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Industry Study

Final Report
Biotechnology

The Dwight D. Eisenhower School for National Security and Resource Strategy
National Defense University
Fort McNair, Washington, D.C. 20319-50

BIOTECHNOLOGY 2015

ABSTRACT: A strong, diverse, innovative economy is a fundamental component of the national security of the United States. The U.S. biotechnology industry already contributes substantially to our robust and growing economy; strengthens U.S. national security, health, and welfare; and is helping to establish an enduring national competitive advantage. The long-term viability and sustainability of industrial, medical, and agricultural biotechnology as key economic drivers will require targeted adjustments to existing U.S. regulations, policies, and practices, and will rely on increased investments in education, research, intellectual property, and data protection; the continued development and embrace of new technologies and systems; and the thorough rebranding of biotechnology as a force for good in the United States and the world.

CDR Lillian Abuan, U.S. Navy
Mr. Art Beasley, Defense Threat Reduction Agency
CDR Mike Brandhuber, U.S. Coast Guard
Col Eric Chapital, U.S. Air Force
Mr. Brannan Chisolm, Office of the Secretary of Defense
Lt Col Rick Erredge, U.S. Air Force
CAPT Dave Gibbs, Royal New Zealand Navy
CDR Stacy Hanna, U.S. Navy
Ms. Katja Helbing, Transportation Security Agency
LTC Dan Kirk, U.S. Army
Mr. Kent May, U.S. Department of State
Lt Col Bill Maxwell, U.S. Air Force
Mr. Ara Mesrobyan, Armenian Ministry of Defense
COL Keith Pritchard, U.S. Army
Mr. Mike Rosenberg, Office of the Secretary of Defense
LTC Dianna Terpin, U.S. Army

Mr. Bradley Calhoun, Faculty
Col Sam Price, U.S. Air Force, Faculty
CAPT Bob Wagner, U.S. Coast Guard, Faculty
Mr. Bob Houston, Federal Bureau of Investigation, Faculty

PLACES VISITED

Domestic:
Amyris Biotechnologies, Emeryville, CA
Arcadia Biosciences, Inc., Davis, CA
Bio-Rad, Hercules, CA
DNA 2.0, Menlo Park, CA
Energy Biosciences Institute, Berkeley, CA
Joint BioEnergy Institute, Emeryville, CA
Monsanto, Woodland, CA
Sandia National Laboratories, Livermore, CA
University of California, Davis, Davis, CA
Biotechnology Industry Organization, Washington, DC
Biogen Idec, Cambridge, MA
Broad Institute of MIT and Harvard, Cambridge, MA
Draper Laboratory, Cambridge, MA
Harvard Stem Cell Institute Boston Children's Hospital, Boston, MA
MIT Lincoln Laboratory, Lexington, MA
GlaxoSmithKline, Rockville, MD
Montgomery College, Germantown, MD
National Institutes of Health, Bethesda, MD
University of Maryland BioPark, Baltimore, MD
U.S. Food and Drug Administration, Silver Spring, MD

International:
Malaysian Biotechnology Information Centre (MABIC), Malaysia
Ministry of Science, Technology and Innovation (MOSTI), Malaysia
Sime Darby Plantation and R&D Facility, Malaysia
U.S. Embassy, Kuala Lumpur, Malaysia
Agency for Science Technology and Research (A*STAR), Singapore
Bio-Rad, Singapore
U.S. Naval Research Medical Center Singapore, Singapore
U.S. Embassy, Singapore

The Bioeconomy and National Security – A True Imperative

America's growing economic strength is the foundation of our national security and a critical source of our influence abroad.
President Barack Obama – 2015 National Security Strategy

A strong, secure United States depends on a diverse, innovative, and growing economy. The U.S. biotechnology industry contributes substantially to our healthy economy and helps to establish an enduring national competitive advantage. Targeted adjustments to existing regulations, policies, and practices; increased investment in scientific education and research; and simplification of intellectual property and data protection regulations and practices can further spur development and marketization of new technologies in a segment of the economy that is critical to U.S. prosperity and national security. Only biotechnology can address some of the nation's most pressing challenges, including medical care, food security, and sustainable energy for a growing, aging population. Government actions and policies that protect, sustain, and grow the bioeconomy are nothing short of imperative, and will sustain the position of the United States as a responsible global leader while increasing American prosperity and security.

The Great Recession of 2008 dealt a blow to U.S. prosperity and highlighted the importance of an innovative, resilient, science and knowledge-based economy. As the world grows more interdependent, increasing tension between human consumption and global sustainability creates pressing challenges. Arable land is decreasing, but the global population is growing, threatening the world's food supply.[1] Medical advances allow us to live longer, healthier lives, compounding the effects of population growth and increasing the need for affordable healthcare and sustained investment in medical technologies, including biotechnology. The traditional U.S. reliance on fossil fuels exacerbates the complexities of political and diplomatic relationships with some foreign governments, and contributes to the carbon emissions that are rapidly changing our climate.

These challenges threaten U.S. national security and global sustainability. Yet, innovative solutions are within reach and could be even more effective, sustainable, and affordable with the right mix of industry, academic, scientific, and government action. Biotechnology – the use of biological processes, organisms, or systems to manufacture products intended to improve the quality of human life – can play a strong role in addressing complex global problems while driving growth, innovation, and sustainability in a diverse and vibrant U.S. economy.[2] The agricultural, industrial, medical, and defense segments of biotechnology all have roles to play in nourishing and growing an innovative economy, establishing an enduring national competitive advantage, and strengthening U.S. national security and the well-being of our population. Targeted adjustments to existing policies and practices in education, research, intellectual property and data protection, and regulatory systems will go a long way toward helping U.S. scientists and industry rehabilitate biotechnology's "brand" from one that inspires fear, aversion, and misunderstanding to one that is widely accepted and understood as a force for good.

The Dwight D. Eisenhower School for National Security and Resource Strategy's Class of 2015 Biotechnology Industry Study Group studied various aspects of the industry, including basic science, research and development, intellectual property and data protection, entrepreneurship and marketization, manufacturing and production, and the regulatory framework. The team visited biotechnology firms, academic institutions, non-profit organizations, industry groups, and government offices in Boston, Washington DC, Singapore, Malaysia, and the San Francisco Bay Area, and hosted experts from the field at the National Defense University. This report, assembled from sources including professional articles, journals, news reports, interviews, and guest speakers, offers the group's findings on the current state of the industry and recommends targeted

actions the government can take now to help biotechnology drive and grow the economy of the United States and enhance the national security, prosperity, and well-being of the U.S. population.

PART ONE – INDUSTRY OVERVIEW

The Bioeconomy Defined – As Diverse as Biology Itself

Biotechnology comprises a number of relatively young and quickly growing industry segments and includes a wide range of firms engaged in business and research activities using living organisms and technology to develop products and services.[3] These segments are in the fields of medicine, agriculture, and industry and have shown great promise, respectively, by "healing, feeding, and fueling" the nation.

The U.S. biotechnology industry includes large multinational corporations, small entrepreneurial firms, public and private research entities, dedicated biotechnology investment companies, and academia. Last year in the United States, some 1,900 firms generated revenue nearing $100 billion while delivering biotechnologies that heal, feed, and fuel.[4]

The United States enjoys a distinct competitive advantage, but it is not the only developed nation with aspirations for further technological innovation, and it is not alone in the migration to more innovative industries. China and India's rapidly growing populations and associated urbanization will require significant innovation and advancement in technology, including biotechnology – and potentially at a growth rate greater than that of the United States. As James Greenwood writes in *Unleashing the Promise of Biotechnology: Advancing American Innovation to Cure Disease and Save Lives*, "Although the U.S. remains a leader in medical, agricultural and industrial biotechnology innovation, global competition is rapidly increasing. To sustain our global leadership, the U.S. needs continued investment and policies focused on supporting and incentivizing the next generation of biotechnology innovations."[5]

Although the biotechnology industry in the United States is similar in some ways to that in other countries, key differences exist. The U.S. government (USG) funds a wide variety of research, but market forces dictate product development. Where market failures exist, the government may choose to intervene and contract with companies to produce goods beneficial to national welfare. Examples include biofuels and certain therapeutics critical to warfighters. European and other western countries mirror the U.S. model, with governments playing a supporting role. By contrast, government largely controls and directs the biotechnology industries in many Asian countries, with decisions about research and investment driven by national strategic and economic choices rather than market forces.

