BIOMEDICAL ENGINEERING AND PHYSIOLOGY (BME)

BME 5010 Integrative Physiology of Health and Disease (2 Credits)
I. Lanza, A. Matveyenko (Fall) – This course takes an integrated approach to lead students to a deeper understanding of fundamental concepts in human physiology. The goal is to foster critical thinking about how organ systems normally work, and to gain fundamental insight into processes that contribute to disease states. A combination of didactic instruction and learner-centered approaches are used to engage students in understanding structural and functional concepts from cell to organism. This course is the second in a series of courses (BME 5010, BME 5011, and BME 5012). In this course, topics will focus on key foundational principles of cellular physiology, followed by the nervous system and renal physiology. Student evaluations will involve graded quizzes and exams based on assigned readings and information covered during faculty-guided sessions. Student engagement and participation in discussions will also be taken into consideration during evaluation.
Grading: Standard Letter

BME 5011 Integrative Physiology of Health and Disease II (2 Credits)
I. Lanza, A. Matveyenko (Winter) - This course takes an integrated approach to lead students to a deeper understanding of fundamental concepts in human physiology. The goal is to foster critical thinking about how organ systems normally work, and to gain fundamental insight into processes that contribute to disease states. A combination of didactic instruction and learner-centered approaches are used to engage students in understanding structural and functional concepts from cell to organism. This course is the second in a series of courses (BMEP 5010, BMEP 5020, and BMEP 5030). In this course, topics will include gastrointestinal, endocrine, and reproductive, and immune systems, again with emphasis on anatomical and functional concepts that drive normal physiology and pathophysiological underpinnings of major diseases/disorders. Student evaluations will involve graded quizzes and exams based on assigned readings and information covered during faculty-guided sessions. Student engagement and participation in discussions will also be taken into consideration during evaluation.
Prerequisites: BME 5010
Grading: Standard Letter

BME 5012 Integrated Physiology of Health and Disease III (2 Credits)
I. Lanza (Spring) - This course takes an integrated approach to lead students to a deeper understanding of fundamental concepts in human physiology. The goal is to foster critical thinking about how organ systems normally work, and to gain fundamental insight into processes that contribute to disease states. A combination of didactic instruction and learner-centered approaches are used to engage students in understanding structural and functional concepts from cell to organism. This course is the third in a series of courses (BMEP 5010, BMEP 5011, and BMEP 5012). In this course, topics will include respiratory, cardiovascular, and musculoskeletal systems, again with emphasis on anatomical and functional concepts that drive normal physiology and pathophysiological underpinnings of major diseases/disorders. Student evaluations will involve graded quizzes and exams based on assigned readings and information covered during faculty-guided sessions. Student engagement and participation in discussions will also be taken into consideration during evaluation.
Prerequisites: (BME 5010, and BME 5011)
Grading: Standard Letter

BME 5020 Quantitative Biomedical Imaging and Signal Processing (2 Credits)
M. Urban, S. Leng (Fall) – This course will provide an introduction an introduction to the fundamental concepts related to medical imaging and biomedical signal processing with a quantitative emphasis. Concepts related to acquisition of biological signals and analysis related to time-domain and frequency-domain evaluation of signals will be covered. The course will also cover radiographic imaging including mammography and fluoroscopy. This course is the first in a series of courses (BME 5020, BME 5021, BME 5022).
Grading: Standard Letter

BME 5021 Quantitative Biomedical Imaging and Signal Processing II (2 Credits)
M. Urban, S. Leng (Winter) - This course will provide an introduction an introduction to the fundamental concepts related to medical imaging and biomedical signal processing with a quantitative emphasis. Statistics related imaging and signal processing and descriptors of image quality will be covered. Diagnostic imaging modalities including x-ray computed tomography (CT), single positron emission computed tomography (SPECT), and positron emission tomography (PET) will be covered. This course is the second in a series of courses (BME 5020, BME 5021, BME 5022).
Prerequisites: BME 5020
Grading: Standard Letter

