) network, and forum participants.

JULY 2013–JANUARY 2014

A series of fortunate events

Citizens have long asked to be involved in science and technology policy deliberations, and scientists and science agencies regularly express interest in working with the public on questions of national interest—but there is no designated space for this to happen. When it does occur, serendipity plays an outsized role.

Jason L. Kessler (former program executive, NASA Asteroid Grand Challenge): In 2010, after years of prioritizing the moon as a destination, NASA set the goal of sending astronauts to an asteroid as a steppingstone to Mars. In 2013, NASA released an integrated strategy to support human space exploration and to protect Earth: the Asteroid Initiative. One part of the initiative was the Asteroid Grand Challenge, which "focused on finding all asteroid threats to human populations and knowing what to do about them," according to the program description. The grand challenge was supposed to accelerate NASA's efforts to locate potentially hazardous asteroids through nontraditional collaborations. This was revolutionary.

One outcome of all the activity around asteroids was the release of a request for information (RFI) in late June of 2013. Given the technical challenges, NASA's integrated Mission Directorate team sought to source ideas outside of the agency to prepare and improve the mission design. RFIs are a traditional way to engage externally, but it wasn't clear that this RFI would reach the type of nontraditional partners the grand challenge was seeking. The RFI had six parts, primarily on technical components—as you'd expect from a science and engineering agency—but the sixth, which the grand challenge team successfully lobbied for, called for "Partnerships and Participatory Engagement."

Mahmud Farooque (principal coordinator, ECAST): By 2013, the academics, informal science educators, and policy people who made up ECAST had completed our first demonstration project but we were in a bind. Three years before, we had united to create ECAST with the aim of improving outcomes for science and technology through dialogue with informed citizens, building a framework for engagement in public forums called participatory technology assessment (pTA). Over the subsequent years, we brought universities, science museums, and nonpartisan think tanks together with the public to inform United Nations policy negotiations on biological diversity. But even though decisionmakers welcomed the idea of complementing expert assessment with public participation, we discovered that the combination did not fit easily with agencies' existing decisionmaking mechanisms.

Fortuitously, two ECAST interns, Carole Mabry and Katie Reeves, undergraduate and graduate students at the University of Georgia and University of Michigan, respectively, had chosen to focus on space policy. On July 8, Carole published a blog post on NASA's public outreach, which got the attention of some readers at NASA, who then sent us an email mentioning the Asteroid Initiative's RFI.

Part 6 of the RFI immediately caught our attention. Although the text didn't specifically call out pTA, it mentioned crowdsourcing and citizen science and the goal of broadening public participation. It also posed questions relevant to ECAST's policy and programming: *What would make participating in the Asteroid Initiative highly desirable …? How can we generate momentum with near-term goals? How do you see the Asteroid Initiative contributing to our nation's future role in space?*

The RFI seemed to have been written with ECAST in mind, but there was one big challenge: we had just three days to put a response together. This was one place where a trait that often worked to our disadvantage—being interdisciplinary and institutionally distributed—turned out to be an asset because the task didn't fall entirely on one set of shoulders.

We reframed NASA's questions to show that a pilot pTA could provide useful answers along with other benefits: "By tasking these citizen forums to write a report for decisionmakers … new perspectives and public and technical values are brought forward that can help NASA better plan and implement missions." We touted our "highly interdisciplinary" credentials and mentioned that a pilot study would cost under $200,000.

Jason L. Kessler: The grand challenge team was pleasantly surprised to receive 55 submissions for Part 6—many more than we anticipated and from a refreshingly diverse set of proposers. The ECAST proposal, with its combined academic and citizen science team, hands-on experience, and a proven method for engaging a diverse set of citizens, fit extremely well with initial action plans for the grand challenge—but it could also help with other important mission planning decisions. The relatively affordable proposal helped our team envision a way to engage the public early and get a jumpstart on our mandate. ECAST presented their proposal, alongside other applicants, at a workshop in Houston, Texas.

Given the interest in policy conversations coming out of the workshop, the grand challenge team began exploring how to start working with ECAST as soon as possible. We decided on a cooperative agreement rather than a grant because it ensured the government could influence the design of the work after the award.

APRIL–AUGUST 2014
Planning and pitfalls

Even before the public could be engaged, ECAST's group of interdisciplinary academics and NASA's mission-oriented bureaucracy encountered unexpected turbulence. To navigate rising expectations and keep the project from foundering, the leaders had to work across cultures to establish trust.

Jason L. Kessler: NASA is filled with brilliant problem-solvers and people who spend their time developing requirements and working to execute those requirements. Traditionally, NASA has either had the answers or was responsible for finding them. For many at NASA, the grand challenge's mandate to look outside the agency for answers was completely foreign. We put in effort to explain to our colleagues that we sometimes needed to step back from developing the answers and instead provide questions.

The grand challenge team believed part of the value in engaging with the ECAST team was their ability to communicate technically complicated material. So we highlighted this when we enrolled people within NASA to participate in the initial planning meetings. The result was that those who showed up at the kickoff meetings were curious, open, and willing to cocreate with the ECAST team.

Mahmud Farooque: As we started this project, ECAST had to change the way we worked while also navigating uncertainty about what NASA wanted. With a grant, we would usually get a year to design a pTA ourselves, figuring out who to engage, what questions to ask, what information to provide, and what outputs to generate for policy and decisionmakers. For this project, we needed to work much faster and more collaboratively, and that required learning to understand our partners.

In May 2014, both teams met at NASA headquarters for two days. By the end, we understood that the grand challenge team wanted to hear from those in the American public who don't engage with other space events, academic conferences, or NASA socials. And they wanted to know what this vast majority of the public thought about options to detect asteroids and prevent them from threatening the planet. Those insights could provide guidance for both the Asteroid Initiative and outreach strategies.

ECAST proposed two day-long deliberations to be held in December 2014, one at the Museum of Science in Boston and one at the Arizona Science Center in Phoenix. Each meeting would target about 100 people, recruited to represent the demographic diversity of the two locations. We chose three themes to explore: (1) Asteroid Detection, (2) Asteroid Mitigation, and (3) Asteroid Mission Governance.

Jason L. Kessler: When the grand challenge team briefed our NASA colleagues about the ECAST plan, there was so much support that leadership requested that we accelerate the timeline. In particular, a part of the Asteroid Initiative called the Asteroid Redirect Mission (ARM) had reached a decision point where the agency had to choose between two strategy options.

The ARM was a response to President Obama's vision of having astronauts visit an asteroid by 2025. It proposed bringing an asteroid into the moon's orbit where astronauts could rendezvous with it. Option A would send a robotic spacecraft to capture a small asteroid about 10 meters in diameter. Option B would send a different kind of spacecraft to an asteroid ten times as large, where it would use a set of robotic arms to collect a boulder off the asteroid's surface. A and B had much in common, but they were also riddled with uncertainties and complex scientific, technological, and economic tradeoffs.

