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MEASURES FOR VICTORY

Securing American Biotechnology Leadership

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[2] The views expressed herein are solely those of the author. Nothing in this statement represents a finding, recommendation, opinion, or conclusion of any Committee, Subcommittee, Department, Organization, or Institution the author may be affiliated with.

BIOLOGY IS A STRATEGIC DOMAIN

Unlocking biology as a general-purpose technology could add up to a third to our nation's GDP, make supply chain and manufacturing resilience real for most physical inputs to our economy, help secure Americans and others from biological threats, and create a foundation of optionality underlying economic and political freedom at home and abroad.[3,4] These are not far away or abstract claims made lightly. A mRNA virus took a US Navy carrier out of action earlier this decade. Many essential medicine supply chains can be reshored via leap-frog advances in bio-based manufacturing. A brewing process that makes a medicine can be reprogrammed to make energetics. New World Screwworm could likely be eradicated, not just pushed back, with next generation biotechnology approaches to insect control. And so on.

The sheer number, diversity, and urgency of biotechnology applications make the field more challenging to understand where things stand, and where public investments or governance can make a difference.

BIOTECHNOLOGY WAS BORN HERE

Warren Weaver of the Rockefeller Foundation organized funding for what became molecular biology in the 1930s. His choice mattered because molecules turn out to be the physical level of resolution at which living systems operate and can be reprogrammed or composed.

It then took 40 years of extraordinary basic science until a foundation of knowledge filled in sufficient to unlock the beginnings of modern biotechnology. As one example, restriction enzymes, zinc fingers, TALENs, and CRISPR-Cas systems illustrate a four-decade US-led run advancing foundational tools enabling ever better gene editing and, in turn, everything gene editing enables. DNA sequencing, polymerase chain reaction, DNA synthesis, gene and genome assembly, generative biology, synthetic cell biology, and many more examples can be found of other extraordinarily powerful foundational biotechnology tools that were pioneered and advanced in the United States.

Making real practical applications of modern biotechnology depends on such tools. Recombinant insulin for treating diabetes was made real with first generation gene editing. So were better enzymes for laundry detergents and ice-structuring proteins for low fat ice creams. Because the United States led in the basic science of molecular biology we led in the development of the tools for molecular biotechnology. Because we led the world in developing the tools for biotechnology we developed the world-leading bioeconomy, accounting for 25% of biotechnology's global economic impacts. We will lose our lead if we stutter or stumble at all on basic bioscience research or foundational tool development.

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[3] https://www.uscc.gov/hearings/made-china-2025-who-winning
[4] https://science.house.gov/hearings?ContentRecord_id=6788C987-B83B-4608-9279-281F100FEA9D

WE UNDERESTIMATE BEIJING ON BIOTECHNOLOGY

When I visited Beijing around 2010, I had dinner with the then Minister of Agriculture. I asked him what he found surprising about China; having "sufficient food and water" was his response. China must feed about four times as many people using less farmland than the United States. I share this anecdote to respectfully suggest that those in Washington DC and other Western capitals may still not fully understand the depth and diversity motivating the practical and sustained urgency behind China's ascendance as a global biotechnology power.

Operational mastery of living matter will provide a platform supporting bottom up and distributed manufacturing of anything bioengineers can learn to encode in DNA. I ask you to not think about biotechnology in the context of existing organisms and natural lineages. Do not limit your thinking to the de-extinction of dire wolves and woolly mammoths either. Ponder what it will mean to become capable of programming the bottom-up self-assembly of complex materials and objects with atomic precision. Ponder what will become the foundations of a deep and structural transformation in our ability to manufacture and transform materials and energy on a planetary scale. Ponder when the beyond astronomical possibilities of what biology could be become accessible to the tools of generative and synthetic biology.

Now imagine President Xi, prioritizing goals that include "complete domestic circulation" of China's economy, to "improve and stabilize" supply chains, to "improve the mix of scientific and technological inputs and outputs," to "ensure harmony between humans and nature," and to "develop a bottom-up (public health) system that ensures early detection, warning, and response so as to control diseases as they arise."[5] Imagine considering and acting consistently over multiple five year planning cycles to advance solutions for provisioning sufficient joules, bits, and atoms for the Chinese people and others. While we chase amorphous self-serving ambitions and change course every few years, Beijing can see the value of seizing the 21st century's "reality engine."

