

BIOMEDICAL ENGINEERING

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Academic Programs

Program name	Program type
Biomedical Engineering	BS, MS

Biomedical Engineering

Biomedical engineering is an interdisciplinary field in which the principles and tools of traditional engineering fields, such as mechanical, materials, electrical, and chemical engineering, are applied to biomedical problems. Engineering plays an increasingly important role in medicine in projects that range from basic research in physiology to advances in biotechnology and the improvement of health care delivery. By its very nature, biomedical engineering is broad and requires a foundation in the engineering sciences as well as in physiology and other biological sciences.

The BS degree program in Biomedical Engineering is accredited by the Engineering Accreditation Commission of ABET, <http://www.abet.org/>.

Undergraduate Program BS Biomedical Engineering

Program Mission and Goals

The mission of the Biomedical Engineering program is to maintain an effective learning environment that enables and empowers graduates for careers of service, leadership and distinction in engineering or other fields. Our approach is to use a participatory, learn-by-doing, "hands-on" laboratory, projects and design centered approach to achieve this end.

To succeed in this mission, the educational objectives of the program are to facilitate graduates to:

1. Utilize a knowledge base with a core foundation in engineering, physical and biological sciences, which will enable them to apply their skills to a variety of challenges in their chosen field. Our graduates will demonstrate innovation, creativity, adaptability and critical thinking to solve problems in disciplines related to biomedical engineering that are relevant to industry, academia, or medicine, and health related fields.
2. Demonstrate leadership in their chosen fields and make decisions that are socially and ethically responsible. Our graduates will function effectively in multidisciplinary team environments and communicate effectively to a variety of audiences.
3. Build and expand upon their undergraduate foundations by engaging in learning opportunities throughout their careers.

The program offers a four-year curriculum leading to a B.S. degree. The main educational objectives of the program are to prepare graduates who will excel in the biomedical engineering profession, understand

that their education is a continuous enterprise, and seek graduate degrees for increased flexibility and mobility. The curriculum provides a sound theoretical background, practical engineering knowledge and solid laboratory exposure. It highlights an immediate introduction to the major, strong personal interaction with faculty, strong partnerships with industrial participants and a signature laboratory emphasis.

The application of engineering to medicine and biology underpins a strong and growing segment of the industrial sector and continues to be an area of inherent interest to students. The need for well educated professionals in this interdisciplinary area has become more acute as the technology being applied has become more sophisticated. Evolution in computing, electronics, signal analysis and mechatronic systems have resulted in dramatic improvements in diagnostic efforts, therapeutic approaches and bioindustrial applications. Studies of biological materials, physiological mechanisms, biochemical kinetics and heat and mass transport in biological systems require engineering expertise. With the advent of research into artificial organs, prosthetic devices and tissue engineering, applied medical research and applied biological research has taken on a distinct engineering aspect.

Biomedical engineering combines engineering expertise with medical needs for the enhancement of health care. It is a branch of engineering in which knowledge and skills are developed and applied to define and solve problems in biology and medicine. Students choose the biomedical engineering field to be of service to people; for the excitement of working with living systems; and to apply advanced technology to the complex problems of medical care.

Some well established specialty areas exist within the field of biomedical engineering: *bioinstrumentation*, *biomechanics*, *biomaterials*, *systems physiology*, *tissue engineering*, *clinical engineering*, and *rehabilitation engineering*.

Bioinstrumentation is the application of electronics and measurement principles and techniques to develop devices used in diagnosis and treatment of disease. Computers are becoming increasingly important in bioinstrumentation, from the microprocessor used to do a variety of small tasks in a single purpose instrument to the extensive computing power needed to process the large amount of information in a medical imaging system. *Biomechanics* is mechanics applied to biological or medical problems. It includes the study of motion, of material deformation, of flow within the body and in devices, and transport of chemical constituents across biological and synthetic media and membranes. *Biomaterials* describes both living tissue and materials used for implantation. Understanding the properties of the living material is vital in the design of implant materials. *Systems physiology* is the term used to describe that aspect of biomedical engineering in which engineering strategies, techniques and tools are used to gain a comprehensive and integrated understanding of the function of living organisms ranging from bacteria to humans. *Tissue engineering* is a rapidly developing field that combines engineered materials with living cells to restore or replace lost organ function. *Clinical engineering* is the application of technology for health care in hospitals. The clinical engineer is a member of the health care team along with physicians, nurses and other hospital staff. *Rehabilitation engineering* is a new and growing specialty area of biomedical engineering. Rehabilitation engineers expand capabilities and improve the quality of life for individuals with physical impairments.