BME 5022 Quantitative Biomedical Imaging and Signal Processing III (2 Credits)
M. Urban (Spring) - This course will provide an introduction an introduction to the fundamental concepts related to medical imaging and biomedical signal processing with a quantitative emphasis. Concepts related to acquisition of biological signals and analysis related to time-domain and frequency-domain evaluation of signals in multiple dimensions will be covered. Diagnostic imaging modalities including radiographic imaging, x-ray computed tomography, digital radiography, nuclear medicine, magnetic resonance imaging, and ultrasound will be covered. This course is the second in a series of courses (BMEP 5020, BMEP 5021, BMEP 5022).
Prerequisites: (BME 5020, and BME 5021)
Grading: Standard Letter

BME 5030 Biomedical Applications of Engineering Principles (2 Credits)
A. Asp, J. Lujan (Fall) – This course provides an overview of the application of engineering principles to address biomedical problems. It focuses on how engineering concepts and techniques can be utilized to solve biomedical challenges and advance healthcare. Through a combination of didactic lectures, case studies, and hands-on projects, students will gain an understanding of various engineering disciplines and their applications in the biomedical field, as well as how to analyze, design, and develop engineering solutions to biomedical problems.
Grading: Standard Letter

BME 5031 Biomedical Applications of Engineering Principles II (2 Credits)
A. Asp, B. Brinkmann, N. Ince (Winter) - This course provides an overview of the application of engineering principles to address biomedical problems. It focuses on how engineering concepts and techniques can be utilized to solve biomedical challenges and advance healthcare. Through a combination of didactic lectures, case studies, and hands-on projects, students will gain an understanding of various engineering disciplines and their applications in the biomedical field, as well as how to analyze, design, and develop engineering solutions to biomedical problems. This is the second in the course series (BMEP 5030, 5031, 5032).
Prerequisites: BME 5030
Grading: Standard Letter

BME 5032 Biomedical Applications of Engineering Principles III (2 Credits)
J. Luis Lujan (Spring) - This course provides an overview of the application of engineering principles to address biomedical problems. It focuses on how engineering concepts and techniques can be utilized to solve biomedical challenges and advance healthcare. Through a combination of didactic lectures, case studies, and hands-on projects, students will gain an understanding of various engineering disciplines and their applications in the biomedical field, as well as how to analyze, design, and develop engineering solutions to biomedical problems. This is the third in the course series (BMEP 5030, 5031, 5032).
Prerequisites: (BME 5030, and BME 5031)
Grading: Standard Letter

BME 5160 Introduction to Radiation Physics (4 Credits)
J. Johnson, S. Wan Chan Tseung (Odd/993: Fall, Winter) – This is an introductory graduate course designed for those interested in the radiation sciences. The course will introduce the student to the basic concepts and physical principles that underlie modern radiation physics including atomic structure, radiation, interactions of radiation with matter, introduction to cavity theory, biological effects of radiation (dose), x-ray production and dosimetry techniques.
Grading: Standard Letter

BME 5250 Anatomy for Biomedical Engineers (2 Credits)
Y. Salinas Alvarez (Odd: Winter) – Students dissect selected regions of the human body and learn correct names and locations of associated anatomical structures. Each student then gives a detailed presentation to the class of the region studied.
Grading: Sat / Unsat

BME 5450 Laboratory Methods in Biomedical Image Processing (3 Credits)
D. Holmes (Fall) – An introduction to important concepts in applied biomedical imaging, including digital processing of images, image signal characteristics, histogram analysis, domain processing, digital filters, image compression, reconstruction from projections, discussions of image composition, interactive 3D display, image processing and segmentation, registration and quantitative analysis. Practical applications in basic science and medicine are discussed. Students will use ANALYZE biomedical imaging software developed at Mayo to investigate these topics.*offered any quarter if enough students are participating*
Grading: Standard Letter

BME 5453 Fundamental Concepts in Biomechanics (3 Credits)
K. Kaufman (Winter) – This course is an introduction to biomechanics and addresses the fundamental topics of kinematics and kinetics.
Grading: Standard Letter

