Beyond the Label: The Strategic Imperative of the Bioeconomy

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I. Introduction

The resilience of America's pharmaceutical supply chain has become an increasingly important policy issue as concerns have grown regarding foreign ownership, manufacturing concentration, and strategic dependencies within the healthcare sector. These issues warrant continued attention. However, they represent only one dimension of a broader transformation occurring across biotechnology and the global bioeconomy.

This testimony is informed by more than two decades of experience at the intersection of biotechnology, national security, counterintelligence, public health, and emerging technologies, including support for Operation Warp Speed and service advising the United States Government on emerging and disruptive technologies. The observations presented herein are intended to provide a broader strategic framework through which foreign ownership and control within America's pharmaceutical supply chain may be evaluated.

The central proposition of this testimony is straightforward:

America's pharmaceutical supply chain cannot be fully understood in isolation because it is embedded within a broader bioeconomy ecosystem that increasingly influences healthcare, agriculture, manufacturing, artificial intelligence, energy, economic competitiveness, and national security.

Accordingly, understanding what lies *behind* the pharmaceutical label first requires looking *beyond* the label itself.

The country listed on a pharmaceutical package identifies where a product was manufactured. It does not identify where scientific capability resides, where manufacturing expertise is accumulating, where clinical knowledge is generated, who establishes technical standards, where biological data are being transformed into strategic advantage, or where the next generation of biotechnology innovation will emerge. Increasingly, these less visible elements determine long-term national resilience.

The evidence presented throughout this testimony suggests that biotechnology has evolved beyond an individual economic sector to become enabling infrastructure supporting multiple sectors of critical national importance. Viewed through that broader lens, pharmaceutical resilience becomes inseparable from the Nation's capacity to sustain scientific leadership, advanced manufacturing, agricultural productivity, workforce development, and technological innovation throughout the biological century.

II. Beyond the Label

Traditional assessments of pharmaceutical resilience have appropriately focused on manufacturing location, active pharmaceutical ingredient production, foreign ownership, and geographic concentration within critical supply chains. These remain important considerations. Increasingly, however, they no longer capture the principal sources of long-term strategic advantage.

The pharmaceutical label identifies the physical origin of a product. It does not reveal where scientific knowledge is generated, where manufacturing capability is refined, where clinical experience accumulates, where regulatory expertise matures, or where future innovation ecosystems are being developed. Those capabilities increasingly determine which nations possess the capacity to continuously discover, manufacture, improve, and commercialize successive generations of biotechnology.

This distinction reflects an important evolution in strategic competition. Historically, biotechnology policy appropriately emphasized intellectual property protection and preventing unauthorized technology transfer. While those concerns remain valid, competition increasingly extends beyond acquiring today's technologies. Nations are now investing in the scientific, industrial, educational, regulatory, and manufacturing ecosystems capable of producing tomorrow's innovations on a sustained basis.

This broader perspective also changes how foreign ownership should be evaluated. Ownership of manufacturing facilities represents one component of a much larger system. Equally important are the movement of talent, the location of clinical development, the accumulation of manufacturing expertise, the governance of biological and clinical data, participation in standards development, and long-term investments in research, infrastructure, and workforce development. Viewed individually, these activities may appear unrelated. Viewed collectively, they determine where future biotechnology leadership will reside.

Accordingly, the strategic question extends beyond where medicines are manufactured today. It includes whether the United States will continue to possess the integrated scientific, manufacturing, regulatory, industrial, and educational ecosystem necessary to discover, develop, manufacture, and continuously improve the medicines upon which future generations will depend.

The ecosystem—not the label—is increasingly the strategic signal.

III. The Bioeconomy: From Economic Sector to Strategic Infrastructure

Understanding what lies beyond the pharmaceutical label requires recognizing a broader structural transformation occurring within biotechnology itself.

