The Department of Bioengineering offers students a broad education built on fundamentals in science, mathematics, and engineering, with a focus on the biological applications of engineering. The program is designed to provide a rigorous engineering training along with a comprehensive understanding of the biological constraints intrinsic to designing artificial systems to interface with, augment, replace, repair, or monitor living systems. These constraints depend on the properties of the biological system involved and the functionality that is being created. The living system may be the human body; an ecosystem; or, more broadly, a bioreactor, tissue culture system, or any system with living components. The presence of naturally occurring biological tissue places special constraints on the design and implementation of artificial constructs and their interface to living systems. Bioengineers are engineers with comprehensive understanding of the engineering requirements intrinsic to working within a biological context.

Bioengineering is a relatively new field driven by 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. With that in mind, the bioengineering program has been designed to provide a rigorous engineering education that endows a broad understanding of the quantitative analysis of biological systems and a deep expertise in one of four areas of bioengineering. The curriculum is structured around a core of six courses that quantitatively analyze biological systems from multiple points of view. The core provides the fundamentals of quantitative physiology, electrical engineering in the context of excitable tissues; basics of mechanical engineering in the context of the musculoskeletal system; and thermodynamics, heat transfer, and fluids mechanics within the context of physiological systems. On completion of the core, students choose one of four concentrations (bioimaging and signal processing, cell and tissue engineering, biomechanics, or biomedical devices), which provides the opportunity to develop a deep level of expertise in an important area of bioengineering. The curriculum culminates with a two-semester capstone course to provide experience in design and implementation of a novel bioengineering project.

Program Objectives
Program educational objectives describe what graduates are expected to attain within a few years after graduation. The program educational objectives of the BS in bioengineering program are to prepare graduates to:

- Be technically proficient, innovative, and rigorous problem solvers who excel in the professional practice of engineering while maintaining a high standard of professional and ethical responsibility.
- Be multifaceted and able to work with and demonstrate leadership in multidisciplinary teams.
- Pursue advanced degrees in engineering, medicine, and other fields that leverage their technical and problem-solving skills.

Mission of the Department
The program is committed to providing a multidisciplinary education, making connections from the classroom and laboratory to research, co-op, and co-curricular experiences. The curriculum provides fundamentals in mathematics, physical sciences, and engineering science; laboratory experiences; as well as an emphasis on the special considerations intrinsic to design within a biological context. Through the university's general educational requirements, students gain awareness of the impact of engineering decisions in a broader societal and ethical context. The department encourages professional development through active participation and leadership in student organizations, societies, and departmental activities. As a result, the bioengineering program is designed to prepare students for success in industrial careers; graduate programs; or professional medical, law, and business schools.

Overview of Programs Offered
The Department of Bioengineering offers a Bachelor of Science in Bioengineering. Five-year Bachelor of Science in Bioengineering/Master of Science programs are also available in the following Master of Science disciplines: bioimaging and signal processing, cell and tissue engineering, biomedical devices, and biomechanics.

Other Programmatic Features
By participating in our cooperative education program, our graduates will have an opportunity to explore what career objectives fit their own skills and interests. The goal of this component of our program is to offer students valuable professional experience and contacts that will help get them started in their professional career, as well as to develop career management skills. The co-op program parallels the academic program in level of responsibility and sophistication.

The department also offers significant research opportunities throughout all fields of bioengineering, including participating in research centers based in our department and college, as well as new interdisciplinary graduate and professional master’s programs.

The bioengineering curriculum is an innovative plan that is continuously and carefully assessed and evaluated to ensure that graduates of the program are fully prepared for success as professional bioengineers and are prepared for graduate or professional school.

