Biomedical Engineering

Email: bme@wustl.edu
Website: https://bme.wustl.edu/academics/graduate-programs/index.html

Courses

BME 5050 Professional and Personal Pathways to the PhD Program
This course is designed to guide PhD students as they embark on their first year in the Biomedical Engineering program. Topics include choosing a thesis lab and mentor, creating individual development plans, career exploration, and building mentor realtionships through networking.
Credit 1 unit.
Typical periods offered: Fall

BME 5190 Advanced Cognitive, Computational, and Systems Neuroscience
This course will develop critical thinking and analysis skills with regard to topics in Cognitive, Computational and Systems Neuroscience. A focus of the course will be aimed toward quantitative literacy, statistical methodology, and experience with the tools and best practices needed to conduct state-of-the-art research in modern studies of brain and behavior. Particular topics include machine learning, Big Data, reproducibility, equitable research and scientific visualization. Students will be provided with foundational and theoretical tools to ensure maximal scientific rigor in their own research by enabling them to think carefully about core issues in experimental design, and about key challenges and controversies that arise in relation to hypothesis testing, statistical inference and data management.
Credit 3 units.
Typical periods offered: Spring

BME 5230 Biomaterials Science
An understanding of the interactions between biological systems and artificial materials is of vital importance in the design of medical devices. This course will introduce the principles of biomaterials science, unifying knowledge from the fields of biology, materials science, surface science, and colloid science. The course will be taught from the primary scientific literature, focusing on the study of protein/surface interactions and hydrogel materials.
Credit 3 units.
Typical periods offered: Fall

BME 5300 Molecular Cell Biology for Engineers
This course is designed for upper-level undergraduates and first-year graduate students with a background in engineering. It covers the biology of cells of higher organisms: protein structure and function; cellular membranes and organelles; cell growth and oncogenic transformation; cellular transport, receptors, and cell signaling; and the cytoskeleton, the extracellular matrix, and cell movement. Emphasis will be placed on examples relevant to biomedical engineering. In addition to lecture material, a focus will be placed on understanding the experimental techniques used in cell biology and the critical analysis of primary literature. Note that this course does not count for engineering topics credits and that it is meant to fulfill a life science requirement for engineering or physical sciences graduate students.
Credit 3 units.
Typical periods offered: Spring

BME 5330 Biomedical Signal Processing
This course is designed for graduate students with little or no background in biomedical signal processing, with an emphasis on time- and frequency-domain analyses of biomedical signals and their applications to a variety of real-world biomedical problems. Technical topics of this course include a review of linear signals and systems theory, biomedical system modeling, time-domain analysis, frequency transforms, frequency-domain analysis, linear filter design, signal truncation and sampling, discrete Fourier transform, and fast Fourier transform. Application topics include noise analysis of biomedical signals and frequency analysis and machine learning in biomedical image processing. Concepts learned in class will be applied using software tools to biomedical signals such as biological rhythms, EMG, ECG, EEG, and biomedical images.
Credit 3 units.
Typical periods offered: Spring

BME 5380 Cell Signal Transduction
This course will cover the elements of cell signal transduction important to human development, homeostasis and disease. Lectures will be combined with primary literature review to cover canonical signaling and current topics within the field. Spatial, time and dose-dependent aspects of signaling will be of particular focus. Topics include G protein-coupled receptors, receptor tyrosine kinases, adhesion signaling, the MAPK cascade, lipid signaling, the DNA damage response, and autocrine, paracrine and juxtacrine signaling.
Credit 3 units.
Typical periods offered: Fall, Spring

BME 5401 Biomedical Data Science
This course will cover data analysis, statistical methods, AI, machine learning, predictive modeling, and data visualization, with applications to medicine and health. As part of the course, BME faculty will present biomedical data science topics from their research areas. Students will learn to prepare, transform, visualize, validate, model, and communicate information about datasets, and they will design and implement an independent project to address a biomedical data science problem. Prior Python experience required.
Credit 3 units.
Typical periods offered: Fall

BME 5430 Molecular and Cellular Engineering
The ability to engineer biological function at the cellular level holds tremendous potential for both basic and applied science. This course aims to provide knowledge and practical proficiency in the methods available for measuring and controlling the molecular organization of eukaryotic cells. Topics to be covered include genome engineering using viral- and CRISPR-Cas systems; spatial and temporal control of proteins and their interactions; methods for characterizing and engineering post-translational modifications; and the relationship between cellular organization and function in migration, immune cell target recognition, and differentiation. Examples from recent scientific literature will provide the foundation for these topics.
Credit 3 units.
Typical periods offered: Spring

