Science and Culture: The art of designing life

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Artist Howard Boland arrived for his 2012 exhibit at the headquarters of London's newspaper *The Guardian* toting Erlenmeyer flasks, plastic tubing, and glowing bacteria. Boland was eager to set up his exhibit "Stress-o-stat." He hit a snag. Although Boland had followed safety protocols, security staff took one look at the biohazard symbols on his project materials and ejected him from the premises. It's a common problem for Boland, one of an emerging breed of artists who use or address synthetic biology in their work.

In "Rewilding with Synthetic Biology," artist Alexandra Daisy Ginsberg imagines a forest landscape replete with manmade creations that help sustain and remediate the ecosystem. In a separate artwork called "Mobile Bioremediation Unit" (*Inset*), Ginsberg conjures up one such creation, a synthetic slug-like organism that would bioremediate the forest soil by changing the soil pH with an alkali hygroscopic fluid, until a genetic kill-switch ends its service at 28 days. Images courtesy of Alexandra Daisy Ginsberg.

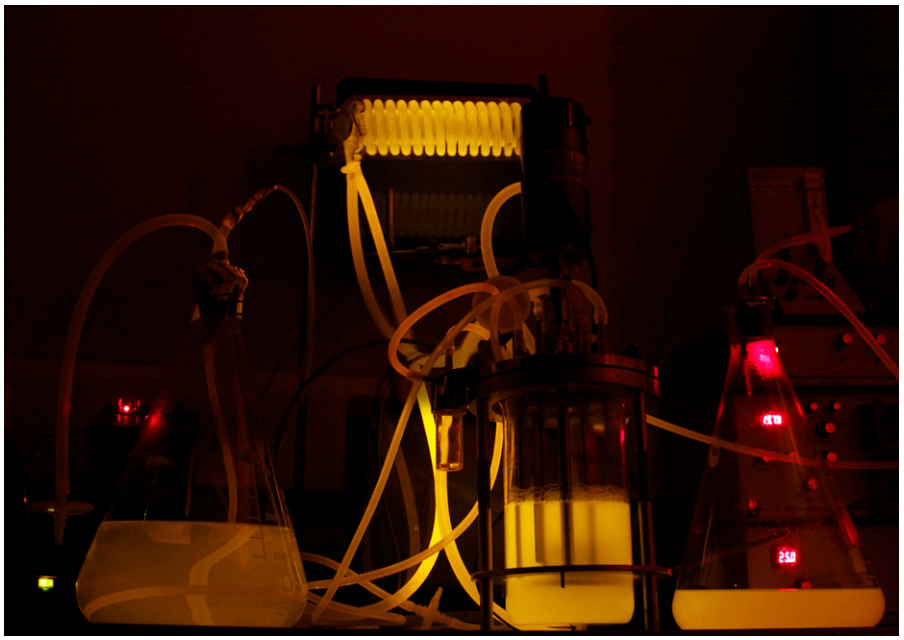
Most biologists are keen to understand the natural world. Synthetic biologists are keen to find ways to alter it, whether modifying organisms to produce ingredients for medicines, machines, or makeup. The common element of design makes artists natural collaborators for synthetic biologists; it also makes artists natural commentators on the field. The result: In recent years, multiple artists and exhibitions have made forays into science, seeking to apply the tools of synthetic biology to their creations, to illuminate the inner workings of living organisms for viewers, or to probe questions about what the synthetic biologists should or shouldn't create in a world where scientists can seemingly modify nature at will.

Experimental Art

Boland, who has a background in mathematics and computer art, was intrigued by the emergence of the "Bio-Art" movement, in which practitioners work with living material, such as selectively bred plants, genetically engineered bacteria, or their own bodies. Boland wanted to control the living materials directly himself, so he proposed a doctoral project to the University of Westminster in London and worked in the molecular biology laboratory of Mark Clements, where he learned how to manipulate living organisms. Eager to do more than use artistic metaphors to explore scientific concepts, Boland sought ways to directly illustrate biological processes for viewers.

Among the end products of his studies and laboratory work was "Stress-o-stat." Boland was interested in how bacteria growing in a nutritious broth will eventually polish off all of the nutrients, starve, and stop dividing. His exhibit made the starvation process visible. He attached the promoter for a gene involved in stress response, catalase, to a gene encoding fluorescent proteins in bacteria. And he rigged a feeder system so he could drip rich or impoverished broth onto the cultures, which would cycle between dull and glowing states.

In another piece, "Transient Images," Boland wanted to exhibit how certain bacteria



In "Stress-o-stat," artist Howard Boland sought to illuminate the processes inside living cells. Engineered bacteria, containing a promoter for a gene involved in a stress response that's attached to a gene encoding fluorescent proteins, glow as they run out of nutrients. Image courtesy of Howard Boland.

can depolarize dye molecules, turning them colorless. His "paintbrushes," in this case, were bacteria from London's sewer system that degrade dyes. He arranged several dye-filled bottles in an array and varied the starting amount of bacteria so the dyes would disappear at differing rates. As the bottles turned clear, his self-portrait appeared in the array, only to disappear once all of the dye was gone.

These and other pieces culminated in a one-man show in April 2013 at the Royal Institute of Great Britain in London. It was the first exhibition in the United Kingdom to include genetically modified organisms. "There is a fear factor in the general population around synthetic biology," Boland says. After seeing these kinds of exhibits, viewers should "come back with a different experience of these organisms."

