

## Course 20 Restricted Electives List

2 BE Restricted Electives are required (21-24 units)

4 Unrestricted Electives are required. (48 units)

### *Guidelines for Restricted Electives*

- BE Restricted electives in BE should prepare students for advanced graduate work or for practice.
- Restricted Electives should be advanced (Jr/Sr) subjects with at least some pre-reqs from fresh/soph curriculum.
- Survey subjects (no or minimal pre-reqs) should in general be taken with unrestricted elective credit
- Individual advisors can work with students to provide flexibility; e.g., an advisor may suggest that a student take an intro-level subject as an unrestricted elective and a pair of upper-level subjects as restricted electives
- For students in the class of 20.011 or later, at least one BE restricted elective must be have a Course 20 number (it is recommended that students in the Clases of 2009 and 2010 also follow this policy)
- The BE UG student board is preparing a guide to restricted electives, and the BE associate advisors are good resources for information until the guide is published.
- Students who wish to obtain credit for a restricted elective that does not appear on the list may petition the BE UG programs committee. Petitioning is not a mere formality –the committee seriously evaluates the addition of new subjects to the list based on student interest, but some requests are not approved on either a global or individual level hence you must have alternate plans if your petition is not approved. If you wish to petition, you should fill out a petition form in the BE UG Programs office (Room 16-429). The UG programs committee meets 2-3 times per term. You should allow 6-8 weeks to have your petition considered after submission. Petitions should be submitted at least one term in advance of enrollment, so that alternate plans can be implemented if the petition is not approved.

\*The courses listed under "Foundational Tools" can be used to fulfill the Restricted Elective requirements

### **Emphasis Areas (& Assigned Emphasis Organizer):**

Emphasis Areas are intended to provide guidance on available subjects within a particular emphasis area of biological engineering research and application. There is no requirement that both BE restricted electives have to be in the same emphasis area.

- Biomechanics and Biophysics (Prof. Peter So & Prof. Matt Lang)
- BioMEMS & Biological Instrumentation (Prof. Jay Han & Prof. Peter So)
- Synthetic Biology & Macromolecular Design (Prof. Michael Yaffe)
- Computational & Systems Biology (Prof. Michael Yaffe)
- Microbial and Ecological Systems (Prof. Eric Alm & Prof. David Schauer)
- Pharmacology & Toxicology (Prof. John Essigmann)
- Cell & Tissue Engineering (Prof. Linda Griffith)
- Human Pathophysiology & Public Health (Prof. David Schauer)
- Neuroscience (Prof. Linda Griffith)

### **Biomechanics and Biophysics (Peter So, with Matt Lang)**

The biophysics focus area will build a foundation in the physical principles underlying Nature's machinery from both a theoretical and experimental perspective spanning single molecule measurements of biological motors to cell and tissue level machinery. The area encompasses foundational subjects in experimental biophysics including introduction of advanced measurements such as imaging and spectroscopy and skills used to build instrumentation.

