Biomedical Engineering, Ph.D.

The Biomedical Engineering faculty have special interest and expertise in four thrust areas: Biophotonics, Biomedical Micro/Nanoscale Systems, Bioimaging and Computation, and Molecular and Cellular Engineering. Biophotonics faculty are interested in photomedicine, laser microscopy, optical coherence tomography, medical imaging, and phototherapy. Biomedical Micro/Nanoscale Systems faculty are interested in molecular engineering, polymer chemistry, molecular motors, design and fabrication of microelectromechanical systems (MEMS), integrated microsystems to study intercellular signaling, and single molecule studies of protein dynamics. Biomedical Computation faculty are interested in computational biology, biomedical signal and image processing, medical imaging, computational methods in protein engineering, and data mining.

Because of its interdisciplinary nature, biomedical engineering attracts students with a variety of backgrounds. Thus, the requirements for admission are tailored to students who have a bachelor's degree in an engineering, physical science, or biological science discipline, with a grade point average of 3.20 or higher in their upper-division course work. The minimum course work requirements for admission are six quarters of calculus through linear algebra and ordinary differential equations, three quarters of calculus-based physics, three quarters of chemistry, and two quarters of biology. Students without a physics, chemistry, or engineering undergraduate degree may be required to take additional relevant undergraduate engineering courses during their first year in the program; any such requirements will be specifically determined by the BME Graduate Committee on a case-by-case basis and will be made known to the applicant at the time of acceptance to the program.

The recommended minimum combined verbal and quantitative portion of the GRE is 310, or a minimum combined MCAT score in Verbal Reasoning, Physical Sciences, and Biological Sciences problems of 508. A minimum score of 94 on the Test of English as a Foreign Language (TOEFL iBT) is recommended of all international students whose native language is not English. In addition, all applicants must submit three letters of recommendation.

Exceptionally promising UCI undergraduates may apply for admission through The Samueli School of Engineering's accelerated M.S. program, however, these students must satisfy the course work and letters of recommendation requirements described above.

Core Requirement

Both the M.S. and Ph.D. require the students to complete 42 course units. These units include six core courses, the BME 298 seminar series, two elective courses, and four units of independent research.

A. Complete the following core courses:	
BME 210	Molecular and Cellular Engineering
BME 220	Sensory Motor Systems
BME 221	Organ Transport Systems
BME 230A	Applied Engineering Mathematics I
BME 230B	Applied Engineering Mathematics II
BME 240	Introduction to Clinical Medicine for Biomedical Engineering
B. Complete:	
BME 298	Seminars in Biomedical Engineering (three quarters)
C. Complete two electives	
D. Complete four units of independent research	

The core courses cover the basics of cells, tissues, and physiology at the microscopic and macroscopic scale, engineering mathematics, and clinical theory. Core requirements can be waived for students entering the Ph.D. program with an M.S. degree in Biomedical Engineering.

Elective Requirement

The two elective courses required to fulfill the course requirements for the M.S. and Ph.D. are offered within The Henry Samueli School of Engineering and the Schools of Biological Sciences, Physical Sciences, and Medicine. The electives must provide breadth in biomedical engineering, but also provide specific skills necessary to the specific research the student may undertake as part of the degree requirements. The selection of these courses should be based upon approval of the student's faculty advisor. Upper-division undergraduate courses and courses outside of the HSSoE may be selected upon approval of the BME Graduate Advisor. Elective requirements can be waived for students entering the Ph.D. program with an M.S. in Biomedical Engineering.

The Ph.D. requires the achievement of an original and significant body of research that advances the discipline. Students with a B.S. may enter the Ph.D. program directly, provided they meet the background requirements described above. The Graduate Committee will handle applicants on a case-by-case basis, and any specific additional courses required by the student will be made explicit at the time of admission.

Each student will match with a faculty advisor, and an individual program of study is designed by the student and their faculty advisor. Two depth courses are required beyond that of the M.S. degree in preparation for the qualifying examination. Six milestones are required: (1) successful completion of 42 units of course work beyond the bachelor's degree, as listed under "Core Requirement" and "Elective Requirement" above; (2) successful completion of a preliminary examination; (3) establishing an area of specialization by taking two depth courses and three quarters of BME 298 during

the second year; (4) formal advancement to candidacy by successfully passing the qualifying examination; (5) students in their third or fourth year must present results of their current research in the BME seminar series; and (6) completion of a significant body of original research and the submission of an acceptable written dissertation and its successful oral defense. During their research project, students are expected to enroll in at least 12 units of independent research per quarter. Students entering the Ph.D. program with an M.S. in Biomedical Engineering cannot receive another M.S. in Biomedical Engineering from UCI. Therefore, the requirements for milestone (1) can be waived, and the award of the Ph.D. is based on achieving milestones (2)–(6).

