Written Testimony of:
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U.S. House of Representatives

The Future of Biotechnology: Energy, Agriculture, and Manufacturing

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Chairman Comstock, Ranking Member Lipinksi, and distinguished Members of the Subcommittee on Research and Technology, I thank you for the opportunity to testify before you today on the future of biotechnology and its applications for energy, agriculture, and manufacturing.

I am Reshma Shetty, co-founder and President of Ginkgo Bioworks. I hold a Ph.D. in Biological Engineering from MIT and have been active in the field of biotechnology for over 10 years. I would like to provide an overview of Ginkgo Bioworks along with synopsis of the science behind biological engineering. I will focus my testimony on two key areas relating to U.S. biotechnology:

1. The importance of Federal funding for realizing the commercial and economic potential of biotechnology in the United States.
2. Current and future biotechnology applications.

Before I discuss these key issues, I would like to thank the Subcommittee for its continued leadership and advocacy for the National Science Foundation. Without the NSF's support, it is likely that I would not be here before you today.

- An NSF STEM fellowship supported my own graduate education.
- NSF grants provided early critical support to both the iGEM competition – an international intercollegiate competition in synthetic biology which has grown from 5 U.S. teams to more than 250 teams representing over 32 countries and to SynBERC - a major U.S. research consortium in synthetic biology. Together, iGEM and SynBERC have directly or indirectly educated a significant share of the U.S. workforce in synthetic biology including myself.
- Finally, in 2015, Ginkgo raised more than $50M in private capital. This fundraising was only possible because of the early investments made by Federally-funded research awards from NSF, DOE ARPA-E, NIST and DOE ARPA-E in Ginkgo Bioworks.

Ginkgo Bioworks was founded in 2008 by a team of 5 MIT PhDs, including Tom Knight who is widely considered to be the father of synthetic biology. We now employ 50 people; 13 of whom reside in Congresswoman Clark's 5th District of Massachusetts. Ginkgo Bioworks is the organism company: we design and license microbes such as yeast to customers. These microbes can create a wide variety of products that are either costly or inaccessible through conventional manufacturing techniques. Analogous to the microelectronics industry, we use a centralized

factory or foundry for microbe design and fabrication. Our first foundry is Bioworks1: a highly automated, 18,000 square foot facility in Boston, Massachusetts. Ginkgo currently has more than 20 microorganisms under contract with a variety of customers including Fortune 50 companies.

Synopsis of the science

Fermentation is a process by which cooking is done with microbes rather than heat. Fermentation is a deep part of most cultures: beer, wine, cheese, yogurt, bread, coffee and chocolate all involve microbes. We can use the tools of biotechnology – our ability to read and write DNA - to study fermentation and to design microbes to make new products from fermentation. We call these new products "cultured products" and they include new ingredients like sweeteners, flavors, fragrances, new foods such as animal-free meat and milk and new materials like silk and leather.

New and emerging technologies Ginkgo is developing or supporting

Figure 1: Ginkgo Bioworks' organism foundry: Bioworks1

To date, much of biological research has been done in what is effectively an artisanal process. Apprentices study for years under a master to learn the techniques and approaches needed to perform biological research. Indeed, technically skilled biologists are often said to have "good hands." At Ginkgo, we take an engineer's approach to biological design. We apply software, automation and standardization to the process of microbe design and fabrication. This spring, we launched our first foundry for organism design called Bioworks1. Bioworks1 automates what are traditionally by hand processes required for biological engineering through the use of integrated software and hardware. Thus, we seek to usher in a new kind of manufacturing: manufacturing for the design and construction of microbes to spec for customers.

Bioworks1 is the first generation of Ginkgo's organism engineering foundry. We are currently in the process of building a second foundry—Bioworks2 — which is scheduled for completion in 2016. We have adopted Intel's chip fabrication facility philosophy; when a new wafer is invented, a new fabrication facility is built as opposed to shutting down and reconfiguring the existing fabs. By allowing the existing fabrication facilities continue to operate Intel increases their total production capacity with each new chip. Bioworks2 will be twice as large as Bioworks1 and will scale and improve upon our existing capabilities. Ginkgo already has plans for Bioworks3 in place. Each new foundry both expands our domestic organism manufacturing capabilities and spurs job creation in a wide variety of professional fields from construction to science.

Current or potential practical applications

Ginkgo is actively working with various governmental and commercial entities on several applications for biotechnology including:

Cultured ingredients: The 2014 global flavors and fragrance market was worth an estimated $27.5 billion[1] and will continue to grow as more people enter the middle class. The U.S. can capture that market with cultured ingredients. By engineering yeast strains to produce the desired ingredients we can move growth and manufacture processes to the United States. For example, Ginkgo is currently designing yeast to produce a culture rose scent. The introduction of a cultured rose will mark the first new rose oil on the market in 150 years. Cultured ingredients have several advantages over the corresponding plant extract including:

- Lower cost of goods
- Improved product consistency
- Supply stability
- Supply chain transparency
- 'Unlimited' scale
- Remove allergens
- No pesticide residues
- Lower environmental impact
- Creates skilled and non-skilled labor requirements

***Probiotics*:** According to the CDC, "*Each year in the United States, at least 2 million people become infected with bacteria that are resistant to antibiotics and at least 23,000 people die each year as a direct result of these infections. Many more people die from other conditions that were complicated by an antibiotic-resistant infection*."[2] With DARPA's support, we are developing probiotics to prevent drug resistant bacterial infections in the gut by specifically preventing the acquisition of antibiotic resistance genes in the gut microbiome. This technology allows existing antibiotics to continue to be an effective treatment for infection and does not negatively effect the existing gut microbiome.

