

# BIOE - BIOENGINEERING

## BIOE404 Biomechanics (3 Credits)

Introduction to the fundamentals of biomechanics including force analysis, mechanics of deformable bodies, stress and strain, multiaxial deformations, stress analysis, and viscoelasticity. Biomechanics of soft and hard tissues.

**Prerequisite:** MATH246, BIOE120, ENES102, BIOE121, and BIOE241; and must have completed or be concurrently enrolled in BIOE371.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

## BIOE411 Tissue Engineering (3 Credits)

A review of the fundamental principles involved in the design of engineered tissues and organs. Both biological and engineering fundamentals will be considered.

**Prerequisite:** Must have completed at least one biology course; and (BIOE120, BIOE121, BIOE241, MATH246, and MATH241). Or permission of ENGR-Fischell Department of Bioengineering department.

**Recommended:** BSCI330 and BIOE340.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Credit Only Granted for:** BIOE411 or CHBE487.

## BIOE413 Stem Cell Engineering (3 Credits)

Provides an introduction to the role of stem cells in tissue growth and development, the engineering of stem cells and their environments for regenerative medicine applications, and disease modeling. Topics covered will include basic stem cell biology and mechanobiology; experimental methods for growing, differentiating, studying, and characterizing stem cells; stem cell integration into engineered microenvironments (e.g., tissue scaffolds and biomaterials, organ-on-chip devices, 3D-printed biomaterials); stem cell engineering in clinical applications and disease models; and ethical, commercialization, and regulatory issues in the field of stem cell engineering.

**Prerequisite:** BIOE241, BIOE120, BIOE121, and MATH246; and must have completed or be concurrently enrolled in BIOE340.

**Jointly offered with:** BIOE613.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Credit Only Granted for:** BIOE413, BIOE689J, or BIOE613.

## BIOE414 Macroscale Biomechanics (3 Credits)

An overview of current problems in movement biomechanics. After taking this course, students will be able to 1) Describe the engineering tools needed to study human movement 2) Recognize a variety of clinical research and practice, and 3) Use the framework provided by the course to pursue their own self-teaching and research on these topics. Topics covered include muscle mechanics, joint mechanics, EMG and EEG signal applications, ultrasonography and elastography, anthropometry, human movement 3-D kinematics, inverse dynamics, forward dynamics, work, power and energy. Biomechanics tools will be used to investigate clinical problems. Students will also do research projects on related topics.

**Prerequisite:** BIOE120, BIOE121, BIOE241, MATH246, and ENES102.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Credit Only Granted for:** BIOE414 or BIOE489Z.

**Formerly:** BIOE489Z.

## BIOE415 Engineering Design for Global Health (3 Credits)

Many medical technologies are not available in low and middle-income countries due to the cost, infrastructure, and medical expertise required to implement and sustain them. There is tremendous potential to increase access to health care through developing more affordable biomedical technologies, but effective design requires deep understanding of the problem. The goal of this course is to introduce the human-centered design framework and how it can be applied to design new biomedical technologies to solve challenges in global health.

**Prerequisite:** BIOE120, BIOE121, and MATH246.

**Jointly offered with:** BIOE615.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Credit Only Granted for:** BIOE415, BIOE615, BIOE489Y, or BIOE689I.

**Formerly:** BIOE489Y.

## BIOE416 Cardiovascular Engineering (3 Credits)

An overview of engineering applications in the cardiovascular system. Covers cardiovascular anatomy, physiology and pathophysiology in the context of cell and tissue mechanics, fluid mechanics, thermodynamics, biotransport, neurovascular coupling, and imaging. Includes design of cardiovascular devices, sensors, biomaterials, and tissue engineered constructs.

**Prerequisite:** BIOE331 and BIOE340.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Credit Only Granted for:** BIOE416 or BIOE489V.

**Formerly:** BIOE489V.

## BIOE420 Bioimaging (3 Credits)

Examines the physical principles behind major biomedical imaging modalities and new ways of using images for bio-related applications.

**Prerequisite:** MATH246, BIOE120, BIOE121, and BIOE241.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

## BIOE431 Fundamentals of Biosensor Techniques, Instrumentation, and Applications (3 Credits)

A thorough review of fundamental concepts of biosensing systems, principles of common detection methods, and modern applications of biosensors. Primarily literature driven. Students will obtain a detailed understanding of cutting-edge biosensing techniques, the instrumentation used, and the application space. Students also will develop skills in using current literature as a source of knowledge.

