



ADVANCING THE AMERICAN BIOECONOMY

A strong American bioeconomy -- the biology-derived infrastructure, innovation, products, technology and data that stimulate economic growth -- is key to future U.S. leadership in biotechnology and global competitiveness. The National Science Foundation (NSF) is driving fundamental research that is advancing future industries; accelerating innovation; improving health; and building a sustainable U.S. economy.

10 BIG IDEAS: UNDERSTANDING THE RULES OF LIFE

It has taken 3.5 billion years of evolutionary innovation to discover diverse solutions to life's toughest challenges, from harnessing quantum phenomena for energy and sensing to finding ways to thrive in even the most extreme environments. With a new suite of investments within the Understanding the Rules of Life Big Idea, NSF is strengthening U.S. leadership in the global bioeconomy through integrative research to understand and manipulate those evolutionary innovations.

Understanding the Rules of Life projects will uncover new tools to describe and manipulate genomes; new means of sensing processes at multiple biological scales simultaneously; and new data and computational approaches, including artificial intelligence, in bioinformatics and modeling to unveil the regulation of complex living systems. These advances vastly improve the ability to understand life's deepest mysteries, while enabling new capabilities to create innovative biotechnologies for societal benefit and economic prosperity.

PROVIDING THE RESOURCES FOR U.S. INNOVATION

NSF invests in both information and instrumentation resources needed to push the frontiers of scientific knowledge and innovation. Notably, growing the bioeconomy increasingly depends on easy access to and manipulation of diverse, distributed and very large datasets. NSF investments in cyberinfrastructure -- including data, software, networking, computing and people -- are improving data capture, storage, security and access, and enabling data processing and analysis at unprecedented scales.

NSF provides resources that are critical to basic scientific and technological innovations across scales and scientific disciplines, including:

- Access to databases, such as via the Protein Data Bank.
- Physical and digital biological collections like iDigBio and living biological collections through the Collections in Support of Biological Research program.
- Computational capacity for research, such as access to Frontera, the world's fastest academic supercomputer; cloud computing; and other emerging computing platforms.
- Center-scale research efforts to protect the growing social and economic benefits of cyber systems and data, through the Secure and Trustworthy Cyberspace program.
- Major facilities, like NSF's National High Magnetic Field Laboratory (MagLab), and major instrumentation, like the newly funded 1.2 gigahertz Nuclear Magnetic Resonance spectrometer, supported by NSF's Mid-Scale Research Infrastructure program.
- Resources to develop and disseminate new research and computational tools, such as the Infrastructure Innovation for Biological Research program.

TRAINING FOR THE INDUSTRIES OF TOMORROW

A strong bioeconomy requires investment in a new generation of scientists trained to pursue questions beyond the traditional scientific disciplines and biological sub-disciplines. NSF is investing in new modes of training -- from K-12 through graduate education and beyond -- that develop skill sets in cutting-edge technologies; promote highly collaborative team science; and foster greater diversity in the workforce, which is essential to advance the frontiers of what is possible through research and development.

For example, through Non-Academic Research for Internships for Graduate Students (INTERN), graduate students develop skills that prepare them for success in a broad range of career paths, from innovation and entrepreneurship to leadership and management. NSF also seeks to broaden participation in STEM fields during precollege years and at the undergraduate level to ensure a diverse pool of future STEM degree holders through funding opportunities like S-STEM, Computer Science for All (CSforAll) and Research Assistantships for High School Students (RAHSS).

ADVANCING THE BIOECONOMY ACROSS THE RESEARCH AND INNOVATION CONTINUUM

The research and innovation enterprise is a continuum spanning from basic science to translation, product development, commercialization and sustainability. A leader in the U.S. basic science enterprise, NSF also supports research and innovation across this continuum to advance American bioeconomic leadership.

Fundamental Research

Fundamental biological research to discover basic scientific principles -- without necessarily a clear application in view -- is the engine that drives innovation leading to growth across all bioeconomic sectors, including health care, pharmaceuticals, manufacturing and agriculture.

NSF's convergent approach spans disciplines and scales, making critical advances at the frontiers between life and physical sciences. For example, the NSF-Simons Research Centers for Mathematics of Complex Biological Systems bridge biology and mathematics to uncover the complex rules guiding fundamental biological processes, providing valuable insight for the development and successful implementation of future biotechnologies and applications.

Future Manufacturing to Advance the Bioeconomy

NSF investments in fundamental research will unlock scientific and technological advances to drive the future of advanced manufacturing, from new materials, processes and design methods to innovative new machines and technologies. NSF supports biomanufacturing, cybermanufacturing and ecomanufacturing research to enable emergence of new industries that don't exist today; meet growing societal needs and challenges; and reinforce U.S. manufacturing competitiveness far into the future.

For example, for more than three decades, NSF has supported Engineering Research Centers (ERCs) in biomanufacturing, biotechnology and health care. ERCs promote collaboration among researchers in different scientific disciplines and partnerships between industry and universities to produce both technological innovations that strengthen the competitive position of industry and engineering graduates who will be creative innovators in a global economy.

Clearing the Path to Commercialization

NSF helps American researchers advance their discoveries from innovation to application. For example, the NSF Innovation Corps™ (I-Corps™) program prepares scientists and engineers to extend their focus beyond the university laboratory and accelerates the economic and societal benefits of NSF-funded basic research projects that are ready to move toward commercialization. I-Corps links NSF grantees with established entrepreneurs, helping them transform their ideas into marketable products and services. The Small Business Innovation Research (SBIR)/Small Business Technology Transfer (STTR) programs similarly help to commercialize high-risk, high-impact technologies, awarding \$200 million annually to startups and small businesses across the country.

AMPLIFYING INVESTMENTS THROUGH PARTNERSHIP

Collaboration with other government agencies, industry and private foundations is essential to the development of a strong American bioeconomy. NSF leverages partnerships with key stakeholders across sectors in several ways. For example, NSF program officers act as liaisons to the Manufacturing USA Institutes, which consist of agency, industry and academic partners working to bridge the gap between academic and industry practice. NSF also invites proposals for basic research that have the potential to translate to the institutes or to use infrastructure at the institutes. NSF also catalyzes partnerships to leverage expertise, inspire research questions, drive innovation and provide critical workforce development opportunities, such as through the Industry-University Cooperative Research Centers (IUCRC) program and Grant Opportunities for Academic Liaison with Industry (GOALI) proposals.

ENSURING A SOCIALLY RESPONSIBLE BIOECONOMY

To better accelerate biotechnology product adoption and socially responsible use, NSF supports research on ethical questions and impacts arising from innovative new technologies and their integration into society. For example:

- **Societal and Ethical Impacts of Innovation:** NSF's Science and Technology Studies program and Ethical and Responsible Research program fund workshops and studies investing in a range of topics, including societal and social justice issues in synthetic biology; ethics and responsible innovation in genome engineering; and possible governance challenges that may arise in the current era of rapid scientific, technological and economic change.
- **Predicting Future Risks and Impacts:** NSF investment in ecoforecasting improves the ability to predict environmental consequences of major advances related to the bioeconomy. These advancements in predictive modeling capabilities are critical to measuring risks related to genomic manipulation of organisms; reducing uncertainty in developing regulations around new biotechnologies; and to aspects of biosecurity such as identifying and predicting the impact of biothreats.