If ECAST could complete the workshops by November of 2014, then the insights gained from the public deliberations could actually be considered as part of the final decisionmaking process for ARM. No longer speaking in generalities and theories, we could be positioned to inform an actual technical decision. For the grand challenge team, this was a dream come true; proof that our efforts to convince colleagues of the value of nontraditional engagement had succeeded and that public insights were welcomed as potential input for an important technical decision.

The grand challenge was supposed to accelerate NASA's efforts to locate potentially hazardous asteroids through nontraditional collaborations. This was revolutionary.

Mahmud Farooque: For ECAST, the request to move up the forum date was exciting and unsettling. Exciting because here was a rare opportunity to incorporate public values into the process of making an actual, consequential agency decision. Unsettling because we had no experience doing content development, participant recruitment, forum hosting, and the rest in such a short time! After some frantic emailing between the teams, we decided to move up the forum dates and finish analysis of responses to the ARM options by the end of November. Further results could come later.

But then we hit a new snag. ECAST's social scientists had started by framing broad, context-setting questions about the Asteroid Initiative with the aim of using them to develop actual deliberation questions, which we intended to finalize in a meeting between the teams later in the summer. However, when the grand challenge team shared our framing questions with NASA program leads, they interpreted them as provocative questions about the mission overall—causing some unanticipated and potentially deal-breaking tensions.

Jason L. Kessler: I had to quickly explain to my colleagues that the social scientists were just asking questions. Unless you have someone with a foot in both camps to translate what's happening within each organization, small misunderstandings like this can derail a collaboration. Also, during the summer of 2014, ARM was controversial: the science community was divided about its merits, and there were tensions over the budget. The grand challenge team was committed to use ECAST not to try to "sell" ARM to the public, but to engage citizens about technical considerations for the overall initiative.

However, just as we were preparing to meet in Boston in August, the space press reported on concerns raised about ARM at a scientific meeting. The broader NASA team became worried that the ECAST engagement could exacerbate negative feelings toward the mission. Our team arrived in Boston minus a few NASA experts, but we were still determined to focus on the "how" of capturing an asteroid rather than on the "why" or "what."

Mahmud Farooque: Somewhat oblivious to the tension, but generally aware of expert skepticism around public deliberation, ECAST wanted our NASA colleagues to experience a pTA session firsthand. ECAST forum deliberations are immersive and engaging in ways that most public discussions are not. They also make great icebreakers.

So we held a simulated forum that focused on conserving Boston's historical sites from the threat of rising sea levels. After a quick overview of projected impacts from climate change, forum participants deliberated benefits and tradeoffs of three mitigation options for protecting the Old North Church in Boston.

Jason L. Kessler: This was the perfect way to begin. It was hands-on, lowered tensions, and provided a tangible example of what was possible. NASA subject-matter experts could envision how their expertise could be organized to engage the lay public.

Mahmud Farooque: By the afternoon, when we presented a mockup of a proposed deliberation session on asteroid detection, the NASA experts were eager to jump in. The discussion was refreshingly generative and useful. The NASA team, coming from different parts of the agency, began to bounce ideas off one another. This back-and-forth gave us clarity about what the agencywide initiative needed.

By the day's end, we were no longer talking about what we needed to take off the table, but what else we could add. Out of our separate anxieties, we had realized that we could work together productively toward the same objective.

NOVEMBER 2014

A surprising "electric buzz"

The forums revealed a deep and unrecognized public interest in protecting the planet from asteroids. Unexpectedly, the meeting between citizens and experts also had a powerful emotional charge.

Mahmud Farooque: The ECAST and NASA teams worked furiously to meet deadlines for the first forum in Arizona and the second in Boston. We planned to start each with a live planetarium show on asteroids, followed by four discussion sessions on detecting asteroids, mitigating planetary threats, evaluating asteroid retrieval options, and creating pathways for the journey to Mars. Each session started with specially produced ten-minute educational videos. In addition, we created interactive game boards, information briefs, and a training program for moderators. We planned the logistics of the day meticulously, from parking to lunches, as we recruited a representatively diverse mini-public.

> Traditionally, NASA has either had the answers or was responsible for finding them. For many at NASA, the grand challenge's mandate to look outside the agency for answers was completely foreign.

We usually generate a large pool of applicants, expecting that at least 20% won't turn up. We used a flat $100 stipend to incentivize participation, particularly for lower-income participants, and we also took care to minimize participants who were somehow affiliated with space or NASA via professional, advocacy, or social networks. We ended up with 113 confirmed participants for Phoenix and 106 for Boston, and planned for a maximum of 80 in each city.

That produced the first surprise of the day: on the first morning of the event at the Arizona Science Center, 98 people showed up. We called for more lunches and were happy to learn that the caterer was still loading the van. Attendance in Boston was similarly high, reflecting the fact that the public was genuinely interested in this topic. A second happy surprise was that this enthusiasm came from the general public we had sought to reach—not just space fans.

David Gamez (participant in the Phoenix forum): They gave us a welcome inside of the Dorrance Planetarium. They had the mood lighting and some music from the movie *Armageddon*. Then they started talking about space, technology, and science intersecting. There was a movie that came out at the time, *Interstellar*, so it was really good timing. The buzz was electric.

After we left the science center, we moved to the downtown Phoenix campus…. We sat at tables of eight people with a facilitator and a recorder. We watched videos and discussed details, and then we had a scenario where there was an asteroid coming to Earth. We didn't have a lot of time, and this asteroid was projected to cause trillions of dollars of damage and hundreds of thousands or millions lost in human life. And everyone at the table was saying, OK, we need to nuke this thing. We're gonna go *Armageddon*-style. I had some hesitation with that because of the nuclear fallout since it was so close to Earth—I just wasn't sure if that would be the best route possible. And everyone was trying to give their two cents on trying to figure out, like, "OK, is nuclear fallout really the problem?" Like, is that really going to stop you in the face of losing hundreds of millions of lives? And then later on, I came to the point of saying, "Well, OK, then maybe we should just nuke this rock in space." And other people were saying, "Oh, you're starting to finally come around." And it was some playful banter, but some really thought-provoking banter as well.

Mahmud Farooque: The session devoted to asteroid mitigation required participants to discuss how to assess the threat posed by an incoming asteroid, and then consider the costs and uncertainties of different mitigation strategies. The teams pondered details ranging from the time available to the scale of the possible impact. As the back and forth in David's group shows, the participants not only embraced the complexity of the choices and constraints given, they debated their preferred options with each other quite comfortably and provided a robust defense for their final choice. Surprisingly, the majority of the groups, like David's, overcame some reluctance to settle on possible nuclear detonations. However, as David describes, the decision was clearly tortured, suggesting that the public could be interested in developing alternative technological responses to incoming asteroids. The conversations also suggested how such issues might be communicated with the public.

