

# BIOENGINEERING

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## Overview

### Mission Statement

The Department of Bioengineering bridges the fields of engineering and medicine with a core mission of applying engineering principles and analyses to improving human health. The department will fulfill this mission by providing opportunities for training, research, and service in bioengineering to faculty, students, and residents of Colorado and the greater Rocky Mountain region.

### Program Objectives

The Department of Bioengineering offers high-quality training in bioengineering that is both flexible and multidisciplinary. A design-based focus permeates every aspect of our training philosophy which can be summarized by the following question: what does the user want and how can I best utilize my bioengineering training to achieve this need? Our academic instruction focuses on developing core competencies in life sciences, quantitative methods, technology, and research methods.

## Graduate Program

All graduate students begin the program with intensive study of the bioengineering core. In consultation with an advisor, each student chooses elective courses, training pathways, and research to fit talents, preparation, and career plans. Students earn the MS, MS-MBA, MD-MS, MD/PhD, or PhD degree in bioengineering with a choice of training pathways in basic research, clinical applications, or commercialization of medical technologies. Graduate Education Policies and Procedures apply to all programs. Please consult our website ([ucdenver.edu/bioengineering](http://ucdenver.edu/bioengineering)) (<http://www.ucdenver.edu/bioengineering/>) for more information on admissions requirements, degree requirements, core courses, training pathways, faculty research areas and student learning outcomes.

## Admission Requirements

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1. Application
2. Application fee - \$50 domestic; \$75 international
3. Statement of purpose – must be an original essay submitted with application. Scanned copies will not be accepted for submission.
4. Resume – must be submitted with application  
Bioengineering applicants must complete essay questions and an application background survey ([https://engineering.ucdenver.edu/docs/librariesprovider29/college-of-engineering-and-applied-science/bioengineering/academic-program-documents/bioe\\_applicant\\_background\\_survey.pdf?sfvrsn=79a597b8\\_2](https://engineering.ucdenver.edu/docs/librariesprovider29/college-of-engineering-and-applied-science/bioengineering/academic-program-documents/bioe_applicant_background_survey.pdf?sfvrsn=79a597b8_2)). Contact the department ([bioengineering@cuanschutz.edu](mailto:bioengineering@cuanschutz.edu)) for more information

5. Official transcripts – we require one official copy of each previous transcript. Send e-transcripts to Graduate Admissions at [graduateadmissions@ucdenver.edu](mailto:graduateadmissions@ucdenver.edu)
6. Letters of recommendation – three are required (two for civil engineering); a 4th is optional
7. GRE scores are not required. If choosing to submit, send scores officially through ETS using code #4875.

## Eligibility Requirements

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Applicants to the master of science in bioengineering should meet the following minimum requirements:

1. Prior GPA in most recent degree of 3.0 (B) or higher
2. Completion of a bachelor's degree in engineering from an accredited United States institution or comparable international institution, or
3. Completion of a bachelor's degree in a bioscience-related field with:
  - three semesters of calculus
  - one semester of differential equations and linear algebra
  - one semester of statistics
  - one semester of mechanics
  - one semester of circuits
  - one semester of computer programming

Students may be admitted to the graduate bioengineering program with the provision that, in addition to the required courses, they take any missing courses at CU Denver.

All math requirements must be completed prior to matriculation. There are no exceptions to this.

## Programs

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- Assistive Technology and Inclusive Engineering Certificate (<http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/bioengineering/assistive-technology-inclusive-engineering-certificate/>)
- Bioengineering Dual, MS-MBA (<http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/bioengineering/bioengineering-dual-ms-mba/>)
- Bioengineering, MD-MS (<http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/bioengineering/bioengineering-md-ms/>)
- Bioengineering, MD-PhD (<http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/bioengineering/bioengineering-md-phd/>)
- Bioengineering, MS (<http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/bioengineering/bioengineering-ms/>)
- Bioengineering, PhD (<http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/bioengineering/bioengineering-phd/>)
- Medical Device Design and Entrepreneurship Certificate (<http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/bioengineering/medical-device-design-entrepreneurship-certificate/>)