Probing the Possibilities

Other artists aim to raise questions about what biological tinkerers are up to. Synthetic biologists throw around the term "design" frequently, but often fail to address crucial quandaries, says Pablo Schyfter, a social scientist at the University of Edinburgh in the United Kingdom: Why are we choosing this particular material? What is it about living things that makes them useful? To explore such issues, Schyfter and collaborators set up the Synthetic Aesthetics project, funded by the National Science Foundation and the United Kingdom Engineering and Physical Sciences Research Council. The initiative's mission: examine the relationship between art, design, and synthetic biology, providing a starting point for discussion and debate. Six artist–scientist pairs were asked to explore that relationship over two weeks together in the laboratory and two weeks in the studio in 2010 (1).

One pair, a synthetic biologist and an artist with an interest in the sense of smell, addressed mankind's dual relationship with bacteria, in which some kinds are appreciated, others abhorred. The pair cultured cheeses, normally an enjoyable microbial byproduct, from the typically undesirable bacteria on people's bodies. Although some human bacteria are the same as found in cheese, it wouldn't be safe to taste cheeses made from unknown microbes. But a good whiff is risk-free; they displayed cheeses cultured from microbe donors such as Michael Pollan, an author known for writing about humans' relationship with food, at the Dublin Science Gallery in 2013 and 2014.

Another pairing, between an architect and a scientist, used computer modeling and the structure of xylem cells, which make up a plant's vasculature, as a tool to design novel architectural structures. The residents sought not to replicate nature exactly, but to follow the structure molded by evolution to devise forms that would have otherwise been difficult to conceive of (none have been built yet).

Other projects outside of Synthetic Aesthetics have received high-profile attention; for example, designers at SymbioticA, a self-described "artistic laboratory" at the University of Western Australia in Perth, engineered a tiny jacket out of living mouse cells. In 2008, the Museum of Modern Art in New York exhibited the piece, called "Victimless Leather," as part of a show called *Design and the Elastic Mind*.

Projects like these "open up all these different ways of thinking about the [scientific] subject matter from a cultural perspective," says Alexandra Daisy Ginsberg, a designer and artist who co-organized Synthetic Aesthetics. Schyfter claims that participant presentations from Synthetic Aesthetics have helped synthetic biologists think more critically about the meaning of the word "design."

Natural Enhancements

Some designers are so bold as to envision the future. In a separate work of fanciful, science-inspired illustrations, called *Designing for the Sixth Extinction*, Ginsberg, who is pursuing a doctorate in design interactions at the Royal College of Art in London, addressed the wide-reaching implications of synthetic biology in the context of the human-triggered mass extinction that some believe is underway. She was inspired during a 2013 Wildlife Conservation Society meeting in Cambridge, United Kingdom. Ginsberg watched as conservationists and synthetic biologists engaged in an intriguing discussion about how engineered organisms might support natural ones. Ginsberg started to wonder: How would such novel organisms be classified in the kingdom of life? Would they be considered living or machines? What would a walk in the woods look like with these new, manmade critters, and is that indeed a desirable scenario?

Based on conversations with scientists and conservationists, Ginsberg imagined taking such manipulations to the extreme: a slug-like "Mobile Bioremediation Unit" that neutralizes polluted acidic soils, for example, or the porcupine-shaped "Autonomous Seed Disperser" that collects seeds in its hairy spines and drops them elsewhere. She worked with computer artists to add her creations to a photograph of a real-life forest, and complemented the large picture with excerpts from faux patent applications and 3D-printed, plastic models of the slugs.

Ginsberg sought to generate debate with her designs. "I'm not saying this is a good solution," she says. "It's saying, 'How would we feel about this?'" Multiple editions of *Designing for the Sixth Extinction* are on exhibit at London's Design Museum

until March 31, 2016 and Karlsruhe's Center for Art and Media until February 28, 2016, and will be on display at the Cooper Hewitt, Smithsonian Design Museum in New York City from February 12 to August 21, 2016.

Synthetic biologists need people like Ginsberg to conceive of the broad consequences of their cutting-edge creations, says Drew Endy, a bioengineer at Stanford University in Palo Alto, California, who cowrote the Synthetic Aesthetics grant and helped select the residents. After all, these are not idle musings. Scientists at the Oxford, United Kingdom biotech company Oxitec are releasing into the wild genetically engineered mosquitoes that produce sterile offspring, part of controversial efforts to mitigate mosquito-transmitted diseases, such as dengue fever and malaria (2, 3). Other researchers are designing customized bacteria to clean soils (4). And designing organisms has gotten easier recently with the advent of gene-editing technology, which has proven both promising and controversial (5).

Scientists, policy experts, and bioethicists raise questions surrounding such work, but Endy believes designers can often offer a richer, more evocative vision of the consequences. Those consequences entail several fundamental questions, say Ginsberg, Endy, and others: What might scientists design? What should they design? And who gets to decide?

1 Ginsberg AD, Calvert J, Shyfter P, Elfick A, Endy D (2014) *Synthetic Aesthetics: Investigating Synthetic Biology's Designs on Nature* (MIT Press, Cambridge, MA).
2 Carvalho DO, et al. (2015) Suppression of a field population of Aedes aegypti in Brazil by sustained release of transgenic male mosquitoes. *PLoS Negl Trop Dis* 9(7):e0003864.
3 Gantz VM, et al. (2015) Highly efficient Cas9-mediated gene drive for population modification of the malaria vector mosquito *Anopheles stephensi*. *Proc Natl Acad Sci USA* 112:E6736–E6743.
4 Singh JS, Abhilash PC, Singh HB, Singh RP, Singh DP (2011) Genetically engineered bacterial: An emerging tool for environmental remediation and future research perspectives. *Gene* 480(1-2):1–9.
5 Dance A (2015) Core Concept: CRISPR gene editing. *Proc Natl Acad Sci USA* 112(20):6245–6246.