BioBuilding for Teachers

Welcome! We're glad you've found these pages.
The curricular materials in Synthetic Biology offered here present exciting possibilities for teaching, as well as a non-zero amount of energy on your part to implement the content in your classroom. It's hoped that the materials in this "teacher resources" space will minimize the barrier for trying some or all of the units. We've offered tips and practical advice for getting started, as well as assessment tools and reagents lists. We're eager to hear what you need, how it goes, and any of your ideas for improving and extending the units. Please email us through BioBuilder (info AT biobuilder DOT org) to share your feedback and experiences, or to request reagents.
As for navigating this site: you can link back to the student's home page and to the student's materials themselves through the glossary link on the tool bar or by clicking on the name of the lab at the top of each resource page you find here.
Good luck, have fun, and please let us know how it goes and what more you need...

Why teach Synthetic Biology?

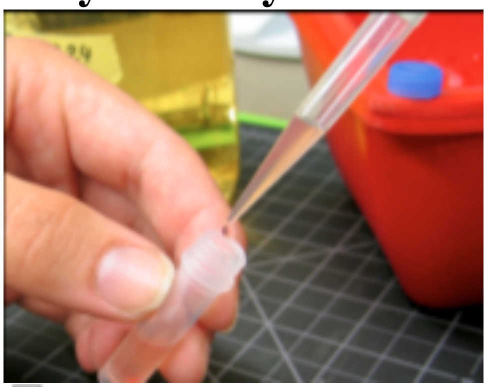


photo from Ginkgo Bioworks
For the last decade teachers have introduced genetic engineering techniques to students. It is becoming commonplace for students in biology and AP Biology courses to conduct a standard set of "experiments" using gel electrophoresis and bacterial transformation techniques. Though they include important laboratory techniques, these experiments are limited in several ways, including the time available for students to perform the work, non-trivial equipment needs and, most significantly, the limited range of experimental problems and teaching materials that are available. Consequently, almost all teachers conduct the same set of experiments every year using materials packaged by supply companies. Students who perform these experiments learn several basic techniques, but that is where the laboratory experience ends. There is little room for student inquiry or creativity. The students are more technicians than scientists.

What is Synthetic Biology?

A solution to this problem comes not from biology but the relatively new field of Synthetic Biology. Synthetic biologists apply engineering principles and extend genetic engineering techniques to construct new genetic systems. The synthetic biology approach provides teachers and students with a means to learn molecular biology, genetic engineering and microbiology methods in an engineering setting. The students learn while designing, or testing designs of, engineered biological systems. In addition, this approach provides science teachers with a means of exploring numerous state and national technology standards that are hard to address in most science classes.
Like genetic engineering, synthetic biology makes use of techniques such as gel electrophoresis, polymerase chain reaction("PCR"), restriction enzymes, and cloning. For decades now, these techniques have been used to transfer genes that exist in one organism into the genome of another, and most students are familiar with human insulin producing bacteria and genetically modified organism used for food.

However, synthetic biologists are not limited to moving existing genes into existing genomes. By constructing new genetic systems, they have designed bacteria that can change color upon contacting toxins and produce a drug to fight malaria. While it would be impossible for all students to design bacteria like these, they can follow the work of the iGEM competition. This is an annual competition among synthetic biology undergraduates from around the world. Recently, MIT iGEM students have engineered bacteria that can smell like bananas and yogurt that can clean teeth. The banana smelling bacteria are an inspiration for one of the labs you'll find here.

Using BioBuilder to Teach Engineering

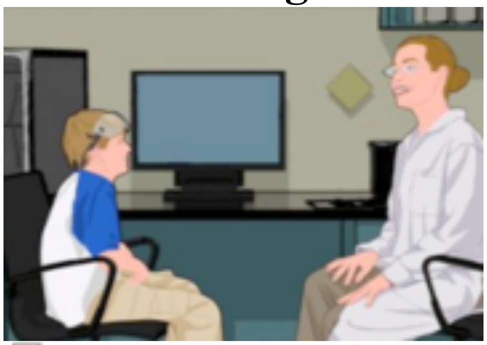
The engineering approach taught here focuses on two important principles: abstraction, and standardization, and relies on numerous enabling technologies such as DNA synthesis. These principles and technologies provide biology teachers with a means to extend the teaching of molecular genetic techniques into real world, authentic applications. In the way that physics teachers can have students create functioning circuits and computer teachers can have students create 3-D animations, biology teachers can have students safely design, construct and analyze engineered biological systems. For example, teachers can order the materials and conduct bacterial transformations to grow bacteria in a rainbow of colors.

Importantly, though, biology teachers can use these available materials to conduct engineering challenges with students. For example, existing devices can be altered to meet a new design criteria, and the differing designs and their results can be compared. Students gain first-hand experience with in the engineering paradigm: **Design-->Build-->Analyze.** Of course, since the engineering activities are performed in the context of living systems, the students will have to understand the underlying science. For instance, they will need to understand what a promoter and a ribosome binding site are, and what a population growth curve is if they are to rationally design and measure them. Through synthetic biology, students can learn these concepts within an authentic context of engineering challenges. These tools of synthetic biology provide biology students with a means to be more than technicians; they can be engineers.

Each of the components of this curriculum focuses on different, but related, aspects of both biology and synthetic biology:

- Eau that Smell is a laboratory exercise that compares two alternative genetic designs. Both programs should make the cells smell like ripe bananas as the cells grow, and the lab requires that the students generate a bacterial population growth curve to compare the output of the competing banana-smell designs.
- The iTune device lab examines the role of parts, such as promoters and ribosome binding sites, in predicting the output of a genetic device. The students measure b-galactosidase enzymatic activity as the device's output, thereby looking through the lens of molecular genetics to predict and then evaluate a device's behavior.
- Picture This consists of three activities that focus on circuit design. Students examine a two component sensing system that has been engineering to produce bacterial photographs. [Picture This] activities include a downloadable program to model the genetic system and change experimental parameters, an exercise to model the same system using electronic parts on a bread board, and an opportunity to send a stencil that will be turned into a bacterial photograph.
- What a Colorful World examines the role of the cellular chassis in system performance. Students transform different strains of E. coli with DNA that turns the cells several bright colors. Students then observe how different the color intensity can be from strain to strain, despite being encoded by the same DNA sequence.
- The essay requires students consider the potential of synthetic biology as well as the risks.
- In the design assignment, students identify a problem that could be effectively addressed with a biotechnology, and then specify a living system they believe could meet the challenge.

BioBuilder.org



This teaching unit has been developed in conjunction with the BioBuilder website. BioBuilder.org provides educational animations for students and teachers to explore the underpinnings of synthetic biology. The curricula presented here consist of labs, an essay assignment, a design assignment, and links to teacher and student resources, including BioBuilder. BioBuilder also has single page "BioPrimers" that can be used to frame the material you'll find here, as well as additional topics that might be of interest. All the material is modular and can be taught completely, in any order, or as individual exercises to supplement an existing program. The pages have links at the bottom and on the side tool bar to allow for easy navigation within the unit.

Once you've tried this content, or even before you give it a go, take a look at the BioBuilder "Join a Discussion" link. If you have feedback or hints or funny stories to share, please add them to that collection! We'd love to hear from you.