## BIOTECHNOLOGY

**Biotechnology Funding**[1]

(Dollars in Millions)

| | FY 2022 Actual | FY 2023 Estimate Base | Disaster Relief Supplemental | | FY 2023 Estimate Total | FY 2024 Request |
|---|---|---|---|---|---|---|
| | | | Base | CHIPS and Science | | |
| BIO | $118.00 | $122.75 | $25.25 | - | $148.00 | $176.88 |
| CISE | 9.65 | 6.92 | - | - | 6.92 | 6.92 |
| EDU | 9.37 | 9.00 | - | - | 9.00 | 10.00 |
| ENG | 92.00 | 92.00 | - | - | 92.00 | 106.50 |
| GEO Programs | 10.00 | 10.00 | - | - | 10.00 | 10.00 |
| GEO: OPP | 1.60 | 1.60 | - | - | 1.60 | 2.00 |
| MPS | 75.63 | 62.20 | - | - | 62.20 | 62.20 |
| SBE | 1.68 | 1.50 | - | - | 1.50 | 1.50 |
| TIP | 30.00 | 35.31 | 17.27 | 16.48 | 69.06 | 93.05 |
| IA | 22.52 | 1.00 | - | - | 1.00 | 1.00 |
| **Total** | **$370.45** | **$342.28** | **$42.52** | **$16.48** | **$401.28** | **$470.05** |

[1] Funding displayed may have overlap with other topics and programs.

### Overview

Since the first genetic engineering experiments over 50 years ago, the U.S. has become a world leader in biotechnology, with resulting biotechnological products contributing over $900 billion in economic activity, approximately 5 percent of the U.S. GDP, in recent years[1]. As a field, biotechnology comprises the data, tools, research infrastructure, workforce capacity, and innovations that enable the discovery, utilization, and reprogramming of living organisms, their constituent components, and their biologically related processes. Advances in biotechnology areas include genome sequencing, editing, and synthesis; synthetic and engineered biology; chemical biology and chemical genetics; imaging and biosensing; and computational methods, including artificial intelligence and biomolecule structure prediction. Across these areas, multi-disciplinary, bio-related approaches from engineering, mathematics, physical sciences, social and behavioral sciences, and computational sciences are spurring rapid development in biotechnology capabilities that drive innovation for the U.S. bioeconomy. These capabilities also provide solutions to societal challenges, such as climate change and infectious disease, and provide the foundational and use-inspired research that will lead to the creation of goods and services that contribute to the agriculture, health, security, manufacturing, energy, and environmental sectors of the nation.

NSF has long supported the breadth of fundamental research that catalyzes the development of biotechnology. Current investments from programs in almost every directorate include research and infrastructure across scales--from the molecular, to the organism and ecosystem--encompassing

[1] Hodgson, A., Alper, J., Maxon, M.E. 2022. The U.S. Bioeconomy: Charting a Course for a Resilient and Competitive Future. New York, New York: Schmidt Futures. https://doi.org/10.55879/d2hrs7zwc.

studies from foundational to use-inspired, carried out by individual investigators, collaborative teams, and multi-institutional centers. NSF also invests in educational programs to prepare and enable a workforce to support U.S. needs in biotechnology, and NSF funds research on the ethical, social, legal, economic, and environmental consequences of synthetic biology and other biotechnologies that contribute to public understanding and socially responsible use. These investments enable biotechnology innovations that not only address societal problems, such as climate change, food security, and clean energy, but also promote development of a robust supply chain of biologically derived materials needed to ensure U.S. resilience to global interruptions. Biotechnology promises to enable new modes of computation, including for information storage, retrieval, and processing; foods and feedstocks that will provide raw materials for new bioindustries; new organs and organisms engineered for multiple purposes; technologies capable of sensing emerging infectious agents; self-healing materials for sustainable infrastructure; and other heretofore unimagined products, processes and technologies inspired by, or developed with, living systems. Biotechnology advances will enable novel predictive tools and platform technologies to empower the U.S. to react rapidly to new and emerging biological threats, to address economic and societal challenges, and to respond with solutions for unanticipated problems.

NSF has responded to many reports and policy papers—including from the Office of Science and Technology Policy (OSTP)[2], the National Academies of Science, Engineering and Mathematics[3], the Government Accountability Office[4], the Bioeconomy Research and Development Initiative included in the CHIPS and Science Act of 2022[5], and Executive Order 14081, Advancing Biotechnology and Biomanufacturing Innovation for a Sustainable, Safe and Secure American Bioeconomy[6]—to lead and coordinate interagency activities to promote synthetic and engineering biology, to develop next-generation tools to advance biotechnology, and to develop bold goals and research and development needs necessary to advance all sectors of the bioeconomy. NSF investments in FY 2022 and FY 2023 aimed at biotechnology innovation included programs for: Accelerating Innovations in Biomanufacturing Approaches through Collaboration between NSF and the DOE Bioenergy Technologies Office-funded Agile Biofoundry; Building Synthetic Microbial Communities for Biology, Mitigating Climate Change, Sustainability, and Biotechnology, Semiconductor Synthetic Biology Circuits for Communication and Information Storage; EFRI: Engineering Living Systems; EFRI: Brain-inspired Dynamics for Engineering Energy-Efficient Circuits and Artificial Intelligence; and new tracks on Sustainable Materials for Global Challenges and Food and Nutrition Security in the FY 2022 Convergence Accelerator solicitation. These programs build on programs initiated in FY 2021, e.g., Designing Synthetic Cells Beyond the Bounds of Evolution; Sentinel Cells for Surveillance and Response to Emergent Infectious Diseases; and Molecular Foundations for Biotechnology, and prior-year investments, e.g., Enabling Discovery Through Genomics; Future Manufacturing; Materials Innovation Platforms; Plant Synthetic Biology; and Reproducible Cells and Organoids via Directed-Differentiation Encoding. They also build on investments at the intersection of biotechnology and artificial intelligence and quantum sciences through the National Artificial Intelligence Research

