The Department of Bioengineering is driven by the conviction that the interface of engineering and medicine will be one of the great intellectual adventures of the 21st century. To prepare students for this adventure, the department strives to create an atmosphere of innovation and creativity that fosters excellence in instruction and research and provides a foundation for programs that drive forward the cutting edge of knowledge while establishing translational collaborations with clinical and industrial researchers.

Bioengineering is a relatively new field built on the recognition that engineering of biological systems or systems that interface with living systems requires a multidisciplinary approach that takes into account the mechanical, electrical, chemical, and materials properties of the biological system. Students with backgrounds from biochemistry to computer science and many fields in between are attracted to bioengineering as a field with the potential to make a great impact on human health. The MS and PhD programs are designed to integrate students with very different backgrounds and provide them with the coursework and research experience that will take advantage of their unique backgrounds and, where appropriate, fill in gaps in their backgrounds to help them grow into a more broadly informed student.

Recognizing the breadth of disciplines that contribute to bioengineering projects, the MS program allows students to choose one of four concentrations (bioimaging and signal processing, cell and tissue engineering, biomechanics, or biomedical devices) to develop deep expertise in an area of particular interest and encourages individual research through a one-semester master’s project or two-semester projects, the MS program allows students to choose one of four concentrations (bioimaging and signal processing, cell and tissue engineering, biomechanics, or biomedical devices) to develop deep expertise in an area of particular interest and encourages individual research through a one-semester master’s project or two-semester master’s thesis.

The PhD program spans four core research areas for which the department has particular strengths: imaging, instrumentation and signal processing; biomechanics, bioransport, and mechanobiology; molecular, cell, and tissue engineering; and computational and systems biology. Coursework is designed to strengthen student backgrounds in those areas most relevant to the interests of each student.

Mission of the Department
The mission of the Department of Bioengineering is the education of students in the fundamental principles and practice of bioengineering and, through basic and applied research, the creation of new knowledge at the interface of engineering and medicine to support development of new technologies for improvement of human health and healthcare.

Overview of Programs Offered
The Department of Bioengineering offers a Master of Science (MS) and a Doctor of Philosophy (PhD) in Bioengineering. The MS and PhD degree programs are only offered as full-time programs.

Candidates pursuing an MS or PhD are able to select thesis topics from a diverse range of faculty research. New graduate students may learn about ongoing research topics from individual faculty members, faculty websites, and bioengineering seminars.

Graduate Certificate Options
Students enrolled in a master’s degree have the opportunity to also pursue one of the many engineering graduate certificate options in addition to or in combination with the MS degree. Students should consult their faculty advisor regarding these options (http://catalog.northeastern.edu/graduate/engineering/graduate-certificate-programs/).

GORDON INSTITUTE OF ENGINEERING LEADERSHIP OPTION
Students have the opportunity to pursue the Gordon Engineering Leadership Program (http://catalog.northeastern.edu/graduate/gordon-institute/) in combination with the MS degree.

Programs
Doctor of Philosophy (PhD)
- Bioengineering (http://catalog.northeastern.edu/graduate/engineering/bioengineering/bioengineering-bachelors-degree-entrance-phd/)

Master of Science in Bioengineering (MSBioE)
- Bioengineering (http://catalog.northeastern.edu/graduate/engineering/bioengineering/bioengineering-msbioe/)

Courses
Bioengineering Courses
Search BIOE Courses using FocusSearch (http://catalog.northeastern.edu/class-search/?subject=BIOE)

BIOE 5060. Special Topics in Bioengineering. (4 Hours)
Focuses on topics of timely interest to students of science and engineering. Topic varies from semester to semester. When appropriate, the course takes advantage of unique opportunities afforded by visiting faculty and guests. May be repeated once.

BIOE 5115. Dynamical Systems in Biological Engineering. (4 Hours)
Introduces the theoretical analysis and modeling of dynamical systems in biology, ranging from molecular to population applications. Topics include difference and differential equation models, with basic theory including nondimensionalization, steady states, linearization, stability, eigenvalues, global behavior, singular perturbations, multistability, hysteresis, cooperativity, periodic solutions, excitable systems, bifurcations; and an introduction to spatial (PDE) models. Develops all concepts in the context of concrete biological applications, such as gene regulation; chemical reaction networks and stoichiometry; drug models and PK/PD; receptor/ligand interactions; synthetic constructs; action potential generation; enzymatic reactions; population interactions; epidemiology; epigenetic phenomena, including differentiation and transport; chemotaxis; and diffusion.

