Department of Biomedical Engineering

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Overview

Biomedical engineering combines engineering expertise with medical needs for the enhancement of health care. It is a branch of engineering in which knowledge and skills are developed and applied to define and solve problems in biology and medicine. Students choose the biomedical engineering field to be of service to people, for the excitement of working with living systems, and to apply advanced technology to the complex problems of medical care. Biomedical engineers may be called upon to design instruments and devices, to bring together knowledge from many sources to develop new procedures, or to carry out research to acquire knowledge needed to solve new problems.

During the last 20 years, we have witnessed unprecedented advances in engineering, medical care, and the life sciences. The combination of exploding knowledge and technology in biology, medicine, the physical sciences, and engineering, coupled with the changes in the way health care will be delivered in the next century, provide a fertile ground for biomedical engineering. Biomedical engineering, at the confluence of these fields, has played a vital role in this progress. Traditionally, engineers have been concerned with inanimate materials, devices, and systems, while life scientists have investigated biological structure and function. Biomedical engineers integrate these disciplines in a unique way, combining the methodologies of the physical sciences and engineering with the study of biological and medical problems. The collaboration between engineers, physicians, biologists, and physical scientists is an integral part of this endeavor and has produced many important discoveries in the areas of artificial organs, artificial implants, and diagnostic equipment.

The Department offers a B.S. in Biomedical Engineering (BME), a four-year engineering curriculum accredited by the Engineering Accreditation Commission of ABET (http://www.abet.org). This program prepares students for a wide variety of careers in Biomedical Engineering in industry, hospitals, and research laboratories or for further education in graduate school.

The Department also offers a B.S. in Biomedical Engineering: Premedical (BMEP), a four-year engineering curriculum taken with required premedical courses. It is one of many majors that can serve as preparation for further training in medical, veterinary, or allied health professions. It is also suitable for students interested in pursuing graduate work in Biomedical Engineering and other biomedical areas such as physiology, neurosciences, and bioinformatics. The curriculum has less engineering content but more biological sciences and chemistry course work than the Biomedical Engineering major. The undergraduate major in Biomedical Engineering: Premedical is not designed to be accredited, therefore is not accredited by ABET.

Areas of graduate study and research include biophotonics, biomedical nanoscale systems, biomedical computational technologies, and tissue engineering.

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• Biomedical Engineering
• Biomedical Engineering: Premedical

Undergraduate Major in Biomedical Engineering

Program Educational Objectives: Graduates of the Biomedical Engineering program will (1) promote continuous improvement in the field of biomedical engineering; (2) communicate effectively the relevant biomedical engineering problem to be solved across the engineering, life science, and medical disciplines; (3) apply critical reasoning as well as quantitative and design skills to identify and solve problems in biomedical engineering; and (4) lead and manage biomedical engineering projects in industry, government, or academia that involve multidisciplinary team members. (Program educational objectives are those aspects of engineering that help shape the curriculum; achievement of these objectives is a shared responsibility between the student and UCI.)

Biomedical Engineering students learn engineering and principles of biology, physiology, chemistry, and physics. They may go on to design devices to diagnose and treat disease, engineer tissues to repair wounds, develop cutting-edge genetic treatments, or create computer programs to understand how the human body works.

The curriculum emphasizes education in the fundamentals of engineering sciences that form the common basis of all engineering sub-specialties. Education with this focus is intended to provide students with a solid engineering foundation for a career in which engineering practice may change rapidly. In addition, elements of bioengineering design are incorporated at every level in the curriculum. This is accomplished by integration of laboratory experimentation, computer applications, and exposure to real bioengineering problems throughout the program. Students also work as teams in senior design project courses to solve multidisciplinary problems suggested by industrial and clinical experience.
NOTE: Students may complete only one of the following programs: the major in Biomedical Engineering, the major in Biomedical Engineering: Premedical, or the minor in Biomedical Engineering.

## Admissions

**High School Students:** See School admissions information.

**Transfer Students:** Preference will be given to junior-level applicants with the highest grades overall, and who have satisfactorily completed the following **required** courses: one year of approved calculus, one year of calculus-based physics with laboratories (mechanics, electricity and magnetism), completion of lower-division writing, one year of chemistry (with laboratory), and one additional approved course for the major.

Students are encouraged to complete as many of the lower-division degree requirements as possible prior to transfer. Students who enroll at UCI in need of completing lower-division coursework may find that it will take longer than two years to complete their degrees. For further information, contact The Henry Samueli School of Engineering at 949-824-4334.

## Requirements for the B.S. in Biomedical Engineering

All students must meet the University Requirements.

All students must meet the School Requirements.

