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FUNDING BIOTECHNOLOGY'S FOUNDATIONS TO FUEL PRIVATE SECTOR INNOVATIONS

Testimony[3] presented before a Joint Meeting of the
Research & Technology and Energy Subcommittees of the
Committee on Science, Space, and Technology of the
United States House of Representatives

Hearing on "Pursuing the Golden Age of Innovation: Strategic Priorities in Biotechnology"

5 June 2025

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[3] The views expressed herein are solely those of the author and do not necessarily reflect the opinions or positions of any organization, institution, or individual the author may be affiliated or associated with.

WHY BIOTECHNOLOGY MATTERS AS A TECHNOLOGY

Biology is the next-to-mature general purpose technology.[4] Anything whose production or behavior we can learn to encode in DNA becomes growable or deployable when and where needed. We already use biotechnology to grow essential medicines, foods, fuels, and some materials.[5] Going forward we can leverage biotechnology to help grow data storage systems,[6] electronics,[7] energetics, consumer biologics,[8,9,10] advanced cellular agents,[11] living materials,[12] pervasive bio-sentinels,[13] and more. Emerging biotechnologies will also give us the option of working to make infectious diseases obsolete and of securing biology.[14]

BIOTECHNOLOGY IN CHINA

China has embraced biotechnology via an all-of-nation approach since ~2000.[15,16] One basic motivation includes food security. Compared to the United States, China must feed ~4-fold more people with ~25% less farmland.[17] Another motivation is unbridled curiosity and boundless possibility. The homepage for the Institute of Synthetic Biology at the Shenzhen Institute of Advanced Technology is representative, declaring "与其期待未来，不如自己创造" ("instead of waiting for the future, create it yourself").[18]

Students, entrepreneurs, policy makers, and leaders in China have together created a biotechnology behemoth operating on a national-scale. Many practitioners in China view biotechnology as a domain of multilateral collaboration and opportunity. Debating if China is ahead of the United States in emerging biotechnology is like arguing if the truck in the passing lane full of kids having a good time making money has overtaken the rear or front bumper of your station wagon. In too many key areas including biotechnology education, foundational research, entrepreneurship, and manufacturing China has or will soon pass the United States.[19] For more information please consider my February 2025 testimony before the U.S.-China Economic & Security Review Commission.[20]

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[4] https://www.scsp.ai/2023/04/scsps-platform-panel-releases-national-action-plan-for-u-s-leadership-in-biotechnology/
[5] https://www.planetarytech.earth/bioeconomy-dashboard-1
[6] https://dnastoragealliance.org/
[7] https://www.src.org/program/grc/semisynbio/semisynbio-consortium-roadmap/
[8] https://light.bio/
[9] https://www.norfolkhealthyproduce.com/
[10] https://zbiotics.com/
[11] https://www.darpa.mil/news/2024/rbc-factory
[12] https://www.mycoworks.com/
[13] https://news.mit.edu/2025/engineered-bacteria-emit-signals-spotted-from-distance-0411
[14] https://nap.nationalacademies.org/catalog/27652/future-state-of-smallpox-medical-countermeasures
[15] https://merics.org/en/report/lab-leader-market-ascender-chinas-rise-biotechnology
[16] https://time.com/7289325/biotech-race-with-china/
[17] https://www.cia.gov/the-world-factbook/
[18] https://isynbio.siat.ac.cn/en/
[19] https://www.bostonglobe.com/2025/02/21/opinion/us-china-biotechnology-innovation-manufacturing/
[20] https://www.uscc.gov/sites/default/files/2025-02/Drew_Endy_Testimony.pdf

WHAT IS AT STAKE

From an economic perspective up to "60% of the physical inputs to the global economy"[21] could be made via biotechnology by mid-century, generating ~$30 trillion annually in mostly-new economic activity.[22] How much of this economic opportunity ends up within the United States, our key allies, and partners will most easily depend on actions taken in the next 1,000 days. In turn, the scale of this economic opportunity will drive, and be driven by, ever wider proliferation of biological tools and capacities.

Thus, from a security perspective, we must anticipate and also begin to act now to secure a future in which many more will eventually have the option of accessing tools and knowledge sufficient to cause harm via biotechnology. One boat spraying test microbes off the coast of San Francisco was seemingly sufficient to deliver by fog infectious doses to an entire city.[23] The virus that more recently took offline a U.S. aircraft carrier was encoded by nucleotides not bytes.[24] We must acknowledge what may become possible from a biosecurity perspective and act now to reduce risks. Securing biology really would also minimize infectious diseases from a public health perspective, reducing economic burdens from disease domestically by hundreds of billions.