For much of the past half-century, biotechnology has appropriately been viewed as a distinct scientific discipline and an important sector of the economy. Public discussion has traditionally focused on pharmaceuticals, vaccines, medical research, agricultural biotechnology, and more recently synthetic biology. While these remain essential components of the biotechnology enterprise, they no longer fully describe biotechnology's strategic significance.

Biotechnology increasingly functions as an enabling capability supporting multiple sectors of critical national infrastructure simultaneously.

Healthcare, agriculture, advanced manufacturing, and artificial intelligence increasingly depend upon advances in biotechnology. Sectors once viewed largely independently are becoming interconnected through shared biological capabilities, data, manufacturing platforms, and innovation ecosystems.

This convergence fundamentally changes how biotechnology should be understood. Earlier generations witnessed similar transformations as electricity evolved from an emerging technology into essential infrastructure supporting virtually every sector of modern society. Likewise, the internet evolved from a communications network into foundational infrastructure enabling commerce, finance, education, healthcare, manufacturing, and government. The strategic importance of these technologies ultimately resided less in the products they created than in the systems they enabled.

Biotechnology is undergoing a comparable transition. Its strategic value no longer resides solely in what it produces, but increasingly in what it enables across multiple sectors of critical national infrastructure.

This distinction carries important implications for public policy. Decisions affecting healthcare increasingly influence agriculture. Agricultural policy increasingly influences manufacturing. Manufacturing increasingly depends upon artificial intelligence, biological data, workforce development, and resilient supply chains. Sectors that have historically been considered independently are becoming increasingly interconnected through the expanding capabilities of biotechnology.

The bioeconomy should therefore be viewed not simply as another sector of the economy, but as strategic infrastructure supporting national resilience, economic competitiveness, scientific leadership, and long-term prosperity.

Recognizing this transformation provides a more useful framework for understanding the increasingly global competition now taking shape around biotechnology.

IV. Global Biotech Competition: Building Innovation Ecosystems

Recognizing the bioeconomy as strategic infrastructure also changes how global competition should be understood.

For much of the twentieth century, technological competition was often measured by individual achievements. The Space Race, for example, was symbolized by satellite launches, lunar exploration, and advances in aerospace engineering. Those accomplishments were never solely about rockets. They reflected national investments in education, research institutions, manufacturing, engineering, supply chains, and scientific talent. The visible achievements were manifestations of a much broader innovation ecosystem.

Increasingly, nations are not competing simply to develop the next breakthrough therapy or medical device. They are competing to establish the scientific, industrial, manufacturing, regulatory, educational, and financial ecosystems capable of producing successive generations of innovation. Long-term competitiveness is becoming less dependent upon individual discoveries than upon the capacity to repeatedly generate, scale, and continuously improve biological technologies.

This broader perspective provides a more useful framework for understanding China's biotechnology strategy.

China's biotechnology initiatives are often discussed individually through programs such as **Healthy China 2030**[1], the **14th and emerging 15th Five-Year Plans**[2], **China Standards 2035**[3], precision agriculture, industrial biotechnology, artificial intelligence, and biomanufacturing. Viewed independently, these appear to represent separate policy initiatives. Viewed collectively, they reflect a coordinated effort to strengthen the enabling infrastructure supporting long-term biotechnology leadership.

Importantly, this observation should not be interpreted solely through the lens of geopolitical competition. China's biotechnology strategy reflects recognition of a series of real and interconnected national challenges, including an aging population, declining workforce demographics, rising healthcare demands, food security, environmental sustainability, and the need to sustain long-term economic growth. Biotechnology is increasingly viewed as an enabling capability capable of addressing these domestic challenges while simultaneously strengthening industrial capacity, technological leadership, and long-term national resilience.

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[1] *Healthy China 2030 Planning Outline, State Council of the People's Republic of China (2016).*

[2] *The Fourteenth Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Outline of Vision 2035* (2021).

