February 22, 2019

Health & Physiology

# BioBitsTM: Making Hands-on Biology Experiences Accessible for Everyone

by **Ally Huang**[1] | PhD student; **Jessica Stark**[2] | PhD student; **Peter Nguyen**[3] | Wyss Technology Fellow

[1]: Massachusetts Institute of Technology, Department of Biological Engineering, USA
[2]: Department of Chemical and Biological Engineering, Northwestern University, USA
[2]: Wyss Institute for Biologically Inspired Engineering, Harvard University, USA

This Break was edited by, Max Caine, *Editor in chief*, TheScienceBreaker

ABSTRACT

*With low-cost protein expression technology, we developed cheap and easy-to-use kits to teach molecular biology lessons, allowing access to hands-on biology activities for low-resource classrooms.*

*Image credits: Pixabay – CC0*

Molecular biology is difficult to teach in schools, since the concepts can't be seen and are instead represented with abstract diagrams in textbooks. Some schools have introduced hands-on activities, such as growing cells that glow green, to illustrate these ideas in real life and facilitate learning. However, such activities are limited to schools with specialized resources: expensive equipment is required to handle and store the live microorganisms and biological components, making it prohibitively costly and complicated for many schools. To tackle these challenges, we developed a variety of low-cost, hands-on, just-add-water activities to teach biology concepts. Our activities use freeze-dried, cell-free (FD-CF) technology: similar to how an engine can still work if taken out of a car, we extract the essential machinery from cells and combine them into a cell-free reaction that can still turn DNA into proteins, circumventing the need to grow live cells in a classroom. We then freeze-dry these reactions to form pellets that are stable at room temperature, eliminating the need for specialized freezers for storage. Students simply add water to use the FD-CF pellets to turn DNA into proteins, making this system both inexpensive and easy to use in any setting.

Because we want these activities to be engaging, we created protein outputs that students can easily detect. First, we developed FD-CF reactions that produce visible fluorescent proteins to teach students about the central dogma of biology (DNA

goes to RNA goes to proteins). We tested a variety of different brightly colored proteins, spanning from reds to oranges to yellows to greens, which can be seen under UV light. These outputs were further developed into educational lab activities. In one such activity, students add different amounts of DNA to FD-CF pellets and observe varying levels of fluorescence produced, demonstrating how protein expression can be controlled. We also used fluorescent FD-CF reactions to create a design or picture (like a biological Lite-Brite!). We include data showing a few experiments and designs from actual middle and high school students to demonstrate how easy it is to use these kits. We also developed affordable portable hardware, like a USB-powered incubator to heat the reactions to enhance protein expression and a battery-powered LED-illuminator to visualize the fluorescent proteins, so the reactions can be easily integrated into classrooms.

Next, we developed FD-CF reactions that produce different types of enzymes. One of these enzymes is able to catalyze the biochemical conversion of a chemical called isoamyl alcohol into isoamyl acetate, also known as banana oil, which the students can detect by smell. The other enzyme is able to catalyze the formation of hydrogels, which the students can touch and manipulate by hand. These reactions engage students via multiple senses, and teachers can use them to teach concepts like enzyme kinetics. Finally, we created FD-CF reactions that were linked to nucleic acid-based biosensors, which could detect very specific DNA sequences – in fact, they were sensitive enough to differentiate between DNA (that students can extract themselves) from a kiwi versus DNA extracted from a banana! Allowing the students to explore the world around them from a molecular perspective helps them understand these concepts better.

Together, these activities represent a set of next-generation synthetic biology educational kits called BioBitsTM that address the need for easy-to-implement, accessible, and hands-on biology demonstrations. The kits utilized FD-CF reactions to bring molecular and synthetic biology experiments into a classroom setting in an affordable manner, without the need for specialized equipment or refrigeration. In fact, we estimate that one of these kits, which contains enough activities for a 30-person classroom, costs only around $100. Notably, the demonstrations presented here are modular so that teachers can incorporate these explorations into their curricula as they see fit depending on the content they wish to teach and the classroom time available. We envision developing an open-source community around the BioBitsTM kits, allowing users to discuss and develop new ideas for lessons or to even design, build, and test new genetic constructs for the BioBitsTM parts library. Our BioBitsTM kits contain just a few examples of the potential activities that can be developed using FD-CF reactions, and as noted above, new modules could be created to teach additional biological concepts. Together, our BioBitsTM kits promise to engage more students in the life sciences and biotechnology.