### Major Requirements

**Mathematics and Basic Science Courses:**

Students must complete a minimum of 48 units of mathematics and basic sciences including:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
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</thead>
<tbody>
<tr>
<td>BIO SCI 194S</td>
<td>Safety and Ethics for Research</td>
</tr>
<tr>
<td>CHEM 1A- 1B- 1C</td>
<td>General Chemistry and General Chemistry and General Chemistry</td>
</tr>
<tr>
<td>CHEM 1LC</td>
<td>General Chemistry Laboratory</td>
</tr>
<tr>
<td>MATH 2A- 2B</td>
<td>Single-Variable Calculus and Single-Variable Calculus</td>
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<tr>
<td>MATH 2D</td>
<td>Multivariable Calculus</td>
</tr>
<tr>
<td>MATH 2E</td>
<td>Multivariable Calculus</td>
</tr>
<tr>
<td>MATH 3A</td>
<td>Introduction to Linear Algebra</td>
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<tr>
<td>MATH 3D</td>
<td>Elementary Differential Equations</td>
</tr>
<tr>
<td>PHYSICS 7C</td>
<td>Classical Physics</td>
</tr>
<tr>
<td>PHYSICS 7LC</td>
<td>Classical Physics Laboratory</td>
</tr>
<tr>
<td>PHYSICS 7D- 7E</td>
<td>Classical Physics and Classical Physics</td>
</tr>
<tr>
<td>PHYSICS 7LD</td>
<td>Classical Physics Laboratory</td>
</tr>
<tr>
<td>STATS 8</td>
<td>Introduction to Biological Statistics</td>
</tr>
</tbody>
</table>

**Engineering Topics Courses:**

Students must complete a minimum of 28 units of engineering design including:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>BME 1</td>
<td>Introduction to Biomedical Engineering</td>
</tr>
<tr>
<td>BME 50A- 50B</td>
<td>Cell and Molecular Engineering and Cell and Molecular Engineering</td>
</tr>
<tr>
<td>BME 60A- 60B- 60C</td>
<td>Engineering Analysis/Design: Data Acquisition and Engineering Analysis/Design: Data Analysis and Engineering Analysis/Design: Computer-Aided Design</td>
</tr>
<tr>
<td>BME 110A- 110B- 110C</td>
<td>Biomechanics I and Biomechanics II and Biomechanics III</td>
</tr>
<tr>
<td>BME 111</td>
<td>Design of Biomaterials</td>
</tr>
<tr>
<td>BME 120</td>
<td>Sensory Motor Systems</td>
</tr>
<tr>
<td>BME 121</td>
<td>Quantitative Physiology: Organ Transport Systems</td>
</tr>
<tr>
<td>BME 130</td>
<td>Biomedical Signals and Systems</td>
</tr>
<tr>
<td>BME 140</td>
<td>Design of Biomedical Electronics</td>
</tr>
<tr>
<td>BME 150</td>
<td>Biotransport Phenomena</td>
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</tbody>
</table>
BME 170  Biomedical Engineering Laboratory
BME 180A-180B-180C  Biomedical Engineering Design and Biomedical Engineering Design and Biomedical Engineering Design

**Engineering Electives:**
Students select, with the approval of a faculty advisor a minimum of 12 units of engineering topics needed to satisfy school and major requirements. (The nominal Biomedical Engineering program will require 182 units of courses to satisfy all university and major requirements. Because each student comes to UCI with a different level of preparation, the actual number of units will vary.)

**Engineering Professional Topics Course:**
ENGR 190W  Communications in the Professional World

**Optional Specialization in Biophotonics**
Select three of the following:
- BME 135  Photomedicine
- BME 136  Engineering Medical Optics
- BME 137  Introduction to Biomedical Imaging
- BME 138  Spectroscopy and Imaging of Biological Systems
- EECS 180A  Engineering Electromagnetics I

These courses will also satisfy the Engineering Electives requirement.

**Optional Specialization in Micro and Nano Biomedical Engineering**
Select three of the following:
- BME 147  Microfluidics and Lab-on-a-Chip
- BME 148  Microimplants
- CBEMS 141  Nano-Scale Materials and Applications
- ENGRMAE 153  Advanced BIOMEMS Manufacturing Techniques

These courses will also satisfy the Engineering Electives requirement.

**Planning a Program of Study**
The sample program of study chart shown is typical for the major in Biomedical Engineering. Students should keep in mind that this program is based upon a sequence of prerequisites, beginning with adequate preparation in high school mathematics, physics, and chemistry. Students who are not adequately prepared, or who wish to make changes in the sequence for other reasons, must have their program approved by their faculty advisor. Biomedical Engineering majors must consult at least once every year with the academic counselors in the Student Affairs Office and with their faculty advisors.

