DEPARTMENT OF BIOLOGICAL ENGINEERING

The mission of the Department of Biological Engineering (BE) is to educate next-generation leaders and to generate and translate new knowledge in a new bioscience-based engineering discipline fusing engineering analysis and synthesis approaches with modern molecular-to-genomic biology. Combining quantitative, physical, and integrative principles with advances in mechanistic molecular and cellular bioscience, biological engineering increases understanding of how biological systems function as both physical and chemical mechanisms; how they respond when perturbed by factors such as medical therapeutics, environmental agents, and genetic variation; and how to manipulate and construct them toward beneficial use. Through this understanding, new technologies can be created to improve human health in a variety of medical applications, and biology-based paradigms can be generated to address many of the diverse challenges facing society across a broad spectrum, including energy, the environment, nutrition, and manufacturing.

The department’s premise is that the science of biology is as important to the development of technology and society in the 21st century as physics and chemistry were in the 20th century, and that an increasing ability to measure, model, and manipulate properties of biological systems at the molecular, cellular, and multicellular levels will continue to shape this development. A new generation of engineers and scientists is learning to address problems through their ability to measure, model, and rationally manipulate the technological and environmental factors affecting biological systems. They are applying not only engineering principles to the analytical understanding of how biological systems operate, especially when impacted by genetic, chemical, physical, infectious, or other interventions; but also a synthetic design perspective to creating biology-based technologies for medical diagnostics, therapeutics, and prosthetics, as well as for applications in diverse industries beyond human health care.

Undergraduate Study

Bachelor of Science in Biological Engineering (Course 20)
The Department of Biological Engineering (BE) (http://web.mit.edu/be) offers an undergraduate curriculum emphasizing quantitative, engineering-based analysis, design, and synthesis in the study of modern biology from the molecular to the systems level. Completion of the curriculum leads to the Bachelor of Science in Biological Engineering and prepares students for careers in diverse fields ranging from the pharmaceutical and biotechnology industries to materials, devices, ecology, and public health. Graduates of the program will be prepared to enter positions in basic research or project-oriented product development, as well as graduate school or further professional study.

The required core curriculum includes a strong foundation in biological and biochemical sciences, which are integrated with quantitative analysis and engineering principles throughout the entire core. Students who wish to pursue the Bachelor of Science in Biological Engineering (http://catalog.mit.edu/degree-charts/biological-engineering-course-20) are encouraged to complete the Biology General Institute Requirement during freshman year and may delay completion of Physics II until the fall term of sophomore year if necessary. The optional subject Introduction to Biological Engineering Design, offered during the spring term of freshman year, provides a framework for understanding the Biological Engineering SB program.

Students are encouraged to take the sophomore fall-term subject 20.110[J] Thermodynamics of Biomolecular Systems. This subject also fulfills an SB degree requirement in Biology. Students are also encouraged to take Organic Chemistry I and Differential Equations during their sophomore year in order to prepare for the introductory biological engineering laboratory subject that provides context for the lecture subjects and a strong foundation for subsequent undergraduate research in biological engineering through Undergraduate Research Opportunities Program projects or summer internships.

The advanced subjects required in the junior and senior years introduce additional engineering skills through lecture and laboratory subjects and culminate in a senior design project. These advanced subjects maintain the theme of molecular to systems–level analysis, design, and synthesis based on a strong integration with biology fundamentals. They also include a variety of restricted electives that allow students to develop expertise in one of six thematic areas: systems biology, synthetic biology, biophysics, pharmacology/toxicology, cell and tissue engineering, and microbial systems. Many of these advanced subjects are jointly taught with other departments in the School of Engineering or School of Science and may fulfill degree requirements in other programs.

Minor in Biomedical Engineering
An interdepartmental Minor in Biomedical Engineering (http://catalog.mit.edu/interdisciplinary/undergraduate-programs/minors/biomedical-engineering) is available to all undergraduate students outside the BE (Course 20) major. See Interdisciplinary Programs (http://catalog.mit.edu/interdisciplinary/undergraduate-programs/minors/biomedical-engineering) for detailed information.

Minor in Toxicology and Environmental Health
The Department of Biological Engineering offers an undergraduate Minor in Toxicology and Environmental Health. The goal of this program is to meet the growing demand for undergraduates to acquire the intellectual tools needed to understand and assess the impact of new products and processes on human health, and to provide a perspective on the risks of human exposure to synthetic and natural chemicals, physical agents, and microorganisms.
Given the importance of environmental education at MIT, the program is designed to be accessible to any MIT undergraduate. The program consists of three required didactic core subjects and one laboratory subject, as well as one restricted elective. The prerequisites for the core subjects are 5.111 / 5.112 Principles of Chemical Science or 3.091 Introduction to Solid-State Chemistry plus Introductory Biology (7.012 / 7.013 / 7.014 / 7.015 / 7.016).

### Core Subjects
- 20.102 Stem Cells in Organogenesis, Carcinogenesis, and Atherogenesis
- 20.104[J] Environmental Cancer Risks, Prevention, and Therapy
- 20.106[J] Systems Microbiology

### Laboratory Core
Select one of the following:
- 5.310 Laboratory Chemistry
- 7.02[J] Introduction to Experimental Biology and Communication
- 20.109 Laboratory Fundamentals in Biological Engineering

### Restricted Electives
Select one of the following:
- 1.080A & 1.080B Environmental Chemistry I and Environmental Chemistry II
- 1.089 Environmental Microbiology
- 5.07[J] Biological Chemistry I
- 7.05 General Biochemistry
- 7.06 Cell Biology
- 7.28 Molecular Biology
- 20.URG Undergraduate Research Opportunities
- 22.01 Introduction to Nuclear Engineering and Ionizing Radiation

### Total Units
60-66

### Inquiries
For further information on the undergraduate programs, see the Biological Engineering website (http://web.mit.edu/be) or contact the BE Academic Office (be-acad@mit.edu), Room 16-267, 617-452-2465.

### Graduate Study

#### Master of Engineering in Biomedical Engineering
The Master of Engineering in Biomedical Engineering (MEBE) program is a five-year program leading to a bachelor’s degree in a science or engineering discipline along with a Master of Engineering in Biomedical Engineering. The program emphasizes the fusion of engineering with modern molecular-to-genomic biology, as in our SB and PhD degree programs. Admission to the MEBE program is open only to MIT undergraduate students, and requires candidates to demonstrate adequate quantitative and engineering credentials through their undergraduate coursework.

In addition to satisfying the requirements of their departmental program, candidates also are expected to complete the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.03</td>
<td>Differential Equations</td>
<td>12</td>
</tr>
<tr>
<td>5.12</td>
<td>Organic Chemistry I</td>
<td>12</td>
</tr>
<tr>
<td>5.07[J]</td>
<td>Biological Chemistry I</td>
<td>12</td>
</tr>
<tr>
<td>or 7.05</td>
<td>General Biochemistry</td>
<td></td>
</tr>
<tr>
<td>Select one of the following:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.005</td>
<td>Thermal-Fluids Engineering I</td>
<td>12</td>
</tr>
<tr>
<td>6.002</td>
<td>Circuits and Electronics</td>
<td></td>
</tr>
<tr>
<td>Select two of the following:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.010</td>
<td>Uncertainty in Engineering</td>
<td>24</td>
</tr>
<tr>
<td>2.086</td>
<td>Numerical Computation for Mechanical Engineers</td>
<td></td>
</tr>
<tr>
<td>3.016</td>
<td>Computational Methods for Materials Scientists and Engineers</td>
<td></td>
</tr>
<tr>
<td>6.041A &amp; 6.041B</td>
<td>Introduction to Probability I and Introduction to Probability II</td>
<td></td>
</tr>
<tr>
<td>18.05</td>
<td>Introduction to Probability and Statistics</td>
<td></td>
</tr>
</tbody>
</table>

Applications to the MEBE program are accepted from students in any of the departments in the School of Engineering or School of Science. Students interested in applying to the MEBE program should submit a standard MIT graduate application by the end of their junior year; they are informed of the decision by the end of that summer.

