5-Year Strategic Plan
For
Graduate Program/Group in Biological Engineering and Small-scale Technologies
January, 2009

I. Overview

The engineering sciences are undergoing a vast and fundamental metamorphosis from isolated disciplines to more integrative and multidisciplinary topics. The Biological Engineering and Small-scale Technologies (BEST) Graduate Group at UC Merced offers a multidisciplinary research and training program for masters degree and doctoral students who want to be at the forefront of this revolution in biologics engineering and nanotechnology. Research projects are available on topics ranging from fundamental characterization of materials to tissue engineering, and coursework will provide a solid background in the tools of biologics, biosensors, and integration of modern materials. The graduate group will offer opportunities for students interested in multidisciplinary projects at the interface between biological engineering, nanotechnology, bioelectrical engineering, mechanical engineering, computer science, and materials characterization and design.

During it second year as an active graduate program, BEST graduate group already has grown to 16 faculty from both the School of Natural Sciences and the School of Engineering and 15 graduate students with research projects that fall into the four research themes (described below). The growing graduate group and expected research synergy implies the need for additional faculty to deepen the research base within these research themes. The current BEST faculty would be spread across many departments and schools in a traditionally organized university. While this diversity of disciplinary expertise should be a strength in developing innovative research programs, it is essential that the group develop a critical mass of expertise in a selected set of areas to allow it to recruit top students and faculty and to be competitive for large research and training grants.

II. Research Themes in the Biological Engineering and Small-scale Technologies

As described in the introduction, there are many exciting research opportunities within the broad area of Biological Engineering and Small-scale Technologies. The research interests of the founding faculty have fostered a focus broadly research areas that include Bioengineering and Materials. These themes are all examples of the integration and overlap the research in these two broad areas.

Research Themes

1) Tissue/Biological Materials Engineering

The area of tissue engineering is, by nature, cross disciplinary in that it employs cell culture methods combined with identification and development of appropriate materials, scaffolding architecture, technologies for cell delivery, and nutrient transport strategies while also synergizing with nanobioengineering and bio-inspired materials.

2) Biological/Physiological Modeling and Control

Biological Modeling and Control is an interdisciplinary research area combining the fields of engineering, cell biology, and chemistry. Examples include the design of components for biomedical devices and tissue engineering, and chemical optimization of molecules with biological properties.

3) Biosensor Design and Fabrication

Sensors and “bots” that can replace defective physiological counterparts in humans and animals; implants and prosthetics constructed from nanocomposites that closely resemble natural tissue; and biosensors, which can be designed to nanodimensions, mounted on a single chip and used in remote diagnoses

4) Micro/Nano Fabrication

Microfabrication for development of micro-array platforms for cell signaling and analysis is a cutting edge area of research for single cell analyses. Much convergence between engineering and biology are also at the nanoscale level – the level of biological molecules, molecular aggregates and cellular processes – has begun to offer new, rich areas of study and commercialization. Examples of the devices, processes, interactions and

materials that are of interest include self-assembly of materials, structures and devices, interactions between nanoparticles and biological tissue.

Resource Needs for the BEST Graduate Group

Three out of four of our research themed-FTE requests will require at least 400 square feet of lab space for junior researchers and up to 1,000 square feet for senior researchers with large laboratories. This is justified by the existence of very large funding sources for life sciences research. Federal agencies provide approximately $30 billion per year and research funding is also available from many foundations and private companies. These funding sources are all highly competitive and successfully acquiring funding requires a strong research program. The 4 research themes described above build on excellence in the foundational sciences, but also are well aligned with the newest academic and research priorities of the funding agencies and foundations. Most major research universities are also creating research programs in bioengineering and materials, but their natural advantages in having already established research programs and facilities may be somewhat offset by having larger institutional barriers to building multidisciplinary research efforts.

Faculty

The BEST critically needs new faculty hires to enable the research programs described above. The BEST faculty are presently drawn from the Schools of Natural Sciences and Engineering. Many of the BEST priorities for faculty hires are represented in the strategic plans from these two schools. Specifically, the BEST faculty endorse the hiring requests for the bioengineering, materials, electrical engineering and mechanical engineering research programs, including the areas of tissue engineering, biology modeling, bio-microfacbrication, and nanotechnology. The BEST faculty would also place a special emphasis on future faculty recommendations in areas that bridge traditional disciplines and faculty whose research involves integrating multiple techniques to solve problems in materials and bioengineering.

