U.S. HOUSE OF REPRESENTATIVES
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
HEARING CHARTER

Engineering our Way to a Sustainable Bioeconomy

Tuesday, March 12, 2019
10:00 am – 12:00 pm
2318 Rayburn House Office Building

Purpose

On Tuesday, March 12, 2019, the Subcommittee on Research and Technology of the Committee on Science, Space, and Technology will hold a hearing to review the opportunities and challenges with new and emerging bioscience and biotechnologies with application in agriculture, energy, and manufacturing; to examine the role of the federal government in research and development (R&D) and oversight of such science and technologies; and to examine the status of U.S. leadership in engineering biology. An additional purpose of this hearing is to receive testimony on the *Engineering Biology Research and Development Act*, which would establish a federal R&D initiative in engineering biology.

Witnesses

- **Dr. Rob Carlson**, Managing Director of Bioeconomy Capital
- **Dr. Kevin Solomon**, Assistant Professor of Agricultural & Biological Engineering at Purdue University
- **Dr. Eric Hegg,** Professor of Biochemistry and Molecular Biology, Michigan State University; Michigan State University Subcontract Lead, Great Lakes Bioenergy Research Center
- **Dr. Sean Simpson**, Chief Scientific Officer and Co-Founder of LanzaTech
- **Dr. Laurie Zoloth**, Margaret E. Burton Professor of Religion and Ethics, and Senior Advisor to the Provost for Programs in Social Ethics at the University of Chicago

Overarching Questions

- What are the new and emerging biotechnologies and what are their potential applications for the energy, agriculture, and manufacturing sectors as well as potential benefits for the environment?

- What are the potential ethical, security, and other societal concerns related to engineering biology R&D. How should those concerns be integrated into governance for R&D and into engineering biology and related curricula and research training?
- What is the state of the workforce in engineering biology?
- What is the appropriate role of the federal government in supporting engineering biology R&D? Is there a need for a federal interagency initiative and strategy for engineering biology R&D as proposed in the *Engineering Biology R&D Act*? If so, does the legislative proposal adequately address what is needed to maintain U.S. leadership in engineering biology?

Engineering Biology and Applications

Engineering biology[1] is a multidisciplinary field at the interface of biological, physical, chemical, and information sciences and engineering. By applying tools from engineering, computing, and physical sciences to biological systems, researchers are able to study, mimic and design new biological systems to develop or improve existing products, processes, and systems. The applications to energy, agriculture, and advanced manufacturing are vast, and many such applications are already in the commercial marketplace. Researchers are also excited about the potential benefits to human and environmental health. Dr. Solomon, a witness for this hearing, does fundamental research to understand the design principles of microbial systems and to expand the toolbox for engineering biology for potential application across multiple sectors.

The growth of engineering biology has accelerated due to the increased speed and affordability of enabling technologies, including DNA sequencing and gene editing tools. In the case of DNA sequencing, the cost to sequence the human genome has fallen from the $2.7 billion it cost in 2001 to sequence the very first human genome[2] to less than $1000 in 2018[3]. The tools developed to sequence the human genome are being used to sequence the genomes of countless microorganisms and plants in research labs across the country.

The gene editing tool that is now driving a significant amount of research is CRISPR/Cas-9. This technology uses "molecular scissors" to create a break in DNA. Along with deleting DNA bases, these technologies can insert new DNA bases into the break. Besides being more precise, less expensive, and easier to use than older gene editing technologies, these new gene editing technologies are much faster.

[1] Presently, there is not an agreed upon name or definition for what to call the emerging research field at the intersection of biology, the physical sciences, engineering, and information technology. Some refer to this field as engineering biology; others call it synthetic biology.

[2] National Human Genome Research Institute http://www.genome.gov/sequencingcosts/.

[3] https://www.genome.gov/27541954/dna-sequencing-costs-data/

There has been a lot of coverage of Chinese researcher He Jiankui's recent use of CRISPR to edit genes in the embryos of twin girls to help them resist HIV, including allegations that the Chinese government was fully aware of his plans all along.[4] Dr. He's announcement was met with a tremendous outcry from U.S. and other scientists around the world. Current U.S. law prohibits any human germline editing, and the consensus among U.S. scientists is to continue to take a very slow and restricted approach.[5] While human gene editing raises significant ethical and governance issues, the focus of this hearing is on gene editing and other engineering biology tools for application in microorganisms and plants for energy, agriculture, the environment, and manufacturing.