Current Condition of the U.S. Bioeconomy

The biotechnology industry in the United States is young, healthy, and growing. There are more than 250 biotechnology health care products and vaccines available. More than 13 million farmers use agricultural biotechnology to protect and increase crop yields while reducing environmental impact. Over 50 bio-refineries, designed to test and refine technologies that will produce biofuels and chemicals from renewable biomass while mitigating greenhouse gas emissions, are in various stages of development across North America.[6] The Biotechnology Industry Organization (BIO) and Battelle released a comprehensive report that asserts *"biotechnology continues to be one of the most important drivers of recent innovation and job*

creation – and given the incredible advances in science, our industry is poised to be at the forefront of innovation and economic growth for generations to come."[7] Despite the promise, many factors make it prohibitive – or at least very difficult – for new firms to enter and thrive in the biotechnology industry. The following Porter's Five Forces Model demonstrates the industry's competitive complexity, with challenges including strong rivalry, high barriers to entry, and a high threat for non-biotechnology substitutes. Notwithstanding the risks, the industry's overall strengths incentivize firms to get in and stay in the game.

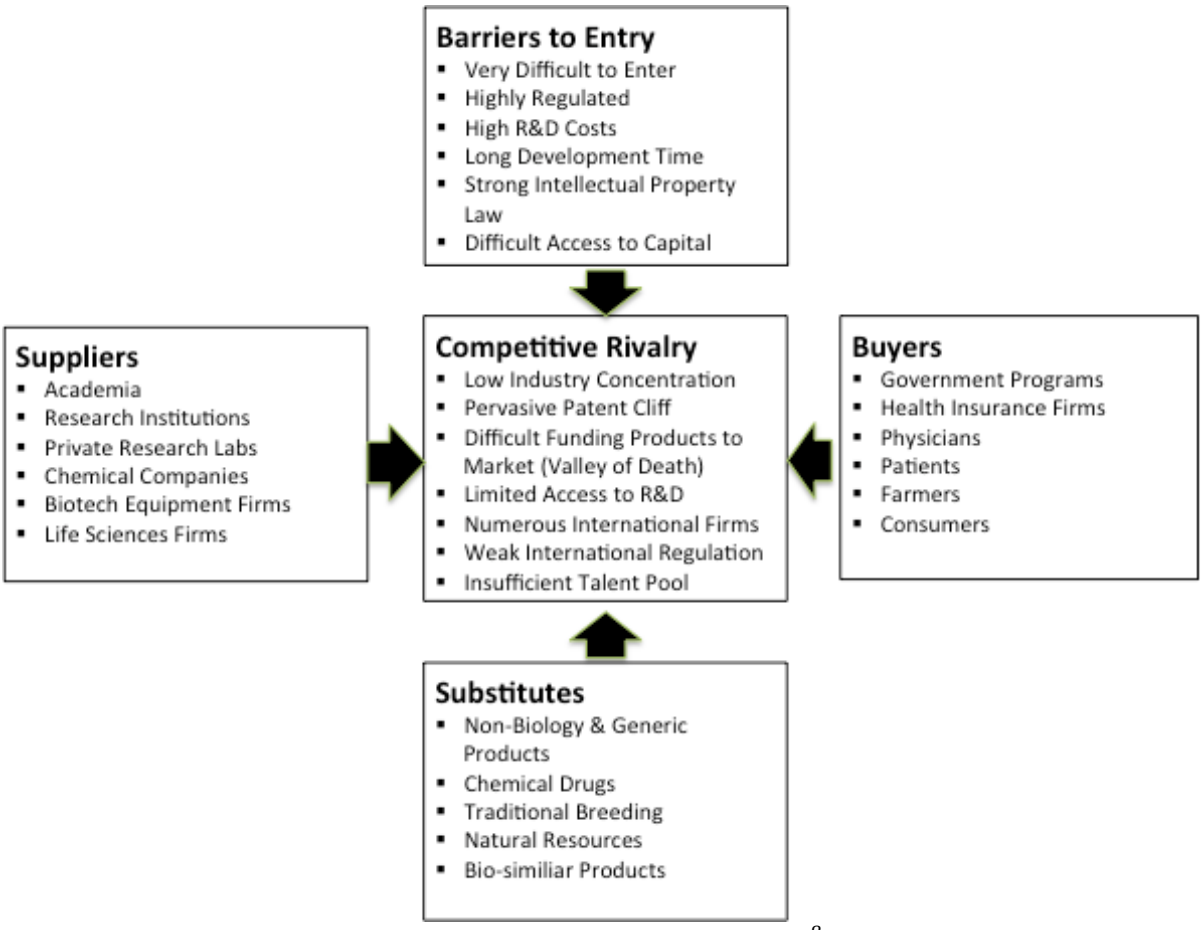

Figure 1. Five Forces Assessment[8]

A Resilient Industry

Biotechnology successfully weathered and continued to thrive during the 2008 Great Recession. Unleashing the full potential of the medical, agricultural, and industrial biotechnology segments can strengthen the U.S. position as a global economic leader while enhancing the national security, prosperity, and well-being of our growing population.

Medical Biotechnology – "Heal"

Medical biotechnology represents the largest of the three major segments, accounting for approximately 50% of sales.[9] The medical biotechnology industry in the United States produces

biologic drugs, vaccines, diagnostics, and other products, and focuses research and development efforts on treatments for cancers, infectious diseases, autoimmune conditions, HIV/AIDS, and certain diseases where no effective treatments exist.[10] Recently, advancements in vaccines, medications, and diagnostic testing have paved the way for so-called "personalized medicine," in which healthcare decisions – including diagnostic tests, biologic medicines, and other treatments – are tailored to the individual patient based on genetic and other factors.

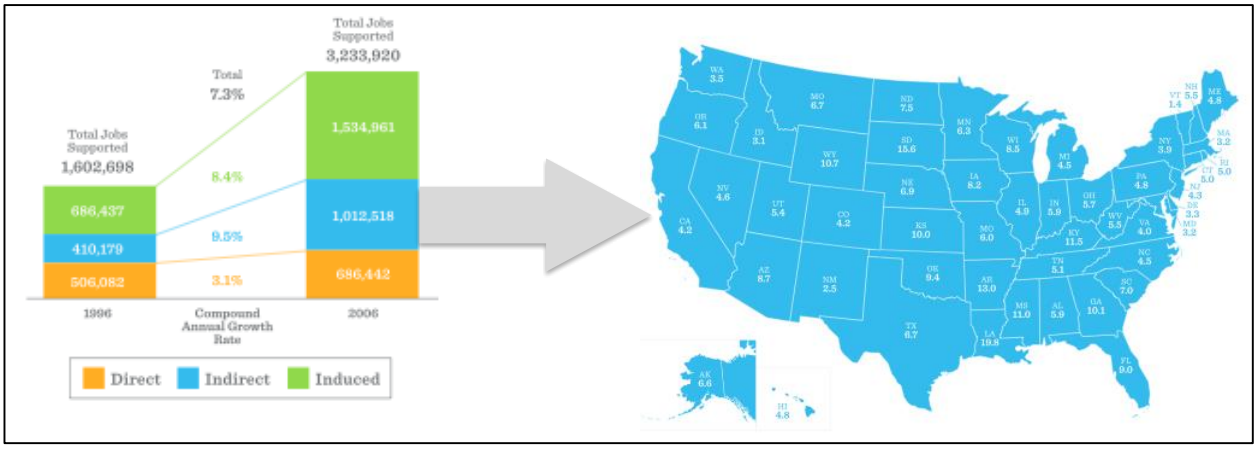

Figure 2. Medical Biotech Economic Impact[11]

While the value of such innovations to the health of our population is obvious, the medical biotechnology industry also serves as a significant driver behind a robust, diverse U.S. economy. As illustrated in Figure 2, the medical biotechnology sector employed 1.3 million Americans in 2006 and generated 6.2 million additional related jobs across the entire U.S. economy. Over the past decade, research, testing, and medical lab jobs have increased by 24% in the United States. These gains persisted through the recent recession, with the subsector adding 6% to the employment base since 2007.[12]

Agricultural Biotechnology – "Feed"

As one of our nation's largest industries, agricultural biotechnology is heavily based on advances in biological research and development. Key agricultural biotechnology products include corn, soybeans, cotton, canola, and crop seeds.[13] Agricultural applications of biotechnology have helped create a more sustainable food supply by increasing crop yield, reducing agriculture's environmental impact, and enhancing plant resistance. An example of this is the enhanced ability of agricultural biotechnology-produced corn plants to resist insects, resulting in healthier plants and increased food, feed, and fuel stocks while reducing the need for insecticide applications.[14]

