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$15,000 "Eat it!" Lemelson-MIT Student Prize Graduate Winner

Syn-SCOBY, a smart sensing water filter and DEPCOS for ultra-safe water applications

The Challenges: Solving the many water supply problems around the globe requires innovative solutions from multiple disciplines. The field of engineered living materials (ELMs) is becoming increasingly popular because it uses synthetic biology's potential to harness the power of nature to solve global challenges, creating a more sustainable future. Through studying synthetic biology-powered biosensors, Zijay discovered that living cells could be applied to water quality monitoring without the use of electricity for remote areas of the world. This method is considered a strong competitor for next generation water applications among researchers because of its high sensitivity, modularity, and low-cost. However, it's not a viable solution for widespread real-world deployment due to scalability and safety. The first challenge is that most microbes that are used as biosensors cannot support and sustain themselves as standalone devices. ELMs aim to echo the remarkable properties of creatures in nature, such as trees, to create novel, growable, multi-functional materials using genetically-engineered organisms. The most pioneering ELM work was created using nano-to micro-scale bacterial biofilm, which has rather small yields and usually requires costly processing. Secondly, releasing genetically modified microorganisms (GMMs) into the field for food, water, or agricultural applications is risky due to the uncertainty of wild-type organisms acquiring undesirable abilities, such as antibiotic-resistance, from the GMMs.

The Solutions: Zijay's inspiration for his primary invention came from SCOBY, the floating biofilm added to the popular fermented tea, kombucha. The SCOBY (symbiotic culture of bacteria and yeast) contains a rich cellulose that is produced by the bacteria found in the kombucha culture (commonly called the Mother). This cellulose rich structure of the SCOBY served as a model for his invention of a new ELM that is a robust synthetic symbiotic culture of bacteria and yeast, called Syn-SCOBY. Zijay's Syn-SCOBY invention allows for the sustainable production of engineered bacterial cellulose-based materials without the need for lab equipment. The bacterial cellulose (BC) is a natural biological material with impressive physical properties that can produce high amounts of materials for a low cost. Zijay invented a variety of novel BC-based ELMs containing reprogrammed yeast cells through a synthetic SCOBY approach that uses a co-culture of the model yeast found in kombucha and other fermented food and drinks. Syn-SCOBY's bacterial living materials can sense, detect and respond to environmental pollutants, as well as be used as living Polaroid films that grow images based on projected light patterns. The simple incubation method, which is the same as home-brewed kombucha tea, allows contamination detectors for food and water supply to be produced by anyone in a resource-limited area for low cost. Starting with only engineered SCOBY, table sugar, and tea, this novel Syn-SCOBY system empowers the sustainable production of BC-based ELMs with programmable properties under room temperature within three days. The method is robust and resistant to contaminates, so that 800M people without access to clean water could easily grow Syn-SCOBY smart filters at home.

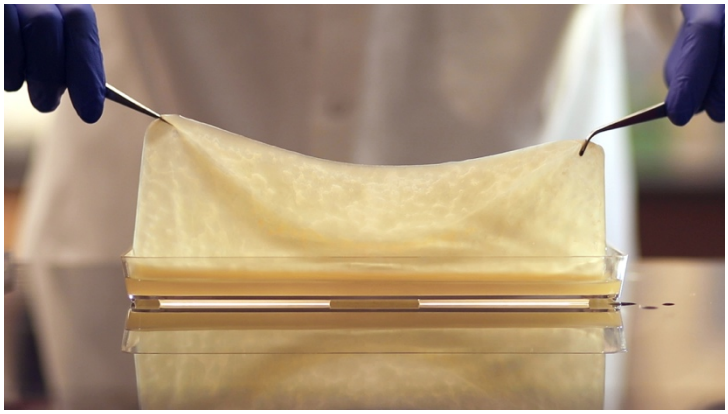

Figure 1: Syn-SCOBY prototype

Figure 2: Prototype of hydrogel-based encapsulation system (DEPCOS).

Zijay's second invention, DEployable Physical COntainment Strategy (DEPCOS), solves the challenges in deploying GMMs for environmental uses. DEPCOS is a robust hydrogel-based encapsulation system that enables the safe deployment of GMMs for environmental applications, leveraging cells equipped with genetic circuits that can sense and record pollutant

signals. The tough hydrogels provide physical and chemical containment of GMMs and remain functional, while being protected from harsh circumstances such as antibiotics and low pH. The technology was tested using a water sample from the Charles River in Massachusetts and showed the detection of a pollutant sensitivity higher than state toxicity regulations. In addition to DEPCOS' use in sensing chemical pollutants in environmental applications, the technology can be used to sense chemicals present on human skin or in the environment through wearable devices such as gloves and tattoos.

Commercialization: Zijay has filed a provisional patent application for Syn-SCOBY and has received several technology licensing inquiries from a variety of industries spanning from pharmaceutical to fashion. BC, the major structural component of Syn-SCOBY, has long been used commercially in textiles, cosmetics, foods, and wound dressing. Syn-SCOBY further improves BC's functionalities by incorporating enzymes and living biosensors that could upgrade BC's utilization in its current $1B market, at no extra cost. Notably, the sensing version of Syn-SCOBY is an ideal packaging material that senses environmental changes or light exposure during transport. Syn-SCOBY with sensing capability could serve as a smart filter for primary water monitoring and treatment. Syn-SCOBY also shows promise as a leather replacement and more futuristically, a self-cleaning textile with embedded enzymes.

Zijay's secondary invention, DEPCOS, is patent pending for its application on the safe deployment of engineered microbes for water quality monitoring, and its extended use in wearable devices.