In addition to the objectives for all engineering programs, the goal of the BS program in Biomedical Engineering is the preparation of engineering professionals who have: (1) an understanding of biology and physiology; (2) an ability to apply advanced mathematics to problems at the interface

of engineering and biology; (3) an ability to measure and interpret data from living systems; and (4) an ability to address the problems associated with the interaction between living and nonliving systems.

Concentrations

Bioinstrumentation

The bioinstrumentation concentration prepares students for entry level jobs in the biomedical devices industry where a deeper understanding of electrical engineering skills are necessary.

Mechanical Design

The mechanical design concentration prepares students for employment in the product development, design, or manufacturing fields in the biomedical device industry.

General Curriculum in Biomedical Engineering

A General Curriculum in Biomedical Engineering is also an option. It is not a formal concentration. Students are encouraged to select from one of the concentrations listed above, but those who do not declare a concentration will default to the General Curriculum.

Graduate Programs

MS Biomedical Engineering

General Characteristics

The Master of Science degree program in Biomedical Engineering is well-suited for those individuals who desire depth in engineering application to living systems, with a strong pragmatic and rigorous, hands-on educational experience. Graduates will be well-equipped to make significant contributions to the biomedical field.

Prerequisites

For admission as a classified graduate student, an applicant must possess a bachelor's degree in engineering or a closely related physical science with a minimum grade point average of 3.0 in the last 90 quarter units (60 semester units) attempted. Applicants for graduate engineering programs are required to submit scores for the General Test of the Graduate Record Examination. Applicants are also required to submit 3 letters of reference in support of their application. A college level biology course, with laboratory, for biology majors is highly recommended. Applicants who meet these standards but lack prerequisite coursework may be admitted as conditionally classified students and must make up any deficiencies before advancement to candidacy. Applicants from other academic disciplines, such as biology or chemistry are encouraged to apply and may be admitted to the program conditionally in order to make up deficiencies in prerequisite coursework. Information regarding specific admission requirements and classification as a graduate student may be obtained from the Graduate Coordinator, Biomedical Engineering.

Program of Study

Graduate students must file formal study plans with their advisor, department, college, and university graduate studies office no later than the end of the first quarter in residence. The formal program of study must include a minimum of 45 units with:

1. At least 27 units of the 45 unit program at the 500 level.
2. A thesis or project as the required culminating experience.

MS Biomedical Engineering, Specialization in Regenerative Medicine Characteristics

Prepares students for careers in regenerative medicine and related fields. Specifically, our graduates are prepared for immediate employment in cell therapy, tissue engineering, biopharma, or medical technology companies, and as research specialists/laboratory managers at universities or research institutes. Program graduates are also well-prepared to matriculate into bioengineering doctoral programs or graduate programs in the health professions.

Culminating Experience

Students who obtain a degree in the Master of Science in Biomedical Engineering with a specialization in Regenerative Medicine are not required to complete a "thesis" through BMED 599. In place of the thesis as a culminating experience, students complete a Project during a 9-month internship at a company or research laboratory¹ (ASCI/ BIO/BMED 593). The Project Report is evaluated by their Cal Poly and Internship Mentor; their Project Presentation is evaluated by their Cal Poly and Internship Mentors, and Program Director.

¹Students will complete their internship at one of our partner institutions. An updated list of our current partners can be found on our program website - regenmed.calpoly.edu.

Blended BS + MS Biomedical Engineering Program

A blended program provides an accelerated route to a graduate professional degree, with simultaneous conferring of both Bachelor's and Master's degrees. Students in the blended program are provided with a seamless process whereby they can progress from undergraduate to graduate status. Students are required to complete all requirements for both degrees, including senior project for the Bachelor's degree.