Energy Sector Applications

For the energy sector, engineering biology has the potential to reduce our dependence on fossil fuels by engineering mircoorganisms such as bacteria and algae to produce fuels and by developing more sustainable biofuel feedstocks. Although promising, advanced biofuels still struggle to compete with gasoline and other fossil fuels for market share because of the higher cost of production. As researchers at universities, Department of Energy National Labs, and companies continue to improve efficiency and bring down production costs through engineering biology, biofuels will become more competitive. LanzaTech, which will be represented by Dr. Sean Simpson on the panel, converts waste carbon from industrial processes to commodity chemicals and biofuels, including jet fuel. The DOE funded Great Lakes Bioenergy Center, represented on the panel by Dr. Eric Hegg, conducts engineering biology research on dedicated bioenergy crops to enhance their environmental and economic value.

Agricultural Applications

The ability to modify agricultural crops is not new. For centuries, people have been altering the genomes of plants using traditional breeding techniques. In the 1970s and 1980s, it became possible to use recombinant DNA techniques[6] to modify the genomes of plants. Using those technologies, foreign DNA (usually a single engineered gene) is introduced into plant genomes to create a crop with a desired property such as insect resistance. New and emerging techniques, enabled by engineering biology, are more powerful than traditional techniques because they can construct, edit, and re-engineer the genomes of plants. They allow for multiple genes to be inserted, opening the door for creating crops with more desirable traits that cannot be achieved through a simple addition of a single gene. Additionally, these techniques could delete or edit multi-gene traits to produce better outcomes for food quality, storage, and processing. Moreover, engineering biology could create new feedstocks that would allow farmers to produce larger yields on smaller land.

---

[4] https://www.vox.com/2019/3/4/18245864/chinese-scientist-crispr

[5] https://www.nap.edu/catalog/24623/human-genome-editing-science-ethics-and-governance

[6] Recombinant DNA technology uses enzymes to cut and paste together DNA sequences.

Manufacturing Applications
Traditional manufacturing of goods has relied on ingredients and production processes that have been known for hundreds of years. Engineering biology has led to a revolution in those processes by using microorganisms to make a synthetic version of the ingredients used in the traditional industrialization process. The benefits of having microorganisms make ingredients include using less energy and producing less waste, not relying on petroleum products, and the ability to make ingredients that are difficult and/or expensive to manufacture using traditional processes. Additionally, engineering biology could be used to improve the performance and sustainability of materials used across sectors and in our daily lives. Examples include bio-based packing materials and plastic replacements. Pharmaceutical manufacturing is also being revolutionized by engineering biology.

Ethical, Legal, Environmental, and Societal Issues in Engineering Biology
Since engineering biology will allow researchers to create biological systems that do not occur naturally and to re-engineer existing biological systems to perform novel tasks, there are myriad ethical, legal, environmental, and societal issues to be considered. These issues include any potential harm new systems could have on human health and the environment, as well as concerns about ensuring equitable distribution of benefits from engineering biology applications. Researchers in this field have discussed the need to build things like "kill switches"—self-destruction mechanisms for genetically engineered microbes once they are no longer useful or in case of an accidental or malicious release. Along with funding research in this area, it is important to support public outreach and public engagement for this research to ensure public health and safety as well as to educate the general public about the technology.

A 2015 Woodrow Wilson report on synthetic biology funding found that less than one percent of total U.S. funding was focused on risk research and approximately one percent was focused on the ethical, legal, and social issues. Dr. Zoloth is a bioethicist who works closely with scientists and engineers to help frame the ethics questions that should be considered in research and education in engineering biology, including for non-human health applications.

Security Issues for Engineering Biology
Especially with the democratization of technologies such as gene sequencing and gene editing, security is yet another significant concern for engineering biology R&D. Specific concerns include: intentional misuse of a pathogen for direct harm to a population or to disrupt markets; accidental misuse of a biological organism; misuse of biological information; supply chain insecurity; and the consequences of loss of U.S. leadership in engineering biology. The National Academies recently launched a new study, *Safeguarding the Bioeconomy: Finding Strategies for Understanding, Evaluating, and Protecting the Bioeconomy while Sustaining Innovation and*

Growth[7], which will include a focus on economic and national security risks. Dr. Carlson will also testify about the security concerns.

