

BIOENGINEERING

GEORGE R. BROWN SCHOOL OF ENGINEERING

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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 bioengineering undergraduate program will prepare students for careers in rapidly developing areas of biomedical engineering and bioprocessing. Our unified and comprehensive program leading to the BS degree in bioengineering will:

- Provide students with a fundamental understanding of mathematics and the natural, life, and medical sciences
- Teach students bioengineering principles and their applications in life and medical sciences
- Develop critical problem-solving skills in bioengineering
- Develop the ability to communicate effectively and participate in interdisciplinary teams
- Expose students to a broad education that prepares them for diverse careers

Undergraduates in bioengineering will have the training to pursue further education in graduate school or medical school and will have strong preparation for a career in the biotechnology industry.

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 14–15). 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.

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 Module

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*

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*

*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.

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 57–58).

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 December 31 deadline. The Graduate Admissions Committee begins its deliberations in late November. Application materials received after the December 31 deadline will not be considered.

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

Candidates for the MBE degree must complete the following course work:

1. Curriculum must be approved by the Graduate Academic Affairs Committee of the bioengineering department. (This will be done on a case-by-case basis).
2. 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 30 must be taken as BIOE courses, including Fundamentals of Systems Physiology (BIOE 572)
 - Introduction to Partial Differential Equations (MATH 381) (3 hours)
 - 1 additional engineering course (3 hours)
 - 3 additional courses approved by the Graduate Academic Affairs Committee (9 hours)

In summary, the credit hours required are:

- 15 credit hours of BIOE courses
- 3 credit hours of MATH 381
- 3 credit hours of one additional engineering course
- 9 credit hours of additional courses approved by the Graduate Academic Affairs Committee
- 30 Total credit hours

MS Program—Candidates for the MS degree must:

- Complete at least 18 approved semester hours of foundation, supporting, and advanced courses with high standing
- 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 bioengineering

See BIOE in the Courses of Instruction section.