**Sample Program of Study — Biomedical Engineering**

**Freshman**

<table>
<thead>
<tr>
<th>Semester</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
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<tbody>
<tr>
<td></td>
<td>MATH 2A</td>
<td>MATH 2B</td>
<td>MATH 2D</td>
</tr>
<tr>
<td></td>
<td>CHEM 1A</td>
<td>CHEM 1B</td>
<td>CHEM 1C</td>
</tr>
<tr>
<td></td>
<td>BME 1</td>
<td>PHYSICS 7C</td>
<td>CHEM 1LC</td>
</tr>
<tr>
<td></td>
<td>General Education</td>
<td>PHYSICS 7LC</td>
<td>PHYSICS 7D</td>
</tr>
<tr>
<td></td>
<td></td>
<td>General Education</td>
<td>PHYSICS 7LD</td>
</tr>
</tbody>
</table>

**Sophomore**

<table>
<thead>
<tr>
<th>Semester</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>MATH 3A</td>
<td>MATH 3D</td>
<td>MATH 2E</td>
</tr>
<tr>
<td></td>
<td>PHYSICS 7E</td>
<td>BME 50A</td>
<td>BME 50B</td>
</tr>
<tr>
<td></td>
<td>BME 60A</td>
<td>BME 60B</td>
<td>BME 60C</td>
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<tr>
<td></td>
<td>General Education</td>
<td></td>
<td>STATS 8</td>
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</tbody>
</table>

**Junior**

<table>
<thead>
<tr>
<th>Semester</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BME 110A</td>
<td>BME 110B</td>
<td>BME 110C</td>
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<tr>
<td></td>
<td>BME 120</td>
<td>BME 121</td>
<td>BME 111</td>
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<tr>
<td></td>
<td>BME 130</td>
<td>BME 140</td>
<td>BME 150</td>
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<tr>
<td></td>
<td>ENGR 190W</td>
<td>General Education</td>
<td>BIO SCI 194S</td>
</tr>
</tbody>
</table>
Undergraduate Major in Biomedical Engineering: Premedical

Program Educational Objectives: Graduates of the Biomedical Engineering: Premedical program will: (1) demonstrate a broad knowledge in the field of biomedical engineering; (2) demonstrate critical reasoning as well as quantitative skills to identify, formulate, analyze and solve biomedical problems; (3) qualify to pursue entry into a medical college, or medical research in biomedical engineering, or other professional heal programs. (Program educational objectives are those aspects of engineering that help shape the curriculum; achievement of these objectives is a shared responsibility between the student and UCI.) The major program objective is to prepare students for medical school. The curriculum is designed to meet the requirements for admission to medical schools, but is also suitable for those planning to enter graduate school in biomedical engineering, physiology, biology, neurosciences, or related fields. It has less engineering content and more biological sciences than the accompanying Biomedical Engineering major. It is one of many majors that can serve as preparation for further training in medical, veterinary, or allied health professions.

The Biomedical Engineering: Premedical curriculum provides future physicians with a quantitative background in biomechanics, physiology, and biotransport. Such a background is increasingly important because of the heavy utilization of biomedical technology in modern medical practice. The curriculum includes courses in the sciences that satisfy the requirements of most medical schools.

Admissions

High School Students: See School admissions information.

Transfer Students: Preference will be given to junior-level applicants with the highest grades overall, and who have satisfactorily completed the following required courses: one year of approved calculus, one year of calculus-based physics with laboratories (mechanics, electricity and magnetism), completion of lower-division writing, one year of chemistry (with laboratory), and one additional approved course for the major. Students are encouraged to complete as many of the lower-division degree requirements as possible prior to transfer. Students who enroll at UCI in need of completing lower-division coursework may find that it will take longer than two years to complete their degrees. For further information, contact The Henry Samueli School of Engineering at 949-824-4334.

Requirements for the B.S. in Biomedical Engineering: Premedical

All students must meet the University Requirements.
All students must meet the School Requirements.

Major Requirements

Mathematics and Basic Science Courses:
Students must complete a minimum of 48 units of mathematics and basic sciences including:

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>CHEM 1A-1B-1C</td>
<td>General Chemistry and General Chemistry</td>
</tr>
<tr>
<td>CHEM 1LC-1LD</td>
<td>General Chemistry Laboratory and General Chemistry Laboratory</td>
</tr>
<tr>
<td>CHEM 51A-51B-51C</td>
<td>Organic Chemistry and Organic Chemistry and Organic Chemistry</td>
</tr>
<tr>
<td>CHEM 51LB-51LC</td>
<td>Organic Chemistry Laboratory and Organic Chemistry Laboratory</td>
</tr>
<tr>
<td>MATH 2A-2B</td>
<td>Single-Variable Calculus and Single-Variable Calculus</td>
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<td>PHYSICS 7D-7E</td>
<td>Classical Physics and Classical Physics</td>
</tr>
<tr>
<td>PHYSICS 7LD</td>
<td>Classical Physics Laboratory</td>
</tr>
</tbody>
</table>
Students select, with the approval of a faculty advisor, any additional basic science course needed to satisfy school and major requirements.

