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/engineering/leadership/) in combination with the MS degree.

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

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 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 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.

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/biomaterials 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.

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 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.
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 tomography; and therapeutic interventional techniques, including photodynamic therapy, laser thermal therapies, and fluorescence-guided surgeries. EECE 5648 and BIOE 5648 are cross-listed.

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. Graduate students interested in taking this course should have completed an equivalent introductory circuits course.

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.

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. Requires prior completion of BIOL 1117 or equivalent.

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 6964. Co-op Work Experience. 0 Hours.
Provides eligible students with an opportunity for work experience. May be repeated without limit.

BIOE 6965. Co-op Work Experience Abroad. 0 Hours.
Provides eligible students with an opportunity for work experience abroad. 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 7100. Special Topics in Biomedical Imaging and Signal Processing. 4 Hours.
Offers various topics of interest in biomedical imaging and signal processing for advanced study depending on the interests of the faculty and students. May be repeated up to two times.

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 7300. Special Topics in Biomechanics. 4 Hours.
Offers various topics of interest in biomechanics for advanced study depending upon the interests of the faculty and students. May be repeated up to two times.
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 7400. Special Topics in Biomedical Devices. 4 Hours.
Offers various topics of interest in biomedical devices for advanced study depending upon the interests of the faculty and students. May be repeated up to two times.

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. Dissertation 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 996. Research. 0 Hours.
Offers students an opportunity to conduct full-time research under faculty supervision. May be repeated without limit.

BIOE 9990. Dissertation. 0 Hours.
Offers theoretical and/or experimental work conducted under the auspices of the department. Must be taken in two consecutive semesters. May be repeated once.

BIOE 9996. Dissertation Continuation. 0 Hours.
Offers continued dissertation work conducted under the supervision of a departmental faculty member. May be repeated without limit.