**Prerequisite:** CHEM135, PHYS260, PHYS261, BSCI330, BIOE120, BIOE121, BIOE241, and MATH246; or permission of ENGR-Fischell Department of Bioengineering department.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

## BIOE433 Optical Microscopy (3 Credits)

Includes a large variety of techniques central in many fields of biological and engineering research as well as clinical medicine. This course will provide a comprehensive overview of the fundamentals of optical microscopy. At a fundamental level, the course will cover the interaction of light with tissue, cells and biomaterials, and the mathematical foundations that describe optical systems.

**Prerequisite:** BIOE120, BIOE121, BIOE241, BIOE371, and MATH246.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Credit Only Granted for:** BIOE489I or BIOE433.

**Formerly:** BIOE489I.

**BIOE437 Computer-Aided Design in Bioengineering (3 Credits)**

Introduction to Computer-Aided Design (CAD). Lecture topics will summarize design methodology, review best-practices in hardware development, and discuss engineering applications. The course will culminate in a student-selected project leveraging CAD.

**Prerequisite:** BIOE120, BIOE121, BIOE241, and MATH246; or permission of ENGR-Fischell Department of Bioengineering department.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Credit Only Granted for:** BIOE437, BIOE689V, ENME414, ENME272, or ENAE488D.

**Formerly:** BIOE689V.

**BIOE442 Python: Introduction to Programming and Data Analysis (3 Credits)**

Provides an introduction to structured programming, computational methods, and data analysis techniques with the goal of building a foundation allowing students to confidently address problems in research and industry. Fundamentals of programming, algorithms, and simulation are covered from a general computer science perspective, while the applied data analysis and visualization portion makes use of the Python SciPy stack.

**Prerequisite:** BIOE241, BIOE120, BIOE121, and MATH241; or permission of ENGR-Fischell Department of Bioengineering department.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Credit Only Granted for:** BIOE489A or BIOE442.

**Formerly:** BIOE489A.

**BIOE447 Clinical Experiences in Bioengineering (3 Credits)**

An immersion experience in the clinical settings in which biomedical engineering strategies, technologies, and practices are applied. An emphasis will be placed on both clinical problems and engineering solutions.

**Prerequisite:** BIOE221.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Credit Only Granted for:** BIOE489O or BIOE447.

**Formerly:** BIOE489O.

**BIOE453 Biomaterials (3 Credits)**

Examination of the structure and function of natural biomaterials, and cell-extracellular matrix interactions. Study physical properties of synthetic biomaterials for biomedical applications. Understanding molecular level interactions between biomolecules and biomaterials to design novel biomaterials with desirable characteristics. Application of biomaterials as implants, drug delivery systems, biosensors, engineered materials such as artificial skin and bone growth scaffolds will be covered.

**Prerequisite:** CHEM231, MATH246, CHEM232, BIOE120, BIOE121, and BIOE241.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Credit Only Granted for:** BIOE453, CHBE457, or ENMA425.

**BIOE457 Biomedical Electronics & Instrumentation (4 Credits)**

Students learn fundamental concepts of electronics, assembly of electronic components into functional circuits, and integration of functional electronic devices and circuits into a system. In the lab component, students will learn to assemble and evaluate circuits and systems.

**Prerequisite:** BIOE120, BIOE121, BIOE241, PHYS261, MATH246, and PHYS260.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**BIOE461 Synthetic Biology and Biological Engineering (3 Credits)**

Students are introduced to the scientific foundation and concepts of synthetic biology and biological engineering. Current examples that apply synthetic biology to fundamental and practical challenges will be emphasized. The course will also address the societal issues of synthetic biology, and briefly examine interests to regulate research in this area.

**Prerequisite:** BIOE120, BIOE121, BIOE241, and MATH246; or permission of ENGR-Fischell Department of Bioengineering department.

**Recommended:** Completion of BSCI222 and/or BSCI330 recommended.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**BIOE462 Therapeutic Development and Delivery (3 Credits)**

The ultimate purpose of the pharmaceutical and biotechnology industries is the development and delivery of therapeutics. This course covers fundamentals of engineering and the pharmaceutical sciences related to therapeutics, including basic pharmaceuticals/drug delivery, pharmacokinetics, biomolecular kinetics, and regulatory issues.

Specific focus is placed on biotherapeutics, including antibodies and protein engineering, RNA and DNA therapeutics (gene therapy and RNAi), extracellular vesicle biotechnology (exosomes), and cell-based therapies, including stem cells. The use of delivery technologies to enable therapeutics (e.g. nanomedicine) will also be discussed.

**Prerequisite:** BIOE120, BIOE121, BIOE241, MATH246, and BSCI330; and must have completed or be concurrently enrolled in BIOE340.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Credit Only Granted for:** BIOE489P or BIOE462.

