BIOENGINEERING

GEORGE R. BROWN SCHOOL OF ENGINEERING

CHAIR
Jennifer West

PROFESSORS
John Clark
Michael Deem
Rebekah Drezek
Mary Farach-Carson
Ariel Fernandez
Fathi Ghorbel
Naomi Halas
Lydia Kavraki
Jianpeng Ma
John McDevitt
Antonios Mikos
Rebecca Richards-Kortum
Ka-Yiu San
Frank Tittel
Kyriacos Zygourakis

PROFESSOR EMERITUS
William Akers
David Hellums

ASSOCIATE PROFESSORS
Jane Grande-Allen
Jeffrey Hartgerink
Robert Raphael

ASSISTANT PROFESSORS
Michael Diehl
Ramon Gonzalez
Oleg Igoshin
Jeffrey Jacot
Ching-Hwa Kiang
Laura Segatori
Jonathan Silberg
Junghae Suh
Tomasz Tkaczyk

SENIOR RESEARCH SCIENTIST
Joel Moake

PROFESSORS IN THE PRACTICE OF BIOENGINEERING
Maria Oden
Ann Saterbak

ADJUNCT PROFESSORS
Kyriacos Athanasiou
William Brownell
Ill-Min Chung
Jing-Fei Dong
Rena D'Souza
Mauro Ferrari
Charles Fraser
Craig Hartley
Karen Hirschi
Daniel Kim
King Li
Gabriel Lopez-Berestein
Peter Saggau
Jacqueline Shanks
Wayne Smith
Karen Storthz
Stephen Wong
Samuel Miao-Sin Wu

ADJUNCT ASSOCIATE PROFESSORS
Mary Dickinson
Anne M. Gillenwater
Kathryn Peek
Rolando Rumbaut
Mark Wong

ADJUNCT ASSISTANT PROFESSORS
Sharmila Anandasabapathy
Michael Beauchamp
Neel Bhatavadekar
Miguel Cruz
Joseph Ludwig
Anshu Mathur
John Oghalai
Fred Pereira
Rajesh Uthamanthil
Yunzhi Yang
Tse-Kuan Yu

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. 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 three technical elective courses. 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 second 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 *Fundamentals of 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*

Chemistry
CHEM 121 *General Chemistry*
CHEM 122 *General Chemistry*
CHEM 211 *Organic Chemistry*

Computational and Applied Mathematics
CAAM 210 *Introduction to Engineering Computation*

Electrical Engineering
ELEC 243 *Introduction to Electronics*

Math
MATH 101 *Single Variable Calculus I*
MATH 102 *Single Variable Calculus II*
MATH 211 *ODEs and Linear Algebra*
MATH 212 *Multivariable Calculus*

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 two of the four listed advanced laboratory modules: BIOE 442, 443, 444, and 445.

Three technical elective courses, at least two of which must be at the senior level, will be required. All three elective courses must be engineering courses.

A combination of technical electives must be selected that meets a minimum of six engineering points. The technical elective courses and their engineering points will be announced in future course listings.

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.

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.

- Show evidence on their undergraduate transcript of completion of fundamentals of systems physiology, cell biology, and statistics. (If courses were not taken for an undergraduate degree, they must be completed at the beginning of the MBE program. Only one of these courses may be used as credit toward the 30 hours of required courses.)
- Curriculum has to be approved by the Academic Affairs Committee of the bioengineering department. This will be done on a case-by-case basis.
- A total of 30 credit hours is required (courses must be above and beyond the requirement for the undergraduate degree). Of these 30 hours, at least 24 must be taken at Rice.
- At least 15 credit hours must be taken as BIOE courses.
- Required courses include:
  - *Principles of Bioengineering Part I* (BIOE 561, 3 credit hours)
  - *Principles of Bioengineering Part II* (BIOE 562, 3 credit hours)
  - *Design and Analysis of Experiments, Module I* (BIOE 548, 1.5 credit hours)
  - *Design and Analysis of Experiments, Module II* (BIOE 549, 1.5 credit hours)
  - Two additional BIOE elective courses (6 hours)
  - 400-level or higher MATH, STAT, or CAAM course (3 hours)
  - One additional engineering course (3 hours)
  - Three additional elective courses approved by the Academic Affairs Committee (9 hours).
- Maintain an average GPA of 3.0 or higher.

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:

- Show evidence on their undergraduate transcript of completion of fundamentals of systems physiology, cell biology, and statistics. (If courses were not taken for an undergraduate degree, they must be completed at the beginning of the PhD program. Only one of these courses may be used as credit for the 30 required courses.)
- Complete at least 30 approved semester hours of foundation, supporting, and advanced courses with high standing.
- Fulfill a teaching requirement. After their first semester in residence, students may be asked to spend the equivalent of six to 10 hours per week for a total of three semesters on teaching assignments.
- Submit a thesis proposal. PhD students must submit and successfully defend their thesis proposals by the end of their fourth semester in residence.
- 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.