Finally, from a soft-power perspective most of the world will eventually adopt someone's "biotechnology stack," consisting of content, capacities, and policies that make routine partnering with biology to solve problems. Whose stack gets adopted matters. Not only for economic flourishing and national security but for supporting and strengthening relationships and creating or deploying leverage. Taken together we must consider biology as a strategic domain and act accordingly, soon enough to compete, lead, and win.

NATURE OF BIOTECHNOLOGY COMPETITIONS

Competitions come in different "flavors." In convergent competitions falling behind is not an existential issue, you can catch up later (e.g., competing coffee chains). In divergent competitions taking the lead generates advantages that accumulate, making it increasingly difficult for competitors to catch up (e.g., web search). In some cases divergent competitions produce winner-take-all outcomes that lock others into the winner's entrenched solution (e.g., social networks, operating systems).

At least some of the most-critical races in emerging biotechnology are taking the form of divergent or winner-take-all competitions. Consider a research manuscript posted last Saturday,

[21] https://www.mckinsey.com/industries/life-sciences/our-insights/the-bio-revolution-innovations-transforming-economies-societies-and-our-lives
[22] https://www.forbes.com/sites/johncumbers/2022/09/12/white-house-inks-strategy-to-grow-trillion-dollar-us-bioeconomy/
[23] https://en.wikipedia.org/wiki/Operation_Sea-Spray
[24] https://en.wikipedia.org/wiki/COVID-19_pandemic_on_USS_Theodore_Roosevelt

"DNA framework array enables ultra-high throughput DNA synthesis."[25] The Shanghai-based authors "present a DNA framework-based bottom-up enzymatic synthesis strategy that enables single-molecule level control of DNA synthesis with high-throughput" claiming a 10,000 fold potential improvement in DNA synthesis density and costs. What does this mean? DNA encodes all life. Being best at building DNA provides an advantage for all of biotechnology. The authors are using bioengineered DNA as a molecular scaffold for building more DNA. The newly synthesized DNA is being built by an enzyme that is itself DNA encoded. More simply, biology is being bioengineered to help bioengineer biology, creating a positive feedback and conditions sufficient for divergent competition. I know of no sustained federal effort seeking to systematically advance the building of DNA despite advocating for such work for 22 years.[26]

Potential winner-take all competitions are currently setting up, too. For example, iGEM is a global genetic engineering "olympics"[27] that runs on an open-source DNA code base. Students around the world access and contribute to the iGEM codebase. Most recently, the physical production of the iGEM DNA distribution moved from Boston to Shenzhen, as labs and companies in Boston could suddenly no longer afford to conduct the work. As a second example, researchers are increasingly close to building simple synthetic cells from purified mixtures of biomolecules.[28,29] The first so-constructed cells will be Sputnik-like – demonstrations most useful for more sophisticated demonstrations. Over time such work will lead to operating systems for life, routinizing bioengineering at the cellular scale. Whoever develops such capacities first will gain a powerful platform underlying biotechnology globally (i.e., like UNIX).

FIGHTING TO FUND BIOTECHNOLOGY'S FOUNDATIONS

From a "War on Cancer"[30] to a "Cancer Moonshot"[31] gaining public support and funding for urgent applications of biotechnology has always been easier than fundamental discovery science and tool development. Even our nation's bastions of foundational research – NSF, NIST, DOE – are overdriven by Congressional guidance towards short term utility and translation.[32,33] Over time U.S. public funding for biotechnology becomes misallocated. We tend to spend precious public treasure on the immediate applications of biotechnology.[34] But because the applications of biotechnology are boundless, demands for appropriations grow unbounded, all while we fail to sustain sufficient public investment in the foundational science and tool development needed to generate evergreen improvements in how we partner with biology to solve problems. No other

[25] https://www.biorxiv.org/content/10.1101/2025.05.30.657018v1
[26] https://dspace.mit.edu/handle/1721.1/38455
[27] https://igem.org/
[28] https://www.biorxiv.org/content/10.1101/2021.03.03.433818v1
[29] https://www.buildacell.org/
[30] https://en.wikipedia.org/wiki/War_on_cancer
[31] https://en.wikipedia.org/wiki/21st_Century_Cures_Act
[32] https://www.energy.gov/eere/bioenergy/about-bioenergy-technologies-office
[33] https://www.nsf.gov/tip/about-tip
[34] The pressures to do so are justified (e.g., cure diseases, save environments, win now) but hinder progress longer term.

domain of emerging technology has seen its development hindered by overbiasing towards immediate applications as much as biotechnology.