BME 5460 Finite Element Methods (3 Credits)
D. Dragomir-Daescu (Spring) – This is a combination of in-class teaching and self-directed study to help the students acquire a working knowledge of Finite Element Analysis (FEA). The goal is to teach the fundamental principles using tutorials and computer labs for an accelerated understanding of how the students can use FEA in their specific area of biomedical engineering research.
Grading: Standard Letter

BME 5704 Bioinstrumentation and Signal Processing (3 Credits)
D. Holmes (Spring) – This course will provide an introduction to basic principles of bioinstrumentation and related signal processing. The course will begin with discussion of the basics of sensing and theoretical treatment of signals, with an emphasis on bioinstrumentation applications. The remaining portion of the course will focus on analog and digital signal processing, involving both theoretical analysis and practical implementation.
Grading: Standard Letter

BME 5740 Magnetic Resonance Imaging Systems (3 Credits)
S. Riederer (Odd: Spring) – An introduction to physics and engineering aspects of modern diagnostic magnetic resonance imaging (MRI).
Grading: Standard Letter

BME 5800 Introduction to Medical Imaging (2 Credits)
S. Leng, S. Hsieh (993: Fall, Winter, Spring) – Will not be offered Fall 2025. An introduction to fundamental principles of medical imaging acquisition and analysis. Diagnostic imaging modalities to be covered include radiographic imaging, x-ray computed tomography, digital radiography, nuclear medicine, ultrasound and magnetic resonance imaging. This course has been accredited by the Commission on Accreditation of Medical Physics Education Programs (CAMPEP); please contact the instructor for further information. This course will be offered as student cohort requires.
Grading: Standard Letter

BME 6000 Tutorial in Exercise Physiology (2 Credits)
M. Joyner (Approval Required) – This course is designed for selected physiology graduate students who seek a broad overview in integrative physiology. The focus will be on presenting broad biological concepts related to integration, regulation, homeostasis, and the multitude of organ systems and how they adapt to various environmental and physical stresses. The course meets once a week for 1½ to 2 hours. It is taught using a collegial problem- solving approach. Students take a major role in where the course goes. The course runs one full academic year. Offered only once per year with consent of instructor required prior to registration.
Grading: Standard Letter

BME 6100 Medical Health Physics (2 Credits)
G. Sturchio (Spring) – Radiation protection philosophy and principles as applied to the medical environment: protection of patients, public, and employees; procedures for obtaining Nuclear Regulatory Commission license. This course has been accredited by the Commission on Accreditation of Medical Physics Education Programs (CAMPEP); please contact the instructor for further information.
Prerequisites: BME 5100
Grading: Standard Letter

BME 6151 Radiation Oncology Physics (3 Credits)
N. Remmes, J. Ma, D. Moseley (Winter) – Physics principles of the application of ionizing radiation in radiation therapy, including radiation characteristics, dose calculation, treatment planning/dosimetry, brachytherapy and quality assurance. This course has been accredited by the Commission on Accreditation of Medical Physics Education Programs (CAMPEP); please contact the instructor for further information.
Prerequisites: BME 5160
Grading: Standard Letter

BME 6300 Tutorial in Neurophysiology (3 Credits)
G. Sieck (Approval Required) – This course will provide an understanding of the basic concepts in cell and neurophysiology. The application of current experimental methods and techniques will be emphasized. Classic papers from the literature will be assigned and discussed. Laboratory demonstrations and computer modeling will be included if class size permits.
Grading: Standard Letter

BME 6301 Tutorial in Autonomic Neurophysiology (1 Credit)
D. Linden (Fall) – The goal of this course is to provide students the framework to research, present and discuss topics of interest in autonomic neurophysiology.
Grading: Sat / Unsat

BME 6302 Tutorial in Ultrasonic Imaging (2 Credits)
M. Fatemi (Approval Required) – Principles of ultrasound physics and interaction of ultrasound with biological tissues; principles and methods of tissue imaging using ultrasound; evaluating mechanical properties of tissue by ultrasound; measuring blood flow and tissue motion by Doppler method; artifacts in ultrasound imaging and in Doppler techniques; overview of recent and advanced techniques in medical ultrasound clinical applications of ultrasound.
Grading: Standard Letter