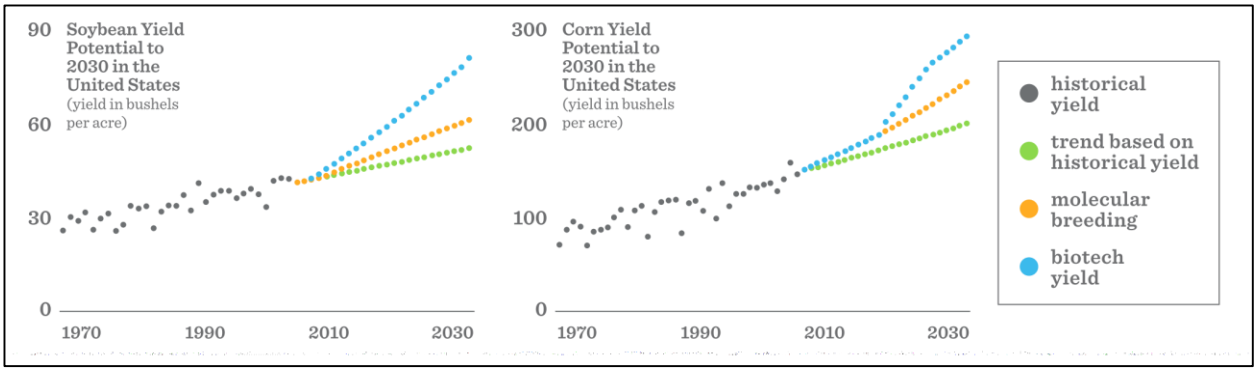

Figure 3. Yield Projections [15]

As illustrated in Figure 3, yield potential for biotechnology-produced soybeans and corn is projected to increase through 2030. The USDA estimated 2010 U.S. revenues from genetically modified crops at $76 billion, and the International Service for the Acquisition of Agri-Biotech Applications (ISAAA) reports that the United States produces more than half of all biotech crops in the world.[16] BIO confirms the "*global value of biotech seed alone was $13.2 billion in 2011, with the end product of commercial grain from biotech maize, soybean grain and cotton valued at approximately $160 billion per year, and is projected to increase 10% - 15% annually*."[17]

Industrial Biotechnology – "Fuel"

Industrial biotechnology primarily focuses on enzymes, biofuels, and nanotechnology.[18] Biofuels address one of the most significant economic and geopolitical challenges facing the United States – namely, the U.S. historical dependence on foreign oil. Advancements in domestic oil and gas production technologies, recent hydraulic fracturing initiatives, and increased investments in alternative energy technologies have all helped the United States reduce oil imports in the short term. Sustainable and renewable fuels are likely to make up an increasing part of the long-term solution to foreign oil dependency.

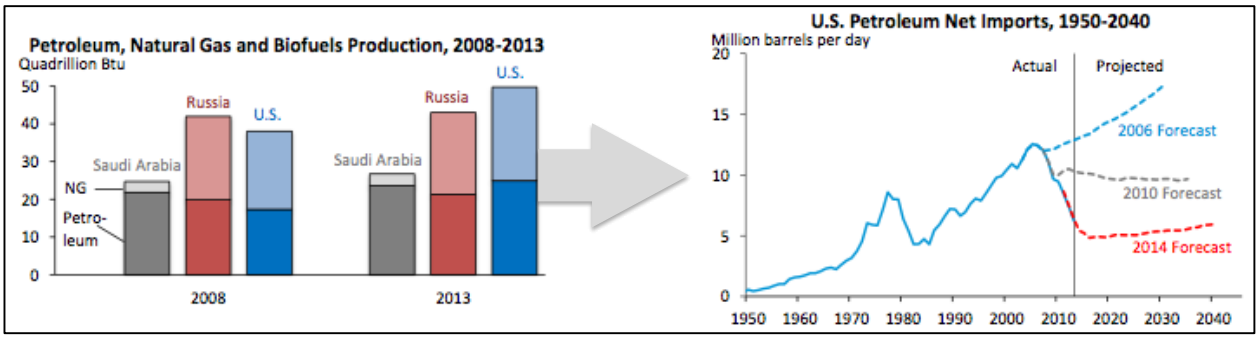

Figure 4. Alternative Fuel Production and Petroleum Import Forecast[19]

Figure 4 illustrates the proportionate decrease of projected U.S. petroleum imports as a result of alternative fuels production, compared to key international energy production competitors. 2010 U.S. revenues from industrial biotechnology were roughly $100 billion.[20] Industrial biotech has contributed an additional 6.2 million jobs through indirect employment and 1.6 million jobs through direct employment, and continues to create and sustain high-wage jobs, paying over 80% more than the private sector average salary and growing at a rapid rate.[21]

The development of enhanced methods and processes for producing goods and services triggers both domestic and foreign direct investment. Fueled by innovation, this investment drives a perpetual cycle of new financial and human capital that directly feeds critical biotechnology research and development, employs more than 1.3 million Americans, generates a demand for high-skilled labor, incentivizes Science, Technology, Engineering, and Mathematics (STEM) education, and contributes approximately 2% to the U.S. GDP.[22] The U.S. Department of Commerce states that innovation has been responsible for two-thirds of U.S. economic growth since World War II.[23] Innovation is the cornerstone of the nation's prosperity, and its direct and sustained benefits are clearly visible in the contributions of medical, agricultural, and industrial biotechnology to a growing U.S. economy.[24]

PART TWO – FRAMING THE FUTURE

Key Challenges: The Role of Government

A few targeted improvements in the way the USG engages with and supports the biotechnology industry will help the market reward scientific advancements and commercial promise while still allowing the government to shape the safety and efficacy of biotechnology to benefit the U.S. population. Sustaining and exploiting the enviable lead of the United States across the global bioeconomy will require political will and government-wide coordination in addressing existing issues and seizing emerging opportunities. The following industry challenges serve as a framework for the recommendations offered later in this report.

Human Capital

Continued innovation, research, and development will require a properly educated and trained workforce to meet the highly technical biotechnology industry's needs. The USG has made some progress by investing in and prioritizing STEM coursework in primary and secondary education, but the investment needs to increase or the United States risks falling rapidly behind other, emerging biotechnology producers – particularly in Asia, where government investment in STEM education is already a strong and well-established strategic priority for many partner and competitor nations. Tables 1 and 2 demonstrate the varied education requirements and vast employment potential in the biotechnology industry.

Currently, the biotechnology workforce in the United States is also limited by immigration laws, regulations, and policies unfavorable toward the retention of foreign workers with U.S. degrees and specialized knowledge. Demand among educated professionals to work in the United States is high: within a single week in 2014, U.S. Citizenship and Immigration Services received 172,500 applications for the 85,000 H-1B temporary worker visas available for the coming year.[25] With a record 886,000 international students currently studying at U.S. universities, it is no surprise that 85 percent of Indian and Chinese students are concerned about obtaining permission to work in the United States after finishing their studies.[26] According to immigration analyst Neil Ruiz, "Some of them will do a calculation—do I want to go through all these obstacles and uncertainty to stay here, or do I want to just go home and open a business or work for a corporation there?"[27] U.S. innovation and technology advancement suffers when the United States lets much-needed talent go elsewhere.

Regulatory Framework

Given the sensitive nature of manipulating biological organisms, the biotechnology industry is appropriately subject to careful regulation. Many view existing regulations as outdated and inconsistent across the various segments of the industry. The 1986 Coordinated Framework (CF) for Biotechnology has been in place for nearly 30 years and most observers applaud the wisdom of this early approach to bioeconomy regulation. The CF laid out the comprehensive federal policy for products and research involving agricultural, pharmaceutical, and other commercial products using "genetic modification techniques."[28] It "sought to achieve a balance between regulation adequate to ensure health and environmental safety while maintaining sufficient regulatory flexibility to avoid impeding the growth of an infant industry."[29] Profound and ever more rapid developments in the field of biotechnology have widened gaps and inefficiencies in the CF and altered the cost-benefit ratio of certain regulations that have become outmoded. It is time to bring the CF in line with today's infinitely more complex and innovative reality.

Intellectual Property

Biotechnology is especially dependent on novel ideas to drive industry growth. Industry advocates are vocal supporters of the need to provide assurances to inventors that their ideas and inventions will be protected. Standards that enable and safeguard the discoveries of biotechnology companies help those firms profit and invest in further research and development to find the next breakthrough.[30] Translating ideas into the development of commercially viable technology platforms, and ultimately delivering safe, effective products serves both the American public and a strong, growing economy.

The optimum policy must carefully balance the intellectual property (IP) protections so vital to private investment with data protection and sharing of promising information by government, academic, and industry stakeholders. Policies that encourage and help develop databases that consolidate and protect data associated with public funds and investment in science and technology will further strengthen the biotechnology industry and recoup value that is currently lost. Table 3 depicts the biotechnology "ecosystem" with IP protection and sharing at its core function. Table 4 demonstrates the power of different kinds of alliances and partnerships in bringing products to market, where the sharing of IP was central.

Capital Investment and Marketization

The resource-intense journey from biotech idea to marketplace is a perilous one, and the primary threat is the "Valley of Death." Depicted in Tables 5 and 6, the Valley of Death is industry vernacular to describe the danger of fatal failure as innovations move from discovery to marketization. Authors Philip Auerswald and Lewis Branscomb describe the Valley of Death as "the gap between demonstrating the soundness of a technical concept and readying the product technology for the market."[31]

During this period in technology transition, "purely technical risks are coupled with the market risks inherent in innovation."[32] Early research funding, often provided by government or university sources, runs out before venture capital or established technology firms come to the table with development and marketization dollars, causing many ideas to go unrealized. The valley

is made deeper by government regulations that drive up costs for technological development. This gap in resourcing technology transition has a major impact on the marketization of innovative ideas. As described by economist Martin Weitzman and cited by Auerswald and Branscomb, "the ultimate limits to growth may lie not as much in our ability to generate new ideas, so much as our ability to process an abundance of potentially new seed ideas into usable forms."[33]

However, there are actions the USG can take in an effort to help shallow the Valley of Death. Success here will result in increased private investment and will have the effect of expanding the economic pie. To continue to drive U.S. economic growth and prosperity, the biotechnology industry needs to help government develop policies that minimize the failure of innovative biopharmaceuticals and other biotechnology products.