**Engineering Topics Courses:**

Students must complete the following engineering topics including:

- BIO SCI 97: Genetics
- BIO SCI 98: Biochemistry
- BIO SCI 99: Molecular Biology
- BIO SCI 100: Scientific Writing
- BIO SCI D103: Cell Biology
- or BIO SCI D104: Developmental Biology
- BIO SCI D111L: Developmental and Cell Biology Laboratory
- BIO SCI E112L-M114L-M116L: Physiology Laboratory and Biochemistry Laboratory and Molecular Biology Laboratory (select two of these three courses)
- BIO SCI 194S: Safety and Ethics for Research
- BME 1: Introduction to Biomedical Engineering
- BME 60A-60B-60C: Engineering Analysis/Design: Data Acquisition and Engineering Analysis/Design: Data Analysis and Engineering Analysis/Design: Computer-Aided Design
- BME 110A-110B: Biomechanics I and Biomechanics II
- BME 111: Design of Biomaterials
- BME 120: Sensory Motor Systems
- BME 121: Quantitative Physiology: Organ Transport Systems
- BME 130: Biomedical Signals and Systems
- BME 150: Biotransport Phenomena

Students select, with the approval of a faculty advisor, at least three additional engineering topics courses needed to satisfy school and major requirements.

(The nominal Biomedical Engineering: Premedical program will require 189 units of courses to satisfy all university and major requirements. Because each student comes to UCI with a different level of preparation, the actual number of units will vary).

**Planning a Program of Study**

The sample program of study chart shown is typical for the major in Biomedical Engineering: Premedical. Students should keep in mind that this program is based upon a sequence of prerequisites, beginning with adequate preparation in high school mathematics, physics, and chemistry. Students who are not adequately prepared, or who wish to make changes in the sequence for other reasons, must have their program approved by their faculty advisor. Biomedical Engineering: Premedical majors must consult at least once every year with the academic counselors in the Student Affairs Office and with their faculty advisors.

**Sample Program of Study — Biomedical Engineering: Premedical**

- **Freshman**
  - **Fall**
    - MATH 2A
    - CHEM 1A
    - BME 1
    - General Education
  - **Winter**
    - MATH 2B
    - CHEM 1B
    - PHYSICS 7C
    - General Education
  - **Spring**
    - MATH 2D
    - CHEM 1C
    - CHEM 1LC
    - PHYSICS 7D
- **Sophomore**
  - **Fall**
    - MATH 3A
    - CHEM 1LD
    - CHEM 51A
    - PHYSICS 7E
    - BME 60A
  - **Winter**
    - MATH 3D
    - CHEM 51B
    - CHEM 51LB
    - BME 60B
    - General Education
  - **Spring**
    - CHEM 51C
    - CHEM 51LC
    - BME 60C
    - General Education
    - General Education
- **Junior**
  - **Fall**
    - BIO SCI 97
    - BME 110A
    - BME 120
  - **Winter**
    - BIO SCI 98
    - BME 110B
    - BME 121
  - **Spring**
    - BIO SCI 99
    - BME 111
    - BME 150
Minor in Biomedical Engineering

The minor in Biomedical Engineering requires a total of nine courses—two advanced mathematics courses, five core Biomedical Engineering courses, and two Biomedical Engineering electives. Some of these courses may include prerequisites that may or may not be part of a student’s course requirements for their major. Private biomedical industry has indicated a keen interest in engineers that have a more traditional engineering degree (i.e., electrical engineering), but also possess some in-depth knowledge of biomedical systems. Hence, the minor in Biomedical Engineering is designed to provide a student with the introductory skills necessary to perform as an engineer in the biomedical arena.

Admissions. Students interested in the minor in Biomedical Engineering must have a UCI cumulative GPA of 2.5 or higher.

NOTE: Students may not receive both a minor in Biomedical Engineering and a specialization in Biochemical Engineering within the Chemical Engineering major.

Requirements for the Minor in Biomedical Engineering

Mathematics Courses:

MATH 3A  Introduction to Linear Algebra
MATH 3D  Elementary Differential Equations

Engineering Topics Courses:

BME 1  Introduction to Biomedical Engineering
BME 50A-50B  Cell and Molecular Engineering and Cell and Molecular Engineering
BME 120  Sensory Motor Systems

BME 121  Quantitative Physiology: Organ Transport Systems

Technical Electives:

Students select, with the approval of a faculty advisor, two technical elective courses:

BME 110A  Biomechanics I
BME 110B  Biomechanics II
BME 130  Biomedical Signals and Systems
BME 135/BIO SCI D130  Photomedicine
BME 136  Engineering Medical Optics
BME 140  Design of Biomedical Electronics
BME 160  Tissue Engineering
BME 199  Individual Study
CBEMS 154  Polymer Science and Engineering
EECS 179  Microelectromechanical Systems (MEMS)
EECS 188  Optical Electronics

Graduate Study in Biomedical Engineering

The Biomedical Engineering faculty have special interest and expertise in four thrust areas: Biophotonics, Biomedical Micro/Nanoscale Systems, Bioimaging & Computation, and Molecular & 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.