Sue Hakala (participant in the Phoenix forum): I represent the older woman demographic. I've been invited to a number of focus groups, but this one was particularly memorable. And I thought of it again when I heard about the DART mission. One thing that made this session special was that we had a representative from NASA there, and I chit-chatted with him during the coffee break.

There were probably six to eight tables of people deliberating. At the end of a session someone from our table stood up and gave the summary of our results, and all of the tables said the same thing! When it came to something as critical as a meteorite zooming to Earth that can kill us all, it was really important not to put this in the hands of a private company. Why? Because they would turn to the Earth and say just, "Well, how much is it worth to you?" And it was interesting that every single group said the exact same thing—which was that we wanted NASA to do the job.

Mahmud Farooque: This agreement on NASA's role in planetary defense was one of the biggest surprises of the forums. Back in 2014, it wasn't clear who would lead planetary defense—within NASA, many felt that the agency's role should be confined to supporting astronomers as they observed potential threats. We probed public opinion on this in two separate ways, giving options that included an international partnership led by NASA, private industry, the international scientific community, and other variations. The first time the question was asked, the focus was on cost, and participants overwhelmingly felt a US-led international partnership would be fairest—splitting the burden. However, when the question was asked again, indirectly, after participants had been discussing impact scenarios, support shifted toward the NASA-led international consortium and away from private industry or any of the other options. What was surprising was that participants had a sophisticated grasp of the complexity of planetary defense: they mentioned twice as many plausible governance challenges as had been provided in the background material.

Lindley Johnson (planetary defense officer, NASA): I think it was one of the first times that we directly saw the opinion of the public about planetary defense—and how important they thought it was for NASA to be doing it. It was one of the first times we had seen that public reaction. Asteroids had certainly always been talked about in Hollywood movies and that kind of thing. But to actually interface with the public and talk about this subject and see their support and how important they thought it was [was illuminating]. And they were disappointed that NASA wasn't already doing a lot in this area. I think that's the only time in my 40 years of government service that I've ever talked directly with the public.

Jason L. Kessler: When the Asteroid Grand Challenge first made the argument for nontraditional engagements to help accelerate the hunt for hazardous asteroids, we didn't really know what would come out of it. It sounded nice, but how it would actually manifest was wildly unknown. After the first forum in Arizona, and even more so after the second in Boston, it was clear the results could exceed even our most optimistic expectations. In my closing remarks that day I described what happened in the room as "magic," and I still think that captured the mood. My only regret is that more of my NASA colleagues weren't there to see it.

> We were no longer talking about what we needed to take off the table, but what else we could add. Out of our separate anxieties, we had realized that we could work together productively.

The NASA subject-matter experts who attended found it to be an exciting and valuable day because they got to hear taxpayers' thoughts on how NASA should spend its budget. I felt we'd accomplished a lot. Not only had we captured priorities and insight from a representative lay public, but we had also proven to the extended NASA team the value and benefit of this type of engagement.

DECEMBER 2014
Data-digging for decisionmaking

To make the results of the forums useful for decisionmaking, the researchers had to go beyond providing simple statistics by delving into participants' motivations for a qualitative picture of how the public perceives tradeoffs.

Mahmud Farooque: As soon as the forums were done, we had to find out what NASA really needed to know to help with decisionmaking on ARM. The data were clear: the public in both forums showed a strong preference for option B, which involved retrieving a boulder from the surface of a big asteroid, over option A, which was to capture a very small asteroid. Overall, they favored option B by 3 to 1 over A.

But we needed to provide more than that—we needed to give the public's rationale. So we went back to the notes from individual tables to reconstruct participants' thought processes, the knowledge they used, and how they arrived at their decisions. This led us toward a more qualitative presentation of the results, which NASA subject-matter experts found more persuasive and useful. Essentially, forum participants saw option B as having more benefits, particularly because it could be used to improve our understanding of technologies that could be later used for planetary defense.

Jason L. Kessler: Having accelerated the project's timeline, the grand challenge team was glad to have raw results available in December 2014 to present to NASA leadership before they made the critical decision about ARM. It was understood by the grand challenge team that the data from the public forums were not a part of the final decision criteria. However, NASA leadership did seek a summary of the initial findings as additional information for consideration.

Not only had we captured priorities and insight from a representative lay public, but we had also proven to the extended NASA team the value and benefit of this type of engagement.

Lindley Johnson: Maybe it's a little biased on my part, but I felt that we were already pretty well in tune with what the public would think. I mean, who wouldn't want to be for saving Earth from an asteroid, right? We were asking them to choose between two approaches—A involved using a robot to capture a small asteroid, but B had more benefits from the standpoint of planetary defense. I pretty much was expecting them to kind of take what we felt was the most logical approach and reaction, which was A. But they chose B.

Prior to the meeting, NASA was struggling with which approach to take. And although I won't say it was the deciding factor, it was definitely maybe the one that pushed it over the threshold that there was more public support for that option B approach.

And, in general, I think the public is pretty logical about how they go about things. There are certainly exceptions when you talk to individuals. But as a whole, the herd follows pretty much what makes sense.

DECEMBER 2022

The long arc

The Asteroid Initiative was cancelled in 2017. As we went back through our notes from 2013 and 2014 to write this article, we reflected on how the pTA project became possible, why it hasn't been replicated since, and what it would take to regularly involve citizens in science and technology decisionmaking.

Jason L. Kessler: Eight years after the forums, technology and subject-matter experts at NASA still have an appreciation for the value of engaging citizens. I've heard about the forums from people within the agency as well as others who've moved on. So there's recognition about the value it brings to us; what's missing is the interstitial tissue that enables it to happen.

Normally, communication with the public would fall to a communications team, which is mostly involved in transmitting information. To have two-way communication on technical matters requires someone to own that engagement process. In our case, that was the ECAST team. Then, on the science and technology side, the experts need to have a willingness to engage with nonexperts and believe that there will be value added from that engagement. Crucially, there needs to be a champion or broker who creates a vision of the possibilities from this type of exchange and who can absorb some of the risk for an organization that is stepping outside its comfort zones.

Mahmud Farooque: For ECAST, finding this sweet spot between championing, brokering, and codesigning a participatory engagement process and informing decisions about science and technology has proven elusive. Other federal agencies that do science have followed NASA's example and supported pTA activities at much larger scale, but they have not used it to inform programmatic or administrative decisions.

For members of ECAST, this has raised an existential question about the possible value of institutionalization. Should we stay loosely affiliated and keep pushing disciplinary and organizational boundaries from the outside while searching for open policy windows to become involved in decisionmaking? Or should we try to organize formally or work to become part of a mandated or sanctioned participatory decisionmaking capacity inside of agencies?

Jason L. Kessler: As exciting as the experience of two-way decisionmaking was, and as meaningful as the results were, there were no more pTAs. What made this possible was that that the Asteroid Grand Challenge had a budget, support from the highest levels within NASA, and a mandate to support nontraditional collaboration. I had a role to pursue this type of thing and a willingness to take the risks associated with this nascent type of engagement on behalf of my technical counterparts within my agency and the lay public outside. To discover and develop the utility of shared decisionmaking, I believe leaders of technical organizations should support an office or team with the capacity and resources to champion more such engagements over the long term.