The Biotechnology Brand

Despite its profound benefits in medicine, agriculture, food production, and industry, significant distrust persists among U.S. consumers toward biotechnology. Even well-informed consumers are willing to pay a premium to avoid certain genetically modified foods,[34] which should be a concern to all stakeholders in the bioeconomy.

There are many reasons for the resistance to biotech products in the United States. Certainly the complexity of the science makes informed discussion with consumers difficult. The record low levels of trust in the competence and capability of government may be another contributing factor.[35] This distrust makes the job of casting often vague doubts and suspicions on biotechnology products – from foods to medicines to fuels – easy work for opponents and competitors. A Malaysian biotechnology advocate likened discussions on biotechnology to those on religion. For many, facts do not prove adequate weapons against beliefs.[36]

Based on discussions with the range of actors involved in the bioeconomy, we came to see the prevailing anti-GM, anti-biotech sentiment and the accompanying avoidance of biotech products as a very large elephant in the room of the U.S. economy. Asked about the reasons for the persistent distrust and suspicion of biotechnology among consumers, many academics seemed genuinely puzzled that people did not understand the science. Trade groups acknowledged the need to better educate stakeholders, and pointed to informational web sites and other sources. Companies, incredibly, sometimes claimed the resistance from consumers surprised them, while acknowledging they needed to do more to reach out and deliver a positive message about the benefits of biotechnology.[37] It struck us as a serious concern that very intelligent people in science, government, industry, and consumer groups appeared to have determined the best marketing is none at all, and the best method to win the argument about the safety, efficacy, and necessity of biotechnology is perhaps not to have the conversation.

Coordination, Data, and Sharing

Unity of effort across the "triple helix" of government, industry, and academia remains elusive, as myriad government, non-governmental organizations (NGO), and industry partners strive to find common grounds for progress but are often inhibited by competition, steep development costs, and the need for a satisfactory return on investment.

Opportunities to strike the right balance abound, and progress in this regard starts with research. The National Institutes of Health (NIH) receives approximately $30 billion annually and serves as the clearinghouse for funding research. Currently, "more than 80% of the NIH's funding

is awarded through almost 50,000 competitive grants to more than 300,000 researchers at more than 2,500 universities, medical schools, and other research institutions in every state and around the world."[38] Presumably, NIH's role as distributor of funding places it in a perfect position to have visibility over the entire research effort. NIH could improve visibility and transparency by sharing enterprise-wide research efforts with the rest of the industry.

Advancing the science is critical, but turning new information into actual products is another challenge, and it is no surprise that private firms' bottom lines prompt them to be cautious about sharing research and clinical trial results in the public domain. This tension is natural, and will never go away. However, the biotechnology industry needs to find ways to share successes and failures as much as possible to facilitate biotechnology product marketization and help grow the U.S. economy. Again, NIH is in a perfect place to make a difference. Where possible, exploiting government-held or academically-owned patents through licensing to get products to market could help significantly. As the agency with the most visibility on how federal research dollars are distributed, NIH is positioned to coordinate and integrate healthcare research and development efforts.

Outlook: Tremendous Potential

Research and commercial advancements indicate a future bioeconomy that knows no bounds, and the primary opportunities for growth are in the "heal, feed, and fuel" segments. Although biodefense presents an enduring need for the United States, lagging government funding stalls private investment and keeps the segment from fully developing. None of this is possible without a diverse, innovative, and growing economy. To fully capitalize on biotechnology's promise hinges upon an economic and regulatory environment that facilitates technological advancement and innovation.

Impact of Globalization

The globalization of technology has begun to level the economic playing field across developed nations and has enabled a large percentage of developing countries to chart a path to enhanced GDP growth. China's economy surpassed the U.S. economy in 2015.[39] Whether the United States succeeds in closing the domestic output gap depends in large part on innovative technology and robust investments to further develop the economy, increase and rebalance trade, and boost the U.S. competitive advantage on a global scale. Biotechnology has surfaced as a critical economic industry in the country's effort to maintain technological superiority over key competitors, including China and India.

Half a century ago, when the Soviets beat us into space with the launch of a satellite called Sputnik… we unleashed a wave of innovation that created new industries and millions of new jobs. This is our generation's Sputnik moment.[40]

—President Barack Obama, State of the Union Address, January 25, 2010

Important Drivers Going Forward

To determine how biotechnology can help to grow an increasingly innovative U.S. economy that contributes to the nation's prosperity and security, we must determine where the nexus lies between the key components of economic growth (population, capital, and innovation) and the major sectors of the biotechnology industry (medical, agricultural, and industrial). The White House has produced three principal documents in the past four years that help to answer this question: 1) the National Security Strategy (2015), 2) the National Bioeconomy Blueprint (2012), and 3) A Strategy for American Innovation (2011). Each of these roadmaps highlights the strategic importance of one common denominator: innovation.

Innovation, the process "by which individuals and organizations generate new ideas and put them into practice," serves as the foundation of American economic growth and competitiveness.[41] A growing, innovation-based economy has the potential to increase income, produce higher quality jobs, and improve the overall prosperity, health, and quality of life for the U.S. population.

To heal the sick, feed the hungry, and efficiently meet our energy needs without endangering our environment, we will continue to need innovation and growth in the medical, agricultural, and industrial biotechnology segments. The United States has the opportunity to lead the world in a second, innovative "industrial revolution," and in doing so we can re-establish our global primacy as a nation that leads and contributes to the prosperity and well-being of all people across the globe. American capital and innovation through biotechnology and other science-based industries are among the critical economic catalysts needed to foster U.S. economic growth, continue to generate resources for the nation's security, and promote prosperity for all Americans.

To reach its full potential, the biotechnology industry must continue to develop and deliver life-changing products to the world's markets – including in our own domestic markets, where skepticism and misunderstanding of biotechnology products among the American public persists. Striking the right balance between responsible regulation and forward-leaning investment and development policies will be critical to the long-term health of the biotechnology industry.

Recommended Government Actions

Given the combined challenges of an aging population, rising health care costs and entitlement spending, the negative impacts of carbon emissions and the accompanying need for renewable and sustainable energy, and the drive for more productive and resilient food sources, the USG has a significant interest in responsibly encouraging and facilitating the growth of our nation's bioeconomy. The following recommended actions would help to address existing challenges and position the United States to leverage biotechnology as a key driver of economic growth and national prosperity.

Human Capital

Pursue legislation and other reforms to tie U.S. visa laws, regulations, and policies to market demand. Prioritize employment visa approval for foreigners who have acquired critical STEM skills through education in the United States. Build a technically advanced and innovative work force through continued investment and emphasis on STEM education for U.S. students.

Expansion of the Optional Practical Training (OPT) program that "allows foreign-student graduates on F-1 visas (i.e. nonimmigrant students) to work full time in the United States for up to 12 months (29 months for STEM degree holders) after receiving their U.S. degrees,"[42] expansion and reform of the H-1B temporary worker visa program, and prioritization of employment visa approval for foreign students who have studied science and technology in the United States will all help encourage and foster a strong and innovative bioeconomy. Neil Ruiz, a Senior Policy Analyst at the Brookings Institution, proposes that "the OPT program is just a temporary solution to a larger problem that requires legislation, and the president should work with Congress on a bill to allow foreign graduates from accredited schools to apply directly for green cards." Whether through legislation, regulatory reform, policies more favorable to immigration and economic growth, or some combination of all of the above, the United States will benefit from thoughtful reform aimed at encouraging foreigners to continue contributing to the U.S. economy beyond graduation rather than "sea turtling" back home to strengthen their own economies instead.[43]

Intellectual Property

Endorse and promote government, academic, and industry consortiums and agreements designed to share research success and failures, build databases for information sharing, and collaboratively bring products to market through strong IP and licensing agreements that both protect and share IP.

Innovative organizations like the University of Maryland's Office of Technology Commercialization, the Maryland Bio Park, and, on a smaller scale, the Biomarker Consortium, have systems in place to work on common issues, share data, and develop licensing agreements to bring products to market, while safeguarding the IP that is critical to U.S. competitive advantage. A collaborative effort between private donors, Harvard University, and the Massachusetts Institute of Technology, the Broad Institute also serves as a coordinating body and business incubator designed to translate ideas and research into marketable products.