BME 5440 Biomedical Instrumentation
This course will include operational and instrumentation amplifiers for bioelectric event signal conditioning, interfacing and processing; instrumentation noise analysis and filter design; A/D converters and hardware and software principles as related to sampling, storing, processing, and display of biosignals; modeling, analysis, and operation of transducers, sensors, and electrodes, for physiological and imaging systems; and an introduction to ultrasound, X-ray, and optical imaging systems. In addition, students will be involved in three projects of designing and building instrumentation amplifier and filter systems, ultrasound systems, and optical systems.
Credit 3 units.
Typical periods offered: Spring

BME 5501 Translational Neuroengineering
This course focuses on the design of bioelectric devices for use in clinical patients. Neural stimulators (e.g., deep brain, vagal) will be the basis for a case-study approach to designing and developing new bioelectrical medical devices. This project-based course will introduce the student to the use of finite element solvers to design novel stimulators. In addition to the engineering design aspects, issues such as product liability, FDA approval, and so on will be discussed.
Credit 3 units.
Typical periods offered: Spring

BME 5590 Intermediate Biomechanics
This course covers several of the fundamental theories of solid mechanics that are needed to solve problems in biomechanics. The theories of nonlinear elasticity, viscoelasticity, and poroelasticity are applied to a large range of biological tissues including bone, articular cartilage, blood vessels, the heart, skeletal muscle, and red blood cells. Other topics include muscle activation, the biomechanics of development and functional adaptation, and the mechanics of hearing.
Credit 3 units.
Typical periods offered: Fall

BME 5642 Human-Machine Interfaces
This course will provide an overview of neurorehabilitation technologies for individuals with neuromotor disorders. Topics will include the neurophysiology of human motor and sensory systems, motor control and adaptation, and neuroplasticity in the damaged brain and spinal cord. Human-machine interface systems including prostheses, orthoses and exoskeletons, wheelchairs, neuroprosthetics, brain-machine interfaces, and wearable robots will be discussed with an emphasis on their clinical applications for restoration of motor and sensory functions. Lecture material and assignments will draw from current scientific literature and research. Registration will be split between undergraduate and graduate students.
Credit 3 units.
Typical periods offered: Fall, Spring

BME 5650 Biosolid Mechanics
Introduction to the mechanical behaviors of biological tissues of musculoskeletal, cardiac and vascular systems. Topics to be covered include static force analysis and nonlinear optimization theory; linearly elastic models for stress-strain analysis and solutions to relevant problems in bioelasticity; models of active structures (e.g., muscles); strain energy methods and nonlinear tissue behaviors; and introductory theory for finite element analysis. Emphasis will be placed on modeling stress-strain relations with relevance to biological tissues.
Credit 3 units.
Typical periods offered: Fall, Spring

BME 5690 Cardiac Electrophysiology
This course is an introduction to cardiac electrophysiology with an emphasis on arrhythmia mechanisms, experimental methods, and clinical applications. Topics will include modeling of cardiac arrhythmias, mapping of cardiac electric activity, pacemakers and defibrillators, and ablation of cardiac tissue.
Credit 3 units.
Typical periods offered: Fall

BME 5700 Mathematics of Imaging Science
This course will expose students to a unified treatment of the mathematical properties of images and imaging. This will include an introduction to linear vector space theory, operator theory on Hilbert spaces, and concepts from applied functional analysis. Further, concepts from generalized functions, Fourier analysis, and radon transform will be discussed. These tools will be applied to conduct deterministic analyses of imaging systems that are described as continuous-to-continuous, continuous-to-discrete, and discrete-to-discrete mappings from object properties to image data. In addition, imaging systems will be analyzed in a statistical framework where stochastic models for objects and images will be introduced. Familiarity with Engineering-level mathematics, Calculus, Linear algebra, introduction to Fourier analysis is expected. Prerequisite: Senior standing or permission of instructor.
Credit 3 units.
Typical periods offered: Fall

BME 5720 Biological Neural Computation
This course will consider the computations performed by the biological nervous system with a particular focus on neural circuits and population-level encoding/decoding. Topics include, Hodgkin-Huxley equations, phase-plane analysis, reduction of Hodgkin-Huxley equations, models of neural circuits, plasticity and learning, and pattern recognition & machine learning algorithms for analyzing neural data. Note: Graduate students in psychology or neuroscience who are in the Cognitive, Computational, and Systems Neuroscience curriculum pathway may register in L41 5657 for three credits. For non-BME majors, conceptual understanding, and selection/application of right neural data analysis technique will be stressed. Hence homework assignments/examinations for the two sections will be different, however all students are required to participate in a semester long independent project as part of the course.
Credit 3 units.
Typical periods offered: Spring