- Neural Engineering Graduate Certificate (<http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/bioengineering/neural-engineering-graduate-certificate/>)

## Faculty

### Professors

**Robin Shandas**, PhD robin.shandas@cuanschutz.edu  
Specialties: Novel methods for translational bioengineering

**Keith Neeves**, PhD keith.neeves@cuanschutz.edu  
Specialties: Hematology and oncology

### Associate Professors

**Richard Benninger**, PhD richard.benninger@cuanschutz.edu  
Specialties: Optical microscopy, pancreatic islet biology and biophysics, diabetes

**Cathy Bodine**, PhD cathy.bodine@cuanschutz.edu  
Specialties: Assistive technology, rehabilitation engineering

**Emily Gibson**, PhD emily.gibson@cuanschutz.edu  
Specialties: Microfluidics technology, optical microscopy, and spectroscopy

**Kendall Hunter**, PhD kendall.hunter@cuanschutz.edu  
Specialties: Soft tissue mechanics, vascular and cardiac imaging diagnostics, translational biomechanics

**Jeffrey Jacot**, PhD jeffrey.jacot@cuanschutz.edu  
Specialties: Stem cells and heart tissue engineering

**Daewon Park**, PhD daewon.park@cuanschutz.edu  
Specialties: Biomaterials, drug delivery, tissue engineering and regenerative medicine

### Research Associate Professors

**Richard Weir**, PhD richard.weir@cuanschutz.edu  
Specialties: Neural engineering, biomechatronic design, and rehabilitation engineering

### Assistant Professors

**Morris Huang**, PhD morris.huang@cuanschutz.edu (morris.huang@cuanschutz.edu)  
Specialties: Mechatronics, usability testing Assistive technology for mobility, clinical assessment tools

**Chelsea Magin**, PhD chelsea.magin@cuanschutz.edu  
Specialties: regulatory affairs and pulmonary engineering

**Bradford Smith**, PhD bradford.smith@cuanschutz.edu  
Specialties: Lung structure-function relationships, optimized mechanical ventilation, and high-performance computing

### Assistant Research Professors

**Brisa Peña**, PhD brisa.penacastellanos@cuanschutz.edu (brisa.penacastellanos@cuanschutz.edu)  
Specialties: Material science, atomic force microscopy, cardiac tissue engineering, and miRNA delivery

## Instructors

**Mary Bevilacqua**, mary.bevilacqua@cuanschutz.edu (mary.bevilacqua@cuanschutz.edu)  
Specialties: Design and prototyping

**Steven Lammers**, PhD steven.lammers@cuanschutz.edu  
Specialties: 3D printing & design, bioprintable materials, tissue engineering of 3D cellularized scaffolds

**Eric Roth**, PhD eric.roth@cuanschutz.edu  
Specialties: design, safety & compliance

## Affiliated Faculty

Students receive instruction from affiliate faculty in the University of Colorado system, including CU Boulder and the CU School of Medicine. Faculty research areas include imaging and biophotonics, cardiovascular biomechanics and hemodynamics, orthopedic biomechanics, neuromuscular control and assistive technology, surgery and urological sciences, ophthalmology, neuroscience engineering, polymers and diabetes. Please consult our website ([ucdenver.edu/bioengineering](http://www.ucdenver.edu/bioengineering)) (<http://www.ucdenver.edu/bioengineering/>) for more information.

## Bioengineering (BIOE) Courses

**BIOE 5010 - Cell and Molecular Biology for Bioengineers (3 Credits)**  
Introduction to cellular and molecular biology, with a focus on using engineering methods and literature to analyze structure and function of cells throughout lifecycle and multiple scales. Design experiments to test hypotheses. Max Hours: 3 Credits.  
Grading Basis: Letter Grade

**BIOE 5011 - Systems Physiology for Bioengineers (3 Credits)**  
Use engineering principles to study key physiological systems. Topics: cardiovascular, neuroscience, urological, or renal medicine. Related engineering principles: pressure-flow relationships, stress-strain, electromechanical coupling and signal transduction. Prereq: Graduate standing in Bioengineering or instructor permission. Max Hours: 3 Credits.  
Grading Basis: Letter Grade

