Department of Biomedical Engineering

Abraham Lee, Department Chair
3120 Natural Sciences II
949-824-9196
http://www.eng.uci.edu/dept/bme

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.

On This Page:
• 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>Core Courses:</th>
<th>Safety and Ethics for Research</th>
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<tbody>
<tr>
<td>BIO SCI 194S</td>
<td>General Chemistry</td>
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<tr>
<td>CHEM 1A- 1B- 1C</td>
<td>General Chemistry</td>
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<tr>
<td>CHEM 1LC</td>
<td>General Chemistry Laboratory</td>
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<tr>
<td>MATH 2A- 2B</td>
<td>Single-Variable Calculus</td>
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<td>MATH 2D</td>
<td>Multivariable Calculus</td>
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<td>MATH 2E</td>
<td>Multivariable Calculus</td>
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<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>
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<tr>
<td>PHYSICS 7C</td>
<td>Classical Physics</td>
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<tr>
<td>PHYSICS 7LC</td>
<td>Classical Physics Laboratory</td>
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<tr>
<td>PHYSICS 7D- 7E</td>
<td>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>
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</table>

Engineering Topics Courses:

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

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

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<tr>
<th>Freshman</th>
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<tr>
<td>MATH 2A</td>
<td>MATH 2B</td>
<td>MATH 2D</td>
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<tr>
<td>CHEM 1A</td>
<td>CHEM 1B</td>
<td>CHEM 1C</td>
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<tr>
<td>BME 1</td>
<td>PHYSICS 7C</td>
<td>PHYSICS 7D</td>
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<tr>
<td>General Education</td>
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<tr>
<th>Sophomore</th>
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<td>Fall</td>
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<tr>
<td>MATH 3A</td>
<td>MATH 3D</td>
<td>MATH 2E</td>
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<tr>
<td>PHYSICS 7E</td>
<td>BME 50A</td>
<td>BME 50B</td>
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<tr>
<td>BME 60A</td>
<td>BME 60B</td>
<td>BME 60C</td>
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<tr>
<td>General Education</td>
<td>General Education</td>
<td>STATS 8</td>
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<tr>
<th>Junior</th>
<th>Winter</th>
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<tr>
<td>Fall</td>
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<tr>
<td>BME 110A</td>
<td>BME 110B</td>
<td>BME 110C</td>
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<tr>
<td>BME 120</td>
<td>BME 121</td>
<td>BME 111</td>
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<tr>
<td>BME 130</td>
<td>BME 140</td>
<td>BME 150</td>
</tr>
<tr>
<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 health 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>Title</th>
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<tbody>
<tr>
<td>CHEM 1A- 1B- 1C</td>
<td>General Chemistry and 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>
</tr>
<tr>
<td>MATH 2D</td>
<td>Multivariable Calculus</td>
</tr>
<tr>
<td>MATH 3A</td>
<td>Introduction to Linear Algebra</td>
</tr>
<tr>
<td>MATH 3D</td>
<td>Elementary Differential Equations</td>
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<tr>
<td>PHYSICS 7C</td>
<td>Classical Physics</td>
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<tr>
<td>PHYSICS 7LC</td>
<td>Classical Physics Laboratory</td>
</tr>
<tr>
<td>PHYSICS 7D- 7E</td>
<td>Classical Physics and Classical Physics</td>
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<tr>
<td>PHYSICS 7LD</td>
<td>Classical Physics Laboratory</td>
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</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:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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<tbody>
<tr>
<td>BIO SCI 97</td>
<td>Genetics</td>
</tr>
<tr>
<td>BIO SCI 98</td>
<td>Biochemistry</td>
</tr>
<tr>
<td>BIO SCI 99</td>
<td>Molecular Biology</td>
</tr>
<tr>
<td>BIO SCI 100</td>
<td>Scientific Writing</td>
</tr>
<tr>
<td>BIO SCI D103</td>
<td>Cell Biology</td>
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<tr>
<td>or BIO SCI D104</td>
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<tr>
<td>BIO SCI D111L</td>
<td>Developmental and Cell Biology Laboratory</td>
</tr>
<tr>
<td>BIO SCI E112L- M114L- M116L</td>
<td>Physiology Laboratory and Biochemistry Laboratory and Molecular Biology Laboratory (select two of these three courses)</td>
</tr>
<tr>
<td>BIO SCI 194S</td>
<td>Safety and Ethics for Research</td>
</tr>
<tr>
<td>BME 1</td>
<td>Introduction to Biomedical Engineering</td>
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<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>
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<tr>
<td>BME 110A- 110B</td>
<td>Biomechanics I and Biomechanics II</td>
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<td>BME 111</td>
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<td>BME 150</td>
<td>Biotransport Phenomena</td>
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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**