Prerequisite(s): MATH 2341 with a minimum grade of D- or GE 2361 with a minimum grade of D- or graduate program admission
BIOE 5235. Biomedical Imaging. (4 Hours)
Presents the foundations of modern medical imaging, including imaging principles, imaging mathematics, imaging physics, and image-generation techniques. Includes X-ray, ultrasound, computed tomography, and magnetic resonance imaging.

Prerequisite(s): BIOE 3210 with a minimum grade of D- or graduate program admission

BIOE 5250. Design, Manufacture, and Evaluation of Medical Devices. (4 Hours)
Covers engineering design challenges intrinsic to the development of biomedical devices, including clinical evaluation, manufacture, and testing of medical devices and the constraints that FDA regulations place on these processes. Topics include quality systems, design control, cybersecurity concerns, the role of standards in global device regulation, and the design process. Students are asked to form teams and to carry out a semester-long conceptual design project to develop a design overview, design plan, design input specifications, and verification test procedures for a novel medical device.

BIOE 5410. Molecular Bioengineering. (4 Hours)
Introduces the fundamentals of molecular structure and function that underpin engineering of biological macromolecules. Builds on this base with the application of design concepts for molecules and methods of structural and functional analyses and strategies for design and redesign of therapeutic molecules. Projects seek to provide students with experience in conceptual design to create strategies to address significant health concerns.

Prerequisite(s): (BIOL 1111 with a minimum grade of D- or BIOL 1115 with a minimum grade of D-); BIOE 2355 with a minimum grade of D-; MATH 1342 with a minimum grade of D-) or graduate program admission

BIOE 5420. Cellular Engineering. (4 Hours)
Analyzes the techniques that form the foundation of molecular cell engineering, including recombinant DNA, cloning and genomics, prokaryotic and eukaryotic gene regulation and single-cell gene expression, structure, dynamics of gene regulatory networks, metabolism and cellular energetics, cell structure, cytoskeleton and cellular motors, synthetic gene circuits, and metabolic engineering.

Prerequisite(s): BIOE 2355 with a minimum grade of D- or graduate program admission

BIOE 5430. Principles and Applications of Tissue Engineering. (4 Hours)
Applies the principles of biology and biomedical engineering to the creation of artificial organs for transplantation, basic research, or drug development. Requires integration of knowledge of organic chemistry, cell biology, genetics, mechanics, biomaterials, nanotechnology, and transport processes to create functional organs. Reviews basic cell culture techniques, structure function relationships, cellular communication, natural and artificial biomaterials, and the basic equations governing cell survival and tissue organization.

Prerequisite(s): BIOE 2355 with a minimum grade of D- or graduate program admission

BIOE 5440. The Cell as a Machine. (4 Hours)
Introduces the key roles that physical forces, the extracellular matrix, and cytoskeletal structure play in the development of human diseases. The cell is viewed as an engineering system that is capable of sensing physical cues from its environment, integrating such information from different mechano-sensors, and responding to changes in its external environment in a coherent manner. Uses mathematical and computational models to explain how cells sense and respond to physical cues.

Prerequisite(s): (BIOE 2350 with a minimum grade of D-; BIOE 3380 with a minimum grade of D-) or graduate program admission

BIOE 5450. Stem Cell Engineering. (4 Hours)
Covers engineering principles and approaches in stem cell research and their application in tissue engineering and regenerative medicine. Emphasizes recent technology and engineering tools used to understand and manipulate stem cells. Topics covered include embryonic and adult stem cell biology fundamentals; quantitative modeling of stem cell signaling; genetic/biochemical/biophysical/biomechanical/biomatical tools to control stem cell fate and differentiation; epigenetic editing and cellular reprogramming; engineering biomimetic and bioreactor environments to develop stem-cell-based therapies; and various applications in tissue development, diseases, and regeneration.

Prerequisite(s): (BIOE 5420 with a minimum grade of C-; BIOE 5430 with a minimum grade of C-)

BIOE 5510. Bioengineering Products/Technology Commercialization. (4 Hours)
Focuses on the translation and commercialization of bioengineering products and technology. Offers students an opportunity to gain essential entrepreneurship skills through studying and exercising the key elements and processes in establishing and launching a biotechnology startup. Examines how to assess bioengineering product and technology opportunities, evaluate the technology's market potential, navigate the landscape of intellectual property protection and FDA regulation for bioengineering products, form a biotechnology startup company, write a business plan, and pitch startups to prospective investors. Covers fundamentals of engineering economics.