BME 5744 Open Challenges in Systems Neuroscience
The objective of this course is to introduce advanced graduate engineering students to key challenges for the next generation of systems neuroscientists. One-half of the course will introduce students to the neural bases of canonical behavioral motifs. One-half of the course will have students identify and present a proposal for how to study an open challenge in the treatment of neurological/psychiatric disorders (e.g., dystonia, epilepsy, depression, addiction) at either circuit or system level. Grades will be assigned to correspond with performance on the written report covering an open-challenge. This course will also be open to non-engineers upon request.
Credit 3 units.
Typical periods offered: Spring

BME 5750 Molecular Basis of Bioelectrical Excitation
Ion channels are the molecular basis of membrane excitability in all cell types, including neuronal, heart, and muscle cells. This course presents the structure and the mechanism of function of ion channels at the molecular level. It introduces the basic principles and methods in the ion channel study as well as the structure-function relation of various types of channels. Exemplary channels that have been best studied will be discussed to illustrate the current understanding.
Credit 3 units.
Typical periods offered: Fall

BME 5771 Biomedical Product Development
Advances in science and technology have opened the healthcare field to innovation now more than any other time in history. Engineers and inventors can make real and rapid improvements to patient treatments, length of hospital stay, procedure time, cost containment, and accessibility to treatment. However, a successful transition from idea to implementation requires careful market analysis and strategy planning. This course will address the steps in this process, including personal and team strength assessement, medical need validation, brainstorming initial solutions, market analysis, solution evaluation, regulatory, patent, and intellectual property concerns, manufacturability, risk assessment and mitigation, and global considerations. Students will be expected to review resource material prior to coming to class in order to facilitate active class discussion and team-based application of the material during class; regular attendance will be key to course success. The course will focus on applying product development techniques to several real unmet medical needs; students will thus perform analysis and create reports and presentations for several different product solutions. Peer and faculty evaluations will provide feedback to improve individual technique. In addition, throughout the semester, local biomedical entrepreneurs will visit to share their expertise and experiences.
Credit 3 units.
Typical periods offered: Fall, Spring

BME 5780 Engineering for Women's Health
Engineering approaches have many uses in improving women's health across the lifespan and across the globe, from basic science understanding through to clinical implementation at the point of care. This course will include female reproductive anatomy and physiology across the lifespan and touch on several challenges and pathologies in women's health. Topics will include menstruation, contraception, endometriosis, pain, pregnancy complications, sexually transmitted infections, infertility, pelvic floor disorders, cancers of the female reproductive tract, menopause, cardiovascular disease, and osteoporosis. There will be a focus on unmet needs in women's health based on different contexts of care, including well-funded tertiary medical centers, US healthcare deserts, and underserved settings within the US and around the world. The current clinical standard of care and emerging engineering research and startup technologies for each topic will be covered and enhanced by inclusion of expert women's health engineering speakers with backgrounds in academic research, women's health engineering startups, large companies, and device manufacturing. Students will complete case studies, one business pitch for a women's health technology of their choosing, and one in-depth project on a women's health engineering topic of their choosing.
Credit 3 units.
Typical periods offered: Fall

BME 5901 Integrative Cardiac Electrophysiology
Quantitative electrophysiology of the heart, integrating from the molecular level (ion channels, regulatory pathways, cell signaling) to the cardiac cell (action potential and calcium transient), multicellular tissue (cell-cell communication) and the whole heart.
Credit 3 units.
Typical periods offered: Fall

BME 5910 Biomedical Optics I: Principles
This course covers the principles of optical photon transport in biological tissue. This course covers the principles and applications of optical photon transport in biological tissue. Topics include a brief introduction to biomedical optics, single-scatterer theories, Monte Carlo modeling of photon transport, convolution for broad-beam responses, radiative transfer equation, diffusion theory and applications, sensing of optical properties and spectroscopy, and photoacoustic imaging principles and applications.
Credit 3 units.
Typical periods offered: Fall

BME 5911 Cardiovascular Biophysics Journal Club
This journal club is intended for beginning graduate students, advanced undergraduates, and MSTP students with a background in the quantitative sciences (engineering, physics, math, chemistry, etc). The subjects covered are inherently multidisciplinary. We will review landmark and recent publications in quantitative cardiovascular physiology, mathematical modeling of physiologic systems and related topics such as chaos theory and nonlinear dynamics of biological systems. Familiarity with calculus, differential equations, and basic engineering/thermodynamic principles is assumed. Knowledge of anatomy/physiology is optional.
Credit 1 unit.
Typical periods offered: Fall, Spring

BME 5920 Biomedical Optics II: Imaging
This course covers optical imaging technologies. Topics include ballistic imaging, optical coherence tomography, Mueller optical coherence tomography, diffuse optical tomography, photoacoustic tomography, and ultrasound-modulated optical tomography.
Credit 3 units.
Typical periods offered: Spring

