Bioengineering, PhD

Biology can inspire engineering. Increasingly, discoveries in the life sciences reveal processes, complexity, and control without analogy in the world of traditional engineering. Current methods of producing nanoscale control over molecules cannot reproduce the organization found in even the simplest organisms. Energy capture, robust control, remediation, and self-assembly are all employed by biosystems with efficiency unparalleled by anything in today's laboratories. At the same time, traditional engineering disciplines struggle to find new approaches to the complex challenges of 21st-century technology. The last fifty years of basic life science research have gradually revealed the layers of complexity intrinsic to biological processes, unmasking the fundamental underpinnings on which biological systems are constructed. Bioinspired engineering has the potential to transform the technological landscape of the 21st century. Astonishingly, it represents merely one of the myriad opportunities presented at the interface of biology and engineering.

The field of bioengineering is broad and includes all research at the interface of engineering and biology—this includes bioprocesses, environmental microbiology, biomaterials and tissue engineering, bioelectricity, biomechanics, biomedical and biological imaging, nanotechnology in medicine and the environment, and engineering design for human interfacing. At Northeastern University, bioengineering PhD students have an opportunity to be trained to appreciate advances in bioengineering across a wide range of disciplines while they perform highly focused and cutting-edge bioengineering research with one of our faculty members.

The interdisciplinary PhD in Bioengineering program reflects departmental research strengths in multiple areas. Students accepted to the bioengineering program will undertake a rigorous core curriculum in basic bioengineering science, followed by a flexible selection of electives tailored to their dissertation research.

There are four key areas of research strength in our department.

Area 1—Imaging, Instrumentation, and Signal Processing

The Imaging, Instrumentation, and Signal Processing track reflects Northeastern's outstanding research profile in developing new technologies for visualizing biological processes and disease. Our department has active federally funded research spanning a broad spectrum of relevant areas in instrument design, contrast agent development, and advanced computational modeling and reconstruction methods. Example research centers include the Chemical Imaging of Living Systems Institute, the Translational Biophotonics Cluster, and the B-SPIRAL signal processing group.

Area 2—Biomechanics, Biotransport, and Mechanobiology

Motion, deformation, and flow of biological systems in response to applied loads elicit biological responses at the molecular and cellular levels that support the physiological function of tissues and organs and drive their adaptation and remodeling. To study these complex interactions, principles of solid, fluid, and transport mechanics must be combined with measures of biological function. The Biomechanics, Biotransport, and Mechanobiology track embraces this approach and leverages the strong expertise of Northeastern faculty attempting to tie applied loads to biological responses at multiple length and time scales.

Area 3—Molecular, Cell, and Tissue Engineering

Principles for engineering living cells and tissues are essential to address many of the most significant biomedical challenges facing our society today. These application areas include engineering biomaterials to coax and enable stem cells to form functional tissue or to heal damaged tissue; designing vehicles for delivering genes and therapeutics to reach specific target cells to treat a disease; and uncovering therapeutic strategies to curb pathological cell behaviors and tissue phenotypes. At a more fundamental level, the field is at the nascent stages of understanding how cells make decisions in complex microenvironments and how cells interact with each other and their surrounding environment to organize into complex three-dimensional tissues. Advances will require multiscale experimental, computational, and theoretical approaches spanning molecular-cellular-tissue levels and integration of molecular and physical mechanisms, including the role of mechanical forces.

Area 4—Computational and Systems Biology

We aim to understand the rules governing emergent systems-level behavior and to use these rules to rationally engineer biological systems. We make quantitative measurements, often at the single-cell level, to test different conceptual frameworks and discriminate among different classes of models. Our faculty are leaders in developing and applying both theoretical methods, e.g., control theory, and experimental methods, e.g., single-cell proteomics by mass-spec, to biological systems. At the organ and tissue levels, 3D scans acquired through medical imaging methods (e.g., US, CT, MRI, etc.) may be used to reconstruct virtual models of targeted systems. Noninvasive measures of the physiological function can then inform numerical simulations to predict the behavior of biological systems over time, with the goal of estimating the progression toward pathological endpoints or to test the efficacy of targeted surgical procedures and pharmaceutical treatments (e.g., drug delivery).