The impacts of Beijing's pro-biotech posture are hard to overstate. There is a joy and enthusiasm for biotechnology throughout China's education, research, and business ecosystems that spill over globally. Last fall while attending the global genetic-engineering Olympics I helped start decades ago, I spoke with a 20-year-old man from Shanghai who was dressed in a crawfish costume. His project was to bioengineer better enzymes for reclaiming and repurposing the materials comprising crawfish shells. I asked him why this might matter. He said that when Chinese astronauts travel to Mars, they will need to have spicy crawfish soup for lunch; he wanted Chinese astronauts on Mars to more readily remember that they are Chinese. Most students in this competition are now from China; some US students even travel to China to find teams to join and compete on. Why? From Shenzhen to Tianjin, biotechnology's vibe is good in China.

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[5] http://en.qstheory.cn/2021-01/14/c_604551.htm

WHERE AMERICAN BIOTECHNOLOGY STANDS IN RELATION TO CHINA

My February 2025 testimony before the USCC provided a full stack "snapshot in time" assessment of the then-state of play regarding biotechnology competition.[6] Bottom line up front: the United States has not suddenly gotten bad at biotechnology; rather, we are being overtaken by a more determined, hardworking, and better organized and resourced competitor.

For example, the Shenzhen Institute of Advanced Technology continues to operate as a world-unique, national lab-like facility for research and translation in synthetic biology, announcing in May their leadership of a 10-year Asia-wide initiative advancing synthetic cell research.[7] While an academic colleague in Minnesota announced earlier this month a world-first synthetic cell just barely capable of growth and division, Shenzhen has a 5,000-person team ready to take such work forward with speed and scale.

As another example, in April 2026 Stanford's Center on China's Economy and Institutions reported that, in 2020, China surpassed the United States in the number of clinical trials overall, and in the number of clinical trials for novel medicines in 2023.[8] In 2025, one-third of the pharmaceutical industry's licensing spend went to sourcing new medicines from China.[9] And in June 2026, the US-China Biomedical Competitiveness Scorecard, based on a survey of US-based leaders in industry and academia, reported China and the US are now tied on scientific discovery, China dominating clinical trials, manufacturing, and supply chains, and the US leading on technology transfer, talent, and finance.[10]

Senator Todd Young put matters plainly last month, stating that "China's biotech strategy is clear, and it's a playbook we have seen before — corner the market, scale the technology, and then strangle supply chains to gain strategic advantages."[11] Senator Young's statement is consistent with what I know; unpublished analysis I reviewed this month suggests China is on track to bring online more new industrial biomanufacturing capacity than the rest of the world combined.

Congress' National Security Commission on Emerging Biotechnology went further, writing, "The CCP is taking action across five key domains of biotechnology prioritization, all of which were included in the NSCEB's April 2025 action plan: National Strategy, Regulations, Infrastructure, Investment, and Data." Restated, Washington and others have been writing the playbooks for biotechnology leadership that Beijing is already reading and running with. They will likely read this testimony too and act accordingly.

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[6] https://www.uscc.gov/sites/default/files/2025-02/Drew_Endy_Testimony.pdf
[7] https://english.cas.cn/newsroom/research-news/202605/t20260528_1159994.shtml
[8] https://sccei.fsi.stanford.edu/china-briefs/china-now-global-drug-innovation-powerhouse-industrial-policy-had-little-do-it
[9] https://www.biopharmadive.com/news/china-biotech-drug-licensing-deals-pipeline/758283/
[10] https://wewillcure.com/insights/innovation-index/united-states-vs-china-biotech-scorecard
[11] https://www.biotech.senate.gov/press-releases/u-s-vs-chinese-action-against-key-nsceb-recommendations/

BIOLOGY IS THE LAST BASIC SCIENCE TO UNLOCK AS A TECHNOLOGY

Physics and chemistry were the two basic sciences humanity mastered in the 19th and 20th centuries. Biology is following and is already far enough along to matter, yet still not close to realizing its full potential.

Why? Living matter has unique physical properties that are qualitatively unlike those found in the substrates from which other modern technologies are built.

To help make sense of my claim first take a step back. Technologies operate across up to three dimensions: energy, information, and matter (i.e., joules, bits, and atoms). Advances unlock when one dimension is added to the others. A wheel by itself (atoms only) rolls down a hill. A wheel combined with a motor and energy source (atoms and joules) can ascend a grade. Wheels combined with motors, fuel, sensors, and computing (atoms, joules, and bits) can become self-driving cars.

Living matter begins at the intersection of joules, bits, and atoms: photosynthesis (joules), genomes (bits), and ribosomes (atoms that wrangle atoms). The dimensions are intertwined from the start. DNA is information as matter, for example. Even simple living cells are stuffed up to forty percent full of molecules, thousands of distinct kinds. There is still not one natural living cell for which we understand all its life-essential molecules. Each molecule is moving spontaneously due to background thermal energy, colliding randomly with other molecules a billion times a second. Together molecules comprise cells, the fundamental units of life. Cells take simple chemical inputs and make more cells. Each new cell differs slightly from its parent, at random, leading to profound differences over generations. Meanwhile, molecular machines inside cells decode genetic instructions that make molecules from scratch, with atomic precision.