BME 6380 Open Science Methods in Computational (Neuro)Biology (2 Credits)
D. Hermes (Winter, Spring) - Recent advances in Open Science are resulting in an explosion of openly available data, computational tools and data visualization methods. In this course, students will learn about and become familiar with some data and tools in systems (neuro) biological research. The course will combine lectures with hands on practice, to encourage active learning of reproducible computing practices and help bridge the gap between theory and research. Student evaluations will involve participation on laboratory assignments and student presentations. The course will include a final project that will serve as the final exam
Grading: Sat / Unsat

BME 6490 Advanced Topics in Biomedical Image Processing (3 Credits)
C. Schwarz, A. Manduca (Spring) – This course will survey a variety of advanced topics in biomedical imaging. There will be some flexibility to choose topics of specific interest to the class in the later part of the course. Many applications of algorithms to specific biomedical situations will be studied in detail as "case studies" to understand how well the algorithms studied work in practice and what the real-world problems are.
Prerequisites: BME 5450
Grading: Standard Letter

BME 6500 Special Topics in Imaging Science (2 Credits)
TBA (Approval Required) – Special topics in the imaging sciences applied to biomedical problems and data; including 3-D imaging, volume rendering, surface rendering, image segmentation, image registration and fusion, shape description and analysis, multi-spectral analysis and classification, virtual reality visualization, image modeling.
Prerequisites: BME 5450
Grading: Standard Letter

BME 6600 Physiology & Biomedical Engineering Seminars (1 Credit)
L. Lujan, M. Fogarty (Approval Required) (Winter) – Presentations of research topics related to physiology and biomedical engineering. All BMEP students are required to attend seminars. In addition to attendance, students are required to give two short (30 min) presentations related to their own research projects, one prior to the start of winter quarter in their third year and the second in their fifth year. Students should register in the quarter in which they give their second presentation. Class locations will vary.
Grading: Sat / Unsat

BME 6650 Biomedical Engineering & Physiology Journal Club (1 Credit)
D. Holmes, (Fall, Winter, Spring) – The Biomedical Engineering Journal Club provides a forum for discussion of recent advances in biomedical engineering and physiology. Development of critical reading and writing skills will be incorporated as they apply to manuscript and grant reviewing and writing. Each student is expected to present at least one paper per year. Faculty will be invited to participate as appropriate. Students are required to attend for 3 consecutive quarters in a given year - fall, winter and spring (register for course in spring).
Grading: Sat / Unsat

BME 6720 Deep Learning for Medical Imaging (3 Credits)
T. Kline, M. Murphy (Spring) – This course will cover deep learning methods, with particular emphasis on applications in medical imaging. Moderate Python programming skills are required. The course will consist of a series of videos to be viewed on the student's own time, and classroom time will consist of discussion of principles covered. The course will also include a major project that serves as the "final exam" for the course.
Grading: Standard Letter

BME 6730 Laboratory Methods in Magnetic Resonance Imaging (2 Credits)
H. Edmonson (Even: Winter) – Introduction to MRI laboratory methods. Firsthand experience in basic and advanced MR image acquisition strategies, experimental tradeoffs, image reconstruction, and data interpretation.
Prerequisites: BME 5740
Grading: Sat / Unsat

BME 6740 Advanced Topics in MRI Systems (3 Credits)
S. Riederer (Even: Winter) – A technical study of advanced topics in contemporary magnetic resonance imaging (MRI). Topics to be discussed include vascular imaging and flow assessment, motion effects and compensation, echo-planar imaging, parallel acquisition, cardiac imaging, and diffusion.
Prerequisites: BME 5740
Grading: Sat / Unsat

BME 6755 X-ray Computed Tomography (3 Credits)
L. Yu, S. Leng, C. McCollough (Even: Fall) – The objective of this course is to give students in-depth training in X-ray computed tomography, including analytical and iterative reconstruction; dose measurement, management and reduction; cardiac and multi-energy CT; current clinical applications; and emerging techniques. Hands-on lab work and programming will be required as part of this course.
Grading: Standard Letter

