GRADUATE STUDY

in Biomedical Engineering

A joint department of the Case School of Engineering and the Case Western Reserve University School of Medicine
Founded in 1968 as one of the pioneer programs in the world, the Case Western Reserve University Department of Biomedical Engineering has established highly successful and comprehensive graduate programs in research and education. The department consistently remains a top-ranked biomedical engineering program for graduate studies according to U.S. News and World Report.

Our mission is to promote human health through education and research that bridges the gap between medicine and engineering. Our faculty and students play leading roles ranging from basic science discovery to the creation, clinical translation, and commercialization of new technologies, devices and therapies. In short, we are "Engineering Better Health." The cornerstone of our success has been active collaborations between students and faculty in classrooms and research laboratories and beyond. Collaborations are also greatly facilitated by our prime location adjacent to the outstanding research and clinical resources at Case Western Reserve’s School of Medicine, University Hospitals Case Medical Center (UHCMC), the Cleveland Clinic, The Louis Stokes Cleveland VA Medical Center, and MetroHealth Medical Center. Their close proximities allow prospective students the opportunity to work in a variety of world-class research laboratories.

The department continues to evolve to match the recent accelerated pace of biomedical engineering developments. As a joint program in the schools of engineering and medicine, our cutting-edge research spans a wide range of new interdisciplinary engineering discoveries and biomedical applications. The department is associated with over 20 research centers and over $41.7 million in current grants. Our research and education programs are strongly integrated with industry through job opportunities for graduates, sponsored research, and industrial training activities. The department’s faculty members have diverse backgrounds, which enable students to pursue highly interdisciplinary work.

### ABOUT THE PROGRAM

#### Biomaterials, Drug Delivery, and Tissue Engineering

From targeted drug delivery to biologically-inspired material design, the area of biomaterials, drug delivery, and tissue engineering covers a broad range of topics, including polymers, biomimetics, regenerative medicine, stem cells, and controlled-release therapeutics. Research in this area applies scientific principles and mathematical analysis to the development of new methodologies, materials, and models. The therapeutic applications are as varied as the materials investigated. The research based on underlying biological mechanisms leads to biomimetic materials development.

#### Biomedical Imaging

The rapidly growing field of biomedical imaging enables one to visualize physiological structures, measure biological functions, and evaluate cellular and molecular events without invasive procedures. Imaging technologies include: magnetic resonance (MRI), positron emission tomography (PET), single photon emission computed tomography (SPECT), ultrasound (US), computed tomography (CT), and optical imaging methods: optical coherence tomography (OCT), bioluminescence, fluorescence, and novel technologies as cryo-imaging. State-of-the-art research facilities are available in the Biomedical Engineering Department, the Case Center for Imaging Research (CCIR), and the affiliated departments of radiology at the adjacent hospitals. These include high-field MR imaging and spectroscopy systems for both small animals and humans, nuclear microPET and SPECT/CT scanners, OCT and bioluminescence/fluorescence imaging systems. Support facilities include animal husbandry and preparation, human clinical trials, and histopathology.

### RESEARCH AREAS

#### Biomedical Sensors

Biomedical sensing integrates biologically-derived sensing components with transducers to measure the output of biological substances. Sensing research includes the development and use of electrochemical and optical mini- to micro-sensors for in vitro and in vivo applications. Micro-fabricated devices, such as BioMEMS chips, are developed for sensing applications.

#### Metabolic Systems

Mathematical modeling and computer simulation are used to analyze changes in cellular metabolism of the heart, skeletal muscle, brain and liver, as well as their integrated effects in the human body. Metabolic changes are associated with exercise, diet, and disease. Human studies are conducted to evaluate responses to exercise under normal and diseased conditions. Other experimental studies deal with skeletal muscle and cardiac responses to changes in oxygen and other chemical factors.

#### Cardiac and Vascular Systems

State-of-the-art imaging technologies and mathematical modeling are combined with molecular biology methods to study the various aspects cardiac electrical, chemical, and mechanical functions. Engineering principles and multidisciplinary approaches are employed for integrative characterization of cardiac function.

#### Musculoskeletal Mechanics

Engineering mechanics are applied to study the structure and function of musculoskeletal systems. This research leads to the design of clinical interventions, including artificial joints, prosthetic limbs, dental implants, bone healing, and methods to counteract loss of bone and muscle during space travel.
The Department of Biomedical Engineering at Case Western Reserve University offers a diverse and challenging set of degree programs designed to produce graduates who are poised to be leaders in business, government, and academia. The major fields of study include: Biomaterials, Drug Delivery, and Tissue Engineering; Biomedical Imaging; Neural Engineering and Neural Prosthetics; Biomedical Sensors; Metabolic Systems; Cardiac and Vascular Systems; and Musculoskeletal Mechanics.

**Master of Science**

The M.S. program in Biomedical Engineering provides an opportunity to work on biomedical research or design in many fields of biomedical engineering application. The 30 credit hours required may be accomplished in three ways:

1. 9 credit hours of M.S. thesis research, 21 credit hours of regular coursework, and 9 credit hours of thesis research
2. A 3 credit-hour M.S. project and a minimum of 27 credit hours of coursework
3. 30 credit hours of coursework without a project (for practicing professionals only)

More details are available on the BME web site at http://bme.case.edu.

