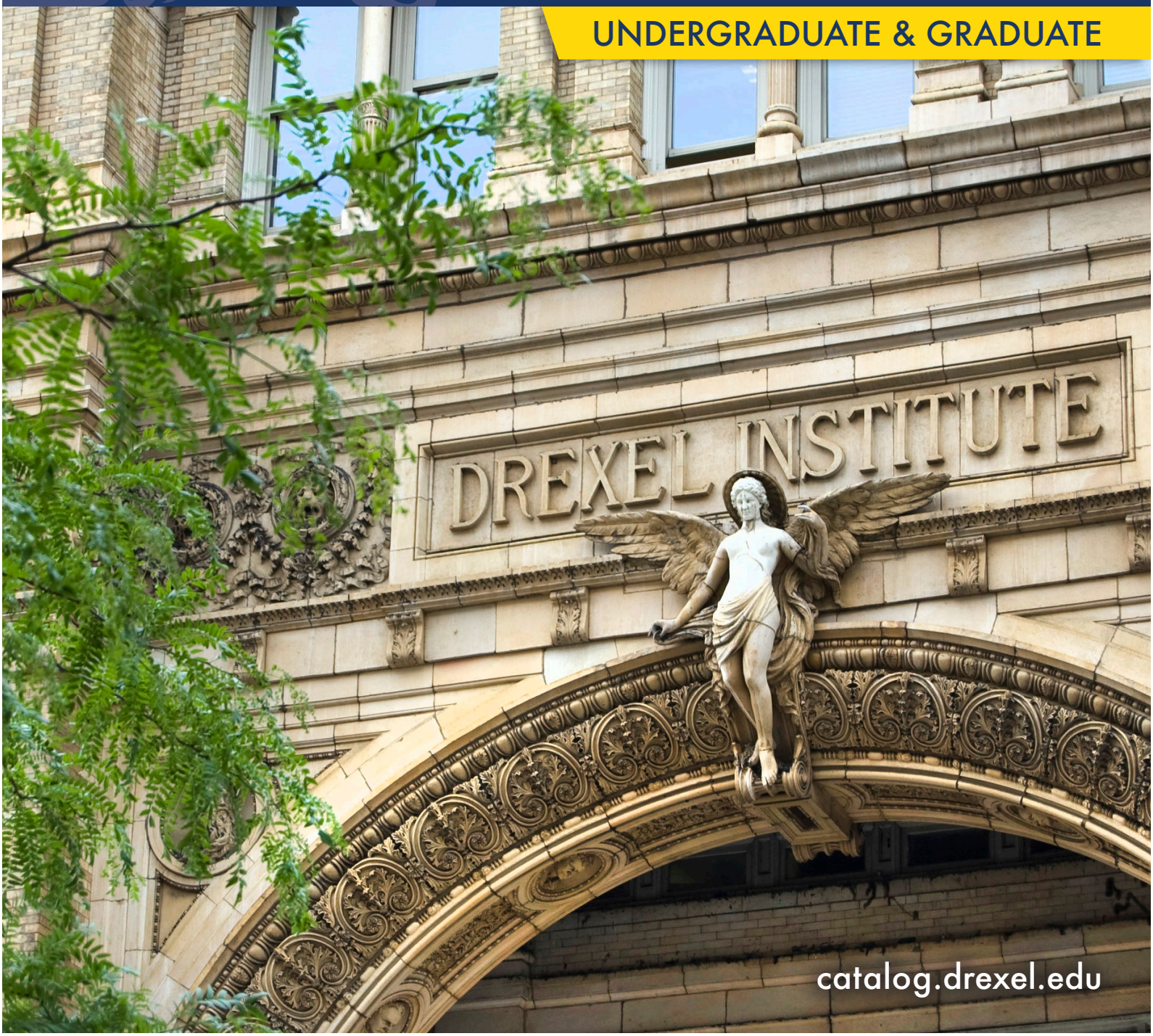
DREXEL UNIVERSITY
School of
Biomedical Engineering,
Science and Health Systems

CATALOG
2014-2015

UNDERGRADUATE & GRADUATE



catalog.drexel.edu

School of Biomedical Engineering Science & Health Systems

Mission Statement

The mission of the School of Biomedical Engineering, Science and Health Systems is to promote health and quality of life through education, research and innovation that integrates engineering and life sciences in a global context.

The School of Biomedical Engineering, Science, and Health Systems (http://www.biomed.drexel.edu/new04/default.cfm) is a nationally recognized center for research in biomedical engineering and science offering multi-disciplinary instruction on a full- and part-time basis at the graduate and undergraduate levels.

The School of Biomedical Engineering, Science, and Health Systems offers a bachelor of science program in biomedical engineering with a choice of five concentration areas: biomaterials and tissue engineering, biomechanics and human performance engineering, biomedical informatics, biomedical devices and imaging, and neuroengineering.

Major

- Biomedical Engineering

Concentrations

- Biomaterials and Tissue Engineering
- Biomechanics and Human Performance Engineering
- Biomedical Informatics
- Biomedical Devices and Imaging
- Neuroengineering

About the School

The School of Biomedical Engineering, Science, and Health Systems (http://www.biomed.drexel.edu) (formerly the Biomedical Engineering and Science Institute, founded in 1961) is a leader in biomedical engineering and biomedical science research and education. The undergraduate program was inaugurated in September 1998 and has steadily grown to attract the highest ability students at the University. The undergraduate biomedical engineering curriculum is accredited by the Engineering Accreditation Commission of ABET (http://www.abet.org) .

The School's academic thrust areas, both in research and education, are at the forefront of biosensing, bioimaging, bioinformation engineering and integrated bioinformatics, drug delivery, biomedical ultrasound & optics, bionanotechnology, cellular tissue engineering, neuroengineering and human performance. Emerging initiatives include skin bioengineering, pediatric engineering and homeland security technologies. Various departments at Drexel University offer courses that are suited for students in biomedical engineering and biomedical science. The School's curriculum complements the strengths of the Colleges of Arts & Sciences, Business, Engineering, Computing & Informatics, Law and Medicine. As a whole, the curriculum offers the advanced knowledge needed for industrial careers, health professions, graduate research or careers in highly specialized fields such as pre-professional health (medical, dental, and veterinary) and pre-law.

The marriage of technology with biology and medicine drives the 21st Century industrial enterprise. Consistent with this mission, the School strives for clinical and industrial relevance in our academic pursuits. The School maintains a strong entrepreneurship program in biomedical technologies. The School's alliance with regional economic development agencies and corporations together with advisors from business development, legal, and investment communities sustains the growth of this program. The students and faculty of the School are committed to move their discoveries from laboratories to clinical practice or home use. The success of theTranslational Research in Biomedical Technologies program has been recognized and funded regionally as well as nationally.

The School has experienced remarkable growth in recent years thanks to our outstanding research portfolio, high quality and innovative undergraduate program, and our multidisciplinary approach to education and research. Another competitive advantage is the unique free-standing university-level administrative structure with its own tenure-track faculty lines, budget and space. This helps transcend the traditional organizational boundaries of engineering, sciences and medicine. The School's independence allows the pursuit of growth and collaborations in various disciplines. The School's small size provides agility to reconfigure and reorganize in response to emerging opportunities. The University Strategic Plan recognizes our School of Biomedical Engineering, Science and Health Systems as “Drexel’s prototype of academic integration. ”

Metropolitan Philadelphia has one of the nation’s highest concentrations of medical institutions and pharmaceutical, biotechnology, medical device and systems industry. The School has forged strategic partnerships with select universities, research institutes, health care institutions and industries in the region. The School enjoys a close working relationship with our Drexel College of Medicine as well as alliances with prominent medical institutions in the region to develop joint research and educational programs. These include University of Pennsylvania, Thomas Jefferson University, the Fox Chase Cancer Center and the Wistar Institute. These collaborative initiatives provide students with ample opportunities in basic and clinical research as well as innovative academic programs.

Applicants to the graduate program must meet the requirements for admission to graduate studies at Drexel University. Candidates for degrees in the School of Biomedical Engineering, Science and Health Systems are required to maintain academics standards applicable to all graduate students at Drexel University.

Co-operative Education

Co-op and career opportunities available to students include employment in the medical device, equipment, and systems industry; the biomaterial and implant industry; the pharmaceutical industry; the biotechnology and agricultural industry; the telemedicine and tele-health industry; health care; medical and clinical information and management systems; and biomedical technology transfer. Preprofessional options available in the academic programs of the School prepare students for admission to schools of medicine, dentistry, and veterinary medicine. Students may also choose to continue their education at the graduate level to prepare for careers in research and development in biomedical engineering and science.

Visit the Drexel Steinbright Career Development Center (http://www.drexel.edu/scdc) page for more detailed information on co-op and post-graduate opportunities.

Special Programs

Accelerated Bachelor's/Master's Dual Degree Program

The Accelerated BS/MS degree program provides opportunities for strongly motivated students with high ability to progress toward their educational goals at an accelerated pace. The program makes it possible for top engineering students to obtain both degrees in the same time period that it takes most students to obtain a bachelor's degree.

Preprofessional Programs

Students who want to prepare for admission to schools of medicine, dentistry, or veterinary medicine, including the BA/BS/MD and early assurance programs at the Drexel College of Medicine, may obtain professional counseling and assistance from the Office of Preprofessional Programs, 215-895-2437.

University Honors

Program Students in the Biomedical Engineering program may apply for admission to the University Honors Program. Admission depends on superior academic performance at Drexel and may be approved after a personal interview with the Honors Committee.

University Leadership Program

Drexel graduates in Biomedical Engineering will be the leaders of their profession--and their communities--in the twenty-first century. The University Leadership Program helps cultivate leadership skills and engages students in exploring the complex aspects of successful leadership by offering multi-dimensional courses featuring service learning.

Biomedical Engineering, Science and Health Systems Faculty

Fred D. Allen, PhD *(University of Pennsylvania)*. Assistant Professor. Tissue engineering, cell engineering, orthopedics, bone remodeling, wound healing, mechanotransduction, signal transduction, adhesion, migration.

Sriram Balasubramanian, PhD *(Wayne State University)*. Assistant Professor. Structural characteristics of the pediatric thoracic cage using CT scans and developing an age-equivalent animal model for pediatric long bones.

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Hualou Liang, PhD *(Chinese Academy of Sciences)*. Associate Professor. Neuroengineering, neuroinformatics, cognitive and computational neuroscience, neural data analysis and computational modeling, biomedical signal processing.

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Adrian C. Shieh, PhD *(Rice University)*. Assistant Professor. Contribution of mechanical forces to tumor invasion and metastasis, with a particular emphasis on how biomechanical signals may drive the invasive switch, and how the biomechanical microenvironment interacts with cytokine signaling and the extracellular matrix to influence tumor and stromal cell behavior.

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Biomedical Engineering

Bachelor of Science in Biomedical Engineering (BMES): 197.5 - 201.5 quarter credits

About the Program

Biomedical Engineering is an innovative Bachelor of Science degree program developed and delivered in collaboration with the College of Engineering, the College of Arts and Sciences and the College of Computing & Informatics. It prepares students to conceive, design, and develop devices and systems that improve human health and quality of life. Biomedical engineering is the convergence of life sciences with engineering. From child car seats and football helmets to drug-delivery systems, minimally invasive surgery, and noninvasive imaging technology, the work of the biomedical engineer makes a difference in everyone's life.

The undergraduate biomedical engineering curriculum is designed to strike a balance between academic breadth in biomedical engineering and specialization in one of five concentration areas: biomaterials and tissue engineering, biomechanics and human performance engineering, biomedical bioinformatics, biomedical devices and imaging, and neuroengineering.

This program is accredited by the Engineering Accreditation Commission of ABET (http://www.abet.org) .

Concentrations

The undergraduate biomedical engineering curriculum is designed to strike a balance between academic breadth in biomedical engineering and specialization in an area of concentration. Each concentration has its own degree requirements for graduation, and its own plan of study:

- Biomaterials and Tissue Engineering
- Biomechanics and Human Performance Engineering
- Biomedical Informatics
- Biomedical Devices and Imaging
- Neuroengineering

The degree program provides innovative experiences in hands-on experimentation and engineering design as well as opportunities for personal growth and development of leadership and communication skills.

Working with a faculty advisor, students can select their core and elective courses from the curricula offered by the School of Biomedical Engineering, Science, and Health Systems and the Departments of Biology, Chemistry, Physics, Mathematics, Chemical Engineering, Mechanical Engineering, Materials Science and Engineering, Electrical and Computer Engineering, and the College of Computing & Informatics.

Program Educational Objectives

Graduates from the School's undergraduate biomedical engineering program are expected to achieve success in their professional lives and contribute to the good of the global community. The School's specific objectives for its alumni include the following:

Objective 1: Professional Presence

As a result, within a few years, the graduate has established an Internet presence, either through professional organizations, social networking and/or other activities which demonstrate an appreciation and use of modern technological capabilities.

Objective 2: Workforce Skilled in Integrating Engineering, Design, and Life Sciences

As a result, graduates will identify opportunities to contribute to society from a variety of positions, ranging from biomedical engineering,

biotechnology design and development to practicing physicians, lawyers, innovators, entrepreneurs and business managers. The graduate may also pursue further education in the form of graduate and professional degrees.

Objective 3: Leadership in Research, Innovation and Design

As a result, within a few years of graduation, the graduate will have made significant or meaningful contributions in his or her chosen field, either thorough research publications and/or presentations, the development of a product or process, obtaining patents for new products and/or processes, or other evidence of contributing to the advancement of knowledge, particularly in fields integrating engineering and the life sciences.

Objective 4: Ethical Reasoning, Behavior and Professionalism

As a result, within a few years of graduation, the graduate will demonstrate adherence to the professional codes of conduct appropriate to his or her field of study and/or practice, as well as exhibit behavior consistent with accepted standards of fiduciary responsibility, risk/benefit analysis and professional accountability.

Objective 5: Communication

As a result, graduates will have outstanding communication skills as evidenced by their professional presentations, and in their productive interactions with co-workers. The graduates may also use their communication skills to foster collaborative effort among co-workers and/or may represent his or her company, institution and/or laboratory to other interested parties.

Objective 6: Personal Engagement

As a result, within a few years, the graduate will be working independently and in diverse groups to effectively and efficiently achieve personal and organizational goals, engage in community or public service, create a product or process that fills a social need, and/or participate in educating individuals about an issue of societal concern.

Student Learning Outcomes

To support our graduates in achieving success in the program educational objectives, the biomedical engineering program is designed to facilitate student learning and achievement on the following Student Learning Outcomes, which indicate our students' skills sets at the time of graduation.

Outcome 1: Communication

The graduate employs an understanding of audience, purpose and context to communicate effectively in a range of situations using appropriate media while displaying a significant aptitude for presenting scientific and technical materials to diverse audiences.

Outcome 2: Engagement

The graduate uses his or her knowledge and skills, including those associated with engineering and life science, to make a positive difference on issues of public concern.

Outcome 3: Ethical Reasoning, Behavior, and Professionalism

The graduate recognizes ethical issues, considers multiple points of view, and uses critical ethical reasoning to determine the appropriate behavior to follow. The graduate thus demonstrates a high level of integrity and a positive work ethic combined with a thorough understanding of the ethical implications and obligations associated with the practice of biomedical engineering.

Outcome 4: Innovation and Design

The graduate often asks questions and makes observations that lead to new ideas or hypotheses. He or she formulates highly original solutions while moving beyond the conventional to new methods blending creative and practical approaches, methods and designs which may involve pioneering applications along the interface of engineering and biology. The graduate has the ability to create quality products and processes that are state-of-the-practice in his or her field.

Outcome 5: Leadership

The graduate is able to articulate a vision or goal in such a manner as to promote collaboration and successful implementation. The graduate displays a willingness to overcome adversity and work diligently in pursuit of goals, thus serving as a role model for others.

Outcome 6: Problem-Solving Abilities

The graduate is able to creatively solve problems from both analytic and synthetic perspectives using multiple approaches, integrating the life sciences, engineering, and the humanities. The graduate is able to recognize, incorporate and adapt to the limitations and consequences of applying various problem solutions.

Outcome 7: Research Abilities

The graduate is able to collect and process data, information and knowledge to answer specific questions or generate new conceptual models and hypotheses. The graduate evaluates these models and hypotheses using the appropriate experimental, mathematical and statistical approaches.

Outcome 8: Human Resources and Interactions

The graduate is able to work either independently or in diverse groups to effectively and efficiently respond to academic and work requirements.

Outcome 9: Technological Skills

The graduate makes appropriate use of technologies to communicate, collaborate, solve problems, make decisions, and conduct research, as well as foster creativity and life-long learning. The graduate is able to use state-of-the-art technological resources and tools and keeps up on advancements in her or her field of study and/or practice.

Additional Information

More information about the School's undergraduate program can be found at the School of Biomedical Engineering, Sciences and Health Systems' Academic Program (http://www.biomed.drexel.edu/new04/Content/ug_prog/academic_programs) web page.

Students are also encouraged to contact the School's Director for Student Services:

Caryn Glaser
Director of Student Services
School of Biomedical Engineering, Science and Health Systems
215.895.2237
glasercb@drexel.edu

Career and professional counseling is provided independently by the student's staff and faculty advisors. Information regarding undergraduate faculty advisors is available on the School's Undergraduate Advisors (http://www.biomed.drexel.edu/new04/Content/ug_prog/academic_programs/advisorslist.cfm) page.