Programs
Bachelor of Science in Bioengineering (BSBioE)
- Bioengineering (http://catalog.northeastern.edu/undergraduate/engineering/bioengineering/bsbioe)

Accelerated Programs
See Accelerated Bachelor/Graduate Degree Programs (http://catalog.northeastern.edu/undergraduate/engineering/accelerated-bachelor-graduate-degree-programs/#programtext)
Bioengineering Courses

BIOE 1990. Elective. 1-4 Hours.
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

BIOE 2000. Introduction to Engineering Co-op Education. 1 Hour.
Seeks to prepare students for the first co-op experience. Focuses on skills that provide a basis for successful co-op engagement including expectations and requirements, an introduction to professional credentials, resume construction, self-assessment and goal setting, interviewing, professional and co-op ethics, issues of diversity in the workplace community, academic planning and decision making, and an introduction to career portfolios.

BIOE 2350. Biomechanics. 4 Hours.
Designed to acquaint students with concepts of stress, strain, and constitutive laws as applied to problems in biomechanics. Introduces rigid body and deformable body mechanics. Focuses on basic foundations of solid mechanics using vectors and tensors. Illustrative examples from tissue and cell biomechanics are given where appropriate.

BIOE 2355. Quantitative Physiology for Bioengineers. 4 Hours.
Introduces engineering and science students to core knowledge and understanding of physiological systems and processes. Focuses on quantitative analysis of human physiological systems. Topics include the physical and chemical foundations of physiology; coupled forces and flows; electrical, mechanical, and chemical potentials and their conjugated fluxes; and the physiology of excitable tissue. Examines cell structure, function, and homeostasis with a particular focus on membrane transport, osmotic pressure, cell signaling, and cellular energetics.

BIOE 2365. Bioengineering Measurement, Experimentation, and Statistics. 4 Hours.
Introduces the fundamentals of biomedical data acquisition and statistical analysis. Engineering statistics topics include descriptive statistics, probability distributions, hypothesis testing, analysis of variance, and experiment design. Applies these statistical topics by analyzing data obtained from laboratory exercises in BIOE 2366. Laboratory exercise topics include cell culture, mechanical testing, modeling medical imaging data, 3D printing, and bioprinting. Emphasizes using MATLAB software to analyze data on the computer.

BIOE 2366. Lab for BIOE 2365. 1 Hour.
Offers associated laboratory exercises for BIOE 2365. Requires lab reports from all students.

BIOE 2949. Introductory Directed Research in Bioengineering. 4 Hours.
Offers an opportunity to pursue project and other independent inquiry opportunities under faculty supervision for first- and second-year students. The course is initiated with a student-developed proposal, including expected learning outcomes and research products, which is approved by a faculty member in the department. Permission of instructor required.

BIOE 2990. Elective. 1-4 Hours.
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

BIOE 3000. Professional Issues in Engineering. 1 Hour.
Offers students an opportunity to reflect on both academic and co-op experiences in the context of planning for the senior year and beyond. Topics include professional and ethical issues; resolving ethical conflicts; awareness of engineers as professionals in a diverse world; strengthening decision-making skills; career portfolios; and lifelong learning needs, goals, and strategies. Students reflect upon issues of diversity from their experience in the university and in their cooperative education placements. Explores the role of different work and learning styles and diverse personal characteristics in the workplace and the classroom. Professional issues include impact of the cultural context, both in the United States and around the world, on the client, government relations, and workplace.

BIOE 3210. Bioelectricity. 4 Hours.
Discusses principles of circuits, signals, and systems in the context of operating principles of bioelectrical systems at multiple physiological scales. Offers students an opportunity to obtain the fundamental background required to interface biological systems with circuits and sensors for measurements. Covers fundamentals of structure and function of electrically active tissue including nerves, brain, and muscle, including heart.

BIOE 3310. Transport and Fluids for Bioengineers. 4 Hours.
Covers the fundamental principles of processes and systems in which mass, energy, and momentum are transported in typical biological problems. Emphasizes momentum transport for incompressible and compressible fluids (fluid flow) and energy transport. The methods taught are relevant to the analysis of physiological systems, processing, and separation of biological materials.

BIOE 3380. Biomolecular Dynamics and Control. 4 Hours.
Focuses on the principles of thermodynamics and kinetics applied to the analysis and design of biomolecular systems. Covers foundational topics—such as mass and energy balances, chemical equilibria, and enzyme kinetics—in a biological context. Introduces the role of feedback and feed-forward control in biomolecular networks, emphasizing basic analytical and computational methods, including the use of MATLAB, for analyzing how these regulatory structures affect the dynamics of small-scale, prototypical networks.

