

# BIOENGINEERING

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## **DEGREES OFFERED: BSB, MBE, MS, PHD**

Graduate programs in bioengineering offer concentrations in areas such as biomedical imaging and diagnostics, cellular and biomolecular engineering, computational and theoretical bioengineering, drug delivery and biomaterials, supramolecular biophysics and bioengineering, and tissue engineering and

biomechanics. Undergraduate programs in bioengineering offer concentrations in areas that include cellular and molecular engineering; bioinstrumentation, imaging, and optics; and biomaterials and biomechanics. Research areas include biomechanical engineering, biological systems modeling, bioinformatics, biomaterials, biomedical lasers, cellular and molecular engineering, controlled release technologies, metabolic engineering, spectroscopy, statistical mechanics, systems engineering and instrumentation, thrombosis, tissue engineering, and transport processes.

**Undergraduate Program**—The overall goal of the BS degree in bioengineering is to prepare students to succeed in professional careers by equipping them with the conceptual and technical expertise sought after by top graduate and medical schools, as well as by companies seeking technical skills in bioengineering.

The educational objectives that students are expected to exhibit or achieve after graduation with the BS degree in bioengineering from Rice University are:

- Critical problem solving skills
- Fundamental understanding of math and the natural, life, and medical sciences
- Knowledge of bioengineering principles and their applications
- Ability to conduct scientific inquiry in bioengineering
- Ability to design solutions to real-world engineering problems
- Ability to communicate and work effectively with others
- Preparation for professional challenges that arise in a rapidly-changing field

The BSB degree is organized around a core of required courses and a selection of elective courses from 3 areas of specialization. The specialization electives provide a flexibility that can be used to create a focus in cellular and molecular engineering; bioinstrumentation, imaging, and optics; or biomaterials and biomechanics. Because of the number of options, students should consult early with departmental advisors to plan a program that meets their needs.

## DEGREE REQUIREMENTS FOR BS IN BIOENGINEERING

For general university requirements, see Graduation Requirements (pages 16–19). The curriculum for a BS degree in bioengineering requires 94 credit hours, which count toward the total of 134 hours required to graduate.

**Preparation**—As freshmen, students considering a major in bioengineering should take MATH 101 and 102, CHEM 121 and 122, PHYS 101 or PHYS 125, PHYS 102 or PHYS 126, and CAAM 210. Sophomore students should take MATH 211 and 212, CHEM 211, BIOS 201, ELEC 243 and MECH 211. BIOE 252 should be taken in the 1st semester of the sophomore year. BIOE 330, BIOE 320, and BIOE 322 should be taken the 2nd semester of the sophomore year.

Students majoring in bioengineering must complete the following courses.

### Core Courses

#### ***Bioengineering***

BIOE 252 *Bioengineering Fundamentals*

BIOE 320 *Systems Physiology Laboratory Module*

BIOE 322 *Systems Physiology*

BIOE 330 *Bioreaction Engineering*

BIOE 332 *Thermodynamics*

BIOE 342 *Tissue Culture Laboratory*

BIOE 370 *Biomaterials*

BIOE 372 *Biomechanics*

BIOE 383 *Biomedical Instrumentation*

BIOE 385 *Biomedical Instrumentation Laboratory*

BIOE 391 *Numerical Methods*

BIOE 420 *Biosystems Transport and Reaction Processes*

BIOE 440 *Statistics for Bioengineers*

BIOE 442\* *Tissue Engineering Laboratory Module*

BIOE 443\* *Bioprocessing Laboratory Module*

BIOE 444\* *Biomechanical Testing Laboratory Module*

BIOE 445\* *Advanced Bioinstrumentation Laboratory Module*

BIOE 451 *Bioengineering Design I*

BIOE 452 *Bioengineering Design II*

### **Biosciences**

BIOS 201 *Introductory Biology*

BIOS 341 *Cell Biology*

### **Computational and Applied Mathematics**

CAAM 210 *Introduction to Engineering Computation*

\*Students must take advanced laboratory module in their specialization area: BIOE 442 or BIOE 443 for cellular and molecular engineering; BIOE 442 or 444 for biomaterials and biomechanics; and BIOE 445 for bioinstrumentation, imaging and optics. Students must take one other advanced laboratory module for a total of 2 of the 4 listed modules (BIOE 442, 443, 444, and 445).

## **SPECIALIZATION AREAS**

Three specialization area elective courses, at least 2 of which must be at the senior level, will be required in 1 of the 3 areas:

- Cellular and molecular engineering
- Bioinstrumentation, imaging, and optics
- Biomaterials and biomechanics

The elective courses in these concentration areas will be announced in future course listings. All 3 specialization courses must be engineering courses.

**Undergraduate Minor**—The Department of Bioengineering collaborates with a number of departments to offer Rice undergraduate students a minor in global health technologies (GLHT) through the Beyond Traditional Borders (BTB) initiative—a unique, multidisciplinary program to educate and train students to reach beyond traditional disciplinary and geographic boundaries to understand, address, and solve global health disparities. With complementary contributions from the humanities, social sciences, policy, bioscience, and engineering programs at Rice, the GLHT minor prepares students to integrate diverse perspectives as they develop solutions to the complex problems of global health, using the formal approach of the engineering design process.

