LEAP
Synthetic Biology
Leadership Excellence Accelerator Program

The Biodesign Challenge: Seeding a Generation of Biodesigners to Shape Future Synthetic Biology Products and Applications

Daniel Grushkin
Genspace Community Biology Lab, Brooklyn, NY
dgrushkin@genspace.org

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Abstract
Structured as a multi-university competition, the Biodesign Challenge is an education program that partners biologists with art and design students to envision the future of biotech. It seeks to educate a generation of biodesigners—biotechnology professionals working at the intersection of biotech and society. The program is building a community of scientists, artists, and designers who explore how biotech can create new industries, fit into and change already-built industries, and reveal biotech's ethical, social, and environmental implications. In addition, BDC displays student projects at galleries and museums—including the Museum of Modern Art—to foster public dialogue about desired futures. The program piloted in 2016 in nine US universities and is now in 23 universities worldwide.

Synthetic biology needs design

Many, including the White House, say that we have entered the biotech century. (1) Biotechnology—specifically genetic technologies, including genomics, microbiomics, synthetic biology, and genetic engineering—underpins an emergence of new medicines, foods, fuels, materials, manufacturing processes, and more. Yet, despite the rhetoric of promising advances, we are seeing a critical gap as biotech prepares to enter our lives.

Biotech has played an equivocal role in society. It has excited the public about new medicines and greener modes of production, but it has also created fear. Concern about risks associated with modified foods, environmental mismanagement, and genetic privacy pervade national debates about the future of biotechnology. We simply don't have a commonly accepted ethical framework to move the science from the lab to the general public.

[1] This paper is a working version. Please contact the author at dgrushkin@genspace.org to provide feedback. For the most recent version of this strategic action plan, visit http://synbioleap.org

Historically, experts in the field predicted that industrial synthetic biology would thrive in the shadow of consumer ignorance. Synthetic biology companies would produce single chemicals within consumer products, and their biotech provenance would be concealed in the long lists of ingredients on the backs of packaging.

This has proven false in two ways. Run-ins with nongovernmental organizations—specifically ETC and Friends of the Earth, which campaigned against Ecover and Evolva in 2014—demonstrate that even business-to-business synthetic biology companies need to engage the public proactively. Secondly, a slew of biotech startups—specifically those developing materials, fabrics, and cosmetics—are creating consumer products that require deeper public engagement in order to build a customer base.
Outside of a handful of examples, the synthetic biology community miscalculated the consumer reaction to its products. In its initial foray into biofuels in the early 2000s, the community misunderstood how its products fit into an industrial ecosystem. It has misunderstood markets and how the public might react to its products. And it has only begun to explore the implications of the widespread adoption of synthetic biology. (2)

We posit that these are not technological failures but failures of design. Synthetic biologists themselves have taken the ad hoc role of designers, and have neglected to include professional designers at the outset of their product development. In a profile in *The New Yorker*, one of the field's pioneers, Jay Keasling, admitted that the first commercial application of synthetic biology, the production of semi-synthetic artemisinin, came as an afterthought while he was developing his research.

The first time Jay Keasling remembers hearing the word "artemisinin," about a decade ago, he had no idea what it meant. "Not a clue," Keasling, a professor of biochemical engineering at the University of California at Berkeley, recalled. (3)

Scientists take the utility of their research on faith. But technology, no matter how sophisticated, is useless in itself. Only when it is applied to human problems, needs, and in some cases, human questions does it find utility. Today's lab training does not prepare synthetic biologists to understand people, their needs, or their desires. Nor does it prepare them to understand how biotech fits into a broader landscape of industries and markets.

The synthetic biology community must more fully understand that the problems it works on are not just technical, or biological, but also human. As such, synthetic biology needs biodesigners—designers who can work at the interface of biotechnology and the society. Until synthetic biology embraces human-centered design, until synthetic biologists partner with designers at the beginning of their research rather than at the end, synthetic biology will struggle with public and consumer acceptance.

What is biodesign?

