"A central goal of synthetic biology is to make biology easier to engineer. The principle of abstraction lays the foundation for the acceleration of our ability to build a wide range of complex biological systems. The ability for engineers and scientists who are interested in designing these systems to choose from a set of standardized devices, rather than working-up from the DNA-level will expand the field and make way for innovation. Building systems will give us insight into how the analogous systems work in nature, but they also open the door for devices that can advance human quality of life. Applications have the potential to affect many areas, such as biological "machines" that are effective sensors, produce chemical compounds cheaply and efficiently, clean up the environment, or help fix our bodies.

The International Genetically Engineered Machines (iGEM) competition is committed to training the next generation of synthetic biologists by challenging undergraduates to design a relevant biological system using a kit of standardized, interchangeable parts. This summer, I and at least 7 other MIT undergraduates, will be participating in the competition. The team will have six faculty advisors: Dr. Bathe, Dr. Kuldell, Dr. Maheshri, Dr. Niles, Dr. Prather, and Dr. Weiss; along with graduate student mentors. I will be working specifically with Dr. Kuldell. About 180 teams from around the world will participate and present their projects at the iGEM Jamboree in the fall. The iGEM competition is central in building the interdisciplinary community of synthetic biology.

For the remainder of spring term, the team will have weekly meetings, during which we will learn the basic principles of biological design and come up with a solid plan for the project. During the summer we will work full-time on the implementation of our project: conducting experiments and computational modeling. In the time leading up to the Jamboree, we will prepare for the presentation of our project, which involves making a website, a poster, and a talk.

At this time, a project idea has not been decided upon. However, during the MIT iGEM team application process, I proposed that we implement a "firefly" simulation on an E. coli biofilm.

The StarLogo program (http://education.mit.edu/starlogo/) simulates the self-organized synchronization of flashing fireflies with the following set of simple rules:

1. Each firefly has an intrinsic flashing frequency

2. Flashes are timed by the progressive excitation of a chemical. Once the excitation reaches a threshold level, a flash is emitted and the excitation level is set to zero.

3. If a firefly senses a certain amount of luminescence from its neighbors, it will reset its excitation to zero in order to flash simultaneously.

I propose a similar simulation, except implemented with an E. coli biofilm. This project can build upon the 2009 Harvard iGEM team's work on optical communication. A red firefly luciferase will be expressed in E. coli. A resettable counter or timer will be found or engineered, and connected to luciferase expression. For E. coli to recieve the light signals of its neighbors, we can use the interaction between the red-light sensitive Arabidopsis thaliana phytochrome PhyB and its integrating factor PIF3. This interaction can be connected to the action of resetting the timer. To demonstrate the firefly E. coli behavior, I propose first looking at how two or three cells flash together, and then progressively scale the number of cells up until one is able to see the signal propagate through the colony. Additionally, we could add one or more “trigger” cells—cells that emit light at a certain frequency but do not adjust their clocks to those around them—and observe the system response.

This project draws upon optical communication, quorum sensing, and synchronization, all of which are important in building effective biosensors. Furthermore, the study of quorum sensing and synchronization may lend some insight into how biological systems in nature are able to respond cleanly and predictably even though the individual elements (cells) are relatively noisy.

I see iGEM as an exciting opportunity to learn how synthetic biology is done in an even more fundamental way than would be possible with an ordinary UROP, since I will be working with other undergrads to design and carry out the project, rather than working on an assigned project. I will learn much more than the sum of the computational and experimental techniques I use—I would acquire an entire way of thinking about biological systems. Equally exciting is the prospect of meeting and working with fresh undergrads who are as excited about building and manipulating life as I am, and with seasoned grad students and faculty who are at the heart of the field of synthetic biology right now. "