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://be.mit.edu*) 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 (*https://catalog.mit.edu/degree-charts/biological-engineering-course-20*) are encouraged to complete the Biology General Institute Requirement during their first 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 the first 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 (*https://catalog.mit.edu/interdisciplinary/undergraduate-programs/minors/biomedical-engineering*) is available to all undergraduate students outside the BE (Course 20) major, described in detail under Interdisciplinary Programs.

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	Metakaryotic Stem Cells in Carcinogenesis: Origins and Cures	12
20.104[J]	Environmental Cancer Risks, Prevention, and Therapy	12
20.106[J]	Applied Microbiology	12
Laboratory Core		
Select one of the following:		12-18
5.310	Laboratory Chemistry	
20.109	Laboratory Fundamentals in Biological Engineering	
7.002 & 7.003[J]	Fundamentals of Experimental Molecular Biology and Applied Molecular Biology Laboratory	
Restricted Electives		
Select one of the following:		12
1.080	Environmental Chemistry	
1.089	Environmental Microbial Biogeochemistry	
5.07[J]	Introduction to Biological Chemistry	
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://be.mit.edu*) or contact the BE Academic Office (*be-acad@mit.edu*), Room 16-267, 617-452-2465.

Graduate Study

Graduate students in the Department of Biological Engineering can carry out their research as part of a number of multi-investigator, multidisciplinary research centers at MIT, including the Center for Biomedical Engineering, the Center for Environmental Health Sciences (*https://catalog.mit.edu/mit/research/center-environmental-health-sciences*), the Division of Comparative Medicine (*https://catalog.mit.edu/mit/research/division-comparative-medicine*), and the Synthetic Biology Engineering Research Center (*http://www.synberc.org*). These opportunities include collaboration with faculty in the Schools of Engineering (*https://catalog.mit.edu/schools/engineering*) and Science (*https://catalog.mit.edu/schools/science*), the Koch Institute for Integrative Cancer Research (*https://catalog.mit.edu/mit/research/koch-institute-integrative-cancer-research*), the Whitehead Institute for Biomedical Research (*https://catalog.mit.edu/mit/research/whitehead-institute-biomedical-research*), and the Broad Institute (*https://catalog.mit.edu/mit/research/broad-institute*), along with the Harvard University School of Medicine, Harvard University School of Dental Medicine, Harvard School of Public Health, and Boston University School of Medicine.

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:

18.03	Differential Equations	12
5.12	Organic Chemistry I	12
5.07[J]	Introduction to Biological Chemistry	12
or 7.05	General Biochemistry	
Select one of the following:		12
2.005	Thermal-Fluids Engineering I	
6.2000	Electrical Circuits: Modeling and Design of Physical Systems	
Select two of the following:		24
1.010	Probability and Causal Inference	
2.086	Numerical Computation for Mechanical Engineers	
6.3700	Introduction to Probability	
18.05	Introduction to Probability and Statistics	

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:		24
20.410[J]	Molecular, Cellular, and Tissue Biomechanics	
20.420[J]	Principles of Molecular Bioengineering	
20.430[J]	Fields, Forces, and Flows in Biological Systems	
Biomedical Engineering Electives		
Select 24 units from a selection of graduate subjects from various departments in the School of Engineering, including HST. [1]		24
Bioscience Elective		
Select one biological science subject in addition to organic chemistry and biochemistry. This must be a laboratory subject if one was not taken as part of the student’s undergraduate curriculum		18
Total Units		**66**

[1] *A list of suggested subjects is available from the BE Academic Office (be-acad@mit.edu), Room 16-267.*

Thesis

The student is required to complete a thesis that must be approved by the program director. The thesis is an original work of research, design, or development. If the supervisor is not a member of the Department of Biological Engineering, a reader who belongs to the BE faculty must also approve and sign the thesis. The student submits a thesis proposal by the end of the fourth year.