Mahmud Farooque *has been shepherding the ECAST network since its inception and serves as the associate director of Arizona State University's Consortium for Science, Policy & Outcomes.* ***Jason L. Kessler*** *is an author, executive coach, entrepreneur, and currently serves as NASA's program executive for the Small Business Innovation Research and Small Business Technology Transfer programs. As a consultant, he combined strategy, design, and facilitation to create learning experiences to enable better outcomes in environmental and climate change programming for clients in the developing world.*

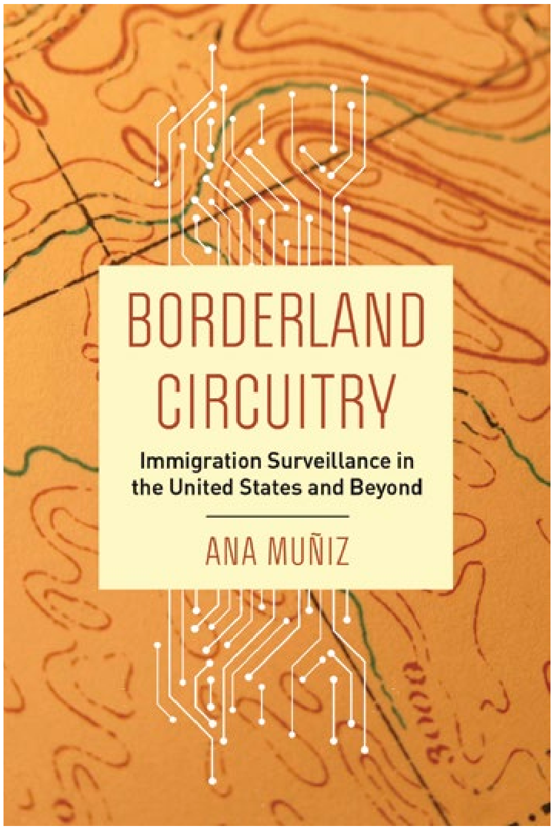
A Kafkaesque Border System

TONY PAYAN

It has become clear that the development, deployment, and use of technologies is rarely neutral. Many technologies may be used for both good and evil. And although technologies may provide significant social, political, and economic advantages, disparities in access to them may exacerbate or even create new inequalities. Moreover, the data and algorithms on which many technologies run can include, embedded within them, social and cultural biases that mirror the prejudices of society.

Ana Muñiz's book, *Borderland Circuitry: Immigration Surveillance in the United States and Beyond*, builds on observations like these to showcase the ill uses of surveillance technology primarily on the US-Mexico border. Muñiz, an assistant professor of criminology, law, and society at the University of California, Irvine, explores how surveillance and law enforcement technology is used to disadvantage and criminalize particular groups of people, reflecting broader biases in US society, and with profound and disproportionately negative consequences for migrants and minorities. All this, Muñiz argues, is built into the technologies of border surveillance.

Borderland Circuitry examines how US law enforcement and intelligence agencies develop, deploy, and use surveillance technologies, such as biometrics, facial recognition, drone flights, and mass databases. While the rationale for using these technologies is



Borderland Circuitry: Immigration Surveillance in the United States and Beyond
by Ana Muñiz. Oakland, CA: University of California Press, 2022, 244 pp.

ostensibly to gain and maintain control of the nation's borders, Muñiz reports on how border agencies view these technological functions expansively, going well beyond the border. This is salient information, as scholars have for years studied the distinction between the border as a physical barrier (e.g., the border wall) and the invisible barrier (surveillance technology) that reaches into communities deep within, and sometimes outside, the United States. Muñiz calls this "jurisdictional buoyancy," to which law enforcement and intelligence agencies are particularly prone. Other experts, such as the political scientists Matthew Holden Jr. and James Q. Wilson, have labeled the same phenomenon as bureaucratic imperialism. It has led, in Muñiz's account, to a "broader range and greater number of people [who] are eligible to have their information maintained in the database."

Although *Borderland Circuitry* focuses on federal agencies, Muñiz argues that there is increasing cooperation among local law enforcement and intelligence agencies at all levels. This cooperation has helped these organizations identify, stigmatize, criminalize, and deport immigrants, and also punish Black and Brown communities faster and more efficiently. The book argues that this is intentional, that agencies built targeting systems to subjugate more individuals and groups by phenotype and culture. It is what Muñiz calls a "racialized system in its own right."

Part of the book's value is in what it reveals about the mechanics of how surveillance technology works within the larger system. *Borderland Circuitry* includes thorough descriptions of how US agencies profile and target migrants and minorities with surveillance technologies: using trial and error, often in partnership with private companies, and sometimes without any real justification. Most importantly, according to the book, the creation and deployment of such technologies is based on racial lines, utilizing built-in racial bias. And the efficiency and power of these systems continues to grow: databases of local, state, and federal law enforcement agencies, intelligence bureaus, and border bureaucracies are increasingly interconnected. Muñiz argues that this is another part of the design, allowing better targeting of migrants and minorities in a political effort to subdue them. This system of border surveillance, according to the book's argument, is wholly objectionable and should be eliminated; the author advocates "not only abolishing the border as a physical thing but also abolishing the colonizing social relations, capitalist exploitation, climate destruction, and politics of empire that make the border possible."

If this sounds like a sweeping argument, it is, and its lack of nuance weakens it. The critique is broad, with little room for subtleties—for example, distinguishing between documented and undocumented migrants or criminal and law-abiding individuals. Consider the book's treatment of gangs: labeling someone a gang member in law enforcement databases, regardless of the soundness of that designation, may have serious consequences for that person, their family, and even their community. This is certainly a power that can be abused. Yet *Borderland Circuitry* argues that gangs and gang membership are largely constructions—"racialized, often unjustifiable, sometimes fabricated," Muñiz writes—of law enforcement and intelligence agencies as a method of immigrant and minority control. But gangs are not made-up groups: they are dangerous and may pose a legitimate threat, often most acutely to some of those same individuals and communities that Muñiz focuses on. As the gang example shows, *Borderland Circuitry* makes little effort to parse out and distinguish categories of non-white populations or socioeconomic groups and their treatment by the border system. Such parsing might have allowed a stronger, if more limited, case to be made against certain parts and uses of the system.

A richer development of *Borderland Circuitry*'s main arguments would have required contextualizing the book's valuable empirical evidence within existing theoretical frameworks. For example, examining biases in surveillance technology within the context of critical race theory—the interdisciplinary study of how conceptions of race and ethnicity affect a variety of social structures—might help better illuminate the mutual reinforcement of biases and technologies, and their relationship to historical inequities. Another potentially relevant concept is the philosopher Michel Foucault's "biopower": the idea that state authority endeavors to grow, optimize, and multiply, subjecting everyone and everything to precise controls. Invoking biopower could help make sense of the political motivation to limit the movement of minorities, since the ability to move—including crossing borders—is power.