[3] *China Standards 2035 (战略性新兴产业标准化发展规划 / associated national standardization policy initiatives).*

At the same time, these investments extend well beyond domestic policy objectives. Leadership in biotechnology increasingly creates opportunities to shape international standards, expand manufacturing capacity, strengthen supply chain relationships, influence global markets, and deepen scientific and commercial partnerships. The same biotechnology ecosystem that supports domestic resilience also strengthens a nation's ability to expand economic influence and exercise long-term strategic leadership within the global bioeconomy.

Viewed collectively, China's biotechnology initiatives should therefore be understood not as isolated sector-specific programs, but as mutually reinforcing investments in an integrated national strategy. The principal lesson for the United States is not that China has adopted this approach. It is that biotechnology has evolved into a strategic capability capable of simultaneously advancing healthcare, agriculture, manufacturing, economic prosperity, and international influence.

The strategic implication extends beyond any single country. As biotechnology assumes greater importance across healthcare, agriculture, manufacturing, and national security, more nations are likely to pursue similar ecosystem-based strategies. The principal question for the United States is therefore not whether others will invest in biotechnology. It is whether America will continue strengthening the innovation ecosystem that has historically made it the global leader in scientific discovery, entrepreneurship, and technological advancement.

Strategic competition within the biological century will increasingly be measured not by isolated breakthroughs, but by the resilience, adaptability, and productivity of the ecosystems that produce them.

V. Advanced Therapeutics: Learning as a Strategic Asset

Advanced therapeutics provide a useful illustration of how strategic competition within the bioeconomy is evolving.

Historically, competitive advantage was often evaluated by where a therapy was discovered or manufactured. Increasingly, however, the strategic value of advanced therapeutics extends well beyond the physical product itself. Every stage of research, clinical development, manufacturing, regulatory review, and patient care generates new information that contributes to future innovation.

Clinical trials generate evidence regarding safety, efficacy, patient selection, treatment response, and long-term outcomes. Manufacturing operations generate process knowledge, quality improvements, operational efficiencies, and production experience. Regulatory interactions refine scientific understanding while improving future product development. Collectively, these activities produce continuous learning that extends well beyond any single therapeutic product. Unlike traditional manufacturing, advanced therapeutics become more valuable over time

because every patient, every manufacturing campaign, and every regulatory interaction contributes to a continuously expanding body of knowledge that improves future therapies.

Figure 1 illustrates the increasingly global distribution of innovative drug development. While the United States remains the world's leading biotechnology innovator, scientific capability, clinical development, and manufacturing capacity are expanding internationally. This evolution reflects the emergence of a more globally distributed biotechnology ecosystem rather than a single geographic center of innovation.