A blended program is available for MS Biomedical Engineering.

Eligibility

Majors that are eligible for the blended program in MS Biomedical Engineering are:

- BS Biomedical Engineering
- BS Chemistry
- BS Computer Engineering
- BS Electrical Engineering
- BS Mechanical Engineering
- BS Materials Engineering

Participation in a blended program is based upon prior academic performance and other measures of professional promise. Refer to [Graduate Education \(https://catalog.calpoly.edu/graduateeducation/#graduateandpostbaccalaureateadmissionrequirements/\)](https://catalog.calpoly.edu/graduateeducation/#graduateandpostbaccalaureateadmissionrequirements/) for more information and for the minimum criteria required to be eligible for a blended program at Cal Poly. Contact the Graduate Program Coordinator in the Biomedical Engineering department for any additional eligibility criteria.

BMED Courses

BMED 101. Introduction to the Biomedical Engineering Major. 1 unit

Term Typically Offered: F

Prerequisite: Biomedical or General Engineering Freshmen.

Introduction to major topics in Biomedical Engineering. Time management, study skills and class scheduling necessary for academic success. Overview of university services. Professional pathways and ethics. Review of career opportunities. 1 seminar.

BMED 102. Introduction to Biomedical Engineering Analysis. 1 unit

Term Typically Offered: W

Prerequisite: BMED 101.

General introduction to bioengineering analysis applied to representative topics in biomechanics, biofluidics, bioinstrumentation, biomaterials, biotechnology, and related areas. Review of technological needs, testing procedures, governmental regulation, quality of life, and ethical issues. 1 seminar.

BMED 212. Introduction to Biomedical Engineering Design. 3 units

Term Typically Offered: F, W, SP

Prerequisite: MATH 143.

General introduction to bioengineering design, including examples of engineering analysis and design applied to representative topics in biomechanics, bioinstrumentation, biomaterials, biotechnology, and related areas. A review of technological needs, design methodology, testing procedures, statistical analysis, governmental regulations, evaluation of costs and benefits, quality of life, and ethical issues. 2 lectures, 1 laboratory.

BMED 213. Bioengineering Fundamentals. 2 units

Term Typically Offered: F, W, SP

2020-21 or later catalog: GE Area B2

2019-20 or earlier catalog: GE Area B2

Sustainability Related

Prerequisite: MATH 142; for engineering students only. Corequisite: BIO 213. Recommended: CHEM 124.

Treatment of the engineering applications of biology. Genetic engineering and the industrial application of microbiology. Systems physiology with engineering applications. Structure and function relationships in biological systems. The impact of life on its environment. Course may be offered in classroom-based or online format. 2 lectures. Crosslisted as BMED/BRAE 213. Fulfills GE B2.

BMED 270. Selected Topics. 1-4 units

Term Typically Offered: TBD

Prerequisite: Open to undergraduate students and consent of instructor.

Directed group study of selected topics. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 lectures.

BMED 300. Research Experience for Undergraduates. 1 unit

Term Typically Offered: F,W,SP,SU

CR/NC

Prerequisite: Consent of instructor.

Laboratory, field, or engineering education research experience. Development of research skills and techniques. Interested students consult with a faculty member prior to enrolling to clarify expectations and deliverables. Total credit limited to 12 units. Credit/No Credit grading only. Course offered online only.

BMED 310. Biomedical Engineering Measurement and Analysis. 4 units

Term Typically Offered: F, W

Prerequisite: EE 201; and CPE/CSC 101, CSC 231, CSC 232, or CSC 234.

Fundamentals of biomedical engineering analysis. Use and application of tools and analytical methods used by bioengineers. 3 lectures, 1 laboratory.

BMED 330. Intermediate Biomedical Design. 4 units

Term Typically Offered: W, SP

Prerequisite: MATE 210, ME 328, STAT 312. Recommended: BMED 420, BMED 460.

Design of biomedical devices and systems using various machine elements and components including gears, welded connections, prime movers. Decision modeling based on technical and economic feasibility. 3 lectures, 1 laboratory.