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Courses

BMES 124 Biomedical Engineering Freshman Seminar I 1.0 Credit
This course is intended to introduce freshman biomedical engineering students in the School of biomedical Engineering, Science and Health Systems at Drexel University to academic programs and opportunities, ongoing research projects and University resources to ensure a successful educational experience at Drexel and beyond. Through class discussions and guest lecture presentations, the students are provided with information and contacts necessary to begin a plan of academic study.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 125 Foundations of Biomedical Engineering 2.0 Credits
This course is intended to introduce new transfer biomedical engineering students in the School of biomedical Engineering, Science and Health Systems at Drexel University academic programs and opportunities, ongoing research projects and University resources to ensure a successful educational experience at Drexel and beyond. Through class discussions and guest lecture presentations, the students are provided with information and contact necessary to begin a plan of academic study.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 126 Biomedical Engineering Freshman Seminar II 1.0 Credit
This course is intended to introduce freshman biomedical engineering students to the career embodied by the School's current concentration areas. Each area will be discussed in terms of the current state of the art, research possibilities and career opportunities. The curricula for each concentration will be discussed in detail so as to facilitate students' knowledge of how each curriculum relates to the research and employment opportunities in that field.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 130 Problem Solving in Biomedical Engineering 2.0 Credits
This course integrates fundamental principles of biology, chemistry, engineering, mathematics and physics into a framework for the study of biomedical engineering. In this course, students will use both engineering and scientific approaches to problem-solving. They will learn about the differences between engineering design and biological evolution. They will also learn to apply basic principles of chemistry, physics and mathematics to specific biological and physiological problems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MATH 122 [Min Grade: D] and CHEM 102 [Min Grade: D] and PHYS 101 [Min Grade: D]

BMES 201 Programming and Modeling for Biomedical Engineers I 3.0 Credits
This course aims to introduce students with some fundamental concepts about programming in MATLAB to give the ability to solve basic bioengineering problems. The course introduces the basics of programming using Matlab, including programming environment and tools. Fundamental programming techniques and concepts such as loops, switches and logical operators, functions and file handling are covered. Applications in bioengineering for basic numerical problem solving are discussed.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MATH 200 [Min Grade: D] and PHYS 102 [Min Grade: D] and BIO 122 [Min Grade: D] and (BMES 130 [Min Grade: D] or BMES 125 [Min Grade: D])

BMES 202 Programming and Modeling for Biomedical Engineers II 3.0 Credits
The course aims to introduce students to advanced programming concepts and tools to solve numerical problems in bioengineering. It provides the foundation for biosimulation and biocomputation classes. This course introduces advanced programming methods and computational tools for numerical analysis, model design and graphics. Higher level level lunctionality in Matlab such as SIMULINK, symbolic processing and CAD related tools are discussed.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 201 [Min Grade: D]

BMES 212 The Body Synthetic 3.0 Credits
The Body Synthetic introduces concepts underlying biological and engineering principles involved in the design and construction of prosthetic devices used to replace various parts of the human body.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: (TDEC 122 [Min Grade: D] or BIO 122 [Min Grade: D]) and (BMES 130 [Min Grade: D] or BMES 125 [Min Grade: D])

BMES 235 Living Systems Engineering 4.0 Credits
This course introduces the biomedical engineering students to engineering principles applied to biological and physiological systeTs. This course focuses.on evolution, adaptation, energy, thermodynamics, fluid dynamics and control systems in living organrsms.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 122 [Min Grade: D] and CHEM 102 [Min Grade: D] and MATH 200 [Min Grade: D] and PHYS 102 [Min Grade: D] and BMES 130 [Min Grade: D] and BIO 201 [Min Grade: D]

BMES 301 Laboratory I: Experimental Biomechanics 2.0 Credits
This course deals with experimental aspects of biomechanics, specifically with the testing mechanical properties of biological tissues.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (TDEC 114 [Min Grade: D] or MATH 200 [Min Grade: D]) and (TDEC 115 [Min Grade: D] or PHYS 201 [Min Grade: D]) and (TDEC 211 [Min Grade: D] or ENGR 231 [Min Grade: D]) and MEM 202 [Min Grade: D]

BMES 302 Laboratory II: Biomeasurements 2.0 Credits
This course introduces students to the measurement of physiological/biological/functional signals. Four specific signals will be collected and analyzed. Students are expected to analyze type of signal to be collected, possible measurement techniques and potential data analysis and then collect and analyze each signal.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: ECE 201 [Min Grade: D] (Can be taken Concurrently) (BMES 222 [Min Grade: D] or BIO 201 [Min Grade: D]) and (TDEC 231 [Min Grade: D] or ENGR 103 [Min Grade: D])

BMES 303 Laboratory III: Biomedical Electronics 2.0 Credits
This course introduces students to the widespread application of electronics and electronic devices in biomedical engineering. The course reinforces concepts learned in ECE 201 with hands-on experimentation related to biomedical applications such as telemedicine and medical devices.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (ECE 201 [Min Grade: D] and TDEC 231 [Min Grade: D]) or ENGR 232 [Min Grade: D]

BMES 304 Laboratory IV: Ultrasound Images 2.0 Credits
This course introduces students to the engineering principles of acoustical measurements by combining hands-on laboratory experiences with lectures. Students will learn the engineering/physical principles of measuring sound velocity in different materials, attenuation, and directivity of a circular transducers.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (BIO 201 [Min Grade: D] or BMES 235 [Min Grade: D]) and ECE 201 [Min Grade: D] and (TDEC 231 [Min Grade: D] or ENGR 103 [Min Grade: D])

BMES 305 Laboratory V: Musculoskeletal Anatomy for Biomedical Engineers 2.0 Credits
This course provides an opportunity for students to study the anatomy and biomechanics of select articulations of the human body. While the main emphasis will be on the musculoskeletal structures associated with each articulation, major neural and vascular structures will be studied as well.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: (BIO 201 [Min Grade: D] or BMES 235 [Min Grade: D]) and MEM 202 [Min Grade: D]

BMES 310 Biomedical Statistics 4.0 Credits
This course is designed to introduce biomedical engineering students to the fundamentals of biostatistics necessary for medical research. Topics covered include measurements, sampling, basic hypothesis testing, analysis of variance and regression. Medical applications are emphasized.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: ENGR 231 [Min Grade: D]

BMES 315 Experimental Design in Biomedical Research 4.0 Credits
This course is designed to introduce students to the fundamental principles of experimental design and statistical analysis as applied to biomedical research with animals and humans. Topics to be covered include experimental design, clinical design, and protocol submission and review.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 310 [Min Grade: D]

BMES 325 Principles of Biomedical Engineering I 3.0 Credits
This course is the first part of a two-term sequence which introduces biomedical engineering students to engineering principles applied to biological and physiological systems. This course focuses on bioethical questions, biomechanics, human performance engineering, biomaterials and tissue engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 122 [Min Grade: D] and CHEM 102 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and MEM 202 [Min Grade: D] and ENGR 220 [Min Grade: D] and ENGR 232 [Min Grade: D]

BMES 326 Principles of Biomedical Engineering II 3.0 Credits
This course is the second part of a two-term sequence which introduces biomedical engineering students to engineering principles applied to biological and physiological systems. This course focuses on bioinformatics, neuroengineering, biosignal processing, biosensors, and medical imaging.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 325 [Min Grade: D] and BIO 201 [Min Grade: D] and (BMES 202 [Min Grade: D] or ENGR 202 [Min Grade: D])

BMES 330 Biological Rhythm in Pharmacology and Toxicology 3.0 Credits
This course covers the fundamentals of biological rhythms with particular emphasis on the influence these cycles have on the susceptibility of organism to physical, chemical, and /or toxic agents.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman
Prerequisites: BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]

BMES 331 Computers in Health Systems I 3.0 Credits
Introduces the allied health professional to basic computer applications on personal computers. Includes word processing, spreadsheets, databases, and networking (e.g., e-mail and information search and retrieval) in a primarily Windows environment. Designed for individuals with little or no computer background. Students are encouraged to bring in their own work-related problems or projects to provide immediate application of knowledge learned to the student's professional healthcare environment.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 332 Computers in Health Systems II 3.0 Credits
Continues the general overview of computers for people in the allied health professions, using specific examples from health care. Offers further study of and practice with special scientific (e.g., statistics, graphing) and medical clinical decision-support software. Introduces algorithms and formal programming methods.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman

BMES 335 Biomedical Informatics I 3.0 Credits
Introduces information and information handling systems for people in the allied health professions, with specific examples drawn from health care. Covers locating, manipulating, and displaying information in the health system setting.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore

BMES 336 Biomedical Informatics II: Hospital and Patient Information 3.0 Credits
Continues BMES 335. Emphasizes medical records and hospital and patient information handling. Examines the problems of patient information flow within the health care system. Introduces conventional and proposed patient and hospital information systems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 335 [Min Grade: D]

BMES 338 Biomedical Ethics and Law 3.0 Credits
Introduces the wide spectrum of ethical, regulatory, and legal issues facing health care practitioners and health-related research workers. Helps students become aware of the ethical and legal issues involved in their work. Helps students understand how legal and ethical decisions should be made in health-related matters, as well as what sources of help and guidance are available.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman

BMES 340 Health Care Administration 3.0 Credits
This course provides students with an analysis of health care administration process, including: planning, organizing, designing, decision-making, leading, and controlling. Presents methods and techniques that can contribute to the effective performance of administrative duties.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman

BMES 345 Mechanics of Biological Systems 3.0 Credits
This course introduces the fundamentals of mechanics of deformable bodies as they relevant to biologicaltissues and biomaterials. Major topics include stress and strain, mechanical properties of biologicaltissues and biomaterials, axial loading, torsion, bending, and viscoelasticity, These concepts will be applied to biological examples such as long bones, the heart, blood vessels, and orthopaedic implants.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MEM 202 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D])

BMES 350 Med & Bio Effects Of Light 3.0 Credits
Examines the role of environmental lighting in human physiological and psychological processes. Topics include vitamin D synthesis and calcium regulation; light effects on bilirubin in newborns; photoactivation and DNA in skin; effects of nonionizing radiation on the immune systems; environmental lighting and human vision; light effects on biological rhythms and sleep; photosensitivity diseases related to interior lighting; the therapeutic uses of light; and light and the aging eye.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman
Prerequisites: BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]

BMES 363 Robotics in Medicine I 3.0 Credits
This course provides an introduction to the use of haptics (the use of somtaosensory information) in the design of robotic devices in surgery. Topics covered include actuators, sensors, nonportable feedback, portable force feedback, tactile feedback interfaces, haptic sensing and control systems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MEM 238 [Min Grade: D]

BMES 365 Robotics in Medicine II 3.0 Credits
This course covers the use of robots in surgery and included aspects of safety, robot kinematics, analysis of surgical performance using robotic devices, inverse kinematics, velocity analysis and acceleration analysis. Various types of surgeries in which robotic devices are or could be used are presented on a case study basis.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 363 [Min Grade: D]

BMES 372 Biosimulation 3.0 Credits
This course provides the foundation for the mathematical analysis of biomedical engineering systems. It focuses on the essential mathematical methods necessary for further development of modeling and simulation skills in other courses (materials, mechanics, fluids/transport, signals/control system, etc). The course applies the skills in calculus, differential equations and linear algebra gained in ENGR 231 and ENGR 232 to developing analytical techniques for biomedical applications.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and ENGR 231 [Min Grade: D] and ENGR 232 [Min Grade: D] and (BMES 201 [Min Grade: D] and BMES 202 [Min Grade: D]) or (ENGR 201 [Min Grade: D] and ENGR 202 [Min Grade: D])

BMES 375 Computational Bioengineering 4.0 Credits
This course introduces undergraduate students to the mathematical and computational analysis of biological systems. The systems analyzed include the genome, protein and gene networks, cell division cycles, and cellular level disease. Mathematical tools include matrix algebra, differential equations, cellular automata, cluster analysis, etc.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and BMES 325 [Min Grade: D] and BMES 372 [Min Grade: D] and ENGR 231 [Min Grade: D] and (TDEC 221 [Min Grade: D] or ENGR 232 [Min Grade: D])

BMES 381 Junior Design Seminar I 2.0 Credits
This is the first course in a two-course sequence intended to present the basics of engineering design, project management, product development and translational research. This first course focuses on engineering design and product development. A case-study approach is used to illustrate best practices and common mistakes in engineering design.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore

BMES 382 Junior Design Seminar II 2.0 Credits
This is the second course in a two-course sequence intended to present the basics of engineering design, project management, product development and translational research. This second course focuses on project management and quality control. A case-study approach is used to illustrate best practices and common mistakes in management and evaluation of engineering projects.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: BMES 381 [Min Grade: D]

BMES 391 Biomedical Instrumentation I 3.0 Credits
This course introduces the student to the medical instrumentation and provides background on the physical, chemical, electronic and computational fundamentals by which medical instrumentation operates. It is an analytical course exploring the design, operation, safety aspects and calibration of primary electronic instruments.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: ECE 201 [Min Grade: D] and (TDEC 202 [Min Grade: D] or ENGR 210 [Min Grade: D]) and (TDEC 221 [Min Grade: D] or ENGR 231 [Min Grade: D]) and ENGR 232 [Min Grade: D] and (BMES 235 [Min Grade: D] or BIO 203 [Min Grade: D])

BMES 392 Biomedical Instrumentation II 3.0 Credits
Continues BMES 391. Explores the operation, safety aspects, and calibration of primarily optical and acoustical instruments, as well as those involving ionizing radiation. Also examines instrumentation primarily intended for particular departments and areas, such as anesthesia and infusion.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: BMES 391 [Min Grade: D]

BMES 401 Biosensors I 4.0 Credits
Introduces the general topic of microsensors, discusses basic sensing mechanisms for microsensors, and presents various types of conductometric, acoustic, silicon, and optical microsensors. Uses two case studies that include an acoustic immunosensor and silicon glucose sensor to provide students with in-depth knowledge and hands-on experience. Provides additional experience through three laboratory sessions that support the lectures and familiarize students with practical aspects of microsensors. Also discusses applications of microsensors in the medical, chemical, pharmaceutical, environmental, aeronautical, and automotive industries.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D]) and (TDEC 202 [Min Grade: D] or ENGR 210 [Min Grade: D]) and (TDEC 221 [Min Grade: D] or ENGR 231 [Min Grade: D]) and ECE 201 [Min Grade: D] and ENGR 232 [Min Grade: D]

BMES 402 Biosensors II 4.0 Credits
Investigates modern biosensor design methods and addresses the challenges associated with fabrication technologies and instrumentation techniques. Topics include theory and modeling of biosensors, biosensor fabrication steps, and electronic and clinical testing methods. Discusses local and distant sensor data acquisition techniques. Students will design, fabricate and test a biosensor. Essential stages of biosensor manufacturing processes will be outlined. Some or all pre-requisites may be taken as either a pre-requisite or co-requisite. Please see the department for more information.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: BMES 401 [Min Grade: D] (Can be taken Concurrently)

BMES 403 Biosensors III 4.0 Credits
Covers recent advances in biosensor technology and applications, business aspects, and technology transfer issues. Topics include new sensing mechanisms, new technologies, new biomedical applications, the starting of small sensor companies, and the introduction of new sensor technologies into industrial settings. Requires students to develop a technical proposal in the area of biosensors and to review proposals written by their peers. Presentations by regular faculty and industrial and government researchers form an integral part of the course.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: BMES 402 [Min Grade: D]

BMES 405 Physiological Control Systems 3.0 Credits
Introduces the basic concepts of feedback and feed forward controls systems, including characterizations in terms of prescribed constraints, study of input and output relationships for various types of physiological systems, and stability and time-delay problems. Covers mathematical models of physiological systems, with emphasis on non-linear and adaptive systems study.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and ECES 356 [Min Grade: D] and BMES 372 [Min Grade: D]

BMES 409 Entrepreneurship for BMES 3.0 Credits
This course serves as the foundation course in entrepreneurship and is designed to provide students with a complete working knowledge of the modern entrepreneurial and business planning process.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 411 Chronoengineering I: Biological Rhythms in Health and Performance 3.0 Credits
Introduces students to the concepts of biological, and especially circadian, rhythmicity. Advances students' knowledge of biological time-keeping and adaptive functions of biological clocks. Topics include biochemical and physiological models of biological clocks, adjustment to environmental cycles, rhythms in behavior and physiological functions, sleep-wake cyclicity, adaptability of circadian systems, and influences of rhythms on human physiology and behavior. Designed to give students a thorough understanding of the role rhythms play in animal and human behavior, physiology, and medicine.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D])

BMES 412 Chronoengineering II: Sleep Functions in Health and Performance 3.0 Credits
Continues BMES 411. Enhances students' education in the concepts of biological, and especially circadian, rhythmicity. Focuses on sleep patterns, rhythms, evolution, neurology, psychology, and overall function.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: BMES 411 [Min Grade: D]

BMES 421 Biomedical Imaging Systems I: Images 4.0 Credits
Provides an overview of the field of medical imaging. Covers aspects of light imaging; systems theory, convolutions, and transforms; photometry, lenses, and depth of field; image perception and roc theory; three-dimensional imaging; image acquisition and display; and image processing operations, including scanning and segmentation.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: (TDEC 115 [Min Grade: D] and ECES 302 [Min Grade: D] and ECES 304 [Min Grade: D] and BMES 325 [Min Grade: D] and BMES 326 [Min Grade: D]) or PHYS 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (MATH 311 [Min Grade: D] or BMES 310 [Min Grade: D]) and (TDEC 222 [Min Grade: D] or ENGR 231 [Min Grade: D]) and ENGR 232 [Min Grade: D]

BMES 422 Biomedical Imaging Systems II: Ultrasound 4.0 Credits
Intended for students who would like to gain an adequate understanding of diagnostic ultrasound imaging principles and become familiar with developments in this rapidly expanding field. Introduces medical visualization techniques based on ultrasound propagation in biological tissues. Topics include generation and reception of ultrasound, imaging techniques (A-mode, B-mode, M-mode, and Doppler), typical and emerging diagnostic applications, elements of ultrasound exposimetry, and safety aspects from the clinical point of view.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 421 [Min Grade: D]

BMES 423 Biomedical Imaging Systems III 4.0 Credits
Covers volumetric and functional imaging systems. Discusses the principles and algorithms of projection tomography, XCAT, SPECT, PET; the principles of MRI: Bloch equation, slice selection, K-space scanning, volumetric MRI; biochemical imaging; chemical equilibrium equations and Scatchard plots, specific and nonspecific labeling; autoradiography; and flow and dynamical systems: Doppler, mass transport, and phase (MRI) measurement of flow.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 422 [Min Grade: D]

BMES 430 Neural Aspects of Posture and Locomotion 3.0 Credits
Students will study the physiology of ensory/motor systems, with emphasis on modeling of neural systems and biomechanical aspects of functional tasks. Combines information on basic nerve cell activities, synaptic communication and structure/function relationships of skeletal muscle with basic mechanics to study spinal, vestibular and ocular reflexes. Culminates with the study of the control of motor systems with respect to bipedal motion.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (BMES 201 [Min Grade: D] and BMES 202 [Min Grade: D]) or (ENGR 201 [Min Grade: D] and ENGR 202 [Min Grade: D]) and MEM 202 [Min Grade: D]

BMES 432 Biomedical Systems and Signals 3.0 Credits
Introduces various aspects of biomedical signals, systems, and signal processing. Covers topics in the origin and acquisition of biomedical signals; discrete-time signals and linear systems; frequency analysis of discrete-time signals, spectral estimation, data records and digital filters; and compression of biomedical signals through time-domain and frequency-domain coding.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: ECES 302 [Min Grade: D] and ECES 304 [Min Grade: D]

BMES 440 Introduction to Biodynamics 3.0 Credits
The objective of the course is to prepare students for biomechanical modeling, modeling methods, formulation of equations of motion and methods of determination of strength will be applied to human body dynamics. Particular emphasis is placed on the use of Rigid Body and Multi-Body Dynamics.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MEM 202 [Min Grade: D] and (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D]) and MEM 238 [Min Grade: D] and (BMES 235 [Min Grade: D] or BIO 203 [Min Grade: D])

BMES 441 Biomechanics I: Introduction to Biomechanics 4.0 Credits
Teaches students to use mechanical tools to get an introductory appreciation for solving biomechanical problems. Models human performance by using static, quasi-static, and dynamic approaches. Assesses overall loading of the musculoskeletal system during functional activities. Demonstrates introductory methods of estimation of forces in the joints and muscles and evaluates the endurance of the human tissues under traumatic loading conditions. Builds on existing knowledge in mechanics to illustrate the practical application of mechanical tools in the determination of human systems performance.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: MEM 202 [Min Grade: D] and (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D]) and MEM 238 [Min Grade: D] and (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D]) and BIO 203 [Min Grade: D]
Corequisite: BMES 440

BMES 442 Biomechanics II: Musculoskeletal Modeling and Human Performance 4.0 Credits
Teaches students to think biomechanically. Reviews and categorizes the various functional components (tissues) of the musculoskeletal system. Considers constraints of the joints and action of the soft and hard tissues, along with corresponding models. Computes joint and muscle forces. Discusses some aspect of postural stability of the whole musculoskeletal structure and reviews various methods of task performance.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 441 [Min Grade: D]

BMES 443 Biomechanics III: Mechanics of Biological Tissues, Implant Technology and Prosthetics 4.0 Credits
Provides more advanced knowledge of mechanics of materials and offers a general description of mechanical behavior of the variety of the soft and hard tissues of the human body. Considers some prosthetic replacements of tissues as well as entire bone, joint, soft tissue, and system prosthetics. Reviews some specific orthopedic appliances and covers limb prosthetics if time permits. Students plan design projects.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 442 [Min Grade: D]

BMES 444 Biofluid Mechanics 3.0 Credits
This course introduces flow-related anatomy and pathophysiology, and biomedical flow devices and their design challenges. Analysis methods to solve biological fluid mechanics design problems will be introduced and several interdisciplinary team projects will be assigned to apply fluid mechanics to practical biological or medical problems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 451 [Min Grade: D]

BMES 451 Transport Phenomena in Living Systems 4.0 Credits
Introduces students to applications of chemical engineering concepts in biological systems. Shows that chemical engineering approaches to problem solving are ideally suited to investigation of biology. Approaches include material and energy balances, transport phenomena, and kinetics.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: (TDEC 115 [Min Grade: D] or PHYS 201 [Min Grade: D]) and (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D]) and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (TDEC 202 [Min Grade: D] or ENGR 210 [Min Grade: D]) and ENGR 232 [Min Grade: D]

BMES 452 Transport Phenomena in Living Systems II 3.0 Credits
Continues BMES 451. Advances students' understanding of the engineering principles of membrane transport and its consequences at the subcellular (mitochondria), cellular (neuron), and organ (kidney) level. Introduces concepts associated with pharmacokinetics. Provides students with a kinetic approach to analysis of receptors, including the kinetics of ligand-receptor binding, rate constants, and signal transduction.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: BMES 451 [Min Grade: D]

BMES 460 Biomaterials I 4.0 Credits
First course in a three-quarter sequence designed to acquaint students with the behavior of materials used in biomedical application under load (i.e., mechanical properties), their modes of failure and as a function of their environment. This course provides students with the fundamentals needed to proceed with Biomaterials II.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D]) and CHEM 241 [Min Grade: D] and CHEM 242 [Min Grade: D]