BIOE 5560. Physiological Fluid Mechanics. (4 Hours)
Analyzes biofluids and their mechanics, including cardiovascular fluid mechanics. Examples are taken from biotechnology processes and physiologic applications, including the cardiovascular, respiratory, ocular, renal, musculoskeletal, and gastrointestinal systems. Topics include dimensional analysis, particle kinematics in Eulerian and Lagrangian reference frames, constitutive equations and Newtonian/non-Newtonian biofluid models, flow and wave propagation in flexible tubes, and oscillatory and pulsatile flows.

Prerequisite(s): BIOE 3310 with a minimum grade of D- or graduate program admission
BIOE 5640. Computational Biomechanics. (4 Hours)
Identifies and reviews the fundamental conservation principles that
govern structural mechanics and fluid dynamics in biological systems.
Discusses the following numerical analysis techniques: parameter
estimation, finite difference, numerical integration, and finite element
methods. By combining conservation laws with numerical analyses
techniques, develops approaches to describe the physiological function
of various biological systems, allowing for a system of equations to be
used to describe a biological problem and solve this system numerically
to predict its behavior.
Prerequisite(s): BIOE 3310 with a minimum grade of D- or graduate
program admission

BIOE 5648. Biomedical Optics. (4 Hours)
Covers biomedical optics and discusses the theory and practice
of biological and medical applications of lasers. Topics covered
include fundamentals of light propagation in biological tissues;
light-matter interactions such as elastic and inelastic scattering;
fluorescence and phosphorescence; diagnostic imaging techniques
such as confocal fluorescence microscopy, diffuse optical tomography,
and optical coherence tomoscopy; and therapeutic interventional
techniques, including photodynamic therapy, laser thermal therapies,
and fluorescence-guided surgeries. EECE 5648 and BIOE 5648 are cross-
listed.
Prerequisite(s): BIOE 3210 with a minimum grade of D- or EECE 2150 with
a minimum grade of D- or graduate program admission

BIOE 5650. Multiscale Biomechanics. (4 Hours)
Seeks to help students develop and apply scaling laws and continuum
mechanics to biomechanical phenomena at different length scales
starting from a single molecule, moving up to the cellular and tissue
levels. Topics include structure of tissues and the molecular basis for
macroscopic properties; chemical and electrical effects on mechanical
behavior; cell mechanics, motility, and adhesion; biomembranes;
biochemical mechanics and molecular motors; and experimental
methods for probing structures at the tissue, cellular, and molecular
levels.
Prerequisite(s): (BIOE 2355 with a minimum grade of D-; (MATH 2341
with a minimum grade of D- or GE 2361 with a minimum grade of D-)) or
graduate program admission

BIOE 5656. Fields, Forces, and Flows in Biological Systems. (4 Hours)
Introduces the basic driving forces for electric current, fluid flow, and
mass transport, plus their application to a variety of biological systems.
Studies basic mathematical and engineering tools in the context of
biology and physiology. Considers various electrokinetic phenomena as
an example of the coupled nature of chemical-electro-chemical driving
forces. Applications include transport in biological tissues and across
membranes, manipulation of cells and biomolecules, and microfluidics.
Prerequisite(s): ((MATH 2341 with a minimum grade of D- or GE 2361
with a minimum grade of D-); BIOE 2355 with a minimum grade of D-) or
graduate program admission

BIOE 5710. Experimental Systems and Synthetic Bioengineering. (4
Hours)
Introduces experimental aspects of systems and synthetic bioengineering. Offers students an opportunity to learn how to plan and
execute quantitative experiments, how to apply engineering principles
to design laboratory research and to interpret data, and how to design
and implement synthetic genetic or enzymatic circuits. Through team
projects, explores techniques in nucleic acid, protein, and genetic
engineering; quantitative measurements at the single-cell level and
beyond; design and applications of synthetic circuits; and discusses
ethical considerations.
Prerequisite(s): BIOE 2355 with a minimum grade of D- or graduate
program admission

BIOE 5720. Physical Bioengineering. (4 Hours)
Covers biopolymer conformations, cell membrane mechanics, chemical
reaction kinetics and applications to polymerization and molecular
motors, electric fields, and action potential propagation. Recent years
have seen a tremendous growth in the use of ideas and methods from
physical science and engineering to obtain a better understanding
of biological phenomena and for applications of that understanding
to societal needs, ranging from health to agriculture. Underlying
these efforts are principles from statistical physics that establish the
framework for this increasingly popular part of bioengineering.
Prerequisite(s): BIOE 2365 with a minimum grade of D- or BIOE 3380 with
a minimum grade of D- or graduate program admission