One can define "design" as the planning done before creating. A throng of conscious and unconscious goals, values, assumptions, and trade-offs inform that planning. Good design—or at least thoughtful design—acknowledges, examines, and questions these often competing interests. Thoughtless design takes them for granted or assumes they don't exist.

Today's variety of food and ornamental plants, livestock, and pets attest to the fact that humans have been designing living things for millennia. But few have called selective breeding "biological design." The term biological design goes at least as far back as the 1930s. It has referred to designs that look biological or model themselves on living things (biomimicry). It has referred to the structure and function of anatomical parts, the engineering of biological molecules, medical devices, and even intelligent design. The contraction "biodesign" first appears in a 1971 essay by Joseph Fletcher, a philosopher and pioneer in bioethics, who uses it in reference to bioengineering humans. (3)

Roughly a decade ago, a new biodesign practice emerged as a hybrid of bioart and speculative design espoused by Tony Dunne and Fiona Raby at Royal College of Art, London. (4) The practice incorporated lab activities and living materials and often critiqued contemporary biotechnology by exploring alternative applications and futures. Leaders in synthetic biology embraced this iteration of biodesign. The Synthetic Aesthetics program led by Drew Endy, Daisy Ginsberg, and a number of leading social scientists, artists, and scientists offered residencies in each other's labs and studios as part of the exploration. (5)

Figure 1. Mutua, a BDC project from the Southern California Institute of Architecture, illustrates how a wall of bioengineered algae might one day be integrated into kitchens

Biodesign is still an inchoate field that blurs art, design, and science. Its transgression of established boundaries empowers practitioners to explore lab science, biotech's utility in the broader world, and its adoption's cultural implications—all of which are critical to the development of the technology as it enters the world. As biodesign becomes a professional practice, this foundation will prove enormously important as innovators balance consumer and industry demands, ethics, and implications, and scientific feasibility.

Today, a handful of professionals in the biotech industry work in design. They are mainly generalists who have worked in both the biology lab and the design studio, and whose multitudinous roles include marketing and communications, experience and process design, product testing, art direction, partnership strategy, and more. In the rare case, designers in leading roles have transformed entire product pipelines.

In the future, as synthetic biology matures, designers working at the interface of biotech and society will play an increasingly central role in driving innovation and shaping biotech and its products.

New mode of public engagement

Art and design offers effective ways of communicating and critiquing the profound effects biotech has on culture. Works like Heather Dewey-Hagborg's *Stranger Visions,* which presents striking portraits of people who left behind DNA detritus (in the form of cigarette butts and chewed gem) on New York City streets, offers a visceral experience of how genomics can change privacy. Similarly, works like Alexandra Daisy Ginsberg's *Design for the Sixth Extinction* highlight the profound ways in which synthetic biologists may modify ecosystems.

Showcasing the students' work serves as an ideal opportunity to broaden public dialog about biotech. In 2016, BDC projects went on display at MoMA in New York City, The Tech Museum of Innovation in San Jose, and the gallery at the School of Visual Arts. In 2017, projects are slated to go on display in galleries across the world.

Figure 2. SVA students and Chair of the Fine Arts Department Suzanne Anker pose at the BDC Summit gallery show Our Biotech Future(s)

As participation grows, BDC's organizers plan to develop programming around the student projects as a means of public science engagement. Audiences will deepen and nuance their understanding of the promises and perils of biotech by exploring cultural issues through the prism of student projects.

Seeding a generation of biodesigners

Unfortunately, today's biotechnology and design communities are largely siloed. They neither work together nor share a common language. To generate real solutions that are both technically and culturally feasible, these communities must collaborate. An empirical study conducted by the University of Cambridge and published in *The International Journal of Design* concluded that designers participating in scientific research activities can play an instrumental role in the advancement of science and technology. They act as research catalysts by considering the early application of technology and focusing research on overcoming practical hurdles. The ability of designers to "embody ideas and knowledge in artifacts can allow them to contribute to research by stimulating others to develop and evaluate new ideas." (6)

Design graduates today are woefully unprepared to work with biotechnology. Yet new companies will need a workforce of biodesigners who can partner with scientists to develop products and anticipate trade-offs and implications. Meanwhile, the public will need designers fluent in the language of biology who understand how people might use biotech and how its products could shape culture.