Strain improvement: By leveraging the power of Bioworks1, Ginkgo can optimize existing fermentation processes. For example, we have a partnership with Ajinomoto, a global manufacturer of foods, beverages, amino acids, pharmaceuticals and industrial chemicals, to improve their existing fermentation process.

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[1] Leffingwell & Associates. 2010 - 2014 Flavor & Fragrance Industry Leaders. http://www.leffingwell.com/top_10.htm. Accessed December 4, 2015

[2] Centers for Disease Control and Prevention. Antibiotic resistance threats in the United States, 2013. http://www.cdc.gov/drugresistance/threat-report-2013/index.html. Accessed December 3, 2015

Role of the Federal Government in supporting, coordinating and commercializing the science

The U.S. Government has long had a critical role in nurturing nascent industries long before they are attractive to private investment. Historically, this has often happened via a two pronged strategy in which the U.S. Government initially provides R&D funding for critical, high impact technology development and then, as the technology matures, the U.S. Government serves as an early customer for the resulting products. As a result of this activity and customer demand, private investment begins to flow stimulating the creation of a new industry. This pattern played out in the early days of the microelectronics industry in which the U.S. Government was an early customer for integrated circuits via the Apollo and Minuteman programs.

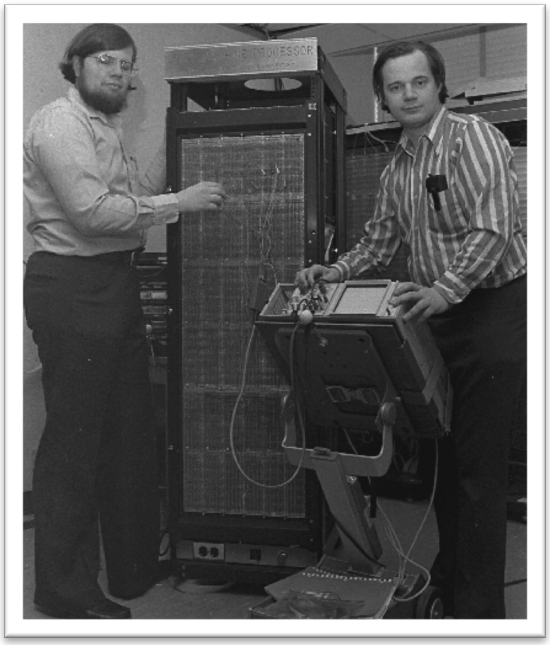

Figure 2: Ginkgo founder Tom Knight (left) standing next to an early computer – a Lisp machine.

The U.S. Government has a similar essential role to play in the future of biotechnology. My co-founders and I were able to bootstrap Ginkgo from scratch on the basis of various federal awards from NSF, DOE ARPA-E, NIST and DARPA. This early U.S. Government R&D funding was critical to allowing us time and resources to refine our foundry approach to designing and fabricating microbes and build our business. Over the past 18 months, we've been able to raise more than $50 million in private investment as a result. Technology developed with NSF and DOE ARPA-E funding directly led to two of our commercial contracts today.

The National Engineering Biology Research and Development Program proposed under H.R. 591 would coordinate and streamline the Federal Government's ongoing and future R&D support in bioengineering. I thank for Representative Johnson for recognizing this need and introducing H.R.591 as well as Representatives Sensenbrenner and Peters for their co-sponsorship. Bipartisan support of this bill is a clear sign that biological engineering R&D supports the national interest.

Economic, technological or regulatory challenges or barriers to bringing the products to market

Unlike with the microelectronics industry, however, the U.S. Government has thus far not been an early customer for the nascent synthetic biology industry. With countries like the United Kingdom and China having well coordinated national programs in synthetic biology, the United States is at risk for losing its competitive edge in this area. By serving as an early customer and

stimulating demand for the products of biotechnology, the U.S. Government could play as central a role to the biotechnology industry as it has in the past for integrated circuits.

A common concern raised regarding biotechnology is whether there will be public acceptance of these cultured products. We are likely to see a significant shift in the public understanding of these technologies in the near future. The first consumer products of biotechnology are entering the marketplace. North Face has partnered with the Japanese biotechnology firm Spiber to product a winter jacket from cultured spider silk. A new generation of food tech companies are advancing cultured meat and cultured milk as animal-free alternatives. The U.S. Government can help to ensure these cultured products make it to the marketplace and are able to fairly compete with traditional products by encouraging the growth of domestic bio-manufacturing capacity. Expanding U.S.-based fermentation capacity will promote job growth and ensure that the U.S. reclaims its manufacturing competitiveness.

Members of the Subcommittee, on behalf of Ginkgo Bioworks, Inc., I would like to thank you for the opportunity to testify on the future of biotechnology. We believe this technology provides new opportunities to enrich consumer experiences and broadens their purchasing options. This is a very exciting time for biological engineering: it has the potential to reinvigorate American manufacturing and drive economic growth and job creation. I would be happy to answer any questions from the Subcommittee.

Thank you.