Capital Investment and Marketization

Develop policies that focus investment and decrease capital risk to shallow the Valley of Death.

The policies that will most effectively enable marketization of biopharmaceutical innovations are those that bridge the Valley of Death, connecting innovators with investors and reducing market failures brought on by the high degree of risk inherent in the process. To support the supply of innovations, the USG should continue to provide government grants and incentives and refine the process for determining the best recipients by supporting improvements for computer simulation, DNA sequence, and stem cell-based testing technologies to identify viable candidates earlier. To reduce the risk to venture capital, the USG should rewrite policies to decrease developmental testing costs. Opening access to national labs, modifying the drug approval process, and developing new channels for drug utilization during drug testing for patients with no other option as a means of funding Phase III trials, are all ways to decrease investment risk. The USG should support strategic alliances that bring together academic ideas and government resources to address industry challenges. Such alliances can reduce the need for capital investment and enable more innovations to succeed, thus improving U.S. market advantage around the world.

Regulation

Targeted Update of the 1986 Coordinated Framework (CF) for Regulation of Biotech Products.

Fundamental revision is unlikely in the current political and fiscal environment.[44] As a result, we recommend focused refinements within the current framework. The priority should be to close existing, well documented gaps in regulatory coverage that, if addressed, would improve trust among stakeholders. Put another way, risk should drive the CF update agenda, as improved risk mitigation has the potential to garner support from both legislative and industry stakeholders.

The Biotechnology Brand

Develop and deliver a strong, flexible, targeted media strategy to educate the public, dispel inaccuracies and myths, and build overall "bioawareness" to promote biotechnology as an essential component of U.S. economic prosperity and an overall force for good.

Key stakeholders from the "triple helix" of the U.S. biotechnology industry need to work together to develop and deliver a public awareness and education plan to help U.S. consumers, lawmakers, businesses, and members of the general public understand and embrace a more positive view of biotechnology and its medical, agricultural, and industrial uses. Biotechnology would benefit from the focused, nuanced, balanced work of an established organization to help educate the public on its possibilities as a driver of economic growth, security, and prosperity rather than a frightening, shapeless threat to health and well being. The Ad Council presents an opportunity to shape and deliver the message. The Ad Council "identifies a select number of significant public issues and stimulates action on those issues through communications programs that make a measurable difference in our society," and has produced vastly popular campaigns from Smokey the Bear to McGruff the Crime Dog to "Just Say No."[45] Social media will be an essential proving ground for the effectiveness of any modern strategy.

Coordination, Data, and Sharing

Charge NIH with coordinating and building transparency in federally funded research efforts.

NIH spreads $30 billion in research funding to over 300,000 researchers representing 2,500 universities and a host of related and unrelated subjects.[46] NIH does not, however, place emphasis on coordinating research, building networks, or sharing data. Further, some believe the paper-thin layer of funding spread across so many research activities comes at the expense of more important national crises like treating and curing Ebola.[47] In the interest of coordination, collaboration, and the elimination of redundancy, we can do better. As the entity disbursing the funding, NIH should be the primary coordinator and integrator for all federally funded research for biomedical purposes. Priority should be given to those researchers collaborating to solve challenging issues.

Essays: A Deeper Look at Three Challenges to the Bioeconomy

Essay 1: The 1986 Biotech Framework Regulation

The 1986 Coordinated Framework (CF) for Biotechnology has been in place for nearly 30 years and most observers applaud the wisdom of this early approach to bioeconomy regulation. The CF laid out the comprehensive federal policy for products and research involving agricultural, pharmaceutical, and other commercial products using "genetic modification techniques."[48] It

"sought to achieve a balance between regulation adequate to ensure health and environmental safety while maintaining sufficient regulatory flexibility to avoid impeding the growth of an infant industry."[49] Rapid and significant developments in biotechnology have widened gaps and inefficiencies in the CF and altered the cost-benefit ratio of certain regulations that have become outmoded. The CF needs adjustments to align with today's infinitely more complex reality.

Review of the Coordinated Framework

The 1986 CF resulted from a debate as to whether the nascent biotech industry would require an entirely new set of regulations, or whether existing regulatory bodies and laws could ensure the safety of the American people while enabling an industry that could provide immense economic benefit and tremendous public good.[50] Given the diversity and scope of the bioeconomy, using existing regulations and agencies was the timeliest option available: implementation would be immediate and the "broad spectrum of products" simply cut across too many agencies for anything approaching a rapid reorganization.[51]

Simply put, the U.S. Department of Agriculture (USDA), the Environmental Protection Agency (EPA), and the Food and Drug Administration (FDA) split the duties of regulating biotech products, with the intent of retaining their areas of expertise. Each of the agencies owes its authority to regulate biotech products to a creative interpretation of laws that in most cases predate modern biotechnology and reflect a mix of regulatory approaches.[52] Regulatory gaps and mismatches in authorities have opened up and worsened over time. The CF as written no longer balances the need to protect the public with the ever-increasing opportunities to grow the U.S. economy (and therefore strengthen America's prosperity and national security) through nimble, flexible support for continued development of a diverse bioeconomy that maximizes and capitalizes on U.S. scientific capacity and human capital.

The Reasons for Change – Science and Trust

Science – a lot can happen in 30 years

Science has slowly crumbled the assumptions that enabled many of the work-arounds in the CF to function, including the core tenets that regulation should focus on the product and not the process, and that genetically engineered organisms do not differ fundamentally from their non-GE counterparts. Functional equivalence flowed from the Central Dogma Theory, which followed a "one-gene, one protein" approach and has since been destroyed as a scientific principle.[53] The regulatory agencies have effectively acknowledged this in practice; there are numerous examples of genetically modified (GM) products receiving higher levels of scrutiny than non-GM products.[54]

Another assumption science has overtaken involves the USDA's authority to regulate biotech products under the Plant Pest Act. Recent developments such as gene guns create gaps in authority.[55] This progress obviates the previous logic, and agency efforts to address this change create the sort of uncertainty helpful to none of the stakeholders involved.[56] Absent revised regulation, emerging technologies and capabilities will only widen existing gaps.

The science regarding GM fish and animals has created holes in the existing statutory authorizations. The FDA claims responsibility to regulate New Animal Drugs and any harmful effects to humans from their production – but not any damage to the environment. The EPA claims to lack jurisdiction regarding animals.[57] Therefore, effects potentially harmful to the environment, but not directly to humans, may fall neither into the FDA's nor the EPA's field of view.

Trust – the Elephant in the Room

The most pressing reason to address the shortcomings in the Coordinated Framework is the significant and growing lack of trust between consumers and industry. Any revisions should acknowledge the perception that there is a "shroud of secrecy surrounding the approval process and the lack of opportunity for public participation."[58] The lack of trust in the marketplace is significant. A careful review of the USDA's 2014 report on genetically modified crops yields significantly more information supporting consumers' willingness to pay a premium to avoid GM products, even in cases where lack of information was not at issue.[59]

And not only is public skepticism toward GM products mirrored by consumers in Europe and elsewhere, it is even more dramatically reflected in the regulatory environment outside the United States.[60] The debate over labeling is at the heart of transparency, with the United States taking the position that since there is fundamentally no difference between a GM product and a non-GM product, there is no reason to provide that information to consumers.[61] The United States can win this debate only by shining light on the regulatory process, providing the truth about the plants and food the nation produces, and promoting a more favorable view of biotechnology among consumers and members of the public.

General Policy Recommendations: Gaps, Inconsistencies, Inexperience and Overlaps

As early as 2006, Gregory Mandel laid out a path for revising the CF by focusing on its Gaps, Inconsistencies, Inexperience and Overlaps.[62] This remains a helpful model to outline a way ahead. Given the significant scientific advances that continue unabated, any gaps that have emerged hold the potential for significant risk. Inconsistencies in definitions or artificial differences in treatment of issues between agencies can be addressed at relatively low cost and could add significant value if their harmonization contributes to an increase in transparency and dialogue with associated stakeholders. The inefficiency created by redundant processes, both in time and money, is a significant problem and contributes to our competitors' ability to gain market share across the wider bioeconomy.

Understand the Environment – Don't Swing for the Fence

The current political environment in the United States makes any significant policy change difficult. For this reason, any revised framework should be limited in scope, should begin with a pragmatic estimation of risk and benefit, and should assess where constituent stakeholder groups have aligned interests.[63] For example, labeling requirements may develop into an area of aligned interests between growers and consumer advocates if used to demonstrate another "quality control system" that represents rigorous evaluation.[64] Pest resistance, gene transfer, animal and fish regulation, and procedural transparency should be the initial areas of focus.[65]

The CF did its job admirably and was able to prevent a massive product safety catastrophe through thoughtful oversight without stifling innovation, a clear goal of its authors.[66] But the time has come to acknowledge the limits inherent in a patchwork system of outdated legislation. As long as a significant majority of reasonable, informed consumers do not trust GM products, the bioeconomy will remain at risk. The central argument for reformers to make is that transparency ensures the bioeconomy's future and opacity seals its fate. Win that argument and a modified framework is within reach – LTC Dan Kirk

Essay 2: Intellectual Property Protection: Discussion and Dissent

Biotechnology is a field that is especially dependent on new ideas to help the industry advance. Industry advocates are vocal on this point because of the need to give incentives to

inventors that their ideas and inventions will be protected from being undermined or stolen. Supporters of the protection of IP call for industry standards that enable biotechnology companies to have their discoveries safeguarded so companies can profit and further research breakthrough discoveries.[67] Translating ideas into commercial biopharmaceutical products requires seguing to a technology platform and ultimately to a healthcare product for public benefit.