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<tr>
<th>Freshman</th>
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<tr>
<td>MATH 2A</td>
<td>MATH 2B</td>
<td>MATH 2D</td>
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<tr>
<td>CHEM 1A</td>
<td>CHEM 1B</td>
<td>CHEM 1C</td>
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<tr>
<td>BME 1</td>
<td>PHYSICS 7C</td>
<td>CHEM 1LC</td>
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<tr>
<td>General Education</td>
<td>PHYSICS 7LC</td>
<td>PHYSICS 7D</td>
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<tr>
<th>Sophomore</th>
<th>Winter</th>
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<td>Fall</td>
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<tr>
<td>MATH 3A</td>
<td>MATH 3D</td>
<td>CHEM 51C</td>
</tr>
<tr>
<td>CHEM 1LD</td>
<td>CHEM 51B</td>
<td>CHEM 51LC</td>
</tr>
<tr>
<td>CHEM 51A</td>
<td>CHEM 51LB</td>
<td>BME 60C</td>
</tr>
<tr>
<td>PHYSICS 7E</td>
<td>BME 60B</td>
<td>General Education</td>
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<tr>
<td>BME 60A</td>
<td>General Education</td>
<td>General Education</td>
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<th>Junior</th>
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<tr>
<td>BIO SCI 97</td>
<td>BIO SCI 98</td>
<td>BIO SCI 99</td>
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<tr>
<td>BME 110A</td>
<td>BME 110B</td>
<td>BME 111</td>
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<td>BME 120</td>
<td>BME 121</td>
<td>BME 150</td>
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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
- 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, Biomaging & 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 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.

**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.

NOTE: Students who entered prior to fall of 2012 should follow the course requirements outlined within the Catalogue of the year they entered. The changes in number of units per course is not intended to change the course requirements for the degree nor to have any impact in the number of courses students are taking.

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 Kruggel, 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, craniomaxillofacial, 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. Fruehauf, 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)

Frank P. Hsu, M.D. University of Maryland, College Park, Department Chair and Professor of Neurological Surgery; Biomedical Engineering; Otolaryngology (biomechanics of cerebral aneurysms, functional neurosurgery, epilepsy)

Christopher C. Hughes, Ph.D. University of London, Francisco J. Ayala Chair and Interim Director of Edwards Lifesciences Center for Advanced Cardiovascular Technology and Professor of Molecular Biology and Biochemistry; Biomedical Engineering (tissue engineering, growth and patterning of blood vessels)

James V. Jester, Ph.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)

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)

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 melanosmas)

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)

Guann-Pyng Li, Ph.D. University of California, Los Angeles, Director of the UCI Division of the California Institute for Telecommunications and Information Technology (Calit2), Director of the Integrated Nanosystems Research Facility and Professor of Electrical Engineering and Computer Science; Biomedical Engineering; Chemical Engineering and Materials Science (high-speed semiconductor technology, optoelectronic devices, integrated circuit fabrication and testing)

John S. Lowengrub, Ph.D. Courant Institute of Mathematical Sciences, UCI Chancellor's Professor of Mathematics; Biomedical Engineering; Chemical Engineering and Materials Science (applied and computational mathematics, mathematical and computational biology)

Ray Luo, Ph.D. University of Maryland, College Park, Professor of Molecular Biology and Biochemistry; Biomedical Engineering; Chemical Engineering and Materials Science (protein structure, noncovalent associations involving proteins)

Marc J. Madou, Ph.D. Ghent University, UCI Chancellor's Professor of Mechanical and Aerospace Engineering; Biomedical Engineering; Chemical Engineering and Materials Science (fundamental aspects of micro/nano-electro-mechanical systems (MEMS/NEMS), biosensors, nanofluidics, biomimetics)
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 tools, 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)
Courses

BME 1. Introduction to Biomedical Engineering. 3 Units.
Introduction to the central topics of biomedical engineering. Offers a perspective on bioengineering as a discipline in a seminar format. Principles of problem definition, team design, engineering inventiveness, information access, communication, ethics, and social responsibility are emphasized.