Imagine if the transistors inside your cell phone were all moving around spontaneously. Imagine if you could feed your cell phone sand and it would spontaneously get bigger until, suddenly, you had two cell phones. Wetware is neither hardware nor software. Biotechnology's foundations are the deep frontier.

BIOTECHNOLOGY'S APPLICATION TRAP

From a historical perspective the United States knows well how to advance and translate foundational science into world leading technologies. Lead development of the tools for measurement, modeling, and tinkering sufficient to lead on foundational science and do the science. Lead development of the tools for design, prototyping, and testing sufficient to translate knowledge into world-leading innovations and innovate. Support and give away the preceding via public funding sufficient to enable private sector entrepreneurship, competition, and industry capable of supplying free markets at scale.

A unique challenge in biotechnology has been and remains the urgency of biotechnology's application layer. Imagine being a computer science researcher and only finding support for new mobile phone apps that help patients or doctors tomorrow. Something that takes weeks or months to have impact has no chance of funding. A new programming language, software compiler, or computer operating system would trigger well intended questions of relevance and dismissal – "which of my diseases will your new compiler cure right away?" ask the sponsors.

Ask a different but related question. Why might big biotechnology advances like CRISPR gene editing only occur once a decade or so? Is it because such opportunities are rare? Or is it because the field of biotechnology overdrives research investments with demands of immediate utility, more so than any other field in the history of emerging technologies? My bet is on the latter. Imagine if ARPA had insisted on immediate utility to the war fighter regarding packet-switching research in 1975.

One underlying difficulty deserves further noting. Democracies answer to voters who, reasonably, want individual returns now or at least soon. Systems not answerable to voters can defer. This additional *"from decision making to returns and accountability"* asymmetry is real and makes biotechnology's application trap still more challenging to navigate. Staying the course will require Congress to fund work whose payoff arrives after the next election.

MEASURING WHAT MATTERS

Start by noting there are different types of competition – converging, diverging, and winner-take-all, for example. In converging competitions falling behind is recoverable; all competitors keep the option of completing the race. In diverging competitions early leads compound; those who fall behind risk being left behind. In winner-take-all competitions the winner's solution becomes the foundation everyone else must build from.

Much of biotechnology's application layer is convergent. Losing the race to develop one drug costs only a single drug. Second- and third-to-market entrants routinely beat the pioneer. But the enabling research infrastructure and translation ecosystem supporting the process of drug development and successful translation to full-scale markets are trickier. Ignored for too long and the capabilities needed to lead in research, manufacturing, and go-to-market sublimate.

Much of biotechnology's discovery and innovation engine is divergent. The reason is that many of the best tools for advancing bioscience and biotechnology are made from biology itself. Just like Hewlett and Packard long ago used electronics to instrument and make better electronics, putting in motion what eventually became Moore's law, discovery and mastery of biomolecules that can be used to control energy, information, and material inside cells become the tools for discovering and mastering the next generation of useful biomolecular tools. Early leads compound.

Finally, as biotechnology fully matures, we should expect that winner-take-most or winner-take-all competitions will emerge. UNIX was developed as a simple operating system with the goal of making computer programming easier. UNIX was developed once, in New Jersey, to the great benefit of the United States. TCP/IP for data-type agnostic packet-based networking and Github for ready reuse and sharing of software code offer similar lessons. Where will the operating system for life at the cellular scale get developed? Who will advance the foundations needed to realize a distributed 'bionet' enabling manufacturing resilience via download-and-grow DNA protocols? Who will host (and control) the content repositories for programming life?

Framed this way we have a better chance of identifying metrics that may be used to guide public investments in emerging biotechnology and hold so-supported programs accountable. Here are twelve representative examples:

(1) Who is the best in the world at building DNA, going from bits to atoms on demand for the polymer of life?
(2) How many life-essential genes of unknown function(s) remain for organisms of greatest practical importance?
(3) How many of the elements on the Periodic Table can we sense, organize, and deploy using biotechnology?
(4) How complex of a genetically encoded system can be bioengineered on demand and shown to work reliably the first time?
(5) How much effort does it take to get a novel biotechnology product prototyped? Who is best at prototyping? How fast are we getting better?
(6) How much effort does it take to get a novel biotechnology product to market? Who is best at bringing new products to market? How fast are we getting better?
(7) Who has the fastest or most efficient biomanufacturing processes, going from feedstock to product at the greatest rates and yields? How far from theoretical performance limits are we?
(8) During the next pandemic, who can best sustain normal operations with the lowest costs and casualty rates?
(9) What fraction of what the United States needs or consumes can be grown in the United States?
(10) What fraction of the global bioeconomy is in or enabled by U.S. biotechnology?
(11) What percentage of people in the United States can read and write DNA? How does our practical bio-literacy level compare to others?
(12) How do Americans feel about biotechnology? How many Americans love biotechnology?