Federal Investments in Engineering Biology

Due to the lack of an agreed upon definition for this field as well as a lack of federal strategy, it is difficult to get a figure for federal investment in engineering biology. GAO produced a report[8] in 2018 at the request of the Science Committee that included some information about federal investments in synthetic biology, but was incomplete in that regard. They found that 10 agencies support synthetic biology research, and 6 of those 10 agencies reported a combined total of at least $211.2 million in support of synthetic biology research in FY 2017.

- The Department of Energy has significant investments in synthetic biology. In 2007, DOE began supporting three bioenergy research centers with synthetic biology being core to much of their work. In 2017, DOE announced a "new phase" to this program with support for four bioenergy research centers funded at a total of $90 million in FY 2019. DOE also funds the Joint Genome Institute to produce high-throughput sequencing in support of its biofuels and environmental mission, funded at $69 million in FY 2019.
- The National Science Foundation (NSF) supports synthetic biology across multiple directorates, including computer and information sciences. They also support the Engineering Biology Research Consortium (EBRC)[9] to lead a road-mapping effort for engineering biology R&D that will be completed this summer. In FY 2017, their total investment in synthetic biology research across the Foundation was approximately $60 million.
- The National Institute of Standards and Technology (NIST) supports research in the area of measurement science and standards for engineering biology. NIST estimates its current investment to be $35-$40 million, including $10 million in support of a biomanufacturing institute through the Manufacturing USA program, and $4 million in internal research. Included in their overall total is a new effort on the microbiome and their work with industry to validate genome sequencing technologies and characterize biologics used in medicine.
- Multiple NIH institutes invest in foundational synthetic biology research to study disease as well as to understand and combat antibiotic resistance. NIH did not report a funding level to GAO.
- NASA supports synthetic biology to enhance the capability and reduce the risk of space exploration. NASA reported to GAO total investments of $5.1 million in FY 2017.

---

[7] http://nas-sites.org/dels/studies/bioeconomy/

[8] https://www.gao.gov/assets/700/694748.pdf

[9] Formerly SynBERC, a Science and Technology Center that was supported by NSF in its earlier form for 10 years.

- EPA uses synthetic biology among other things, to develop new tools - including synthetic tissues - for testing chemical toxicity. EPA reported to GAO total investments of $4.5 million in FY 2017.
- The Defense Advanced Research Projects Agency (DARPA) increased their synthetic biology support significantly under the Obama Administration, including funding the Living Foundries Project to create biologically-based manufacturing platforms,[10] and continues to support synthetic biology research in various projects. DOD reported to GAO total investments of $114 million in FY 2017.

National Strategy for Engineering Biology

In 2012, the Obama White House released the "National Bioeconomy Blueprint" to lay out strategic objectives to realize the potential of the U.S. bioeconomy and to highlight early achievements toward those objectives. The National Bioeconomy Blueprint described five strategic objectives—supporting R&D bioeconomy investments; facilitating the transition of research into the market; developing and reforming regulations; updating training programs; and identifying and supporting public-private partnerships.

Since the release of the National Bioeconomy Blueprint, not much has been done to implement it. It's not clear why, except that the Obama Administration was locked in a battle with Congress over the budget, with science budgets taking significant hits. The Trump White House convened an interagency working group on synthetic biology in 2018. In the meantime, other countries, including China, have made engineering biology a strategic national priority with significant funding. Dr. Rob Carlson's testimony will include comparisons between the U.S. and its competitors in terms of the scale of investment as well as the size of the industry, to the extent that can be measured.

Engineering Biology Legislation

This hearing will serve as a legislative hearing for the *Engineering Biology Research and Development Act*, most recently introduced by Chairwoman Johnson and Rep. Sensenbrenner in the 115th Congress as H.R. 7171. The bill would establish a National Engineering Biology R&D Program. The bill would also establish a framework for greater coordination of federal investments in engineering biology; lead to a national strategy for those investments; expand public-private partnerships; focus on the education and training for the next generation of engineering biology researchers; and address any potential ethical, legal, environmental, and societal issues associated with engineering biology research.

[10] The Living Foundries program established the 1,000 Molecules Project that has the goal of developing 1,000 new chemical building blocks for entirely new materials.