(Design units: 1)
Restriction: Biomedical Engineering Majors have first consideration for enrollment. Biomedical Engr: Premedical Majors have first consideration for enrollment.

BME 50A. Cell and Molecular Engineering. 4 Units.
Physiological function from a cellular, molecular, and biophysical perspective. Applications to bioengineering design.

(Design units: 2)
Corequisite: BME 1
Prerequisite: CHEM 1C
Restriction: Biomedical Engineering Majors have first consideration for enrollment. Chemical Engineering Majors have first consideration for enrollment. Materials Science Engineering Majors have first consideration for enrollment.

BME 50B. Cell and Molecular Engineering. 4 Units.
Physiological function from a cellular, molecular, and biophysical perspective. Applications to bioengineering design.

(Design units: 2)
Prerequisite: BME 50A and PHYSICS 7D
Restriction: Biomedical Engineering Majors have first consideration for enrollment. Biomedical Engr: Premedical Majors have first consideration for enrollment.

BME 60A. Engineering Analysis/Design: Data Acquisition. 4 Units.
Fundamentals of LabVIEW programming, basics of computer-based experimentation, establishing interface between computer and data acquisition instrumentation, signal conditioning basics. Materials fee.

(Design units: 2)
Corequisite: BME 1
Prerequisite: PHYSICS 7D
Restriction: Biomedical Engineering Majors have first consideration for enrollment. Biomedical Engr: Premedical Majors have first consideration for enrollment.

BME 60B. Engineering Analysis/Design: Data Analysis. 4 Units.
Overview of MATLAB; numeric, cell, and structure arrays; file management; plotting and model building; solving linear algebraic equations; differential equations; symbolic process. Materials fee.

(Design units: 1)
Prerequisite: BME 60A and MATH 3A
Overlaps with ENGRCEE 20.
Restriction: Biomedical Engineering Majors have first consideration for enrollment. Biomedical Engr: Premedical Majors have first consideration for enrollment.

BME 60C. Engineering Analysis/Design: Computer-Aided Design. 4 Units.
Introduction to SolidWorks and Computer-Aided Design software; design; analysis; rapid prototyping; visualization and presentation; planning and manufacturing. Materials fee.

(Design units: 2)
Prerequisite: BME 60B
Restriction: Biomedical Engineering Majors have first consideration for enrollment. Biomedical Engr: Premedical Majors have first consideration for enrollment.
BME 110A. Biomechanics I. 4 Units.
Introduction to statics. Rigid bodies, analysis of structures, forces in beams, moments of inertia.

(Design units: 1)
Prerequisite: PHYSICS 7D and PHYSICS 7LD and PHYSICS 7E and MATH 3A and MATH 3D
Restriction: Biomedical Engineering Majors have first consideration for enrollment. Biomedical Engr: Premedical Majors have first consideration for enrollment.

BME 110B. Biomechanics II. 4 Units.
Introduction to dynamics. Kinematics of Particles, Newton's Second Law, System's of Particles, Kinematics of Rigid Bodies, Motion in three dimensions.

(Design units: 1)
Prerequisite: BME 110A
Restriction: Biomedical Engineering Majors have first consideration for enrollment. Biomedical Engr: Premedical Majors have first consideration for enrollment.

BME 110C. Biomechanics III. 4 Units.
Applications of statics and dynamics to biomedical systems. Cellular biomechanics, hemodynamics, circulatory system, respiratory system, muscles and movement, skeletal biomechanics. Applications to bioengineering design.

(Design units: 1)
Prerequisite: BME 110B
Restriction: Biomedical Engineering Majors have first consideration for enrollment.