Note that the above metrics tend to be approach or solution agnostic. Most focus attention or select for improvement in tools, workflows, and systems of innovation and translation.

SMARTER PUBLIC FUNDING

The United States should be smarter with how we spend limited public treasure on advancing and securing biotechnology. The most useful change would be to redirect even a modest amount (~10%) of application-focused funding towards foundational science, tooling innovation, and workflow improvements. Doing so would help guarantee that the United States maintains or reclaims its leadership position for biotechnology's most critical diverging-type competitions. Doing so would also require reversing recent trends by which evermore public funding goes towards immediate economic translation; public treasure spent renewing the soil from which the next harvest of scientific discovery and technical invention arrives is well spent.

We should also consider carefully the potential macroeconomic returns from growing our nation's world-leading position in the global bioeconomy. One presentation last Friday at the public DOE SCAC meeting challenged the United States to grow its direct bioeconomic activities from today's $1 trillion of $4 trillion to $10 trillion of $30 trillion globally within 20 years. Framed this way relatively modest and well managed strategic programs could have extraordinary economic returns.

Finally, we should confront the confusion between academic research carried out by students or postdocs relative to professionally staffed research conducted by corporations or national laboratories. The primary purpose of the former is to produce researchers – students who have become better at science and innovation, who make discoveries and inventions as a bioproduct of their training, and who become professional researchers. The primary purpose of the latter is to get specific tasks done, from the simple to greatest grand challenges. Both types of research, training and directed, are essential to our nation's security and prosperity.

FREEDOM OF SCIENCE, COMPETITION, & LEADERSHIP

China's biotechnology campuses rival what our nation built for high-energy physics last century. Bush's *Science, the Endless Frontier* and Fermilab are the same civilizational act. A nation that had just won a war chose to invest in both understanding and utility. The courage to do both is what we now risk losing just as China claims such confidence.

In 1969, when Senator John Pastore asked Robert Wilson whether Fermilab's accelerators would help defend the nation Wilson replied, "it has nothing to do directly with defending our country, except to help make it worth defending." Wilson could separate the two because our leadership in science and technology was largely uncontested and most frontiers were ours to walk alone.

Such separation is no longer available. In the competition we now face the freedom of American science is not simply part of what makes our country worth defending, it is how we defend it. China's wager is not that people will obey; rather that a watched people will remain productive, that innovation and surveillance hold together indefinitely. Our counter-wager is that free people discover faster. But a wager is not a strategy. Freedom outperforms only when free people hold the tools — and right now we ask American scientists to win a compounding race with instruments we risk no longer building.

ONE SPECIFIC RECOMMENDATION

In my personal capacity I believe there is one action you could take now that is well-aligned with the structure of biotechnology competition and would matter greatly.

Most American high schools offer three basic sciences — physics, chemistry, and biology. NIST under Commerce has a Physical Measurement Laboratory (PML) for all of physics, and a Material Measurement Laboratory (MML) for all of chemistry. For biology, NIST has just two strong-but-modest bio-related divisions within the MML.

NIST needs a fully resourced Biological Measurement Laboratory (BML) for all of biology.

My request is not new. I asked the U.S.-China Economic and Security Review Commission for such a laboratory in February of 2025, and the House Committee on Science, Space, and Technology in June of 2025.

The Commission agreed. The Commission's fourth most-urgent overall recommendation in its November 2025 report to Congress reads: "Resource the National Institute of Standards and Technology (NIST) to establish a Bio-Measurement Laboratory (BML). The BML should develop, support, and promulgate standards for biological measurements, materials, and models; advance measurement science and tools for biotechnology; and ensure U.S. standards are adopted globally as the foundation of the 21st-century bioeconomy."[12]

A bipartisan group of House members also agreed and introduced the Standards and Calibration for American Leadership in Engineering Biology (SCALE Biology) Act in May 2026.[13] Jurisdiction over NIST rests with this Subcommittee.

Because such a laboratory still does not exist, today I am asking a third time. The case has only grown stronger. The competition is live. Congress can and should enable NIST to build and operate a Biological Measurement Laboratory.

There are many other high-leverage investments that could be made as described in my prior testimony and elsewhere. I would be happy to discuss any of these or others.

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[12] https://www.uscc.gov/sites/default/files/2025-11/2025_Annual_Report_to_Congress.pdf
[13] https://mcclaindelaney.house.gov/media/press-releases/rep-mcclain-delaney-announces-new-bipartisan-bill-advance-us-leadership