BME 6820 Advanced Applications in Biomechanics (2 Credits)
K. Zhao (Approval Required) - This course incorporates advanced anatomy, kinematics, kinetics, and protocol development, with a focus on the student's specific research topic and interest. The course will culminate in a project that integrates the methods and applies them to a research question related to the student's thesis work.
Prerequisites: BME 5452
Grading: Sat / Unsat

BME 6840 Laboratory Methods in Biomechanics (2 Credits)
K. Kaufman (Fall) – This course is an introduction to biomechanics laboratory methods, covering techniques spanning from the in-vitro tissue level to in-vivo joint biomechanics. The course will include hands-on experience in material testing, motion tracking, force measurement, EMG measurement, device accuracy testing, and data processing. Students will also become familiar with IRB and IACUC study requirements.
Grading: Standard Letter

BME 6853 Readings in Biomedical Engineering (2 Credits)
BMEP Faculty (Summer) – Review of contemporary topics in Biomedical Engineering literature to be arranged with individual BMEP faculty members. Prior approval from Program Director. Name of faculty with syllabus required for approval.
Grading: Standard Letter

BME 6856 Tutorial in Respiratory Physiology (3 Credits)
G. Sieck (Approval Required) – The goal of this course is to provide an in-depth account of the functional components of the respiratory system and their integration in health and disease.
Grading: Standard Letter

BME 6859 Tutorial in Renal Physiology (2 Credits)
M. Romero (Approval Required) – Renal hemodynamics, glomerular function, mechanisms and regulation of electrolyte transport.
Grading: Standard Letter

BME 6860 Tutorial in Endocrine Physiology (2 Credits)
A. Matveyenko (Approval Required) – This course will provide in depth understanding of key aspects of endocrine physiology in health and under conditions associated with various disease states. Students will be responsible for selecting a scientific topic related to endocrine physiology for detailed study. The course director will be responsible for assigning key research articles and other materials to facilitate student-centric learning process.
Grading: Standard Letter

BME 6862 Tutorial in Neuromotor Control Physiology (2 Credits)
G. Sieck (Approval Required) – The goal of this course is to explore modeling and analysis of complex physiological systems: respiratory control, sleep apnea, and locomotion. A laboratory session and journal reviews are also planned to prove some of the above concepts and their applications.
Grading: Standard Letter

BME 6863 Tutorial in Neural Engineering (2 Credits)
G. Sieck, G. Worrell (Fall, Winter, Spring, Summer) – Course offered at the discretion of the instructors, or Fall term if the first option is not possible. This course is designed to explore the engineering applications in neuroscience. Included topics are the fundamental physical principles governing neural interface systems, relevant anatomy and physiology of the nervous system, and the conceptual design, optimization and implementation of neural interface technology. The course focuses mainly on neural interfaces and prosthetics.
Grading: Standard Letter

BME 6870 Systems Physiology I (3 Credits)
M. Romero (Fall) – In Systems Physiology I; The Cell as a Complex Biological System – the students will obtain a broader view of traditional "Cellular Physiology." All systems are made up of components which must communicate and respond. This course will focus on the fundamental organization that exists at the molecular, cellular, tissue, organism and population levels.
Grading: Standard Letter

BME 6999 Independent Study in Biomedical Engineering and Physiology (3 Credits)
M.Urban (Summer, Fall, Winter, Spring) - Independent studies are arranged on an individual basis in selected advanced topics in biomedical engineering and physiology. Learners are expected to define a topic area and parameters in consultation with a member of the teaching faculty and/or the program director. Specific assessments may vary but are required to demonstrate mastery of the topic. Independent studies are intended to emphasize laboratory/project-based learning (augmented with lecture/book content); this is in comparison to Tutorials which are intended to be primarily theoretical discussions on a topic (augmented with homework/labs). In addition to individual assignments for the course, students will be expected to submit a summary of their learning experience as a final assignment for review by the BMEP Curriculum Committee.
Grading: Sat / Unsat