Some observers argue, however, that overprotection of IP has consequences that outweigh the potential benefits an inventor receives from patent protection. While policymakers have grappled with the concern of incentivizing industry in order to put dollars back into research and development, there has always been a worry that overprotecting innovative ideas could prevent others within the scientific community from capitalizing on new innovation. One legal scholar wrote in the 1990s, in the wake of 1980 Supreme Court case *Diamond v. Chakrabarty* that, "…attempts to justify biopatents as deserved rewards for labor ignore the natural and social origin of most of the value of patented organisms and genes."[68] There thus was still resistance to the idea of protecting biotechnology IP solely for the benefit of the inventor. IP protection measures still meet the scorn of academics when the free and transparent exchange of ideas is perceived as being hampered. Another critic of IP protection observed a few years ago that, "Overly restrictive licensing and unrealistic expectations can deter innovation or improvement by controlling the exchange of information and materials for research or the ability to improve the potential product."[69]

It is likely that despite court rulings, we can expect the debate of openness versus protection to continue into the future. This is because there will continue to be the need for case-by-case review of breakthrough biomedical IP and debate on how fast it can be translated into a product for manufacturing. Detractors of strict patent protection point out that while there is merit in safeguarding some unique ideas and rewarding such innovations, biotechnology has broad human impact whether it is from a naturally occurring process or from one that has been manipulated.[70] This therefore raises the question of to what extent these products or processes should be patentable.

Many maintain that with the 2013 Supreme Court *Association of Molecular Pathology v. Myriad* decision, and the court's denial of a claim of a naturally occurring gene, that a reasonable result could be enhanced collaboration and thus new innovation in the industry. Actually openly sharing innovative treatments, seeking public financing, and rewarding appropriately but not excessively could be a better formula for transforming ideas for the public good, while at the same time providing some profit incentive.[71] One scholar in 2006 was prescient several years before *Myriad* in observing that patent protection had swung too far after *Chakrabarty*. i.e. "… [P]ressure is building to do something to assuage concerns that patents are stifling, not stimulating, innovation. There is a growing sentiment that IP rights are at least indirectly denying the public some of the biomedical…benefits that the public rightly deserves, as part of the social contract for which the patent system was established in the first place."[72] The challenge is finding the balance between protecting and sharing, while understanding the unique dependency of this particular industry on new and innovative ideas.

It is crucial for stakeholders to continue discussion on how to both protect and share intellectual property for the benefit of influencing and resourcing the growth of the biotechnology industry. The Supreme Court provided a basis on which practitioners in the public and private sectors can help grow the industry. Varying views ensued in the nation's attempt to implement a balanced interpretation of the decisions. With only a recent revision of the USPTO's guidance in determining for the biotechnology industry what is patent-eligible, legal tussles over the nature of

IP will continue to be revisited.

As part of the bioeconomy "ecosystem," strategic alliances need to influence ideas and IP at the core of this industry to help shape an environment where concepts are translated into products. While the protection of IP is a necessary element in guaranteeing the future viability of biotech enterprises, the sharing of promising information is also central to the existence of the biotech industry, in which strategic alliances are established because of the variety of academic, industry, and government stakeholders with disparate competencies. – Mr. Mike Rosenberg

Essay 3: The "Valley of Death" and Impact on Economic Growth

Policies that bridge the so-called Valley of Death – a term used to describe the danger of fatal failure in the transition of innovations from discovery to marketization – can help connect innovators with investors and thus contribute positively to the biotechnology industry. USG efforts should engage both the "supply" and "demand" ends of biopharmaceutical development to reduce market failures brought on by the high risk inherent in the process.

Authors Auerswald and Branscomb describe the "Valley of Death" as "the gap between demonstrating the soundness of a technical concept and readying the product technology for the market [where] purely technical risks are coupled with the market risks inherent in innovation.[73,74] The gap exists because early research funding, often provided by government or universities, runs out before development and marketization capital, often provided by venture capital or larger firms, is invested. The gap is often made wider by government regulations that drive up developmental costs for new technologies.

This gap in resourcing technology transition has a major impact on the marketization of innovative ideas in biopharmaceuticals. As described by Weitzman, "the ultimate limits to growth may lie not as much in our ability to generate new ideas, so much as our ability to process an abundance of potentially new seed ideas into usable forms."[75,76]

William Ferguson concludes that "[b]y implementing a program that can simultaneously influence both sides of the Valley of Death, the relevant stakeholders can be drawn together."[77] The biotechnology industry must work with government to develop new policies that reduce the cost impact of regulatory requirements for innovative biopharmaceuticals.

Lost in the Valley

Biopharmaceuticals require a significant investment in research, pre-clinical development and clinical trials to deliver a marketable drug. To describe "Valley of Death" in the context of biopharmaceuticals one must overlap the technology transition process with the pharmaceutical development process. The biopharmaceutical development process is a five-stage process, including basic research, preclinical development, clinical trials (Phase I, II, and III), FDA approval, and post approval and marketing, as shown by Figure 5.[78] Auerswald and Branscomb describe technology transition as a similar five-stage process, including concept invention, early stage development, product development, and production/marketing, and tie each to typical sources of investment, as shown in Figure 6.[79]

The Valley of Death for the biopharmaceutical industry spans up to eight years from preclinical studies through Phase III clinical trials, corresponding with the early stage development through product development period. During this period, threats to the marketization of biopharmaceuticals include scientific failures, failures to resource early developmental stages, and

failures to resource continued development. Auerswald and Branscomb call these "supply side" and "demand side" failures, respectively.

The gap between the supply and demand sides of the Valley of Death is created by a shortfall in capital between the supply of innovation companies and the demand for investment. Market failure often occurs in this tremendously risky phase of biopharmaceutical development. Michael Lawlor writes that "[t]he failure is caused by the degree to which the process of creating new scientific knowledge and technological innovation may be insufficiently appropriable—that is, difficult to establish property rights—to provide profit-seeking investment with sufficient rationale to pursue such research."[80] Lawlor goes on to describe the "possibility that in relatively new technological areas, there may be an additional market failure as firms find the difficulties of translating new laboratory science results into industrially viable technology too risky for private-investment hurdles."[81]

Causes of Failure in the Valley of Death

The high risk of failure creates pressure to delay capital investment until as late as after Phase II trials are in the pipeline. According to Michael Hay, et al, out of the biologics developed for "all indications" in clinical trials, 14.6% of those that transitioned from Phase I to Phase II were ultimately approved for use by the FDA, 21.3% for those that transition from Phase II to Phase III were ultimately approved, 56.1% from Phase III to new drug/biologic license application (ND/BLA) filing were ultimately approved, and 88.8% of those that complete ND/BLA filing were approved.[82] The significant rates of failure combined with the high costs of development explain why investment in the drug development process is often delayed.

Supply side pressure leads to failure when emerging biotech companies cannot acquire sufficient capital to continue development of the innovation. Hay, et al, found that, between 2003 and 2011, 85% of companies developing and testing drugs were "emerging biotech" companies with less than $0.1 billion in sales, 11% were small to mid-sized companies and only 4% were large drug/biotech companies with more than $5 billion in sales.[83] This data shows that most of the firms doing the early research are a diverse selection of emerging biotech companies with capital shortfalls.

The demand side pressure on the biopharmaceutical development process is driven by high investment requirements, the high risk and relatively slow return on investment, and the limited potential for long-term return as exclusivity rights expire. Clinical trials test the safety and efficacy of new biopharmaceuticals and are required by the Federal Food, Drug, and Cosmetic (FD&C) Act. In a study of the FDA regulatory process, Avik Roy found that "Phase III trials are, by far, the biggest expense, and the biggest risk, of new drug development," costing up to 90% of the developmental cost of the drug.[84, 85] The demand side pressure causes the firms to delay in investing in innovations, increasing the market failure.

Policy Recommendations to Shallow the "Valley of Death"

Supply side

Supply side policies include direct investment in early research and shared resource programs. On the supply side, the USG should continue to invest in biotechnology through government grants, prizes, and other incentives while refining the process for determining the best recipients. Matthew Herper, an industry analyst, recommends a combination of supply side improvements to the capital market requirements to shallow the Valley of Death, including computer simulation programing for preclinical testing, DNA sequencing testing, and stem cell

testing to stop development early in failures and thus reduce capital requirements.[86] Herper also recommends focusing on the soundness of the basic science rather than on the end product to increase success and make better use of government capital investment.[87] Herper suggests this shift away from trying to force a particular development would rein in costs[88] and could help decrease capital burdens on emerging companies.