### Restricted Electives

#### **2.71 Optics (U)**

Prereq: 8.02; 18.03; 2.004; or permission of instructor

#### **2.715J/20.487J Optical Microscopy & Spectroscopy for Biology and Medicine (G)**

Prereq: Permission of instructor

#### **2.717J/MAS.857J Optical Engineering (G, H)**

Prereq: 2.710 or permission of instructor

#### **2.785J/3.97J/20.411J/HST.523J Cell-Matrix Mechanics (G, H)**

Prereq: 3.091 or 5.11 or 5.111 or 5.112; 2.005 or 5.60; 7.013, 7.014, or 7.015

**3.052 Nanomechanics of Materials and Biomaterials (U)**

Prereq: 3.032 or permission of instructor

**3.22 Mechanical Behavior of Materials (G, H)**

Prereq: 3.032

**5.08J/7.08J Biological Chemistry II (U)**

Prereq: 5.12; 5.07 or 7.05

**5.64 Biophysical Chemistry (G, H)**

Prereq: 5.13; 5.60; 5.07 or 7.05

**5.65 Molecular Imaging (G, H)**

Prereq: 5.13; 5.60; 5.07 or 7.05

**6.002 Circuits and Electronics (U)**

Prereq: 18.03; 8.02, 8.022 or 6.01

**7.71 Biophysical Chemistry Techniques (G)**

Prereq: 5.13, 5.60; 5.07 or 7.05

**20.462J/3.962J Molecular Principles of Biomaterials (G, H)**

Prereq: Permission of instructor

**BioMEMS / Bioinstrumentation (Prof. Jay Han, Prof. Peter So)**

Major advances in biology almost always concur with novel tools and instrumentations. Using tools in BioMEMS and biophotonics, one can access and manipulate biological systems at a micro/nanometer scale. Understanding various engineering methods used for this purpose would be critical in developing new tools for biotechnology and / or biomedical devices.

*Restricted Electives***6.152J/3.155J Micro/Nano Processing Technology (U)**

Prereq: Permission of instructor

**2.371 Microscale Fluid Mechanics (U)**

Prereq: 2.005; 8.02

**2.372J/6.777J Design and Fabrication of MEMS (G, H)**

Prereq: 6.003 or 2.004, 8.02, or permission of instructor

**2.373J/3.48J/6.778J/10.584J/16.288J Materials and Processes for Microelectromechanical Devices and Systems (G, H)**

Prereq: 6.152J/3.155J; permission of instructor

**2.391J/6.781J Nanoscale Fabrication, Microscopy, Materials, and Applications (G, H)**

Prereq: 6.152, 6.161, 2.710, or permission of instructor

**2.674 Micro/Nano Engineering Laboratory (U)**

Prereq: 2.001; 3.091 or 5.111

**2.782J/3.961J/20.451J/HST.534J Design of Medical Devices and Implants (G, H)**

Prereq: 2.79J or permission of instructor

*Unrestricted Freshmen Elective***6.07J/HST.410J Projects in Microscale Engineering for the Life Sciences (U)**

Prereq: --

**Synthetic Biology & Macromolecular Design (Prof. Mike Yaffe)**

One underlying responsibility of biological engineers is to improve the process of engineering biology, so that it becomes easier to design and build engineered biological systems that address societal needs. This Biological Engineering elective area provides students an opportunity to enhance their foundational and applied understanding of methods for engineering integrated biological systems. Students also study current and expected future applications of biological technologies.

*Foundational Tools***6.002 Circuits and Electronics (U)**

Prereq: 18.03, 8.02, 8.022 or 6.01

*Restricted Electives***7.76 Topics in Protein Biochemistry (G)**

Pre-req: Permission of Instructor

**NEW 20.902/20.947: Advanced Topics in Synthetic Biology (U, G)**

Pre-req: Permission of Instructor

*Introductory (Freshman) Unrestricted Elective***20.020 Introduction to Biological Engineering Design (U)**

Pre-req: --

**Computational & Systems Biology (Prof. Mike Yaffe)**

This focus area of study emphasizes the design and implementation of mathematical and computational tools to analyze large biological datasets such as protein and DNA sequences and structures, gene expression profiles, large-scale signaling compendia, high-throughput automated microscopic image analysis, and evolution of complex biological systems. The area encompasses foundational math and computing subjects as well as subjects that apply computational and systems approaches to biology.

*Foundational Tools***18.06 Linear Algebra (U)**

Prereq: 18.02

– or –

**18.062J/6.042J Mathematics for Computer Science (U)**

Prereq: 18.01

**6.003 Signals and Systems (U)**

Prereq: 6.002 or 6.02

– or –

**6.041 Probabilistic Systems Analysis (U)**

Prereq: 18.02

**6.034 Artificial Intelligence (U)**

Prereq: 6.001 or 6.01

**6.047 Computational Biology: Genomes, Networks, Evolution (U)**

Prereq: 6.006, 6.041, 7.01x; or permission of instructor

*Restricted Electives***20.390 Foundations of Computational and Systems Biology (U)**