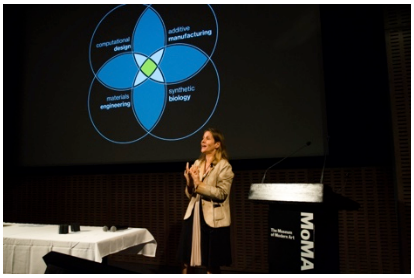


Figure 3. The Museum of Modern Art's Senior Curator of Architecture and Design Paola Antonelli keynotes BDC Summit, 2016

The Biodesign Challenge (BDC) addresses this gap by building a community of scientists, artists, and designers. In its pilot year, BDC has already shown these collaborations to be fruitful. Nine universities, including University of Pennsylvania, Fashion Institute of Technology (FIT), and Maryland Institute College of Art—all led by teams of science, art, and design professors—created projects that offered solutions to environmental contamination, critiques of consumer biotech, and even a number of functional proofs of concept. FIT, for example, produced a yarn from algae as a biodegradable alternative for the highly polluting textiles industry. School of Visual Arts engineered a tomato that contained myoglobin (animal) protein. Students—many with no biology education since high school—succeeded in bioengineering a seedling nicknamed the "beefsteak tomato."

These projects succeeded as provocations and innovations, offering functional solutions that fuse art, design, and biotech. They also demonstrated the efficacy of interdisciplinary collaboration.

How BDC works

The Biodesign Challenge is the flagship art and design education program of Genspace, a 501(c)3 community biology lab dedicated to biology education and innovation. BDC partners scientists with classrooms of art and design students to envision future applications of biotechnology.

During the spring semester of the academic year, the BDC team works with art and design professors to help develop a BDC course, and then acts as matchmakers to pair student teams with scientists. Each June, the top team from each school presents its project and competes for the prize—the Glass Microbe—at MoMA in New York City during the two-day Biodesign Summit.

Figure 4. 2016 BDC winners from FIT—Gian Cui, Aleksandra Gosiewski, Tessa Callaghan, and Aaron Nesser—pose with the overall prize, the Glass Microbe

BDC works with instructors to prepare courses that focus on future applications of biology in design. Classes are encouraged to select a particular theme. Once a theme has been chosen, BDC works hand in hand with instructors to produce curricula and background materials such as policy and scientific papers. In the past, classrooms have focused on water, architecture, medicine, interior spaces, materials, surfaces, manufacturing, and energy.

BDC organizers also connect classrooms with "expert consultants"— scientists in their community. These can include synthetic biologists, ecologists, lifecycle analysts, and other relevant subject-matter experts who can teach students about potential problem areas that biology may address, point out pitfalls of designing with living systems, and assess the feasibility of student designs.

Figure 5. 2016 BDC winners from SCI-Arc—Mun Yi Cheng, Caleb Fisher, Fangyuan Hu, Ryan Odom, Anthony Stoffella, and Xiangtia Sun—pose with the Autodesk Prize for Best Visualization

Midway through the semester, students break into small teams to develop their projects. Each team is expected to produce a slideshow presentation, visual renderings, physical models, and videos. At the end of the term, the instructors and consultants critique and choose the most compelling projects to go to the Biodesign Summit.

In June, teams chosen from each school are invited to New York City for the two-day Biodesign Summit held at MoMA. There, the students present their projects to an audience of museum curators, scientists, professional designers, and companies interested in design and biology. A panel of judges awards trophies to the top teams.