BMES 461 Biomaterials II 4.0 Credits
Second course in a three-quarter sequence in biomaterials. The goal of this course is with an understanding of, and ability to select, appropriate materials for specific applications taking into account mechanical, thermal, and rheological properties taught in Biomaterials I and combining them with the biocompatibility issues covered in the present course.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 460 [Min Grade: D]

BMES 466 Robotics in Medicine III 3.0 Credits
This course covers topics in the design of medical robotic systems, including force and movement analysis for robotic arms, dynamics, computer vision and vision-based control. Thus use of haptics, vision systems and robot dynamics are examined in a cohesive framework.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 365 [Min Grade: D]

BMES 471 Cellular and Molecular Foundations of Tissue Engineering 4.0 Credits
Course is designed to familiarize students with the advanced concepts of cellular and molecular biology and physiology relevant to tissue engineering. The initial part of a two-quarter sequence combining material from cellular/molecular biology, evolutionary/developmental biology with engineering design and biomaterials to educate students in the principles, methods, and technology of tissue engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BIO 218 [Min Grade: D] and BIO 122 [Min Grade: D] and BIO 219 [Min Grade: D] and CHEM 242 [Min Grade: D] and (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D])

BMES 472 Developmental and Evolutionary Foundations of Tissue Engineering 4.0 Credits
Familiarizes students with advanced concepts of developmental and evolutionary biology relevant to tissue engineering. This second part of the two-quarter sequence combines material from cellular/molecular biology and evolutionary design and biomaterials to educate students in the principles, methods, and technology of tissue engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 471 [Min Grade: D]

BMES 475 Biomaterials and Tissue Engineering III 4.0 Credits
This course provides students with in-depth knowledge of factor-mediated tissue engineering and regenerative medicine. Students learn about fundamental repair and regenerative processes and gain an understanding of specific biomaterials being used to mimic and/or enhance such processes. Students also learn about the delivery methods of agents which promote the proper functional development of specialized tissues.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 460 [Min Grade: D] and BMES 461 [Min Grade: D] and BMES 471 [Min Grade: D] and BMES 472 [Min Grade: D]

BMES 477 Neuroengineering I: Neural Signals 3.0 Credits
Introduces the theory of neural signaling. Students will learn the fundamental theory of cellular potentials and chemical signaling, the Hodgkin Huxeley description of action potential generation, circuit representations of neurons and be able to derive and integrate equations describing the circuit as well as design computer models.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: ECES 302 [Min Grade: D] and ECES 304 [Min Grade: D] and ECES 356 [Min Grade: D] and BIO 203 [Min Grade: D] and BMES 405 [Min Grade: D] and BMES 430 [Min Grade: D]

BMES 478 Neuroengineering II: Principles of Neuroengineering 3.0 Credits
This course investigates cutting edge technologies in neuroengineering in a seminar-style format with faculty from the School of Biomedical Engineering and College of Medicine. Three modules cover topics, which vary from year to year. Students are expected to submit written and oral presentations covering each topic.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 477 [Min Grade: D]

BMES 480 Special Topics in Biomedical Engineering & Sciences 12.0 Credits
Covers topics related to the field of health care, systems, and technology. Past topics include health care administration.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit

BMES 483 Quantitative Systems Biology 4.5 Credits
This course uses a systems engineering approach to provide a foundation in systems biology and pathology informatics. Topics covered include the robust complex network of genes and proteins; cell as basic units of life; communication of cells with other cells and the environment; and gene circuits governing development.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: (TDEC 222 [Min Grade: D] or ENGR 232 [Min Grade: D]) and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (BMES 202 [Min Grade: D] or ENGR 202 [Min Grade: D]) and BMES 372 [Min Grade: D] and BMES 375 [Min Grade: D] and CS 172 [Min Grade: D]

BMES 484 Genome Information Engineering 4.5 Credits
This course is designed to provide students with hands-on experience in the application of genomic, proteomic, and other large-scale information to biomedical engineering. The underlying goal is to develop an understanding of highthrough underlying technologies, biological challenges, and key mathematical and computational methods relevant to biomedical engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 483 [Min Grade: D]

BMES 488 Medical Device Development 3.0 Credits
Medical device product development must take into account a diverse set of disciplines to achieve a safe and successful product. This course exposes the student to several of these disciplines with the objective of raising the student¿s awareness of safety throughout the product development life cycle. Students will learn to appreciate the complex engineering decisions that support development of a safe medical device through an examination of risk management, regulatory processes, human factors and clinical studies.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 391 [Min Grade: D] and BMES 392 [Min Grade: D]

BMES 491 [WI] Senior Design Project I 3.0 Credits
This is the first course in a three-quarter capstone design experience for senior biomedical engineering students.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.

BMES 492 Senior Design Project II 2.0 Credits
Continues senior design activities begun in BMES 492.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.

BMES 493 Senior Design Project III 3.0 Credits
Continues the design project begun in BMES 491 and continued through BMES 492.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.

BMES 494 Clinical Practicum I 3.0 Credits
This course provides biomedical engineering students with an extensive exposure to live clinical cardiology procedures, including cardiac catheterization, electrophysiology, echocardiography and nuclear stress testing. Emphasis is placed on identifying important interfaces between engineering and clinical medicine, particularly in areas where clinical needs may be addressed by advances in biomedical engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if major is BME.

BMES 495 Clinical Practicum II 3.0 Credits
This course provides biomedical engineering students with an extensive exposure to live operations in an emergency department and intensive care unit. The students are expected to analyze specific operations within these environments and develop a solution to a process problem within one of these environments. System analysis, design and evaluation are emphasized.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if major is BME.

BMES 496 Clinical Practicum III 3.0 Credits
This course provides biomedical engineering students with an opportunity to observe basic operative and postoperative procedures with the idea of both learning about such procedures and identifying the role of biomedical engineering in these clinical settings.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if major is BME.

BMES 499 Independent Study in Biomedical Engineering and Science 0.5-6.0 Credits
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit

Biomaterials and Tissue Engineering Concentration

About the Program

Bachelor of Science in Biomedical Engineering (BMES): 198.0 quarter credits
The biomaterials and tissue engineering concentration focuses on the fundamental knowledge of natural and synthetic biomaterials and cellular biology and educates students in the emerging field of cellular and tissue engineering.

The concentration in biomaterials and tissue engineering includes courses from the Departments of Biology, Chemistry, and Mechanical Engineering & Mechanics. The program builds on the fundamental knowledge of natural and synthetic biomaterials and cellular biology and educates students in the emerging field of cellular and tissue engineering.

Biomaterials research has recently expanded to include fibrous materials and various prosthetic devices requiring the use of both synthetic and

natural fibers. The emphasis is on improved materials and design of biological replacement tissues through cellular tissue engineering.

Upon graduation, students will be able to:

- select and evaluate biomaterials for use in biomedical applications *in vivo*;
- develop *in vitro* models for drug delivery, drug toxicity and drug discovery choosing the appropriate biomaterials;
- create high-fidelity tissue models *in vitro*;
- develop and evaluate tissue engineering approaches to initiate and promote regenerative processes *in vivo*.

The School maintains extensive facilities and laboratories devoted to areas of research. Visit the School's BIOMED Research Facilities and Laboratory Map (http://www.biomed.drexel.edu/new04/Content/research/facilities) web page for more details about the laboratories and equipment available.

For more information about this concentration, see Drexel's School of Biomedical Engineering, Science, and Health Systems (http://www.biomed.drexel.edu/new04) web site.

Degree Requirements

General education requirements		
HIST 285	Technology in Historical Perspective	3.0
ENGL 101	Composition and Rhetoric I: Inquiry and Exploratory Research	3.0
ENGL 102	Composition and Rhetoric II: The Craft of Persuasion	3.0
ENGL 103	Composition and Rhetoric III: Thematic Analysis Across Genres	3.0
UNIV R101	The Drexel Experience	2.0
Liberal and General Studies Electives (5) *		15.0
Engineering core courses		
MATH 121	Calculus I	4.0
MATH 122	Calculus II	4.0
MATH 200	Multivariate Calculus	4.0
PHYS 101	Fundamentals of Physics I	4.0
PHYS 102	Fundamentals of Physics II	4.0
PHYS 201	Fundamentals of Physics III	4.0
CHEM 101	General Chemistry I	3.5
CHEM 102	General Chemistry II	4.5
BIO 122	Cells and Genetics	4.5
ENGR 100	Beginning Computer Aided Drafting for Design	1.0
ENGR 101	Engineering Design Laboratory I	2.0
ENGR 102	Engineering Design Laboratory II	2.0
ENGR 103	Engineering Design Laboratory III	2.0
ENGR 210	Introduction to Thermodynamics	3.0
ENGR 220	Fundamentals of Materials	4.0
ENGR 231	Linear Engineering Systems	3.0
ENGR 232	Dynamic Engineering Systems	3.0
MEM 202	Statics	3.0
Required Biomedical Engineering courses		
BIO 201	Human Physiology I	4.0
BIO 203	Human Physiology II	4.0
BMES 124	Biomedical Engineering Freshman Seminar I	1.0
BMES 126	Biomedical Engineering Freshman Seminar II	1.0
BMES 130	Problem Solving in Biomedical Engineering	2.0
BMES 201	Programming and Modeling for Biomedical Engineers I	3.0
BMES 202	Programming and Modeling for Biomedical Engineers ll	3.0
BMES 212	The Body Synthetic	3.0
BMES 302	Laboratory II: Biomeasurements	2.0
BMES 303	Laboratory III: Biomedical Electronics	2.0
BMES 310	Biomedical Statistics	4.0
BMES 325	Principles of Biomedical Engineering I	3.0
BMES 326	Principles of Biomedical Engineering II	3.0
BMES 338	Biomedical Ethics and Law	3.0
BMES 372	Biosimulation	3.0
BMES 381	Junior Design Seminar I	2.0
BMES 382	Junior Design Seminar II	2.0
BMES 491 [WI]	Senior Design Project I	3.0
BMES 492	Senior Design Project II	2.0
BMES 493	Senior Design Project III	3.0
ECE 201	Foundations of Electric Circuits	3.0
Biomaterials and Tissue Engineering concentration courses		
BIO 218	Principles of Molecular Biology	4.0
BIO 219 [WI]	Techniques in Molecular Biology	2.5
BMES 301	Laboratory I: Experimental Biomechanics	2.0
BMES 345	Mechanics of Biological Systems	3.0
BMES 375	Computational Bioengineering	4.0
BMES 451	Transport Phenomena in Living Systems	4.0
BMES 460	Biomaterials I	4.0
BMES 461	Biomaterials II	4.0
BMES 471	Cellular and Molecular Foundations of Tissue Engineering	4.0
BMES 472	Developmental and Evolutionary Foundations of Tissue Engineering	4.0
BMES 475	Biomaterials and Tissue Engineering III	4.0
CHEM 241	Organic Chemistry I	4.0
CHEM 242	Organic Chemistry II	4.0
CHEM 244	Organic Chemistry Laboratory I	3.0
CHEM 245	Organic Chemistry Laboratory II	3.0
Total Credits		**198.0**

* General studies electives include all liberal arts electives plus additional subjects, such as business, which do not fall under the subject areas of science, math or engineering. See the Biomedical Engineering General and Liberal Studies List (http://www.drexel.edu/catalog/degree/biomedeng-liberal-list.htm) for approved courses. A certain number of General Studies credits are required for graduation with this major.

Sample Plan of Study

Term 1		**Credits**
BMES 124	Biomedical Engineering Freshman Seminar I	1.0
CHEM 101	General Chemistry I	3.5

ENGL 101	Composition and Rhetoric I: Inquiry and Exploratory Research	3.0
ENGR 100	Beginning Computer Aided Drafting for Design	1.0
ENGR 101	Engineering Design Laboratory I	2.0
MATH 121	Calculus I	4.0
UNIV R101	The Drexel Experience	1.0
	Term Credits	**15.5**
Term 2		
BMES 126	Biomedical Engineering Freshman Seminar II	1.0
CHEM 102	General Chemistry II	4.5
ENGL 102	Composition and Rhetoric II: The Craft of Persuasion	3.0
ENGR 102	Engineering Design Laboratory II	2.0
MATH 122	Calculus II	4.0
PHYS 101	Fundamentals of Physics I	4.0
UNIV R101	The Drexel Experience	1.0
	Term Credits	**19.5**
Term 3		
BIO 122	Cells and Genetics	4.5
BMES 130	Problem Solving in Biomedical Engineering	2.0
ENGL 103	Composition and Rhetoric III: Thematic Analysis Across Genres	3.0
ENGR 103	Engineering Design Laboratory III	2.0
MATH 200	Multivariate Calculus	4.0
PHYS 102	Fundamentals of Physics II	4.0
UNIV 101	The Drexel Experience	0.5
	Term Credits	**20.0**
Term 4		
BIO 201	Human Physiology I	4.0
BMES 201	Programming and Modeling for Biomedical Engineers I	3.0
ENGR 220	Fundamentals of Materials	4.0
ENGR 231	Linear Engineering Systems	3.0
PHYS 201	Fundamentals of Physics III	4.0
	Term Credits	**18.0**
Term 5		
BMES 202	Programming and Modeling for Biomedical Engineers ll	3.0
BMES 212	The Body Synthetic	3.0
BMES 235	Living Systems Engineering	4.0
ENGR 210	Introduction to Thermodynamics	3.0
ENGR 232	Dynamic Engineering Systems	3.0
MEM 202	Statics	3.0
	Term Credits	**19.0**
Term 6		
BMES 301	Laboratory I: Experimental Biomechanics	2.0
BMES 302	Laboratory II: Biomeasurements	2.0
BMES 325	Principles of Biomedical Engineering I	3.0
BMES 372	Biosimulation	3.0
ECE 201	Foundations of Electric Circuits	3.0
HIST 285	Technology in Historical Perspective	3.0
	Term Credits	**16.0**
Term 7		
BMES 303	Laboratory III: Biomedical Electronics	2.0
BMES 310	Biomedical Statistics	4.0
BMES 326	Principles of Biomedical Engineering II	3.0
BMES 345	Mechanics of Biological Systems	3.0
Liberal studies elective		3.0
	Term Credits	**15.0**
Term 8		
BIO 218	Principles of Molecular Biology	4.0
BIO 219 [WI]	Techniques in Molecular Biology	2.5
BMES 338	Biomedical Ethics and Law	3.0
BMES 381	Junior Design Seminar I	2.0
CHEM 241	Organic Chemistry I	4.0
	Term Credits	**15.5**
Term 9		
BMES 375	Computational Bioengineering	4.0
BMES 382	Junior Design Seminar II	2.0
BMES 451	Transport Phenomena in Living Systems	4.0
CHEM 242	Organic Chemistry II	4.0
CHEM 244	Organic Chemistry Laboratory I	3.0
	Term Credits	**17.0**
Term 10		
BMES 460	Biomaterials I	4.0
BMES 471	Cellular and Molecular Foundations of Tissue Engineering	4.0
BMES 491 [WI]	Senior Design Project I	3.0
CHEM 245	Organic Chemistry Laboratory II	3.0
Liberal studies elective		3.0
	Term Credits	**17.0**
Term 11		
BMES 461	Biomaterials II	4.0
BMES 472	Developmental and Evolutionary Foundations of Tissue Engineering	4.0
BMES 492	Senior Design Project II	2.0
General studies elective		3.0
	Term Credits	**13.0**
Term 12		
BMES 475	Biomaterials and Tissue Engineering III	4.0
BMES 493	Senior Design Project III	3.0
Liberal studies elective		3.0
General studies elective		3.0
	Term Credits	**13.0**

Total Credit: 198.5

Opportunities

Metropolitan Philadelphia has one of the highest concentrations of medical institutions and pharmaceutical and biotechnology industries in the nation.The bachelor of science degree in biomedical engineering gives students access to a broad spectrum of career opportunities in medical device and equipment industry; prosthetics and assist devices industry; biomaterials and implants industry; and the telemedicine, pharmaceutical, biotechnology, and agricultural sectors.

Biomedical engineering graduates are also ideally prepared for professional education in medicine, dentistry, veterinary medicine, and law. Those who choose to pursue graduate education can aim for careers in research and development, biomedical technology innovation and transfer, as well as health care technology management.

Visit the Drexel Steinbright Career Development Center (http://www.drexel.edu/scdc) page for more detailed information on co-op and post-graduate opportunities.

Biomedical Engineering, Science and Health Systems Faculty

Fred D. Allen, PhD *(University of Pennsylvania)*. Assistant Professor. Tissue engineering, cell engineering, orthopedics, bone remodeling, wound healing, mechanotransduction, signal transduction, adhesion, migration.

Sriram Balasubramanian, PhD *(Wayne State University)*. Assistant Professor. Structural characteristics of the pediatric thoracic cage using CT scans and developing an age-equivalent animal model for pediatric long bones.

Kenneth A. Barbee, PhD *(University of Pennsylvania)*. Professor. Cellular biomechanics of neural and vascular injury, mechanotransduction in the cardiovascular system, mechanical control of growth and development for wound healing and tissue engineering.

Lin Han, PhD *(Massachusetts Institute of Technology)*. Assistant Professor. Nanoscale structure-property relationships of biological materials, genetic and molecular origins soft joint tissue diseases, biomaterials under extreme conditions, coupling between stimulus-responsiveness and geometry.

Uri Hershberg, PhD *(Hebrew University of Jerusalem, Israel)*. Assistant Professor. Bioinformatics, immunology, neural computation, system biology, somatic selection, autoimmunity, genetic stability, germline diversity, dendritic cell, transcription elements, pathogens, computational and mathematical modeling, complex systems, cognition and inflammation.

Joshua Jacobs, PhD *(University of Pennsylvania)*. Assistant Professor. Neuroengineering, electrocorticography (ECoG), electroencephalography (EEG), single-neuron spiking, brain oscillations, episodic memory, working memory, spatial navigation, conceptual representations.

Dov Jaron, PhD *(University of Pennsylvania) Calhoun Distinguished Professor of Engineering in Medicine*. Professor. Mathematical, computer and electromechanical simulations of the cardiovascular system.

Andres Kriete, PhD *(University in Bremen Germany) Associate Director for Graduate Studies and Academic Operations*. Systems biology, bioimaging, control theory, biology of aging, skin cancer.

Ryszard Lec, PhD *(University of Warsaw Engineering College)*. Professor. Biomedical applications of visoelastic, acoustoptic and ultrasonic properties of liquid and solid media.

Peter Lewin, PhD *(University of Denmark, Copenhagen-Lyngby) Richard B. Beard Professor, School Of Biomedical Engineering, Science & Health Systems*. Professor. Biomedical ultrasonics, piezoelectric and polymer transducers and hydrophones; shock wave sensors.

Hualou Liang, PhD *(Chinese Academy of Sciences)*. Associate Professor. Neuroengineering, neuroinformatics, cognitive and computational neuroscience, neural data analysis and computational modeling, biomedical signal processing.

Donald L. McEachron, PhD *(University of California at San Diego) Associate Director*. Research Professor. Animal behavior, autoradiography, biological rhythms, cerebral metabolism, evolutionary theory, image processing, neuroendocrinology.

Karen Moxon, PhD *(University of Colorado)*. Associate Professor. Cortico-thalamic interactions; neurobiological perspectives on design of humanoid robots.

Banu Onaral, Ph.D. *(University of Pennsylvania) H.H. Sun Professor / Director, School of Biomedical Engineering Science and Health Systems*. Professor. Biomedical signal processing; complexity and scaling in biomedical signals and systems.

Kambiz Pourrezaei, PhD *(Rensselaer Polytechnic University)*. Professor. Thin film technology; nanotechnology; near infrared imaging; power electronics.

Arye Rosen, PhD *(Drexel University) Biomedical Engineering and Electrical Engineering*. Microwave components and subsystems; utilization of RF/microwaves and lasers in therapeutic medicine.

Ahmet Sacan, PhD *(Middle East Technical University)*. Assistant Professor. Indexing and data mining in biological databases; protein sequence and structure; similarity search; protein structure modeling; protein-protein interaction; automated cell tracking.

Joseph J. Sarver, PhD *(Drexel University)*. Teaching Professor. Neuromuscular adaptation to changes in the myo-mechanical environment.

Rahamim Seliktar, PhD *(University of Strathclyde, Glasgow) Vice Director, School of Biomedical Engineering, Science & Health Systems*. Professor. Limb prostheses, biomechanics of human motion, orthopedic biomechanics.