Additional information on application procedures, objectives, and program requirements can be obtained by contacting the BE Academic Office (be-acad@mit.edu), Room 16-127.

### Program Requirements
In addition to thesis credits, at least 66 units of coursework are required. At least 42 of these subject units must be from graduate subjects. The remaining units may be satisfied, in some cases, with advanced undergraduate subjects that are not requirements in MIT’s undergraduate curriculum. Of the 66 units, a minimum distribution in each of three categories is specified below.

#### Bioengineering Core
Select two of the following:
- 20.410[J] Molecular, Cellular, and Tissue Biomechanics
- 20.420[J] Principles of Molecular Bioengineering

Inquiries
For further information on the undergraduate programs, see the Biological Engineering website (http://web.mit.edu/be) or contact the BE Academic Office (be-acad@mit.edu), Room 16-267.
The Biological Engineering graduate program educates students to use engineering principles in the analysis and manipulation of biological systems, allowing them to solve problems across a spectrum of important applications. The curriculum is inherently interdisciplinary in that it brings together engineering and biology as fundamentally as possible and cuts across the boundaries of the traditional engineering disciplines.

The written part of the doctoral qualifying examinations—focused on the core curriculum—is taken after the second term. The student selects a research advisor, typically by the start of the spring term in the first year, and begins research before the end of that year. The oral part of the doctoral qualifying examinations, which focuses on the student’s area of research, is taken prior to December 1 of the third year. A total of approximately five years in residence is needed to complete the doctoral thesis and other degree requirements.

Students admitted to the Biological Engineering graduate program typically have a bachelor’s or master’s degree in science or engineering. Foundational coursework in biochemistry and molecular cell biology is required, either prior to admission or during the first year of graduate study. Students who have not taken biochemistry previously should take 7.05 General Biochemistry or 5.07[J] Biological Chemistry I, and those who have not taken cell biology previously should take 7.06 Cell Biology, prior to taking the core classes. During their first year, students pursue a unified core curriculum in which engineering approaches are used to analyze biological systems and technologies over a wide range of length and time scales. The subjects in the unified core bring central engineering principles to bear on the operation of biological systems from molecular to cell to tissue/organ/device systems levels. These are then supplemented by electives in the biological sciences and engineering to enhance breadth and depth.

### Core

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.420[J]</td>
<td>Principles of Molecular Bioengineering</td>
<td>12</td>
</tr>
<tr>
<td>20.440</td>
<td>Analysis of Biological Networks (Electives)</td>
<td>15</td>
</tr>
</tbody>
</table>

### Electives

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>One graduate subject in biological science offered by the Department of Biology</td>
</tr>
<tr>
<td></td>
<td>One graduate subject from a restricted set of Biological Engineering offerings beyond the core subjects</td>
</tr>
<tr>
<td></td>
<td>One graduate subject in Biological Engineering</td>
</tr>
<tr>
<td></td>
<td>One additional graduate engineering or science subject</td>
</tr>
</tbody>
</table>

Faculty members associated with the program possess a wide range of research interests. Areas in which students may specialize include systems and synthetic biology; biological and physiological transport phenomena; biological imaging and functional measurement; biomolecular engineering; cell and tissue engineering; computational modeling of biological and physiological systems; bioinformatics; design, discovery, and delivery of molecular therapeutics; molecular, cell, and tissue biomechanics; development of in vitro models of the immune system and lymphoid tissue; development of molecular methods...
for direct measurement of mutations in humans; metabolism of foreign compounds; genetic toxicology; the molecular aspects and dosimetry of interactions between mutagens and carcinogens with nucleic acids and proteins; molecular mechanisms of DNA damage and repair; design and mechanisms of action of chemotherapeutic agents; environmental carcinogenesis and epidemiology; molecular mechanisms of carcinogenesis; cell physiology; extracellular regulation and signal transduction; molecular and pathologic interactions between infectious microbial agents and carcinogens; and new tools for genomics, proteomics, and glycomics.

Interdisciplinary Programs

Leaders for Global Operations
The 24-month Leaders for Global Operations (LGO) (http://lgo.mit.edu) program combines graduate degrees in engineering and management for those with previous postgraduate work experience and strong undergraduate degrees in a technical field. During the two-year program, students complete a six-month internship at one of LGO’s partner companies, where they conduct research that forms the basis of a dual-degree thesis. Students finish the program with two MIT degrees: an MBA (or SM in management) and an SM from one of six engineering programs, some of which have optional or required LGO tracks. After graduation, alumni take on leadership roles at top global manufacturing and operations companies.

Polymers and Soft Matter
The Program in Polymers and Soft Matter (PPSM) (http://polymerscience.mit.edu) offers students from participating departments an interdisciplinary core curriculum in polymer science and engineering, exposure to the broader polymer community through seminars, contact with visitors from industry and academia, and interdepartmental collaboration while working towards a PhD or ScD degree.

Research opportunities include functional polymers, controlled drug delivery, nanostructured polymers, polymers at interfaces, biomaterials, molecular modeling, polymer synthesis, biomimetic materials, polymer mechanics and rheology, self-assembly, and polymers in energy. The program is described in more detail under Interdisciplinary Graduate Programs (http://catalog.mit.edu/interdisciplinary/graduate-programs/polymers-soft-matter).

Inquiries
For further information on the graduate programs, see the Biological Engineering website (http://web.mit.edu/be) or contact the BE Academic Office (be-acad@mit.edu), Room 16-267, 617-253-1712.

Faculty and Teaching Staff
Douglas A. Lauffenburger, PhD
Ford Foundation Professor
Head, Department of Biological Engineering
Professor of Biological Engineering
Professor of Chemical Engineering
Professor of Biology

Angela M. Belcher, PhD
James Mason Croft Professor
Associate Head, Department of Biological Engineering
Professor of Biological Engineering
Professor of Materials Science and Engineering

Professors
Eric J. Alm, PhD
Professor of Biological Engineering
Professor of Civil and Environmental Engineering

Christopher B. Burge, PhD
Professor of Biology
Professor of Biological Engineering

Arup K. Chakraborty, PhD
Robert T. Haslam (1911) Professor
Director, Institute for Medical Engineering and Science
Professor of Chemical Engineering
Professor of Biological Engineering
Professor of Chemistry
Professor of Physics

James J. Collins, PhD
Termeer Professor of Medical Engineering
Professor of Biological Engineering
Core Faculty, Institute for Medical Engineering and Science

Peter C. Dedon, MD, PhD
Underwood-Prescott Professor
Professor of Toxicology and Biological Engineering

Bevin P. Engelward, DSc
Professor of Biological Engineering

John M. Essigmann, PhD
William R. (1956) and Betsy P. Leitch Professor in Residence
Professor of Toxicology and Biological Engineering
Professor of Chemistry

James G. Fox, DVM
Professor of Biological Engineering

Ernest Fraenkel, PhD
Professor of Biological Engineering
Linda G. Griffith, PhD  
School of Engineering Professor of Teaching Innovation  
Professor of Biological Engineering  
Professor of Mechanical Engineering  