BMED 355. Electrical Engineering Concepts for Biomedical Engineering. 4 units

Term Typically Offered: W

Prerequisite: EE 201, MATH 344.

Introduction to electrical engineering concepts for biomedical engineers. Continuation of basic circuit analysis. Steady state AC circuit analysis and phasor concepts. Application of the Laplace Transform to transient circuit analysis. Introduction to digital logic gates, combinational and sequential logic circuits. 4 lectures.

BMED 400. Special Problems for Advanced Undergraduates. 2-4 units

Term Typically Offered: F,W,SP,SU

Prerequisite: ME 212; junior standing; and consent of department chair.

Individual investigation, research, studies, or surveys of selected problems. Total degree credit limited to 4 units. Total credit limited to 6 units.

BMED 401. Biomedical Entrepreneurship. 4 units

Term Typically Offered: TBD

Prerequisite: Senior standing and engineering major.

Identification and evaluation of commercial opportunities in the healthcare industry. Methods necessary for rapid iteration and market validation of early-stage prototypes, with emphasis on issues critical to biomedical products, including intellectual property, FDA submission, funding sources, and business models. 3 lectures, 1 laboratory.

BMED 404. Applied Finite Element Analysis. 4 units

Term Typically Offered: F, W

Prerequisite: BMED 410, and CE 207 or CE 208; or CE 406; or ME 328.

Finite element based solutions to engineering problems with an emphasis on elastostatic problems in structural mechanics. The power and pitfalls associated with the finite element method highlighted through practical modeling assignments. Introduces the use of commercial finite element codes. 3 lectures, 1 laboratory. Crosslisted as BMED/CE/ME 404.

BMED 409. Interdisciplinary Study in Biomechanics. 4 units

Term Typically Offered: SP

Prerequisite: BMED 410 and CE 207 or CE 208; or KINE 403; or ME 326.

Examination of human motion biomechanics. Experimental and analytical methods in motion analysis based on rigid body dynamics. Protocols for protection of human subjects in research. Hypothesis-driven research in interdisciplinary teams, including written proposal development and written/oral communication of results to a scientific audience. 1 lecture, 3 activities. Crosslisted as BMED/KINE/ME 409.

BMED 410. Biomechanics. 4 units

Term Typically Offered: W, SP

Prerequisite: CE 204 or CE 208; and ME 212. Corequisite: BMED 310.

Introduction to physiological systems, with emphasis on structure and function of major tissues and organs. Application of mechanics to understand the behavior of these tissues and organs at gross and microscopic levels. Bioelastic solids. Rigid body biomechanics. Biofluids, basic mechanical properties of collagen and elastin, bone, cartilage, muscles, blood vessels, and other living tissues. Application of continuum mechanics to hard and soft tissues. Biomechanical engineering design for clinical applications. 3 lectures, 1 laboratory.

BMED 420. Principles of Biomaterials Design. 4 units

Term Typically Offered: F, SP

Prerequisite: CE 204 or CE 208; and MATE 210. Corequisite: BMED 310.

Fundamentals of materials science as applied to bioengineering design. Biocompatibility of materials. Materials characterization and design. Natural and synthetic polymeric materials. Wound repair, foreign body response, blood clotting. Transplantation biology, artificial organs, and tissue engineering. Medical devices, government regulations, and ethical issues. 3 lectures, 1 laboratory.

BMED 422. Medical Device Evaluation and the FDA Approval Process. 4 units

Term Typically Offered: W

Prerequisite: BMED 420.

Overview of the path to market for new medical devices, including nonclinical and clinical evaluation and the regulatory process. Course covers bench, in vitro, and in vivo models, GLP studies, clinical trials, Quality Systems, and FDA clearance and approval processes. 4 lectures.

BMED 425. Biomedical Engineering Transport. 4 units

Term Typically Offered: F, SP

Prerequisite: ME 302 and ME 341.

Physiological fluid mechanics, convective mass transfer, and diffusion in tissue. Properties of blood. Exchange of fluids between capillary beds and tissue. Coupled diffusion and convection. Application of mass transfer coefficients. Rates of diffusion in various physiologic media. 3 lectures, 1 laboratory.