Doctor of Philosophy and Doctor of Science in Biological Engineering

The Department of Biological Engineering offers a Doctor of Philosophy (PhD) and Doctor of Science (ScD) in Biological Engineering; the program is the same for both degrees. The Biological Engineering doctoral program (*https://catalog.mit.edu/degree-charts/phd-biological-engineering*) 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. Upon successful completion of the program, students are awarded either the PhD or ScD in biological engineering.

Students admitted to the Biological Engineering doctoral 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] Introduction to Biological Chemistry, 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.

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) (*https://catalog.mit.edu/interdisciplinary/graduate-programs/leaders-*

global-operations) 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 eight engineering programs, some of which have optional or required LGO tracks. After graduation, alumni lead strategic initiatives in high-tech, operations, and manufacturing 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 (*https://catalog.mit.edu/interdisciplinary/graduate-programs/polymers-soft-matter*) under Interdisciplinary Graduate Programs.

Inquiries

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

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20.001 Introduction to Professional Success and Leadership in Biological Engineering
Prereq: None
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
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. Subject can count toward the 6-unit discovery-focused credit limit for first-year students.
L. Griffith

20.002 Introduction to Concepts in Biological Engineering
Prereq: None
U (Spring)
1-0-2 units

Introduction to scientific advances in the field of biological engineering. Topics covered include drug discovery and delivery, applications of genetic engineering, creation and uses of biomaterials, and development of biological technology to mitigate human disease and environmental problems. Discusses each selected topic from different angles, highlighting research conducted from the nano- to macro- level to highlight the breadth of biological engineering applications. Students have the opportunity to select a topic of interest and explore that topic in more depth. Subject can count toward the 6-unit discovery-focused credit limit for first-year students. Preference given to first-year students.
B. Meyer

20.005 Ethics for Engineers
Subject meets with 1.082[J], 2.900[J], 6.9320[J], 6.9321, 10.01[J], 16.676[J]
Prereq: None
U (Fall, Spring)
2-0-7 units

Explores how to be an ethical engineer. Students examine engineering case studies along with foundational ethical readings, and investigate which ethical approaches are best and how to apply them as engineers. Topics include justice, rights, cost-benefit analysis, safety, bias, genetic engineering, climate change, and the promise and peril of AI. Discussion-based. All sections cover the same core ethical frameworks, but some sections have a particular focus for engineering case studies, such as Computer Science or Bioengineering. Students are eligible to take any section of the course, regardless of their registered course number. The subject is taught in separate sections. For 20.005, students additionally undertake an ethical-technical analysis of a BE-related topic of their choosing.
D. Lauffenburger, P. Hansen

20.010 Introduction to Experimentation in BE
Prereq: None
U (Fall)
1-0-2 units

Teaches students to ask research questions and use the steps in the experimental method to test hypotheses. Introduces best practices in basic data analysis and interpretation. Additional topics include exploring experimental failures, unexpected results, and troubleshooting. Goal is to prepare students for undergraduate research opportunities and laboratory-based coursework. This is a discussion-based subject and is dependent on group participation. Preference to first- and second-year students.
N. Lyell

20.020 Introduction to Biological Engineering Design Using Synthetic Biology
Prereq: None
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 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. Students may have the option to continue projects for participation in the iGEM competition. Preference to first-year students.
J. Buck

20.051 Introduction to NEET: Living Machines
Prereq: Biology (GIR), Calculus II (GIR), Chemistry (GIR), and Physics I (GIR)
U (Fall, Spring)
2-2-2 units

Focuses on physiomimetics: transforming therapeutic strategy and development. Overview of development of therapies for complex diseases, including disease mechanisms in heterogeneous patient populations, developing therapeutic strategies, modeling these in vitro, and testing the therapies. Explores the five essential technological contributions to this process: computational systems biology, synthetic biology, immuno-engineering, microphysiological systems devices/tissue engineering, and microfluidic device engineering for in vitro models and analysis. Introduces disease modeling, patient stratification, and drug development processes, includes extensive examples from industry, and provides context for choosing a concentration track in the Living Machines thread. Weekly lectures from experts in the field supplemented with structured, short projects in each topic area. Limited to 24; preference to students in the NEET Living Machines thread.
L. Griffith, M. Salek

20.054 NEET - Living Machines Research Immersion
Prereq: 20.051
U (Fall, Spring)
Units arranged
Can be repeated for credit.