**BIOE 5020 - Analytics and Machine Learning in Bioengineering (3 Credits)**  
This course provides mathematical tools essential for graduate level bioengineering work. Studies selected topics from probability, linear algebra, and vector calculus, with emphasis on bioengineering applications. Prereq: Graduate standing in Bioengineering or instructor permission. Max Hours: 3 Credits.  
Grading Basis: Letter Grade

**BIOE 5021 - Numerical Methods for Engineering Analysis (3 Credits)**  
Provides computational skills and knowledge of numerical methods for engineering/scientific computation using Matlab. Topics: root finding, interpolation, difference and integration rules, solution of initial and boundary value ODEs, and introduction to the solution of PDEs. Prereq: Graduate standing in Bioengineering or instructor permission. Max Hours: 3 Credits.  
Grading Basis: Letter Grade

**BIOE 5039 - Mechatronics and Embedded Systems (3 Credits)**

The course focuses on the design and construction of microprocessor-controlled electro-mechanical systems. Lectures review critical circuit topics (Ohm's law, RLC circuits, DC and AC signals, diode and transistor circuits, operational amplifiers, and digital signals), introduce microprocessor architecture and programming, discuss sensor and actuator component selection, robotic systems, and design strategies for complex, multi-system devices. Lab work reinforces lectures and allows hands-on experience with robotic and embedded systems design. Students must design and build an embedded systems device related to assistive technology. Note: Project expenses may be incurred (\$50 maximum). Cross-listed with BIOE 4039. Max Hours: 3 Credits.  
Grading Basis: Letter Grade

**BIOE 5040 - Research Methods for Bioengineers (2 Credits)**

This course introduces research methods that will prepare bioengineering graduate students for completing basic or translational research and communicating the results. Topics include setting expectations with mentors, finding, reading, analyzing, citing, and reviewing scientific literature, technical writing, research presentations, and responsible conduct of research. Restriction: Restricted to Students must be enrolled in the CU BIOE BS/MS program OR be within the first two years of CU BIOE MS/PhD study and have identified a research advisor. Students enrolled in other departments may be admitted with instructor approval. Max hours: 2 Credits.  
Grading Basis: Letter Grade  
Restriction: the BIOE BS/MS program OR BIOE MS/PhD study.  
Typically Offered: Spring.

**BIOE 5041 - Clinical Experiences for Bioengineers (1 Credit)**

This course provides opportunities for clinical experiences such as observing surgeries and touring intensive care units to prepare students for clinical applications and foster collaborations with clinical practitioners. Experiences take place through the school year. Prerequisites: Graduate standing in Bioengineering (MS/PHD). Repeatable. Max Hours: 2 Credits.  
Grading Basis: Letter Grade  
Repeatable. Max Credits: 2.  
Typically Offered: Fall.

**BIOE 5053 - Optics & Microscopy in Biomedical Research (3 Credits)**

Graduate overview of optical imaging, ranging from classical microscopy to advanced non-linear techniques and includes theory, technology and applications in biomedical sciences. This will prepare students for developing and applying state-of-the-art optical imaging in their research. Cross-listed with BIOE 4053. Prereq: Grad standing or permission from the instructor. Max Hours: 3 Credits.  
Grading Basis: Letter Grade

**BIOE 5054 - Regulatory Affairs (3 Credits)**

This course covers standards of quality assurance and regulatory pathways that guide biomedical engineering industry. Cross-listed with BIOE 4054. Restriction: Restricted to BIOE majors or with instructor permission. Max hours: 3 Credits.  
Grading Basis: Letter Grade  
Restriction: Restricted to Bioengineering students with graduate student status.

**BIOE 5057 - Rehabilitation and Assistive Technology (3 Credits)**

This course provides students with an overview of technologies and their use by and for persons with disabilities. Cross-listed with BIOE 4057. Restriction: Restricted to students with BIOE designation, or with instructor permission. Max hours: 3 Credits.  
Grading Basis: Letter Grade  
Restriction: Restricted to Bioengineering students with graduate student status.