[2]https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/national_bioeconomy_blueprint_april_2012.pdf

[3]www.nationalacademies.org/our-work/safeguarding-the-bioeconomy-finding-strategies-for-understanding-evaluating-and-protecting-the-bioeconomy-while-sustaining-innovation-and-growth

[4]www.gao.gov/products/gao-18-656

[5]www.govinfo.gov/link/plaw/117/public/167?link-type=pdf&.pdf

[6]www.whitehouse.gov/briefing-room/presidential-actions/2022/09/12/executive-order-on-advancing-biotechnology-and-biomanufacturing-innovation-for-a-sustainable-safe-and-secure-american-bioeconomy/

Institutes and Quantum Leap Challenge Institutes programs. Together, these new investments complement core programs in research, infrastructure, workforce development, and translation that advance U.S. competitiveness and leadership in biotechnology and the bioeconomy.

**Goals**

1. *Fundamental Research:* Support foundational and use-inspired research in science and engineering that will fuel innovations in biotechnology.
2. *Computing and Physical Infrastructure:* Develop the computing and physical infrastructure necessary to generate fundamental knowledge and advance accompanying biotechnology.
3. *Proof-of-Concept Advances:* Deliver proof-of-concept processes, devices, bio-based robots (biobots), applications, tools, and systems that enable the translation of fundamental advances for scientific and societal benefit.
4. *Education and Workforce Development:* Empower the full spectrum of U.S. talent to build the capacity to achieve the above goals and to generate the biotechnology-literate workers who will implement the results of these breakthroughs.

**FY 2024 Investments**

Fundamental Research

NSF will continue its support in the discovery of foundational biological principles and the development of biotechnologies and other tools that permit measurement and use-inspired manipulation and design of living systems and their components. New interdisciplinary partnerships across the agency will motivate bio-inspired design and stimulate use-inspired solutions, including through programs like Molecular Foundations of Biotechnology.

Computing and Physical Infrastructure

NSF will continue to invest in bioinformatics, computational biology, and artificial intelligence to support biotechnology. New synthesis centers in molecular and cellular biosciences and organismal biology will enable data synthesis and reuse for biological understanding and biotechnology design. To democratize access to essential research resources, NSF will establish a new Biofoundry program to support a network of center scale facilities with the express mission of developing new tools to advance biotechnology at multiple scales—molecular to organismal and ecosystem scale—and including multiple scientific foci, e.g., neurotechnology, artificial organs, bio-inspired materials, and bio-electronic devices. A seminal focus of the Biofoundry program will be to provide equitable access to enabling infrastructure, thereby building infrastructure capacity in institutions and geographic regions not currently well supported by NSF and ensuring that the necessary tools and capabilities for accelerating biotechnology research and development are broadly available to all.

Proof-of-Concept Development

Sustained support for synthetic and engineering biology as a pillar of biotechnology will accelerate the design-build-test-learn cycle and leverage bio-inspired design to develop bio-machines, biobots, and biomanufacturing technologies to address many of today's challenges. Biofoundries are an essential element in this cycle of proof-of-concept development. By providing broad, equitable access to infrastructure, the Biofoundry program will attract partnerships and drive economic acceleration, both in biotechnology and in linked areas of research and economic sectors. For example, biotechnology, robotics, AI, and semiconductor technology might leverage advances in synthetic and

engineering biology to build new storage media and devices that can take advantage of the high information storage capabilities of biological polymers. Advances in neuro- and nanotechnology could enable development of neuro-restorative devices that sense, respond, and learn. Synthetic microorganisms could serve as factories to provide new forms of clean energy and help mitigate impacts of changing climate. Plant biotechnology, aided by high-throughput transformation and phenotyping, could address food security and support advances in precision agriculture through production of crops better adapted to extreme environments or resilient to environmental change. New investments in regional innovation and Future Manufacturing will expand participation within the bioeconomy and accelerate the translation of biotechnology to solve societal problems. Partnerships, such as the pilot with NobleReach Emerge and those with other NSF Lab-to-Market programs such as the NSF Innovation Corps program, as well as new translational lineages such as the Pathways to Enable Open-Source Ecosystems program, will help accelerate the translation of all areas of biotechnology discovery and innovation into market products.

Education and Workforce Development

To prepare a diverse biotechnological workforce, NSF will invest through programs such as the Advanced Technological Education program at two-year institutions. Sites and supplements for Research Experiences for Undergraduates and Research Experiences for Teachers and supplements to support Non-Academic Research Internships for Graduate Students provide additional opportunities for training. The NSF Research Traineeship Program prepares graduate students to conduct research in convergent areas and acquire skills that allow them to succeed in diverse employment settings. NSF will also support training at the postdoctoral and early-career level through fellowships and participation in the NSF Entrepreneurial Fellows and Experiential Learning for Emerging and Novel Technologies programs, to enable scientists and engineers to further the societal benefits of their work. Through the Biofoundry network, NSF will support education and training that engages the broader STEM workforce in discovery and advanced biological and related technologies that can advance the U.S. bioeconomy and ensure national security.