A structured lab research experience in a specific Living Machines track. Students identify a project in a participating research lab, on a topic related to the five tracks in the NEET Living Machines program, propose a project related to the drug development theme, and prepare interim and final presentations and reports while conducting the project. Links to industry-sponsored research projects at MIT are encouraged. Project proposal must be submitted and approved in the term prior to enrollment. Limited to students in the NEET Living Machines thread.
L. Griffith, E. Alm, M. Salek

20.101 Metakaryotic Biology and Epidemiology
Subject meets with 20.A02
Prereq: None
U (Fall)
2-0-4 units

Introduces non-eukaryotic, "metakaryotic" cells with hollow bell-shaped nuclei that serve as the stem cells of human fetal/juvenile growth and development as well as of tumors and atherosclerotic plaques. Studies the relationship of lifetime growth and mutations of metakaryotic stem cells to age-specific death rates. Considers the biological bases of treatment protocols found to kill metakaryotic cancer stem cells *in vitro* and in human pancreatic cancers *in vivo*.
W. G. Thilly

20.102 Metakaryotic Stem Cells in Carcinogenesis: Origins and Cures
Subject meets with 20.215
Prereq: Biology (GIR), Calculus II (GIR), and Chemistry (GIR)
U (Fall)
3-0-9 units

Metakaryotic stem cells of organogenesis, wound healing, and the pathogenic lesions of cancers and atherosclerotic plaques. Metakaryotic cell resistance to x-ray- and chemo-therapies. Common drug treatment protocols lethal to metakaryotic cancer stem cells *in vivo* first clinical trial against pancreatic cancer. Application of a hypermutable/mutator stem cell model to the age-specific mortality from clonal diseases, and the expected responses to metakaryocidal drugs in attempted cure and prevention of tumors or atherosclerotic plaques. Students taking 20.215 responsible for *de novo* computer modeling.
E. V. Gostjeva, W. G. Thilly

20.104[J] Environmental Cancer Risks, Prevention, and Therapy
Same subject as 1.081[J]
Prereq: Biology (GIR), Calculus II (GIR), and 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, 1895-2016, to discover specific historical shifts. Explored in terms of contemporaneously changing environmental risk factors: air-, food- and water-borne chemicals; subclinical infections; diet and lifestyles. Special section on occupational risk factors. Considers the hypotheses that genetic and/or environmental factors affect metakaryotic stem cell mutation rates in fetuses and juveniles and/or their growth rates of preneoplastic in adults.
W. Thilly, R. McCunney

20.106[J] Applied Microbiology
Same subject as 1.084[J]
Prereq: Biology (GIR) and Chemistry (GIR)
U (Fall)
Not offered regularly; consult department
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.
J. C. Niles, K. Ribbeck

20.109 Laboratory Fundamentals in Biological Engineering
Prereq: Biology (GIR), Chemistry (GIR), 6.100B, 18.03, and 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. In this, students complete discovery-based experimental modules drawn from current technologies and active research projects of BE faculty. Generally, topics include DNA engineering, in which students design, construct, and use genetic material; parts engineering, emphasizing protein design and quantitative assessment of protein performance; systems engineering, which considers genome-wide consequences of genetic perturbations; and biomaterials engineering, in which students use biologically-encoded devices to design and build materials. Enrollment limited; priority to Course 20 majors.
N. Lyell, A. Koehler, B. Engelward, L. McClain, B. Meyer, S. Clarke, P. Bhargava

