7 October, 2019

Written statement accompanying the appearance of Bioeconomy Capital Managing Director Dr. Rob Carlson at the White House Summit on America's Bioeconomy*, 7 October, 2019. Dr. Carlson was tasked with addressing the question: "What is Needed to Secure a Flourishing Bioeconomy?"*

Dr. Carlson made the following points in his remarks, which are expanded and elaborated below in this statement.

- The United States today generates at least 2% of GDP from biotechnology. Our vibrant bioeconomy is due to national leadership and early investment in the burgeoning field of biological engineering.
- Biological engineering and biomanufacturing together constitute a flexible and powerful technology platform, mastery of which is critical to the physical and economic security of the nation in the 21st century.
- The U.S. must diligently invest to maintain its lead in developing biotechnology. The potential for losing that lead is a one-time, imminent, event; it is unlikely that our current lead could be regained if lost.
- The U.S. laissez-faire approach to the market and to planning does have its advantages, but also its costs, where the latter now negatively impact our physical and economic security. Our hands-off attitude, coupled to a short-term focus, puts us at risk.
- International competitors have clearly and explicitly described their intent to dominate the global stage in the 21st century using biotechnology, and are investing to implement associated long-term strategic goals. Consequently, to avoid falling inexorably behind, the U.S. must begin to plan and execute on the same multi-decadal timescales as our competitors.
- Policymakers and lawmakers together can choose to increase investment in U.S. bio-technological leadership, an action that is required to ensure U.S. economic and physical security, or they can choose to let our lead lapse, never to be regained.

Written Remarks[1]:

U.S. revenues from engineered biological systems reached at least $388 billion in 2017, or ~2% of GDP[2] (Figure 1). For comparison, if considered as an industrial sector unto itself, biotechnology contributes more to the economy than mining, utilities, or a number of other construction and industrial sectors[3],[4].

1 These remarks quote from Dr. Carlson's recent Congressional testimony on "Engineering Our Way to a Sustainable Bioeconomy", on 12 March, 2019, which remarks are also included here by reference.
2 Carlson, R., "Estimating the biotech sector's contribution to the US economy", Nature Biotechnology, 34, 247–255 (March, 2016). For updates, see the Bioeconomy Dashboard: https://www.bioeconomy.capital/bioeconomy-dashboard/
3 ibid.
4 BEA, GDP By Industry, https://apps.bea.gov/iTable/index_industry_gdpIndy.cfm

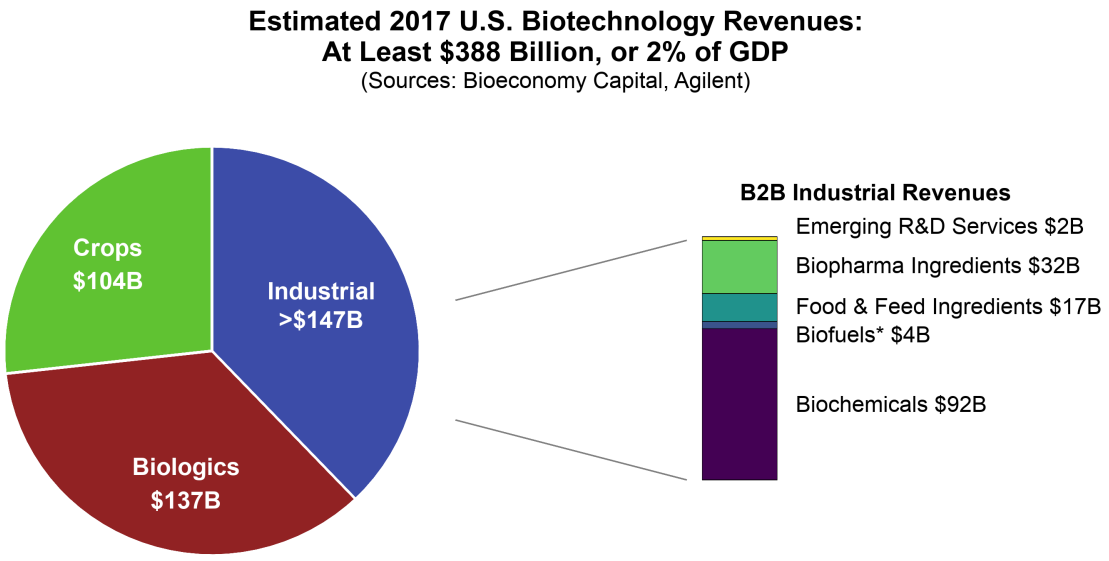

Figure 1: Estimated 2017 U.S. Biotechnology Revenues. Data and methods described at the Bioeconomy Dashboard: https://bioeconomy.capital/bioeconomy-dashboard/.

When compared to the economy as a whole, it is clear that biotechnology is increasingly important both for its absolute size and because it is more stable and resistant to downturns than other sectors, with the caveat that swings in commodities prices can have large impacts on sector revenues through crop revenues (see, for data, analysis, and references, the Bioeconomy Dashboard[5]). Generally, when the rest of the economy slows or contracts, biotechnology has picked up the slack, contributing at least 7% of annual GDP growth during the last recession (Figure 2).