Alan J. Grodzinsky, ScD  
Professor of Biological Engineering  
Professor of Electrical Engineering  
Professor of Mechanical Engineering  

Jongyoon Han, PhD  
Professor of Electrical Engineering  
Professor of Biological Engineering  

Darrell J. Irvine, PhD  
Professor of Biological Engineering  
Professor of Materials Science  

Alan P. Jasanoff, PhD  
Professor of Biological Engineering  
Professor of Nuclear Science and Engineering  
Professor of Brain and Cognitive Sciences  

Roger Dale Kamm, PhD  
Cecil H. Green Distinguished Professor  
Professor of Mechanical Engineering  
Professor of Biological Engineering  

Amy E. Keating, PhD  
Professor of Biology  
Professor of Biological Engineering  

Alexander M. Klibanov, PhD  
Novartis Professor of Chemistry  
Professor of Bioengineering  

Robert Langer, ScD  
David H. Koch (1962) Institute Professor  
Professor of Chemical Engineering  
Professor of Mechanical Engineering  
Professor of Biological Engineering  
Member, Health Sciences and Technology Faculty  

Harvey F. Lodish, PhD  
Professor of Biology  
Professor of Biological Engineering  

Scott R. Manalis, PhD  
Andrew (1956) and Erna Viterbi Professor  
Professor of Biological Engineering  
Professor of Mechanical Engineering  

Leona D. Samson, PhD  
Uncas (1923) and Helen Whitaker Professor  
Professor of Biological Engineering  
Professor of Biology  

Ram Sasisekharan, PhD  
Alfred H. Caspary Professor  
Professor of Biological Engineering  

Peter T. C. So, PhD  
Professor of Biological Engineering  
Professor of Mechanical Engineering  

Steven R. Tannenbaum, PhD  
Underwood-Prescott Professor  
Professor of Toxicology and Biological Engineering  
Professor of Chemistry  

William G. Thilly, ScD  
Professor of Biological Engineering  

Bruce Tidor, PhD  
Professor of Electrical Engineering and Computer Science  
Professor of Biological Engineering  

Krystyn J. Van Vliet, PhD  
Professor of Biological Engineering  
Professor of Materials Science and Engineering  

Christopher A. Voigt, PhD  
Professor of Biological Engineering  

Ron Weiss, PhD  
Professor of Biological Engineering  
Professor of Computer Science  

Forest M. White, PhD  
Professor of Biological Engineering  

Karl Dane Wittrup, PhD  
Carbon P. Dubbs Professor of Chemical Engineering  
Professor of Biological Engineering  

Michael B. Yaffe, MD, PhD  
David H. Koch Professor in Science  
Professor of Biology  
Professor of Biological Engineering  

Associate Professors  
Mark Bathe, PhD  
Associate Professor of Biological Engineering  
Associate Professor of Mechanical Engineering  

Paul C. Blainey, PhD  
Associate Professor of Biological Engineering  

Edward S. Boyden III, PhD  
Associate Professor of Media Arts and Sciences  
Associate Professor of Brain and Cognitive Sciences  
Associate Professor of Biological Engineering
Laurie Boyer, PhD  
Associate Professor of Biological Engineering  
Associate Professor of Biology

Timothy K. Lu, MD, PhD  
Associate Professor of Electrical Engineering and Computer Science  
Associate Professor of Biological Engineering

Jacquin Niles, MD, PhD  
Associate Professor of Biological Engineering

Katharina Ribbeck, PhD  
Eugene Bell Career Development Professor of Tissue Engineering  
Associate Professor of Biological Engineering

Feng Zhang, PhD  
James and Patricia Poitras (1963) Professor of Neuroscience  
Associate Professor of Biological Engineering

**Assistant Professors**  
Michael Birnbaum, PhD  
Assistant Professor of Biological Engineering

Angela N. Koehler, PhD  
Karl Van Tassel (1925) Career Development Professor  
Assistant Professor of Biological Engineering

**Senior Lecturers**  
Alexander Wood, PhD  
Senior Lecturer in Biological Engineering

**Instructors**  
Prerna Bhargava, PhD  
Instructor of Biological Engineering

Sean Aidan Clarke, PhD  
Instructor of Biological Engineering

Maxine Jonas, PhD  
Instructor of Biological Engineering

Natalie Kuldell, PhD  
Laboratory Instructor of Biological Engineering

Steven Wasserman, MS  
Laboratory Instructor of Biological Engineering

**Technical Instructors**  
Josephine Bagnall, PhD  
Technical Instructor of Biological Engineering

Noreen L. Lyell, PhD  
Technical Instructor of Biological Engineering

Leslie Marie McClain, PhD  
Technical Instructor of Biological Engineering

**Research Staff**

**Senior Research Scientists**  
John S. Wishnok, PhD  
Senior Research Scientist of Biological Engineering

**Principal Research Engineers**  
Eliot Frank, PhD  
Principal Research Engineer of Biological Engineering

**Research Scientists**  
Murat Cirit, PhD  
Research Scientist of Biological Engineering

Alexander Cristofaro, PhD  
Research Scientist of Biological Engineering

Robert G. Croy, PhD  
Research Scientist of Biological Engineering

Michael S. DeMott, PhD  
Research Scientist of Biological Engineering

Maria Hottelet Foley, PhD  
Research Scientist of Biological Engineering

Anthony Forget, PhD  
Research Scientist of Biological Engineering

Katya Frois-Moniz, PhD  
Research Scientist of Biological Engineering

Leonid Gaydukov, PhD  
Research Scientist of Biological Engineering

David B. Gordon, PhD  
Research Scientist of Biological Engineering

Elena V. Gostjeva, PhD  
Research Scientist of Biological Engineering

Thomas Gurry, PhD  
Research Scientist of Biological Engineering

Jifa Qi, PhD  
Research Scientist of Biological Engineering

Rahul Raman, PhD  
Research Scientist of Biological Engineering

Ishtiaq Ali Saaem, PhD  
Research Scientist of Biological Engineering

Vidya Subramanian, PhD  
Research Scientist of Biological Engineering
20.001 Introduction to Professional Success and Leadership in Biological Engineering (New)
Prereq: None
U (Fall, Spring)
1-0-2 units
Interactive introduction to the discipline of Biological Engineering through presentations by alumni practitioners, with additional panels and discussions on skills for professional development. Presentations emphasize the roles of communication through writing and speaking, building and maintaining professional networks, and interpersonal and leadership skills in building successful careers. Provides practical advice about how to prepare for job searches and graduate or professional school applications from an informed viewpoint. Prepares students for UROPs, internships, and selection of BE electives.
L. Griffith

20.002 Metakaryotic Biology and Epidemiology
Subject meets with 20.A02
Prereq: None
U (Fall)
2-0-4 units
Introduces non-eukaryotic metakaryotic cells that serve as the stem cells of human fetal/juvenile growth and development. Considers their peculiar modes of genome organization in chromosomal rings, replication via dsRNA/DNA intermediates and amitotic segregation. Explores the hypothesis that high mutation rates in these cells lead to cancers and atherosclerotic plaques and account for the increasing death rates observed with human age.
W. Thilly

20.020 Introduction to Biological Engineering Design Using Synthetic Biology
Subject meets with 20.385
Prereq: None
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: U (Spring)
3-3-3 units
Project-based introduction to the engineering of synthetic biological systems. Throughout the term, students develop projects that are responsive to real-world problems of their choosing, and whose solutions depend on biological technologies. Lectures, discussions, and studio exercises will introduce components and control of prokaryotic and eukaryotic behavior; DNA synthesis, standards, and abstraction in biological engineering; and issues of human practice, including biological safety, security, ethics, and ownership, sharing, and innovation. Preference to freshmen.
N. Kuldell