Adrian C. Shieh, PhD *(Rice University)*. Assistant Professor. Contribution of mechanical forces to tumor invasion and metastasis, with a particular emphasis on how biomechanical signals may drive the invasive switch, and how the biomechanical microenvironment interacts with cytokine signaling and the extracellular matrix to influence tumor and stromal cell behavior.

Wan Young Shih, PhD *(Ohio State University) School of Biomedical Engineering, Science and Health Systems*. Associate Professor. Piezoelectric microcantilever biosensors development, piezoelectric finger development, quantum dots development, tissue elasticity imaging, piezoelectric microcantilever force probes.

Kara Spiller, PhD *(Drexel University)*. Assistant Professor. Cell-biomaterial interactions, biomaterial design, and international engineering education.

Margaret Wheatley, PhD *(University of Toronto) School of Biomedical Engineering, Science and Health Systems, John M. Reid Professor*. Ultrasound contrast agent development (tumor targeting and triggered drug delivery), controlled release technology (bioactive compounds), microencapsulated allografts (*ex vivo* gene therapy) for spinal cord repair.

Yinghui Zhong, PhD *(Georgia Institute of Technology)*. Assistant Professor. Spinal cord repair, and engineering neural prosthesis/brain interface using biomaterials, drug delivery, and stem cell therapy.

Interdepartmental Faculty

Douglas L. Chute, PhD *(University of Missouri) Louis and Bessie Stein Fellow*. Professor. Neuropsychology and rehabilitation; technological applications for the cognitively compromised and those with acquired brain injuries.

Patricia A. Shewokis, PhD *(University of Georgia)*. Professor. Roles of cognition and motor function during motor skill learning; role of information feedback frequency on the memory of motor skills, noninvasive neural imaging techniques of functional near infrared spectroscopy(fNIR) and electroencephalograpy (EEG) and methodology and research design.

Emeritus Faculty

William Freedman, PhD *(Drexel University)*. Professor Emeritus. Motor control; sensory and motor systems; reflexes; eye movements; neural networks.

John M. Reid, PhD *(University of Pennsylvania) Calhoun Professor Emeritus*. Professor Emeritus. Diagnostic ultrasound, wave propagation and scattering in inhomogeneous media, imaging, instrumentation.

Hun H. Sun, PhD *(Cornell University)*. Professor Emeritus. Biological control systems, physiological modeling, systems analysis.

Aydin Tozeren, PhD *(Columbia University) Distinguished Professor and Director, Center for Integrated Bioinformatics, School of Biomedical Engineering, Science & Health Systems*. Professor Emeritus. Breast cell adhesion and communication, signal transduction networks in cancer and epithelial cells; integrated bioinformatics, molecular profiling, 3D-tumors, bioimaging.

Courses

BMES 124 Biomedical Engineering Freshman Seminar I 1.0 Credit
This course is intended to introduce freshman biomedical engineering students in the School of biomedical Engineering, Science and Health Systems at Drexel University to academic programs and opportunities, ongoing research projects and University resources to ensure a successful educational experience at Drexel and beyond. Through class discussions and guest lecture presentations, the students are provided with information and contacts necessary to begin a plan of academic study.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 125 Foundations of Biomedical Engineering 2.0 Credits
This course is intended to introduce new transfer biomedical engineering students in the School of biomedical Engineering, Science and Health Systems at Drexel University academic programs and opportunities, ongoing research projects and University resources to ensure a successful educational experience at Drexel and beyond. Through class discussions and guest lecture presentations, the students are provided with information and contact necessary to begin a plan of academic study.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 126 Biomedical Engineering Freshman Seminar II 1.0 Credit
This course is intended to introduce freshman biomedical engineering students to the career embodied by the School's current concentration areas. Each area will be discussed in terms of the current state of the art, research possibilities and career opportunities. The curricula for each concentration will be discussed in detail so as to facilitate students' knowledge of how each curriculum relates to the research and employment opportunities in that field.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 130 Problem Solving in Biomedical Engineering 2.0 Credits
This course integrates fundamental principles of biology, chemistry, engineering, mathematics and physics into a framework for the study of biomedical engineering. In this course, students will use both engineering and scientific approaches to problem-solving. They will learn about the differences between engineering design and biological evolution. They will also learn to apply basic principles of chemistry, physics and mathematics to specific biological and physiological problems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MATH 122 [Min Grade: D] and CHEM 102 [Min Grade: D] and PHYS 101 [Min Grade: D]

BMES 201 Programming and Modeling for Biomedical Engineers I 3.0 Credits
This course aims to introduce students with some fundamental concepts about programming in MATLAB to give the ability to solve basic bioengineering problems. The course introduces the basics of programming using Matlab, including programming environment and tools. Fundamental programming techniques and concepts such as loops, switches and logical operators, functions and file handling are covered. Applications in bioengineering for basic numerical problem solving are discussed.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MATH 200 [Min Grade: D] and PHYS 102 [Min Grade: D] and BIO 122 [Min Grade: D] and (BMES 130 [Min Grade: D] or BMES 125 [Min Grade: D])

BMES 202 Programming and Modeling for Biomedical Engineers II 3.0 Credits
The course aims to introduce students to advanced programming concepts and tools to solve numerical problems in bioengineering. It provides the foundation for biosimulation and biocomputation classes. This course introduces advanced programming methods and computational tools for numerical analysis, model design and graphics. Higher level level lunctionality in Matlab such as SIMULINK, symbolic processing and CAD related tools are discussed.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 201 [Min Grade: D]

BMES 212 The Body Synthetic 3.0 Credits
The Body Synthetic introduces concepts underlying biological and engineering principles involved in the design and construction of prosthetic devices used to replace various parts of the human body.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: (TDEC 122 [Min Grade: D] or BIO 122 [Min Grade: D]) and (BMES 130 [Min Grade: D] or BMES 125 [Min Grade: D])

BMES 235 Living Systems Engineering 4.0 Credits
This course introduces the biomedical engineering students to engineering principles applied to biological and physiological systeTs. This course focuses.on evolution, adaptation, energy, thermodynamics, fluid dynamics and control systems in living organrsms.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 122 [Min Grade: D] and CHEM 102 [Min Grade: D] and MATH 200 [Min Grade: D] and PHYS 102 [Min Grade: D] and BMES 130 [Min Grade: D] and BIO 201 [Min Grade: D]

BMES 301 Laboratory I: Experimental Biomechanics 2.0 Credits
This course deals with experimental aspects of biomechanics, specifically with the testing mechanical properties of biological tissues.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (TDEC 114 [Min Grade: D] or MATH 200 [Min Grade: D]) and (TDEC 115 [Min Grade: D] or PHYS 201 [Min Grade: D]) and (TDEC 211 [Min Grade: D] or ENGR 231 [Min Grade: D]) and MEM 202 [Min Grade: D]

BMES 302 Laboratory II: Biomeasurements 2.0 Credits
This course introduces students to the measurement of physiological/biological/functional signals. Four specific signals will be collected and analyzed. Students are expected to analyze type of signal to be collected, possible measurement techniques and potential data analysis and then collect and analyze each signal.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: ECE 201 [Min Grade: D] (Can be taken Concurrently) (BMES 222 [Min Grade: D] or BIO 201 [Min Grade: D]) and (TDEC 231 [Min Grade: D] or ENGR 103 [Min Grade: D])

BMES 303 Laboratory III: Biomedical Electronics 2.0 Credits
This course introduces students to the widespread application of electronics and electronic devices in biomedical engineering. The course reinforces concepts learned in ECE 201 with hands-on experimentation related to biomedical applications such as telemedicine and medical devices.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (ECE 201 [Min Grade: D] and TDEC 231 [Min Grade: D]) or ENGR 232 [Min Grade: D]

BMES 304 Laboratory IV: Ultrasound Images 2.0 Credits
This course introduces students to the engineering principles of acoustical measurements by combining hands-on laboratory experiences with lectures. Students will learn the engineering/physical principles of measuring sound velocity in different materials, attenuation, and directivity of a circular transducers.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (BIO 201 [Min Grade: D] or BMES 235 [Min Grade: D]) and ECE 201 [Min Grade: D] and (TDEC 231 [Min Grade: D] or ENGR 103 [Min Grade: D])

BMES 305 Laboratory V: Musculoskeletal Anatomy for Biomedical Engineers 2.0 Credits
This course provides an opportunity for students to study the anatomy and biomechanics of select articulations of the human body. While the main emphasis will be on the musculoskeletal structures associated with each articulation, major neural and vascular structures will be studied as well.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: (BIO 201 [Min Grade: D] or BMES 235 [Min Grade: D]) and MEM 202 [Min Grade: D]

BMES 310 Biomedical Statistics 4.0 Credits
This course is designed to introduce biomedical engineering students to the fundamentals of biostatistics necessary for medical research. Topics covered include measurements, sampling, basic hypothesis testing, analysis of variance and regression. Medical applications are emphasized.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: ENGR 231 [Min Grade: D]

BMES 315 Experimental Design in Biomedical Research 4.0 Credits
This course is designed to introduce students to the fundamental principles of experimental design and statistical analysis as applied to biomedical research with animals and humans. Topics to be covered include experimental design, clinical design, and protocol submission and review.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 310 [Min Grade: D]

BMES 325 Principles of Biomedical Engineering I 3.0 Credits
This course is the first part of a two-term sequence which introduces biomedical engineering students to engineering principles applied to biological and physiological systems. This course focuses on bioethical questions, biomechanics, human performance engineering, biomaterials and tissue engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 122 [Min Grade: D] and CHEM 102 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and MEM 202 [Min Grade: D] and ENGR 220 [Min Grade: D] and ENGR 232 [Min Grade: D]

BMES 326 Principles of Biomedical Engineering II 3.0 Credits
This course is the second part of a two-term sequence which introduces biomedical engineering students to engineering principles applied to biological and physiological systems. This course focuses on bioinformatics, neuroengineering, biosignal processing, biosensors, and medical imaging.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 325 [Min Grade: D] and BIO 201 [Min Grade: D] and (BMES 202 [Min Grade: D] or ENGR 202 [Min Grade: D])

BMES 330 Biological Rhythm in Pharmacology and Toxicology 3.0 Credits
This course covers the fundamentals of biological rhythms with particular emphasis on the influence these cycles have on the susceptibility of organism to physical, chemical, and /or toxic agents.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman
Prerequisites: BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]

BMES 331 Computers in Health Systems I 3.0 Credits
Introduces the allied health professional to basic computer applications on personal computers. Includes word processing, spreadsheets, databases, and networking (e.g., e-mail and information search and retrieval) in a primarily Windows environment. Designed for individuals with little or no computer background. Students are encouraged to bring in their own work-related problems or projects to provide immediate application of knowledge learned to the student's professional healthcare environment.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 332 Computers in Health Systems II 3.0 Credits
Continues the general overview of computers for people in the allied health professions, using specific examples from health care. Offers further study of and practice with special scientific (e.g., statistics, graphing) and medical clinical decision-support software. Introduces algorithms and formal programming methods.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman

BMES 335 Biomedical Informatics I 3.0 Credits
Introduces information and information handling systems for people in the allied health professions, with specific examples drawn from health care. Covers locating, manipulating, and displaying information in the health system setting.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore

BMES 336 Biomedical Informatics II: Hospital and Patient Information 3.0 Credits
Continues BMES 335. Emphasizes medical records and hospital and patient information handling. Examines the problems of patient information flow within the health care system. Introduces conventional and proposed patient and hospital information systems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 335 [Min Grade: D]

BMES 338 Biomedical Ethics and Law 3.0 Credits
Introduces the wide spectrum of ethical, regulatory, and legal issues facing health care practitioners and health-related research workers. Helps students become aware of the ethical and legal issues involved in their work. Helps students understand how legal and ethical decisions should be made in health-related matters, as well as what sources of help and guidance are available.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman

BMES 340 Health Care Administration 3.0 Credits
This course provides students with an analysis of health care administration process, including: planning, organizing, designing, decision-making, leading, and controlling. Presents methods and techniques that can contribute to the effective performance of administrative duties.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman

BMES 345 Mechanics of Biological Systems 3.0 Credits
This course introduces the fundamentals of mechanics of deformable bodies as they relevant to biologicaltissues and biomaterials. Major topics include stress and strain, mechanical properties of biologicaltissues and biomaterials, axial loading, torsion, bending, and viscoelasticity, These concepts will be applied to biological examples such as long bones, the heart, blood vessels, and orthopaedic implants.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MEM 202 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D])

BMES 350 Med & Bio Effects Of Light 3.0 Credits
Examines the role of environmental lighting in human physiological and psychological processes. Topics include vitamin D synthesis and calcium regulation; light effects on bilirubin in newborns; photoactivation and DNA in skin; effects of nonionizing radiation on the immune systems; environmental lighting and human vision; light effects on biological rhythms and sleep; photosensitivity diseases related to interior lighting; the therapeutic uses of light; and light and the aging eye.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman
Prerequisites: BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]

BMES 363 Robotics in Medicine I 3.0 Credits
This course provides an introduction to the use of haptics (the use of somtaosensory information) in the design of robotic devices in surgery. Topics covered include actuators, sensors, nonportable feedback, portable force feedback, tactile feedback interfaces, haptic sensing and control systems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MEM 238 [Min Grade: D]

BMES 365 Robotics in Medicine II 3.0 Credits
This course covers the use of robots in surgery and included aspects of safety, robot kinematics, analysis of surgical performance using robotic devices, inverse kinematics, velocity analysis and acceleration analysis. Various types of surgeries in which robotic devices are or could be used are presented on a case study basis.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 363 [Min Grade: D]

BMES 372 Biosimulation 3.0 Credits
This course provides the foundation for the mathematical analysis of biomedical engineering systems. It focuses on the essential mathematical methods necessary for further development of modeling and simulation skills in other courses (materials, mechanics, fluids/transport, signals/control system, etc). The course applies the skills in calculus, differential equations and linear algebra gained in ENGR 231 and ENGR 232 to developing analytical techniques for biomedical applications.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and ENGR 231 [Min Grade: D] and ENGR 232 [Min Grade: D] and (BMES 201 [Min Grade: D] and BMES 202 [Min Grade: D]) or (ENGR 201 [Min Grade: D] and ENGR 202 [Min Grade: D])

BMES 375 Computational Bioengineering 4.0 Credits
This course introduces undergraduate students to the mathematical and computational analysis of biological systems. The systems analyzed include the genome, protein and gene networks, cell division cycles, and cellular level disease. Mathematical tools include matrix algebra, differential equations, cellular automata, cluster analysis, etc.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and BMES 325 [Min Grade: D] and BMES 372 [Min Grade: D] and ENGR 231 [Min Grade: D] and (TDEC 221 [Min Grade: D] or ENGR 232 [Min Grade: D])

BMES 381 Junior Design Seminar I 2.0 Credits
This is the first course in a two-course sequence intended to present the basics of engineering design, project management, product development and translational research. This first course focuses on engineering design and product development. A case-study approach is used to illustrate best practices and common mistakes in engineering design.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore

BMES 382 Junior Design Seminar II 2.0 Credits
This is the second course in a two-course sequence intended to present the basics of engineering design, project management, product development and translational research. This second course focuses on project management and quality control. A case-study approach is used to illustrate best practices and common mistakes in management and evaluation of engineering projects.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: BMES 381 [Min Grade: D]

BMES 391 Biomedical Instrumentation I 3.0 Credits
This course introduces the student to the medical instrumentation and provides background on the physical, chemical, electronic and computational fundamentals by which medical instrumentation operates. It is an analytical course exploring the design, operation, safety aspects and calibration of primary electronic instruments.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: ECE 201 [Min Grade: D] and (TDEC 202 [Min Grade: D] or ENGR 210 [Min Grade: D]) and (TDEC 221 [Min Grade: D] or ENGR 231 [Min Grade: D]) and ENGR 232 [Min Grade: D] and (BMES 235 [Min Grade: D] or BIO 203 [Min Grade: D])

BMES 392 Biomedical Instrumentation II 3.0 Credits
Continues BMES 391. Explores the operation, safety aspects, and calibration of primarily optical and acoustical instruments, as well as those involving ionizing radiation. Also examines instrumentation primarily intended for particular departments and areas, such as anesthesia and infusion.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: BMES 391 [Min Grade: D]

BMES 401 Biosensors I 4.0 Credits
Introduces the general topic of microsensors, discusses basic sensing mechanisms for microsensors, and presents various types of conductometric, acoustic, silicon, and optical microsensors. Uses two case studies that include an acoustic immunosensor and silicon glucose sensor to provide students with in-depth knowledge and hands-on experience. Provides additional experience through three laboratory sessions that support the lectures and familiarize students with practical aspects of microsensors. Also discusses applications of microsensors in the medical, chemical, pharmaceutical, environmental, aeronautical, and automotive industries.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D]) and (TDEC 202 [Min Grade: D] or ENGR 210 [Min Grade: D]) and (TDEC 221 [Min Grade: D] or ENGR 231 [Min Grade: D]) and ECE 201 [Min Grade: D] and ENGR 232 [Min Grade: D]

BMES 402 Biosensors II 4.0 Credits
Investigates modern biosensor design methods and addresses the challenges associated with fabrication technologies and instrumentation techniques. Topics include theory and modeling of biosensors, biosensor fabrication steps, and electronic and clinical testing methods. Discusses local and distant sensor data acquisition techniques. Students will design, fabricate and test a biosensor. Essential stages of biosensor manufacturing processes will be outlined. Some or all pre-requisites may be taken as either a pre-requisite or co-requisite. Please see the department for more information.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: BMES 401 [Min Grade: D] (Can be taken Concurrently)

BMES 403 Biosensors III 4.0 Credits
Covers recent advances in biosensor technology and applications, business aspects, and technology transfer issues. Topics include new sensing mechanisms, new technologies, new biomedical applications, the starting of small sensor companies, and the introduction of new sensor technologies into industrial settings. Requires students to develop a technical proposal in the area of biosensors and to review proposals written by their peers. Presentations by regular faculty and industrial and government researchers form an integral part of the course.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: BMES 402 [Min Grade: D]

BMES 405 Physiological Control Systems 3.0 Credits
Introduces the basic concepts of feedback and feed forward controls systems, including characterizations in terms of prescribed constraints, study of input and output relationships for various types of physiological systems, and stability and time-delay problems. Covers mathematical models of physiological systems, with emphasis on non-linear and adaptive systems study.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and ECES 356 [Min Grade: D] and BMES 372 [Min Grade: D]

BMES 409 Entrepreneurship for BMES 3.0 Credits
This course serves as the foundation course in entrepreneurship and is designed to provide students with a complete working knowledge of the modern entrepreneurial and business planning process.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 411 Chronoengineering I: Biological Rhythms in Health and Performance 3.0 Credits
Introduces students to the concepts of biological, and especially circadian, rhythmicity. Advances students' knowledge of biological time-keeping and adaptive functions of biological clocks. Topics include biochemical and physiological models of biological clocks, adjustment to environmental cycles, rhythms in behavior and physiological functions, sleep-wake cyclicity, adaptability of circadian systems, and influences of rhythms on human physiology and behavior. Designed to give students a thorough understanding of the role rhythms play in animal and human behavior, physiology, and medicine.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D])

BMES 412 Chronoengineering II: Sleep Functions in Health and Performance 3.0 Credits
Continues BMES 411. Enhances students' education in the concepts of biological, and especially circadian, rhythmicity. Focuses on sleep patterns, rhythms, evolution, neurology, psychology, and overall function.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: BMES 411 [Min Grade: D]

BMES 421 Biomedical Imaging Systems I: Images 4.0 Credits
Provides an overview of the field of medical imaging. Covers aspects of light imaging; systems theory, convolutions, and transforms; photometry, lenses, and depth of field; image perception and roc theory; three-dimensional imaging; image acquisition and display; and image processing operations, including scanning and segmentation.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: (TDEC 115 [Min Grade: D] and ECES 302 [Min Grade: D] and ECES 304 [Min Grade: D] and BMES 325 [Min Grade: D] and BMES 326 [Min Grade: D]) or PHYS 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (MATH 311 [Min Grade: D] or BMES 310 [Min Grade: D]) and (TDEC 222 [Min Grade: D] or ENGR 231 [Min Grade: D]) and ENGR 232 [Min Grade: D]

BMES 422 Biomedical Imaging Systems II: Ultrasound 4.0 Credits
Intended for students who would like to gain an adequate understanding of diagnostic ultrasound imaging principles and become familiar with developments in this rapidly expanding field. Introduces medical visualization techniques based on ultrasound propagation in biological tissues. Topics include generation and reception of ultrasound, imaging techniques (A-mode, B-mode, M-mode, and Doppler), typical and emerging diagnostic applications, elements of ultrasound exposimetry, and safety aspects from the clinical point of view.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 421 [Min Grade: D]