**BIOE 5058 - Intro to Design, Disability, and Aging (3 Credits)**

This course provides an introduction to the topic of disability and aging and the application of bioengineering principles for persons living with functional impairment(s) across the lifespan. Cross-listed with BIOE 4058. Restriction: Restricted to BIOE majors or with instructor permission. Max hours: 3 Credits.  
Grading Basis: Letter Grade  
Restriction: Restricted to Bioengineering students with graduate student status.

**BIOE 5063 - 3D Modeling for Bioengineers (3 Credits)**

Course instills 3D modeling skills specific to biomedical industry. Topics include computer aided design, medical imaging, image processing, patient specific image to three-dimensional model reconstruction, non-uniform rational b-spline surfaces, finite element, computational fluid dynamics analyses, physical modeling using rapid prototyping. Restrictions: Matriculated CEDC students. Max Hours: 3 Credits.  
Grading Basis: Letter Grade  
Typically Offered: Fall, Spring.

**BIOE 5064 - Advanced MatLab For Bioengineers And Life Scientists (3 Credits)**

MatLab programming for graduate bioengineers and life scientists. Topics include MatLab syntax and optimization as well as techniques for working with scalars, time-series, images and multi-dimension datasets. Surface/Curve fitting, modeling, automation and classification will be covered. Cross-listed with BIOE 4064. Max Hours: 3 Credits.  
Grading Basis: Letter Grade

**BIOE 5067 - Human Factors and Usability Testing for Bioengineers (3 Credits)**

This course provides an introduction to human factors testing and evaluation in the context of medical devices and assistive technology (AT). Particular focus will be given towards designing and applying usability testing to inform product design decisions or improvements. Topics include human factor considerations for aging and disabled populations (and their care providers), usability techniques, user experience data collection and interpretation, etc. Students will engage in hands-on human factors assessments such as contextual inquiry of surgery patients, cognitive walkthroughs with simulating disability, and product usability testing and iteration. Max hours: 3 Credits.  
Grading Basis: Letter Grade

**BIOE 5068 - Introduction to Medical Imaging (3 Credits)**

This course will introduce graduate students to the basic physics, technologies, and clinical methodologies underlying Ultrasound, MRI, CT, PET and SPECT imaging systems. The course will include lectures, and visits to campus hospital and research imaging systems as well as hands on ultrasound labs. Cross-listed with BIOE 4068. Max Hours: 3 Credits.  
Grading Basis: Letter Grade

**BIOE 5069 - Advanced Biomechanics for Graduates (3 Credits)**

This course covers advanced topics such as blood flow dynamics, introduction to non-linear finite deformation techniques, blood rheology, and computational techniques. Cross-listed with BIOE 4069. Max hours: 3 credits.

Grading Basis: Letter Grade

**BIOE 5073 - Neural Interfaces and Bionic Limbs (3 Credits)**

This course will introduce graduate students to topics in neural interfaces (Brain machine interfaces, peripheral nerve interfaces etc), the issues involved in the design of mechatronic limb systems and the decoding algorithms used to map the neural interface to the mechatronic limb.

Cross-listed with BIOE 4073. Restrictions: Matriculated CEDC students. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Typically Offered: Spring.

**BIOE 5074 - Introduction to Laboratory Animal Research (3 Credits)**

This course provides basic theoretical and practical knowledge on the use of the most common laboratory animal species, animal models and welfare, general concepts on animal biology and husbandry, and essential principles of anesthesia, analgesia, surgery and peri operative care. Max Hours: 3 Credits.

Grading Basis: Letter Grade

**BIOE 5083 - Polymers in Biomedical Applications (3 Credits)**

This course will introduce graduate students to fundamental synthetic method and basic characteristics of various polymeric biomaterials and their crucial roles in different biomedical applications. It will also cover how the polymers can be modified to enhance biomedical applications.

Cross-listed with BIOE 4083. Prereq: Graduate standing at CU Denver or instructor permission. Max Hours: 3 Credits.

