



BIOMEDICAL ENGINEERING

B.S. IN ENGINEERING, MAJOR IN BIOMEDICAL ENGINEERING

As one of the first programs in the world, biomedical engineering at Case Western Reserve University is a model for education and an international leader in research. The department was founded on the premise that engineering principles provide an important basis for innovation and unique solutions to biomedical problems. Quantitative engineering for biomedical applications remains the cornerstone of the program.

Students are fully engaged not only in the innovative curriculum but also in cutting-edge research programs. They are trained in areas ranging from basic science to the development, clinical evolution and commercialization of new technologies, devices and therapies. The goal of the undergraduate program is to educate professionals who can apply engineering methods to problems involving living systems. The educational philosophy of the department is to develop in students a mastery of fundamentals, creativity, societal awareness, leadership skills and professionalism.

DEPARTMENT HIGHLIGHTS

- The undergraduate program is among the top-ranked BME programs according to *U.S. News and World Report*.
- The Bachelor of Science degree is accredited by the Accreditation Board for Engineering and Technology (ABET).
- Faculty and students have access to the facilities and major labs of the Case School of Engineering and the Case School of Medicine. Major hospitals, including the affiliated Cleveland Clinic, are within walking distance of the campus, providing exceptionally close collaborations and extensive research resources in a clinical environment.
- The Biomedical Engineering Society, run by undergraduates, holds frequent events to highlight research and career opportunities, as well as social activities. This organization recently developed an undergraduate student-to-student mentoring program that won national recognition.

- The biomedical engineering faculty are leaders in education and research. All faculty have active research programs with an average funding per faculty member of more than \$600,000 per year. Typically, undergraduates work alongside faculty and graduate students in the research labs.
- Many faculty hold leadership positions in professional societies, serve on the editorial boards of leading journals and consult with colleagues in the biomedical device industry. One is a member of the National Academy of Engineering.
- The Case School of Engineering features a common first-year curriculum for all engineering undergraduates. These common course requirements make it possible for a student to postpone declaring a major until the sophomore year.
- In addition to the undergraduate degree, the department offers the M.S., a combined B.S./M.S. track, the biomedical entrepreneurship track in the master of engineering and management program and the Ph.D. It also has joint Ph.D. programs in biophysics/bioengineering and neuroscience/bioengineering, as well as the combined Ph.D./M.D.

DEGREE REQUIREMENTS AND COURSE OFFERINGS

The undergraduate program has three major components: (1) introduction to biomedical research and applications; (2) engineering core, which provides a broad background in mathematics, sciences and engineering; (3) biomedical engineering (EBME) core, which integrates engineering with biomedical science to solve biomedical problems; and (4) EBME specialty sequence, which provides depth in a well-defined area. Common BME specialties are biomaterials, tissue engineering biomaterials, biomechanics, bioelectric engineering, biomedical instrumentation, biomedical computing and imaging, and biomedical systems and control. Students may select open electives for educational breadth or depth, or to meet entrance requirements for medical school or other professional career choices. A typical B.S. program requires 129 credit hours.

Examples of undergraduate courses offered by the department are:

- EBME 303 Structure of Biological Materials
- EBME 306 Introduction to Biomaterials
- EBME 307 Biomechanical Prosthetic Systems
- EBME 308 Biomedical Signals and Systems
- EBME 310 Principles of Biomedical Instrumentation
- EBME 350 Quantitative Molecular Bioengineering
- EBME 380 Design for Biomedical Engineers

BACHELOR OF SCIENCE IN ENGINEERING, MAJOR IN BIOMEDICAL ENGINEERING^a

First Year

Class-Lab-Credit Hours

Fall

EBME 105 Introduction to Biomedical Engineering ^b	(3-0-3)
CHEM 111 Chemistry for Engineers	(4-0-4)
MATH 121 Calculus for Science and Engineering I	(4-0-4)
ENGR 131 Elementary Computer Programming	(2-2-3)
SAGES First Year Seminar	(4-0-4)
PHED 101 Physical Education	(0-3-0)

Spring

ENGR 145 Chemistry of Materials	(4-0-4)
MATH 122 Calculus for Science and Engineering II	(4-0-4)
PHYS 121 General Physics I	(4-0-4)
SAGES University Seminar.	(3-0-3)
PHED 102 Physical Education	(0-3-0)

Sophomore Year

Fall

EBME 201 Physiology - Biophysics I	(3-0-3)
MATH 223 Calculus for Science and Engineering III	(3-0-3)
PHYS 122 General Physics II	(4-0-4)
BME specialty sequence course ^c or science elective ^d	(3-0-3)
SAGES University Seminar.	(3-0-3)

Spring

EBME 202 Physiology - Biophysics II	(3-0-3)
MATH 234 Intro to Dynamic Systems	(3-0-3)
ENGR 210 Intro to Circuits & Instrumentation	(3-3-4)
BME specialty sequence course ^c or science elective ^d	(3-0-3)
Humanities/Social Science (H/SS) course	(3-0-3)

a. This is a typical program. Specialty sequences, which include bioelectric engineering, biomaterials-tissue engineering, biomechanics, biomedical, imaging and computing, instrumentation, orthopedic biomaterials, polymer biomaterials, and systems and control, are designed with courses in a desired order that might vary from the one here. Programs must be planned with a faculty adviser in the Department of Biomedical Engineering. More information is available on the BME Web site.

b. This optional course is limited to freshmen. This can be replaced by an open elective.

c. Courses are chosen depending on the BME specialty sequence.