Degree Requirements

Completion of the PhD degree requires students to successfully complete the following requirements:

- Curriculum: The curriculum comprises a strong core of fundamental courses that is coupled with flexible choices of restricted and unrestricted technical electives to provide depth in a particular field of study. The detailed course requirements are outlined below.

For students possessing a baccalaureate in a suitable quantitative or technical field before entering the PhD program, the required course distribution is shown in the table below:

Requirements	Credits
Required core courses	12
Restricted technical electives	8
Unrestricted technical electives	12
Advanced seminar (four semesters)	
Dissertation	
Minimum semester hours required	32

The curriculum for PhD students with "advanced standings," i.e., students with an MS degree in relevant engineering areas awarded at a qualified institution, will be selected from the available core and elective courses under the guidance of the program director and the student's primary advisor. Completion of the PhD degree with an advanced standing requires a minimum of 16 semester hours of coursework to be approved by the graduate director and a completed PhD dissertation.

Requirements	Credits
Advisor-approved coursework	16
Advanced seminar (four semesters)	
Dissertation	
Minimum semester hours required	16

- Qualifying exam (written and oral): To qualify to continue in the PhD program, students must pass the bioengineering qualifying examination in the most relevant of the four department research areas. Students will prepare a six-page written document that will be distributed to the committee before the oral examination. Details of the formal qualification exam procedure and timing are available in the Graduate Handbook (https://bioe.northeastern.edu/community/resources-for-current-students/). In addition, satisfactory research progress and academic standing are required to pass the exam. The qualifying exam is normally taken in the first semester of the student's second year.
- Qualifying exam committee: The qualifying examination committee is composed of three members of the Department of Bioengineering faculty. At least two of three committee members will be from the student's research area. The student's primary research advisor may not sit on the qualifying exam committee.
- PhD dissertation committee: Students normally form their dissertation committee within two years of joining the PhD program. The dissertation committee is composed of a minimum of three members, two of whom must be core faculty from the Department of Bioengineering. The student's primary advisor will be a member of and chair the dissertation committee. This advisor must be a member of the core bioengineering faculty or a faculty member from another department who has an affiliation with the bioengineering department. Students are required to meet annually with their PhD dissertation committee to ensure satisfactory research progress.
- Annual committee meetings and dissertation proposals: PhD students must hold their first committee meetings no later than their third year. The first committee meeting requires the student to write a dissertation proposal in the form of an NIH-style R21 proposal research plan that will be distributed to their dissertation committee at least one week prior to the meeting. Thereafter, students are expected to hold annual progress updates with their committee. At the penultimate committee meeting (which must be held at least four months prior to the dissertation defense), the student will prepare and present a final proposal document to the committee. Successful defense of this proposal will allow the student to progress to the PhD dissertation defense.
- PhD dissertation defense: PhD candidates must satisfactorily complete and defend a dissertation describing original research in bioengineering in an open presentation to the Northeastern bioengineering community, followed by a closed meeting with their dissertation committee in which they are expected to defend their work and answer all relevant questions regarding that work, its significance, and its relationship to ongoing work across the broader research community.
- Dissertation course requirements: After achieving PhD candidacy by passing the qualifying exam, the doctoral candidate, in consultation with their research advisor, must register in two consecutive semesters (may include full summer term) for Dissertation Term 1 (BIOE 9990) and Dissertation Term 2 (BIOE 9991). Upon completion of this sequence, the student must then register for Dissertation Continuation (BIOE 9996) every semester (in each fall and spring term and also in the summer term if summer is the student's last semester) until the dissertation is completed. Students may not register for Dissertation Continuation (BIOE 9996) until they fulfill the two-semester sequence of Dissertation Term 1 (BIOE 9990) and Dissertation Term 2 (BIOE 9991).

