CYBORGS HERE WE COME —

The Army's looking into putting bacteria into its electronics

Army Research Lab scientists are collaborating with biologists.

ERIC TEGLER - 12/1/2016, 11:40 AM

ARL's Eric Proctor

Enlarge / The future of electronics, Army style.

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If you're not familiar with the terms "synthetic biology" or "biohybrid systems," you may want to add them to your vocabulary. If the US Army Research Laboratory (ARL) and other research institutions are able to follow through on their plans, the technology will be mainstream in a decade.

ARL is betting that engineered living organisms—termed synthetic biology—can be integrated into living and non-living (abiotic) systems to perform material synthesis, enhance human performance, provide environmental sensing, and control autonomous biohybrid devices.

"As synthetic biology has realized new capabilities, we've really started looking at how we can engineer organisms to control devices," Bryn Adams affirms. Dr. Adams is a biotechnology research scientist at ARL's Adelphi, Maryland facility. She recently published an editorial in the Synthetic Biology edition of the *Journal of the American Chemical Society* in which she predicted a future where scientists place engineered DNA into systems including engineered versions of the genes for photosynthetic proteins, which could be introduced into bacteria integrated into electronic devices to power them.

Enlarge / Bryn Adams of the Army Research Lab.

“That’s something I definitely hope to see in my career. We’re definitely on track to see synthetic [organisms] first integrated into systems as sensors or actuators, executing a secondary function in a device," Dr. Adams said. "I definitely see the science moving that will allow us to make autonomous biohybrid devices where the biology controls the device, makes the decisions, gives feedback, heals damage.”

Bacteria could be genetically engineered to have both biological tasting or smelling capabilities and to interface with electronics to form an advanced biosensor. Scientists may even one day reach a point where they can engineer microorganisms in functional groups (consortia) that act like symbiotic systems, with different types of bacteria providing complementary functions. The goal would be to develop their coordination and hardiness up to the point where we’re essentially able to 3D print biological structural materials like lumber.

The field of synthetic biology accelerated markedly in the mid-2000s when scientists gained the ability to rapidly and cheaply sequence and synthesize DNA, Dr. Adams explains. Researchers began to understand how they could design organisms from the bottom-up. “When we could make our own DNA, check it, sequence genomes, and determine their function…that’s when doors really opened.”

ARL has been integrating natural organisms into engineered systems for well over a decade, in systems like waste-to-energy production (biofuels). “Now we’re going from some of these natural organisms working for us in the real world to engineering them [for other tasks].”

But placing synthetically engineered cells into living and abiotic systems is an order of magnitude more difficult. Organisms, even photosynthetic ones, need a steady supply of nutrients. Without them, they cease to grow and divide, going dormant or forming spores, no longer functioning. To understand how cells respond to an environment—what they’re telling us—we need to use “readouts” which require DNA sequencing or fluorescent microscopy. Finally, engineered genetic circuits inside cells require a robust host, a carrier cell or “chassis” as ARL calls it, that can withstand the real world. All of these complications make for challenging work.

So far, synthetic biology has generally employed E. coli as a host for engineered genetic circuits. Dr. Adams authored a paper on an experiment she led engineering E.coli so that it could be integrated with abiotic surfaces (minerals, soil, water), including specific metals. But the lab strains of E.coli cells simply aren’t strong enough to survive outside a laboratory setting. (In fact, lab strains were specifically engineered to fail in the real world.) Researchers will have to find another chassis to make the science work.

“That’s what I see as the biggest challenge. We can do really complex things in E.coli, but it is never going to be able to survive things like 3D printing or to withstand the natural environment,” Dr. Adams told Ars. She added that host bacteria must thrive, not merely survive as dormant entities. “We want organisms that are doing transcription, that are reproducing, producing proteins in response to environmental cues.”

Can scientists really identify robust hosts and supply them with nutrients? Bryn Adams says they’re taking the first steps. ARL is collaborating with a variety of research institutions, including MIT, where Professor Chris Voigt has developed a novel broad spectrum DNA transfer system that ARL is now using. The Voigt Lab at MIT has also developed a way to get the cells to report on what they are doing.

A synthetic biology programming language called Cello automates genetic circuit design and allows the bacteria to record environmental conditions in DNA, which can then be read out by sequencing. “That makes it possible for us to build in all sorts of things so we’re not just relying on a GFP [green fluorescent protein] marker,” Dr. Adams says. “Bacteria are never going to be computers. They’ll never do the complicated data processing a computer does, but in E.coli we can already make simple computational tasks take place in the cell in terms of recording information and giving information about things it has experienced. Now it’s just taking that knowledge base and expanding it to other organisms so we can do the same thing.”

With that expansion comes the opportunity integrate engineered cells into living systems, likely within the next five years. The Army would apply such designer-microbes to enhance human performance among other things—potentially making soldiers stronger, faster, immune to certain infections, and even self-healing to a greater extent.

Within the next 10 years we could see microbes act as simple sensors or actuators in non-biological devices. Adams thinks autonomous biohybrid devices wherein microbes regulate or heal the device will happen within her lifetime. The US has some of the best minds in synthetic biology, she says, but it is by no means the only leader in the science. Other nation-states will accelerate its application.

“These are not lab demonstrators,” Adams asserts. “These are things that will be in the field by militaries, governments, and for commercial uses.”

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