Junior Year ^f

Class-Lab-Credit Hours

Fall

EBME 306 Introduction to Biomaterials	(3-0-3)
EBME 313 Biomedical Engineering Lab I	(1-3-2)
ENGL 398N Professional Communication	(3-0-3)
EBME 308 Biomedical Systems & Circuits	(3-3-4)
ENGR 225 Thermo, Fluids, Heat & Mass Transfer	(4-0-4)

Spring

EBME 314 Biomedical Engineering Lab II	(1-3-2)
EBME 310 Principles of Biomedical Instrumentation	(3-0-3)
EBME 360 BME Instrumentation Lab	(0-3-1)
ENGR 200 Mechanics and Materials	(3-0-3)
BME specialty sequence course ^c	(3-0-3)
BME specialty sequence course ^c	(3-0-3)
H/SS course	(3-0-3)

Senior Year

Fall

EBME 398 Senior Project	(0-9-3)
or EBME 380 Design in BME (SAGES Capstone)	(1-6-3)
BME specialty sequence course ^c	(3-0-3)
BME specialty sequence course ^c	(3-0-3)
Statistics ^e	(3-0-3)
H/SS course	(3-0-3)

Spring

EBME 309 Modeling of Biomedical Systems	(3-0-3)
EBME 359 BME Computer Simulation Lab	(0-3-1)
BME specialty sequence course ^c	(3-0-3)
BME specialty sequence course ^c	(3-0-3)
H/SS course	(3-0-3)
Open elective	(3-0-3)

Total 129 Credit Hours

d. Students take at least one math or science course approved by BME department.

e. STAT 312, STAT 333 or STAT 332 fulfill the statistics requirement. Check with sequence advisor to determine the most appropriate class.

f. One EBME course in the junior year will be designated as the SAGES Departmental Seminar.

These requirements incorporate proposed changes to the major that are pending approval as of this printing. Check with the departmental representative for current status, and with advisers for detailed individual schedules.

MINOR

A minor in Biomedical Engineering is offered to students who have completed the Engineering Core requirements. The minor consists of 15 credit hours based on the two physiology courses (EMBE 201 and EBME 202) and an approved set of three electives chosen from among the BME Core courses. These courses can be completed within the context of almost all other undergraduate degree programs at Case.

SPECIAL ACADEMIC PROGRAMS

Premedical education

The department offers a curriculum that includes one science elective and two open electives. Students are free to use these electives to take courses desirable for medical school. Graduates of this curriculum report that certain BME electives were important in preparing for the MCAT. Contact the department or an adviser for specific information.

B.S./M.S. program

Undergraduates with a strong academic record (3.3 GPA) may apply in their junior year for admission to the integrated B.S./M.S. program. A senior research project that begins in the summer after the junior year is designed to expand into an M.S. thesis. Also, the student begins to take graduate courses in the senior year. With continuous progress in research during three summers and the academic years, this program can lead to both the B.S. and M.S. in five years.

Student employment program

The department offers a student employment program, which provides assistance to biomedical engineering majors in finding full-time, part-time, co-op and internship opportunities in both industry and research. Program leaders continually cultivate relationships with current and prospective employers, thus continuing to increase the employment pool for BME graduates. Additionally, students receive career guidance and counseling that is specifically geared toward biomedical engineering students and professional opportunities of interest to them.

The Institute for Management and Engineering (TiME)

This program is a joint effort of the Case School of Engineering and Case's Weatherhead School of Management and offers a B.S. in engineering/master's in engineering management (MEM). Students enter the program in their junior year, when they begin internships in industry. The program currently has tracks for management of manufacturing and biotechnology, and is planning a new track in information technology. This program is particularly attractive to students interested in technical management.

Cooperative education

The optional co-op program in biomedical engineering enables students to combine the normal course of study with a year of paid experience in the industry. The average co-op salary for biomedical engineering majors is \$2,261. The work performed by students is professional in nature, and the conditions of employment and the rate of pay vary among employers.

Co-op adds a fifth year to the undergraduate program, but students earn salaries that help offset educational expenses and gain practical experience that boosts employment options.

There are two seven-month co-op periods; typically, a student will continue the second co-op period with the same company.

RESEARCH AND FACILITIES

Undergraduate students' research backgrounds and interests are varied, and numerous opportunities are available to accommodate them. There are strong collaborations between the Department of Biomedical Engineering and the clinical and basic science departments at Case. In addition, student research projects benefit from numerous research collaborations with area hospitals, which bring a broad range of opportunities, expertise, and perspectives. Current major research areas include:

- Biomaterials/tissue engineering
- Biomedical image processing and analysis
- Biomedical sensing
- Neural engineering and neural prostheses
- Transport and metabolic systems engineering

The department's administrative offices and many biomedical research labs are located in the Wickenden Building, which also houses the Center for Cardiovascular Biomaterials, the Neural Engineering Center and the Modeling in Metabolic Systems Center. There are additional laboratories devoted to optics, microchemical sensors, and biomedical image processing and analysis. At other campus locations, faculty direct facilities such as the Endoscopy Research Laboratory, the Functional Electrical Stimulation Center and the Rehabilitation Engineering Center.

GRADUATES

The department awards approximately 50–60 B.S. degrees annually. Graduates in biomedical engineering are employed in industry, hospitals, research centers, government and universities. Students have accepted positions at Boston Scientific, Medtronic, Philips Medical Systems, St. Jude Medical, Cleveland Medical Devices and the United States Patent and Trademark Office.

**FOR MORE
INFORMATION**

General Bulletin

www.case.edu/bulletin

Office of Undergraduate Admission

Phone: 216/368-4450

E-mail: admission@case.edu

Web site: <http://admission.case.edu>

Case Western Reserve University

10900 Euclid Avenue

Cleveland, OH 44106