**Formerly:** BIOE489P.

**BIOE464 Introduction to Computational Molecular Bioengineering (3 Credits)**

Designed to introduce students to the principles, methods, and software used for simulation and modeling of macromolecules of biological interest such as proteins, lipids, and polysaccharides. Along with experiment and theory, computational modeling provides new tools for analysis, explanation and prediction. The course is also useful for students who plan to use experimental techniques as their primary approach, but who will employ computational modeling as a tool to obtain integrative understanding of complex systems. Finally, the course should be valuable as an introductory overview for students planning to conduct their thesis research in computational modeling of biological systems. Class topics: Basic statistical thermodynamics, Force fields, Molecular dynamics/ monte carlo methods, Conformational analysis, Fluctuations & transport properties, Free-energy calculations, Multiscale modeling.

**Prerequisite:** BIOE120, BIOE241, MATH246, BIOE232, and BIOE372; or permission of ENGR-Fischell Department of Bioengineering department.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Credit Only Granted for:** BIOE489N or BIOE464.

**Formerly:** BIOE489N.

**BIOE468 Selected Topics in Bioengineering (3 Credits)**

Selected topics in Bioengineering will be covered and taught by a variety of department faculty.

**Prerequisite:** BIOE120 and BIOE121.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Repeatable to:** 9 credits if content differs.

**BIOE474 Biopharmaceutical Process Development and Manufacturing (3 Credits)**

Covers the fundamental steps involved in process development and manufacturing of biopharmaceuticals. An overview of different classes of biopharmaceuticals as well as manufacturing requirements for clinical development and regulatory approval will be provided. In depth coverage of manufacturing steps including cell culture, purification and formulation as well as drug product manufacturing, analysis and stability will be covered. Scientific literature will be used to highlight current challenges and novel solutions in each step of the manufacturing process. Scale up considerations, GMP requirements and process economics will also be introduced.

**Prerequisite:** BIOE120.

**Jointly offered with:** BIOE674.

**Restriction:** Must have earned a minimum of 60 credits, Permission of ENGR-Fischell Department of Bioengineering department.

**Credit Only Granted for:** BIOE474, BIOE674, CHBE474, BIOE489T, or BIOE689E.

**Formerly:** BIOE489T.

**BIOE485 Capstone Design I: Entrepreneurship, Regulatory Issues, and Ethics (3 Credits)**

This is the first part of a two-semester senior capstone design course which covers principles involved in engineering design, design approaches, economics of design, ethics in engineering, and patent regulations. It also helps students learn team work and write design project proposals under the mentorship of a faculty advisor.

**Prerequisite:** 21 credits in BIOE courses; and must have completed or be concurrently enrolled in BIOE457.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department; and senior standing; and must be in Engineering: Bioengineering program.

**BIOE486 Capstone Design II (3 Credits)**

This is the second part of the senior capstone design course. This part is independent instruction where faculty mentoring each project team works with students to order supplies, fabricate their proposed design under BIOE485, test the design, write the report and present it to their fellow seniors and board of faculty mentors. Students are taught to convert the blue print of a design to actual device and test it.

**Prerequisite:** Must have completed BIOE485 in the immediately preceding semester.

**Restriction:** Senior standing; and must be in Engineering: Bioengineering program; and permission of ENGR-Fischell Department of Bioengineering department.

**Credit Only Granted for:** BIOE486 or ENBE486.

**Formerly:** ENBE486.

**BIOE488 Research Methods in Bioengineering (1-3 Credits)**

Exploring a variety of research methods in the field of Bioengineering.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Repeatable to:** 9 credits if content differs.

**BIOE489 Special Topics in Bioengineering (1-3 Credits)**

Exploring a variety of topics with Bioengineering.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Repeatable to:** 6 credits.

**BIOE601 Biomolecular and Cellular Rate Processes (3 Credits)**

Presentation of techniques for characterizing and manipulating non-linear biochemical reaction networks. Advanced topics to include mathematical modeling of the dynamics of biological systems; separation techniques for heat sensitive biologically active materials; and rate processes in cellular and biomolecular systems. Methods are applied to current biotechnological systems, some include: recombinant bacteria; plant insect and mammalian cells; and transformed cell lines.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Credit Only Granted for:** BIOE601 or ENCH859B.

**BIOE602 Cellular and Tissue Biomechanics (3 Credits)**

Introduction to the fundamentals of biomechanics including force analysis, mechanics of deformable bodies, stress and strain, multiaxial deformations, stress analysis, and viscoelasticity. Biomechanics of soft and hard tissues.