BME 111. Design of Biomaterials. 4 Units.

(Design units: 3)
Corequisite: BME 50B or BIO SCI 99.
Restriction: Biomedical Engineering Majors have first consideration for enrollment. Biomedical Engr: Premedical Majors have first consideration for enrollment.

BME 114. Genetic Engineering and Synthetic Biology. 4 Units.
Exploring how biological function can be engineered and "synthesized" from the DNA level up.

(Design units: 0)
Prerequisite: CHEM 1C and MATH 3D and BME 50A and BME 50B
Restriction: Biomedical Engineering Majors have first consideration for enrollment.

BME 120. Sensory Motor Systems. 4 Units.
A quantitative and systems approach to understanding physiological systems. Systems covered include the nervous and musculoskeletal systems.

(Design units: 2)
Prerequisite: (BME 60B or EECS 10 or EECS 12 or ENGRCEE 20 or ENGRMAE 10) and MATH 3D and PHYSICS 7D
Restriction: Biomedical Engineering Majors have first consideration for enrollment. Biomedical Engr: Premedical Majors have first consideration for enrollment. Materials Science Engineering Majors have first consideration for enrollment.

Concurrent with BME 220.
BME 121. Quantitative Physiology: Organ Transport Systems. 4 Units.
A quantitative and systems approach to understanding physiological systems. Systems covered include the cardiopulmonary, circulatory, and renal systems.

(Design units: 1)

Prerequisite: (BME 60B or EECS 10 or EECS 12 or ENGRCEE 20 or ENGRMAE 10) and MATH 3A and MATH 3D

Restriction: Biomedical Engineering Majors have first consideration for enrollment. Biomedical Engr: Premedical Majors have first consideration for enrollment. Chemical Engineering Majors have first consideration for enrollment.

BME 130. Biomedical Signals and Systems. 4 Units.
Analysis of analog and digital biomedical signals; Fourier Series expansions; difference and differential equations; convolutions. System models: discrete-time and continuous-time linear time-invariant systems; Laplace and Fourier transforms. Analysis of signals and systems using computer programs.

(Design units: 1)

Corequisite: BME 60B
Prerequisite: MATH 3A and MATH 3D. Recommended: STATS 8.

Restriction: Biomedical Engineering Majors have first consideration for enrollment. Biomedical Engr: Premedical Majors have first consideration for enrollment.

BME 132. Introduction to Computational Biology. 4 Units.

Prerequisite: MATH 2D or MATH 3A or STATS 7 or STATS 8

Same as BIO SCI M123, COMPSCI 183.

Concurrent with MOL BIO 223 and BME 232.

BME 135. Photomedicine. 4 Units.
Studies the use of optical and engineering-based systems (laser-based) for diagnosis, treating diseases, manipulation of cells and cell function. Physical, optical, and electro-optical principles are explored regarding molecular, cellular, organ, and organism applications.

(Design units: 0)

Prerequisite: PHYSICS 3C or PHYSICS 7D

Same as BIO SCI D130.

Restriction: Biomedical Engineering Majors have first consideration for enrollment.

BME 136. Engineering Medical Optics. 4 Units.
Principles of optics and photonics, integration of optical components into systems and devices, and analysis of physiological signals obtained from Biophotonics measurements.

(Design units: 3)

Prerequisite: BME 130 and BME 135

Restriction: Biomedical Engineering Majors have first consideration for enrollment.

Concurrent with BME 251.

BME 137. Introduction to Biomedical Imaging. 4 Units.
Introduction to imaging modalities widely used in medicine and biology, including X-ray, computed tomography (CT), nuclear medicine (PET and SPET), ultrasonic imaging, magnetic resonance imaging (MRI), optical tomography, imaging contrast, imaging processing, and complementary nature of the imaging modalities.

(Design units: 1)

Prerequisite: BME 130 or EECS 50 or EECS 150

Restriction: Biomedical Engineering Majors have first consideration for enrollment.
BME 138. Spectroscopy and Imaging of Biological Systems. 4 Units.
Principles of spectroscopy; absorption; molecular orbitals; multiphoton transitions; Jablonski diagram; fluorescence anisotropy; fluorescence decay; quenching; FRET; excited state reactions; solvent relaxations; instruments; microscopy: wide field, LSM, TPE; fluorescent probes, fluctuations spectroscopy; optical resolution and super-resolution; CARS and SHG microscopy.