Given that it is largely government agencies that develop and utilize surveillance systems, a look at the literature on bureaucracies would have been insightful. Certainly Franz Kafka's work comes to mind with Muñiz's descriptions of the impersonal nature of the bureaucracies that choose and input datapoints in the often punitive immigration system, process these data without regard to the lives they represent, and stream them out summarily in unappealable judgments. As another example, Muñiz refers to the seemingly random way in which surveillance systems are built and abandoned over and over with no apparent rationale. This suggests an alternative to the main hypothesis in *Borderland Circuitry*: rather than—or in addition to—malice or overt racism, a driving factor behind the growth of the surveillance system could be agency ambitions to increase budgets, resources, and discretionary power. Contemplating bureaucratic imperialism as a potential driver might lead to a more nuanced picture of these technological systems. Finally, there are a variety of studies on bureaucratic behavior, including the idea of "iron triangles" developed by the national security and defense analyst Gordon Adams, which describes arrangements whereby politicians profit electorally, interest groups acquire contracts (e.g., the technology companies Muñiz highlights), and bureaucracies maintain their material and discretionary privileges. The iron triangles that have formed around the prison industrial complex or the border industrial complex are prime examples of this.

There are many concepts and ideas from the social sciences that could be brought to bear on this material, and not appealing to them leaves the book at a largely descriptive level. While this doesn't take away from the empirical value of the book, it leaves the reader without a deeper understanding of the context. Placing the research in a broader theoretical understanding of surveillance, control, bureaucracy, and interests would have added enormous value to the text.

Borderland Circuitry performs a valuable service by shedding light on how surveillance technology is developed, deployed, and used to target people. But in its lack of nuance and its focus on race and oppression, other important issues are left out. While surveillance technology can be used to identify, profile, stigmatize, and criminalize people, and do so along racial lines, many people who end up in the system's databases are indeed criminals. The serious issue with fentanyl smuggling and the vast distribution networks within the United States—which often involve gangs and are now implicated in tens of thousands of overdose deaths every year—is a real problem, not one made up by bureaucrats. The book makes no distinction between unjust victims and criminals; instead, it portrays the surveillance system as fully unjust. But consider, for example, that Black and Brown communities often suffer disproportionately at the hands of gang members and criminals, whose information is and should be in the surveillance system. These communities too are entitled to protection, and that protection may require some amount of surveillance.

Ultimately, in its absolutizing critique of surveillance technology, *Borderland Circuitry* fails to address how to avoid throwing out the baby with the bathwater—that is, how to balance surveilling criminals, protecting communities, and enforcing the law, while neutralizing the worst biases technology can incorporate.

The question about what to do with these flawed but important systems cannot be ignored. In the future, surveillance technology will take in more of individuals' information and place it in databases for a variety of purposes. How can society best remove biases and regulate and monitor what is collected and how it is used? To deny that injustices currently exist would be absurd, but abandoning surveillance completely is unrealistic and possibly dangerous. A democratic system requires practices that enable people to hold bureaucracies accountable and limit their power in the deployment and use of surveillance technology. It is better to look to corrective mechanisms in the creation, deployment, and use of surveillance technology than it is to destroy the system altogether. The problems society needs to solve, after all, may not be primarily technological.

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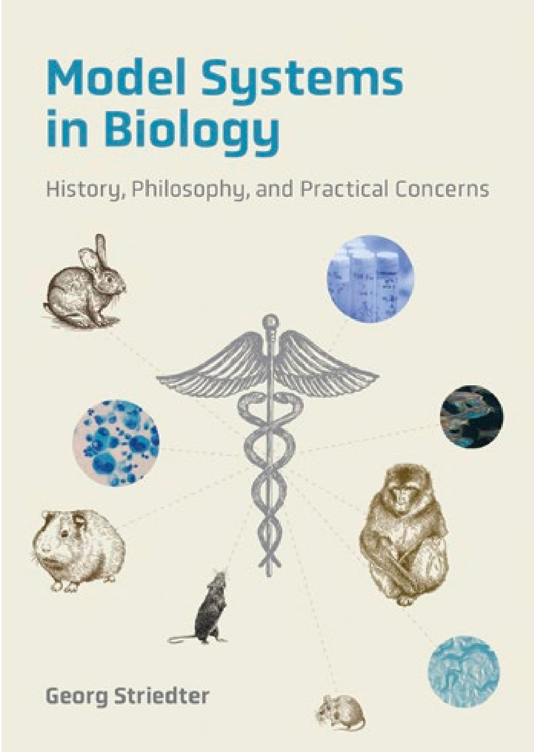
The Art and Ethics of Model Selection

JANE JOHNSON



Model Systems in Biology: History, Philosophy, and Practical Concerns
by Georg Striedter. Cambridge, MA: The MIT Press, 2022, 304 pp.

Biomedicine is credited with many achievements, including the increased longevity and enhanced quality of life of those of us fortunate enough to live in the early twenty-first century. In the context of the current pandemic, biomedical advances have facilitated the rapid development of vaccines that have enabled societies to better manage COVID-19. Yet all is not well with biomedicine; there are crises that threaten the field's ongoing success and bring into question some of its past triumphs. Georg Striedter's new book, *Model Systems in Biology*, does a good job of articulating a number of these challenges, particularly around translating animal research to human disease treatments.

Preclinical research carried out on nonhuman animals is intended to assess the safety and effectiveness of new treatments prior to human trials. It may come as a surprise to people unfamiliar with the field, however, that the animal tests often performed in this type of research have proved extremely poor predictors of what will work in humans. A tiny proportion of the drugs that look promising in animal studies holds up when translated into human clinical trials. After investing huge amounts of money and recruiting human participants to research, most potential new drugs are abandoned before they make it to market.

This crisis in translation links to a replicability crisis in biomedicine and science, in which researchers are unable to successfully reproduce the empirical results of earlier studies. Worryingly, even landmark and highly cited studies fall prey to this problem. For example, the ALS Therapy Development Institute retested scores of drug candidates after apparently promising results in animals and found no evidence of benefits, including eight molecules that had progressed to—and disappointed in—human trials.

Striedter devotes the first chapter to establishing the parlous state of biomedical research—its failures in translation, replicability, extrapolation, and generalization—and then spends most of the remainder of the book exploring the reasons behind these failures.

One issue that looms over the book, and which Striedter touches on at various points, is what might be thought of as a potential crisis in biomedicine's public legitimacy. Although scholars in history and philosophy of science and researchers in the life sciences have been aware of the shortcomings in biomedicine for some time, many of the challenges are not widely appreciated outside the field. The philosophies and methodologies of animal research are implicated in many of these challenges.