20.110[J] Thermodynamics of Biomolecular Systems
Same subject as 2.772[J]
Prereq: (Biology (GIR), Calculus II (GIR), Chemistry (GIR), and Physics I (GIR)) or permission of instructor
U (Fall)
5-0-7 units. REST

Equilibrium properties of macroscopic and microscopic systems. Basic thermodynamics: state of a system, state variables. Work, heat, first law of thermodynamics, thermochemistry. Second and third law of thermodynamics: entropy and its statistical basis, Gibbs function. Chemical equilibrium of reactions in gas and solution phase. Macromolecular structure and interactions in solution. Driving forces for molecular self-assembly. Binding cooperativity, solvation, titration of macromolecules.
M. Birnbaum, C. Voigt

20.129[J] Biological Circuit Engineering Laboratory
Same subject as 6.4880[J]
Prereq: Biology (GIR) and Calculus II (GIR)
U (Spring)
2-8-2 units. Institute LAB

Students assemble individual genes and regulatory elements into larger-scale circuits; they experimentally characterize these circuits in yeast cells using quantitative techniques, including flow cytometry, and model their results computationally. Emphasizes concepts and techniques to perform independent experimental and computational synthetic biology research. Discusses current literature and ongoing research in the field of synthetic biology. Instruction and practice in oral and written communication provided. 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.
B. Engelward

20.201 Fundamentals of Drug Development
Prereq: Permission of instructor
G (Fall, Spring)
4-0-8 units

Team-based exploration of the scientific basis for developing new drugs. First portion of term covers fundamentals of target identification, drug discovery, pharmacokinetics, pharmacodynamics, regulatory policy, and intellectual property. Industry experts and academic entrepreneurs then present case studies of specific drugs, drug classes, and therapeutic targets. In a term-long project, student teams develop novel therapeutics to solve major unmet medical needs, with a trajectory to a "start-up" company. Culminates with team presentations to a panel of industry and scientific leaders.
P. C. Dedon, R. Sasisekharan

20.202 In vivo Models: Principles and Practices
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
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

20.205[J] Principles and Applications of Genetic Engineering for Biotechnology and Neuroscience
Same subject as 9.26[J]
Prereq: Biology (GIR)
U (Spring)
3-0-9 units

See description under subject 9.26[J].
F. Zhang

20.213 Genome Stability and Engineering in the Context of Diseases, Drugs, and Public Health
Prereq: 5.07[J], 7.05, or permission of instructor
U (Spring; second half of term)
4-0-5 units

Studies how DNA damage leads to diseases, and how DNA repair modulates cancer risk and treatment. Also covers how DNA repair impacts genetic engineering, whether by targeted gene therapy or CRISPR-mediated genetic changes. Students gain a public health perspective by examining how DNA-damaging agents in our environment can lead to downstream cancer. Explores the underlying chemical, molecular and biochemical processes of DNA damage and repair, and their implications for disease susceptibility and treatment.
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) and 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. Involves de novo computer modeling of a lifetime disease experience or test of a student-developed hypothesis.
W. G. Thilly

20.219 Selected Topics in Biological Engineering
Prereq: Permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
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

20.230[J] Immunology
Same subject as 7.23[J]
Subject meets with 7.63[J], 20.630[J]
Prereq: 7.06
U (Spring)
5-0-7 units

See description under subject 7.23[J].
S. Spranger, M. Birnbaum

20.260 Computational Analysis of Biological Data
Subject meets with 20.460
Prereq: 6.100A or permission of instructor
U (Spring)
3-0-6 units

Presents foundational methods for analysis of complex biological datasets. Covers fundamental concepts in probability, statistics, and linear algebra underlying computational tools that enable generation of biological insights. Assignments focus on practical examples spanning basic science and medical applications. Assumes basic knowledge of calculus and programming (experience with MATLAB, Python, or R is recommended). Students taking graduate version complete additional assignments.
D. Lauffenburger, F. White