BMED 430. Biomedical Modeling and Simulation. 2 units

Term Typically Offered: F, W

Prerequisite: BMED 310.

Computational methods for anatomical modeling and boundary value problems in the biomechanics of tissues and biomedical devices. Nonlinear biodynamics, heat flow, cardiac impulse propagation, anatomic modeling, and biomechanics. Course may be offered in classroom-based or online format. 1 lecture, 1 laboratory.

BMED 432. Micro/Nano System Design. 4 units

Term Typically Offered: F

Prerequisite: BMED 212 or MATE 210.

Fundamentals of designing micro/nano scale systems employing sensors, actuators and intelligent controls. Explore mechanics, electronics, heat transfer, photonics, fluid mechanics and biometrics at the micrometer and nanometer scale. Discover how scaling impacts design criteria. Investigate the integration of science and engineering and evaluate applications in living systems. Not open to students with credit in MATE 550. 4 lectures.

BMED 434. Micro/Nano Fabrication. 3 units

Term Typically Offered: W

Prerequisite: BMED 212 or MATE 210.

Fabrication science and technology for creating micro and nano scale devices. Explore basic processes such as oxidation, diffusion, ion implantation, etching, chemical and physical vapor deposition, photolithography. Develop an understanding of the science of each process and how to select the right steps for fabricating electronic, photon and micro-electro-mechanical systems devices. 3 lectures. Crosslisted as BMED 434/EE 423/MATE 430.

BMED 435. Microfabrication Laboratory. 1 unit

Term Typically Offered: W

Corequisite: BMED 434/EE 423/MATE 430.

Application of basic processes involved in microfabrication: cleanroom protocol, oxidation, diffusion, photolithography etching and sputtering. Explore process development through fabrication of electronic, photonic or microfluidic devices. Each student will be part of a team that will fabricate and test a device. 1 laboratory. Crosslisted as BMED 435/EE 473/MATE 435.

BMED 436. Characterization of Micro/Nano Scale Structures. 4 units

Term Typically Offered: TBD

Prerequisite: BMED 212 or MATE 210.

Fundamentals of material's surface analysis techniques for exploring structure and composition of micro/nano scale features and films will be assessed. Students will develop data analytics for deciding which technique to apply for morphological, elemental or chemical composition analysis. 4 lectures.

BMED 440. Bioelectronics and Instrumentation. 4 units

Term Typically Offered: F, W

Prerequisite: BMED 310 and EE 201.

Analog and digital circuits in bioinstrumentation. Biomedical signals in continuous and discrete systems. Sampling and digital signal processing. Ultrasound, MRI, CT, Bioelectromagnetics. Electrokinetics. Biophysical phenomena, transducers, and electronics as related to the design of biomedical instrumentation. Potentiometric and amperometric signals and amplifiers. Biopotentials, membrane potentials, chemical sensors. Mechanical transducers for displacement, force and pressure. Temperature sensors. Flow sensors. Light-based instrumentation. Electrical safety. 3 lectures, 1 laboratory.

BMED 445. Biopotential Instrumentation. 4 units

Term Typically Offered: SP
Prerequisite: BMED 440.

Focus on the principles associated with instrumentation used to detect surface biopotentials. Emphasis on circuit level design and laboratory implementation of systems used to detect ECG, EMG and EEG signals. Development of practical experience with analog electronic instrumentation used in the design and testing process. A system level design project related to surface biopotential detection and recording. 2 lectures, 2 laboratories.

BMED 450. Contemporary Issues in Biomedical Engineering. 4 units

Term Typically Offered: F, W, SP
Prerequisite: Senior standing in Biomedical Engineering.

Current and evolving topics in biomedical engineering, including medical and industrial applications. Exploration of contemporary issues in biomedical engineering, including technical and societal implications. The Class Schedule will list topic selected. Total credit limited to 16 units. Course may be offered in classroom-based or online format. 4 lectures.

BMED 455. Biomedical Engineering Design I. 4 units

Term Typically Offered: F, W
Prerequisite: BMED 410.