BMES 423 Biomedical Imaging Systems III 4.0 Credits
Covers volumetric and functional imaging systems. Discusses the principles and algorithms of projection tomography, XCAT, SPECT, PET; the principles of MRI: Bloch equation, slice selection, K-space scanning, volumetric MRI; biochemical imaging; chemical equilibrium equations and Scatchard plots, specific and nonspecific labeling; autoradiography; and flow and dynamical systems: Doppler, mass transport, and phase (MRI) measurement of flow.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 422 [Min Grade: D]

BMES 430 Neural Aspects of Posture and Locomotion 3.0 Credits
Students will study the physiology of ensory/motor systems, with emphasis on modeling of neural systems and biomechanical aspects of functional tasks. Combines information on basic nerve cell activities, synaptic communication and structure/function relationships of skeletal muscle with basic mechanics to study spinal, vestibular and ocular reflexes. Culminates with the study of the control of motor systems with respect to bipedal motion.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (BMES 201 [Min Grade: D] and BMES 202 [Min Grade: D]) or (ENGR 201 [Min Grade: D] and ENGR 202 [Min Grade: D]) and MEM 202 [Min Grade: D]

BMES 432 Biomedical Systems and Signals 3.0 Credits
Introduces various aspects of biomedical signals, systems, and signal processing. Covers topics in the origin and acquisition of biomedical signals; discrete-time signals and linear systems; frequency analysis of discrete-time signals, spectral estimation, data records and digital filters; and compression of biomedical signals through time-domain and frequency-domain coding.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: ECES 302 [Min Grade: D] and ECES 304 [Min Grade: D]

BMES 440 Introduction to Biodynamics 3.0 Credits
The objective of the course is to prepare students for biomechanical modeling, modeling methods, formulation of equations of motion and methods of determination of strength will be applied to human body dynamics. Particular emphasis is placed on the use of Rigid Body and Multi-Body Dynamics.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MEM 202 [Min Grade: D] and (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D]) and MEM 238 [Min Grade: D] and (BMES 235 [Min Grade: D] or BIO 203 [Min Grade: D])

BMES 441 Biomechanics I: Introduction to Biomechanics 4.0 Credits
Teaches students to use mechanical tools to get an introductory appreciation for solving biomechanical problems. Models human performance by using static, quasi-static, and dynamic approaches. Assesses overall loading of the musculoskeletal system during functional activities. Demonstrates introductory methods of estimation of forces in the joints and muscles and evaluates the endurance of the human tissues under traumatic loading conditions. Builds on existing knowledge in mechanics to illustrate the practical application of mechanical tools in the determination of human systems performance.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: MEM 202 [Min Grade: D] and (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D]) and MEM 238 [Min Grade: D] and (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D]) and BIO 203 [Min Grade: D]
Corequisite: BMES 440

BMES 442 Biomechanics II: Musculoskeletal Modeling and Human Performance 4.0 Credits
Teaches students to think biomechanically. Reviews and categorizes the various functional components (tissues) of the musculoskeletal system. Considers constraints of the joints and action of the soft and hard tissues, along with corresponding models. Computes joint and muscle forces. Discusses some aspect of postural stability of the whole musculoskeletal structure and reviews various methods of task performance.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 441 [Min Grade: D]

BMES 443 Biomechanics III: Mechanics of Biological Tissues, Implant Technology and Prosthetics 4.0 Credits
Provides more advanced knowledge of mechanics of materials and offers a general description of mechanical behavior of the variety of the soft and hard tissues of the human body. Considers some prosthetic replacements of tissues as well as entire bone, joint, soft tissue, and system prosthetics. Reviews some specific orthopedic appliances and covers limb prosthetics if time permits. Students plan design projects.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 442 [Min Grade: D]

BMES 444 Biofluid Mechanics 3.0 Credits
This course introduces flow-related anatomy and pathophysiology, and biomedical flow devices and their design challenges. Analysis methods to solve biological fluid mechanics design problems will be introduced and several interdisciplinary team projects will be assigned to apply fluid mechanics to practical biological or medical problems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 451 [Min Grade: D]

BMES 451 Transport Phenomena in Living Systems 4.0 Credits
Introduces students to applications of chemical engineering concepts in biological systems. Shows that chemical engineering approaches to problem solving are ideally suited to investigation of biology. Approaches include material and energy balances, transport phenomena, and kinetics.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: (TDEC 115 [Min Grade: D] or PHYS 201 [Min Grade: D]) and (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D]) and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (TDEC 202 [Min Grade: D] or ENGR 210 [Min Grade: D]) and ENGR 232 [Min Grade: D]

BMES 452 Transport Phenomena in Living Systems II 3.0 Credits
Continues BMES 451. Advances students' understanding of the engineering principles of membrane transport and its consequences at the subcellular (mitochondria), cellular (neuron), and organ (kidney) level. Introduces concepts associated with pharmacokinetics. Provides students with a kinetic approach to analysis of receptors, including the kinetics of ligand-receptor binding, rate constants, and signal transduction.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: BMES 451 [Min Grade: D]

BMES 460 Biomaterials I 4.0 Credits
First course in a three-quarter sequence designed to acquaint students with the behavior of materials used in biomedical application under load (i.e., mechanical properties), their modes of failure and as a function of their environment. This course provides students with the fundamentals needed to proceed with Biomaterials II.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D]) and CHEM 241 [Min Grade: D] and CHEM 242 [Min Grade: D]

BMES 461 Biomaterials II 4.0 Credits
Second course in a three-quarter sequence in biomaterials. The goal of this course is with an understanding of, and ability to select, appropriate materials for specific applications taking into account mechanical, thermal, and rheological properties taught in Biomaterials I and combining them with the biocompatibility issues covered in the present course.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 460 [Min Grade: D]

BMES 466 Robotics in Medicine III 3.0 Credits
This course covers topics in the design of medical robotic systems, including force and movement analysis for robotic arms, dynamics, computer vision and vision-based control. Thus use of haptics, vision systems and robot dynamics are examined in a cohesive framework.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 365 [Min Grade: D]

BMES 471 Cellular and Molecular Foundations of Tissue Engineering 4.0 Credits
Course is designed to familiarize students with the advanced concepts of cellular and molecular biology and physiology relevant to tissue engineering. The initial part of a two-quarter sequence combining material from cellular/molecular biology, evolutionary/developmental biology with engineering design and biomaterials to educate students in the principles, methods, and technology of tissue engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BIO 218 [Min Grade: D] and BIO 122 [Min Grade: D] and BIO 219 [Min Grade: D] and CHEM 242 [Min Grade: D] and (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D])

BMES 472 Developmental and Evolutionary Foundations of Tissue Engineering 4.0 Credits
Familiarizes students with advanced concepts of developmental and evolutionary biology relevant to tissue engineering. This second part of the two-quarter sequence combines material from cellular/molecular biology and evolutionary design and biomaterials to educate students in the principles, methods, and technology of tissue engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 471 [Min Grade: D]

BMES 475 Biomaterials and Tissue Engineering III 4.0 Credits
This course provides students with in-depth knowledge of factor-mediated tissue engineering and regenerative medicine. Students learn about fundamental repair and regenerative processes and gain an understanding of specific biomaterials being used to mimic and/or enhance such processes. Students also learn about the delivery methods of agents which promote the proper functional development of specialized tissues.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 460 [Min Grade: D] and BMES 461 [Min Grade: D] and BMES 471 [Min Grade: D] and BMES 472 [Min Grade: D]

BMES 477 Neuroengineering I: Neural Signals 3.0 Credits
Introduces the theory of neural signaling. Students will learn the fundamental theory of cellular potentials and chemical signaling, the Hodgkin Huxeley description of action potential generation, circuit representations of neurons and be able to derive and integrate equations describing the circuit as well as design computer models.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: ECES 302 [Min Grade: D] and ECES 304 [Min Grade: D] and ECES 356 [Min Grade: D] and BIO 203 [Min Grade: D] and BMES 405 [Min Grade: D] and BMES 430 [Min Grade: D]

BMES 478 Neuroengineering II: Principles of Neuroengineering 3.0 Credits
This course investigates cutting edge technologies in neuroengineering in a seminar-style format with faculty from the School of Biomedical Engineering and College of Medicine. Three modules cover topics, which vary from year to year. Students are expected to submit written and oral presentations covering each topic.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 477 [Min Grade: D]

BMES 480 Special Topics in Biomedical Engineering & Sciences 12.0 Credits
Covers topics related to the field of health care, systems, and technology. Past topics include health care administration.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit

BMES 483 Quantitative Systems Biology 4.5 Credits
This course uses a systems engineering approach to provide a foundation in systems biology and pathology informatics. Topics covered include the robust complex network of genes and proteins; cell as basic units of life; communication of cells with other cells and the environment; and gene circuits governing development.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: (TDEC 222 [Min Grade: D] or ENGR 232 [Min Grade: D]) and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (BMES 202 [Min Grade: D] or ENGR 202 [Min Grade: D]) and BMES 372 [Min Grade: D] and BMES 375 [Min Grade: D] and CS 172 [Min Grade: D]

BMES 484 Genome Information Engineering 4.5 Credits
This course is designed to provide students with hands-on experience in the application of genomic, proteomic, and other large-scale information to biomedical engineering. The underlying goal is to develop an understanding of highthrough underlying technologies, biological challenges, and key mathematical and computational methods relevant to biomedical engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 483 [Min Grade: D]

BMES 488 Medical Device Development 3.0 Credits
Medical device product development must take into account a diverse set of disciplines to achieve a safe and successful product. This course exposes the student to several of these disciplines with the objective of raising the student¿s awareness of safety throughout the product development life cycle. Students will learn to appreciate the complex engineering decisions that support development of a safe medical device through an examination of risk management, regulatory processes, human factors and clinical studies.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 391 [Min Grade: D] and BMES 392 [Min Grade: D]

BMES 491 [WI] Senior Design Project I 3.0 Credits
This is the first course in a three-quarter capstone design experience for senior biomedical engineering students.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.

BMES 492 Senior Design Project II 2.0 Credits
Continues senior design activities begun in BMES 492.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.

BMES 493 Senior Design Project III 3.0 Credits
Continues the design project begun in BMES 491 and continued through BMES 492.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.

BMES 494 Clinical Practicum I 3.0 Credits
This course provides biomedical engineering students with an extensive exposure to live clinical cardiology procedures, including cardiac catheterization, electrophysiology, echocardiography and nuclear stress testing. Emphasis is placed on identifying important interfaces between engineering and clinical medicine, particularly in areas where clinical needs may be addressed by advances in biomedical engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if major is BME.

BMES 495 Clinical Practicum II 3.0 Credits
This course provides biomedical engineering students with an extensive exposure to live operations in an emergency department and intensive care unit. The students are expected to analyze specific operations within these environments and develop a solution to a process problem within one of these environments. System analysis, design and evaluation are emphasized.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if major is BME.

BMES 496 Clinical Practicum III 3.0 Credits
This course provides biomedical engineering students with an opportunity to observe basic operative and postoperative procedures with the idea of both learning about such procedures and identifying the role of biomedical engineering in these clinical settings.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if major is BME.

BMES 499 Independent Study in Biomedical Engineering and Science 0.5-6.0 Credits
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit

Biomechanics and Human Performance Engineering Concentration

About the Program

Bachelor of Science in Biomedical Engineering (BMES): 197.5 quarter credits

The concentration in biomechanics and human performance engineering provides students with the background and skills needed to create work and living environments which improve human health and enhance performance.

The biomechanics concentration applies engineering principles to study the interactions between humans and various machine systems in both working and living environments. Courses in this area of specialization cover such topics as the mechanics of materials, chronobiology, biomechanics, and human factors and cognitive engineering.

Upon graduation, students will be able to:

- model the effects of external forces on the human body and its tissues;
- design implanted prosthetic devices through an understanding of the interaction between biological tissues and engineering material;
- understand neural control of posture and locomotion;
- apply system approaches to the interaction of humans with their environment in order to optimize performance;
- design devices to aid people with disabilities by capitalizing on their engineering skills and human performance criteria.

The School maintains extensive facilities and laboratories devoted to areas of research. Visit the School's BIOMED Research Facilities and Laboratory Map (http://www.biomed.drexel.edu/new04/Content/research/facilities) web page for more details about the laboratories and equipment available.

For more information about this concentration, see Drexel's School of Biomedical Engineering, Science, and Health Systems (http://www.biomed.drexel.edu/new04) web site.

Degree Requirements

General education requirements		
HIST 285	Technology in Historical Perspective	3.0
ENGL 101	Composition and Rhetoric I: Inquiry and Exploratory Research	3.0
ENGL 102	Composition and Rhetoric II: The Craft of Persuasion	3.0
ENGL 103	Composition and Rhetoric III: Thematic Analysis Across Genres	3.0
UNIV 101	The Drexel Experience	2.0
Liberal and General Studies Electives (5)		15.0
Free Elective		2.0
Engineering core courses		
MATH 121	Calculus I	4.0
MATH 122	Calculus II	4.0
MATH 200	Multivariate Calculus	4.0
PHYS 101	Fundamentals of Physics I	4.0
PHYS 102	Fundamentals of Physics II	4.0
PHYS 201	Fundamentals of Physics III	4.0
CHEM 101	General Chemistry I	3.5
CHEM 102	General Chemistry II	4.5
BIO 122	Cells and Genetics	4.5
ENGR 100	Beginning Computer Aided Drafting for Design	1.0
ENGR 101	Engineering Design Laboratory I	2.0
ENGR 102	Engineering Design Laboratory II	2.0
ENGR 102	Engineering Design Laboratory II	2.0
ENGR 103	Engineering Design Laboratory III	2.0
ENGR 210	Introduction to Thermodynamics	3.0
ENGR 220	Fundamentals of Materials	4.0
ENGR 231	Linear Engineering Systems	3.0
ENGR 232	Dynamic Engineering Systems	3.0
MEM 202	Statics	3.0
Required Biomedical Engineering courses		
BIO 201	Human Physiology I	4.0
BIO 203	Human Physiology II	4.0
BMES 124	Biomedical Engineering Freshman Seminar I	1.0
BMES 126	Biomedical Engineering Freshman Seminar II	1.0
BMES 130	Problem Solving in Biomedical Engineering	2.0
BMES 201	Programming and Modeling for Biomedical Engineers I	3.0
BMES 202	Programming and Modeling for Biomedical Engineers ll	3.0
BMES 212	The Body Synthetic	3.0
BMES 302	Laboratory II: Biomeasurements	2.0
BMES 303	Laboratory III: Biomedical Electronics	2.0
BMES 310	Biomedical Statistics	4.0
BMES 325	Principles of Biomedical Engineering I	3.0
BMES 326	Principles of Biomedical Engineering II	3.0
BMES 338	Biomedical Ethics and Law	3.0
BMES 372	Biosimulation	3.0
BMES 381	Junior Design Seminar I	2.0
BMES 382	Junior Design Seminar II	2.0
BMES 491 [WI]	Senior Design Project I	3.0
BMES 492	Senior Design Project II	2.0
BMES 493	Senior Design Project III	3.0
ECE 201	Foundations of Electric Circuits	3.0
Biomechanics and Human Performance Engineering concentration courses		
BMES 301	Laboratory I: Experimental Biomechanics	2.0
BMES 305	Laboratory V: Musculoskeletal Anatomy for Biomedical Engineers	2.0
BMES 345	Mechanics of Biological Systems	3.0
BMES 375	Computational Bioengineering	4.0
or BMES 401	Biosensors I	
BMES 411	Chronoengineering I: Biological Rhythms in Health and Performance	3.0
BMES 412	Chronoengineering II: Sleep Functions in Health and Performance	3.0
BMES 430	Neural Aspects of Posture and Locomotion	3.0
BMES 440	Introduction to Biodynamics	3.0
BMES 441	Biomechanics I: Introduction to Biomechanics	4.0
BMES 442	Biomechanics II: Musculoskeletal Modeling and Human Performance	4.0
BMES 444	Biofluid Mechanics	3.0
BMES 451	Transport Phenomena in Living Systems	4.0
MEM 201	Foundations of Computer Aided Design	3.0
MEM 238	Dynamics	4.0
PSY 101	General Psychology I	3.0
Biomechanics and Human Performance Electives (3)		9.0
Suggested Biomechanics and Human Performance concentration electives		
PSY 213	Sensation and Perception	
PSY 332	Human Factors and Cognitive Engineering	
PSY 410	Neuropsychology	
Total Credits		**205.5**

Sample Plan of Study

Term 1		**Credits**
BMES 124	Biomedical Engineering Freshman Seminar I	1.0
CHEM 101	General Chemistry I	3.5
ENGL 101	Composition and Rhetoric I: Inquiry and Exploratory Research	3.0
ENGR 100	Beginning Computer Aided Drafting for Design	1.0
ENGR 101	Engineering Design Laboratory I	2.0
MATH 121	Calculus I	4.0
UNIV R101	The Drexel Experience	1.0
	Term Credits	**15.5**
Term 2		
BMES 126	Biomedical Engineering Freshman Seminar II	1.0
CHEM 102	General Chemistry II	4.5
ENGL 102	Composition and Rhetoric II: The Craft of Persuasion	3.0
ENGR 102	Engineering Design Laboratory II	2.0
MATH 122	Calculus II	4.0
PHYS 101	Fundamentals of Physics I	4.0
UNIV R101	The Drexel Experience	0.5
	Term Credits	**19.0**
Term 3		
BIO 122	Cells and Genetics	4.5
BMES 130	Problem Solving in Biomedical Engineering	2.0
ENGL 103	Composition and Rhetoric III: Thematic Analysis Across Genres	3.0
ENGR 103	Engineering Design Laboratory III	2.0
MATH 200	Multivariate Calculus	4.0
PHYS 102	Fundamentals of Physics II	4.0
UNIV R101	The Drexel Experience	0.5
	Term Credits	**20.0**
Term 4		
BIO 201	Human Physiology I	4.0
BMES 201	Programming and Modeling for Biomedical Engineers I	3.0
ENGR 220	Fundamentals of Materials	4.0
ENGR 231	Linear Engineering Systems	3.0
PHYS 201	Fundamentals of Physics III	4.0
	Term Credits	**18.0**
Term 5		
BMES 202	Programming and Modeling for Biomedical Engineers ll	3.0
BMES 212	The Body Synthetic	3.0
BMES 235	Living Systems Engineering	4.0
ENGR 210	Introduction to Thermodynamics	3.0
ENGR 232	Dynamic Engineering Systems	3.0
MEM 202	Statics	3.0
	Term Credits	**19.0**
Term 6		
BMES 301	Laboratory I: Experimental Biomechanics	2.0
BMES 302	Laboratory II: Biomeasurements	2.0
BMES 325	Principles of Biomedical Engineering I	3.0
BMES 345	Mechanics of Biological Systems	3.0
BMES 372	Biosimulation	3.0
ECE 201	Foundations of Electric Circuits	3.0
	Term Credits	**16.0**
Term 7		
BMES 303	Laboratory III: Biomedical Electronics	2.0
BMES 310	Biomedical Statistics	4.0
BMES 326	Principles of Biomedical Engineering II	3.0
MEM 230	Mechanics of Materials I	4.0
PSY 101	General Psychology I	3.0
	Term Credits	**16.0**
Term 8		
BMES 305	Laboratory V: Musculoskeletal Anatomy for Biomedical Engineers	2.0
BMES 338	Biomedical Ethics and Law	3.0
BMES 381	Junior Design Seminar I	2.0
BMES 411	Chronoengineering I: Biological Rhythms in Health and Performance	3.0
BMES 430	Neural Aspects of Posture and Locomotion	3.0
Biomechanics & Human Performance Concentration Elective[*]		3.0
	Term Credits	**16.0**
Term 9		
BMES 382	Junior Design Seminar II	2.0
BMES 412	Chronoengineering II: Sleep Functions in Health and Performance	3.0
MEM 238	Dynamics	4.0
BMES 401 or 375	Biosensors I Computational Bioengineering	4.0
Liberal Studies Elective		3.0
	Term Credits	**16.0**
Term 10		
BMES 440	Introduction to Biodynamics	3.0
BMES 441	Biomechanics I: Introduction to Biomechanics	4.0
BMES 451	Transport Phenomena in Living Systems	4.0
BMES 491 [WI]	Senior Design Project I	3.0
Liberal Studies Elective		3.0
	Term Credits	**17.0**
Term 11		
HIST 285	Technology in Historical Perspective	3.0
BMES 442	Biomechanics II: Musculoskeletal Modeling and Human Performance	4.0
BMES 492	Senior Design Project II	2.0
Biomechanics & Human Performance Concentration Elective[*]		3.0
General Studies Elective		3.0
	Term Credits	**15.0**
Term 12		
BMES 444	Biofluid Mechanics	3.0
BMES 493	Senior Design Project III	3.0
General Studies Elective		3.0

Biomechanics & Human Performance Concentration Elective*	3.0
Term Credits	**12.0**

Total Credit: 199.5

* See degree requirements.