(Design units: 1)
Prerequisite: MATH 3A and MATH 3D. Recommended: STATS 8.
Restriction: School of Biological Sciences students only. Biomedical Engineering Majors only. Biomedical Engr: Premedical Majors only.
Concurrent with BME 238.

BME 140. Design of Biomedical Electronics. 4 Units.
Analog and digital circuits in bioinstrumentation. AC and DC circuit analysis, design and construction of filter and amplifiers using operational amplifier, digitization of signal and data acquisition, bioelectrical signal, design and construction of ECG instrument, bioelectrical signal measurement and analysis. Materials fee.

(Design units: 3)
Prerequisite: BME 60C and BME 130
Restriction: Biomedical Engineering Majors have first consideration for enrollment.

BME 147. Microfluidics and Lab-on-a-Chip. 4 Units.
Introduction to principles of microfluidics and state-of-the-art micro Total Analysis Systems (uTAS). Lab-on-a-Chip for bimolecular assays with device design principles for microscale sample preparation, flow transport, bimolecular manipulation, separation and detection, and the technologies for integrating these devices into microsystems.

(Design units: 1)
Prerequisite: BME 110C and BME 111
Restriction: Biomedical Engineering Majors have first consideration for enrollment.
Concurrent with BME 260.

BME 148. Microimplants. 4 Units.
Essential concepts of biomedical implants at the micro scale. Design, fabrication, and applications of several microimplantable devices including cochlear, retinal, neural, and muscular implants.

(Design units: 1)
Prerequisite: BME 111
Restriction: Biomedical Engineering Majors have first consideration for enrollment.
Concurrent with BME 262.

BME 149. Biomedical Microdevices. 4 Units.
In-depth review of microfabricated devices designed for biological and medical applications. Studies of the design, implementation, manufacturing, and marketing of commercial and research bio-medical devices.

(Design units: 0)
Concurrent with BME 261.

BME 150. Biotransport Phenomena. 4 Units.
Fundamentals of heat and mass transfer, similarities in the respective rate equations. Emphasis on practical application of fundamental principles.

(Design units: 1)
Prerequisite: BME 60B and MATH 3A and MATH 3D
Overlaps with CBEMS 125C.
Restriction: Biomedical Engineering Majors have first consideration for enrollment. Biomedical Engr: Premedical Majors have first consideration for enrollment.
BME 160. Tissue Engineering. 4 Units.
Quantitative analysis of cell and tissue functions. Emerging developments in stem cell technology, biodegradable scaffolds, growth factors, and others important in developing clinical products. Applications of bioengineering.

(Design units: 2)
Prerequisite: (BME 50B or BIO SCI 99) and BME 111 and BME 121 and BME 150
Restriction: Biomedical Engineering Majors have first consideration for enrollment. Biomedical Engr: Premedical Majors have first consideration for enrollment.

BME 170. Biomedical Engineering Laboratory. 4 Units.
Measurement and analysis of biological systems using engineering tools and techniques. Laboratory experiments involve living systems with the emphasis on measuring physiological parameters. Labs: Introduction to Electroencephalography, Fiberoptic thermometry, Neurorehabilitation Engineering, Spectroscopy principles of the common pulse oximeter. Materials fee.

(Design units: 1)
Prerequisite: BME 111 and BME 120 and BME 121 and BME 130 and BME 140
Restriction: Biomedical Engineering Majors have first consideration for enrollment.

BME 171. Cell and Tissue Engineering Laboratory. 4 Units.
Techniques in molecular, cellular, and tissue engineering. Topics include bacterial and mammalian cell culture, DNA cloning and gene transfer, fabrication of biomaterial scaffolds, and immunassays and microscopy techniques for cell-based assays.

(Design units: 0)
Prerequisite: BME 160
Restriction: Biomedical Engineering Majors have first consideration for enrollment. Biomedical Engr: Premedical Majors have first consideration for enrollment.