Studies on public attitudes toward animal research suggest support for the practice is contingent on the necessity of this research (i.e., that there are no alternatives) and that the suffering of animals is minimized. Translational failures challenge the necessity and value of animal research and call into question whether the suffering of animals involved can be justified. These failures could pose an existential threat to how biomedical research is practiced and funded.

Despite the many problems in translating preclinical animal research to human treatments, the resources involved in animal research are vast: an entire industry supports animal testing for pharmaceutical companies. Governments pour billions of dollars into animal studies every year. Animal research attracts highly skilled scientists, who could arguably be engaged in other, more productive, pursuits. There are also costs for participants enrolled in clinical trials that may end up having little or no therapeutic value; they might otherwise be receiving well established and less risky treatments, or forgo the extra time, procedures, and travel that clinical studies often require.

And beyond the human costs, there are the significant number of animal lives that are impacted and lost as part of this practice. Disappointingly, Striedter falls into predictable patterns when considering the ethics of animal research, reproducing the all-too-familiar caricature of the animal rights position. The view is linked to extremism, with advocates for animal rights apparently unable to distinguish appropriately between a consideration for the interests of human and nonhuman animals; instead, Striedter writes, advocates "tend to believe that animals and humans have roughly the same capacity for suffering and thought." There is the usual charge of inconsistency, that people who argue for animal rights in research supposedly want it both ways: humans and animals are similar enough to deserve the same rights, but so different that scientists cannot gain any knowledge from undertaking research with them.

Further, Striedter makes the allegedly telling comparison between animals used in research and for food. "Compared with the concerns expressed over animal experiments," he writes, "sympathy for animals we use for food is rather limited." The number of animals used in research is, after all, smaller. From this perspective, researchers are unfairly held to a higher standard, while those who raise animals for food get away with their poor practices, including sometimes slaughtering animals in what Striedter calls a "brutal" fashion and without anesthesia.

Like almost all researchers and regulatory bodies, Striedter adopts a consequentialist approach that turns ethics into a kind of calculation. Scientists weigh up the harms to animals compared to the potential benefits to humans, and so long as basic standards of welfare are adhered to and the bulk of animals come from supposedly uncharismatic or pest species, research can continue. Animal use is permissible, and animal lives are expendable, provided some greater human good is at stake.

There are, however, alternate ethical approaches. For instance, looking at how human research is regulated, people generally don't think that it is okay to balance harms to one group against benefits to another, since this conflicts with a basic principle of justice. Other considerations from human research ethics could also be imported to an animal setting, including special protections for vulnerable groups.

The book's lack of sophistication surrounding issues in animal ethics stands in contrast to the nuance and complexity of Striedter's discussion of model selection. The process of model choice—that is, selecting an animal species that can appropriately mimic relevant aspects of a human disease or drug reaction—is complicated. It involves weighing factors such as economic considerations; animal convenience (e.g., availability, housing needs, experimental tractability, size, reproduction rate, and standardization); the supposed higher predictive value of, say, macaques versus roundworms; history and tradition; the popularity of certain models for answering particular questions; researcher training and experience; regulatory requirements (e.g., the lack of regulation of insects); and so on.

It is telling from the kind of considerations outlined here that what might be thought of as strictly scientific reasons are only a part of model selection. This is perhaps why discussion of the reasons for favoring a particular model are not generally aired publicly. "Biologists do occasionally pen thoughtful commentaries or reviews on the pros and cons of various model systems," Striedter writes, "but the vast majority of these papers advocate primarily for the model that the authors themselves are working on. Few are willing to critique the choices of other biologists." While this may seem prudent, the lack of discussion among biomedical researchers themselves is problematic. Opening up this reasoning to explicit consideration is a significant part of the project of *Model Systems in Biology*—a laudable goal indeed, and one which Striedter largely achieves.

The book provides a seemingly helpful checklist of factors for a researcher to consider when thinking through what model to choose. For example, does the strain of mice proposed become deaf or blind in maturity, limiting its suitability for tests using these modalities? Or if swimming is required as part of spatial memory tasks, rats will likely be preferable over mice. However, it would be difficult in reality to implement such a decisionmaking process. It might appear most promising for relatively junior researchers—Striedter notes he had "young scientists" in mind when writing the book—who don't have entrenched patterns and habits. But given the hierarchy of science, it is unclear that these people always have the autonomy necessary to determine model choices.

And for researchers well established in their practice, many of these choices may effectively be closed off as a consequence of previous decisions to devote time and energy to developing expertise with particular animals in particular institutions. Constraints on space, for instance, mean some facilities that house mice are unable to support comparable numbers of rats, so a researcher cannot simply shift between rodent species. Nonetheless, the book may help these scientists be clearer and more explicit in understanding the factors involved in their research decisions, especially in the context of mentoring the next generation of researchers.

Despite its shortcomings, *Model Systems in Biology* is worth reading. It is an important and timely book that synthesizes a significant body of research across many fields. And it is accessible to nonscientists, meaning it can potentially speak to a broad variety of audiences drawn together by their concerns about biomedical research.

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Moderation to the Barricades

CARL MITCHAM

Liberalism is the political theory that animates the liberal democratic republic by affirming the autonomy of individuals and their rights to property, to freedom of thought and speech, and to participate in government.

Although seldom explicitly invoked by scientists, liberalism also underpins what British chemist Michael Polanyi named the "republic of science," in which "scientists, freely making their own choice of problems and pursuing them in the light of their own personal judgment, are in fact cooperating as members of a closely knit organization." It was the theory embedded implicitly in *Science, the Endless Frontier*, the 1945 report from science administrator Vannevar Bush that influenced the structure of the postwar American research enterprise: "Scientific progress on a broad front results from the free play of free intellects, working on subjects of their own choice, in the manner dictated by their curiosity for exploration of the unknown." Liberalism remains the unstated ideal of many scientists and engineers, for both their own professional communities and the larger societies in which they live.

But today liberalism, and liberal democracy as a form of government, appears beset by problems both internal and external. In this atmosphere, Francis Fukuyama's *Liberalism and Its Discontents* aims to defend and rehabilitate liberalism against its critics and competitors. China's emergence as a global power presents a distinct challenge to the post-Cold War idea of liberalism as the default ideology behind any legitimate government—an idea Fukuyama famously championed in his first book, *The End of History and the Last Man* (1992). Thirty years later, authoritarian leaders appear to be rising around the world, including in liberal democracies themselves. Within the internal dynamics of the liberal order, the emphasis on free markets and individual agency has brought about new problems, which are the focus of this latest book. Founded on these liberal principals and ideals, the republic of science is facing similar challenges.

Fukuyama begins by defining "classical liberalism" as individualist, egalitarian, universalist, and meliorist (i.e., progressive, or making the world better through human effort). For some reason he leaves out liberty or freedom as the unifying ideal of these four characteristics. As the very term implies—and as Enlightenment political philosophers Thomas Hobbes and John Locke originally imagined before the American founders put it into practice—liberalism makes liberty the supreme value in an individualist social ontology in which people freely establish governments.