Engineering design methodology, design process, project planning, decision making, modeling, construction, and testing of an open-ended design project. Preparation of formal engineering reports. Statistical analysis. Governmental regulations. Bioethical issues. 2 lectures, 2 laboratories.

BMED 456. Biomedical Engineering Design II: Senior Project. 4 units

Term Typically Offered: W, SP
Prerequisite: BMED 455.

Engineering design methodology, design process, project planning, decision making, modeling, construction, and testing of an open-ended design project. Preparation of formal engineering reports. Statistical analysis. Governmental regulations. Bioethical issues. 2 lectures, 2 laboratories.

BMED 459. Senior Thesis. 4 units

Term Typically Offered: F,W,SP,SU
Prerequisite: senior standing, and consent of instructor.

Selection and completion of senior thesis under faculty supervision. Projects typical of problems which graduates must solve in their fields of employment. Thesis results presented in a formal report. Minimum commitment of 120 hours.

BMED 460. Engineering Physiology. 4 units

Term Typically Offered: F, W
Prerequisite: BMED 310 and either BIO 231 or BIO 232; or graduate standing.

Physiology for biomedical engineering students, with an emphasis on control mechanisms and engineering principles. Engineering aspects of basic cell functions; biological control systems; muscle; neural; endocrine, and circulatory systems, digestive, respiratory, renal, and reproductive systems; regulation of metabolism, and defense mechanisms. 3 lectures, 1 laboratory.

BMED 470. Selected Advanced Topics. 1-4 units

Term Typically Offered: TBD
Prerequisite: Consent of instructor.

Directed group study of selected topics for advanced students. Open to undergraduate and graduate students. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 lectures.

BMED 471. Selected Advanced Laboratory. 1-4 units

Term Typically Offered: TBD
Prerequisite: Consent of instructor.

Directed group laboratory study of selected topics for advanced students. Open to undergraduate and graduate students. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 laboratories.

BMED 495. Cooperative Education Experience. 1-12 units

Term Typically Offered: F,W,SP,SU
CR/NC
Prerequisite: Sophomore standing and consent of instructor.

Work experience in business, industry, government, and other areas of student career interest. Positions are paid and usually require relocation and registration in course for two consecutive quarters. A fully developed formal report and evaluation by work supervisor is required. Credit/No Credit grading only. No major credit allowed; total credit limited to 24 units.

BMED 500. Individual Study. 2-4 units

Term Typically Offered: F,W,SP,SU
Prerequisite: Graduate standing and consent of department chair.

Individual investigation, research, studies or surveys of selected problems. Advanced study planned and completed under the direction of faculty. Open to graduate students who have demonstrated the ability to do independent work. Total credit limited to 8 units.

BMED 505. Biomedical Signal Transduction and Data Acquisition. 4 units

Term Typically Offered: SP
Prerequisite: BMED 440.

Bridging the physical gap between biological and digital systems. Physics of chemical, mechanical, electrical, thermal, and optical sensors relevant to biomedical engineering. Evaluation of transducer performance and system design. Includes realization of a transducer system relevant to graduate projects. 3 lectures, 1 laboratory.

BMED 510. Principles of Tissue Engineering. 4 units

Term Typically Offered: F
Prerequisite: one of the following: ASCI 438, BIO 361, or BMED 460; or graduate standing.

Exploration of areas including cell source and isolation, scaffold selection and modification, tissue cultivation and bioreactor design, and patient implantation. Applications of tissue engineering for creating skin, cartilage, blood vessels, and other tissues. 3 lectures, 1 laboratory.

BMED 512. Biomedical Engineering Horizons. 4 units

Term Typically Offered: TBD

Prerequisite: Graduate standing, MATH 143, CHEM 125, PHYS 131 or PHYS 141, BIO 161 or consent of instructor.

Examination of the advances in nanotechnology, micro-electro-mechanical systems, materials and clinical technology. Relationship between modern medical achievements and advances in engineering and science, the biomedical engineering industry, and the use of technology in a human context. 4 lectures.