Prereq: 7.05 or 5.07; or 7.01x and 6.001; or permission of instructor

**20.482J/6.581J Foundations of Algorithms and Computational Techniques in Systems Biology (G)**

Prereq: 6.021J, 6.034, 6.046, 6.336J, 7.91J, 18.417, or permission of instructor

– or –

**6.807 Computational Functional Genomics (U)**

Prereq: 7.012, 7.013, 7.014, or 7.015

**9.29J/8.261J Introduction to Computational Neuroscience (U)**

Prereq: 18.03 and 8.02, or permission of instructor

**Microbial and Ecological Systems (Prof. Eric Alm, Prof. David Schauer)**

This area provides an introduction to the systems-level analysis of microorganisms in natural and artificial environments. Students will learn the fundamentals of interpretation of genome-scale measurements, comparative genome analysis, and evolution, genetics, and diversity of microorganisms. Examples highlight the multiple roles of microbes in industrial processes, agricultural systems, human health and disease, bioremediation, and biogeochemical cycling.

*Restricted Electives***1.018J /7.30J Ecology I: The Earth System (U)**

Pre-Req: --

**20.106J/1.084J Systems Microbiology (U)**

Prereq: 5.111, 5.112 or 3.091; 7.012/7.013/7.014

**1.89 Environmental Microbiology (G, H)**

Prereq: 7.014

**7.21 (meets with 7.62) Microbial Physiology (U)**

Prereq: 7.03, 7.05/5.07

**1.82 Problems in Environmental Microbiology and Chemistry (G, H)**

Prereq: permission of instructor

**7.493J/1.87J/20.446J Microbial Genetics and Evolution (G, H, New)**

Prereq: 7.03, 7.05, 7.28, or permission of instructor

## **Pharmacology and Toxicology (Prof. John Essigmann)**

Effects of chemicals, microorganisms and radiation on biological systems studied at the molecular, cellular, tissue, organism and, ultimately, population levels of organization. Applications in public health, drug design and drug development are emphasized.

### Foundational Tools

#### **5.08J/7.08J Biological Chemistry II (U)**

Prereq: 5.12; 5.07 or 7.05

#### **20.106J/1.084J Systems Microbiology (U)**

Prereq: 5.111, 5.112 or 3.091; 7.012/7.013/7.014

#### **20.104J/1.081J/ESD.053J Environmental Risks for Common Disease (U)**

Prereq: Biology (GIR), Chemistry (GIR)

### Restricted Electives

#### **20.102 (meets with 20.215) Macroeconomics and Population Genetics (U)**

Prereq: 18.01

#### **9.15 (meets with 9.150) Biochemistry and Pharmacology of Synaptic Transmission (U)**

Prereq: 9.01, 7.05, or permission of instructor

#### **20.201 Mechanisms of Drug Actions (G, H)**

Prereq: Permission of instructor

#### **20.213 DNA Damage and Genomic Instability (G, H)**

Prereq: 5.07, 7.05, permission of instructor

#### **20.360J/10.499J Tissue Engineering for Analysis, Prevention, and Treatment of Human Disease (U)**

Prereq: 5.07 or 7.05; 7.03; 18.03; 20.110J/2.772J or 5.60

#### **7.37J/20.361J/10.441J Molecular and Engineering Aspects of Biotechnology (U)**

Prereq: 20.110J/2.772J, 2.005, 3.012, or 5.60; 7.06; or permission of instructor

## **Cell & Tissue Engineering (Prof. Linda Griffith)**

A goal of tissue engineering is to build functional 3D tissues for either therapy (in vivo replacement/regeneration) or technology (in vitro models for drug development) applications. Tissue engineering is built on a foundation of cell engineering - quantitative analysis of how cells respond to molecular cues – and requires fundamental design principles for using defined external cues to drive formation of tissues. Biomaterials approaches are needed for controlling cell behavior at the molecular and macroscopic scale, and fabrication of tissues requires integration of microscopic and macroscopic tools which may include manufacturing and design considerations.