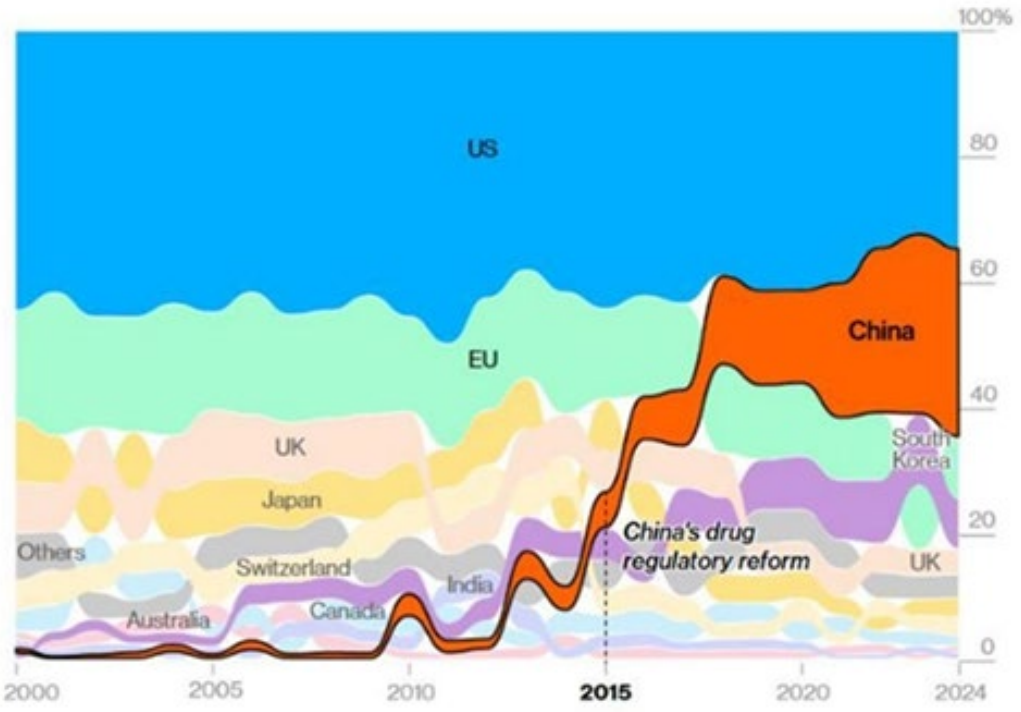

Figure 1. Share of innovative drugs entering development by country over time.

Source: Adapted from publicly available industry analyses (e.g., IQVIA Institute for Human Data Science).

The implications become even more apparent when examining advanced cell therapies. Figure 2 illustrates the development pathway for allogeneic CAR-T cell therapies. Although attention often focuses on where therapies are manufactured or where clinical trials occur, the more consequential observation concerns the movement of knowledge throughout the development process. Clinical data, manufacturing experience, process optimization, regulatory interactions, and operational expertise continuously accumulate as therapies progress from laboratory research through commercial development.

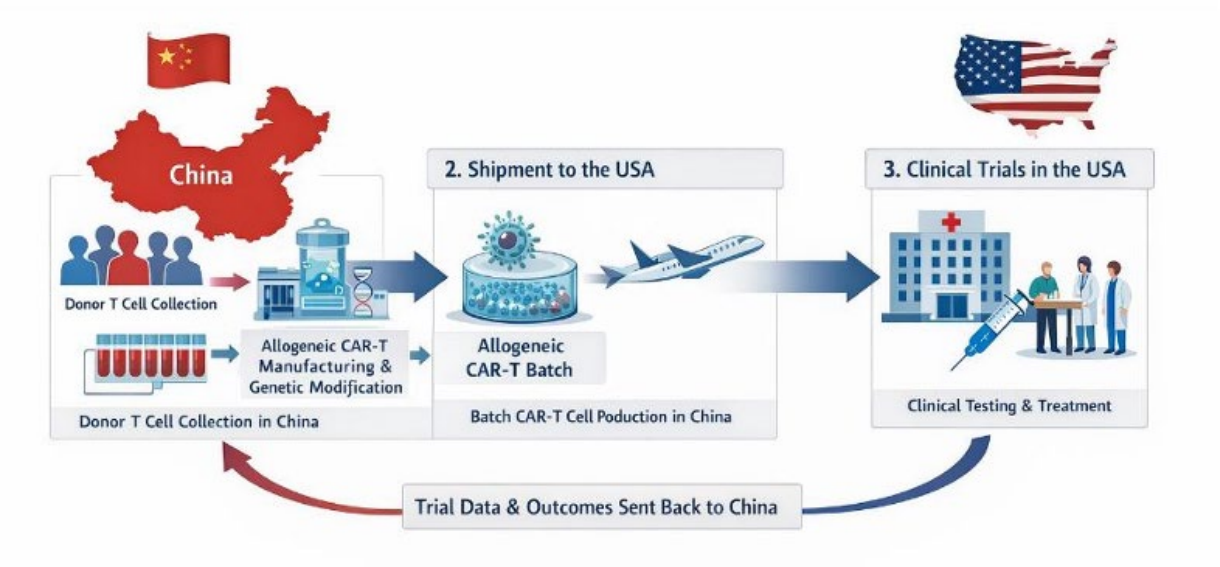

Figure 2. Illustrative Movement of Clinical Development, Manufacturing Experience, and Learning within Global Allogeneic CAR-T Development

Source: Author's illustration based on publicly available clinical trial data and industry analyses.