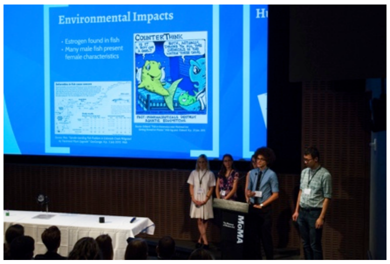


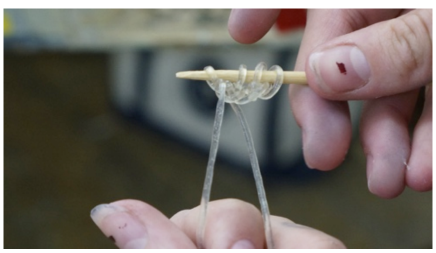
Figure 6. Students from Rensselaer Polytechnic Institute—Amanda Harrold, Kathleen McDermott, Jacob Steiner, Perrine Papillaud, and Jerry Huang—present Live(r) Clear, a bacterial system for removing estrogen from waterways

Select projects from BDC's pilot year

STABILIMENTUM
Mónica Butler, Jiwon Woo
Latin for "support," Stabilimentum is a couture mask that filters air using live spiders and the electrostatic properties of their silk. Inspired by the symbiotic relationship between humans and the microbiome, the fashion accessory explores a symbiosis between human and arachnid.

MYOTOMATO
Andrew Cziraki, Victor Taboada, Darya Warner, John Wells
Raising animals for consumption has proven environmentally costly, ethically controversial, and—with growing demands on food—potentially unsustainable. To supplement protein, MyoTomato proposes bioengineering edible plants to produce myoglobin, a protein normally found in meat. As part of their lab work, the team inserted a DNA sequence naturally found in beef products into a tomato's genome using agrobacteria.



BIOESTERS
Tessa Callaghan, Gian Cui, Aleksandra Gosiewski, Aaron Nesser, Theanne Schiros, Asta Skocir
The textiles industry is a notorious polluter. By creating yarn from extruded bacteria and fungi, Bioesters seeks sustainable alternatives to wearable materials using novel growing and production techniques.

STARTER CULTURE
Gage Branda, Sarah Whelton, Jake O'Hagan, Emma Whitlock
A biomaterials kit designed to introduce makers to the expansive world of biomaterials, the contents of the Starter Culture kit—including media for growing bioplastic, mycelium, and silk proteins—can be propagated like a living culture and shared among makers.

Pilot results and program trajectory

In 2015–2016, the BDC program piloted in nine schools among 135 students. In 2017, BDC doubled in size and expanded to universities in Canada, Colombia, Germany, Guatemala, the Netherlands, and the United Kingdom. These include the world's top institutions such as Royal College of Art, Parsons School of Design, and CalArts. Some 22 schools and 24 classrooms—upwards of 300 students—explored the convergence of biotechnology, art, and design.

In a survey conducted at the end of the fall semester of 2015, 96 percent of students recommended their universities continue to offer the BDC course. One student from Rensselaer Polytechnic Institute wrote, "This course allowed us to broaden our minds and think beyond a couple of years. I think that really pushed us to think big. Other art and design classes are a bit more limiting."

The survey also reported that 93 percent of students saw the value of collaborations between scientist and designers. "I learned that design grounded in biodesign is not a limitation, but a lens through which I had never looked to consider the limitless possibilities that arise when combining biotech and design," one student from New York University wrote.

Within five years, BDC seeks to deepen partnerships with schools, museums, and media in an effort to expand to 50 schools around the world and reach 650 students, 50+ professors, 150 scientists, and hundreds of thousands of spectators at the BDC Summit, in galleries, and online.

Notes

1. United States Department of Health and Human Services. Presidential Commission on Bioethics. *New Directions: The Ethics of Synthetic Biology and Emerging Technologies*. Washington, DC: n.p., 2010.
2. Grushkin, Daniel. "The Sky Was the Limit." *Fast Company* Sept. 2012.
3. Specter, Michael. "A Life of Its Own." *New Yorker* 28 Sept. 2009.
4. Fletcher, Joseph. "Ethical Aspects of Genetic Controls—Designed Genetic Changes in Man." *New England Journal of Medicine* 285.14 (1971): 776-83.
5. Dunne, Anthony, and Fiona Raby. *Speculative Everything: Design, Fiction, and Social Dreaming*. Cambridge, MA: MIT, 2013.
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