Government policy to encourage the development of bioscience clusters and incubator programs could support emerging biotech companies by reducing the large investment required for early stage development. Ghadar, et al, describe the benefit of clustering by showing the historical impact of how "[c]lusters of producers, suppliers, and training centers often arise when business segments require high levels of specialization from multiple contributors" and note that these collections enable an environment that supports early innovation success by the sharing across the disciplines enabled by their colocation.[89] Ghadar, et al, suggest that a cluster for biotechnology could occur within the United States with the right government policies toward advances in shared data systems, support for early research and development, and the use of shared facilities and systems.[90]

This type of alliance may provide the opportunity to merge industry needs, academia ideas and government resources to support industry growth. An example is the biocluster that has emerged as a result of government policy in Singapore. Through a collective effort of the Singapore Health Services Authority (Singapore's regulatory agency); government efforts in research and development support, including the Translational and Clinical Research Flagship Programme, which translates research directly to healthcare; and research collaborative efforts, led by the city-state's Agency for Science, Technology, and Research, Singapore has created "Asia's fastest-growing bio-cluster".[91]

The UK government published an "Innovation & Research Strategy for Growth" and a "Life Sciences Strategy" that promises £180 million to bridge the 'Valley of Death' for new medical breakthroughs by providing for government funding of transitional research before a product gains market investment.[92] This type of government investment targets the supply side.

Demand side

On the demand side, the USG should help lower regulatory and developmental testing costs with the aim of decreasing required investment of venture capital. Opening access to national labs to make better use of facilities that have already been funded could help diffuse the cost of developmental R&D. Using slack capacity in currently funded scientific facilities can benefit emerging biotech companies that require laboratory facilities to conduct research into biopharmaceutical science without additional costs. The 2015 NSS recognizes this potential, noting "[w]e will also keep our [innovative] edge by opening our national labs to more commercial partnerships while tapping research and development in the private sector, including a wide range of start-ups and firms at the leading edge of America's innovation economy."[93]

A second policy change would be to simplify the drug approval process to reduce the excessive expense of Phase III trials. This change would be possible due to advances in data collection techniques and precision analysis. A third policy recommendation is to open new channels for drug approval, like conditional approvals, that would pay for the most expensive phase of clinical trials by selling the drugs in Phase III to patients with no other options.[94] This would allow a company to invest in the costs of development and marketization thereby decreasing financial risk to investors. These demand side policies may decrease financial risk to investors and help motivate earlier investment.

Government policies that may inspire investment are those that reduce the cost of later development, including public-private investment partnerships and altering the approval process. Public-private partnerships in the European Union (EU) are enabling technology advancement in industries, including biotech, through a joint investment of "€22 billion over the next seven years in innovation."[95]

Changes to the requirements for drug approval may allow a biopharmaceutical to survive through the most expensive phase of the approval process, reducing funding requirements while saving lives. Roy recommended a change to allow for a "conditional approval" of drugs after successful Phase II trials for those most in need of a new therapy that could help fund Phase III trials, a policy already allowed in accelerated approval programs.[96] – Lt Col Bill Maxwell

CONCLUSION - THE BIOECONOMY IMPERATIVE

Understanding the inseparable linkage between a strong economy and national security, the USG has great reason to facilitate the responsible growth of the biotechnology industry as an economic driver and a force for good. The impact of biotechnology on healing, feeding and fueling a growing and overburdened world population elevates USG support for the broader bioeconomy to that of an imperative.

Pursuing targeted improvements in the way the USG engages with and supports the biotechnology industry – in the key areas of human capital, intellectual property protection, capital investment and marketization, regulation, coordination, and branding – would help the market reward scientific advancements and commercial promise, while still allowing the government to shape the safety and efficacy of biotechnology for the benefit of the U.S. population. The biotechnology industry, with its proven ability to improve so many aspects of our lives, shows tremendous potential to play an even larger role in a vibrant U.S. economy and deliver fundamental gains for mankind.

TABLES and FIGURES

Table 1: Education and Experience Requirements for Biotechnology jobs

	Minimum Requirements						Other Preferences				
	High School Diploma	Assoc. Degree/Certificate	Bachelor's Degree	Ph.D. Degree	Work Experience	Apprenticeship	Work Experience	Some College Courses	Assoc. Degree/Certificate	Bachelor's Degree	License or Certificatation
Animal Caretaker	●						●	●			●
Animal Technician		●					●				●
Bioinformatics Specialist			●		●		●				
Clinical Research Associate			●		●						●
Documentation Coordinator	●				●				●		
Forensic DNA Analyst			●				●				
Greenhouse and Field Technician		●			●					●	
Greenhouse and Field Worker	●				●				●		
Health and Safety Specialist		●			●					●	●
Instrumentation/Calibration Technician		●				●	●				●
Laboratory Assistant		●					●			●	
Laboratory Automation Specialist		●			●					●	
Laboratory Support Worker	●						●	●			
Laboratory Technician		●			●					●	
Manufacturing Assistant	●				●			●	●		
Manufacturing Technician	●				●				●	●	
Material Handler	●						●				
Quality Assurance Specialist		●			●					●	●
Quality Control Technician		●			●					●	●
Research Associate			●				●				
Sales Representative			●		●						
Scientist				●							
Technical Services Representative		●			●					●	

*From: www.bio-link.org/home/sites/files/**careersinbiotech**20088e-j.pdf*

Table 2: Top 10 biotechnology jobs in next decade[97]

Position	Description
Medical Scientist	Research and investigate biological systems to further understand and treat human diseases
Biological Technician	Set up and maintain labs and instruments for use by biological and medical scientists
Medical / Clinical Lab Technician	Perform tests on blood, fluids, organs, and tissue in labs or health care facilities
Biochemist / Biophysicist	Study effects of drugs on molecules including DNA, RNA, and proteins
Biomedical Engineer	Design and build products including prostheses, MRIs, and CAT scans
Microbiologist	Conduct research to classify and determine functions of microorganisms
Epidemiologist	Collect and analyze data to determine the causes of diseases and prevent future problems
R&D / Process Development Scientist	Responsible for the manufacturing process within a lab, including supervision of lab technicians
Regulatory QA/QC Biomanufacturing Specialists	Supervise a project or job and guaranteeing that all criteria and requirements are met
Bioproduction Operators	Ensure proper manufacturing, packaging, and shipping of products

Table 3: Idea and IP at the Center of the Biotechnology "Ecosystem"