PhD students who have completed the majority of their coursework and not yet reached PhD candidacy should register for Exam Preparation—Doctoral (BIOE 8960) in a section for which their research or academic advisor is listed as the instructor in the online registration system.

Program Requirements

Complete all courses and requirements listed below unless otherwise indicated.

Milestones

Annual review
Qualifying examination (within two years of entry)
Dissertation committee

Annual committee meetings
Area examination (dissertation prospectus/proposal)
Dissertation defense

Core Requirements

Code	Title	Hours
Seminar		
BIOE 7390	Seminar (Register and complete two semesters)	0
BIOE 7391	Student Seminar (Register and complete once in second year and once in fourth year)	0
Required Core		
BIOE 6100	Medical Physiology	4
BIOE 6200	Mathematical Methods in Bioengineering	4
BIOE 7000	Principles of Bioengineering	4
Restricted Bioengineering Technical Electives		
Complete 8 semester hours from the following:		8
BIOE 5235	Biomedical Imaging	
BIOE 5410	Molecular Bioengineering	
BIOE 5420	Cellular Engineering	
BIOE 5430	Principles and Applications of Tissue Engineering	
BIOE 5440	The Cell as a Machine	
BIOE 5630	Physiological Fluid Mechanics	
BIOE 5648	Biomedical Optics	
BIOE 5650	Multiscale Biomechanics	
BIOE 5656	Fields, Forces, and Flows in Biological Systems	
BIOE 5810	Design of Biomedical Instrumentation	
BIOE 5820	Biomaterials	
ME 5665	Musculoskeletal Biomechanics	
Technical Electives		
Complete 12 semester hours from the Elective Course List.		12

Elective Course List

Code	Title	Hours
BIOE 5235	Biomedical Imaging	
BIOE 5250	Design, Manufacture, and Evaluation of Medical Devices	
BIOE 5410	Molecular Bioengineering	
BIOE 5420	Cellular Engineering	
BIOE 5430	Principles and Applications of Tissue Engineering	
BIOE 5440	The Cell as a Machine	
BIOE 5450	Stem Cell Engineering	
BIOE 5630	Physiological Fluid Mechanics	
BIOE 5640	Computational Biomechanics	
BIOE 5648	Biomedical Optics	
BIOE 5650	Multiscale Biomechanics	
BIOE 5656	Fields, Forces, and Flows in Biological Systems	
BIOE 5710	Experimental Systems and Synthetic Bioengineering	
BIOE 5720	Physical Bioengineering	
BIOE 5750	Modeling and Inference in Bioengineering	
BIOE 5760	Method and Logic in Systems Biology and Bioengineering	
BIOE 5800	Systems, Signals, and Controls for Bioengineers	
BIOE 5810	Design of Biomedical Instrumentation	
BIOE 5820	Biomaterials	
BIOL 5307	Biological Electron Microscopy	
BIOL 5543	Stem Cells and Regeneration	
BIOL 5601	Multidisciplinary Approaches in Motor Control	