The Department offers the M.S. and Ph.D. in Biomedical Engineering.
Required Background

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 30. 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 Henry Samueli School of Engineering’s accelerated M.S. and M.S./Ph.D. 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. The core courses cover the basics of cells, tissues, and physiology at the microscopic and macroscopic scale, engineering mathematics, and clinical theory. The core courses are BME 210, BME 220, BME 221, BME 230A, BME 230B, BME 240, and three quarters of BME 298. 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.

Areas of Emphasis

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 organellas; (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.

Bioimaging & 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.

**Master of Science Degree**

**Program details**

Students must successfully complete a minimum of 42 units of course work, as listed under “Core Requirement” and “Elective Requirement” above. A maximum of eight M.S. research units (i.e., BME 296) may be applied toward the 42-unit requirement.

In addition, the M.S. requires conducting a focused research project. Students must select a thesis advisor and complete an original research investigation including a written thesis, and obtain approval of the thesis by a thesis committee. During their research project, students are expected to enroll in at least 12 units of independent research per quarter.

The degree will be granted upon the recommendation of the Chair of the Department of Biomedical Engineering and The Henry Samueli School of Engineering Associate Dean for Student Affairs. The maximum time permitted is three years.

**Doctor of Philosophy Degree**

**Program Details**

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 second year following the passing of the preliminary examination. (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.

**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.

Graduate Program in Mathematical, Computational, and Systems Biology

The graduate program in Mathematical, Computational, and Systems Biology (MCSB) is designed to meet the interdisciplinary training challenges of modern biology and function in concert with selected department programs, including the Ph.D. in Biomedical Engineering. Detailed information is available at the Mathematical, Computational, and Systems Biology website (http://mcsb.uci.edu) and in the Interdisciplinary Studies section of the Catalogue.

Graduate Specialization in Teaching

The graduate specialization in Teaching will allow Engineering Ph.D. students to receive practical training in pedagogy designed to enhance their knowledge and skill set for future teaching careers. Students will gain knowledge and background in college-level teaching and learning from a variety of sources, and experience in instructional practices. Students completing the specialization in Teaching must fulfill all of their Ph.D. requirements in addition to the specialization requirements. Upon fulfillment of the requirements, students will be provided with a certificate of completion. Upon receipt of the certificate of completion, the students can then append “Specialization in Teaching” to their curricula vitae. For details visit the Graduate Specialization in Teaching website (http://www.eng.uci.edu/current/graduate/specialization-in-teaching).

The graduate specialization in Teaching is available only for certain degree programs and concentrations:

- Ph.D. in Biomedical Engineering
- Ph.D. in Electrical and Computer Engineering
- Ph.D. in Engineering with a concentration in Materials and Manufacturing Technology

Faculty

Michael W. Berns, Ph.D. Cornell University, Arnold and Mabel Beckman Chair in Laser Biomedicine and Professor of Surgery; Biomedical Engineering; Developmental and Cell Biology (photomedicine, laser microscopy, biomedical devices)

Elliot L. Botvinick, Ph.D. University of California, San Diego, Associate Professor of Surgery; Biomedical Engineering; Chemical Engineering and Materials Science (laser microbeams, cellular mechanotransduction, mechanobiology)

James P. Brody, Ph.D. Princeton University, Associate Professor of Biomedical Engineering (bioinformatics, micro-nanoscale systems)

Zhongping Chen, Ph.D. Cornell University, Professor of Biomedical Engineering; Electrical Engineering and Computer Science; Otolaryngology; Surgery (biomedical optics, optical coherence tomography, bioMEMS, biomedical devices)

Bernard H. Choi, Ph.D. University of Texas at Austin, Associate Professor of Surgery; Biomedical Engineering (biomedical optics, in vivo optical imaging, microvasculature, light-based therapeutics)

Michelle Digman, Ph.D. University of Illinois at Chicago, Assistant Professor of Biomedical Engineering; Chemical Engineering and Materials Science; Developmental and Cell Biology (quantitative imaging techniques to study spatial-temporal dynamics of signaling protein networks in live cells and tissues)

Timothy L. Downing, Ph.D. University of California, Berkeley, Assistant Professor of Biomedical Engineering (stem cells and tissue engineering)

Enrico Gratton, Ph.D. University of Rome, Professor of Biomedical Engineering; Developmental and Cell Biology; Physics and Astronomy (design of new fluorescence instruments, protein dynamics, single molecule, fluorescence microscopy, photon migration in tissues)

Anna Grosberg, Ph.D. California Institute of Technology, Assistant Professor of Biomedical Engineering; Chemical Engineering and Materials Science (computational modeling of biological systems, biomechanics, cardiac tissue engineering)

Jered Haun, Ph.D. University of Pennsylvania, Assistant Professor of Biomedical Engineering; Chemical Engineering and Materials Science (nanotechnology, molecular engineering, computational simulations, targeted drug delivery, clinical cancer detection)