20.102 Stem Cells in Organogenesis, Carcinogenesis, and Atherogenesis
Subject meets with 20.215
Prereq: Calculus II (GIR), Biology (GIR), Chemistry (GIR)
U (Fall)
3-0-9 units
Study of the amitotic metakaryotic stem cells in fetal/juvenile organogenesis and wound healing. Explores their roles as stem cells in clonal diseases such as cancers and atherosclerosis. Application of a hypermutable/mutator stem cell model to the analysis of age-specific mortality from clonal diseases. Students taking 20.215 do additional research and computer modeling.
E. V. Gostjeva, W. G. Thilly

20.104[J] Environmental Cancer Risks, Prevention, and Therapy
Same subject as 1.081[J]
Prereq: Calculus II (GIR), Biology (GIR), Chemistry (GIR)
U (Spring)
3-0-9 units
Analysis of the history of cancer and vascular disease mortality rates in predominantly European- and African-American US cohorts, 1895-2010, to discover specific historical shifts. Shifts identified are explored in terms of contemporaneously changing environmental risk factors: air-, food- and water-borne chemicals; subclinical infections; diet and lifestyles. Role of occupational data identifying general risk factors. Considers the hypotheses that environmental factors affect metakaryotic stem cell mutation rates in fetuses and juveniles and/or the growth rates of preneoplastic stem cells in adults. Interaction of environmental and inherited risks. Introduces the use of metakaryocidal drugs to treat cancer in clinical trials.
W. Thilly, R. McCunney
20.106[J] Systems Microbiology
Same subject as 1.084[J]
Prereq: Chemistry (GIR), Biology (GIR)
U (Fall)
3-0-9 units
Introductory microbiology from a systems perspective - considers microbial diversity and the integration of data from a molecular, cellular, organismal, and ecological context to understand the interaction of microbial organisms with their environment. Special emphasis on specific viral, bacterial, and eukaryotic microorganisms and their interaction with animal hosts with focus on contemporary problems in areas such as vaccination, emerging disease, antimicrobial drug resistance, and toxicology.
E. Alm, J. Niles

20.109 Laboratory Fundamentals in Biological Engineering
Prereq: Biology (GIR), Chemistry (GIR), 6.0002, 18.03, 20.110[J]
U (Fall, Spring)
2-8-5 units. Institute LAB
Introduces experimental biochemical and molecular techniques from a quantitative engineering perspective. Experimental design, data analysis, and scientific communication form the underpinnings of this subject. Examples of discovery-based experimental modules include DNA engineering in which students design, construct, and use genetic material; parts engineering, which emphasizes protein design and quantitative assessment of protein performance; systems engineering, in which students consider genome-wide consequences of genetic perturbations; and biomaterials engineering, in which students use biologically-encoded devices to design and build materials. Students complete some laboratory time online in advance of each class. Enrollment limited; priority to Course 20 majors.
Fall: A. Belcher, B. Engelward, M. Jonas, N. Lyell, L. McClain
Spring: A. Belcher, L. Samson, M. Jonas, N. Lyell, L. McClain

20.110[J] Thermodynamics of Biomolecular Systems
Same subject as 2.772[J]
Prereq: Calculus II (GIR), Chemistry (GIR), Physics I (GIR)
U (Fall, Spring)
5-0-7 units. REST
Fall: M. Birnbaum C. Voigt
Spring: E. Alm, C. Voigt

20.129[J] Biological Circuit Engineering Laboratory
Same subject as 6.129[J]
Prereq: Biology (GIR), Calculus II (GIR)
U (Spring)
2-8-2 units. Institute LAB
See description under subject 6.129[J]. Enrollment limited.
T. Lu, R. Weiss

20.200 Biological Engineering Seminar
Prereq: Permission of instructor
G (Fall, Spring)
1-0-2 units
Can be repeated for credit.
Weekly one-hour seminars covering graduate student research and presentations by invited speakers. Limited to BE graduate students.
B. Engelward

20.201 Fundamentals of Drug Development
Prereq: Permission of instructor
G (Fall)
4-0-8 units
Addresses the scientific basis for the development of new drugs.
First half of term begins with an overview of the drug discovery process, followed by fundamental principles of pharmacokinetics, pharmacodynamics, metabolism, and the mechanisms by which drugs cause therapeutic and toxic responses. Second half applies principles to case studies and literature discussions of current problems with specific drugs, drug classes, and therapeutic targets.
P. C. Dedon, M. A. Murcko, R. Sasishekharan

Prereq: Permission of instructor
G (Spring)
1-1-4 units
Selected aspects of anatomy, histology, immuno-cytochemistry, in situ hybridization, physiology, and cell biology of mammalian organisms and their pathogens. Subject material integrated with principles of toxicology, in vivo genetic engineering, and molecular biology. A lab/demonstration period each week involves experiments in anatomy (in vivo), physiology, and microscopy to augment the lectures. Offered first half of spring term.
J. G. Fox, B. Marini, M. Whary
20.203[J] Neurotechnology in Action
Same subject as 9.123[J]
Prereq: Permission of instructor
G (Spring)
3-6-3 units
See description under subject 9.123[J].
A. Jasanoff, E. Boyden, M. Jonas

20.205[J] Principles and Applications of Genetic Engineering for Biotechnology and Neuroscience
Same subject as 9.26[J]
Prereq: 7.28, 7.32, or 20.020; 9.01 or 9.09[J]
U (Spring)
3-0-9 units
See description under subject 9.26[J].
F. Zhang

20.207 Biotechnologies in Infectious Disease
Prereq: 7.06, permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Spring)
3-0-9 units
Team-based exploration of current and emerging technologies used in the surveillance, diagnosis, understanding, treatment and prevention of infectious diseases, drawing on basic science and bio-engineering principles. In a term-long project, student teams develop novel technologies to solve major problems in global infectious disease, with a trajectory to a start-up company. Industry experts and academic entrepreneurs present case studies throughout the term, including technology innovations, regulatory sciences, intellectual property and clinical development. Term culminates with team presentations to a panel of industry and scientific leaders.
P. C. Dedon, R. Sasisekharan

20.213 DNA Damage and Genomic Instability
Prereq: 5.07[J], 7.05, permission of instructor
G (Spring; second half of term)
3-0-3 units
Focuses on biochemistry and molecular mechanisms of DNA replication and DNA repair. Analyzes chemistry of DNA damaging events, and analyzes mutagenic and toxic consequences of modifications to DNA structure. Also presents the contrasting perspective that normal DNA processing leads to mutations. Moves from analysis and discussion of key DNA repair pathways to connections between DNA repair and human diseases. Discusses in-depth the chemistry and biochemistry of DNA metabolism. Includes current literature related to the molecular mechanisms of radiation and chemotherapy.
B. P. Engelward

20.215 Macroepidemiology, Population Genetics, and Stem Cell Biology of Human Clonal Diseases
Subject meets with 20.102
Prereq: Calculus II (GIR), 1.00
G (Fall)
3-0-15 units
Studies the logic and technology needed to discover genetic and environmental risks for common human cancers and vascular diseases. Includes an introduction to metakaryotic stem cell biology. Analyzes large, organized historical public health databases using quantitative cascade computer models that include population stratification of stem cell mutation rates in fetal/juvenile tissues and growth rates in preneoplastic colonies and atherosclerotic plaques. Means to test hypotheses (CAST) that certain genes carry mutations conferring risk for common cancers via genetic analyses in large human cohorts.
W. G. Thilly