Hiring priorities

1. Tissue/Biological Materials Engineering: This is our top priority if space is available.

2. Physiological Modeling: This is our second priority, but may have advantages in that this researcher may not require as much wet lab space.

Tissue Engineering

The Tissue Engineering position could also compliment and synergize with the research of a number of faculty in the areas of Stem Cells, Vascular Tissue Engineering, Biomaterials, Nanotechnology, and Microfluidics/Microchip design. We expect that this faculty hire would contribute to our growing undergraduate programs in Materials Science, Bioengineering, Mechanical Engineering, Electrical Engineering, and Life Sciences and the graduate program in Quantitative and Systems Biology. In addition, this faculty position could potentially contribute to helping build a Stem Cell Program at UCM and synergizes with the top priority in QSB to hire a senior stem cell researcher.

The field of tissue engineering is an emerging and ambitious area of research in which scientists seek to build devices that would replace diseased tissues/organs with their biological equivalents, thus completely restoring tissue/organ functionality. This area has been termed Tissue Engineering and/or Regenerative Medicine. The area of tissue engineering is, by nature, cross disciplinary in that it employs cell culture methods combined with appropriate materials, scaffolding architecture, technologies for cell delivery, and nutrient transport strategies while also synergizing with nanobioengineering by employing the use of small nanoparticles or nonocomposite scaffolding materials. For this reason, the tissue engineer would also be expected to contribute significantly to our undergraduate program in Materials Science.

The space need for this position is expected to be wet lab space around 400-1,000 sq ft. This faculty member is expected to teach undergraduate classes in bioengineering or other area and graduate classes in BEST graduate group.

Physiological Modeling

We have been experiencing unprecedented advances into the complex nature of biological systems in recent years. Current advances in biology, genomics, proteomics, cellular level modeling methods, simulation capabilities, new technologies for imaging and measuring biological phenomena and molecular level interfacial characterization tools present the engineering community with unique opportunities to advance the understanding of these biological or even ecological systems to deliver desired functions. Currently the lack of involvement of engineering has hindered the complete understanding of the complex biological systems. Furthermore, there is a need to understand how the desired or additional functionality can eventually be accomplished and integrated over larger scales and complexities from cellular, organism to human level. Systematic modeling incorporating various engineering concepts such as optimization, database management, control and network formation based on large body of experimental results would lead to complete understanding of the non-linear nature of biological/ecological systems. Being an interdisciplinary field between engineering and biology, BEST has a strategic advantage in engineering to address this unique challenge and opportunity.

Modeling expertise at multiple levels is needed to tackle more complex biological projects. This requested multiple-scale modeling position will be at junior level. This faculty member is expected to collaborate with the current faculty members to link various research areas to study specific biological/physiological problems from system point of view. This position will develop quantitative modeling and simulation methods that faithfully represent the complexity of biological/ physiological systems based on experimental data and deal creatively with the hierarchical and nonlinear nature of living systems. This position will integrate knowledge from various research fields to serve a focal point for faculty members to collaborate on projects that can not be addressed from the view point of a single discipline.

The space need for this position is expected to be dry lab space around 400 sq ft. This faculty member is expected to teach undergraduate classes in bioengineering or other area and graduate classes in BEST graduate group.

III. BEST Academics

Overview

In its first 2 years, the BEST Graduate Group recruited and accepted 14 graduate students, 2 have already passed their qualifying examinations. Based on the growth of increasing this number by 8 students each year, we expect to have approximately 30 doctoral graduates students enrolled in the program in 5 years time. Another source of growth for BEST will be graduate programs for M.S. students. A very high percentage, approximately 30%, of our current Bioengineering undergraduates have expressed interest in the M.S. program and are already actively conducting research in various laboratories at UC, Merced. It is reasonable to expect that these students (approximately 7-10 per year) will enroll in the BEST M.S. program beginning in Fall 2009, leading to a total of 45 graduate students in the BEST program by its 5-year anniversary.