The economic impact of biochemical manufacturing is likely to grow significantly over the next decade. Government and private sector investments have resulted in the capability today to biomanufacture every molecule that we now derive from a barrel of petroleum, and, using the extraordinary power of protein and metabolic engineering, to also biomanufacture a wide range of molecules that cannot plausibly be made using existing chemical engineering techniques. This story is not simply about sustainability. The power of biology can be harnessed to give products improved properties. There is enormous economic and technical potential here. The resulting new materials, manufactured using biology, will impact a wide range of industries and products, far beyond what has been traditionally considered the purview of biotechnology[6].

5 Bioeconomy Dashboard: https://www.bioeconomy.capital/bioeconomy-dashboard/
6 "Redesigning Life", *The Economist*, 6 April 2019.

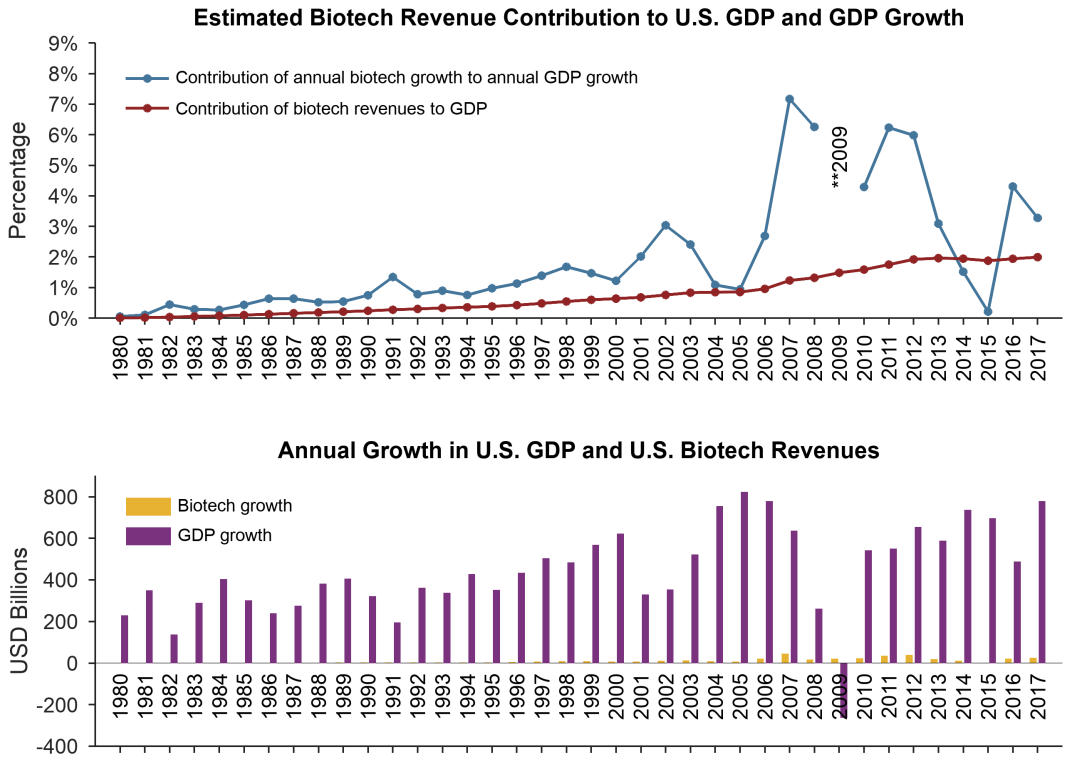

Figure 2: Top: Estimated biotech revenue contribution to U.S. GDP and GDP growth. The 2009 percentage contribution is omitted because GDP growth was negative that year. Bottom: Absolute annual growth in U.S. GDP and biotech revenues. Data and methods described at the Bioeconomy Dashboard: https://bioeconomy.capital/bioeconomy-dashboard/.

For example, our portfolio company Arzeda is now scaling up the biomanufacturing of a methacrylate compound that can be used to dramatically improve the properties of plexiglass. This compound has long been known by materials scientists, and long been desired by chemical engineers for its utility in improving such properties as temperature resistance and hardness, but no one could figure out how to make it economically in large quantities. Arzeda's biological engineers combined enzymes from different organisms with enzymes that they themselves designed, and that have never existed before, to produce the compound at scale. This new material will shortly find its way into such products as windshields, impact resistant glass, and aircraft canopies.

Similarly, our portfolio company Zymergen is developing remarkable new materials that will transform consumer electronics. Zymergen is commercializing a set of films and coatings that have a set of properties unachievable through synthetic chemistry and that will be used to produce flexible electronics and displays. These materials simply cannot be made using the existing toolbox of synthetic chemistry; engineering biology gives access to a combination of material properties that cannot be formulated any other way. Consequently, biological engineering will bring about a renaissance in materials innovation. This transformative power of biological engineering is now being broadly pursued globally.