20.265 Genetics for Biological Engineering
Prereq: 6.100A or permission of instructor
U (Spring; second half of term)
Not offered regularly; consult department
3-0-3 units

Covers topics in genetics from an engineering perspective. Designed to be taken before, concurrently with, or after a traditional genetics class. Focuses primarily on the quantitative methods and algorithms used in genetics and genomics. Provides a strong foundation in genomics and bioinformatics and prepares students, through real-world problem-solving, for upper-level classes in those topics. Basics of modern genomics tools and approaches -- including RNAseq, high-throughout genome sequencing, genome-wide association studies, metagenomics, and others -- presented. Requires some experience with Python programming.
E. Alm

20.305[J] Principles of Synthetic Biology
Same subject as 6.8721[J]
Subject meets with 6.8720[J], 20.405[J]
Prereq: None
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), 6.100B, and 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.
P. Blainey, S. Manalis, E. Frank, S. Wasserman, J. Bagnall, E. Boyden, P. So

20.310[J] Molecular, Cellular, and Tissue Biomechanics
Same subject as 2.797[J], 3.053[J], 6.4840[J]
Subject meets with 2.798[J], 3.971[J], 6.4842[J], 10.537[J], 20.410[J]
Prereq: Biology (GIR) and 18.03
U (Spring)
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. Students taking graduate version complete additional assignments.
M. Bathe, K. Ribbeck, P. T. So

20.315 Physical Biology
Subject meets with 20.415
Prereq: 5.60, 20.110[J], or permission of instructor
U (Fall, Spring)
Not offered regularly; consult department
3-0-9 units
Credit cannot also be received for 8.241

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. 20.315 and 20.415 meet with 8.241 when offered concurrently.
J. Gore, I. Cisse

20.320 Analysis of Biomolecular and Cellular Systems
Prereq: 6.100B, 18.03, and 20.110[J]; *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

20.330[J] Fields, Forces and Flows in Biological Systems
Same subject as 2.793[J], 6.4830[J]
Prereq: Biology (GIR), Physics II (GIR), and 18.03
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 electrokinetics. Applications include biomolecular transport in tissues, electrophoresis, and microfluidics.
J. Han, S. Manalis

20.334 Biological Systems Modeling
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 Bioinstrumentation Project Lab
Prereq: 20.309[J], (Biology (GIR) and (2.004 or 6.3000)), or permission of instructor
U (Spring)
Not offered regularly; consult department
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, P. So, S. Wasserman

20.352 Principles of Neuroengineering
Subject meets with 9.422[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: (7.06 and (2.005, 3.012, 5.60, or 20.110[J])) or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Spring)
4-0-8 units
Credit cannot also be received for 7.371

See description under subject 7.37[J].
Staff

20.363[J] Biomaterials Science and Engineering
Same subject as 3.055[J]
Subject meets with 3.963[J], 20.463[J]
Prereq: 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: (5.60 or 20.110[J]) and permission of instructor
U (Spring)
3-0-6 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

20.370[J] Cellular Neurophysiology and Computing
Same subject as 2.791[J], 6.4810[J], 9.21[J]
Subject meets with 2.794[J], 6.4812[J], 9.021[J], 20.470[J], HST.541[J]
Prereq: (Physics II (GIR), 18.03, and (2.005, 6.2000, 6.3000, 10.301, or 20.110[J])) or permission of instructor
U (Spring)
5-2-5 units

See description under subject 6.4810[J]. Preference to juniors and seniors.
J. Han, T. Heldt

20.373 Foundations of Cell Therapy Manufacturing
Subject meets with 20.473
Prereq: None
U (Spring)
Not offered regularly; consult department
3-0-6 units

