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# Greening for the Greater Good:

## *Research to Fuel the Bioeconomy*

*By Sandy Mau*

In 1973, the field of biotechnology was fundamentally transformed when biochemists Stanley N. Cohen and Herbert W. Boyer successfully transplanted genes from one organism to another. In the nearly fifty years since, capabilities to map and edit human, animal, and plant genomes rapidly advanced alongside breakthroughs in nanotechnology, sensing, and bioinformatics. Enabled by engineering, information science, and computing, bioeconomy research and development promises to revolutionize everything from medicine to materials and from food to fuel.

There is immense potential for transformative biotechnology solutions to improve society and quality of life. Representing 5.1% of U.S. gross domestic product in 2016—nearly $1 trillion—the bioeconomy is flourishing as companies and universities produce applications in agriculture, biomedicine, and bioindustrial sectors (NASEM, 2020). As institutions and companies look to reduce their carbon footprint in the coming decades, investment in biotechnology research has never been more urgent.

Safeguarding the investment from government and commercial sources while ensuring that the United States maintains a leading position in new biotechnology discoveries and translational applications is a priority for the U.S. National Science Foundation (NSF). This was the impetus behind a series of five workshops conducted on behalf of the NSF Biology Directorate by University Industry Demonstration Partnership (UIDP) (uidp.org), a non-profit membership organization comprised of leading innovation companies and research-intensive universities. Beginning in July 2021, UIDP convened interdisciplinary groups of scientists in virtual, two-day workshops to examine specific biotechnology areas where increased research activity could yield results that translate into real-world solutions. The invitation-only events engaged researchers from academia, industry, and government to identify research areas ripe for partnership and collaboration.

"We know that the world's greatest challenges can be addressed with effective, cross-sector collaboration. Governments around the world are ready to invest, sometimes in partnership with industry and nonprofits, in research that can rapidly result in discovery and solutions at scale," said Anthony Boccanfuso, UIDP's president and CEO.

Why does this matter to research leadership? To paraphrase hockey great Wayne Gretzky, smart leaders steer to where the research activity is going to be. UIDP's 2018 workshop, "Catalyzing Industry-University Collaboration in Quantum Technologies," was similarly conducted in collaboration with the NSF and helped inform collaborative research directions in that critical area. NSF has established university-industry collaborative research centers to bolster the nation's standing in quantum science and technology.

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University research leadership can play a critical role in highlighting the findings from these visioning events that point to critical issues on collaboration and topics of highest priority. Academic research in bioeconomy topics, especially when pursued in collaboration with industry partners, has the potential to vastly accelerate R&D advances that provide substantial societal benefit.

"Biotechnology is one of NSF's Emerging Industries and a priority area that engages all directorates across the agency," said Theresa Good, division director for the Division of Molecular and Cellular Biosciences at NSF and chair of the agency's Bioeconomy Coordinating Committee. "In the past,

our investments in fundamental and use-inspired research, infrastructure, and the workforce have advanced the U.S bioeconomy as exemplified by directed evolution enabled biocatalyst design, gene editing enabled acceleration of the development of cellular therapies and bioprocesses for materials, and PCR enabled advances in rapid sequencing and identification of SARS-CoV-2 and other pathogens. All of those enabling technologies, PRC, gene editing via CRISPR, and directed evolution, were the product of curiosity driven discovery research."

The UIDP bioeconomy workshop visioning series focused on five research themes. Reports from the workshop elucidating critical topics and advancements needed to pave the way for translational research point to distinct gaps in the current research landscape for each topic area that can be advanced by collaborative, cross-disciplinary research at the interface between basic and use-inspired research. Key takeaways for research leadership from the first three reports, available publicly on the UIDP website, are explored below.

## Feeding the Planet Sustainably

Feeding a growing population that inhabits a warming planet will require new strategies powered by technological innovations to improve food production and other agricultural products. This workshop sought to define the needs for a new agriculture, identify barriers to progress, and articulate near- and long-term goals. For success to result in products, services, and techniques that generate societal benefit, it is crucial to connect basic research to innovations that translate into practical outcomes. Partnerships across sectors—academic, corporate, and government—can accelerate this process. One partnership model that invests in basic research while enabling rapid development of practical solutions is that of industry-academic research consortia, where both those participating in the research and those investing in it can benefit from collaborative R&D efforts.

Research leadership can lead by instilling a greater sense of urgency, consistently engaging the public in research and its outcomes, and supporting international standards to catalyze research and commercialization efforts.

## World without Waste: A Circular Bioeconomy

The high volume of waste at the end of the plastics lifecycle causes adverse environmental effects, and the linear plastics system itself wastes the valuable carbon and energy that end-of-life plastics contain. Society loses dramatically when spent lithium-ion batteries and other electronics are landfilled without extracting valuable metals, when nutrients are swept from farm fields into rivers, and when industrial waste isn't tapped for the energy, materials, or nutrients within them.

Biological systems offer a dramatic opportunity to increase circularity in our material systems. The workshop explored biological systems design, sustainable biosourced materials and products, biomanufacturing, enabling circularity, regional and international approaches, innovation recipes and collaboration, public engagement, and reducing risk. Achieving a circular bioeconomy requires consensus in the scientific and policy communities and commitment at a high level to address gaps and create a framework for research and collaboration efforts based on economic viability as well as environmental and societal sustainability. An entrepreneurial, circular bioeconomy workforce is also needed, as well as best practices for developing partnerships among suppliers and end-product manufacturers that contribute to a circular bioeconomy.

## Building a Biotechnology Innovation Ecosystem to Mitigate Climate Change

Biotechnological or synthetic biology innovations may be developed to enhance the adaptation, resilience, preservation, and restoration of natural and managed ecosystems in response to climate change. The potential of coupling nature-based practices with synthetic biology tools to guide the development and implementation of biotechnological solutions was the focus of this workshop and the resulting report.

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At this juncture in history, when governments around the world have prioritized reducing carbon emissions and when education institutions in the United States are taking action to reduce their own carbon footprint, the critical research topics detailed in this report provide a blueprint for achieving large-scale climate mitigation via biological solutions. From systems analysis to bioengineering topics, and from research in natural, managed, and industrial systems, the report highlights the biotechnology research and development pathways that will lead the way to mitigate the effects of climate change. These ambitious endeavors must be pursued in parallel to take full advantage of the climate change mitigation potential possible through existing and emerging biotechnologies.

## Leveraging the Reports

Research and development in the bioeconomy holds the promise of feeding the planet sustainably, creating a world without waste, and mitigating many of the effects of climate change. Use-inspired research—exploration and development of ideas and practical solutions—is accelerated through multi-sector collaboration. These reports contain a trove of emerging research directions and recommendations that tap into the wealth of knowledge possessed by hundreds of researchers and are ripe to catalyze bold discoveries across the research landscape. N

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