BME 180A. Biomedical Engineering Design. 3 Units.
Design strategies, techniques, tools, and protocols commonly encountered in biomedical engineering; clinical experience at the UCI Medical Center and Beckman Laser Institute; industrial design experience in group projects with local biomedical companies; ethics, economic analysis, and FDA product approval. Materials fee.

(Design units: 3)
Prerequisite: BME 60C and BME 110C and BME 111 and BME 120 and BME 121 and BME 140. BME 180A, BME 180B, and BME 180C must be taken in the same academic year.
Grading Option: In progress only.
Restriction: Seniors only. Biomedical Engineering Majors only.

BME 180B. Biomedical Engineering Design. 3 Units.
Design strategies, techniques, tools, and protocols commonly encountered in biomedical engineering; clinical experience at the UCI Medical Center and Beckman Laser Institute; industrial design experience in group projects with local biomedical companies; ethics, economic analysis, and FDA product approval. Materials fee.

(Design units: 3)
Prerequisite: BME 180A. BME 180A, BME 180B, and BME 180C must be taken in the same academic year.
Grading Option: In progress only.
Restriction: Seniors only. Biomedical Engineering Majors only.
BME 180C. Biomedical Engineering Design. 3 Units.
Design strategies, techniques, tools, and protocols commonly encountered in biomedical engineering; clinical experience at the UCI Medical Center and Beckman Laser Institute; industrial design experience in group projects with local biomedical companies; ethics, economic analysis, marketing, and FDA product approval. Materials fee.

(Design units: 3)
Prerequisite: BME 180B. BME 180A, BME 180B, and BME 180C must be taken in the same academic year.
Restriction: Seniors only. Biomedical Engineering Majors only.

BME 195. Special Topics in Biomedical Engineering. 1-4 Units.
Studies in selected areas of Biomedical Engineering. Topics addressed vary each quarter.

(Design units: 1-4)
Prerequisite: Prerequisites vary.
Repeatability: Unlimited as topics vary.

BME 197. Seminars in Biomedical Engineering. 2 Units.
Presentation of advanced topics and reports of current research efforts in Biomedical Engineering.

(Design units: 1-2)
Restriction: Seniors only. Biomedical Engineering Majors have first consideration for enrollment.
Concurrent with BME 298.

BME 199. Individual Study. 1-4 Units.
Independent research conducted in the lab of a biomedical engineering core faculty member. A formal written report of the research conducted is required at the conclusion of the quarter.

(Design units: 1-4)
Prerequisite: BIO SCI 194S
Repeatability: May be taken for credit for 8 units.

BME 199P. Individual Study. 1-4 Units.
Supervised independent reading, research, or design for undergraduate Engineering majors. Students taking individual study for design credit are to submit a written paper to the instructor and to the Undergraduate Student Affairs Office in the School of Engineering.

(Design units: 1-4)
Grading Option: Pass/no pass only.
Repeatability: May be repeated for credit unlimited times.

BME 210. Molecular and Cellular Engineering. 4 Units.
Engineering of physiological function at the genetic, cellular, and tissue scales. Topics include cloning and genetic engineering, extracellular matrix biomaterials, principles of regenerative medicine and tissue engineering, and experimental design.

Restriction: Graduate students only.

BME 211. Microscale Tissue Engineering. 4 Units.
Engineering of physiological function at the scale of individual cells. Topics include cell micropatterning, microfluidic tissue culture, engineering the cellular microenvironment, and microphysiological systems.

Restriction: Graduate students only.

BME 212. Cardiovascular Tissue Engineering. 4 Units.
Advanced topics in biomaterials and tissue engineering with a special focus on applications in the cardiovascular system. Devices including vascular grafts and stents, heart valves, and cardiac tissue patches will be examined.

Restriction: Graduate students only.
**BME 213. Systems Cell and Developmental Biology. 4 Units.**
Introduces concepts needed to understand cell and developmental biology at the systems level, i.e., how the parts (molecules) work together to create a complex output. Emphasis on using mathematical/computational modeling to expand/modify insights provided by intuition.