Seminar examines cell therapy manufacturing, the ex vivo production of human cells to be delivered to humans as a product for medical benefit. Includes a review of cell biology and immunology. Addresses topics such as governmental regulations applying to cell therapy production; the manufacture of cell-based therapeutics, including cell culture unit operations, genetic engineering or editing of cells; process engineering of cell therapy products; and the analytics of cell therapy manufacturing processes. Students taking graduate version complete additional assignments.
K. Van Vliet

20.375 Applied Developmental Biology and Tissue Engineering
Subject meets with 20.475
Prereq: (7.06, 20.320, and (7.003[J] or 20.109)) or permission of instructor
U (Spring)
Not offered regularly; consult department
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 morphogenic 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. Griffith

20.380 Biological Engineering Design
Prereq: 7.06, 20.320, and 20.330[J]
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.
J. Collins, A. Koehler, J. Essigmann, K. Ribbeck

20.381 Biological Engineering Design II
Prereq: 20.380 or permission of instructor
U (Spring)
0-12-0 units

Continuation of 20.380 that focuses on practical implementation of design proposals. Student teams choose a feasible scope of work related to their 20.380 design proposals and execute it in the lab.
M. Jonas, J. Sutton, S. Wasserman

20.385 Design in Synthetic Biology
Prereq: (20.020, 20.109, and 20.320) or permission of instructor
U (Spring)
3-3-3 units

Provides an understanding of the state of research in synthetic biology and development of project management skills. 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. Students may have the option to continue projects for participation in the iGEM competition.
J. Buck

20.390[J] Computational Systems Biology: Deep Learning in the Life Sciences
Same subject as 6.8711[J]
Subject meets with 6.8710[J], 20.490, HST.506[J]
Prereq: (6.100B and 7.05) or permission of instructor
Acad Year 2024-2025: U (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

See description under subject 6.8711[J].
D. K. Gifford

20.405[J] Principles of Synthetic Biology
Same subject as 6.8720[J]
Subject meets with 6.8721[J], 20.305[J]
Prereq: None
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 microscopies, 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.
P. Blainey, S. Manalis, S. Wasserman, J. Bagnall, E. Frank, E. Boyden, P. So

20.410[J] Molecular, Cellular, and Tissue Biomechanics
Same subject as 2.798[J], 3.971[J], 6.4842[J], 10.537[J]
Subject meets with 2.797[J], 3.053[J], 6.4840[J], 20.310[J]
Prereq: Biology (GIR) and 18.03
G (Spring)
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. Students taking graduate version complete additional assignments.
M. Bathe, K. Ribbeck, P. T. So

20.415 Physical Biology
Subject meets with 20.315
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units
Credit cannot also be received for 8.241

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. 20.315 and 20.415 meet with 8.241 when offered concurrently.
J. Gore, I. Cisse

20.416[J] Topics in Biophysics and Physical Biology
Same subject as 7.74[J], 8.590[J]
Prereq: None
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
2-0-4 units

See description under subject 8.590[J].
J. Gore, N. Fakhri

20.420[J] Principles of Molecular Bioengineering
Same subject as 10.538[J]
Prereq: 7.06 and 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

20.430[J] Fields, Forces, and Flows in Biological Systems
Same subject as 2.795[J], 6.4832[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: 20.420[J] and permission of instructor
G (Spring)
6-0-9 units

Explores computational and experimental approaches to analyzing complex biological networks and systems. Includes genomics, transcriptomics, proteomics, metabolomics and microscopy. Stresses the practical considerations required when designing and performing experiments. Also focuses on selection and implementation of appropriate computational tools for processing, visualizing, and integrating different types of experimental data, including supervised and unsupervised machine learning methods, and multi-omics modelling. Students use statistical methods to test hypotheses and assess the validity of conclusions. In problem sets, students read current literature, develop their skills in Python and R, and interpret quantitative results in a biological manner. In the second half of term, students work in groups to complete a project in which they apply the computational approaches covered.
B. Bryson, P. Blainey

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, O. Cordero

20.450 Applied Microbiology
Prereq: (20.420[J] and 20.440) or permission of instructor
G (Fall)
Not offered regularly; consult department
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, K. Ribbeck