**BIOE604 Cellular and Physiological Transport Phenomena (3 Credits)**

A study of transport processes, including momentum, energy and mass transport, relevant to biosystems at various scales from physiological to cellular systems. Transport leads to sets of partial differential equations and the course revolves around approaches to solving these equations to arrive at fundamental understanding of the physics of transport in biosystems.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**BIOE605 BIO Graduate Studies I (1 Credit)**

Introduction to the bioengineering graduate program. Students gain exposure to departmental research through lab rotation and to current research in the field through seminar. Students will also gain preparation and guidance on other first-year academic requirements.

**Restriction:** Must be in ENGR: PhD Only-Bioengineering (Doctoral) program.

**BIOE606 BIO Graduate Studies II (1 Credit)**

Second semester continued acclimation to the bioengineering graduate program. Students gain exposure to departmental research through lab rotation and to current research in the field through seminar.

**Restriction:** Must be in ENGR: PhD Only-Bioengineering (Doctoral) program.

**BIOE608 Bioengineering Seminar Series (1 Credit)**

A variety of topics related to Bioengineering will be presented in weekly seminars.

**Restriction:** Must be in one of the following programs (ENGR: PhD Only-Bioengineering (Master's); ENGR: PhD Only-Bioengineering (Doctoral)).

**Repeatable to:** 6 credits if content differs.

**BIOE610 Mathematical Methods in Bioengineering (3 Credits)**

From diffusion problems to light-matter interactions, students will learn basic skills needed to create mathematical models in bioengineering. Students will first be exposed to simplified problems in analytical form, and then more complex problems with the help of computer software programs.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering.

**BIOE611 Advanced Tissue Engineering (3 Credits)**

A review of the fundamental principles involved in the design of engineered tissues and organs. Both biological and engineering fundamentals will be considered.

**Prerequisite:** Must have completed at least one biology course; and MATH241. Or permission of ENGR-Fischell Department of Bioengineering department.

**Recommended:** BSCI330 and BIOE340.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**BIOE612 Physiological Evaluation of Bioengineering Designs (3 Credits)**

Bioengineering designs of biomaterials, biomedical devices, imaging and drug delivery agents, tissue engineering, prosthesis (among others), offer the opportunity to improve health care. This course is aimed at providing knowledge to lead bioengineering designs on the basis of biocompatibility and to provide tools to assess their patho-physiological impact in biological systems.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**BIOE613 Stem Cell Engineering (3 Credits)**

Provides an introduction to the role of stem cells in tissue growth and development, the engineering of stem cells and their environments for regenerative medicine applications, and disease modeling. Topics covered will include basic stem cell biology and mechanobiology; experimental methods for growing, differentiating, studying, and characterizing stem cells; stem cell integration into engineered microenvironments (e.g., tissue scaffolds and biomaterials, organ-on-chip devices, 3D-printed biomaterials); stem cell engineering in clinical applications and disease models; and ethical, commercialization, and regulatory issues in the field of stem cell engineering.

**Jointly offered with:** BIOE413.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering.

**Credit Only Granted for:** BIOE489J, BIOE413, BIOE689J or BIOE613.

**Formerly:** BIOE689J.

**BIOE615 Engineering Design for Global Health (3 Credits)**

Many medical technologies are not available in low and middle-income countries due to the cost, infrastructure, and medical expertise required to implement and sustain them. There is tremendous potential to increase access to health care through developing more affordable biomedical technologies, but effective design requires deep understanding of the problem. The goal of this course is to introduce the human-centered design framework and how it can be applied to design new biomedical technologies to solve challenges in global health.

**Jointly offered with:** BIOE415.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Credit Only Granted for:** BIOE615, BIOE415, BIOE689I, or BIOE489Y.

**Formerly:** BIOE689I.

**BIOE631 Biosensor Techniques, Instrumentation, and Applications (3 Credits)**

A thorough review of fundamental concepts of biosensing systems, principles of common detection methods, and modern applications of biosensors. Primarily literature driven. Students will obtain a detailed understanding of cutting-edge biosensing techniques, the instrumentation used, and the application space. Students also will develop skills in using current literature as a source of knowledge.

**Prerequisite:** Permission of ENGR-Fischell Department of Bioengineering department.

**Credit Only Granted for:** BIOE631, BIOE689Z, or CHPH718Z.

**Formerly:** BIOE689Z.

**BIOE632 Biophotonic Imaging and Microscopy (3 Credits)**

Principles and instrumentation of various biomedical optical techniques, including fluorescence and Raman spectroscopy, confocal and multi-photon microscopy, optical coherence tomography, and diffuse optical tomography. Biomedical applications will also be discussed.

**Recommended:** BIOE420.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Credit Only Granted for:** BIOE432, BIOE632, or BIOE689C.