The directional flow illustrated in Figure 2 represents more than the movement of a therapeutic product. It also reflects the movement of scientific understanding, manufacturing capability, clinical experience, and operational learning. These intangible assets increasingly determine future innovation capacity.

This broader perspective suggests that clinical data should not be viewed solely as evidence supporting regulatory approval. Clinical, manufacturing, and operational data increasingly represent strategic national assets that contribute to future scientific discovery, improved manufacturing processes, artificial intelligence applications, and the development of subsequent generations of biotechnology.

The strategic question is therefore evolving. It is no longer limited to where a therapy was invented or manufactured. It increasingly encompasses where the learning generated by that therapy ultimately resides.

VI. Farm to Pharma: Agriculture, Biomanufacturing, and National Resilience

The evolution of biotechnology extends well beyond healthcare.

Many of these agricultural systems are sustained by family farms operated by older Americans whose stewardship of the land continues to underpin the Nation's food security, renewable feedstocks, and growing bioeconomy.

Agriculture has historically been viewed primarily through the lens of food production. Increasingly, however, agricultural systems support a far broader range of strategic objectives. Biological feedstocks now contribute to food, renewable fuels, industrial materials, specialty chemicals, biomaterials, precision fermentation, and biopharmaceutical manufacturing. The traditional concept of "Farm to Fork" is expanding to include **Farm to Fiber, Farm to Fuel, and Farm to Pharma.**

This broader perspective illustrates the interconnected nature of the bioeconomy. Agricultural production provides the biological feedstocks supporting industrial fermentation and advanced biomanufacturing. Those manufacturing capabilities produce pharmaceuticals, biologics, renewable products, industrial enzymes, advanced therapeutics, and numerous other products supporting healthcare, manufacturing, and economic resilience. Investments in agricultural productivity therefore reinforce manufacturing capacity, which in turn strengthens healthcare resilience and national competitiveness.

The COVID-19 pandemic demonstrated that scientific discovery alone is insufficient to ensure national resilience. Operation Warp Speed successfully accelerated vaccine development while simultaneously revealing the importance of flexible domestic manufacturing capacity capable of translating scientific breakthroughs into scalable production. Discovery and manufacturing are complementary components of the same innovation ecosystem.

Biofoundries represent an increasingly important element of that ecosystem. Rather than functioning solely as research laboratories or emergency production facilities, biofoundries integrate automation, synthetic biology, engineering, advanced analytics, and biomanufacturing into flexible platforms capable of supporting continuous innovation. Their strategic value extends beyond the products they manufacture. They cultivate workforce expertise, process optimization, technology maturation, and operational experience while remaining available to support national priorities during future emergencies.

This capability should be viewed as living infrastructure rather than contingency infrastructure. Biological manufacturing capacity cannot simply be activated during periods of crisis. Skilled personnel, validated manufacturing processes, quality systems, regulatory expertise, and operational knowledge require continuous development. Sustained investment in distributed biomanufacturing therefore strengthens both routine innovation and emergency preparedness.

Viewed through the broader framework of the bioeconomy, agriculture, manufacturing, healthcare, and national resilience no longer represent separate policy domains. They constitute interconnected components of a single strategic ecosystem whose collective performance increasingly influences America's long-term competitiveness.