Opportunities

Metropolitan Philadelphia has one of the highest concentrations of medical institutions and pharmaceutical and biotechnology industries in the nation.The bachelor of science degree in biomedical engineering gives students access to a broad spectrum of career opportunities in medical device and equipment industry; prosthetics and assist devices industry; biomaterials and implants industry; and the telemedicine, pharmaceutical, biotechnology, and agricultural sectors.

Biomedical engineering graduates are also ideally prepared for professional education in medicine, dentistry, veterinary medicine, and law. Those who choose to pursue graduate education can aim for careers in research and development, biomedical technology innovation and transfer, as well as health care technology management.

Visit the Drexel Steinbright Career Development Center (http://www.drexel.edu/scdc) page for more detailed information on co-op and post-graduate opportunities.

Biomedical Engineering, Science and Health Systems Faculty

Fred D. Allen, PhD *(University of Pennsylvania)*. Assistant Professor. Tissue engineering, cell engineering, orthopedics, bone remodeling, wound healing, mechanotransduction, signal transduction, adhesion, migration.

Sriram Balasubramanian, PhD *(Wayne State University)*. Assistant Professor. Structural characteristics of the pediatric thoracic cage using CT scans and developing an age-equivalent animal model for pediatric long bones.

Kenneth A. Barbee, PhD *(University of Pennsylvania)*. Professor. Cellular biomechanics of neural and vascular injury, mechanotransduction in the cardiovascular system, mechanical control of growth and development for wound healing and tissue engineering.

Lin Han, PhD *(Massachusetts Institute of Technology)*. Assistant Professor. Nanoscale structure-property relationships of biological materials, genetic and molecular origins soft joint tissue diseases, biomaterials under extreme conditions, coupling between stimulus-responsiveness and geometry.

Uri Hershberg, PhD *(Hebrew University of Jerusalem, Israel)*. Assistant Professor. Bioinformatics, immunology, neural computation, system biology, somatic selection, autoimmunity, genetic stability, germline diversity, dendritic cell, transcription elements, pathogens, computational and mathematical modeling, complex systems, cognition and inflammation.

Joshua Jacobs, PhD *(University of Pennsylvania)*. Assistant Professor. Neuroengineering, electrocorticography (ECoG), electroencephalography (EEG), single-neuron spiking, brain oscillations, episodic memory, working memory, spatial navigation, conceptual representations.

Dov Jaron, PhD *(University of Pennsylvania) Calhoun Distinguished Professor of Engineering in Medicine*. Professor. Mathematical, computer and electromechanical simulations of the cardiovascular system.

Andres Kriete, PhD *(University in Bremen Germany) Associate Director for Graduate Studies and Academic Operations*. Systems biology, bioimaging, control theory, biology of aging, skin cancer.

Ryszard Lec, PhD *(University of Warsaw Engineering College)*. Professor. Biomedical applications of visoelastic, acoustoptic and ultrasonic properties of liquid and solid media.

Peter Lewin, PhD *(University of Denmark, Copenhagen-Lyngby) Richard B. Beard Professor, School Of Biomedical Engineering, Science & Health Systems*. Professor. Biomedical ultrasonics, piezoelectric and polymer transducers and hydrophones; shock wave sensors.

Hualou Liang, PhD *(Chinese Academy of Sciences)*. Associate Professor. Neuroengineering, neuroinformatics, cognitive and computational neuroscience, neural data analysis and computational modeling, biomedical signal processing.

Donald L. McEachron, PhD *(University of California at San Diego) Associate Director*. Research Professor. Animal behavior, autoradiography, biological rhythms, cerebral metabolism, evolutionary theory, image processing, neuroendocrinology.

Karen Moxon, PhD *(University of Colorado)*. Associate Professor. Cortico-thalamic interactions; neurobiological perspectives on design of humanoid robots.

Banu Onaral, Ph.D. *(University of Pennsylvania) H.H. Sun Professor / Director, School of Biomedical Engineering Science and Health Systems*. Professor. Biomedical signal processing; complexity and scaling in biomedical signals and systems.

Kambiz Pourrezaei, PhD *(Rensselaer Polytechnic University)*. Professor. Thin film technology; nanotechnology; near infrared imaging; power electronics.

Arye Rosen, PhD *(Drexel University) Biomedical Engineering and Electrical Engineering*. Microwave components and subsystems; utilization of RF/microwaves and lasers in therapeutic medicine.

Ahmet Sacan, PhD *(Middle East Technical University)*. Assistant Professor. Indexing and data mining in biological databases; protein sequence and structure; similarity search; protein structure modeling; protein-protein interaction; automated cell tracking.

Joseph J. Sarver, PhD *(Drexel University)*. Teaching Professor. Neuromuscular adaptation to changes in the myo-mechanical environment.

Rahamim Seliktar, PhD *(University of Strathclyde, Glasgow) Vice Director, School of Biomedical Engineering, Science & Health Systems*. Professor. Limb prostheses, biomechanics of human motion, orthopedic biomechanics.

Adrian C. Shieh, PhD *(Rice University)*. Assistant Professor. Contribution of mechanical forces to tumor invasion and metastasis, with a particular emphasis on how biomechanical signals may drive the invasive switch, and how the biomechanical microenvironment interacts with cytokine signaling and the extracellular matrix to influence tumor and stromal cell behavior.

Wan Young Shih, PhD *(Ohio State University) School of Biomedical Engineering, Science and Health Systems*. Associate Professor. Piezoelectric microcantilever biosensors development, piezoelectric finger development, quantum dots development, tissue elasticity imaging, piezoelectric microcantilever force probes.

Kara Spiller, PhD *(Drexel University)*. Assistant Professor. Cell-biomaterial interactions, biomaterial design, and international engineering education.

Margaret Wheatley, PhD *(University of Toronto) School of Biomedical Engineering, Science and Health Systems, John M. Reid Professor*. Ultrasound contrast agent development (tumor targeting and triggered drug delivery), controlled release technology (bioactive compounds), microencapsulated allografts (*ex vivo* gene therapy) for spinal cord repair.

Yinghui Zhong, PhD *(Georgia Institute of Technology)*. Assistant Professor. Spinal cord repair, and engineering neural prosthesis/brain interface using biomaterials, drug delivery, and stem cell therapy.

Interdepartmental Faculty

Douglas L. Chute, PhD *(University of Missouri) Louis and Bessie Stein Fellow*. Professor. Neuropsychology and rehabilitation; technological applications for the cognitively compromised and those with acquired brain injuries.

Patricia A. Shewokis, PhD *(University of Georgia)*. Professor. Roles of cognition and motor function during motor skill learning; role of information feedback frequency on the memory of motor skills, noninvasive neural imaging techniques of functional near infrared spectroscopy(fNIR) and electroencephalograpy (EEG) and methodology and research design.

Emeritus Faculty

William Freedman, PhD *(Drexel University)*. Professor Emeritus. Motor control; sensory and motor systems; reflexes; eye movements; neural networks.

John M. Reid, PhD *(University of Pennsylvania) Calhoun Professor Emeritus*. Professor Emeritus. Diagnostic ultrasound, wave propagation and scattering in inhomogeneous media, imaging, instrumentation.

Hun H. Sun, PhD *(Cornell University)*. Professor Emeritus. Biological control systems, physiological modeling, systems analysis.

Aydin Tozeren, PhD *(Columbia University) Distinguished Professor and Director, Center for Integrated Bioinformatics, School of Biomedical Engineering, Science & Health Systems*. Professor Emeritus. Breast cell adhesion and communication, signal transduction networks in cancer and epithelial cells; integrated bioinformatics, molecular profiling, 3D-tumors, bioimaging.

Courses

BMES 124 Biomedical Engineering Freshman Seminar I 1.0 Credit
This course is intended to introduce freshman biomedical engineering students in the School of biomedical Engineering, Science and Health Systems at Drexel University to academic programs and opportunities, ongoing research projects and University resources to ensure a successful educational experience at Drexel and beyond. Through class discussions and guest lecture presentations, the students are provided with information and contacts necessary to begin a plan of academic study.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 125 Foundations of Biomedical Engineering 2.0 Credits
This course is intended to introduce new transfer biomedical engineering students in the School of biomedical Engineering, Science and Health Systems at Drexel University academic programs and opportunities, ongoing research projects and University resources to ensure a successful educational experience at Drexel and beyond. Through class discussions and guest lecture presentations, the students are provided with information and contact necessary to begin a plan of academic study.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 126 Biomedical Engineering Freshman Seminar II 1.0 Credit
This course is intended to introduce freshman biomedical engineering students to the career embodied by the School's current concentration areas. Each area will be discussed in terms of the current state of the art, research possibilities and career opportunities. The curricula for each concentration will be discussed in detail so as to facilitate students' knowledge of how each curriculum relates to the research and employment opportunities in that field.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 130 Problem Solving in Biomedical Engineering 2.0 Credits
This course integrates fundamental principles of biology, chemistry, engineering, mathematics and physics into a framework for the study of biomedical engineering. In this course, students will use both engineering and scientific approaches to problem-solving. They will learn about the differences between engineering design and biological evolution. They will also learn to apply basic principles of chemistry, physics and mathematics to specific biological and physiological problems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MATH 122 [Min Grade: D] and CHEM 102 [Min Grade: D] and PHYS 101 [Min Grade: D]

BMES 201 Programming and Modeling for Biomedical Engineers I 3.0 Credits
This course aims to introduce students with some fundamental concepts about programming in MATLAB to give the ability to solve basic bioengineering problems. The course introduces the basics of programming using Matlab, including programming environment and tools. Fundamental programming techniques and concepts such as loops, switches and logical operators, functions and file handling are covered. Applications in bioengineering for basic numerical problem solving are discussed.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MATH 200 [Min Grade: D] and PHYS 102 [Min Grade: D] and BIO 122 [Min Grade: D] and (BMES 130 [Min Grade: D] or BMES 125 [Min Grade: D])

BMES 202 Programming and Modeling for Biomedical Engineers II 3.0 Credits
The course aims to introduce students to advanced programming concepts and tools to solve numerical problems in bioengineering. It provides the foundation for biosimulation and biocomputation classes. This course introduces advanced programming methods and computational tools for numerical analysis, model design and graphics. Higher level level lunctionality in Matlab such as SIMULINK, symbolic processing and CAD related tools are discussed.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 201 [Min Grade: D]

BMES 212 The Body Synthetic 3.0 Credits
The Body Synthetic introduces concepts underlying biological and engineering principles involved in the design and construction of prosthetic devices used to replace various parts of the human body.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: (TDEC 122 [Min Grade: D] or BIO 122 [Min Grade: D]) and (BMES 130 [Min Grade: D] or BMES 125 [Min Grade: D])

BMES 235 Living Systems Engineering 4.0 Credits
This course introduces the biomedical engineering students to engineering principles applied to biological and physiological systeTs. This course focuses.on evolution, adaptation, energy, thermodynamics, fluid dynamics and control systems in living organrsms.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 122 [Min Grade: D] and CHEM 102 [Min Grade: D] and MATH 200 [Min Grade: D] and PHYS 102 [Min Grade: D] and BMES 130 [Min Grade: D] and BIO 201 [Min Grade: D]

BMES 301 Laboratory I: Experimental Biomechanics 2.0 Credits
This course deals with experimental aspects of biomechanics, specifically with the testing mechanical properties of biological tissues.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (TDEC 114 [Min Grade: D] or MATH 200 [Min Grade: D]) and (TDEC 115 [Min Grade: D] or PHYS 201 [Min Grade: D]) and (TDEC 211 [Min Grade: D] or ENGR 231 [Min Grade: D]) and MEM 202 [Min Grade: D]

BMES 302 Laboratory II: Biomeasurements 2.0 Credits
This course introduces students to the measurement of physiological/biological/functional signals. Four specific signals will be collected and analyzed. Students are expected to analyze type of signal to be collected, possible measurement techniques and potential data analysis and then collect and analyze each signal.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: ECE 201 [Min Grade: D] (Can be taken Concurrently) (BMES 222 [Min Grade: D] or BIO 201 [Min Grade: D]) and (TDEC 231 [Min Grade: D] or ENGR 103 [Min Grade: D])

BMES 303 Laboratory III: Biomedical Electronics 2.0 Credits
This course introduces students to the widespread application of electronics and electronic devices in biomedical engineering. The course reinforces concepts learned in ECE 201 with hands-on experimentation related to biomedical applications such as telemedicine and medical devices.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (ECE 201 [Min Grade: D] and TDEC 231 [Min Grade: D]) or ENGR 232 [Min Grade: D]

BMES 304 Laboratory IV: Ultrasound Images 2.0 Credits
This course introduces students to the engineering principles of acoustical measurements by combining hands-on laboratory experiences with lectures. Students will learn the engineering/physical principles of measuring sound velocity in different materials, attenuation, and directivity of a circular transducers.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (BIO 201 [Min Grade: D] or BMES 235 [Min Grade: D]) and ECE 201 [Min Grade: D] and (TDEC 231 [Min Grade: D] or ENGR 103 [Min Grade: D])

BMES 305 Laboratory V: Musculoskeletal Anatomy for Biomedical Engineers 2.0 Credits
This course provides an opportunity for students to study the anatomy and biomechanics of select articulations of the human body. While the main emphasis will be on the musculoskeletal structures associated with each articulation, major neural and vascular structures will be studied as well.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: (BIO 201 [Min Grade: D] or BMES 235 [Min Grade: D]) and MEM 202 [Min Grade: D]

BMES 310 Biomedical Statistics 4.0 Credits
This course is designed to introduce biomedical engineering students to the fundamentals of biostatistics necessary for medical research. Topics covered include measurements, sampling, basic hypothesis testing, analysis of variance and regression. Medical applications are emphasized.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: ENGR 231 [Min Grade: D]

BMES 315 Experimental Design in Biomedical Research 4.0 Credits
This course is designed to introduce students to the fundamental principles of experimental design and statistical analysis as applied to biomedical research with animals and humans. Topics to be covered include experimental design, clinical design, and protocol submission and review.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 310 [Min Grade: D]

BMES 325 Principles of Biomedical Engineering I 3.0 Credits
This course is the first part of a two-term sequence which introduces biomedical engineering students to engineering principles applied to biological and physiological systems. This course focuses on bioethical questions, biomechanics, human performance engineering, biomaterials and tissue engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 122 [Min Grade: D] and CHEM 102 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and MEM 202 [Min Grade: D] and ENGR 220 [Min Grade: D] and ENGR 232 [Min Grade: D]

BMES 326 Principles of Biomedical Engineering II 3.0 Credits
This course is the second part of a two-term sequence which introduces biomedical engineering students to engineering principles applied to biological and physiological systems. This course focuses on bioinformatics, neuroengineering, biosignal processing, biosensors, and medical imaging.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 325 [Min Grade: D] and BIO 201 [Min Grade: D] and (BMES 202 [Min Grade: D] or ENGR 202 [Min Grade: D])

BMES 330 Biological Rhythm in Pharmacology and Toxicology 3.0 Credits
This course covers the fundamentals of biological rhythms with particular emphasis on the influence these cycles have on the susceptibility of organism to physical, chemical, and /or toxic agents.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman
Prerequisites: BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]

BMES 331 Computers in Health Systems I 3.0 Credits
Introduces the allied health professional to basic computer applications on personal computers. Includes word processing, spreadsheets, databases, and networking (e.g., e-mail and information search and retrieval) in a primarily Windows environment. Designed for individuals with little or no computer background. Students are encouraged to bring in their own work-related problems or projects to provide immediate application of knowledge learned to the student's professional healthcare environment.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 332 Computers in Health Systems II 3.0 Credits
Continues the general overview of computers for people in the allied health professions, using specific examples from health care. Offers further study of and practice with special scientific (e.g., statistics, graphing) and medical clinical decision-support software. Introduces algorithms and formal programming methods.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman

BMES 335 Biomedical Informatics I 3.0 Credits
Introduces information and information handling systems for people in the allied health professions, with specific examples drawn from health care. Covers locating, manipulating, and displaying information in the health system setting.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore

BMES 336 Biomedical Informatics II: Hospital and Patient Information 3.0 Credits
Continues BMES 335. Emphasizes medical records and hospital and patient information handling. Examines the problems of patient information flow within the health care system. Introduces conventional and proposed patient and hospital information systems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 335 [Min Grade: D]

BMES 338 Biomedical Ethics and Law 3.0 Credits
Introduces the wide spectrum of ethical, regulatory, and legal issues facing health care practitioners and health-related research workers. Helps students become aware of the ethical and legal issues involved in their work. Helps students understand how legal and ethical decisions should be made in health-related matters, as well as what sources of help and guidance are available.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman

BMES 340 Health Care Administration 3.0 Credits
This course provides students with an analysis of health care administration process, including: planning, organizing, designing, decision-making, leading, and controlling. Presents methods and techniques that can contribute to the effective performance of administrative duties.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman

BMES 345 Mechanics of Biological Systems 3.0 Credits
This course introduces the fundamentals of mechanics of deformable bodies as they relevant to biologicaltissues and biomaterials. Major topics include stress and strain, mechanical properties of biologicaltissues and biomaterials, axial loading, torsion, bending, and viscoelasticity, These concepts will be applied to biological examples such as long bones, the heart, blood vessels, and orthopaedic implants.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MEM 202 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D])

BMES 350 Med & Bio Effects Of Light 3.0 Credits
Examines the role of environmental lighting in human physiological and psychological processes. Topics include vitamin D synthesis and calcium regulation; light effects on bilirubin in newborns; photoactivation and DNA in skin; effects of nonionizing radiation on the immune systems; environmental lighting and human vision; light effects on biological rhythms and sleep; photosensitivity diseases related to interior lighting; the therapeutic uses of light; and light and the aging eye.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman
Prerequisites: BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]

BMES 363 Robotics in Medicine I 3.0 Credits
This course provides an introduction to the use of haptics (the use of somtaosensory information) in the design of robotic devices in surgery. Topics covered include actuators, sensors, nonportable feedback, portable force feedback, tactile feedback interfaces, haptic sensing and control systems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MEM 238 [Min Grade: D]

BMES 365 Robotics in Medicine II 3.0 Credits
This course covers the use of robots in surgery and included aspects of safety, robot kinematics, analysis of surgical performance using robotic devices, inverse kinematics, velocity analysis and acceleration analysis. Various types of surgeries in which robotic devices are or could be used are presented on a case study basis.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 363 [Min Grade: D]

BMES 372 Biosimulation 3.0 Credits
This course provides the foundation for the mathematical analysis of biomedical engineering systems. It focuses on the essential mathematical methods necessary for further development of modeling and simulation skills in other courses (materials, mechanics, fluids/transport, signals/control system, etc). The course applies the skills in calculus, differential equations and linear algebra gained in ENGR 231 and ENGR 232 to developing analytical techniques for biomedical applications.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and ENGR 231 [Min Grade: D] and ENGR 232 [Min Grade: D] and (BMES 201 [Min Grade: D] and BMES 202 [Min Grade: D]) or (ENGR 201 [Min Grade: D] and ENGR 202 [Min Grade: D])

BMES 375 Computational Bioengineering 4.0 Credits
This course introduces undergraduate students to the mathematical and computational analysis of biological systems. The systems analyzed include the genome, protein and gene networks, cell division cycles, and cellular level disease. Mathematical tools include matrix algebra, differential equations, cellular automata, cluster analysis, etc.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and BMES 325 [Min Grade: D] and BMES 372 [Min Grade: D] and ENGR 231 [Min Grade: D] and (TDEC 221 [Min Grade: D] or ENGR 232 [Min Grade: D])