BIOE 5750. Modeling and Inference in Bioengineering. (4 Hours)
Develops a set of statistical tools to address poorly posed inverse
problems. Interpreting complex and partial information is a routine task
in research as well as in our daily lives. Such tasks include estimating
quantitative properties of a biological system from indirect noisy
measurements, responding to fluctuating environmental signals, or
breaking encrypted messages. Common to these diverse questions
is a need to construct a predictive model from partial data. Draws on
examples from primary literature in biology to study text recognition, trait
mapping, sequence alignment, decoding cryptographs, processing of
chemoattractive signals to find food, and survival strategies of bacteria in
unpredictable environments.
Prerequisite(s): (BIOE 2355 with a minimum grade of D-; (BIOE 5115 with
a minimum grade of D- or BIOE 5440 with a minimum grade of D-)) or
graduate program admission

BIOE 5760. Method and Logic in Systems Biology and Bioengineering. (4
Hours)
Emphasizes difficulties that lie at the interface of theory and experiment
in bioengineering and systems biology. Covers stem cell engineering,
directed differentiation, engineering biological circuits, cooperativity,
robust adaptation, kinetic proofreading, signal transduction and
information processing in biological systems, network analysis,
dynamical systems, and biological design principles. This course is based
on reading and discussing primary literature that exemplifies approaches
that have revealed new concepts and principles governing biological
systems. Each week, students read and discuss two important papers.
The instructor provides relevant background and frames the examined
papers in the context of the field and their time period as the basis for
class discussion.
Prerequisite(s): BIOE 2355 with a minimum grade of D- or graduate
program admission
BIOE 5800. Systems, Signals, and Controls for Bioengineers. (4 Hours)
Explores the concept of systems and transfer functions to allow engineers to break down a complex system into simpler systems and to combine simpler modules to form complex functions. Presents a set of analytical tools and focuses on applying frequency-domain analyses (e.g., Fourier, Laplace, and Z transforms) to simplify continuous and discrete-time systems and gain insights regarding their stability and frequency responses. Offers students an opportunity to understand, characterize, and combine analog and digital signals produced by electronic and biological circuits, as well as design controllers to achieve desired biosystem behavior. Using this knowledge, students design filters and controllers, both in the analog and digital forms, and measure and manipulate complex real-world bioengineering systems (including image processing for 2D signals).

Prerequisite(s): BIOE 3210 with a minimum grade of D- or graduate program admission

BIOE 5810. Design of Biomedical Instrumentation. (4 Hours)
Investigates the principles of biology and engineering underlying the design and use of biomedical instrumentation. Topics include design of a broad range of instrumentation and monitoring devices, sensors, and integrated systems. Graduate students interested in taking this course should have completed an equivalent introductory circuits course.

Prerequisite(s): (BIOE 2350 with a minimum grade of D-; BIOE 2365 with a minimum grade of D-) or graduate program admission

BIOE 5820. Biomaterials. (4 Hours)
Offers a broad overview of the field of biomaterials (materials used in medical devices that interact with living tissues). Introductory lectures cover biomaterials and their translation from the laboratory to the medical marketplace. Discusses important biomaterials terminology and concepts. Emphasizes material structure-property-function-testing relationships and discusses specific materials used in medical devices and drug delivery. Concludes with introductions to topics in the field, such as biomaterials-tissue interactions, tissue engineering, and regulatory requirements. Considers principles of device design as related to the selection and application of biomaterials.

Prerequisite(s): (CHEM 1151 with a minimum grade of D- or CHEM 1161 with a minimum grade of D-; CHEM 1211 with a minimum grade of D- or CHEM 1217 with a minimum grade of D-) or graduate program admission

BIOE 5850. Design of Implants. (4 Hours)
Uses an interdisciplinary approach to evaluate how a team designs medical implants to meet unmet clinical needs. Covers biomaterials, interfacial phenomena/surface science, phenomena/surface science, the lymphatic system, immune response, aging, mechanical factors, sterilization methods, and human factors. Presents exogenous factors, including intellectual property, regulatory requirements, affordability, product liability, and bioethics. The class is divided into teams that design proprietary medical devices using a unit processes/case study approach presented by experts with firsthand experience in meeting unmet market needs.

Prerequisite(s): BIOE 5820 (may be taken concurrently) with a minimum grade of D-

BIOE 6000. Principles of Bioengineering. (1 Hour)
Covers the fundamentals of bioengineering research topics and methodology for master's-level bioengineering students. Internal and external speakers discuss general topics in bioengineering, including the medical device qualification and regulatory environment, tissue engineering, cell engineering, mechanobiology, drug delivery, bioimaging, neuromotor control, and effective design of experiments. Each student is expected to read, critically evaluate, and present research in a peer-reviewed bioengineering journal article.