Elliot E. Hui, Ph.D. University of California, Berkeley, Associate Professor of Biomedical Engineering (microscale tissue engineering, bioMEMS, cell-cell interactions, global health diagnostics)

Tibor Juhasz, Ph.D. Attila József University, Professor of Ophthalmology; Biomedical Engineering (laser-tissue interactions, high-precision microsurgery with lasers, laser applications in ophthalmology, corneal biomechanics)
Arash Kheradvar, Ph.D. California Institute of Technology, *Associate Professor of Biomedical Engineering; Mechanical and Aerospace Engineering* (cardiac mechanics, cardiovascular devices, cardiac imaging)

Michelle Khine, Ph.D. University of California, Berkeley, *Professor of Biomedical Engineering; Chemical Engineering and Materials Science* (development of novel nano- and micro-fabrication technologies and systems for single cell analysis, stem cell research, in-vitro diagnostics)

Frithjof Krügel, M.D. Ludwig Maximilian University of Munich, *Professor of Biomedical Engineering; Electrical Engineering and Computer Science* (biomedical signal and image processing, anatomical and functional neuroimaging in humans, structure-function relationship in the human brain)

Abraham P. Lee, Ph.D. University of California, Berkeley, *William J. Link Chair in Biomedical Engineering and Department Chair and Professor of Biomedical Engineering; Mechanical and Aerospace Engineering* (Lab-on-a-Chip health monitoring instruments, drug delivery micro/nanoparticles, integrated cell sorting microdevices, lipid vesicles as carriers for cells and biomolecules, high throughput droplet bioassays, microfluidic tactile sensors)

Chang C. Liu, Ph.D. Scripps Research Institute, *Assistant Professor of Biomedical Engineering; Chemistry* (genetic engineering, directed evolution, synthetic biology, chemical biology)

Wendy F. Liu, Ph.D. Johns Hopkins University, *Assistant Professor of Biomedical Engineering; Chemical Engineering and Materials Science* (biomaterials, microdevices in cardiovascular engineering, cell-cell and cell-micro-environment interactions, cell functions and controls)

Beth A. Lopour, Ph.D. University of California, Berkeley, *Assistant Professor of Biomedical Engineering; Mechanical and Aerospace Engineering* (computational neuroscience, signal processing, mathematical modeling, epilepsy, translational research)

Zoran Nenadic, Ph.D. Washington University, *Associate Professor of Biomedical Engineering; Electrical Engineering and Computer Science* (adaptive biomedical signal processing, control algorithms for biomedical devices, brain-machine interfaces, modeling and analysis of biological neural networks)

William C. Tang, Ph.D. University of California, Berkeley, *Professor of Biomedical Engineering; Chemical Engineering and Materials Science; Electrical Engineering and Computer Science* (micro-electro-mechanical systems (MEMS) nanoscale engineering for biomedical applications, microsystems integration, microimplants, microbiomechanics, microfluidics)

Bruce Tromberg, Ph.D. University of Tennessee, *Director of Beckman Laser Institute and Professor of Surgery; Biomedical Engineering; Physiology and Biophysics* (photon migration, diffuse optical imaging, non-linear optical microscopy, photodynamic therapy)

**Affiliate Faculty**

Alpesh N. Amin, M.D. Northwestern University, *Thomas and Mary Cesario Endowed Chair in Medicine and Professor of Medicine; Biomedical Engineering; Paul Merage School of Business; Program in Public Health* (hospital medicine, quality/safety, new technologies in healthcare)

Pierre F. Baldi, Ph.D. California Institute of Technology, *UCI Chancellor's Professor of Computer Science; Biological Chemistry; Biomedical Engineering; Developmental and Cell Biology* (bioinformatics, computational biology)

Bruce Blumberg, Ph.D. University of California, Los Angeles, *Professor of Developmental and Cell Biology; Biomedical Engineering; Environmental Health Sciences; Pharmaceutical Sciences* (gene regulation by nuclear hormone receptors in vertebrate development physiology, endocrine disruption)

Peter J. Burke, Ph.D. Yale University, *Professor of Electrical Engineering and Computer Science; Biomedical Engineering; Chemical Engineering and Materials Science* (nano-electronics, bio-nanotechnology)

Robert Corn, Ph.D. University of California, Berkeley, *Professor of Chemistry; Biomedical Engineering* (analytical, chemical biology, physical chemistry and chemical physics, polymer, materials, nanoscience)

Carl W. Cotman, Ph.D. Indiana University, *Professor of Neurology; Biomedical Engineering; Neurobiology and Behavior*

Nancy A. Da Silva, Ph.D. California Institute of Technology, *Professor of Chemical Engineering and Materials Science; Biomedical Engineering* (molecular biotechnology)

Hamid Djallilian, M.D. University of Minnesota, *Associate Professor of Otolaryngology; Biomedical Engineering* (medical devices, hearing loss, tinnitus, dizziness/imbalance, clinical research)