Grading Basis: Letter Grade

**BIOE 5100 - Image Processing for BIOEs (3 Credits)**

This course provides an overview of basic and advanced image processing algorithms from both a theoretical and a practical perspective with special emphasis in Bioengineering. Topics to be covered include quantization, filtering, texture analysis, Fourier transform, wavelets, morphological operations, image registration, segmentation, machine learning, deep learning, and principal component analysis (PCA). Cross-listed with BIOE 4100. Max hours: 3 credits.

Grading Basis: Letter Grade

Typically Offered: Spring.

**BIOE 5200 - Stem Cell and Regenerative Medicine (3 Credits)**

This Bioengineering course is designed to familiarize students with the application of stem cells in regenerative medicine and in tissue engineering, including the integration of stem cells into damaged tissues.

The course will cover the current state of tissue/organ engineering in the research and clinical settings. Some prior knowledge of cell biology is required to understand the content presented and discuss relevant literature. Max hours: 3 Credits.

Grading Basis: Letter Grade

Typically Offered: Fall.

**BIOE 5300 - Medical Device Design and Entrepreneurship (3 Credits)**

This course will introduce the important processes needed to implement a medical device into a viable entrepreneurial venture with strong focus on the themes of disruption and innovation, investment readiness of a product idea (traction), business and risk analysis, and funding your ideas. At the same time, we will explore your entrepreneurial personality through the three lenses of personal motivation, work passion, and superpowers. Max hours: 3 credits.

Grading Basis: Letter Grade

Typically Offered: Fall.

**BIOE 5420 - Special Topics in Bioengineering (1-6 Credits)**

Special topics of particular interest to graduate students in Bioengineering. Repeatable. Max hours: 12 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 12.

**BIOE 5500 - Bioengineering and Diabetes (1 Credit)**

This course will introduce and reinforce fundamental concepts in metabolism and diabetes pathogenesis and introduce key bioengineering principles in developing diagnostics, treatments and cures for diabetes.

Restriction: Restricted to Bioengineering students with graduate student status. Term offered: Spring.

Grading Basis: Letter Grade

Restriction: Restricted to Bioengineering students with graduate student status.

Typically Offered: Spring.

**BIOE 5840 - Independent Study in Bioengineering (1-6 Credits)**

Graduate level independent study in Bioengineering with a faculty mentor.

Prereq: Graduate standing within the Department of Bioengineering or permission of instructor. Repeatable. Max Hours: 6 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 6.

**BIOE 5939 - Graduate Internship (1-6 Credits)**

Department of Bioengineering Internship. Credit may not be applied toward the MS in Bioengineering degree. Enrollment by department permission only. Max Hours: 6 Credits.

Grading Basis: Letter Grade

**BIOE 6655 - Foundations of Doctoring MS Years (1-5 Credits)**

This course is for CU MD-MS students who are on leave of absence from SOM and wish to maintain clinical exposure and training during the leave. Prereq: Phase I & II SOM classes. Repeatable. Max Hours: 20 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 20.

**BIOE 6950 - Masters Thesis (1-6 Credits)**

Research for Master Thesis under supervision of faculty thesis advisor. Prerequisites: Consent of thesis advisor. Restrictions: Satisfactory progress toward MS-Bioengineering degree. Repeatable. Max hours: 6 Credits.

Grading Basis: Letter Grade with IP

Repeatable. Max Credits: 6.

Additional Information: Report as Full Time.

Typically Offered: Fall, Spring, Summer.

**BIOE 6960 - Master's Project (1-6 Credits)**

Training for Master's Project under the supervision of faculty project advisor. Prereq: Department Consent. Repeatable. Max hours: 6 Credits.

Grading Basis: Letter Grade with IP

Repeatable. Max Credits: 6.

Additional Information: Report as Full Time.

**BIOE 8990 - Doctoral Dissertation (1-10 Credits)**

Research for doctoral dissertation under supervision of faculty advisor.

Prerequisites: Consent of dissertation advisor. Restrictions: Satisfactory progress toward PhD-Bioengineering Degree. Repeatable. Max hours: 10 Credits.

Grading Basis: Letter Grade with IP

Repeatable. Max Credits: 10.

Additional Information: Report as Full Time.

Typically Offered: Fall, Spring, Summer.