BIOE 6100. Medical Physiology. (4 Hours)
Designed to provide bioengineering students with a working knowledge of the integrated behavior of organs and systems in the human body. As such, the student is provided with a comprehensive and intense immersion in each physiological subsystem with the expectation that he or she display knowledge of each at the level equivalent to that of a second-year medical student following his or her exposure to physiology. The specific subsystems covered are muscle physiology, cardiovascular physiology with ECG interpretation, pulmonary physiology with gas exchange mechanics and ventilation/perfusion, renal physiology and water balance, regulation of pH, gastrointestinal physiology, temperature regulation and energy balance, endocrine systems, and reproductive systems. The course does not cover neurophysiology.

BIOE 6200. Mathematical Methods in Bioengineering. (4 Hours)
Offers an overview of quantitative techniques that students will encounter in their research, providing a language and a foundation for more specialized study. Introduces basic concepts from linear algebra, ordinary and partial differential equations, transforms, function approximation, probability, statistics, and numerical computation, illustrated by applications in biology and medicine.

BIOE 6962. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

BIOE 7000. Principles of Bioengineering. (4 Hours)
Designed to introduce new graduate bioengineering students to the fundamentals of bioengineering research topics and methodology. Includes outside speakers to discuss general topics in bioengineering. Examples of course topics include the medical device qualification and regulatory environment, tissue engineering, cell engineering, mechanobiology, drug delivery, bioimaging, neuromotor control, effective design of experiments, writing research proposals for the National Institutes of Health (NIH) and how to evaluate and write a peer-reviewed journal article, etc. Expects students to read, critically evaluate, and present the research in a bioengineering journal article. Students are then expected to extend their article into a hypothesis-driven proposal in NIH format with an oral defense of the proposal.

BIOE 7200. Special Topics in Cell and Tissue Engineering. (4 Hours)
Offers various topics of interest in cell and tissue engineering for advanced study depending upon the interests of the faculty and students. May be repeated up to two times.

BIOE 7374. Special Topics in Bioengineering. (4 Hours)
Offers topics of current interest in bioengineering. May be repeated without limit.
BIOE 7390. Seminar. (0 Hours)
Presents topics of an advanced nature by staff, outside speakers, and students in the graduate program. This course must be attended every semester by all full-time graduate students. May be repeated without limit.

BIOE 7391. Student Seminar. (0 Hours)
Offers students an opportunity to practice clear and concise oral communication of research to an audience of people with a variety of skills and differing expertise. This is an essential skill for anyone seeking a career in scientific research and beyond. It differs from communicating research to a group meeting or a conference presentation, which is comprised of audiences of fellow specialists who are already familiar with the field and its specialized terminology. Students instead present to a diverse, interdisciplinary group of peers (i.e., the Department of Bioengineering and other members of the Northeastern community).

BIOE 7890. Master’s Project. (4 Hours)
Offers analytical and/or experimental work leading to a written report and a final short presentation by the end of the semester.

BIOE 7962. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

BIOE 7978. Independent Study. (1-4 Hours)
Offers theoretical or experimental work under individual faculty supervision. May be repeated for up to 16 total credits.

BIOE 7990. Thesis. (4 Hours)
Offers analytical, research, and/or experimental work conducted under the auspices of the department. May be repeated once.

BIOE 7996. Thesis Continuation. (0 Hours)
Offers continued dissertation work conducted under the supervision of a departmental faculty member.

BIOE 8960. Exam Preparation—Doctoral. (0 Hours)
Offers students an opportunity to prepare for the PhD qualifying exam under faculty supervision. Intended for students who have completed all required PhD course work and have not yet achieved PhD candidacy; students who have not completed all required PhD course work are not allowed to register for this course. May be repeated once.

BIOE 8986. Research. (0 Hours)
Offers students an opportunity to conduct full-time research under faculty supervision. May be repeated without limit.

BIOE 9000. PhD Candidacy Achieved. (0 Hours)
Indicates successful completion of program requirements for PhD candidacy.

BIOE 9986. Research. (0 Hours)
Offers students an opportunity to conduct full-time research under faculty supervision. May be repeated without limit.

BIOE 9990. Dissertation Term 1. (0 Hours)
Offers theoretical and/or experimental work conducted under the auspices of the department.

Prerequisite(s): BIOE 9000 with a minimum grade of S

BIOE 9991. Dissertation Term 2. (0 Hours)
Offers dissertation supervision by members of the department.

Prerequisite(s): BIOE 9990 with a minimum grade of S

BIOE 9996. Dissertation Continuation. (0 Hours)
Offers continued dissertation work conducted under the supervision of a departmental faculty member.

Prerequisite(s): BIOE 9991 with a minimum grade of S or Dissertation Check with a score of REQ