

# BIOMEDICAL ENGINEERING

CU Boulder's Biomedical Engineering program offers students a flexible degree program to achieve their degree and research goals. Biomedical engineering is an exciting, multidisciplinary field that lies at the intersection of medicine, biology and engineering.

With a cross-listed curriculum and an interdisciplinary faculty roster, the BME program delivers a multi-faceted and rigorous education in biomedical engineering. Our department consists of 36 faculty members from multiple backgrounds and disciplines. They conduct research in the areas of biomechanics, tissue engineering, biomaterials, drug delivery, molecular imaging, image-guided therapy, point-of-care diagnostics, biosensors, prosthetics, bioastronautics, systems biology and many more.

Our program offers students the opportunity to take courses in any of the following areas:

- Biomechanics and mechanobiology
- Imaging and diagnostics
- Medical devices
- Therapeutics

The BME program is directed by Dr. Corey Neu. For more information, visit the Biomedical Engineering Program (<https://www.colorado.edu/bme/>) website.

**Course code for this program is BMEN.**

## Master's Degree

- Biomedical Engineering - Master of Science (MS) (<https://catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/biomedical-engineering/biomedical-engineering-master-science-ms/>)

## Doctoral Degree

- Biomedical Engineering - Doctor of Philosophy (PhD) (<https://catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/biomedical-engineering/biomedical-engineering-doctor-philosophy-phd/>)

## Faculty

While many faculty teach both undergraduate and graduate students, some instruct students at the undergraduate level only. For more information, contact the faculty member's home department.

Ahmed, Alaa A. ([https://experts.colorado.edu/display/fisid\\_144736/](https://experts.colorado.edu/display/fisid_144736/))  
Associate Professor; PhD, University of Michigan

Alistar, Mirela ([https://experts.colorado.edu/display/fisid\\_164177/](https://experts.colorado.edu/display/fisid_164177/))  
Assistant Professor; PhD, Technical University of Denmark

Borden, Mark A. ([https://experts.colorado.edu/display/fisid\\_148514/](https://experts.colorado.edu/display/fisid_148514/))  
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Bruns, Carson J. ([https://experts.colorado.edu/display/fisid\\_159851/](https://experts.colorado.edu/display/fisid_159851/))  
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Professor; PhD, University of California, Santa Barbara

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Hayman, Allison P. ([https://experts.colorado.edu/display/fisid\\_156275/](https://experts.colorado.edu/display/fisid_156275/))  
Assistant Professor

Hind, Laurel ([https://experts.colorado.edu/individual/fisid\\_165642/](https://experts.colorado.edu/individual/fisid_165642/))  
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Professor; PhD, Israel Instit of Tech (Israel)

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Associate Professor; PhD, Massachusetts Institute of Technology

## Courses

### **BMEN 5110 (3) Regenerative Biology and Tissue Repair**

Presents the regenerative biology behind tissue systems, along with the regenerative medicine of that tissue with an emphasis on engineering principles, using the assigned reading as a guideline. Follows lectures with class discussions of current papers on the regenerative biology of the same tissue system. In the final 1 & 2 classes assigned to this topic, individual graduate students give 20 min presentations on a relevant regenerative medicine/engineering-focused paper.

**Equivalent - Duplicate Degree Credit Not Granted:** MCEN 5110 and BMEN 4110 and MCEN 4110

**Requisites:** Restricted to any College of Engineering and Applied Science graduate students or to Biomedical Engineering undergraduate majors only.

### **BMEN 5111 (3) Introduction to Microfluidics**

Microfluidics deals with the behavior of fluids in small scale. It is a highly multidisciplinary field at the intersection of engineering, physics, chemistry, biology, medicine, nanotechnology, and biotechnology. This course covers the fundamentals and fabrication of microfluidic devices and their applications, particularly in lab-on-a-chip. Includes lectures, literature discussion, team presentations, and possibly one lab on microfluidic devices. Enhances your understanding of microfluidic technologies and their broad applications.

**Equivalent - Duplicate Degree Credit Not Granted:** MCEN 5111 and MCEN 4111 and BMEN 4111

**Requisites:** Restricted to any College of Engineering and Applied Science graduate students or to Biomedical Engineering undergraduate majors only.

### **BMEN 5113 (3) Mechanics of Cancer**

Cancer is considered to be an organ or an ecosystem, in which a critical component of the tumor microenvironment is mechanical forces. This course will cover the role of mechanics in cancer and cancer-related processes, with a focus on solid mechanics and fluid mechanics. In this course, you will apply engineering principles to come away with an appreciation of how mechanics influences cancer and its etiology as well as the development of future treatments.

**Equivalent - Duplicate Degree Credit Not Granted:** MCEN 4113 and BMEN 4113 and MCEN 5113

**Requisites:** Restricted to any College of Engineering and Applied Science graduate students or to Biomedical Engineering undergraduate majors only.

### **BMEN 5117 (3) Anatomy and Physiology for Biomedical Engineering**

The main objective of this multidisciplinary course is to explore human physiological function from the viewpoint of an engineer. It provides an introduction to human anatomy and physiology with a focus on learning anatomical structures, biological signaling, physiological and pathological conditions, as well as fundamental biomedical engineering concepts that apply quantitative analyses (mass transfer, fluid dynamics, mechanics, modeling) and engineering concepts (e.g., device design to restore defective physiological functions) to understand physiology and pathology. Graduate students will be required to present a primary literature review and lead discussion during a class period, as well as take the lead on the final project: a mock NIH grant proposal.