BMED 515. Introduction to Biomedical Imaging. 4 units

Term Typically Offered: W

Prerequisite: PHYS 132 or PHYS 142, MATH 244, and graduate standing.

Fundamental principles and applications of biomedical imaging, modalities in medicine. Topics focus on optical imaging techniques, such as brightfield, fluorescence, confocal, multiphoton, DIC, OCT, SEM, and other advanced microscopy techniques. 2 lectures, 2 laboratories.

BMED 520. Modeling of Biomedical Systems. 4 units

Term Typically Offered: W

Prerequisite: Graduate standing.

Analytic and computational representation of biomedical systems with applications in physiology and medicine. Emphasis on biomedical engineering systems, applications, and system modeling including the use of modern tools. Serves as a foundation for biomedical engineering graduate electives and research projects. 4 lectures.

BMED 525. Skeletal Tissue Mechanics. 4 units

Term Typically Offered: F, SP

Prerequisite: CE 204 or CE 208; and BMED 460.

Overview of the mechanical properties of various tissues in the musculoskeletal system, the relationship of these properties to anatomic and histologic structures, and the changes in these properties caused by aging, disease, overuse, and disuse. Tissues covered include bone, cartilage and synovial fluid, ligament, and tendon. 4 lectures.

BMED 530. Biomaterials. 4 units

Term Typically Offered: F

Prerequisite: BIO 161, or BIO 213 and BMED/BRAE 213; MATE 210 and graduate standing or consent of instructor.

Structure-function relationships for materials in contact with biological systems. Interactions of materials implanted in the body. Histological and hematological considerations including foreign body responses, inflammation, carcinogenicity, thrombosis, hemolysis, immunogenic and toxic properties. Microbial interaction with material surfaces, degradation. Course may be offered in classroom-based or online format. 4 lectures. Crosslisted as BMED/MATE 530.

BMED 535. Bioseparations and Clinical Diagnostics. 4 units

Term Typically Offered: W

Prerequisite: BMED 425, ME 341 or consent of instructor.

Physicochemical hydrodynamics and microfluidic bioseparations, which includes electrokinetics, colloid science and suspension mechanics in the context of Clinical Diagnostic Systems. Understanding key separation design parameters through a course project, theoretical and numerical models. 4 lectures.

BMED 541. Microcirculation. 3 units

Term Typically Offered: TBD

Prerequisite: BMED 460.

Topic groups include microvessel wall structure, network architecture, flow regulation, transport, inflammation, angiogenesis, arteriogenesis, and rarefaction. Additional focus on patho-physiology and the engineering approaches to assess and treat microvascular dysfunction. Not open to students with credit in BMED 540. 3 lectures.

BMED 542. Microcirculation Laboratory. 1 unit

Term Typically Offered: TBD

Prerequisite: BMED 460.

Laboratory procedures include direct visualization of microvessels by microscopy and indirect assessment by skin temperature, evaluation of microvascular networks by casting and immunostaining, and assessment of vascular wall structure by histology. 1 laboratory.

BMED 550. Current and Evolving Topics in Biomedical Engineering. 4 units

Term Typically Offered: TBD

Prerequisite: Graduate standing in Biomedical Engineering or consent of department chair.

Current topics in biomedical engineering, including medical and industrial applications. Exploration of detailed technical treatment of contemporary issues in biomedical engineering, and examination of technical and societal implications of these subjects. Class Schedule will list topics selected. Total credit limited to 12 units. 4 lectures.

BMED 555. Neural Systems Simulation and Modeling. 4 units

Term Typically Offered: SP

Prerequisite: MATH 244, BMED 440.

The biophysical basis of the Hodgkin-Huxley active membrane model. A detailed description of the dynamics of voltage gated ion channels. The complete Hodgkin-Huxley active membrane model, with an emphasis on its use in simulating the electrical activity of nerve cells. Equivalent circuit/ circuit simulator based approaches to modeling Hodgkin-Huxley neurons. 4 lectures.

BMED 560. Cell Transplantation and Biotherapeutics. 2 units

Term Typically Offered: SP

Prerequisite: ASCI 438, BIO 361, or BMED 460.