VII. Governance, Licensing, and Strategic Influence

As biotechnology increasingly functions as strategic infrastructure, competition extends beyond scientific discovery and manufacturing. It also encompasses the governance frameworks, licensing practices, and technical standards that influence how innovation is developed, validated, commercialized, and ultimately adopted throughout the global economy. As biological innovation becomes increasingly global, governance becomes as important as technology itself. Scientific breakthroughs create new possibilities, but governance frameworks determine how those breakthroughs are trusted, adopted, integrated into society, and translated into long-term strategic advantage.

Licensing has traditionally been viewed as a commercial mechanism for transferring intellectual property. Increasingly, however, licensing transfers far more than legal rights. It often transfers manufacturing expertise, process optimization, regulatory experience, workforce development, and opportunities for continued scientific collaboration. As a result, licensing increasingly influences where scientific capability matures and where innovation ecosystems develop over time.

Technical standards perform an equally important strategic function. Standards are frequently viewed as technical specifications governing interoperability, manufacturing processes, quality systems, or regulatory expectations. In practice, they shape much more than technical performance. Standards influence product design, data exchange, manufacturing systems, regulatory pathways, supply chain interoperability, and ultimately market access. They establish the common framework through which industries operate and technologies are adopted.

If manufacturing determines where products are made, standards increasingly determine where industries grow.

This strategic reality is reflected in China's **China Standards 2035** initiative. Rather than focusing solely on traditional manufacturing sectors, the initiative prioritizes emerging technologies expected to shape future economic competitiveness, including artificial intelligence, quantum technologies, and biotechnology. These technologies were not selected independently. Together, they represent converging capabilities expected to influence future industries, global supply chains, and technological leadership.

The strategic significance extends well beyond technical specifications. Standards influence investment decisions, product design, regulatory acceptance, workforce training, software development, procurement requirements, and international market access. In many respects, standards become the operating architecture upon which future industries are built. Nations and organizations that help establish widely adopted standards are often positioned to influence the direction of research, manufacturing, and global markets long after individual technologies have evolved.

This principle extends across the broader bioeconomy. As biotechnology converges with artificial intelligence, advanced manufacturing, precision agriculture, and digital infrastructure, leadership in standards development will increasingly influence how biological data are governed, how manufacturing systems communicate, how artificial intelligence models are

validated, and how future biotechnology products gain acceptance in domestic and international markets.

For the United States, continued leadership will depend not only upon scientific excellence, but also upon sustained participation in the international institutions that shape governance, standards development, and trusted scientific collaboration. Leadership in the biological century will increasingly be measured not only by who develops the next breakthrough, but also by who helps establish the frameworks through which future breakthroughs are evaluated, manufactured, trusted, and adopted throughout the world.

The strategic challenge confronting the United States is therefore larger than strengthening an individual supply chain or protecting a single technology. It is whether America will continue to cultivate the scientific institutions, manufacturing capacity, agricultural productivity, workforce, governance, and innovation ecosystem necessary to lead the biological century. Success will increasingly depend not upon optimizing individual components, but upon strengthening the resilience and competitiveness of the bioeconomy as an integrated national capability.

VIII. Recommendations

The observations presented throughout this testimony suggest that strengthening America's pharmaceutical resilience requires a broader strategic approach than securing individual supply chains alone. The following recommendations are offered as strategic considerations for Congress.

Recognize the Bioeconomy as Strategic Infrastructure. Biotechnology should increasingly be evaluated as enabling infrastructure supporting healthcare, agriculture, manufacturing, artificial intelligence, energy, and national competitiveness. This broader perspective provides a more effective framework for evaluating long-term resilience than examining individual sectors independently.

Continue Advancing the National Security Commission on Emerging Biotechnology's Vision[4]. The National Security Commission on Emerging Biotechnology has provided Congress with one of the most comprehensive roadmaps for strengthening America's biotechnology enterprise. Its work successfully translated highly technical scientific developments into practical policy considerations spanning research, workforce development, manufacturing, infrastructure, standards, investment, and national security. As the Commission concludes its statutory mission, its contributions warrant continued implementation. Equally important, Congress should ensure that future mechanisms exist to provide similarly independent, multidisciplinary technical

[4] National Security Commission on Emerging Biotechnology, Charting the Future of Biotechnology (Final Report, 2025).

assessments as biotechnology continues to evolve. The need for trusted scientific and strategic translation will only increase in the years ahead.