20.219 Selected Topics in Biological Engineering
Prereq: Permission of instructor
G (Fall, Spring)
Units arranged
Can be repeated for credit.
Detailed discussion of selected topics of current interest. Classwork in various areas not covered by regular subjects.
Staff
20.260 Analysis and Presentation of Complex Biological Data
Prereq: Permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: U (IAP)
2-0-2 units
Illustrates best practices in the statistical analysis of complex biological datasets and the graphical representation of such analyses. Covers fundamental concepts in probability and statistical theory as well as principles of information design. Provides mathematical concepts and tools that enable students to make sound judgments about the application of statistical methods and to present statistical results in clear and compelling visual formats. Assignments focus on key concepts and their application to practical examples. Assumes basic knowledge of calculus and programming in MATLAB or R.
P. Blainey

20.300 Advanced Workshop in Biological Engineering Communication: Professors Share Their Practices
Prereq: Permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: U (IAP)
3-0-0 units
Working scientists and engineers discuss best practices for written, visual, and oral communication in the classroom, the lab, and the workplace. In a series of lectures, successful academics and industry professionals share how they prepare papers, talks, and graphics. Recitations allow deeper exploration of the lecture topics. With faculty guidance, students develop their own projects during workshops. Emphasizes systematic approaches and transferable skills such as effective drafting and revision. Topics include creating compelling visuals to represent data and concepts; formal/informal writing, from research papers to cover letters; and developing memorable talks and presentations. Examples drawn from biological engineering research. Enrollment limited; preference to Course 20 majors.
E. Alm, J. Goldstein, A. Stachowiak

20.305[J] Principles of Synthetic Biology
Same subject as 6.580[J]
Subject meets with 6.589[J], 20.405[J]
Prereq: None
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: U (Fall)
3-0-9 units
Introduces the basics of synthetic biology, including quantitative cellular network characterization and modeling. Considers the discovery and genetic factoring of useful cellular activities into reusable functions for design. Emphasizes the principles of biomolecular system design and diagnosis of designed systems. Illustrates cutting-edge applications in synthetic biology and enhances skills in analysis and design of synthetic biological applications. Students taking graduate version complete additional assignments.
R. Weiss

20.309[J] Instrumentation and Measurement for Biological Systems
Same subject as 2.673[J]
Subject meets with 20.409
Prereq: Biology (GIR), Physics II (GIR), 6.0002, 18.03; or permission of instructor
U (Fall, Spring)
3-6-3 units
Sensing and measurement aimed at quantitative molecular/cell/tissue analysis in terms of genetic, biochemical, and biophysical properties. Methods include light and fluorescence microscopies, and electro-mechanical probes (atomic force microscopy, optical traps, MEMS devices). Application of statistics, probability, signal and noise analysis, and Fourier techniques to experimental data. Enrollment limited; preference to Course 20 undergraduates.
Fall: P. Blainey, S. Manalis, E. Frank, S. Wasserman, J. Bagnall
Spring: E. Boyden, P. So, S. Wasserman, J. Bagnall, E. Frank

20.310[J] Molecular, Cellular, and Tissue Biomechanics
Same subject as 2.797[J], 3.053[J], 6.024[J]
Prereq: 2.370 or 2.772[J]; 18.03 or 3.016; Biology (GIR)
U (Fall)
4-0-8 units
Develops and applies scaling laws and the methods of continuum mechanics to biomechanical phenomena over a range of length scales. 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. Experimental methods for probing structures at the tissue, cellular, and molecular levels.
M. Bathe, K. Van Vliet, M. Jonas
20.315 Physical Biology
Subject meets with 8.241, 20.415
Prereq: 20.110[J], 5.60, or permission of instructor
U (Spring)
3-0-9 units

Focuses on current major research topics in quantitative, physical biology. Covers synthetic structural biology, synthetic cell biology, microbial systems biology and evolution, cellular decision making, neuronal circuits, and development and morphogenesis. Emphasizes current motivation and historical background, state-of-the-art measurement methodologies and techniques, and quantitative physical modeling frameworks. Experimental techniques include structural biology, next-generation sequencing, fluorescence imaging and spectroscopy, and quantitative biochemistry. Modeling approaches include stochastic rate equations, statistical thermodynamics, and statistical inference. Students taking graduate version complete additional assignments.

M. Bathe, J. Gore

20.320 Analysis of Biomolecular and Cellular Systems
Prereq: 20.110[J], 18.03, 6.0002; Coreq: 5.07[J] or 7.05
U (Fall)
4-0-8 units

Analysis of molecular and cellular processes across a hierarchy of scales, including genetic, molecular, cellular, and cell population levels. Topics include gene sequence analysis, molecular modeling, metabolic and gene regulation networks, signal transduction pathways and cell populations in tissues. Emphasis on experimental methods, quantitative analysis, and computational modeling.

F. White, K. D. Wittrup

Same subject as 2.793[J], 6.023[J]
Prereq: Physics II (GIR); 2.005, 6.021[J], or permission of instructor,
Coreq: 20.309[J]
U (Spring)
4-0-8 units

Introduction to electric fields, fluid flows, transport phenomena and their application to biological systems. Flux and continuity laws, Maxwell’s equations, electro-quasistatics, electro-chemical-mechanical driving forces, conservation of mass and momentum, Navier-Stokes flows, and electrophoresis. Applications include biomolecular transport in tissues, electrophoresis, and microfluidics.

J. Han, S. Manalis

20.334 Biological Systems Modeling (New)
Prereq: 20.330[J] or permission of instructor
U (Fall; first half of term)
1-0-5 units

Practices the use of modern numerical analysis tools (e.g., COMSOL) for biological systems with multi-physics behavior. Covers modeling of diffusion, reaction, convection and other transport mechanisms. Analysis of microfluidic devices as examples. Discusses practical issues and challenges in numerical modeling. No prior knowledge of modeling software required. Includes weekly modeling homework and one final modeling project.

J. Han

20.345[J] Bioinstrumentation Project Lab
Same subject as 6.123[J]
Prereq: Biology (GIR), and 2.004 or 6.003; or 20.309[J]; or permission of instructor
U (Spring)
2-7-3 units

In-depth examination of instrumentation design, principles and techniques for studying biological systems, from single molecules to entire organisms. Lectures cover optics, advanced microscopy techniques, electronics for biological measurement, magnetic resonance imaging, computed tomography, MEMs, microfluidic devices, and limits of detection. Students select two lab exercises during the first half of the semester and complete a final design project in the second half. Lab emphasizes design process and skillful realization of a robust system. Enrollment limited; preference to Course 20 majors and minors.

E. Boyden, M. Jonas, S. F. Nagle, P. So, S. Wasserman, M. F. Yanik

20.352 Principles of Neuroengineering
Subject meets with 9.422[J], 20.452[J], MAS.881[J]
Prereq: 20.330[J], 20.452[J], MAS.881[J]
Prereq: Permission of instructor
U (Fall)
3-0-9 units

Covers how to innovate technologies for brain analysis and engineering, for accelerating the basic understanding of the brain, and leading to new therapeutic insight and inventions. Focuses on using physical, chemical and biological principles to understand technology design criteria governing ability to observe and alter brain structure and function. Topics include optogenetics, noninvasive brain imaging and stimulation, nanotechnologies, stem cells and tissue engineering, and advanced molecular and structural imaging technologies. Includes design projects. Students taking graduate version complete additional assignments. Designed for students with engineering maturity who are ready for design.