Same as DEV BIO 232.

Restriction: Graduate students only.

**BME 215. Linking Modeling and Experiments in Bioengineering. 4 Units.**
Overview of modeling based on experimental techniques in bioengineering. Construct and evaluate models of varying complexity and to relate them to experimental data.

Prerequisite: BME 220 and BME 221

Restriction: Graduate students only.

**BME 216. Directed Evolution. 4 Units.**
Directed evolution harnesses the processes of Darwinian evolution for biomolecular engineering goals. This class will begin with fundamental principles in evolutionary biology and move on to the experimental evolution techniques and their applications.

Restriction: Graduate students only.

**BME 220. Sensory Motor Systems. 4 Units.**
A quantitative and systems approach to understanding physiological systems. Systems covered include the nervous and musculoskeletal systems.

Restriction: Graduate students only.

Concurrent with BME 120.

**BME 221. Organ Transport Systems. 4 Units.**
A quantitative and systems approach to understanding physiological systems. Systems covered include the cardiopulmonary, circulatory, and renal systems.

Restriction: Graduate students only.

**BME 222. Biofluid Mechanics. 4 Units.**
Introduces principles of biofluid mechanics in a research oriented scheme and approaches a wide spectrum of biofluid related problems in human body and solutions that involves engineering concepts.

Restriction: Graduate students only.

**BME 223. Critical Thinking in Cardiovascular Research. 2 Units.**
Interpretation and critical assessment of current cardiovascular research in basic science, application of engineering tools, and clinical cardiology and cardiovascular surgery. Open only to graduate students engaged in research.

Restriction: Graduate students only.

**BME 224. Molecular and Cellular Biophotonics. 4 Units.**
Principles underlying the application of photonic technologies to biomolecular and cellular systems. Sample technologies Optical Tweezers, Linear and Nonlinear Optical Microscopy and Fluorescence Lifetime and Correlation Methods, and their use to investigate emergent problems in Molecular, Cellular, and Developmental Biology.

Same as CHEM 224.

Restriction: Graduate students only.

**BME 225. Tissue and Organ Biophotonics. 4 Units.**
Principles underlying the application of photonic technologies to tissues, organs, organisms. Sample technologies include Optical Coherence Tomography, Optical Speckle Imaging, Optoacoustic Imaging, Wide-Field Spectroscopic Imaging, Diffuse Optical Spectroscopy. Addressing the use of these technologies to detect/monitor disease and physiological processes.

**BME 230A. Applied Engineering Mathematics I. 4 Units.**
Analytical techniques applied to engineering problems in transport phenomena, process dynamics and control, and thermodynamics.
BME 230B. Applied Engineering Mathematics II. 4 Units.
Focuses on biomedical system identification. Includes fundamental techniques of model building and testing such as formulation, solution of governing equations, sensitivity theory, identifiability theory, and uncertainty analysis.

Restriction: Graduate students only.

BME 232. Introduction to Computational Biology. 4 Units.

Same as MOL BIO 223.

Restriction: Graduate students only.

Concurrent with BIO SCI M123 and COMPSCI 183 and BME 132.

BME 233. Dynamic Systems in Biology and Medicine. 4 Units.
Introduces principles of system theory to analyze biological, biochemical, physiological, and bioengineering systems. Analytical and computational tools are used to model and analyze dynamic systems such as population, neuronal and heart dynamics, biochemical and physiological systems, oxygen diffusion and similar.

Restriction: Graduate students only.

BME 234. Neuroimaging Data Analysis. 4 Units.
Knowledge and understanding of recent techniques for the analysis of healthy and pathological structure and function in neuroimaging data.

Restriction: Graduate students only.

BME 238. Spectroscopy and Imaging of Biological Systems. 4 Units.
Principles of spectroscopy; absorption; molecular orbitals; multiphoton transitions; Jablonski diagram; fluorescence anisotropy; fluorescence decay; quenching; FRET; excited state reactions; solvent relaxations; instruments; microscopy: wide field, LSM, TPE; fluorescent probes, fluctuations spectroscopy; optical resolution and super-resolution; CARS and SHG microscopy.

Restriction: Graduate students only.