James Earthman, Ph.D. Stanford University, *Professor of Chemical Engineering and Materials Science; Biomedical Engineering* (biomaterials, dental and orthopaedic implants, green materials, nanocrystalline alloys, deformation and damage processes)

Aaron P. Esser-Kahn, Ph.D. University of California, Berkeley, *Associate Professor of Chemistry; Biomedical Engineering; Chemical Engineering and Materials Science* (chemical biology, organic and synthetic, polymer, materials, nanoscience)

Gregory R. Evans, M.D. University of Southern California, *Professor of Surgery; Biomedical Engineering* (aesthetic surgery, breast augmentation, cosmetic plastic surgery, craniofacial, hand surgery, head and neck reconstruction, liposuction, oncology, pelvic bone reconstruction, peripheral nerve regeneration, reconstructive microsurgery, replantation, tissue engineering)
Lisa Flanagan-Monuki, Ph.D. University of California, San Diego, Assistant Professor of Neurology; Biomedical Engineering (stem cells, neural, embryonic, neuron)

Ron D. Frostig, Ph.D. University of California, Los Angeles, Professor of Neurobiology and Behavior; Biomedical Engineering

John P. Fruehaufl, M.D. Rush University, Professor of Medicine; Biomedical Engineering; Pharmaceutical Sciences (in-vitro cancer models using 3-D tissue systems to predict drug response)

Steven P. Gross, Ph.D. University of Texas at Austin, Professor of Developmental and Cell Biology; Biomedical Engineering; Physics and Astronomy (force generation by molecular motors in living cells)

Zhibin Guan, Ph.D. University of North Carolina at Chapel Hill, Professor of Chemistry; Biomedical Engineering; Chemical Engineering and Materials Science (chemical biology, organic and synthetic, polymer, materials, nanoscience)

Gultekin Gulsen, Ph.D. Bogazici University, Associate Professor of Radiological Sciences; Biomedical Engineering; Electrical Engineering and Computer Science; Physics and Astronomy (in vivo molecular imaging, diffuse optical tomography, fluorescence tomography, photo-magnetic imaging, multi-modality imaging)

Ranjan Gupta, M.D. Albany Medical College, Professor of Orthopaedic Surgery; Anatomy and Neurobiology; Biomedical Engineering (hand and upper extremity surgery)

Baruch D. Kuppermann, M.D. University of Miami, Professor of Ophthalmology; Biomedical Engineering (ocular manifestations of AIDS, risk factors for the development of retinopathy of prematurity post partum, photodynamic therapy for the treatment of choroidal melanomas)

Young Jik Kwon, Ph.D. University of Southern California, Professor of Pharmaceutical Sciences; Biomedical Engineering; Chemical Engineering and Materials Science; Molecular Biology and Biochemistry (gene therapy, drug delivery, cancer-targeted therapeutics, combined molecular imaging and therapy, cancer vaccine)

Jonathan Lakey, Ph.D. University of Alberta, Associate Professor of Surgery; Biomedical Engineering (islet transplantation for patients with diabetes, improving methods of islet isolation, characterization and developing novel methods of islet transplantation, biopolymer and encapsulation technologies)

Arthur D. Lander, Ph.D. University of California, San Francisco, Donald Bren Professor and Professor of Developmental and Cell Biology; Biomedical Engineering; Logic and Philosophy of Science; Pharmacology (systems biology of development, pattern formation, growth control)

Thay Q. Lee, Ph.D. Gothenburg School of Business, Economics and Law, Professor in Residence of Orthopaedic Surgery; Biomedical Engineering; Physical Medicine and Rehabilitation (research biomechanics)

Joyce H. Keyak, Ph.D. University of California, San Francisco, Professor in Residence of Radiological Sciences; Biomedical Engineering; Mechanical and Aerospace Engineering (bone mechanics, finite element modeling, quantitative computed tomography, prosthetic implants, osteoporosis, metastatic tumors in bone, radiation therapy)

John P. Fruehaufl, M.D. University of Southern California, Jack H. Skirball Endowed Chair and Professor of Ophthalmology; Biomedical Engineering (mechanics of wound healing and the inter-relationship of mechanical force, cell-matrix interaction, and gene expression, cellular basis of corneal transparency and the role of water-soluble proteins in isolated cell light scattering, three-dimensional and temporal imaging of cells in intact living tissue)

Arthur D. Lander, Ph.D. University of California, San Francisco, Professor of Ophthalmology; Biomedical Engineering; Pharmacology (systems biology of development, pattern formation, growth control)
John Middlebrooks, Ph.D. University of California, San Francisco, Professor of Otolaryngology; Biomedical Engineering; Cognitive Sciences; Linguistics; Neurobiology and Behavior (hearing research, neurophysiology, psychophysics, auditory prosthesis, computational neuroscience)