At least 32 countries around the world have identified biological engineering as a strategic technology and are investing accordingly[7]. Many of these countries view domestic development of biotechnology and biomanufacturing as a less capital-intensive path to economic development than that pursued by the United States, Europe, and Japan in the 20th century.

The government of China, in particular, has clearly stated its intention to become a dominant global power via domestic development and mastery of biotechnology. Repeated declarations by the country's leaders demonstrate that they believe biotechnology is a critical tool in their efforts to maintain China's economic development and to sustain the health of its population, the country's greatest resource. In 2002, President Jiang Zemin stated publicly that the government would use all means available to improve the health of the population, including genetic modification of its citizens[8]. In September of 2008, Premier Wen Jiabao stated, “To solve the food problem, we have to rely on big science and technology measures, rely on biotechnology, rely on [genetic modification].”[9] The “food problem” to which the Premier referred is a combination of a still-increasing population and a recent, precipitous decrease in arable land[10]. On January 9, 2006, Premier Wen Jiabao announced a plan to “catch up with the most advanced nations in biotechnology” while strengthening “independent” or “indigenous” innovation[11]. These plans and statements have continued apace more than a decade, resulting in significant domestic investment and innovation. As of 2018, the Chinese government reportedly had a goal of growing the domestic bioeconomy at 15% annually[12]. As of 2015 the bioeconomy was $700B, or ~4% of Chinese GDP, and the government has a target of more than doubling this to $1.6T, and ~5% of GDP by 2020[13].

The U.S. government should take at face value these consistent statements by Chinese government officials about the perceived national importance of biotechnology. Beyond domestic techno-economic policy, these statements lay out a clear vision for how China intends to 1) develop and acquire biotechnology, and 2) use that technology in the national interest. For example, the explicit PLA technology acquisition strategy has been translated as “Obtain jade from the rocks of others’ mountains”, and described by the PLA itself as a process of “picking flowers in foreign lands to make honey in China (异国采花，中华酿蜜)”[14],[15]. The most aggressive statement of intent that I have come across, which I presented in public for the first time to the recent National Academy of Sciences study on “Securing the Bioeconomy”, is from a high-level Communist Party and Chinese National Academy of Sciences official: “As Europe won in the 19th century using industry, and the U.S. won in the 20th using information technology, so China will win in the 21st using biology.”[16] This language, and the purpose it conveys, is unequivocal; it highlights the imperative requirement to organize U.S. public and private resources to meet national needs.

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7 Organisation for Economic Cooperation and Development. Emerging Policy Issues in Synthetic Biology, 2014.
8 Carlson, R., “Causes and Consequences of Bioeconomic Proliferation: Implications for U.S. Physical and Economic Security", Biodefense Net Assessment 2012, Homeland Security Studies and Analysis Institute, 2011.
9 ibid.
10 ibid.
11 ibid.
12 Personal Communication, Yin Li, Deputy Director-General of Bureau of International Cooperation, CAS, Global Bioeconomy Summit, Berlin, 2018.
13 ibid.
14 “A New Direction for China's Defense Industry”, E. Medeiros, et al, RAND Corporation, 2005, p 55.
15 “Picking flowers, making honey: The Chinese military’s collaboration with foreign universities”, Alex Joske, Australian Strategic Policy Institute (ASPI), 2018.
16 Robert Carlson, “Securing the Bioeconomy” presentation at U.S. National Academy of Sciences, January, 2019.

Fortunately, private and public sector goals in the bioeconomy are entirely aligned in this regard. Any action that benefits one sector reinforces both sectors. In other words, industry investments that generate returns for shareholders generally contribute to continued national economic success and, therefore, to national security, while government investments in education and R&D directly deliver national security benefits and, more broadly, supply the private sector with skilled labor and new science and technology. Nevertheless, increased communication and coordination are required to ensure resources are directed appropriately. This collaboration might take the form of a public-private partnership with the mission of ensuring continued U.S. leadership in biotechnology and the bioeconomy throughout the 21st century. Leaving long-term planning to "the market" will result in a catastrophic U.S. national security failure, as "the market" typically cannot see beyond the next quarter and frequently forgets what time it was five minutes ago. In contrast, our competitors have substantively longer attention spans, as demonstrated by their organized increase in scientific and economic output over the last two decades. In response the U.S. government must organize a domestic collaboration between the public and private sectors to accelerate biotechnology in the national interest, and this effort must be recognized as a long-term commitment. That collaboration must begin immediately.

Investing to develop and maintain the lead in advanced bioengineering and biomanufacturing will require concerted attention and effort. This is not a sprint to be won, but rather a long-term competition that will require continual effort; there is no finish line, and no time limit. But there is a looming, and exigent, deadline for organizing ourselves to compete. It is not an exaggeration to classify this race as an extension of the Great Game of international affairs, because that is precisely the way our competitors describe it. We must be engaged for the long haul, and we must begin today.

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