BMES 381 Junior Design Seminar I 2.0 Credits
This is the first course in a two-course sequence intended to present the basics of engineering design, project management, product development and translational research. This first course focuses on engineering design and product development. A case-study approach is used to illustrate best practices and common mistakes in engineering design.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore

BMES 382 Junior Design Seminar II 2.0 Credits
This is the second course in a two-course sequence intended to present the basics of engineering design, project management, product development and translational research. This second course focuses on project management and quality control. A case-study approach is used to illustrate best practices and common mistakes in management and evaluation of engineering projects.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: BMES 381 [Min Grade: D]

BMES 391 Biomedical Instrumentation I 3.0 Credits
This course introduces the student to the medical instrumentation and provides background on the physical, chemical, electronic and computational fundamentals by which medical instrumentation operates. It is an analytical course exploring the design, operation, safety aspects and calibration of primary electronic instruments.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: ECE 201 [Min Grade: D] and (TDEC 202 [Min Grade: D] or ENGR 210 [Min Grade: D]) and (TDEC 221 [Min Grade: D] or ENGR 231 [Min Grade: D]) and ENGR 232 [Min Grade: D] and (BMES 235 [Min Grade: D] or BIO 203 [Min Grade: D])

BMES 392 Biomedical Instrumentation II 3.0 Credits
Continues BMES 391. Explores the operation, safety aspects, and calibration of primarily optical and acoustical instruments, as well as those involving ionizing radiation. Also examines instrumentation primarily intended for particular departments and areas, such as anesthesia and infusion.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: BMES 391 [Min Grade: D]

BMES 401 Biosensors I 4.0 Credits
Introduces the general topic of microsensors, discusses basic sensing mechanisms for microsensors, and presents various types of conductometric, acoustic, silicon, and optical microsensors. Uses two case studies that include an acoustic immunosensor and silicon glucose sensor to provide students with in-depth knowledge and hands-on experience. Provides additional experience through three laboratory sessions that support the lectures and familiarize students with practical aspects of microsensors. Also discusses applications of microsensors in the medical, chemical, pharmaceutical, environmental, aeronautical, and automotive industries.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D]) and (TDEC 202 [Min Grade: D] or ENGR 210 [Min Grade: D]) and (TDEC 221 [Min Grade: D] or ENGR 231 [Min Grade: D]) and ECE 201 [Min Grade: D] and ENGR 232 [Min Grade: D]

BMES 402 Biosensors II 4.0 Credits
Investigates modern biosensor design methods and addresses the challenges associated with fabrication technologies and instrumentation techniques. Topics include theory and modeling of biosensors, biosensor fabrication steps, and electronic and clinical testing methods. Discusses local and distant sensor data acquisition techniques. Students will design, fabricate and test a biosensor. Essential stages of biosensor manufacturing processes will be outlined. Some or all pre-requisites may be taken as either a pre-requisite or co-requisite. Please see the department for more information.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: BMES 401 [Min Grade: D] (Can be taken Concurrently)

BMES 403 Biosensors III 4.0 Credits
Covers recent advances in biosensor technology and applications, business aspects, and technology transfer issues. Topics include new sensing mechanisms, new technologies, new biomedical applications, the starting of small sensor companies, and the introduction of new sensor technologies into industrial settings. Requires students to develop a technical proposal in the area of biosensors and to review proposals written by their peers. Presentations by regular faculty and industrial and government researchers form an integral part of the course.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: BMES 402 [Min Grade: D]

BMES 405 Physiological Control Systems 3.0 Credits
Introduces the basic concepts of feedback and feed forward controls systems, including characterizations in terms of prescribed constraints, study of input and output relationships for various types of physiological systems, and stability and time-delay problems. Covers mathematical models of physiological systems, with emphasis on non-linear and adaptive systems study.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and ECES 356 [Min Grade: D] and BMES 372 [Min Grade: D]

BMES 409 Entrepreneurship for BMES 3.0 Credits
This course serves as the foundation course in entrepreneurship and is designed to provide students with a complete working knowledge of the modern entrepreneurial and business planning process.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 411 Chronoengineering I: Biological Rhythms in Health and Performance 3.0 Credits
Introduces students to the concepts of biological, and especially circadian, rhythmicity. Advances students' knowledge of biological time-keeping and adaptive functions of biological clocks. Topics include biochemical and physiological models of biological clocks, adjustment to environmental cycles, rhythms in behavior and physiological functions, sleep-wake cyclicity, adaptability of circadian systems, and influences of rhythms on human physiology and behavior. Designed to give students a thorough understanding of the role rhythms play in animal and human behavior, physiology, and medicine.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D])

BMES 412 Chronoengineering II: Sleep Functions in Health and Performance 3.0 Credits
Continues BMES 411. Enhances students' education in the concepts of biological, and especially circadian, rhythmicity. Focuses on sleep patterns, rhythms, evolution, neurology, psychology, and overall function.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: BMES 411 [Min Grade: D]

BMES 421 Biomedical Imaging Systems I: Images 4.0 Credits
Provides an overview of the field of medical imaging. Covers aspects of light imaging; systems theory, convolutions, and transforms; photometry, lenses, and depth of field; image perception and roc theory; three-dimensional imaging; image acquisition and display; and image processing operations, including scanning and segmentation.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: (TDEC 115 [Min Grade: D] and ECES 302 [Min Grade: D] and ECES 304 [Min Grade: D] and BMES 325 [Min Grade: D] and BMES 326 [Min Grade: D]) or PHYS 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (MATH 311 [Min Grade: D] or BMES 310 [Min Grade: D]) and (TDEC 222 [Min Grade: D] or ENGR 231 [Min Grade: D]) and ENGR 232 [Min Grade: D]

BMES 422 Biomedical Imaging Systems II: Ultrasound 4.0 Credits
Intended for students who would like to gain an adequate understanding of diagnostic ultrasound imaging principles and become familiar with developments in this rapidly expanding field. Introduces medical visualization techniques based on ultrasound propagation in biological tissues. Topics include generation and reception of ultrasound, imaging techniques (A-mode, B-mode, M-mode, and Doppler), typical and emerging diagnostic applications, elements of ultrasound exposimetry, and safety aspects from the clinical point of view.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 421 [Min Grade: D]

BMES 423 Biomedical Imaging Systems III 4.0 Credits
Covers volumetric and functional imaging systems. Discusses the principles and algorithms of projection tomography, XCAT, SPECT, PET; the principles of MRI: Bloch equation, slice selection, K-space scanning, volumetric MRI; biochemical imaging; chemical equilibrium equations and Scatchard plots, specific and nonspecific labeling; autoradiography; and flow and dynamical systems: Doppler, mass transport, and phase (MRI) measurement of flow.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 422 [Min Grade: D]

BMES 430 Neural Aspects of Posture and Locomotion 3.0 Credits
Students will study the physiology of ensory/motor systems, with emphasis on modeling of neural systems and biomechanical aspects of functional tasks. Combines information on basic nerve cell activities, synaptic communication and structure/function relationships of skeletal muscle with basic mechanics to study spinal, vestibular and ocular reflexes. Culminates with the study of the control of motor systems with respect to bipedal motion.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (BMES 201 [Min Grade: D] and BMES 202 [Min Grade: D]) or (ENGR 201 [Min Grade: D] and ENGR 202 [Min Grade: D]) and MEM 202 [Min Grade: D]

BMES 432 Biomedical Systems and Signals 3.0 Credits
Introduces various aspects of biomedical signals, systems, and signal processing. Covers topics in the origin and acquisition of biomedical signals; discrete-time signals and linear systems; frequency analysis of discrete-time signals, spectral estimation, data records and digital filters; and compression of biomedical signals through time-domain and frequency-domain coding.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: ECES 302 [Min Grade: D] and ECES 304 [Min Grade: D]

BMES 440 Introduction to Biodynamics 3.0 Credits
The objective of the course is to prepare students for biomechanical modeling, modeling methods, formulation of equations of motion and methods of determination of strength will be applied to human body dynamics. Particular emphasis is placed on the use of Rigid Body and Multi-Body Dynamics.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MEM 202 [Min Grade: D] and (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D]) and MEM 238 [Min Grade: D] and (BMES 235 [Min Grade: D] or BIO 203 [Min Grade: D])

BMES 441 Biomechanics I: Introduction to Biomechanics 4.0 Credits
Teaches students to use mechanical tools to get an introductory appreciation for solving biomechanical problems. Models human performance by using static, quasi-static, and dynamic approaches. Assesses overall loading of the musculoskeletal system during functional activities. Demonstrates introductory methods of estimation of forces in the joints and muscles and evaluates the endurance of the human tissues under traumatic loading conditions. Builds on existing knowledge in mechanics to illustrate the practical application of mechanical tools in the determination of human systems performance.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: MEM 202 [Min Grade: D] and (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D]) and MEM 238 [Min Grade: D] and (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D]) and BIO 203 [Min Grade: D]
Corequisite: BMES 440

BMES 442 Biomechanics II: Musculoskeletal Modeling and Human Performance 4.0 Credits
Teaches students to think biomechanically. Reviews and categorizes the various functional components (tissues) of the musculoskeletal system. Considers constraints of the joints and action of the soft and hard tissues, along with corresponding models. Computes joint and muscle forces. Discusses some aspect of postural stability of the whole musculoskeletal structure and reviews various methods of task performance.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 441 [Min Grade: D]

BMES 443 Biomechanics III: Mechanics of Biological Tissues, Implant Technology and Prosthetics 4.0 Credits
Provides more advanced knowledge of mechanics of materials and offers a general description of mechanical behavior of the variety of the soft and hard tissues of the human body. Considers some prosthetic replacements of tissues as well as entire bone, joint, soft tissue, and system prosthetics. Reviews some specific orthopedic appliances and covers limb prosthetics if time permits. Students plan design projects.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 442 [Min Grade: D]

BMES 444 Biofluid Mechanics 3.0 Credits
This course introduces flow-related anatomy and pathophysiology, and biomedical flow devices and their design challenges. Analysis methods to solve biological fluid mechanics design problems will be introduced and several interdisciplinary team projects will be assigned to apply fluid mechanics to practical biological or medical problems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 451 [Min Grade: D]

BMES 451 Transport Phenomena in Living Systems 4.0 Credits
Introduces students to applications of chemical engineering concepts in biological systems. Shows that chemical engineering approaches to problem solving are ideally suited to investigation of biology. Approaches include material and energy balances, transport phenomena, and kinetics.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: (TDEC 115 [Min Grade: D] or PHYS 201 [Min Grade: D]) and (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D]) and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (TDEC 202 [Min Grade: D] or ENGR 210 [Min Grade: D]) and ENGR 232 [Min Grade: D]

BMES 452 Transport Phenomena in Living Systems II 3.0 Credits
Continues BMES 451. Advances students' understanding of the engineering principles of membrane transport and its consequences at the subcellular (mitochondria), cellular (neuron), and organ (kidney) level. Introduces concepts associated with pharmacokinetics. Provides students with a kinetic approach to analysis of receptors, including the kinetics of ligand-receptor binding, rate constants, and signal transduction.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: BMES 451 [Min Grade: D]

BMES 460 Biomaterials I 4.0 Credits
First course in a three-quarter sequence designed to acquaint students with the behavior of materials used in biomedical application under load (i.e., mechanical properties), their modes of failure and as a function of their environment. This course provides students with the fundamentals needed to proceed with Biomaterials II.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D]) and CHEM 241 [Min Grade: D] and CHEM 242 [Min Grade: D]

BMES 461 Biomaterials II 4.0 Credits
Second course in a three-quarter sequence in biomaterials. The goal of this course is with an understanding of, and ability to select, appropriate materials for specific applications taking into account mechanical, thermal, and rheological properties taught in Biomaterials I and combining them with the biocompatibility issues covered in the present course.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 460 [Min Grade: D]

BMES 466 Robotics in Medicine III 3.0 Credits
This course covers topics in the design of medical robotic systems, including force and movement analysis for robotic arms, dynamics, computer vision and vision-based control. Thus use of haptics, vision systems and robot dynamics are examined in a cohesive framework.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 365 [Min Grade: D]

BMES 471 Cellular and Molecular Foundations of Tissue Engineering 4.0 Credits
Course is designed to familiarize students with the advanced concepts of cellular and molecular biology and physiology relevant to tissue engineering. The initial part of a two-quarter sequence combining material from cellular/molecular biology, evolutionary/developmental biology with engineering design and biomaterials to educate students in the principles, methods, and technology of tissue engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BIO 218 [Min Grade: D] and BIO 122 [Min Grade: D] and BIO 219 [Min Grade: D] and CHEM 242 [Min Grade: D] and (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D])

BMES 472 Developmental and Evolutionary Foundations of Tissue Engineering 4.0 Credits
Familiarizes students with advanced concepts of developmental and evolutionary biology relevant to tissue engineering. This second part of the two-quarter sequence combines material from cellular/molecular biology and evolutionary design and biomaterials to educate students in the principles, methods, and technology of tissue engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 471 [Min Grade: D]

BMES 475 Biomaterials and Tissue Engineering III 4.0 Credits
This course provides students with in-depth knowledge of factor-mediated tissue engineering and regenerative medicine. Students learn about fundamental repair and regenerative processes and gain an understanding of specific biomaterials being used to mimic and/or enhance such processes. Students also learn about the delivery methods of agents which promote the proper functional development of specialized tissues.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 460 [Min Grade: D] and BMES 461 [Min Grade: D] and BMES 471 [Min Grade: D] and BMES 472 [Min Grade: D]

BMES 477 Neuroengineering I: Neural Signals 3.0 Credits
Introduces the theory of neural signaling. Students will learn the fundamental theory of cellular potentials and chemical signaling, the Hodgkin Huxeley description of action potential generation, circuit representations of neurons and be able to derive and integrate equations describing the circuit as well as design computer models.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: ECES 302 [Min Grade: D] and ECES 304 [Min Grade: D] and ECES 356 [Min Grade: D] and BIO 203 [Min Grade: D] and BMES 405 [Min Grade: D] and BMES 430 [Min Grade: D]

BMES 478 Neuroengineering II: Principles of Neuroengineering 3.0 Credits
This course investigates cutting edge technologies in neuroengineering in a seminar-style format with faculty from the School of Biomedical Engineering and College of Medicine. Three modules cover topics, which vary from year to year. Students are expected to submit written and oral presentations covering each topic.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 477 [Min Grade: D]

BMES 480 Special Topics in Biomedical Engineering & Sciences 12.0 Credits
Covers topics related to the field of health care, systems, and technology. Past topics include health care administration.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit

BMES 483 Quantitative Systems Biology 4.5 Credits
This course uses a systems engineering approach to provide a foundation in systems biology and pathology informatics. Topics covered include the robust complex network of genes and proteins; cell as basic units of life; communication of cells with other cells and the environment; and gene circuits governing development.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: (TDEC 222 [Min Grade: D] or ENGR 232 [Min Grade: D]) and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (BMES 202 [Min Grade: D] or ENGR 202 [Min Grade: D]) and BMES 372 [Min Grade: D] and BMES 375 [Min Grade: D] and CS 172 [Min Grade: D]

BMES 484 Genome Information Engineering 4.5 Credits
This course is designed to provide students with hands-on experience in the application of genomic, proteomic, and other large-scale information to biomedical engineering. The underlying goal is to develop an understanding of highthrough underlying technologies, biological challenges, and key mathematical and computational methods relevant to biomedical engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 483 [Min Grade: D]

BMES 488 Medical Device Development 3.0 Credits
Medical device product development must take into account a diverse set of disciplines to achieve a safe and successful product. This course exposes the student to several of these disciplines with the objective of raising the student¿s awareness of safety throughout the product development life cycle. Students will learn to appreciate the complex engineering decisions that support development of a safe medical device through an examination of risk management, regulatory processes, human factors and clinical studies.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 391 [Min Grade: D] and BMES 392 [Min Grade: D]

BMES 491 [WI] Senior Design Project I 3.0 Credits
This is the first course in a three-quarter capstone design experience for senior biomedical engineering students.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.

BMES 492 Senior Design Project II 2.0 Credits
Continues senior design activities begun in BMES 492.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.

BMES 493 Senior Design Project III 3.0 Credits
Continues the design project begun in BMES 491 and continued through BMES 492.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.

BMES 494 Clinical Practicum I 3.0 Credits
This course provides biomedical engineering students with an extensive exposure to live clinical cardiology procedures, including cardiac catheterization, electrophysiology, echocardiography and nuclear stress testing. Emphasis is placed on identifying important interfaces between engineering and clinical medicine, particularly in areas where clinical needs may be addressed by advances in biomedical engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if major is BME.

BMES 495 Clinical Practicum II 3.0 Credits
This course provides biomedical engineering students with an extensive exposure to live operations in an emergency department and intensive care unit. The students are expected to analyze specific operations within these environments and develop a solution to a process problem within one of these environments. System analysis, design and evaluation are emphasized.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if major is BME.

BMES 496 Clinical Practicum III 3.0 Credits
This course provides biomedical engineering students with an opportunity to observe basic operative and postoperative procedures with the idea of both learning about such procedures and identifying the role of biomedical engineering in these clinical settings.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if major is BME.

BMES 499 Independent Study in Biomedical Engineering and Science 0.5-6.0 Credits
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit

Biomedical Informatics Concentration

About the Program

Bachelor of Science in Biomedical Engineering (BMES): 199.0 quarter credits
The biomedical informatics concentration focuses on the management, analysis and visualization of data that is generated in molecular and cellular biology, genomics and other areas of biology and biomedicine. Students are trained in the development of useful computational models of living systems and novel informatics technologies in life sciences.

Bioinformatics is an emerging field of science that is concerned with the management, analysis and visualization of the flood of data being generated in molecular and cellular biology, genomics and other areas of biology and biomedicine. The field of bioinformatics enables information at the gene, protein, cell, tissue, organ, and system level to be integrated

and interpreted for early detection, accurate diagnosis, and effective treatment of complex diseases such as cancer.

The biomedical informatics concentration includes courses in biology, computer science, and information technology. The concentration introduces information handling systems for people in the allied health professions, with specific examples drawn from health care and covers locating, manipulating, and displaying information in the health system setting. Students are also introduced to the mathematical and computational analysis of biological systems. The systems analyzed include the genome, protein and gene networks, cell division cycles, and cellular level disease. Mathematical tools include matrix algebra, differential equations, cellular automata, and cluster analysis.

Upon graduation, students will be able to:

- select, access and integrate bioinformatics related databases for applications in genomics and proteomics;
- apply biostatistical techniques to analyze high-throughput data for genotyping, gene expression and proteomics data;
- develop and evaluate computational models to describe and simulate gene regulatory, protein and metabolic networks.

The School maintains extensive facilities and laboratories devoted to areas of research. Visit the School's BIOMED Research Facilities and Laboratory Map (http://www.biomed.drexel.edu/new04/Content/research/facilities) page for more details about the laboratories and equipment available.

For more information about this concentration, see Drexel's School of Biomedical Engineering, Science, and Health Systems (http://www.biomed.drexel.edu/new04) website.