E. S. Boyden, III
20.361[J] Molecular and Engineering Aspects of Biotechnology
Same subject as 7.37[J], 10.441[J]
Prereq: 2.005, 3.012, 5.60, or 20.110[J]; 7.06; or permission of instructor
U (Spring)
4-0-8 units
Credit cannot also be received for 7.371
See description under subject 7.37[J].
H. Lodish, L. Griffith

20.363[J] Biomaterials Science and Engineering
Same subject as 3.055[J]
Subject meets with 3.963[J], 20.463[J]
Prereq: 3.034, 20.110[J], or permission of instructor
U (Fall)
3-0-9 units
Covers, at a molecular scale, the analysis and design of materials used in contact with biological systems, and biomimetic strategies aimed at creating new materials based on principles found in biology. Topics include molecular interaction between bio- and synthetic molecules and surfaces; design, synthesis, and processing approaches for materials that control cell functions; and application of materials science to problems in tissue engineering, drug delivery, vaccines, and cell-guiding surfaces. Students taking graduate version complete additional assignments.
D. Irvine, K. Ribbeck

20.365 Engineering the Immune System in Cancer and Beyond
Subject meets with 20.465
Prereq: 20.110[J], 5.60, or 7.10; permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: U (Spring)
3-0-9 units
Examines strategies in clinical and preclinical development for manipulating the immune system to treat and protect against disease. Begins with brief review of immune system. Discusses interaction of tumors with the immune system, followed by approaches by which the immune system can be modulated to attack cancer. Also covers strategies based in biotechnology, chemistry, materials science, and molecular biology to induce immune responses to treat infection, transplantation, and autoimmunity. Students taking graduate version complete additional assignments.
D. Irvine, M. Birnbaum

20.370[J] Cellular Neurophysiology and Computing
Same subject as 2.791[J], 6.021[J], 9.21[J]
Subject meets with 2.794[J], 6.521[J], 9.021[J], 20.470[J], HST.541[J]
Prereq: Physics II (GIR); 18.03; 2.005, 6.002, 6.003, 6.071, 10.301, 20.110[J], or permission of instructor
U (Fall)
5-2-5 units
See description under subject 6.021[J]. Preference to juniors and seniors.
J. Han, T. Heldt

20.375 Applied Developmental Biology and Tissue Engineering (New)
Subject meets with 20.475
Prereq: 7.06, 20.320, and 7.02[J] or 20.109; or permission of instructor
U (Spring)
3-0-9 units
Addresses the integration of engineering and biology design principles to create human tissues and organs for regenerative medicine to drug development. Provides an overview of embryogenesis, how morphogenetic phenomena are governed by biochemical and biophysical cues. Analyzes in vitro generation of human brain, gut, and other organoids from stem cells. Studies the roles of biomaterials and microreactors in improving organoid formation and function; organoid use in modeling disease and physiology in vitro; and engineering and biological principles of reconstructing tissues and organs from postnatal donor cells using biomaterials scaffolds and bioreactors. Includes select applications, such as liver disease, brain disorders, and others. Students taking graduate version complete additional assignments.
L. Boyer, L. Griffith

20.380 Biological Engineering Design
U (Fall, Spring)
5-0-7 units
Illustrates how knowledge and principles of biology, biochemistry, and engineering are integrated to create new products for societal benefit. Uses case study format to examine recently developed products of pharmaceutical and biotechnology industries: how a product evolves from initial idea, through patents, testing, evaluation, production, and marketing. Emphasizes scientific and engineering principles, as well as the responsibility scientists, engineers, and business executives have for the consequences of their technology. Instruction and practice in written and oral communication provided. Enrollment limited; preference to Course 20 undergraduates.
Fall: J. Collins, A. Koehler
Spring: J. Essigmann, K. Ribbeck
20.385 Understanding Current Research in Synthetic Biology
Subject meets with 20.020
Prereq: 20.109, 20.320; or permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: U (Spring)
3-3-3 units
Provides an in-depth understanding of the state of research in synthetic biology. Critical evaluation of primary research literature covering a range of approaches to the design, modeling and programming of cellular behaviors. Focuses on developing the skills needed to read, present and discuss primary research literature, and to manage and lead small teams. Students mentor a small undergraduate team of 20.020 students. Open to advanced students with appropriate background in biology.

N. Kuldell

Same subject as 6.802[J]
Subject meets with 6.874[J], 20.490, HST.506[J]
Prereq: Biology (GIR), 6.0002 or 6.01; 7.05; or permission of instructor
U (Spring)
3-0-9 units
Provides an introduction to computational and systems biology. Includes units on the analysis of protein and nucleic acid sequences, protein structures, and biological networks. Presents principles and methods used for sequence alignment, motif finding, expression array analysis, structural modeling, structure design and prediction, and network analysis and modeling. Techniques include dynamic programming, Markov and hidden Markov models, Bayesian networks, clustering methods, and energy minimization approaches. Exposes students to emerging research areas. Designed for students with strong backgrounds in either molecular biology or computer science. Some foundational material covering basic programming skills, probability and statistics is provided for students with less quantitative backgrounds. Students taking graduate version complete additional assignments.

D. K. Gifford, T. S. Jaakkola

20.405[J] Principles of Synthetic Biology
Same subject as 6.589[J]
Subject meets with 6.580[J], 20.305[J]
Prereq: None
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Fall)
3-0-9 units
Introduces the basics of synthetic biology, including quantitative cellular network characterization and modeling. Considers the discovery and genetic factoring of useful cellular activities into reusable functions for design. Emphasizes the principles of biomolecular system design and diagnosis of designed systems. Illustrates cutting-edge applications in synthetic biology and enhances skills in analysis and design of synthetic biological applications. Students taking graduate version complete additional assignments.

R. Weiss

20.409 Biological Engineering II: Instrumentation and Measurement
Subject meets with 2.673[J], 20.309[J]
Prereq: Permission of instructor
G (Fall, Spring)
2-7-3 units
Sensing and measurement aimed at quantitative molecular/cell/tissue analysis in terms of genetic, biochemical, and biophysical properties. Methods include light and fluorescence microscopes, electronic circuits, and electro-mechanical probes (atomic force microscopy, optical traps, MEMS devices). Application of statistics, probability, signal and noise analysis, and Fourier techniques to experimental data. Limited to 5 graduate students.

Fall: P. Blainey, S. Manalis, S. Wasserman, J. Bagnall, E. Frank
Spring: E. Boyden, P. So, S. Wasserman, J. Bagnall, E. Frank

20.410[J] Molecular, Cellular, and Tissue Biomechanics
Same subject as 2.798[J], 3.971[J], 6.524[J], 10.537[J]
Prereq: Biology (GIR); 2.002, 2.006, 6.013, 10.301, or 10.302
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Fall)
3-0-9 units
Develops and applies scaling laws and the methods of continuum mechanics to biomechanical phenomena over a range of length scales. 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. Experimental methods for probing structures at the tissue, cellular, and molecular levels.

R. D. Kamm, K. J. Van Vliet
20.415 Physical Biology
Subject meets with 8.241, 20.315
Prereq: Permission of instructor
G (Spring)
3-0-9 units

Focuses on current major research topics in quantitative, physical biology. Topics include synthetic structural biology, synthetic cell biology, microbial systems biology and evolution, cellular decision making, neuronal circuits, and development and morphogenesis. Emphasizes current motivation and historical background, state-of-the-art measurement methodologies and techniques, and quantitative physical modeling frameworks. Experimental techniques include structural biology, next-generation sequencing, fluorescence imaging and spectroscopy, and quantitative biochemistry. Modeling approaches include stochastic rate equations, statistical thermodynamics, and statistical inference. Students taking graduate version complete additional assignments.