With Hobbes the ideal was a negative freedom: to escape the evils of a "state of nature" dominated by unremitting conflict that vitiates the peaceful cognitive and material productivity envisioned by Hobbes's mentor, the philosopher Francis Bacon. For Locke, the positive goal was to protect private property in order to "promote the general welfare," in the words of the US Constitution (on which Locke's philosophy was an important influence).

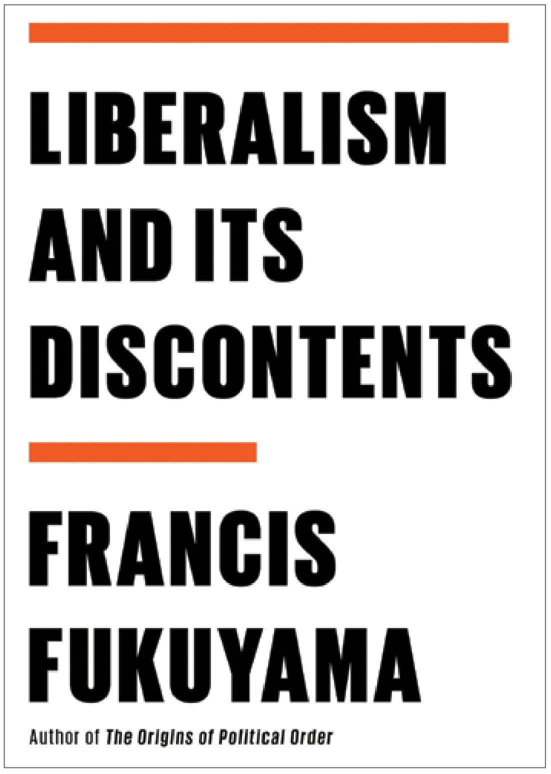
Liberalism further affirms, from Immanuel Kant's moral philosophy, that humans have the freedom to self-legislate, to make rational moral choices. And finally, liberalism (at least in its British and American iterations) argues for the gradual advancement of freedom throughout out the world in a process similar to advances in the sciences: "In a free marketplace of ideas," Fukuyama writes, "good ideas will in the end drive out bad ones through deliberation and evidence." In his formulation, social progress rides on the back of scientific progress:

The liberal Enlightenment understood itself as the victory of human reason over superstition and obscurantism…. Modern science was able to defeat these alternative approaches ultimately because it could produce repeatable results. The manipulation of nature produced the modern economic world, where continuing growth though technological advance could be taken for granted. Scientific approaches to health led to huge increases in longevity; and technology conferred on states huge military advantages that could be used to defend or to conquer.

Although Fukuyama has been portrayed as a cheerleader for liberalism, he has always been a more complex—and critically restless—thinker. Even in his first book, he recognized that the global triumph of liberalism was full of complications and contradictions, as the second part of his title suggested. The "last man" is nineteenth-century philosopher Friedrich Nietzsche's metaphor for the bourgeois degeneration of heroism and great deeds into lives of commerce and entertainment: "little pleasures by day and little pleasures by night," in Nietzsche's words.

After 9/11, Fukuyama's end-of-history argument was contested by thinkers who often referenced some version of political scientist Samuel Huntington's "clash of civilizations" thesis—that cultural and religious identities, rather than national political systems such as liberalism or communism, are the "central lines of conflict in global politics." Fukuyama's new book revisits what he still contends properly anchors any political discourse for the foreseeable future (which is what he meant by "end" in "the end of history"): "To paraphrase what Winston Churchill once said about democracy, liberalism is the worst form of government, except for all the rest" (p. 128). For Fukuyama, defending liberalism can constitute a Churchill-like heroism appropriate for our time.

Fukuyama argues that liberal theory must be defended against distortions in how freedom and free agency are conceived. There are two primary forms of distorting excess: economic individualism (free markets) and radical interpretations of psychosocial autonomy (identity politics). These challenges are echoed in efforts to defend and reform a scientific enterprise that is founded on similar liberal principles.



Liberalism and Its Discontents
by Francis Fukuyama. New York, NY: Farrar, Straus and Giroux, 2022, 192 pp.

Excessive economic individualism manifests as neoliberalism. Neoliberal market fundamentalism, Fukuyama writes, "allied to what Americans label libertarianism, whose single underlying theme is hostility to an overreaching state and belief in the sanctity of individual freedom," pushed liberalism "to a counterproductive extreme." Through deregulation and the offloading of many public social programs into the private sector, it "promoted two decades of rapid economic growth [while] destabilizing the global economy and undermining its own success." Contrary to this libertarian ethos, the need for at least some government regulation is clearly demonstrated by, among other problems, the contemporary worsening gaps in income inequality and the hazards posed by a changing climate.

In science, neoliberalism can distort research by enabling it to be captured by commercial interests. The sociologist Robert Merton identified a scientific ethos characterized by communalism, universalism, disinterestedness, and organized skepticism. But, as the organizational theorist Ian Mitroff pointed out in the 1970s, these characteristics skew toward secrecy, particularism, interestedness, and dogmatism under neoliberal conditions. Entrepreneurial pressures to translate scientific results into market success, for instance, promote extreme intellectual property protectionism and promotional hype.

From neoliberal excess, Fukuyama shifts to more philosophically fraught issues of psychosocial autonomy and identity politics. "Individual autonomy was carried to an extreme by liberals on the right who thought primarily about economic freedom" and property rights, he notes. "But it was also carried to extremes by liberals on the left, who valued a different type of autonomy centered around individual self-actualization." The pursuit of personal autonomy replaces the utility maximizers of economic models with sovereign self-creators. In the first moment, self-creating autonomy, independent of reference to any substantive good, turns the process of choosing or deciding itself into the primary good. The assertion of the primacy of the "I" makes it hard to recognize the authority of any "we"—except a "we" that "I" choose to assert. Extreme individualists don't like to join any group that they don't create.

Sovereign-self individuals seek the liberty to act, not just within a given social and moral context, but to create their own contexts. In line with this notion, sovereign-self scientists seek liberation from social responsibilities; the ideal is often Albert Einstein or Stephen Hawking leading the scientific life as an end in itself, with Bush's "free play of free intellects" as the model.

In a second moment, however, the "me" of the sovereign self inevitably discovers itself externally classified as a member of some "we" at intersectional odds with one or more other sociocultural groupings. For those who find imposed identities psychosocially constraining, material security becomes insufficient for unencumbered self-actualization. Even in the nineteenth century, John Stuart Mill's great manifesto for liberalism, *On Liberty*, argued that the mass cultivating of truly "experimental lives" required the weakening of social norms regarding family and religion. At some point, Fukuyama argues, liberalism "turns on itself" and demands freedom not only for individuals but for all sociocultural identities—and rights to identify as such, to make sociocultural identity an element in self-actualization.