**Equivalent - Duplicate Degree Credit Not Granted:** MCEN 4117 or MCEN 5117 BMEN 4117

**Requisites:** Restricted to graduate Biomedical Engineering students only.

### **BMEN 5127 (3) Biomedical Ultrasound**

Covers the design of ultrasound systems for medical imaging and therapy, including the physics of wave propagation, transducers, pulse-echo imaging, flow and tissue characterization, and microbubble contrast, with an emphasis on current topics in biomedical ultrasound. Includes lectures on theory, practice and special topics; a laboratory on wave propagation; oral presentations on current literature; programming exercises for data processing; and a team design project.

**Equivalent - Duplicate Degree Credit Not Granted:** MCEN 5127 and BMEN 4127 and MCEN 5127

**Requisites:** Restricted to graduate students only.

**Grading Basis:** Letter Grade

**BMEN 5157 (3) Modeling of Human Movement**

Human movement analysis is used in physical rehabilitation, sport training, human-robot interaction, animation, and more. Course provides a systematic overview of human movement on multiple levels of analysis, with an emphasis on the phenomenology amenable to computational modeling. Covers muscle physiology, movement-related brain areas, musculoskeletal mechanics, forward and inverse dynamics, optimal control and Bayesian inference, learning and adaptation. Inspires students to see and appreciate the complexities of movement control in all aspects of daily life.

**Equivalent - Duplicate Degree Credit Not Granted:** MCEN 5157 and MCEN 4157 and BMEN 4157

**Requisites:** Restricted to graduate students in the College of Engineering and Applied Science or undergraduate Biomedical Engineering (BMEN) majors with 57+ credits (Junior or Senior).

**BMEN 5171 (3) Biofluids on the Micro Scale**

Introduces fundamental physical concepts and basic mechanisms of biological fluids in microscale. Elaborates on the application of fluid mechanics principles to major biological systems, including human organ systems and animal locomotion in microscale. Covers physiologically relevant fluid flow phenomena on the cellular level and the underlying physical mechanisms from an engineering perspective. Related state-of-art technologies such as organ-on-a-chip and micro/nano fabrication will be emphasized. Will enhance your understanding of organ-on-a-chip technologies and their broad applications.

**Equivalent - Duplicate Degree Credit Not Granted:** MCEN 5171 and MCEN 4171 and BMEN 4171

**Requisites:** Restricted to any College of Engineering and Applied Science graduate students or to Biomedical Engineering undergraduate majors only.

**BMEN 5231 (3) Computational Fluid Dynamics**

This course is an in-depth introduction to the basic principles and applications of computational fluid dynamics (CFD). Students learn about fundamental CFD concepts such as discretization, meshing, error and accuracy; and focus on computational solutions of flow and transport problems using the finite element method. Students conduct multiple hands-on simulation-based activities and exercises on canonical and realistic engineering flow/transport problems. Final project for the course culminates in a mini-conference/symposium where students present their work.

**Equivalent - Duplicate Degree Credit Not Granted:** MCEN 5231 and MCEN 4231 and BMEN 4231

**Requisites:** Restricted to any College of Engineering and Applied Science graduate students or to Biomedical Engineering undergraduate majors only.

**BMEN 5292 (3) Materials and Devices in Medicine**

The main objective of this multidisciplinary course is to provide students with a broad survey of biomaterials and their use in medical devices for restoring or replacing the functions of injured, diseased, or aged human tissues and organs. The topics to be covered include: evolution in the medical device industry, a broad introduction to the materials used in medicine and their chemical, physical, and biological properties, discovery of medical problems, potential impacts of treatment innovations, existing devices and design considerations for several major physiological systems (cardiovascular, neuromuscular, skeletal, pulmonary, renal, dermal), materials interaction with the human body, basic mechanisms of wound healing, biocompatibility issues, testing methods and techniques in accordance with standards and relevant regulations, biofunctionalities required for specific applications, as well as state-of-the-art approaches for the development of new regenerative materials targeting cellular mechanisms. Sam

**Requisites:** Requires prerequisite course of MCEN 4117 or MCEN 5117 (minimum grade C-). Restricted to any College of Engineering and Applied Science graduate students or to Biomedical Engineering undergraduate majors only.

**BMEN 5840 (1-6) Independent Study**

Provides opportunities for independent study at the graduate level. Subject and/or project agreed upon by the student and instructor to fit the needs of the student.

**Repeatable:** Repeatable for up to 30.00 total credit hours.

**Requisites:** Restricted to graduate Biomedical Engineering students only.

**BMEN 5939 (1-6) Biomedical Engineering Internship**

Grants credit to international graduate students for conducting research via professional research opportunities in the biomedical engineering field. Students are responsible for securing their own internships.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**BMEN 6519 (1-3) Special Topics in Biomedical Engineering**

Credit hours and subject matter to be arranged.

**Repeatable:** Repeatable for up to 12.00 total credit hours. Allows multiple enrollment in term.

**BMEN 6949 (1) Master's Candidate for Degree**

Credit hours and subject matter to be arranged.

**BMEN 6950 (1-6) Master's Thesis**

Work with a faculty advisor on a masters thesis.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate Biomedical Engineering students only.

**BMEN 7840 (1-6) Independent Study**

Provides opportunities for independent study at the graduate (PhD) level. Subject and/or project agreed upon by the student and instructor to fit the needs of the student.

**Requisites:** Restricted to Biomedical Engineering BMEN-PhD students only.

**BMEN 8990 (1-10) Doctoral Dissertation**

Work with a faculty advisor on a doctoral dissertation.

**Repeatable:** Repeatable for up to 60.00 total credit hours.

**Requisites:** Restricted to Biomedical Engineering (BMEN) Ph.D. graduate students only.