Topics include the etiology, patho-physiology, and rodent models for various forms of disease, such as inflammatory, autoimmune, and monogenic diseases, as well as nucleic acid, protein, and cellular-based therapies for these conditions. Not open to students with credit in BMED 545. 2 lectures.

BMED 561. Cell Transplantation and Biotherapeutics Laboratory. 2 units

Term Typically Offered: SP

Prerequisite: ASCI 438, BIO 361, or BMED 460; and STAT 218 or STAT 312. Corequisite: BMED 560.

Procedures include rodent handling, anesthesia, surgically modeling disease, biotherapy delivery, and visualizing/measuring therapeutic efficacy. Additional focus on experimental design, data collection, and analysis. 2 laboratories.

BMED 563. Biomedical Engineering Graduate Seminar. 2 units

Term Typically Offered: W, SP

Prerequisite: Graduate standing or consent of instructor.

Selected topics of interest to biomedical engineering and other graduate students. Open to graduate students and selected seniors. A forum to share information about research and research tools; an opportunity to discuss topics of interest with professionals in the field, academics, and other graduate students. The Class Schedule will list topic selected. Total credit limited to 4 units. 1 seminar, 1 laboratory.

BMED 570. Selected Advanced Topics. 1-4 units

Term Typically Offered: TBD

Prerequisite: Graduate standing or consent of instructor.

Directed group study of selected topics for graduate students. Open to undergraduate and graduate students. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 lectures.

BMED 571. Selected Advanced Laboratory. 1-4 units

Term Typically Offered: TBD

Prerequisite: Graduate standing or consent of instructor.

Directed group laboratory study of selected topics for advanced students. Open to undergraduate and graduate students. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 laboratories.

BMED 583. Research Experience for Regenerative Medicine Students. 2 units

Term Typically Offered: SP

Prerequisite: Graduate standing in the Specialization in Regenerative Medicine for the MS in Biological Sciences; or Specialization in Regenerative Medicine for the MS in Biomedical Engineering; or the Animal Science Specialization for the MS in Agriculture.

Independent research experience in biological or biomedical research. Proposal writing and literature review; experimental design, implementation and troubleshooting; oral and poster presentations. 1 seminar and supervised work. Crosslisted as ASCI/BIO/BMED 583. Formerly ASCI/BIO/BMED 594.

BMED 591. Thesis Project Design Laboratory I. 2 units

Term Typically Offered: F

Prerequisite: Graduate standing.

Selection and completion of project by individuals or team which is typical of problems graduates must solve in their fields of employment or applied research. Project may involve, but is not limited to, physical modeling and testing of integrated design projects, costs, planning, scheduling and research and may involve students from several disciplines. Formulation of outline, literature, review and project schedule. 2 laboratories.

BMED 592. Thesis Project Design Laboratory II. 2 units

Term Typically Offered: SP

Prerequisite: BMED 591 or consent of instructor.

Continuation of BMED 591. Completion of project by individuals or team which is typical of problems graduates must solve in their fields of employment or applied research. Project may involve, but is not limited to, physical modeling and testing of integrated design projects, costs, planning, scheduling and research. Formulation of outline, literature review, and project schedule. 2 laboratories.

BMED 593. Regenerative Medicine Internship. 3-5 units

Term Typically Offered: F, W, SP

Prerequisite: Graduate standing in the Specialization in Regenerative Medicine for the MS in Biological Sciences; or the Specialization in Regenerative Medicine for the MS in Biomedical Engineering; or the Specialization in Animal Science for the MS in Agriculture.

Supervised graduate research and/or development in stem cell science or regenerative medicine and engineering. Provides students with an off-campus industrial or university internship. Total credit limited to 10 units. Crosslisted as ASCI/BIO/BMED 593.

BMED 599. Design Project (Thesis). 1-9 units

Term Typically Offered: F,W,SP,SU

Prerequisite: Graduate standing.

Selection by individual or group, with faculty guidance and approval, of topic for independent research or investigation resulting in a thesis or project to be used to satisfy the degree requirement. An appropriate experimental or analytical thesis or project may be accepted. Total credit limited to 9 units.