M. Bathe, J. Gore

20.416[J] Topics in Biophysics and Physical Biology
Same subject as 7.74[J], 8.590[J]
Prereq: None
G (Fall)
2-0-4 units

Provides broad exposure to research in biophysics and physical biology, with emphasis on the critical evaluation of scientific literature. Weekly meetings include in-depth discussion of scientific literature led by distinct faculty on active research topics. Each session also includes brief discussion of non-research topics including effective presentation skills, writing papers and fellowship proposals, choosing scientific and technical research topics, time management, and scientific ethics.

I. Cisse, N. Fakhri, M. Guo

20.420[J] Principles of Molecular Bioengineering
Same subject as 10.538[J]
Prereq: 7.06, 18.03
G (Fall)
3-0-9 units

Provides an introduction to the mechanistic analysis and engineering of biomolecules and biomolecular systems. Covers methods for measuring, modeling, and manipulating systems, including biophysical experimental tools, computational modeling approaches, and molecular design. Equips students to take systematic and quantitative approaches to the investigation of a wide variety of biological phenomena.

A. Jasanoff, E. Fraenkel

Same subject as 2.795[J], 6.561[J], 10.539[J]
Prereq: Permission of instructor
G (Fall)
3-0-9 units

Molecular diffusion, diffusion-reaction, conduction, convection in biological systems; fields in heterogeneous media; electrical double layers; Maxwell stress tensor, electrical forces in physiological systems. Fluid and solid continua: equations of motion useful for porous, hydrated biological tissues. Case studies of membrane transport, electrode interfaces, electrical, mechanical, and chemical transduction in tissues, convective-diffusion/reaction, electrophoretic, electroosmotic flows in tissues/MEMs, and ECG. Electromechanical and physicochemical interactions in cells and biomaterials; musculoskeletal, cardiovascular, and other biological and clinical examples. Prior undergraduate coursework in transport recommended.

M. Bathe, A. J. Grodzinsky

20.440 Analysis of Biological Networks
Prereq: Permission of instructor
G (Spring)
6-0-9 units

Conceptual and experimental approaches to analyzing complex biological networks and systems, from molecules to human populations, focusing on human pathophysiology and disease. Moving from single component analysis to pathways and networks, combines didactic lectures with in-depth analysis of current literature and computational analysis. Emphasizes the chemistry and biochemistry of underlying biological processes. Topics include linking genes/SNPs to disease, defining pathways, analysis of pathways in vivo, systems-level analysis, and applications of network biology. First half of term focuses on fundamental biological processes and tools/analyses needed by biological engineers, and the second half elaborates on these fundamentals by covering complex biological processes. Students acquire skills in the fundamentals of grant preparation using an NIH format and make an oral presentation.

P. Blainey, M. Yaffe

20.445[J] Methods and Problems in Microbiology
Same subject as 1.86[J], 7.492[J]
Prereq: None
G (Fall)
3-0-9 units

See description under subject 7.492[J]. Preference to first-year Microbiology and Biology students.

M. Laub
20.446[J] Microbial Genetics and Evolution
Same subject as 1.87[J], 7.493[J], 12.493[J]
Prereq: 7.03, 7.05, or permission of instructor
G (Fall)
4-0-8 units
See description under subject 7.493[J].
A. D. Grossman, E. Alm

20.450 Molecular and Cellular Pathophysiology
Prereq: 20.420[J], 20.440; or permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Fall)
4-0-8 units
Compares the complex molecular and cellular interactions in health and disease between commensal microbial communities, pathogens and the human or animal host. Special focus is given to current research on microbe/host interactions, infection of significant importance to public health, and chronic infectious disease. Classwork will include lecture, but emphasize critical evaluation and class discussion of recent scientific papers, and the development of new research agendas in the fields presented.
J. C. Niles, J. Runstadler

20.452[J] Principles of Neuroengineering
Same subject as 9.422[J], MAS.881[J]
Subject meets with 20.352
Prereq: Permission of instructor
G (Fall)
3-0-9 units
See description under subject MAS.881[J].
E. S. Boyden, III

20.454[J] Revolutionary Ventures: How to Invent and Deploy Transformative Technologies
Same subject as 9.455[J], 15.128[J], MAS.883[J]
Prereq: Permission of instructor
G (Fall)
2-0-7 units
See description under subject MAS.883[J].
E. Boyden, J. Bonsen, J. Jacobson

20.463[J] Biomaterials Science and Engineering
Same subject as 3.963[J]
Subject meets with 3.055[J], 20.363[J]
Prereq: 3.034, 20.110[J], or permission of instructor
G (Fall)
3-0-9 units
Covers, at a molecular scale, the analysis and design of materials used in contact with biological systems, and biomimetic strategies aimed at creating new materials based on principles found in biology. Topics include molecular interaction between bio- and synthetic molecules and surfaces; design, synthesis, and processing approaches for materials that control cell functions; and application of materials science to problems in tissue engineering, drug delivery, vaccines, and cell-guiding surfaces. Students taking graduate version complete additional assignments.
D. Irvine, K. Ribbeck

20.465 Engineering the Immune System in Cancer and Beyond
Subject meets with 20.365
Prereq: Permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Spring)
3-0-9 units
Examines strategies in clinical and preclinical development for manipulating the immune system to treat and protect against disease. Begins with brief review of immune system. Discusses interaction of tumors with the immune system, followed by approaches by which the immune system can be modulated to attack cancer. Also covers strategies based in biotechnology, chemistry, materials science, and molecular biology to induce immune responses to treat infection, transplantation, and autoimmunity. Students taking graduate version complete additional assignments.
D. Irvine, M. Birnbaum

20.470[J] Cellular Neurophysiology and Computing
Same subject as 2.794[J], 6.521[J], 9.021[J], HST.541[J]
Subject meets with 2.791[J], 6.021[J], 9.21[J], 20.370[J]
Prereq: Physics II (GIR); 18.03; 2.005, 6.002, 6.003, 6.071, 10.301, 20.110[J], or permission of instructor
G (Fall)
5-2-5 units
See description under subject 6.521[J].
J. Han, T. Heldt
20.475 Applied Developmental Biology and Tissue Engineering (New)
Subject meets with 20.375
Prereq: Permission of instructor
G (Spring)
3-0-9 units
This subject addresses the integration of engineering and biology design principles to create human tissues and organs for regenerative medicine to drug development. Overview of embryogenesis; how morphogenic phenomena are governed by biochemical and biophysical cues. Analysis of in vitro generation of human brain, gut, and other organoids from stem cells. Roles of biomaterials and microreactors in improving organoid formation and function. Organoid use in modeling disease and physiology in vitro. Engineering and biological principles of reconstructing tissues and organs from postnatal donor cells using biomaterials scaffolds and bioreactors. Select applications such as liver disease, brain disorders, and others. Graduate students will have additional assignments.
L. Boyer, L. Griffith

Same subject as 6.581[J]
Subject meets with 6.503
Prereq: 6.021[J], 6.034, 6.046[J], 6.336[J], 18.417, or permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Spring)
3-0-9 units
See description under subject 6.581[J].
B. Tidor