Sabee Y. Molloi, Ph.D. University of Wisconsin-Madison, Professor of Radiological Sciences; Biomedical Engineering; Electrical Engineering and Computer Science (quantitative aspects of medical x-ray imaging and its applications to cardiac and breast imaging)

Jogeshwar Mukherjee, Ph.D. Jodhpur National University, Professor in Residence of Radiological Sciences; Biomedical Engineering; Physiology and Biophysics (preclinical imaging, radiopharmaceutical design and development, PET imaging and quantitation, neuroscience)

J. Stuart Nelson, Ph.D. University of California, Irvine, Professor of Surgery; Biomedical Engineering (laser surgery, port wine stains, hemangiomas, vascular birthmarks)

Qing Nie, Ph.D. Ohio State University, Director of Center for Complex Biological Systems and Professor of Mathematics; Biomedical Engineering (computational mathematics, systems biology, cell signaling, stem cell)

Pranav Patel, M.D. Saint Louis University, Chief, Division of Cardiology; Director of Cardiac Catheterization Laboratory and Cardiac Care Unit (CCU) and Health Sciences Associate Clinical Professor of Medicine; Biomedical Engineering (intravascular imaging (OCT and IVUS), interventional cardiology research-coronary artery disease and peripheral vascular disease, medical quality and outcomes research, cardiac hemodynamics: fractional flow reserve and coronary flow reserve, preventive cardiology research)

David J. Reinkensmeyer, Ph.D. University of California, Berkeley, Professor of Anatomy and Neurobiology; Biomedical Engineering; Mechanical and Aerospace Engineering; Physical Medicine and Rehabilitation (robotics, mechatronics, biomedical engineering, rehabilitation, biomechanics, neural control of movement)

Phillip C-Y Sheu, Ph.D. University of California, Berkeley, Professor of Electrical Engineering and Computer Science; Biomedical Engineering; Computer Science (database systems, interactive multimedia systems)

Andrei M. Shkel, Ph.D. University of Wisconsin-Madison, Professor of Mechanical and Aerospace Engineering; Biomedical Engineering; Electrical Engineering and Computer Science (design and advanced control of micro-electro-mechanical systems (MEMS), precision micro-sensors and actuators for telecommunication and information technologies, MEMS-based health monitoring systems, disposable diagnostic devices, prosthetic implants)

Zuzanna S. Siwy, Ph.D. Silesian University of Technology, Professor of Physics and Astronomy; Biomedical Engineering; Chemistry (biosensing, nanotechnology, condensed matter physics)

Ramesh Srinivasan, Ph.D. Tulane University, Department Chair and Professor of Cognitive Sciences; Biomedical Engineering (cognitive neuroscience, brain development, consciousness, perception, EEG, brain dynamics)

Roger F. Steinert, M.D. Harvard University, Irving H. Leopold Chair in Ophthalmology and Professor of Ophthalmology; Biomedical Engineering (cataract surgical technique and management of complications, refractive surgery, corneal transplantation)

Vasan Venugopalan, ScD Massachusetts Institute of Technology, Department Chair and Professor of Chemical Engineering and Materials Science; Biomedical Engineering; Mechanical and Aerospace Engineering; Surgery (laser-induced thermal, mechanical and radiative transport processes for application in medical diagnostics, therapeutics, biotechnology, micro-electro-mechanical systems (MEMS))

Szu-Wen Wang, Ph.D. Stanford University, Professor of Chemical Engineering and Materials Science; Biomedical Engineering (combining principles of self-assembly with nature-inspired macromolecular systems to engineer new materials and therapeutic strategies)

H. Kumar Wickramasinghe, Ph.D. University of London, Henry Samuei Endowed Chair in Engineering and Department Chair and Professor of Electrical Engineering and Computer Science; Biomedical Engineering; Chemical Engineering and Materials Science (nanoscale measurements and characterization, scanning probe microscopy, storage technology, nano-bio measurement technology)

Brian Wong, M.D. Johns Hopkins University, Professor of Otolaryngology; Biomedical Engineering (biomedical optics, tissue engineering, development of surgical instrumentation)

Xiangmin Xu, Ph.D. Vanderbilt University, Associate Professor of Anatomy and Neurobiology; Biomedical Engineering; Electrical Engineering and Computer Science (local cortical circuits)

Albert Fan Yee, Ph.D. University of California, Berkeley, Professor of Chemical Engineering and Materials Science; Biomedical Engineering; Chemistry (materials science aspects of polymers and soft materials, particularly on how they are used to impact nanotechnology)

Fan-Gang Zeng, Ph.D. Syracuse University, Professor of Otolaryngology; Anatomy and Neurobiology; Biomedical Engineering; Cognitive Sciences (cochlear implants and auditory neuroscience)

Weian Zhao, Ph.D. McMaster University, Associate Professor of Pharmaceutical Sciences; Biomedical Engineering (stem cell therapy, diagnostics, biosensors, nano- and microtechnology, aptamers)