Biological Engineering and Small-scale Technologies (BEST)
Strategic Academic Vision: 2013-2020

Principal Authors: Kara McCloskey, Changqing Li, Jennifer Lu, Victor Munoz, Wei-Chun Chin

Executive Summary: The BEST graduate program is a highly interdisciplinary program, perhaps the most interdisciplinary group on campus, comprised of 26 faculty members whose research and home units are in Biological Engineering (BIOE), Materials Science and Engineering (MSE), Physics (PHYS), Mechanical Engineering (ME), Biological Sciences , and Chemistry (CHEM). Moreover, BEST is currently the primary graduate program for faculty in MSE and BIOE and secondary graduate program for many of our interdisciplinary faculty in the STEM sciences. Moving forward, as MSE develops their own primary graduate program, it is expected that BEST will become the primary home for BIOE faculty with remaining interdisciplinary synergies as described below. Therefore, this strategic plan will address the specific needs and vision of the BIOE faculty in BEST graduate and the BIOE undergraduate programs.

• **Consistency with one or more of UC Merced's proposed Themes;** BIOE and BEST currently serve 164 BIOE undergraduates, and 22 graduate students (over 80% are doctoral level). The Biological Engineering research focus also contributes to the 2009 Strategic Vision theme of "Human Health", and as we progress forward to 2020, we envision that BEST will continue to foster this theme. Here, we present our vision and strategy to build the BIOE faculty numbers from only 4 (5, including Victor Munoz joining us this summer, 2014) to 25 BIOE faculty and a BEST Graduate Group comprising a focused, but still very much interdisciplinary group of 30 primary faculty and 50 graduate students.

• **Focus on Interdisciplinary research;** Bioengineers tend to focus more on addressing the "critical need in human health" more than the "interesting question". For this reason, Bioengineers are trained to learn to collaborate with the majority of disciplines in the sciences. Although this interdisciplinary focus provides many challenges - especially when thinking about course-work and training that needs to be both in-depth and flexible to meet the needs of the interdisciplinary projects, it is a very appropriate model that naturally promotes an interdisciplinary approach.

• **Evidence of significant collaboration across or within Schools;** BEST is one of the most collaborative graduate program at UCM, with active membership from 5 distinct units - 3 within the School of Engineering and 2 within the School of Natural Sciences (Table 1). This is largely due to the fact that Bioengineering major is also a relatively new major that is in and of itself, highly interdisciplinary by definition. A few specific active or proposed collaborations are ongoing between: McCloskey and Fillipp, McCloskey and Leppert, McCloskey and Gopinathan, Chin and Hirleman, Chin and Barlow, Tung and Lu, and Viney and Lu. Many of our BEST faculty also participate actively in partnerships with HSRI, SNRI, and our National Labs, as well as, graduate programs in QSB and MCB.

Table 1: ***Current BEST membership***

BIOE	MSE	ME	MCB	PHYS	CHEM
Kara McCloskey	*Christopher Viney*	*Yanbao Ma*	*Miriam Barlow*	*Sayantani Ghosh*	*Meng-Lin Tsao*
Victor Munoz	*Valerie Leppert*	*Ming-Hwan Lee*	*Clarissa Nobile*	*Ajay Gopinathan*	*Tao Ye*
Wei-Chun Chin	*Lilian Davila*	*Ashlie Martini*	*Fabian Filipp*	*Linda Hirst*	
Ariel Escobar	*Jennifer Lu*	*Dan Hirleman*	*David Ojcius*	*Jing Xu*	
Changqing Li	*Vincent Tung*	*Jian-Qiao Sun*	*Fred Wolf*	*Jay Sharping*	

The Future of Biological Engineering

According to the U.S. Bureau of Labor Statistics (BLS), biomedical engineering is expected to be the fastest-growing job market in the United States during the next seven years, rising by about 62 percent by 2020. Bioengineers focus on exciting projects like the development of biocompatible prostheses, various diagnostic and therapeutic medical devices ranging from clinical equipment to micro-implants, imaging equipment, regenerative tissue growth, pharmaceutical drugs and therapeutic biological. In the interest of building a competitive, yet interdisciplinary program at UCM, our BIOE and BEST faculty have identified the following 5 thrust areas for building at UCM. These thrust areas were chosen are based on faculty and student interests, funding availability, and student recruitment.

Tissue Engineering (including Biomaterials) is defined as the application of engineering principles to building/repairing tissues like blood vessels, heart muscle, nerves, cartilage, and bone. It is one of the largest growing areas of biomedical engineering. In fact, a majority of the research presented at Bioengineering's largest conference, Biomedical Engineering Society (BMES), is topically related to tissue engineering. Concepts and discoveries from the fields of molecular and cell biology, including stem cell biology, physiology and immunology are also readily incorporated into research activities for tissue engineering. Recent advancements in stem cell research provide exciting opportunities and new directions in stem cell differentiation and functions are new frontiers in cell and tissue engineering. This thrust also synergizes well with stem cell biologists at UCM (largely in MCB).