**Doctor of Philosophy**

The department's Ph.D. programs are designed to prepare candidates for a lifetime of creativity in research and professional engineering practice. Each Ph.D. student must pursue a unique research environment. Additionally, students learn teaching techniques and enhanced communications and presentation skills.

The Ph.D. core courses include:

- EBME 451 Molecular and Cellular Physiology
- EBME 452 Tissue and Organ Systems Physiology
- EBME 403 Biomedical Instrumentation
- EBME 409 Systems and Signals in Biomedical Engineering

Other degree requirements include:

- EBME 611/612 Departmental Seminars
- EBME 400T/500T/600T Graduate Teaching/Mentoring
- EBME 621/622 BME Research Rotations

Additional coursework and other requirements can be found on the departmental web site at http://bme.case.edu.
Typical career paths for those students 
awarded M.S. degrees are continuing 
studies for doctoral or medical degrees, or 
pursuing full-time positions in industry, a 
research institute, or the government. Those students pursuing Ph.D. degrees can 
choose academic career paths. Graduates 
may join a university directly as a faculty 
member, but more commonly, new 
graduates begin in postdoctoral studies 
positions followed by faculty appointments. Alternatively, upon graduation, Ph.D. 
students may also pursue careers directly in 
industry, medical or research institutes, or the government. Some of these positions 
may require entrance at the postdoctoral 
level. However, in some sectors, 
students may join organizations at the full 
performance level of scientist or researcher.

Awards

Greater Cleveland: Life on America’s North Coast

Many people have heard of Cleveland, but few who have not been here really know 
this exciting, modern city. While it proudly celebrates its industrial roots, 
Cleveland is in the midst of an exciting transformation toward a more diverse, 
technology-focused economy. Throw in a reasonable cost of living, amenities like the 
Rock and Roll Hall of Fame and Museum, and the natural beauty of Ohio’s North 
Coast, and you have quite a place to call 
home. The city of Cleveland also features entertainment, major league sports, and 
outdoor activities. You may witness a 
Broadway production or opera at the 
Playhouse Square, dance the night away in 
one of the city’s thriving entertainment 
districts, cheer on the Browns, Cavaliers, Indians or one of the area’s minor league 
baseball, soccer, and hockey teams, sail on 
Lake Erie, or hike or bike Cleveland’s 
famed “Emerald Necklace,” the 
Metroparks that surround the city and dot the shoreline.

Student Life & Environment

In addition to an outstanding academic and research experience, graduate students 
can also experience an enhanced sense of 
student community through the Graduate 
Student Association (GSA). GSA is the 
graduate student voice of the Department 
of Biomedical Engineering at the 
university. Its membership includes every 
bioengineering engineering graduate student. The GSA provides graduate students with 
a forum for vocalizing opinions regarding 
department and university-wide issues. 
The GSA also provides an opportunity for 
fellowship among graduate students. It 
sponsors social events and service projects 
that allow graduate students and their 
families to come together with each other, 
as well as faculty members and staff in a 
fun social setting.

Admissions

Students admitted to our BME graduate education program typically have a B.S. or 
M.S. in engineering, natural sciences, or 
mathematical sciences. A minimal 
mathematical background includes 
calculus through differential equations. A 
minimal science and engineering 
background includes a combined total of 
three years of physical, chemical, 
and engineering sciences. Undergraduate 
course grades should average higher than a 
B- or undergraduate class ranking should 
be in the top 20 percent. In previous 
graduate studies, course grades should 
average at least a B+. The Graduate Record 
Examination (GRE) Quantitative score 
should be at least in the 80th percentile or 
higher. For students whose first language is 
not English, a minimum TOEFL score of 
600 is required for unconditional 
admission. Applicants for research 
assistantships will be chosen based on their 
exciting credentials, backgrounds, and 
interests in relation to funded research 
projects of faculty.

Application Procedure

To apply for graduate studies in the 
Department of Biomedical Engineering, 
visit the School of Graduate Studies at 
http://www.case.edu/provost/gradstudies/ 
appinfo.html. Please direct any inquiries 
regarding the application process to:

BME Graduate Admissions Coordinator 
Email: bmedept@case.edu 
Phone: (216)-368-4094

Nearly all graduate students in the 
Department of Biomedical Engineering 
Ph.D. program receive financial support 
with possible additional support from 
other degree programs. The cost of living 
in the Cleveland area is among the most 
reasonable in the country. In fact, most 
students spend just $14,000 to $17,000 
each year on living expenses. Competitive 
financial aid opportunities are available to 
doctoral students, and the department 
aggressively recruits academically gifted 
candidates. Fellowship programs not only 
provide top scholars with attractive stipend 
and tuition awards, but also can be 
supplemented with discretionary funding for 
educational expenses.

Government-sponsored fellowships are 
available to United States citizens who are 
couraged to apply. Among these are:

• National Institutes of Health (NIH) Fellowships
• National Science Foundation (NSF) Fellowships
• National Defense Science and Engineering Graduate (NDSEG) Fellowships
• NASA Graduate Student Research Program (GSRP)
• Ohio Space Grant Consortium (OSGC) Scholarships and Fellowships
• Department of Biomedical Engineering Training Grants

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