BIOL 6300	Biochemistry
BIOL 6301	Molecular Cell Biology
BIOL 6401	Research Methods and Critical Analysis in Molecular Cell Biology
CAEP 6202	Research, Evaluation, and Data Analysis
CHEM 5612	Principles of Mass Spectrometry
CHEM 5620	Protein Chemistry
CHEM 5621	Principles of Chemical Biology for Chemists
CHEM 5638	Molecular Modeling
CHEM 7247	Advances in Nanomaterials
CHEM 7317	Analytical Biotechnology
CHME 5630	Biochemical Engineering
CS 5100	Foundations of Artificial Intelligence
CS 5200	Database Management Systems
CS 5310	Computer Graphics
CS 5330	Pattern Recognition and Computer Vision
CS 5335	Robotic Science and Systems
CS 5400	Principles of Programming Language
CS 5600	Computer Systems
CS 5800	Algorithms
CS 6140	Machine Learning
CS 6200	Information Retrieval
CS 6410	Compilers
EECE 5606	Micro- and Nanofabrication
EECE 5642	Data Visualization
EECE 7200	Linear Systems Analysis
EECE 7202	Electromagnetic Theory 1
EECE 7203	Complex Variable Theory and Differential Equations
EECE 7204	Applied Probability and Stochastic Processes
EECE 7205	Fundamentals of Computer Engineering
EECE 7211	Nonlinear Control
EECE 7213	System Identification and Adaptive Control
EECE 7214	Optimal and Robust Control
EECE 7271	Computational Methods in Electromagnetics
EECE 7310	Modern Signal Processing
EECE 7323	Numerical Optimization Methods
EECE 7337	Information Theory
EECE 7352	Computer Architecture
EECE 7353	VLSI Design
EECE 7364	Mobile and Wireless Networking
EECE 7368	High-Level Design of Hardware-Software Systems
IE 7315	Human Factors Engineering
ME 5650	Advanced Mechanics of Materials
ME 5654	Elasticity and Plasticity
ME 5655	Dynamics and Mechanical Vibration
ME 5657	Finite Element Method
ME 5658	Continuum Mechanics
ME 5659	Control Systems Engineering
ME 5665	Musculoskeletal Biomechanics
ME 6200	Mathematical Methods for Mechanical Engineers 1
ME 6260	Introduction to Microelectromechanical Systems (MEMS)
ME 7238	Advanced Finite Element Method
ME 7275	Essentials of Fluid Dynamics
NNMD 5470	Nano/Biomedical Commercialization: Concept to Market
OR 6205	Deterministic Operations Research

PHSC 5100	Concepts in Pharmaceutical Science
PHSC 6218	Biomedical Chemical Analysis
PHSC 6290	Biophysical Methods in Drug Discovery
PHYS 7301	Classical Mechanics/Math Methods
PHYS 7321	Computational Physics
PHYS 7741	Biological Physics 2
PMST 6250	Advanced Physical Pharmacy
PMST 6252	Pharmacokinetics and Drug Metabolism
PMST 6254	Advanced Drug Delivery Systems
PT 5138	Neuroscience
PT 5139	Lab for PT 5138
PT 5150	Motor Control, Development, and Learning
PT 5151	Lab for PT 5150
SLPA 6301	Speech Science

Dissertation

Code	Title	Hours
Complete the following two courses:		
BIOE 9990	Dissertation Term 1	
BIOE 9991	Dissertation Term 2	

Program Credit/GPA Requirements

32 total semester hours required
Minimum 3.000 GPA required

Advanced Entry Program Requirements

Complete all courses and requirements listed below unless otherwise indicated.

Milestones

Annual review
Qualifying examination (within two years of entry)
Dissertation committee
Area examination (dissertation prospectus/proposal)
Dissertation defense

Core Requirements

Code	Title	Hours
Seminar		
BIOE 7390	Seminar (Register and complete two semesters)	0
BIOE 7391	Student Seminar (Register and complete once in second year and once in fourth year)	0
Approved Coursework		
Complete 16 semester hours from the Elective Course List.		16

Elective Course List

Code	Title	Hours
BIOE 5235	Biomedical Imaging	
BIOE 5250	Design, Manufacture, and Evaluation of Medical Devices	
BIOE 5410	Molecular Bioengineering	
BIOE 5420	Cellular Engineering	
BIOE 5430	Principles and Applications of Tissue Engineering	
BIOE 5440	The Cell as a Machine	
BIOE 5450	Stem Cell Engineering	
BIOE 5630	Physiological Fluid Mechanics	
BIOE 5640	Computational Biomechanics	
BIOE 5648	Biomedical Optics	
BIOE 5650	Multiscale Biomechanics	