### Restricted Electives

#### **20.340J/3.051J Materials for Biomedical Applications (U)**

Prereq: 3.091 or 5.11 or 5.111; 7.012/7.013/7.014; 3.00 or 3.012, 5.60 or 2.005

#### **20.441J/2.79J/3.96J/HST.522J Biomaterials-Tissue Interactions (G)**

Prereq: 3.091; 5.111 or 5.112; 2.005 or 5.60; 7.012 or 7.013

#### **20.360J/10.499J Tissue Engineering for Analysis, Prevention, and Treatment of Human Disease (U)**

Prereq: 5.07 or 7.05; 7.03; 18.03; 20.110 or 5.60

#### **7.37J/10.441J/20.361J Molecular & Engineering Aspects of Biotechnology (U)**

Prereq: 20.110, 2.005, 3.012, or 5.60; 7.06; or permission of instructor

#### **20.342 (meets with 20.442) Molecular Structure of Biological Materials (U)**

Prereq: 5.07 or 7.05; permission of instructor

#### **20.451J/2.782J/3.961J/HST.524J Design of Medical Devices and Implants (G)**

Prereq: 2.79J or permission of instructor

#### **3.052 Nanomechanics of Materials and Biomaterials (U)**

Prereq: 3.032, or permission of instructor

#### **20.411J/2.785J/3.97J/HST.523J Cell Matrix Mechanics (G)**

Prereq: 3.091 or 5.11 or 5.111 or 5.112; 2.005 or 5.60; 7.012, 7.013, 7.014 or 7.015

#### **3.962J/20.462J Molecular Principles of Biomaterials (G)**

Prereq: Permission of instructor

## **Human Pathophysiology (Prof. David Schauer)**

This area focuses on the application of molecular and cellular approaches to organ- and organism-level processes. A foundation in quantitative physiology prepares students for application areas such as human metabolism, immunity, and pathophysiology (changes associated with disease). It also includes application to public health.

### Restricted Electives

#### **20.370J/2.791J/6.021J Quantitative Physiology: Cells and Tissues (U)**

Prereq: Physics II (GIR), 18.03, 2.005, 6.002, 6.003, 6.071, 10.301, or permission of instructor

#### **20.371J/2.792K/6.022J/HST.542J Quantitative Physiology: Organ Transport Systems (U)**

Prereq: 18.03, 8.02, or permission of instructor

#### **7.20J/HST.540J Human Physiology (U)**

Prereq: 7.05

#### **7.23 (meets with 7.63) General Immunology (U)**

Prereq: 7.03, 7.05, 7.06, or permission of instructor

#### **7.27 Principles of Human Disease (U)**

Prereq: 7.03, 7.05, 7.06

#### **20.450 Molecular and Cellular Pathophysiology (G)**

Prereq: 20.420, 20.440, or permission of instructor

## **Neuroscience (Prof. Linda Griffith)**

Reflecting the diversity of neuroscience at MIT, the neuroscience emphasis area contains a mix of molecular and cellular science subjects and cognitive/computational subjects. Some subjects may require the freshman-level subject 9.01, which BE suggests as an unrestricted elective for interested students.

### Restricted Electives

#### **9.02 Systems Neuroscience Laboratory (U)**

Prereq: 9.01

#### **9.07 Statistics for Brain & Cognitive Science (U)**

Prereq: 18.01, 18.02, or permission of instructor

#### **9.173J/20.483/22.56J, HST.561J Noninvasive Imaging in Biology and Medicine (G, H)**

Prereq: 18.03, 8.03, or permission of instructor

#### **9.29J/8.261J Introduction to Computational Neuroscience (U)**

Pre-req: 18.03, 8.02, or permission of instructor

#### **7.29J/9.09J Cellular Neurobiology (U)**

Prereq: 7.05

#### **9.15 Biochemistry and Pharmacology of Synaptic Transmission (U)**

Prereq: 9.01, 7.05, or permission of instructor

#### **9.472J/20.472J Neuroimaging Cells and Circuits (G)**

Prereq: permission of instructor

#### **MAS.881J/9.422J/20.452J Principles of Neuroengineering (G, H)**

Prereq: 8.03, 6.003, and 9.01, or permission of instructor

### Unrestricted (Introductory-level) Elective

#### **9.01 Introduction to Neuroscience (U)**

Prereq: Physics II (GIR), or permission of instructor