The preliminary examination will normally be taken at the end of the first year (May). A student must take it within two years of matriculating in the program and must either have passed all of the core courses or have an M.S. in Biomedical Engineering prior to taking the examination. The Preliminary Examination Committee prepares the examination and sets the minimum competency level for continuing on in the Ph.D. program. Students who fail may retake the examination the following year. Students who fail the second attempt will not be allowed to continue in the program. However, they may be eligible to receive a Master's degree upon completion of an original research investigation including a written thesis (refer to Master of Science Degree requirements). In the event a Ph.D. student decides not to continue in the program, the thesis-only option for the M.S. will still be enforced. After passing the preliminary examination at the Ph.D. competency level, students will match with a BME faculty advisor and design an individual program of study with their advisor.

Advancement to candidacy must be completed by the end of the summer of the third year of the Ph.D. program. (Special exceptions can be made, but a formal request with justification must be supplied in writing to the BME Graduate Advisor.) The qualifying examination follows campus and The Henry Samueli School of Engineering guidelines and consists of an oral and written presentation of original work completed thus far, and a coherent plan for completing a body of original research. The qualifying examination is presented to the student's graduate advisory committee, which is selected by the student and faculty advisor and must have a minimum of five faculty (including the faculty advisor). Of these five faculty, three must be BME faculty. In addition, one faculty member must have his/her primary appointment outside the Department of Biomedical Engineering. The fifth member must have his/her primary appointment outside of The Henry Samueli School of Engineering.

The Ph.D. is awarded upon submission of an acceptable written dissertation and its successful oral defense. The degree is granted upon the recommendation of the graduate advisory committee and the Dean of Graduate Division. The normative time for completion of the Ph.D. is five years (four years for students who entered with a master's degree). The maximum time permitted is seven years.

Requirements listed here pertain to students enrolled in academic year 2012–13 or later. Students enrolled before this date may refer to a previous version of this *Catalogue*.

Although a student is not required to formally choose a specific research focus area, four research thrust areas have been identified for the program: Biophotonics, Biomedical Micro/Nanoscale Systems, Bioimaging & Computation, and Molecular & Cellular Engineering. These areas capitalize on existing strengths within The Henry Samueli School of Engineering and UCI as a whole, interact in a synergistic fashion, and will train biomedical engineers who are in demand in both private industry and academia.

Biophotonics. This research area includes the use of light to probe individual cells and tissues and whole organs for diagnostic and therapeutic purposes. The research areas include both fundamental investigation on the basic mechanisms of light interaction with biological systems and the clinical application of light to treat and diagnose disease. Current and future foci of the faculty are (1) microscope-based optical techniques to manipulate and study cells and organelles; (2) development of optically based technologies for the non-invasive diagnosis of cells and tissues using techniques that include fiber-optic-based sensors, delivery systems, and imaging systems; and (3) development of optically based devices for minimally invasive surgery.

Biomedical Micro/Nanoscale Systems. This class of research areas encompasses the understanding, use and design of biomedical devices and systems that are at the micron or submicron level. Current strengths within The Henry Samueli School of Engineering and the UCI faculty as a whole include biomaterials, micro-electromechanical systems (MEMS), and the design of new biomedical molecules. The focus of biomedical engineering research in this area is the integration of micro and nano-scale systems with the needs of clinical medicine. Projected areas of growth include (1) micro/nano-electromechanical systems (M/NEMS) for biomedical devices, biofluid assay and micro implantable prosthesis (2) programmable DNA/ molecular microchip for sequencing and diagnostics; (3) cellular, tissue, and organ constructs on-a-chip; and (4) biomaterials and self-assembled nanostructures for biosensors and drug delivery.

Biomedical Imaging & Computation. Biomedical computational technologies include both advanced computational techniques, as well as advanced biomedical database systems and knowledge-base systems. Computational technologies that will be developed in this research area include (1) methods for biomedical analysis and diagnosis such as physical modeling of light-tissue interactions, atomic-level interactions, image processing, pattern recognition, and machine-learning algorithms; (2) language instruction and platform standardization; and (3) machine-patient interfaces. Areas of research related to biomedical database systems include the development of new technologies which can capture the rich semantics of biomedical information for intelligent reasoning.

Molecular & Cellular Engineering. Rapid developments in genetics, molecular biology, and cellular biology have extended the reach of engineering into the subcellular, cellular, and tissue size scales. As a result, several new fields including genetic engineering, cell-based therapy, and tissue engineering have emerged and matured in the past decades with the broad goal of extracting and applying engineering design principles to the most fundamental levels of biological organization.

Program in Law and Graduate Studies (J.D./M.S.-BME; J.D./Ph.D.-BME)

Highly-qualified students interested in combining the study of law with graduate qualifications in the BME program are invited to undertake concurrent degree study under the auspices of UC Irvine's Program in Law and Graduate Studies (PLGS). Students in this program pursue a coordinated curriculum leading to a J.D. from the School of Law in conjunction with a Master's or Ph.D. in the BME program. Additional information is available from the PLGS Program Director's Office, 949-824-4158, or by email to plgs@law.uci.edu. A full description of the program, with links to all relevant application information, can be found at the School of Law Concurrent Degree Programs website (http://www.law.uci.edu/academics/interdisciplinary-studies/concurrent-degrees.html) and in the Law School section of the *Catalogue*.