One of the classes that can be taken to satisfy the Biomedical Engineering Minor (BME) and that is required in the Chemical-Biological Engineering (10B) major is 10.28, Biological Engineering Laboratory. In this course students get hands on experience with bioprocesses and work with technology that is widely used in the pharmaceutical industry. They also have the opportunity to develop their communication skills through the demanding Communication Intensive (CI) portion of the course, which involves weekly assignments on a chosen topic and a final oral presentation. Finally, they pursue a novel research project of their own, where they write their own proposals and devise their own experiments.

The lab portion of the course is divided into two modules: the fermentation module and the cell culture module. In fermentation, students learn how to use a Stirred Tank Reactor (STR) and work in pairs to conduct experiments. The reactor is an elaborate machine with various inputs and outputs used to pump air in and out, control the pH and temperature, and take samples. The reactor is connected to a Primary Control Unit (PCU) and a computer. The PCU allows the student to control various parameters of the reactor, such as aeration and agitation in the vessel. The computer shows the measurements taken during the experiment such as dissolved oxygen concentration, pH, and temperature. The STR is often used in the course to grow E. coli and to measure a quantity known as the $k_L$ value, the oxygen volumetric mass transfer coefficient. The $k_L$ value allows one to determine how well oxygen is being transferred from the gas phase into the liquid phase in the reactor. This coefficient is very important when a company needs to scale up a particular process. To scale up a reaction, the $k_L$ value must be kept constant, so the company needs to change the parameters and dimensions of a reactor accordingly.

In the cell culture module, students learn a variety of lab techniques. They learn how to use a Wave Bioreactor, another device used to grow cells at a known agitation and aeration rate. The Wave is a disposable reactor that, put simply, looks like a big bag. It is kept on a rocking machine that rocks it back and forth at a fixed rate and angle. Students grow mammalian cells in these reactors as opposed to the bacterial cells that they grow in the fermentation module. Because mammalian cells are used, sterile technique is very important in this module. The students handle all cells and
Hands-on Learning with Bioreactors

media in sterile biosafety cabinets, using the proper techniques they learned from their instructors. Students also learn how to sample the Wave reactors in a sterile fashion. They use these samples to measure the cell density, pH, and metabolite concentration of their reaction volumes.

In addition to learning lab techniques, the students learn how to analyze and write scientific papers in the CI portion of the course. At the beginning of the semester students choose a specific subject that they would like to pursue throughout the course. They read two papers on that subject and thoroughly analyze and discuss the data in those papers, comparing their conclusions and implications. Ultimately, they write a final paper that analyzes the two articles and discusses possibilities for future research in their given topic. At the end of the term, they give a presentation on the work they have done.

Perhaps the most exciting part of the course is the independent project. Students choose a topic from a list and propose a set of experiments they would like to run. For example, a project this year requires that students optimize production of monoclonal antibodies using an external spin-filter bioreactor. A spinfilter is a device that filters out spent media from the reactor, allowing one to add and remove media continuously. Students in this project are free to change whatever parameters and perform whatever experiments they like as long as they justify their decisions and as long as the experiments are feasible with the equipment available and in the time given. Before they begin they write a thorough proposal that details their experiments, the background of their topic, the economics involved, and the advantages of their proposal. It is important to note that these are novel research projects. For instance, there is little to no literature on external perfusion spin filters; most research has been done with internal spin filters.

The staff of 10.28 is composed of undergraduate and graduate teaching assistants and of various lecturers who speak every week. Lecturers include Dr. Jean-Francois Hamel, Professor Kristala Jones Prather, and Institute Professor Daniel Wang. All instructors in the class are dedicated and attentive, and they make this complex course run very smoothly. It is a great experience for anyone interested in biological research; this course gives students a set of valuable tools and challenges them to think both independently and collaboratively and to communicate their ideas in a concise, clear manner.