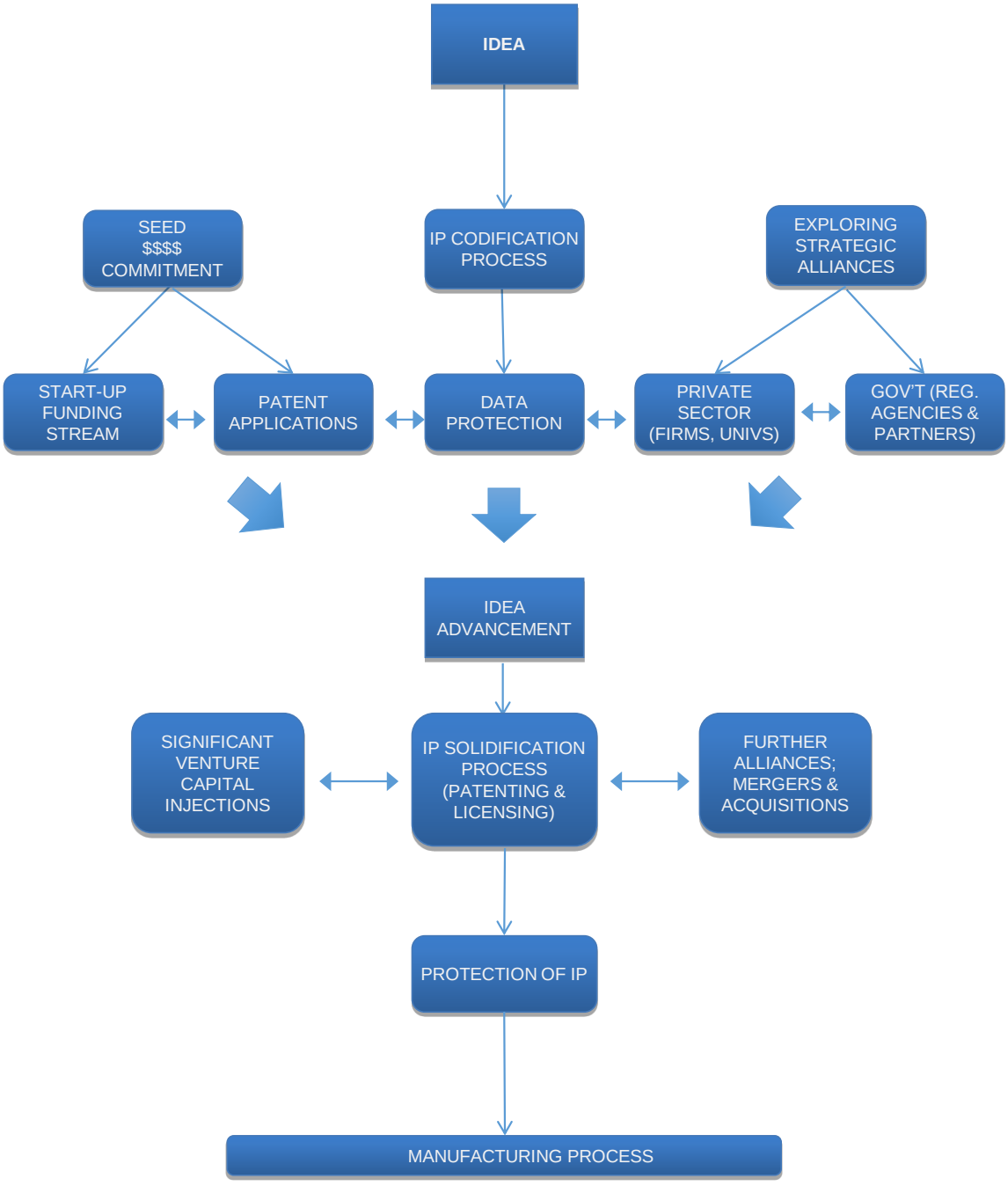

Table 4: Partnerships

Contractual Mechanism	Private Sector Partners	Public Sector Partners	Funding	Products
Licensing* (2015)	--NewLink Genetics --Merck	--NIH --Public Health Agency of Canada	$50M (Merck) $30M (NIH)	Ebola vaccine
Cooperative Agreement** (2014 - 2019)	--Lilly --GSK --AbbVie (*et al*)	NIH	$220M through NIH AMPS program	Alzheimers, Lupus, and Type 2 Diabetes treatments
Acquisition*** (2015)	Biogen Idec acquiring Convergence Pharmaceuticals	N/A	Biogen Idec paying $675M for the acquisition	Neuropathic pain treatment

***** This licensing arrangement will be between the licensor (in this case NewLink Genetics) and the licensee (Merck) on finalizing the development towards a start-up manufacturing process, which is Merck's expertise and for which it possesses the industrial capacity. Merck will pay $50 million to NewLink for rights and privileges to manufacture the vaccine. Original research and technology originated under the Public Health Agency of Canada. NIH is contributing $30 million in support costs to vaccine development. [98]

** The NIH Accelerated Medicines Partnerships (AMP) program is designed for the purpose of avoiding intellectual property restrictions, and creating a repository of data and analyses accessible to the scientific community. NIH expects that all information, data, protocols, resources, and methods developed by AMP investigators will be shared quickly and in a timely way with other investigators in the consortium and with the general research community, "unencumbered by any intellectual property claims." [99]

*******Biogen Idec acquisition of UK biotechnology firm Convergence Pharmaceuticals, along with its IP, will occur over several milestones, the first of which will include a payment from Biogen of $200 million, followed subsequently by a final $475 million. Convergence acknowledged Biogen's larger capacity to manufacture and bring the UK company's invention to market.[100]

Figure 5: The FDA Drug Development Path

Figure from Thaul, Susan. How FDA Approves Drugs and Regulates Their Safety and Effectiveness. Washington, D.C.: Congressional Research Service, 2012.

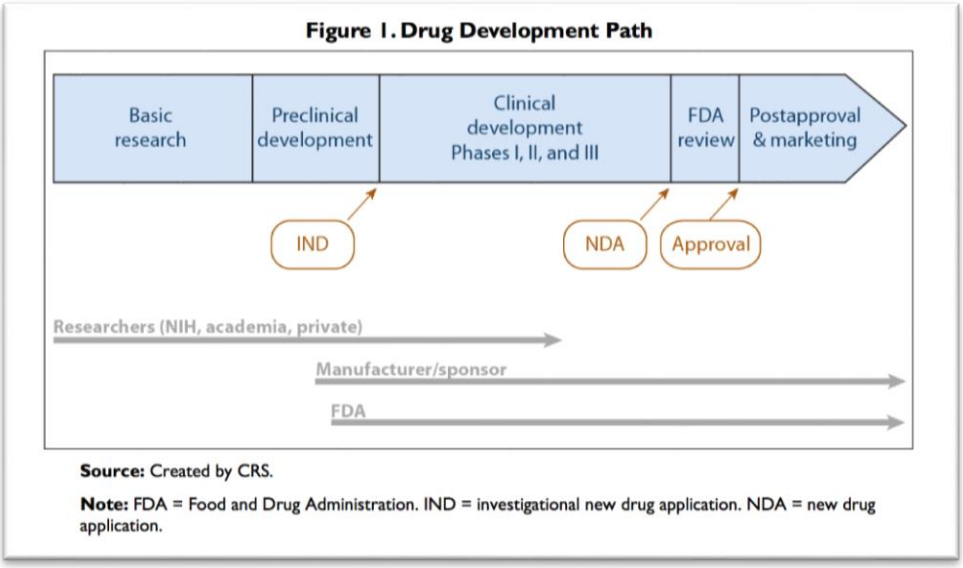

Figure 6: The Valley of Death Path

Figure from Auerswald, Philip E. and Lewis M. Branscomb. "Valleys of Death and Darwinian Seas: Financing the Invention to Innovation Transition in the United States." Journal of Technology Transfer 28, no. 3-4 (08, 2003): p. 229.

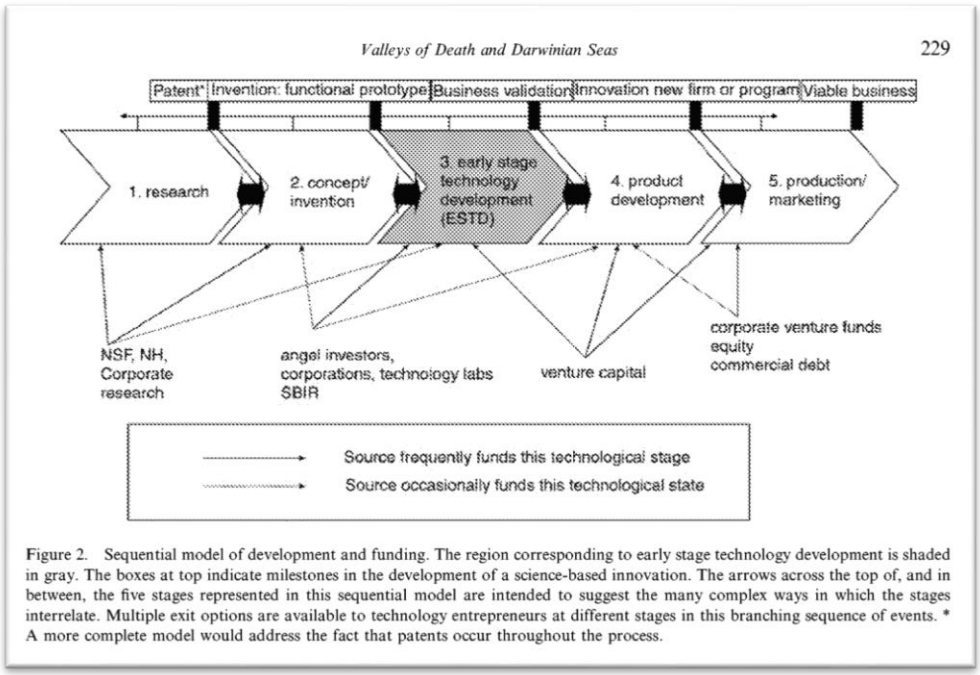

Figure 2. Sequential model of development and funding. The region corresponding to early stage technology development is shaded in gray. The boxes at top indicate milestones in the development of a science-based innovation. The arrows across the top of, and in between, the five stages represented in this sequential model are intended to suggest the many complex ways in which the stages interrelate. Multiple exit options are available to technology entrepreneurs at different stages in this branching sequence of events. * A more complete model would address the fact that patents occur throughout the process.

Endnotes

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[14] Ibid.

[15] Ibid.

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[17] "Battelle/BIO State Bioscience Jobs, Investments and Innovation 2014. A Robust Bioscience Industry with Strong Prospects for Growth."; "The Pharmaceutical and Biotech Industries in the United States."

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[36] The discussion took place during the seminar visit to Malaysia and was non-attributional. However, the remarks were made describing routine interactions with Malaysian farmers and local government officials. The speaker was clear that most of the engagements with fellow citizens had the feel and tone of a religious discussion. The speaker used the word "religious" to describe the resistance to reason and scientific explanation.

[37] "Snuck up on us" was a phrase used once and a sentiment expressed during several encounters.

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