Strengthen the Nation's Ability to Assess the Global Bioeconomy. Effective policy depends upon effective situational awareness. Biotechnology should increasingly be assessed not solely as a biosecurity issue, but as a driver of strategic competition, industrial capability, economic competitiveness, healthcare innovation, agricultural resilience, and geopolitical influence. The Intelligence Community should continue strengthening its capacity to assess these developments while expanding support to departments and agencies responsible for implementing national bioeconomy policy, including the Departments of Health and Human Services, Agriculture, Commerce, and Energy. The ability to continuously understand developments across the global bioeconomy should itself be viewed as a strategic national capability. Assessments of the bioeconomy should routinely integrate expertise from the life sciences, engineering, agriculture, manufacturing, artificial intelligence, economics, and national security to better identify emerging opportunities, strategic dependencies, and risks before they become national vulnerabilities.

Protect America's Learning Ecosystems. Clinical data, manufacturing expertise, regulatory science, operational knowledge, and workforce experience increasingly represent strategic national assets. Policies that responsibly steward these learning ecosystems while preserving scientific collaboration will strengthen America's long-term biotechnology leadership.

Invest in Resilient Biomanufacturing Capacity. Distributed biomanufacturing, biofoundries, workforce development, and resilient agricultural feedstock supply chains should be viewed as long-term investments in national capability. These assets strengthen innovation during normal operations while enhancing national resilience during future emergencies.

IX. Conclusion

The issues examined throughout this testimony extend well beyond foreign ownership of America's pharmaceutical supply chain. They encompass healthcare, agriculture, manufacturing, artificial intelligence, energy, scientific research, workforce development, economic competitiveness, and national security. The strategic implications therefore extend well beyond the jurisdiction of any single committee or department.

That broader perspective is particularly appropriate for the Senate Special Committee on Aging. The generations represented by this Committee made extraordinary sacrifices to build the Nation we have inherited. They cultivated America's farms, strengthened its industries, built its universities, advanced its scientific enterprise, expanded its healthcare system, and created opportunities that many of us have been privileged to enjoy. The biotechnology innovations discussed throughout this testimony rest upon foundations that they helped build over decades of hard work, service, perseverance, and sacrifice.

The most meaningful way we can honor those contributions is not simply by expressing our gratitude, but through responsible stewardship.

Stewardship means preserving what they built, strengthening it where necessary, and preparing it for challenges they could not have anticipated. It means recognizing that the bioeconomy is not simply another sector of the economy, but a strategic foundation upon which the health, resilience, prosperity, and security of future generations will increasingly depend.

Ultimately, looking beyond the pharmaceutical label reveals a much larger national responsibility. The question before Congress is not simply how to secure today's medicines. It is how to ensure that America continues to lead in scientific discovery, agricultural innovation, advanced manufacturing, and biotechnology so that future generations inherit a Nation that is healthier, stronger, and more resilient than the one entrusted to us.

Every parent makes an unspoken promise to the next generation: not simply to leave behind a better world, but to create opportunities for their children to achieve even more than they themselves were able to achieve.

As a Nation, we inherit that same responsibility.

The strategic imperative of the bioeconomy is ultimately not about biology. It is about fulfilling that enduring promise by honoring the sacrifices of those who came before us and ensuring that the generations who follow inherit an America whose greatest achievements still lie ahead.

If looking behind the label helps secure today's medicines, then looking beyond the label will help ensure that future generations inherit a Nation capable of discovering, producing, and continuously advancing the innovations upon which their health, prosperity, and security will depend.

That is the enduring responsibility before us.