For obviously critical tool platforms (e.g., DNA synthesis, strain engineering) the U.S. private sector has attempted to fill the gap. But more often than not the private sector fails to mature new tool platforms fast enough to realize venture-returns and sustain commercial success. Consider why the price of building genes in the U.S. has not improved significantly since Gen9 was acquired in 2017.[35] Ponder how much money the U.S. government spends annually sourcing or making DNA to support the research scientists most want to do. Wonder why the U.S. government has not created something akin to a "strategic DNA initiative"[36] to improve the sourcing of DNA to support all public and private sector biotechnology research. If we wait too much longer we can anticipate learning new acronyms akin to TSMC[37] but for building DNA, perhaps SDMC (Shanghai DNA Manufacturing Corporation).

The single most impactful qualitative change Congress could make to improve U.S. biotechnology competitiveness going forward, to avoid duplication of effort between the public and private sectors, and to make best use of precious public treasure, would be to prioritize spending public funds on foundational discovery science and biotechnology tool development. Whichever nation best understands biology, from cells to ecosystems, will hold an extraordinary advantage in imagining and making biotechnologies real. Whichever nation best sustains improvements in the tools needed to measure, model, and make biology will get there first.

OPPORTUNITIES WITHIN THE JURISDICTION OF THE US HCSST

(1) Task and support NIST in creating a Bio-Measurement Laboratory (BML). The NIST BML should push the limits of measurement science in biology to establish and promulgate standards that accelerate scaling of the US bioeconomy and guarantee that as much of the world as possible is operating on America's biotechnology stack. Leading in biometrology and standards setting will advantage all US activities including in artificial intelligence for biotechnology, biotechnology regulation, biosafety and biosecurity policy, and more. World-leading standards are also essential for enabling and improving reproducibility in and public trust of the life sciences. Support must go for staffing and research at NIST itself and not pass through to outside centers, institutes, or partners.

(2) Task and support DOE in creating one or more National Biotechnology Accelerators whose primary mission is to relentlessly improve how researchers practice biotechnology and its underlying workflows (i.e., measuring, modeling, and making with biology). History teaches us that public treasure gains the highest leverage when taxpayer money

[35] https://www.prnewswire.com/news-releases/ginkgo-bioworks-acquires-leading-synthetic-dna-provider-gen9-300393701.html
[36] https://en.wikipedia.org/wiki/Strategic_Computing_Initiative
[37] https://en.wikipedia.org/wiki/TSMC

supports developing the tools that entrepreneurs later build upon for free.[38] World-leading biotechnology tools are an absolute requirement if the United States is to be the world leader in biotechnology. Such accelerators would be distinct from and complementary to the Centers for Biotechnology called for by NSCEB Recommendation 4.3A.[39]

(3) Task and support DOE in creating one or more Large Language Laboratories (LLLs) whose mission is to guarantee the United States has the world leading foundation models in biology and biotechnology. Such LLLs would also be distinct from and complementary to the Centers called for by NSCEB Recommendation 4.3A.

(4) Reorient the National Science Foundation to primarily support foundational science and engineering research in biology and biotechnology. Within this portfolio include support for foundational grand challenges in biotechnology consistent with NSCEB Recommendation 4.3B. Organizationally, create and support a virtual directorate joint between NSF ENG and NSF BIO that is purpose built for 21st century biotechnology. Task NSF with exploring more effective models for allocating research funds.[40]

(5) Establish a National Biotechnology Coordination Office (NBCO) within the Executive Office of the President consistent with NSCEB Recommendation 1.1A.[41]

SELECTED NEEDS OUTSIDE DIRECT JURISDICTION OF THE US HCSST

In February 1975 scientists gathered at Asilomar, CA to discuss biosafety frameworks for first-generation genetic engineering. In February 2025 a 50th anniversary summit occured.[42] Over two dozen entreaties have since been endorsed by summit participants and should become available via Rice University's digital library this week. Among the most-endorsed entreaties will be calls for a renewed de-escalation of nation-state bioweapons programs, for the development of more equitable bioeconomies (e.g., half of those who need lack reliable access to insulin[43]), and for better approvals processes and governance of biotechnologies deployed beyond conventional containment frameworks.

Returning to biosecurity, a number of Congressional actions will be needed to secure biology. Leading on biotechnology and growing the U.S. bioeconomy are necessary but insufficient. A comprehensive study from Hoover's Bio-Strategies & Leadership team detailing a holistic and resilient strategy for securing biology will become available later this summer.[44]

[38] https://nap.nationalacademies.org/read/24656/chapter/1
[39] https://www.biotech.senate.gov/final-report/chapters/chapter-4/section-3/
[40] https://www.hypothesisfund.org/
[41] https://www.biotech.senate.gov/final-report/chapters/chapter-1/section-1/
[42] https://www.spiritofasilomar.org/
[43] https://www.doctorswithoutborders.org/latest/diabetes-only-half-people-who-need-insulin-world-have-access-it
[44] https://victory.stanford.edu/