BME 5940 Ultrasound Imaging
Ultrasound imaging is the most widely used medical imaging modality in the world. This course offers an introduction to the medical ultrasound field. It exposes students to fundamental physical principles of ultrasound, ultrasound imaging, and ultrasound therapy. It will also introduce emerging ultrasound technologies in industry and clinics. Students will learn via lectures, homework, lab exercises, and a final project to gain knowledge, learn the ability to think critically, and develop problem-solving skills.
Credit 3 units.
Typical periods offered: Fall

BME 5950 Drug Delivery Systems: Principles and Applications
The course will introduce approaches for delivering pharmaceuticals including; routes of administration, dosage forms, transport out of dosage forms, transport across biological barriers, and pharmacokinetics. The course will examine classical approaches to drug delivery and survey the latest products and research in the field. Students will achieve a quantitative understanding of drug delivery practice and theory emphasizing principles in mass transport phenomena.
Credit 3 units.
Typical periods offered: Spring

BME 5999 Independent Study
Independent research investigation on a topic of special interest for graduate students. This course is restricted to PhD students in Biomedical Engineering and Master's students in both Biomedical Engineering and Imaging Science programs. Students must complete and submit required registration forms prior to enrollment.
Credit 6 units.
Typical periods offered: Fall, Spring, Summer

BME 6030 Teaching Assistantship - Advanced
This is a pass/no pass course for the fulfillment of the advanced teaching requirement which is required for the Ph.D. degree. A form obtained from the BME department must be submitted to their thesis mentor upon completion of requirements for approval in order to receive a grade.
Credit 0 units.
Typical periods offered: Spring

BME 6993 Teaching Assistantship - Basic
This is a pass/no pass course for the fulfillment of the basic teaching requirement which is required for the Ph.D. degree. A form obtained from the BME department must be submitted to the instructor at the end of the semester for approval in order to receive a grade.
Credit 0 units.
Typical periods offered: Spring

BME 7998 Masters Research
Independent research investigation on a topic of special interest for thesis-track students. This course is restricted to students enrolled in the Master of Science in Biomedical Engineering or Master of Science in Imaging Science programs. Students must complete and submit required registration forms prior to enrollment.
Credit 6 units.
Typical periods offered: Fall, Spring

BME 8887 BME Doctoral Seminar Series
This is a credit option for BME students who attend regularly scheduled BME seminars (or approved substitute seminars). A satisfactory grade is obtained by submission of a two-page peer-reviewed paper written by one of the regularly scheduled BME seminar speakers whose seminar the student attended. Papers are to be submitted to the Graduate Student Administrator for review by the Director of Doctoral Studies.
Credit 1 unit.
Typical periods offered: Fall, Spring

BME 8888 Graduate Seminar
This is a pass/no-pass course which is required for the Ph.D. degree. A passing grade is required for each semester of full-time enrollment (6 units or more). A passing grade is received by attendance at the regularly scheduled BME seminars.
Credit 0 units.
Typical periods offered: Fall, Spring

BME 8991 Research Rotation for BME Doctoral Students
This course provides doctoral students with the opportunity to gain hands-on research experience by working in multiple labs or research settings. Students will rotate through various research labs, allowing them to learn different techniques, methodologies, and approaches to scientific inquiry. The rotations help students identify their primary research interests and potential dissertation advisors. Throughout the course, students will be expected to actively participate in research activities, present their findings, and submit reports on their experiences. The goal is to broaden students' perspectives, enhance their technical skills, and facilitate informed decisions about their future research focus. This course awards no course credit.
Credit 0 units.
Typical periods offered: Fall, Spring

BME 8992 Research Rotation for BME Doctoral Students
This course provides doctoral students with the opportunity to gain hands-on research experience by working in multiple labs or research settings during their first year of study. Students will rotate through various research labs, allowing them to learn different techniques, methodologies, and approaches to scientific inquiry. The rotations help students identify their primary research interests and potential dissertation advisors. Throughout the course, students will be expected to actively participate in research activities, present their findings, and submit reports on their experiences. The goal is to broaden students' perspectives, enhance their technical skills, and facilitate informed decisions about their future research focus. A maximum of six credits are allowed to count toward the BME PhD coursework requirement.
Credit 3 units.
Typical periods offered: Fall, Spring, Summer

BME 8998 Doctoral Research
This course is designed for doctoral candidates to conduct advanced, original research in their field of study, leading to the completion of their dissertation. Students will engage in in-depth literature reviews, formulate research questions, develop and implement research methodologies, collect and analyze data, and write their dissertation under the guidance of their faculty advisor and dissertation committee. The course emphasizes critical thinking, scholarly integrity, and the advancement of knowledge. Regular meetings with the advisor and periodic progress reports are required. Successful completion is necessary for the awarding of the doctoral degree.
Credit 9 units.
Typical periods offered: Fall, Spring