Academic Resource Needs

A central part of a successful graduate program is the diversity of advanced courses offered by the program. The BEST graduate program requires 4 full graduate courses for its Ph.D. program, and it is expected that many students will take more than this minimum. In its first 2 academic years, BEST has offered the 2 “core” graduate courses (BEST 200: Special Topics in Bioengineering and BEST 201: Special Topics in Materials) as well as 3 optional graduate level courses (BEST 217: Lab on a Chip, BEST 214: Tissue Engineering Design, and BEST 210: Structure and Properties of Materials). In order to provide additional graduate training, the BEST faculty have been leading individualized study sections (BEST 299), although this is option neither ideal nor sustainable.

Courses approved:
BEST 200: Special Topics in Bioengineering

BEST 201: Special Topics in Materials
BEST 210: Structure and Properties of Materials

BEST 217: Lab on a Chip (Microfabrication)
BEST 214: Tissue Engineering Design

Additional BEST Courses planned:
Biophysics
Electrophysiology of the Cell
Biotransport
Entrepreneurship
Biomolecular and Cellular Rate Processes
Cellular and Tissue Biomechanics
Bionanotechnology
Medical Imaging

We have been unable to offer a larger selection of courses due to very low faculty numbers in core areas of the program (Materials and Bioengineering). We have only 4 faculty in Material Science and 4 faculty in Bioengineering and are all overcommitted with undergraduate teaching. We also plan to develop "biological engineering" and "materials" tracks in the growing program, but we do not have faculty available to teach graduate level courses. We will need a least 4 more faculty, 2 each in these 2 "core" areas before we can build our planned "tracks" into the academic program or apply for a permanent graduate group status.

IV. Milestones and Assessments for the BEST Graduate Group

Research Programs

The success of the UC Merced BEST Graduate Group involves many components. First and foremost, is the success of the individual faculty in producing important research results leading to recognition, high-impact publications, patents, program growth in faculty and student numbers, technology transfer, and continued research support. However, another metric for success will be UC Merced's effectiveness in developing unique, multidisciplinary research programs based on the cross-disciplinary principles of the university. Success in this metric will make the program competitive for special funding for research centers and training programs, and will also help attract strong faculty, post-docs and graduate students to UC Merced. Another long term metric will be the impact of the research programs at UC Merced on the community.

Other important near-term metrics regarding the success of the BEST graduate program is the proportion of students entering that attains a doctoral degree, as well as students winning competitive awards and fellowships. Another important near-term metric is the number of students that gain post-doctoral appointments and employment in industry.

As previously mentioned, the BEST faculty envision developing 2 "emphasis tracks" for graduate students including a "Materials" and "Bioengineering" track that would closely match traditional training programs. Unfortunately, this development is not possible until larger due faculty numbers are available to contribute to teaching BEST courses.

In addition, the BEST graduate program and has been, very successfully, coordinating with the QSB graduate program in supporting a research seminar series that invites speakers every Friday during the academic year. This is especially beneficial while BEST grows as a program and while the funding situation for research seminars remains very low. We hope that as BEST grows as a program, and as the funding situation improves, BEST and QSB can both support individual seminar series.

Academic Programs

An important metric in evaluating the success of our academic life sciences programs will be the graduate and undergraduate enrollments. Assessment of the success of the BEST program will involve monitoring both the competitiveness of the graduate student applicants to the programs and the long term career success of its graduates. Despite its newness and small size, the BEST graduate group at UC Merced is attracting academically strong students. This Fall 2008, the BEST graduate group a made 12 offers to graduate student applicants with 6 students accepting (50%) and have now joined our graduate program. The average undergraduate GPA for our graduate students in Academic Year 2008-2009 was 3.49 and the average Quantitative GRE was 767, which is at approximately at the 85th percentile. The current average GPA for our BEST graduate students from their work at UCM is approximately 3.8, with many students with a 4.0 GPA. We also had 2 students advance to candidacy during fall, 2008 and are anticipating graduating our first 2 M.S. students this spring/summer 2009. With the exception of 1 graduate student that is struggling a little academically, all of our BEST graduate students are currently excelling in their programs at UCM.