From the perspective of this new demand, liberalism itself is just another historically contingent identity, one that has in fact promoted a false social ontology, overly rationalist social contract theories, and empty legal processes while hypocritically oppressing other identities and cultures. To this view, individualism, egalitarianism, universalism, and meliorism are just Western concepts that can't be dissociated from their exploitative, colonialist histories.

Fukuyama argues back. "While individualism may be the historically contingent by-product of Western civilization, it has proven to be highly attractive to people of varied cultures once they are exposed to the freedom it brings." Although "there are types of cultural autonomy that are not consistent with liberal principles," he continues, no political order is more inclusive and broadly beneficial. Liberalism's rationalism has been "strongly associated with the project of mastering nature through science and technology, and using the latter to bend the given world to suit human purposes."

Against a suite of discontents with liberal societies—that "they are self-indulgently consumerist; that don't provide a strong sense of community or common purpose; they are too permissive and disrespect deeply held religious values; they are too diverse; they are not diverse enough; they are too lackadaisical about achieving genuine social justice; they tolerate too much inequality; they are dominated by manipulative elites and don't respond to the wishes of ordinary people"—Fukuyama argues that neither religious conservatives, nationalist conservatives, authoritarians, nor radical left progressives offer any realistic alternatives.

What is needed instead, he says, is moderation of right and left liberal excesses. Right-wing economic liberals should recognize the legitimate role for some measure of government regulation and the provisioning of some level of social welfare. Left wing self-actualization liberals must accept limits to radical autonomy—an achievable goal since, as Fukuyama notes, many people "are happy to limit their freedom of choice by accepting religious and moral frameworks that connect them with other people."

Fukuyama also devotes a chapter to the difficulties of bringing moderating liberal principles to bear in the digital environment. Founded explicitly on neoliberal principles, digital communication technologies often embody the excesses and distortions that plague liberal societies. Digital platforms allow rapid and widespread dissemination of misinformation, lies, and conspiracy theories while at the same time posing challenges to the effective sharing of scientific knowledge. Under these mutating political circumstances, Fukuyama calls on liberalism to refine and reapply its basic principles. "The unanswered question for the future," he writes, "is whether liberal societies can overcome the internal divisions that they themselves have created."

One doesn't have to look hard to see many entries from Fukuyama's list of discontents in contemporary discussions about science and science policy. Scientists and scientific institutions too have been accused of greed (focusing on research that makes themselves or their corporate patrons money), undermining social cohesion (through the disruptive churn of discovery and innovation), subordinating religious values (in stem cell research, for instance), being slow to promote social justice (in lacking diversity), and overall elitism. In response, the scientific community sticks with some version of Fukuyama's defense: there is still no better useful knowledge production institution than that of modern science, even though it needs some reforms. But in the research community, too, whether science can overcome the discontents to which it has contributed is an unanswered question.

__Carl Mitcham__ is a professor of philosophy at Renmin University of China. His most recent book is Steps Toward a Philosophy of Engineering *(2020).*

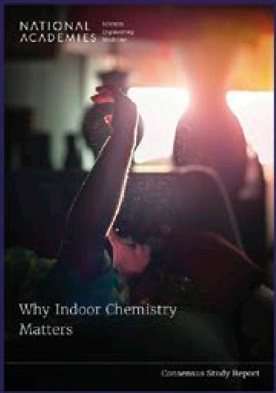
Altar

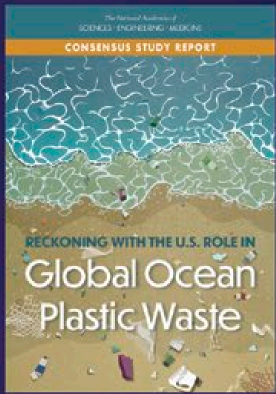
With her sculpture *Altar*, Smriti Keshari provides a visual and emotional exploration of the dawning age of artificial intelligence (AI). Until 2016, many players believed that the ancient game of Go was so complex that it required human intuition and creativity. But then AlphaGo, an AI system, defeated Go master Lee Sedol in four out of five games, using a maneuver that human players considered a "rookie move." Today this ploy, called "Move 37," has become symbolic of creative thinking in AI. In *Altar*, Keshari depicts the infamous move through pseudocode, which programmers use to represent the implementation of an algorithm before converting to actual code.

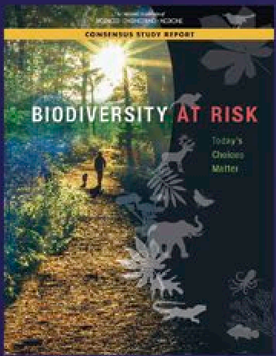
Keshari is an Indian American artist and director who creates bold, visceral works in films, live shows, and art installations. She is an artist-in-residence with the National Theatre in London, Brooklyn Academy of Music, and Pioneer Works in New York City. Her work has been supported by the MacArthur Foundation, Carnegie Corporation of New York, Ford Foundation, and others.

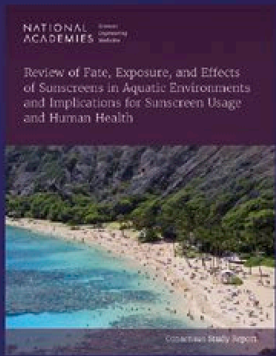
Altar, organized by Cultural Programs of the National Academy of Sciences in collaboration with The Science & Entertainment Exchange, is on view at the National Academy of Sciences Building, 2101 Constitution Avenue NW, Washington, DC, through September 15, 2023.

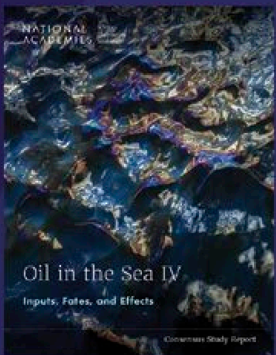
SMRITI KESHARI, *Altar*, 2019, gold acrylic, LED light tube, 36 x 18 x 96 inches. (Photo: Kevin Allen.)

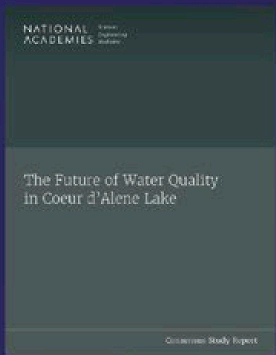


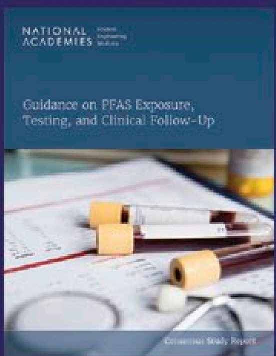


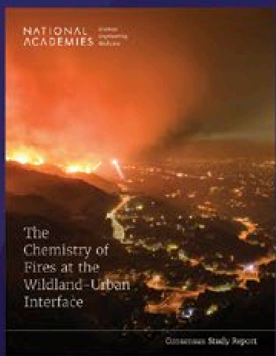












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