Biomedical Imaging is a significant research and education area in biomedical engineering. Biomedical imaging track in the Bioengineering (BIOE) undergraduate program and BEST Graduate Program of UC Merced will emphasize biomedical imaging instrumentation development, biomedical imaging algorithms improvement, and biomedical biomarkers synthesis. Faculty in biomedical imaging track will also build a small animal imaging facility at the UC Merced campus to enhance the ongoing research in biological engineering and biological sciences. Despite prevalent misunderstandings on this campus, we do NOT need a hospital to build a strong program in the biomedical sciences since human clinical trials are not local endeavors. However, what we DO critically need is to develop a small animal imaging facility for research in the biological and biomedical sciences. This will also help retain the large grant dollars that are currently sent collaborating institutions (due to the lack of these facilities at UCM).

Biomolecular Engineering is a broader thematic area, but brings together tissue, cellular and molecular engineering, synthetic biology, bio-nanotechnology and biological computation capacity within UCM campus. The major directions are: 1) to implement a general strategy for the development of nano-biosensors based on rheostatic protein conformational changes and develop important/critical applications in biomedicine (e.g. valley fever) and the environment (pollutant detection, etc.), 2) to develop small, simplified-optimized versions of proteins - of particular interest to biomedical or biotechnological/commercial communities - so that they can be efficiently produced, synthesized and employed at the industrial and/or pharmaceutical applications. This theme fits very well within focal areas of the entire campus (environment, water, food, energy, medicine), and includes biomaterials and instrumentation in many ways as well. The required computational components of this theme support future interactions with SNS faculty working in biological modeling, biophysics and chemical biology.

Microfabrication technologies originate from the microelectronics industry, the earliest microfabrication processes were used for integrated circuit fabrication. Microfabrication is actually a collection of technologies (microlithography, doping, thin films, etching, bonding, and polishing) which are utilized in making microdevices. In BIOE and BEST, we are most interested in using these technologies for small-scale studies like “lab-on-a-chip” and bio-micro-mechanical-systems (BIOEMEMS). This research thrust specifically synergizes with some of the interests of our Mechanical Engineering faculty, specifically Min Hwan Lee, Venkattraman Ayyaswamy, and Yanbao Ma.

Nanotechnology is an integrated field to address previously untouchable issues in medicine such as building artificial organs and unique biosensing capacities. The ability to control molecular and nanoscale arrangement will allow tuning phonon, photo and electron properties and thus rationally engineering optical, electrical and thermal property accordingly. Synergizing with our faculty in Materials Science and Engineering, this research thrust will emphasize the creation of novel platforms that integrate/incorporate unique properties of nanoscale materials for directing cell shape and facilitating cell-materials interactions on the nano-scale.

Hiring priorities:

1) Biomedical instrument for cellular imaging (one hire). Examples include Photoaccoustic imaging, optical coherent tomography (OCT), Raman, and advanced optical microscopes.
2) Biomedical imaging sensor synthesis (two hires). Examples are nanoparticle sensors, radiotracers, etc.
3) Tissue Engineering/Regenerative Medicine (two hires). Specific areas of synergy with current faculty research include the neural and cardiovascular areas.
4) Microfabrication (two hires).
5) Biomedical imaging reconstruction and process (one hire). Examples are 3D reconstruction algorithm development for CT, MRI, PET, Optical and ultrasound.
6) Experimental protein engineering with preferable emphasis on combinatorial protein chemistry (e.g. phage display), directed evolution and integration of protein-based hybrid devices (lab on a chip type) with applications on the implementation and production of biosensors, novel protein-based devices for biomedicine, molecular scaffolds for tissue engineering, or novel-optimized enzymes for environmental, food-processing, energy applications.
7) Computational biomolecular design with interest in developing novel biological functionalities, optimized-simplified macromolecular devices for engineering applications or biological/physiological modeling

• **Availability of external funds:** External funding is critical to the success of a BEST program. With the exception of folks working on theoretical/biomodeling problems, most of the BEST faculty require the external funding in order to support their research programs. Luckily, the funding agencies are highly variable including: several programs within both the National Science Foundation and National Institutes of Health. State level funding from the California Institute of Regenerative Medicine (CIRM) has already funded over $10 million of research at UCM, and 3 million to BEST faculty. Private funding is also available through American Heart Association, etc.

• **Evidence that program already has an established research reputation;** The evidence for success of our small BEST graduate program lies in the funding of our faculty, student fellowships, scientific presentations, and publishing in peer-reviewed journals. Despite our small size, our ability to secure external funding (from NIH, NSF, CIRM, AHA, etc.), publish, and help our graduate students with fellowship awards has been noted both on the local campus and broader research community.

• **Feasibility to accomplish program goals within the time frame of the 2020 project;** The feasibility to grow our program relies firmly in the administration’s ability to financially support these hires, and provide appropriate laboratory space. I am pleased to note that UCM has reached a critical mass such that recruitment of highly desirable junior and senior colleagues is much easier in recent years. The BEST group consists of an energetic and productive (albeit small) research community that is attractive most all of our applicants.

• **Ability of program to address important research questions or grand challenges;** Grand challenges in bioengineering include: early detection of human diseases, immunization and prevention of diseases, reduction of health care cost, functional imaging of cells and tissues, predictive modeling of cells, organs and body, artificial organs, and targeted intervention of diseases. The biomedical imaging thrust will focus on early detection of human diseases, especially cancer. The biosensors developed from our biomolecular engineering folks work very specifically on the development of biosensors for intervention and prevention of diseases. Stem cell and tissue engineers work towards repair/replacement of failing organs, as well as, predictive models of cellular fate and development. Together these thrusts are poised to significantly impact the field of bioengineering and contribute to new products ($) and entrepreneurship at UCM, as well as, improving the current state of human health.