BIOE 5656	Fields, Forces, and Flows in Biological Systems
BIOE 5810	Design of Biomedical Instrumentation
BIOE 5820	Biomaterials
BIOE 7200	Special Topics in Cell and Tissue Engineering
BIOL 5307	Biological Electron Microscopy
BIOL 5543	Stem Cells and Regeneration
BIOL 5601	Multidisciplinary Approaches in Motor Control
BIOL 6300	Biochemistry
BIOL 6301	Molecular Cell Biology
BIOL 6401	Research Methods and Critical Analysis in Molecular Cell Biology
CAEP 6202	Research, Evaluation, and Data Analysis
CHEM 5620	Protein Chemistry
CHEM 5621	Principles of Chemical Biology for Chemists
CHEM 5638	Molecular Modeling
CHEM 7247	Advances in Nanomaterials
CHEM 7317	Analytical Biotechnology
CHME 5630	Biochemical Engineering
CS 5100	Foundations of Artificial Intelligence
CS 5200	Database Management Systems
CS 5310	Computer Graphics
CS 5330	Pattern Recognition and Computer Vision
CS 5335	Robotic Science and Systems
CS 5400	Principles of Programming Language
CS 5600	Computer Systems
CS 5800	Algorithms
CS 6140	Machine Learning
CS 6200	Information Retrieval
CS 6410	Compilers
EECE 5606	Micro- and Nanofabrication
EECE 5642	Data Visualization
EECE 7200	Linear Systems Analysis
EECE 7202	Electromagnetic Theory 1
EECE 7203	Complex Variable Theory and Differential Equations
EECE 7204	Applied Probability and Stochastic Processes
EECE 7205	Fundamentals of Computer Engineering
EECE 7211	Nonlinear Control
EECE 7213	System Identification and Adaptive Control
EECE 7214	Optimal and Robust Control
EECE 7271	Computational Methods in Electromagnetics
EECE 7310	Modern Signal Processing
EECE 7323	Numerical Optimization Methods
EECE 7337	Information Theory
EECE 7352	Computer Architecture
EECE 7353	VLSI Design
EECE 7364	Mobile and Wireless Networking
EECE 7368	High-Level Design of Hardware-Software Systems
IE 7315	Human Factors Engineering
ME 5650	Advanced Mechanics of Materials
ME 5654	Elasticity and Plasticity
ME 5655	Dynamics and Mechanical Vibration
ME 5657	Finite Element Method
ME 5658	Continuum Mechanics
ME 5659	Control Systems Engineering
ME 5665	Musculoskeletal Biomechanics

ME 6200	Mathematical Methods for Mechanical Engineers 1
ME 6260	Introduction to Microelectromechanical Systems (MEMS)
ME 7238	Advanced Finite Element Method
ME 7275	Essentials of Fluid Dynamics
NNMD 5470	Nano/Biomedical Commercialization: Concept to Market
OR 6205	Deterministic Operations Research
PHSC 5100	Concepts in Pharmaceutical Science
PHSC 6218	Biomedical Chemical Analysis
PHSC 6290	Biophysical Methods in Drug Discovery
PHYS 7301	Classical Mechanics/Math Methods
PHYS 7321	Computational Physics
PHYS 7741	Biological Physics 2
PMST 6250	Advanced Physical Pharmacy
PMST 6252	Pharmacokinetics and Drug Metabolism
PMST 6254	Advanced Drug Delivery Systems
PT 5138	Neuroscience
PT 5139	Lab for PT 5138
PT 5150	Motor Control, Development, and Learning
PT 5151	Lab for PT 5150
SLPA 6301	Speech Science

Dissertation

Code	Title	Hours
Complete the following two courses:		
BIOE 9990	Dissertation Term 1	
BIOE 9991	Dissertation Term 2	

Program Credit/GPA Requirements

16 total semester hours required
Minimum 3.000 GPA required