BIOE 3990. Elective. 1-4 Hours.
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

BIOE 4790. Capstone Design 1. 4 Hours.
Offers the first in a two-course sequence of capstone design. Introduces principles of engineering design and applies them to the design of bioengineered devices. Topics consist of ethics, cost engineering, research methods, intellectual property, technical report writing, and FDA design control—including inputs, outputs, verification, validation, and design history files. Students are formed into teams and paired with a faculty advisor and supporter. Project support can be departmental, industrial, or external. Students defend a preliminary design project proposal in written and oral form before a faculty jury.

BIOE 4792. Capstone Design 2. 4 Hours.
Continues BIOE 4790. Offers students an opportunity to apply design principles to create a device or process to solve a relevant bioengineering problem. Teams develop, construct, and evaluate prototypes under real-world fiscal, regulatory, and safety conditions. Progress is monitored through a series of oral presentations in design gate review meetings. The design process is documented in a design history file that is reviewed throughout the course. Requires students to complete a working prototype or simulation, as appropriate, and a final written report.
BIOE 4970. Junior/Senior Honors Project 1. 4 Hours.
Focuses on in-depth project in which a student conducts research or produces a product related to the student's major field. Combined with Junior/Senior Project 2 or college-defined equivalent for 8-credit honors project. May be repeated without limit.

BIOE 4971. Junior/Senior Honors Project 2. 4 Hours.
Focuses on second semester of in-depth project in which a student conducts research or produces a product related to the student's major field. May be repeated without limit.

BIOE 4990. Elective. 1-4 Hours.
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

BIOE 4991. Research. 4 Hours.
Offers an opportunity to conduct research under faculty supervision. May be repeated without limit.

BIOE 4992. Directed Study. 1-4 Hours.
Offers theoretical or experimental work under the direction of members of the department under a chosen topic. Course content depends on instructor. May be repeated without limit.

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 5100. 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. Requires prior completion of BIOL 1117 or equivalent.

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.

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.

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 5320. Advanced Biomedical Measurements and Instrumentation. 4 Hours.
Offers a comprehensive analysis of the principles underlying biomedical instrumentation, including ECG, EEG, CAT scanning, MRI imaging, and other biomedical laboratory tools. Includes associated laboratory exercises within the course material.

BIOE 5380. Advanced Biomolecular Dynamics and Control. 4 Hours.
Applies the foundational principles of thermodynamics and kinetics to the analysis and design of biomolecular systems. Briefly reviews mass and energy balances, chemical equilibria, and enzyme kinetics. Emphasizes more advanced topics, such as the effect of external fields (e.g., mechanical forces, electrical potential) on biomolecular reaction equilibria and kinetics, the spatiotemporal dynamics of reactions in the context of mass transport, and the effect of spatial compartmentation on biomolecular propagation of information. Examines the role of feedback and feedforward control in biomolecular networks, focusing on analyzing how these regulatory structures affect adaptation and oscillatory behavior of small- and large-scale networks. Intended for students in the College of Engineering and in the College of Science. Students from other disciplines are invited to enroll—requires prior knowledge of differential and integral calculus, systems of ordinary differential equations and linear algebra, coding in Matlab, and familiarity with chemical kinetics and thermodynamics.

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.

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.

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.
**BIOE 5630. 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.

**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; biomolecular mechanics and molecular motors; and experimental methods for probing structures at the tissue, cellular, and molecular levels.

**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-mechanical driving forces. Applications include transport in biological tissues and across membranes, manipulation of cells and biomolecules, and microfluidics.

**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.

**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.

**BIOE 5850. Design of Implants. 4 Hours.**
Studies the use of cell-matrix control volumes; stress analysis in design processes; anatomical fit, shape, and size of implants; biomaterials; surgical implantation procedures; testing for safety and efficacy; and design of clinical trials. Covers applications to orthopedic devices, soft tissue implants, artificial organs, and dental implants.