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

20.460 Computational Analysis of Biological Data
Subject meets with 20.260
Prereq: None
G (Spring)
3-0-6 units

Presents foundational methods for analysis of complex biological datasets. Covers fundamental concepts in probability, statistics, and linear algebra underlying computational tools that enable generation of biological insights. Assignments focus on practical examples spanning basic science and medical applications. Assumes basic knowledge of calculus and programming (experience with MATLAB, Python, or R is recommended). Students taking graduate version complete additional assignments.
D. Lauffenburger, F. White

20.463[J] Biomaterials Science and Engineering
Same subject as 3.963[J]
Subject meets with 3.055[J], 20.363[J]
Prereq: 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
G (Spring)
3-0-6 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

20.470[J] Cellular Neurophysiology and Computing
Same subject as 2.794[J], 6.4812[J], 9.021[J], HST.541[J]
Subject meets with 2.791[J], 6.4810[J], 9.21[J], 20.370[J]
Prereq: (Physics II (GIR), 18.03, and (2.005, 6.2000, 6.3000, 10.301, or 20.110[J])) or permission of instructor
G (Spring)
5-2-5 units

See description under subject 6.4812[J].
J. Han, T. Heldt

20.473 Foundations of Cell Therapy Manufacturing
Subject meets with 20.373
Prereq: None
G (Spring)
Not offered regularly; consult department
3-0-6 units

Seminar examines cell therapy manufacturing, the ex vivo production of human cells to be delivered to humans as a product for medical benefit. Includes a review of cell biology and immunology. Addresses topics such as governmental regulations applying to cell therapy production; the manufacture of cell-based therapeutics, including cell culture unit operations, genetic engineering or editing of cells; process engineering of cell therapy products; and the analytics of cell therapy manufacturing processes. Students taking graduate version complete additional assignments.
K. Van Vliet

20.475 Applied Developmental Biology and Tissue Engineering
Subject meets with 20.375
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
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. Griffith

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)
Not offered regularly; consult department
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.
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 Computational Systems Biology: Deep Learning in the Life Sciences
Subject meets with 6.8710[J], 6.8711[J], 20.390[J], HST.506[J]
Prereq: Biology (GIR) and (6.041 or 18.600)
G (Spring)
3-0-9 units

Presents innovative approaches to computational problems in the life sciences, focusing on deep learning-based approaches with comparisons to conventional methods. Topics include protein-DNA interaction, chromatin accessibility, regulatory variant interpretation, medical image understanding, medical record understanding, therapeutic design, and experiment design (the choice and interpretation of interventions). Focuses on machine learning model selection, robustness, and interpretation. Teams complete a multidisciplinary final research project using TensorFlow or other framework. Provides a comprehensive introduction to each life sciences problem, but relies upon students understanding probabilistic problem formulations. Students taking graduate version complete additional assignments.
D. K. Gifford

20.507[J] Introduction to Biological Chemistry
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].
B. Pentelute, E. Nolan

20.535[J] Protein Engineering
Same subject as 10.535[J]
Prereq: 18.03 and (5.07[J] or 7.05)
G (Spring)
3-0-9 units

See description under subject 10.535[J].
K. D. Wittrup

20.554[J] Advances in Chemical Biology
Same subject as 5.54[J], 7.540[J]
Prereq: 5.07[J], 5.13, 7.06, and permission of instructor
G (Fall)
3-0-9 units

See description under subject 5.54[J].
L. Kiessling, M. Shoulders

20.560 Statistics for Biological Engineering
Prereq: Permission of instructor
G (Spring; second half of term)
Not offered regularly; consult department
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

20.561[J] Eukaryotic Cell Biology: Principles and Practice
Same subject as 7.61[J]
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
4-0-8 units