**See GLOBAL HEALTH TECHNOLOGIES in the Departments and Interdisciplinary Programs section for minor requirements.**

### **Chemistry**

CHEM 121 *General Chemistry*

CHEM 122 *General Chemistry*

CHEM 211 *Organic Chemistry*

### **Math**

MATH 101 *Single Variable Calculus I*

MATH 102 *Single Variable Calculus II*

MATH 211 *ODEs and Linear Algebra*

MATH 212 *Multivariable Calculus*

### **Electrical Engineering**

ELEC 243 *Introduction to Electronics*

### **Mechanical Engineering**

MECH 211 *Engineering Mechanics*

### **Physics**

PHYS 101, PHYS 111, or PHYS 125 *Mechanics*

PHYS 102, PHYS 112, or PHYS 126 *Electricity and Magnetism*

**Graduate Program**—To train the next generation of leaders in bioengineering, we have built an innovative teaching program that transcends boundaries between bioengineering, basic science, and clinical medicine, integrating the academic, industrial, and societal perspectives.

Our hands-on approach to education is supported by a long standing tradition of cross-disciplinary research and education. The Rice bioengineering program is a comprehensive training program that provides student with:

- A fundamental understanding of the life and medical sciences
- Advanced analytical and engineering capabilities,
- Translational research that transfers biotechnical advances from bench to bedside

With this educational background, graduates will be well prepared to participate in independent or collaborative research and development endeavors in industry or academia.

### DEGREE REQUIREMENTS FOR MBE AND MS AND PHD IN BIOENGINEERING

For general university requirements, see Graduate Degrees (pages 61–62).

To make sure scores are available when admission decisions are made, applicants need to register to take the GRE and TOEFL as required before September for the year in which they are applying. Applicants should request transcripts and letters of recommendation before September, as well, to give senders time to get the material to Rice University by the January 15 deadline. The Graduate Admissions Committee begins its deliberations in late November. Application materials received after the January 15 deadline will not be considered. Once admitted, departmental policy requires full-time students to be registered for at least 12 credit hours each semester.

**MBE Program**—The Master of Bioengineering degree is intended for those having a BA or BS degree in an engineering or science discipline.

To obtain a Master of Bioengineering degree, the following requirements must be completed.

1—Curriculum has to be approved by the Academic Affairs Committee of the bioengineering department. This will be done on a case-by-case basis.

2—A total of 30 credit hours is required (courses must be above and beyond the requirement for the undergraduate degree) as follows:

- At least 15 credit hours of the 24 must be taken as BIOE courses, including *Fundamentals of Systems Physiology* (BIOE 572, 3 hours) and *Design and Analysis of Experiments* (BIOE 541, 3 hours)
- *Cell Biology* (BIOS 341, 3 hours)
- *Intro to Partial Differential Equations* (MATH 381) or a 400-level or higher MATH, STAT, or CAAM course (3 hours)
- One additional engineering course (3 hours)
- Two additional courses approved by the Academic Affairs Committee (6 hours).

In summary, the credit hours required are:

- Completion of 30 total credit hours, with 15 credit hours of BIOE courses
- Completion of 3 credit hours of BIOS 341

- Completion of 3 credit hours of MATH 381 or 400-level or higher MATH/STAT/CAAM course
- Completion of 3 credit hours of one additional engineering course, and
- Completion of 6 credit hours of additional courses approved by the Academic Affairs Committee
- Maintain an average GPA of 3.0 or higher.

**MS Program**—Candidates for the MS degree must:

- Complete at least 18 approved semester hours of foundation, supporting, and advanced courses while maintaining a grade point average of 3.0
- MS students must earn additional credits they need for graduation by registering for the master's research course BIOE 600 during the terms they are engaged in research.
- Fulfill a teaching requirement
- Submit an original research thesis
- Defend the thesis in a public oral examination

**PhD Program**—Candidates for the PhD degree must:

- Complete at least 30 approved semester hours of foundation, supporting, and advanced courses with high standing. With departmental approval, the course requirements may be reduced to not less than 22 hours for students already holding an MS degree.
- Fulfill a teaching requirement. After their 1st semester in residence, students may be asked to spend the equivalent of 6 to 10 hours per week for a total of 3 semesters on teaching assignments.
- Submit a thesis proposal. PhD students must submit and successfully defend their thesis proposals by the end of their 4th semester in residence.
- Complete a 3- to 6-month internship. This requirement may be waived for those with adequate previous relevant experience.
- Submit a thesis that provides evidence of their ability to carry out original research in a specialized area of bioengineering.
- Defend the thesis in a public oral examination.

Graduate students take required courses and electives in the following areas:

- Molecular, cellular, and tissue engineering
- Imaging and optics
- Biomaterials, biomechanics, and tissue engineering
- Computational and theoretical bioengineering
- Supramolecular biophysics and bioengineering

**See BIOE in the Courses of Instruction section.**