**BIOE640 Polymer Physics (3 Credits)**

Graduate course covering theoretical aspects of the behavior of polymeric materials. It covers statistical properties and thermodynamics of single chain and multichain systems.

**Prerequisite:** ENMA471; or permission of instructor.

**Credit Only Granted for:** ENMA620 or BIOE640.

**BIOE650 Quantitative Physiology of the Cell (3 Credits)**

Introduction to quantitative aspects of neuronal, skeletal muscle, and cardiac physiological systems, with an emphasis on cellular function and plasticity. Complements BIOE603: Electrophysiology of the Cell.

**Recommended:** MATH246, MATH141, and MATH241.

**Credit Only Granted for:** BIOE689Q or BIOE650.

**Formerly:** BIOE689Q.

**BIOE651 Applied Mathematics in Bioengineering (3 Credits)**

Students will use and learn mathematical concepts that are directly relevant to their career as a bioengineer. They will apply these concepts to various bioengineering applications while also learning industry-relevant analytical software.

**Restriction:** Restricted to Master's of Engineering - Bioengineering students; or permission of Fischell Department of Bioengineering.

**Credit Only Granted for:** BIOE651 or BIOE658M.

**Formerly:** BIOE658M.

**BIOE652 Regulatory Affairs in Medical Product Development (3 Credits)**

An introductory course on regulations associated with the development and production of medical devices and pharmaceuticals.

**Restriction:** Restricted to Master's of Engineering - Bioengineering students; or permission of Fischell Department of Bioengineering.

**Credit Only Granted for:** BIOE652, ANTH627 or BIOE658R.

**Formerly:** BIOE658R.

**BIOE654 Physiology for Bioengineers (3 Credits)**

Bioengineering-based designs of biomaterials, biomedical devices, imaging and drug delivery agents, tissue engineering, and prosthesis (among others), offer the opportunity to improve health care. This course is aimed at providing biological knowledge to lead bioengineering designs on the basis of biocompatibility and to provide tools to assess their patho-physiological impact in biological systems.

**Restriction:** Restricted to Master's of Engineering - Bioengineering students; or permission of Fischell Department of Bioengineering.

**Credit Only Granted for:** BIOE654 or BIOE658P.

**Formerly:** BIOE658P.

**BIOE658 Special Topics in Bioengineering (M.Eng.) (1-3 Credits)**

Special topics in Bioengineering.

**Restriction:** Must be in the Master of Engineering program or Post-Baccalaureate Certificate of Engineering program; and permission of ENGR-Fischell Department of Bioengineering department.

**Repeatable to:** 99 credits if content differs.

**BIOE664 Computational Molecular Bioengineering (3 Credits)**

Designed to introduce students to the principles, methods, and software used for simulation and modeling of macromolecules of biological interest such as proteins, lipids, and polysaccharides. Along with experiment and theory, computational modeling provides new tools for analysis, explanation and prediction. The course is also useful for students who plan to use experimental techniques as their primary approach, but who will employ computational modeling as a tool to obtain integrative understanding of complex systems. Finally, the course should be valuable as an introductory overview for students planning to conduct their thesis research in computational modeling of biological systems. Class topics: Basic statistical thermodynamics, Force fields, Molecular dynamics/ monte carlo methods, Conformational analysis, Fluctuations & transport properties, Free-energy calculations, Multiscale modeling.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering.

**Credit Only Granted for:** BIOE489N, BIOE464, BIOE689U, or BIOE664.

**Formerly:** BIOE689U.

**BIOE674 Biopharmaceutical Process Development and Manufacturing (3 Credits)**

Covers the fundamental steps involved in process development and manufacturing of biopharmaceuticals. An overview of different classes of biopharmaceuticals as well as manufacturing requirements for clinical development and regulatory approval will be provided. In depth coverage of manufacturing steps including cell culture, purification and formulation as well as drug product manufacturing, analysis and stability will be covered. Scientific literature will be used to highlight current challenges and novel solutions in each step of the manufacturing process. Scale up considerations, GMP requirements and process economics will also be introduced.

**Jointly offered with:** BIOE474.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Credit Only Granted for:** BIOE674, BIOE474, CHBE474, BIOE489T, or BIOE689E.

**Formerly:** BIOE689E.

**BIOE689 Special Topics in Bioengineering (1-3 Credits)**

Research Oriented Individual Instruction course.

**Repeatable to:** 6 credits if content differs.

**BIOE799 Master's Thesis Research (1-6 Credits)****BIOE898 Pre-Candidacy Research (1-8 Credits)****BIOE899 Doctoral Dissertation Research (1-8 Credits)**