See description under subject 7.61[J]. Enrollment limited.
M. Krieger, M. Yaffe

20.586[J] Science and Business of Biotechnology
Same subject as 7.546[J], 15.480[J]
Prereq: None. *Coreq: 15.401*; permission of instructor
G (Spring)
3-0-6 units

Covers the new types of drugs and other therapeutics in current practice and under development, the financing and business structures of early-stage biotechnology companies, and the evaluation of their risk/reward profiles. Includes a series of live case studies with industry leaders of both established and emerging biotechnology companies as guest speakers, focusing on the underlying science and engineering as well as core financing and business issues. Students must possess a basic background in cellular and molecular biology.
J. Chen, A. Koehler, A. Lo, H. Lodish

20.630[J] Immunology
Same subject as 7.63[J]
Subject meets with 7.23[J], 20.230[J]
Prereq: 7.06 and permission of instructor
G (Spring)
5-0-7 units

See description under subject 7.63[J].
S. Spranger, M. Birnbaum

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
Can be repeated for credit.

For Course 20 students participating in off-campus professional experiences in biological engineering. Before registering for this subject, students must have an offer from a company or organization and must identify a BE advisor. Upon completion, student must submit a letter from the company or organization describing the experience, along with a substantive final report from the student approved by the MIT advisor. Subject to departmental approval. Consult departmental undergraduate office.
Staff

20.930[J] Research Experience in Biopharma
Same subject as 7.930[J], CSB.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.
C. Burge

20.945 Practical Experience in Biological Engineering
Prereq: None
G (Fall, IAP, Spring, Summer)
0-1-0 units

For Course 20 doctoral students participating in off-campus research, academic experiences, or internships in biological engineering. For internship experiences, an offer of employment from a company or organization is required prior to enrollment; employers must document work accomplished. A written report is required upon completion of a minimum of four weeks of off-campus experience. Proposals must be approved by department.
K. Ribbeck, P. Blainey

20.950 Research Problems in Biological Engineering
Prereq: Permission of instructor
G (Fall, IAP, 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 advisor. Forms and instructions for the proposal and final report are available in the BE Undergraduate Office.
Consult Staff

20.C01[J] Machine Learning for Molecular Engineering
Same subject as 3.C01[J], 10.C01[J]
Subject meets with 3.C51[J], 7.C01, 7.C51, 10.C51[J], 20.C51[J]
Prereq: Calculus II (GIR), 6.100A, and 6.C01
U (Spring)
2-0-4 units

See description under subject 3.C01[J].
R. Gomez-Bombarelli, C. Coley, E. Fraenkel

20.C51[J] Machine Learning for Molecular Engineering
Same subject as 3.C51[J], 10.C51[J]
Subject meets with 3.C01[J], 7.C01, 7.C51, 10.C01[J], 20.C01[J]
Prereq: Calculus II (GIR), 6.100A, and 6.C51
G (Spring)
2-0-4 units

See description under subject 3.C51[J].
R. Gomez-Bombarelli, C. Coley, E. Fraenkel

20.EPE UPOP Engineering Practice Experience
Engineering School-Wide Elective Subject.
Offered under: 1.EPE, 2.EPE, 3.EPE, 6.EPE, 8.EPE, 10.EPE, 15.EPE, 16.EPE, 20.EPE, 22.EPE
Prereq: None
U (Fall, Spring)
0-0-1 units
Can be repeated for credit.

See description under subject 2.EPE. Application required; consult UPOP website for more information.
K. Tan-Tiongco, D. Fordell

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: 2.EPE
U (Fall, IAP, Spring)
1-0-0 units

See description under subject 2.EPW. Enrollment limited to those in the UPOP program.
K. Tan-Tiongco, D. Fordell

20.S900 Special Subject in Biological Engineering
Prereq: Permission of instructor
U (Fall, Spring, Summer)
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.S901 Special Subject in Biological Engineering
Prereq: None
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.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, IAP, Spring, Summer)
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.S948 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.S949 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