Concurrent with BME 138.

BME 240. Introduction to Clinical Medicine for Biomedical Engineering. 4 Units.
An introduction to clinical medicine for graduate students in biomedical engineering. Lectures and rotations through nephology, gastroenterology, pulmonary, and critical care cardiology.

Restriction: Graduate students only. Biomedical Engineering Majors only.

BME 250. Biospectroscopy . 4 Units.
Principles of optical spectroscopy for biomedical engineering. Will focus on optical spectroscopy of biological relevant molecules, spectroscopy in cells and tissue. Spectroscopy techniques based on fluorescence.

Restriction: Graduate students only.

BME 251. Engineering Medical Optics. 4 Units.
Principles of optics and photonics, integration of optical components into systems and devices, and analysis of physiologic signals obtained from Biophotonics measurements.

Restriction: Graduate students only.

Concurrent with BME 136.

BME 252. Critical Thinking in Biophotonics. 2 Units.
Critical thematic review of current research papers in the field of Biophotonics.

Repeatability: May be taken for credit 2 times.

Restriction: Graduate students only.
BME 260. Microfluids and Lab-On-A-Chip. 4 Units.  
Introduction to microfluidics and state-of-the-art micro Total Analysis Systems (uTAS). Lab-on-a-Chip for biomolecular assays with device design principles for microscale sample preparation, flow transport, biomolecular manipulation, separation and detection, and the technologies for integrating these devices into microsystems.  
Restriction: Graduate students only.  
Concurrent with BME 147.

BME 261. Biomedical Microdevices. 4 Units.  
In-depth review of microfabricated devices designed for biological and medical applications. Studies of the design, implementation, manufacturing, and marketing of commercial and research bio-medical devices.  
Restriction: Graduate students only.  
Concurrent with BME 149.

BME 262. Microimplants. 4 Units.  
Essential concepts of biomedical implants at the micro scale. Design, fabrication, and applications of several microimplantable devices including cochlear, retinal, neural, and muscular implants.  
Restriction: Graduate students only.  
Concurrent with BME 148.

BME 263. Nanomedicine. 4 Units.  
Covers the use of inorganic nanocrystals and nanocarriers for molecular detection of human disease and targeted drug delivery. Techniques for synthesis and bioconjugation, molecular targeting, adhesion dynamics, and unique physical properties of nanomaterials.  
Restriction: Graduate students only.

BME 264. Auditory Science and Technology. 2 Units.  
Advanced topics in auditory science and technology from cochlear mechanics to cochlear implants.  
Repeatability: May be repeated for credit unlimited times.  
Restriction: Graduate students only.

BME 290. Critical Thinking and Writing. 4 Units.  
Critical thinking and writing are essential ingredients for success in scientific research. Examines examples from the scientific literature to extract principles of good scientific reasoning, experimental design, and writing.  
Restriction: Graduate students only.

BME 295. Special Topics in Biomedical Engineering. 1-4 Units.  
Studies in selected areas of Biomedical Engineering. Topics addressed vary each quarter.  
Prerequisite: Prerequisites vary.  
Repeatability: Unlimited as topics vary.

BME 296. Master of Science Thesis Research. 1-16 Units.  
Individual research or investigation conducted in the pursuit of preparing and completing the thesis required for the M.S. in Engineering.  
Repeatability: May be repeated for credit unlimited times.  
Restriction: Graduate students only.

BME 297. Doctor of Philosophy Dissertation Research. 1-16 Units.  
Individual research or investigation conducted in the pursuit of preparing and completing the dissertation required for the Ph.D. in Engineering.  
Repeatability: May be repeated for credit unlimited times.
BME 298. Seminars in Biomedical Engineering. 2 Units.
Presentation of advanced topics and reports of current research efforts in biomedical engineering. Designed for graduate students in the Biomedical Engineering program.

Grading Option: Satisfactory/unsatisfactory only.

Repeatability: May be repeated for credit unlimited times.

Concurrent with BME 197.

BME 299. Individual Research. 1-16 Units.
Individual research or investigation under the direction of an individual faculty.

Repeatability: May be repeated for credit unlimited times.