20.486[J] Case Studies and Strategies in Drug Discovery and Development
Same subject as 7.549[J], 15.137[J], HST.916[J]
Prereq: None
G (Spring)
2-0-4 units
Aims to develop appreciation for the stages of drug discovery and development, from target identification, to the submission of preclinical and clinical data to regulatory authorities for marketing approval. Following introductory lectures on the process of drug development, students working in small teams analyze how one of four new drugs or drug candidates traversed the discovery/development landscape. For each case, an outside expert from the sponsoring drug company or pivotal clinical trial principal investigator provides guidance and critiques the teams' presentations to the class.
S. R. Tannenbaum, A. J. Sinskey, A. W. Wood

20.487[J] Optical Microscopy and Spectroscopy for Biology and Medicine
Same subject as 2.715[J]
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units
See description under subject 2.715[J].
P. T. So, C. Sheppard

20.490 Foundations of Computational and Systems Biology
Subject meets with 6.802[J], 6.874[J], 20.390[J], HST.506[J]
Prereq: Biology (GIR), 6.0002 or 6.01; or 7.05; or permission of instructor
G (Spring)
3-0-9 units
Provides an introduction to computational and systems biology. Includes units on the analysis of protein and nucleic acid sequences, protein structures, and biological networks. Presents principles and methods used for sequence alignment, motif finding, expression array analysis, structural modeling, structure design and prediction, and network analysis and modeling. Techniques include dynamic programming, Markov and hidden Markov models, Bayesian networks, clustering methods, and energy minimization approaches. Exposes students to emerging research areas. Designed for students with strong backgrounds in either molecular biology or computer science. Some foundational material covering basic programming skills, probability and statistics is provided for students with less quantitative backgrounds. Students taking graduate version complete additional assignments.
D. K. Gifford, T. S. Jaakkola

20.507[J] Biological Chemistry I
Same subject as 5.07[J]
Prereq: 5.12
U (Fall)
5-0-7 units. REST
Credit cannot also be received for 7.05
See description under subject 5.07[J].
E. Nolan, A. Klivanov

20.554[J] Frontiers in Chemical Biology
Same subject as 5.54[J], 7.540[J]
Prereq: 5.13, 5.07[J], 7.06, permission of instructor
G (Fall)
2-0-4 units
See description under subject 5.54[J].
L. Kiessling
20.560 Statistics for Biological Engineering
Prereq: Permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (IAP)
2-0-2 units
Provides basic tools for analyzing experimental data, interpreting statistical reports in the literature, and reasoning under uncertain situations. Topics include probability theory, statistical tests, data exploration, Bayesian statistics, and machine learning. Emphasizes discussion and hands-on learning. Experience with MATLAB, Python, or R recommended.
S. Olesen

20.902 Independent Study in Biological Engineering
Prereq: Permission of instructor
U (Fall, Spring)
Units arranged
Can be repeated for credit.
Opportunity for independent study under regular supervision by a faculty member. Projects require prior approval, as well as a substantive paper. Minimum 12 units required.
Staff

20.903 Independent Study in Biological Engineering
Prereq: Permission of instructor
U (Fall, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.
Opportunity for independent study under regular supervision by a faculty member. Projects require prior approval, as well as a substantive paper. Minimum 6-12 units required.
Staff

20.920 Practical Work Experience
Prereq: None
U (Fall, IAP, Spring, Summer)
0-1-0 units
For Course 20 students participating in off-campus work experiences in biological engineering. Before registering for this subject, students must have an employment offer from a company or organization and must identify a BE supervisor. Upon completion of the work, student must submit a letter from the employer describing the work accomplished, along with a substantive final report from the student approved by the MIT supervisor. Subject to departmental approval. Consult departmental undergraduate office.
Staff

20.930[J] Research Experience in Biopharma
Same subject as 7.930[J]
Prereq: None
G (Fall)
2-10-0 units
Provides exposure to industrial science and develops skills necessary for success in such an environment. Under the guidance of an industrial mentor, students participate in on-site research at a local biopharmaceutical company where they observe and participate in industrial science. Serves as a real-time case study to internalize the factors that shape R&D in industry, including the purpose and scope of a project, key decision points in the past and future, and strategies for execution. Students utilize company resources and work with a scientific team to contribute to the goals of their assigned project; they then present project results to the company and class, emphasizing the logic that dictated their work and their ideas for future directions. Lecture component focuses on professional development.
S. Clarke

20.950 Research Problems in Biological Engineering
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged
Can be repeated for credit.
Directed research in the fields of bioengineering and environmental health. Limited to BE students.
Staff

20.951 Thesis Proposal
Prereq: Permission of instructor
G (Fall, Spring, Summer)
0-24-0 units
Thesis proposal research and presentation to the thesis committee.
Staff

20.960 Teaching Experience in Biological Engineering
Prereq: Permission of instructor
G (Fall, Spring)
Units arranged
Can be repeated for credit.
For qualified graduate students interested in teaching. Tutorial, laboratory, or classroom teaching under the supervision of a faculty member. Enrollment limited by availability of suitable teaching assignments.
Staff
20.BME Undergraduate Research in Biomedical Engineering
Prereq: None
U (Fall, Spring)
Units arranged [P/D/F]
Can be repeated for credit.

Individual research project with biomedical or clinical focus, arranged with appropriate faculty member or approved supervisor. Forms and instructions for the proposal and final report are available in the BE Undergraduate Office.
*Consult BE Department*

20.EPW UPOP Engineering Practice Workshop
Engineering School-Wide Elective Subject.
Offered under: 1.EPW, 2.EPW, 3.EPW, 6.EPW, 10.EPW, 16.EPW, 20.EPW, 22.EPW
Prereq: None
U (Fall, IAP)
1-0-0 units

See description under subject 2.EPW. Enrollment limited.
*Staff*

20.S900 Special Subject in Biological Engineering
Prereq: Permission of instructor
U (Fall)
Units arranged [P/D/F]
Can be repeated for credit.

Detailed discussion of selected topics of current interest. Classwork in various areas not covered by regular subjects.
*Staff*

20.S940 Special Subject in Biological Engineering
Prereq: Permission of instructor
U (Fall, Spring)
Units arranged
Can be repeated for credit.

Detailed discussion of selected topics of current interest. Classwork in various areas not covered by regular subjects.
*Staff*

20.S947 Special Subject in Biological Engineering
Prereq: Permission of instructor
G (Fall, Spring)
Units arranged
Can be repeated for credit.

Detailed discussion of selected topics of current interest. Classwork in various areas not covered by regular subjects.
*Staff*

20.S952 Special Subject in Biological Engineering
Prereq: Permission of instructor
G (Fall, Spring)
Units arranged [P/D/F]
Can be repeated for credit.

Detailed discussion of selected topics of current interest. Classwork in various areas not covered by regular subjects.
*Staff*

20.THG Graduate Thesis
Prereq: Permission of instructor
G (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.

Program of research leading to the writing of an SM or PhD thesis; to be arranged by the student and the MIT faculty advisor.
*Staff*

20.THU Undergraduate BE Thesis
Prereq: None
U (Fall, IAP, Spring)
Units arranged
Can be repeated for credit.

Program of research leading to the writing of an SB thesis; to be arranged by the student under approved supervision.
*Staff*
20.UR Undergraduate Research Opportunities
Prereq: None
U (Fall, IAP, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.
Laboratory research in the fields of bioengineering or environmental health. May be extended over multiple terms.
S. Manalis

20.URG Undergraduate Research Opportunities
Prereq: None
U (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.
Emphasizes direct and active involvement in laboratory research in bioengineering or environmental health. May be extended over multiple terms.
Consult S. Manalis