Degree Requirements

General education requirements		
HIST 285	Technology in Historical Perspective	3.0
ENGL 101	Composition and Rhetoric I: Inquiry and Exploratory Research	3.0
ENGL 103	Composition and Rhetoric III: Thematic Analysis Across Genres	3.0
ENGL 103	Composition and Rhetoric III: Thematic Analysis Across Genres	3.0
UNIV R101	The Drexel Experience	2.0
Liberal and General Studies Electives (5)		15.0
Engineering core courses		
MATH 121	Calculus I	4.0
MATH 122	Calculus II	4.0
MATH 200	Multivariate Calculus	4.0
PHYS 101	Fundamentals of Physics I	4.0
PHYS 102	Fundamentals of Physics II	4.0
PHYS 201	Fundamentals of Physics III	4.0
CHEM 101	General Chemistry I	3.5
CHEM 102	General Chemistry II	4.5
BIO 122	Cells and Genetics	4.5
ENGR 100	Beginning Computer Aided Drafting for Design	1.0
ENGR 101	Engineering Design Laboratory I	2.0
ENGR 102	Engineering Design Laboratory II	2.0
ENGR 103	Engineering Design Laboratory III	2.0
ENGR 210	Introduction to Thermodynamics	3.0
ENGR 220	Fundamentals of Materials	4.0
ENGR 231	Linear Engineering Systems	3.0
ENGR 232	Dynamic Engineering Systems	3.0
MEM 202	Statics	3.0
Required Biomedical Engineering courses		
BIO 201	Human Physiology I	4.0
BIO 203	Human Physiology II	4.0
BMES 124	Biomedical Engineering Freshman Seminar I	1.0
BMES 126	Biomedical Engineering Freshman Seminar II	1.0
BMES 130	Problem Solving in Biomedical Engineering	2.0
BMES 201	Programming and Modeling for Biomedical Engineers I	3.0
BMES 202	Programming and Modeling for Biomedical Engineers ll	3.0
BMES 212	The Body Synthetic	3.0
BMES 302	Laboratory II: Biomeasurements	2.0
BMES 303	Laboratory III: Biomedical Electronics	2.0
BMES 310	Biomedical Statistics	4.0
BMES 325	Principles of Biomedical Engineering I	3.0
BMES 326	Principles of Biomedical Engineering II	3.0
BMES 338	Biomedical Ethics and Law	3.0
BMES 372	Biosimulation	3.0
BMES 381	Junior Design Seminar I	2.0
BMES 382	Junior Design Seminar II	2.0
BMES 491 [WI]	Senior Design Project I	3.0
BMES 492	Senior Design Project II	2.0
BMES 493	Senior Design Project III	3.0
ECE 201	Foundations of Electric Circuits	3.0
Biomedical Informatics concentration courses		
BIO 219 [WI]	Techniques in Molecular Biology	2.5
BIO 218	Principles of Molecular Biology	4.0
BMES 315	Experimental Design in Biomedical Research	4.0
BMES 375	Computational Bioengineering	4.0
BMES 401	Biosensors I	4.0
BMES 483	Quantitative Systems Biology	4.5
BMES 484	Genome Information Engineering	4.5
CS 171	Computer Programming I	3.0
CS 172	Computer Programming II	3.0
CS 260	Data Structures	3.0
CS 265	Advanced Programming Tools and Techniques	3.0
INFO 110	Human-Computer Interaction I	3.0
INFO 200	Systems Analysis I	3.0
INFO 210	Database Management Systems	3.0
Bioinformatics concentration electives (2)		6.0
Suggested Bioinformatics Electives		
BMES 335	Biomedical Informatics I	
BMES 336	Biomedical Informatics II: Hospital and Patient Information	
Total Credits		**199.0**

Sample Plan of Study

Term 1		Credits
BMES 124	Biomedical Engineering Freshman Seminar I	1.0
CHEM 101	General Chemistry I	3.5
ENGL 101	Composition and Rhetoric I: Inquiry and Exploratory Research	3.0
ENGR 100	Beginning Computer Aided Drafting for Design	1.0
ENGR 101	Engineering Design Laboratory I	2.0
MATH 121	Calculus I	4.0
UNIV R101	The Drexel Experience	1.0
	Term Credits	**15.5**
Term 2		
BMES 126	Biomedical Engineering Freshman Seminar II	1.0
CHEM 102	General Chemistry II	4.5
ENGL 102	Composition and Rhetoric II: The Craft of Persuasion	3.0
ENGR 102	Engineering Design Laboratory II	2.0
MATH 122	Calculus II	4.0
PHYS 101	Fundamentals of Physics I	4.0
UNIV R101	The Drexel Experience	0.5
	Term Credits	**19.0**
Term 3		
BIO 122	Cells and Genetics	4.5
BMES 130	Problem Solving in Biomedical Engineering	2.0
ENGL 103	Composition and Rhetoric III: Thematic Analysis Across Genres	3.0
ENGR 103	Engineering Design Laboratory III	2.0
MATH 200	Multivariate Calculus	4.0
PHYS 102	Fundamentals of Physics II	4.0
UNIV R101	The Drexel Experience	0.5
	Term Credits	**20.0**
Term 4		
BIO 201	Human Physiology I	4.0
BMES 201	Programming and Modeling for Biomedical Engineers I	3.0
ENGR 220	Fundamentals of Materials	4.0
ENGR 231	Linear Engineering Systems	3.0
PHYS 201	Fundamentals of Physics III	4.0
	Term Credits	**18.0**
Term 5		
BMES 202	Programming and Modeling for Biomedical Engineers ll	3.0
BMES 212	The Body Synthetic	3.0
BMES 235	Living Systems Engineering	4.0
ENGR 210	Introduction to Thermodynamics	3.0
ENGR 232	Dynamic Engineering Systems	3.0
MEM 202	Statics	3.0
	Term Credits	**19.0**
Term 6		
BIO 218	Principles of Molecular Biology	4.0
BIO 219 [WI]	Techniques in Molecular Biology	2.5
BMES 325	Principles of Biomedical Engineering I	3.0
BMES 372	Biosimulation	3.0
CS 171	Computer Programming I	3.0
ECE 201	Foundations of Electric Circuits	3.0
	Term Credits	**18.5**
Term 7		
BMES 303	Laboratory III: Biomedical Electronics	2.0
BMES 310	Biomedical Statistics	4.0
BMES 326	Principles of Biomedical Engineering II	3.0
CS 172	Computer Programming II	3.0
INFO 110	Human-Computer Interaction I	3.0
	Term Credits	**15.0**
Term 8		
BMES 302	Laboratory II: Biomeasurements	2.0
BMES 315	Experimental Design in Biomedical Research	4.0
BMES 338	Biomedical Ethics and Law	3.0
BMES 381	Junior Design Seminar I	2.0
CS 265	Advanced Programming Tools and Techniques	3.0
INFO 200	Systems Analysis I	3.0
	Term Credits	**17.0**
Term 9		
BMES 375	Computational Bioengineering	4.0
BMES 382	Junior Design Seminar II	2.0
CS 260	Data Structures	3.0
INFO 210	Database Management Systems	3.0
General Studies Electives		3.0
	Term Credits	**15.0**
Term 10		
BMES 401	Biosensors I	4.0
BMES 491 [WI]	Senior Design Project I	3.0
HIST 285	Technology in Historical Perspective	3.0
General Studies Elective		3.0
Biomedical Informatics Concentration Elective (See degree requirements)		3.0
	Term Credits	**16.0**
Term 11		
BMES 483	Quantitative Systems Biology	4.5
BMES 492	Senior Design Project II	2.0
Biomedical Informatics Concentration Elective (See degree requirements)		3.0
General Studies Elective		3.0
	Term Credits	**12.5**
Term 12		
BMES 484	Genome Information Engineering	4.5
BMES 493	Senior Design Project III	3.0
General Studies Electives		6.0
	Term Credits	**13.5**
Total Credit: 199.0		

Opportunities

Metropolitan Philadelphia has one of the highest concentrations of medical institutions and pharmaceutical and biotechnology industries

in the nation.The bachelor of science degree in biomedical engineering gives students access to a broad spectrum of career opportunities in medical device and equipment industry; prosthetics and assist devices industry; biomaterials and implants industry; and the telemedicine, pharmaceutical, biotechnology, and agricultural sectors.

Biomedical engineering graduates are also ideally prepared for professional education in medicine, dentistry, veterinary medicine, and law. Those who choose to pursue graduate education can aim for careers in research and development, biomedical technology innovation and transfer, as well as health care technology management.

Visit the Drexel Steinbright Career Development Center (http://www.drexel.edu/scdc) page for more detailed information on co-op and post-graduate opportunities.

Biomedical Engineering, Science and Health Systems Faculty

Fred D. Allen, PhD *(University of Pennsylvania)*. Assistant Professor. Tissue engineering, cell engineering, orthopedics, bone remodeling, wound healing, mechanotransduction, signal transduction, adhesion, migration.

Sriram Balasubramanian, PhD *(Wayne State University)*. Assistant Professor. Structural characteristics of the pediatric thoracic cage using CT scans and developing an age-equivalent animal model for pediatric long bones.

Kenneth A. Barbee, PhD *(University of Pennsylvania)*. Professor. Cellular biomechanics of neural and vascular injury, mechanotransduction in the cardiovascular system, mechanical control of growth and development for wound healing and tissue engineering.

Lin Han, PhD *(Massachusetts Institute of Technology)*. Assistant Professor. Nanoscale structure-property relationships of biological materials, genetic and molecular origins soft joint tissue diseases, biomaterials under extreme conditions, coupling between stimulus-responsiveness and geometry.

Uri Hershberg, PhD *(Hebrew University of Jerusalem, Israel)*. Assistant Professor. Bioinformatics, immunology, neural computation, system biology, somatic selection, autoimmunity, genetic stability, germline diversity, dendritic cell, transcription elements, pathogens, computational and mathematical modeling, complex systems, cognition and inflammation.

Joshua Jacobs, PhD *(University of Pennsylvania)*. Assistant Professor. Neuroengineering, electrocorticography (ECoG), electroencephalography (EEG), single-neuron spiking, brain oscillations, episodic memory, working memory, spatial navigation, conceptual representations.

Dov Jaron, PhD *(University of Pennsylvania) Calhoun Distinguished Professor of Engineering in Medicine*. Professor. Mathematical, computer and electromechanical simulations of the cardiovascular system.

Andres Kriete, PhD *(University in Bremen Germany) Associate Director for Graduate Studies and Academic Operations*. Systems biology, bioimaging, control theory, biology of aging, skin cancer.

Ryszard Lec, PhD *(University of Warsaw Engineering College)*. Professor. Biomedical applications of visoelastic, acoustoptic and ultrasonic properties of liquid and solid media.

Peter Lewin, PhD *(University of Denmark, Copenhagen-Lyngby) Richard B. Beard Professor, School Of Biomedical Engineering, Science & Health Systems*. Professor. Biomedical ultrasonics, piezoelectric and polymer transducers and hydrophones; shock wave sensors.

Hualou Liang, PhD *(Chinese Academy of Sciences)*. Associate Professor. Neuroengineering, neuroinformatics, cognitive and computational neuroscience, neural data analysis and computational modeling, biomedical signal processing.

Donald L. McEachron, PhD *(University of California at San Diego) Associate Director*. Research Professor. Animal behavior, autoradiography, biological rhythms, cerebral metabolism, evolutionary theory, image processing, neuroendocrinology.

Karen Moxon, PhD *(University of Colorado)*. Associate Professor. Cortico-thalamic interactions; neurobiological perspectives on design of humanoid robots.

Banu Onaral, Ph.D. *(University of Pennsylvania) H.H. Sun Professor / Director, School of Biomedical Engineering Science and Health Systems*. Professor. Biomedical signal processing; complexity and scaling in biomedical signals and systems.

Kambiz Pourrezaei, PhD *(Rensselaer Polytechnic University)*. Professor. Thin film technology; nanotechnology; near infrared imaging; power electronics.

Arye Rosen, PhD *(Drexel University) Biomedical Engineering and Electrical Engineering*. Microwave components and subsystems; utilization of RF/microwaves and lasers in therapeutic medicine.

Ahmet Sacan, PhD *(Middle East Technical University)*. Assistant Professor. Indexing and data mining in biological databases; protein sequence and structure; similarity search; protein structure modeling; protein-protein interaction; automated cell tracking.

Joseph J. Sarver, PhD *(Drexel University)*. Teaching Professor. Neuromuscular adaptation to changes in the myo-mechanical environment.

Rahamim Seliktar, PhD *(University of Strathclyde, Glasgow) Vice Director, School of Biomedical Engineering, Science & Health Systems*. Professor. Limb prostheses, biomechanics of human motion, orthopedic biomechanics.

Adrian C. Shieh, PhD *(Rice University)*. Assistant Professor. Contribution of mechanical forces to tumor invasion and metastasis, with a particular emphasis on how biomechanical signals may drive the invasive switch, and how the biomechanical microenvironment interacts with cytokine signaling and the extracellular matrix to influence tumor and stromal cell behavior.

Wan Young Shih, PhD *(Ohio State University) School of Biomedical Engineering, Science and Health Systems*. Associate Professor. Piezoelectric microcantilever biosensors development, piezoelectric finger development, quantum dots development, tissue elasticity imaging, piezoelectric microcantilever force probes.

Kara Spiller, PhD *(Drexel University)*. Assistant Professor. Cell-biomaterial interactions, biomaterial design, and international engineering education.

Margaret Wheatley, PhD *(University of Toronto) School of Biomedical Engineering, Science and Health Systems, John M. Reid Professor*. Ultrasound contrast agent development (tumor targeting and triggered

drug delivery), controlled release technology (bioactive compounds), microencapsulated allografts (*ex vivo* gene therapy) for spinal cord repair.

Yinghui Zhong, PhD *(Georgia Institute of Technology)*. Assistant Professor. Spinal cord repair, and engineering neural prosthesis/brain interface using biomaterials, drug delivery, and stem cell therapy.

Interdepartmental Faculty

Douglas L. Chute, PhD *(University of Missouri) Louis and Bessie Stein Fellow*. Professor. Neuropsychology and rehabilitation; technological applications for the cognitively compromised and those with acquired brain injuries.

Patricia A. Shewokis, PhD *(University of Georgia)*. Professor. Roles of cognition and motor function during motor skill learning; role of information feedback frequency on the memory of motor skills, noninvasive neural imaging techniques of functional near infrared spectroscopy(fNIR) and electroencephalograpy (EEG) and methodology and research design.

Emeritus Faculty

William Freedman, PhD *(Drexel University)*. Professor Emeritus. Motor control; sensory and motor systems; reflexes; eye movements; neural networks.

John M. Reid, PhD *(University of Pennsylvania) Calhoun Professor Emeritus*. Professor Emeritus. Diagnostic ultrasound, wave propagation and scattering in inhomogeneous media, imaging, instrumentation.

Hun H. Sun, PhD *(Cornell University)*. Professor Emeritus. Biological control systems, physiological modeling, systems analysis.

Aydin Tozeren, PhD *(Columbia University) Distinguished Professor and Director, Center for Integrated Bioinformatics, School of Biomedical Engineering, Science & Health Systems*. Professor Emeritus. Breast cell adhesion and communication, signal transduction networks in cancer and epithelial cells; integrated bioinformatics, molecular profiling, 3D-tumors, bioimaging.

Courses

BMES 124 Biomedical Engineering Freshman Seminar I 1.0 Credit
This course is intended to introduce freshman biomedical engineering students in the School of biomedical Engineering, Science and Health Systems at Drexel University to academic programs and opportunities, ongoing research projects and University resources to ensure a successful educational experience at Drexel and beyond. Through class discussions and guest lecture presentations, the students are provided with information and contacts necessary to begin a plan of academic study.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 125 Foundations of Biomedical Engineering 2.0 Credits
This course is intended to introduce new transfer biomedical engineering students in the School of biomedical Engineering, Science and Health Systems at Drexel University academic programs and opportunities, ongoing research projects and University resources to ensure a successful educational experience at Drexel and beyond. Through class discussions and guest lecture presentations, the students are provided with information and contact necessary to begin a plan of academic study.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 126 Biomedical Engineering Freshman Seminar II 1.0 Credit
This course is intended to introduce freshman biomedical engineering students to the career embodied by the School's current concentration areas. Each area will be discussed in terms of the current state of the art, research possibilities and career opportunities. The curricula for each concentration will be discussed in detail so as to facilitate students' knowledge of how each curriculum relates to the research and employment opportunities in that field.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 130 Problem Solving in Biomedical Engineering 2.0 Credits
This course integrates fundamental principles of biology, chemistry, engineering, mathematics and physics into a framework for the study of biomedical engineering. In this course, students will use both engineering and scientific approaches to problem-solving. They will learn about the differences between engineering design and biological evolution. They will also learn to apply basic principles of chemistry, physics and mathematics to specific biological and physiological problems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MATH 122 [Min Grade: D] and CHEM 102 [Min Grade: D] and PHYS 101 [Min Grade: D]

BMES 201 Programming and Modeling for Biomedical Engineers I 3.0 Credits
This course aims to introduce students with some fundamental concepts about programming in MATLAB to give the ability to solve basic bioengineering problems. The course introduces the basics of programming using Matlab, including programming environment and tools. Fundamental programming techniques and concepts such as loops, switches and logical operators, functions and file handling are covered. Applications in bioengineering for basic numerical problem solving are discussed.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MATH 200 [Min Grade: D] and PHYS 102 [Min Grade: D] and BIO 122 [Min Grade: D] and (BMES 130 [Min Grade: D] or BMES 125 [Min Grade: D])

BMES 202 Programming and Modeling for Biomedical Engineers II 3.0 Credits
The course aims to introduce students to advanced programming concepts and tools to solve numerical problems in bioengineering. It provides the foundation for biosimulation and biocomputation classes. This course introduces advanced programming methods and computational tools for numerical analysis, model design and graphics. Higher level level lunctionality in Matlab such as SIMULINK, symbolic processing and CAD related tools are discussed.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 201 [Min Grade: D]

BMES 212 The Body Synthetic 3.0 Credits
The Body Synthetic introduces concepts underlying biological and engineering principles involved in the design and construction of prosthetic devices used to replace various parts of the human body.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: (TDEC 122 [Min Grade: D] or BIO 122 [Min Grade: D]) and (BMES 130 [Min Grade: D] or BMES 125 [Min Grade: D])

BMES 235 Living Systems Engineering 4.0 Credits
This course introduces the biomedical engineering students to engineering principles applied to biological and physiological systeTs. This course focuses.on evolution, adaptation, energy, thermodynamics, fluid dynamics and control systems in living organrsms.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 122 [Min Grade: D] and CHEM 102 [Min Grade: D] and MATH 200 [Min Grade: D] and PHYS 102 [Min Grade: D] and BMES 130 [Min Grade: D] and BIO 201 [Min Grade: D]

BMES 301 Laboratory I: Experimental Biomechanics 2.0 Credits
This course deals with experimental aspects of biomechanics, specifically with the testing mechanical properties of biological tissues.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (TDEC 114 [Min Grade: D] or MATH 200 [Min Grade: D]) and (TDEC 115 [Min Grade: D] or PHYS 201 [Min Grade: D]) and (TDEC 211 [Min Grade: D] or ENGR 231 [Min Grade: D]) and MEM 202 [Min Grade: D]

BMES 302 Laboratory II: Biomeasurements 2.0 Credits
This course introduces students to the measurement of physiological/biological/functional signals. Four specific signals will be collected and analyzed. Students are expected to analyze type of signal to be collected, possible measurement techniques and potential data analysis and then collect and analyze each signal.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: ECE 201 [Min Grade: D] (Can be taken Concurrently) (BMES 222 [Min Grade: D] or BIO 201 [Min Grade: D]) and (TDEC 231 [Min Grade: D] or ENGR 103 [Min Grade: D])

BMES 303 Laboratory III: Biomedical Electronics 2.0 Credits
This course introduces students to the widespread application of electronics and electronic devices in biomedical engineering. The course reinforces concepts learned in ECE 201 with hands-on experimentation related to biomedical applications such as telemedicine and medical devices.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (ECE 201 [Min Grade: D] and TDEC 231 [Min Grade: D]) or ENGR 232 [Min Grade: D]

BMES 304 Laboratory IV: Ultrasound Images 2.0 Credits
This course introduces students to the engineering principles of acoustical measurements by combining hands-on laboratory experiences with lectures. Students will learn the engineering/physical principles of measuring sound velocity in different materials, attenuation, and directivity of a circular transducers.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (BIO 201 [Min Grade: D] or BMES 235 [Min Grade: D]) and ECE 201 [Min Grade: D] and (TDEC 231 [Min Grade: D] or ENGR 103 [Min Grade: D])

BMES 305 Laboratory V: Musculoskeletal Anatomy for Biomedical Engineers 2.0 Credits
This course provides an opportunity for students to study the anatomy and biomechanics of select articulations of the human body. While the main emphasis will be on the musculoskeletal structures associated with each articulation, major neural and vascular structures will be studied as well.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: (BIO 201 [Min Grade: D] or BMES 235 [Min Grade: D]) and MEM 202 [Min Grade: D]

BMES 310 Biomedical Statistics 4.0 Credits
This course is designed to introduce biomedical engineering students to the fundamentals of biostatistics necessary for medical research. Topics covered include measurements, sampling, basic hypothesis testing, analysis of variance and regression. Medical applications are emphasized.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: ENGR 231 [Min Grade: D]

BMES 315 Experimental Design in Biomedical Research 4.0 Credits
This course is designed to introduce students to the fundamental principles of experimental design and statistical analysis as applied to biomedical research with animals and humans. Topics to be covered include experimental design, clinical design, and protocol submission and review.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 310 [Min Grade: D]

BMES 325 Principles of Biomedical Engineering I 3.0 Credits
This course is the first part of a two-term sequence which introduces biomedical engineering students to engineering principles applied to biological and physiological systems. This course focuses on bioethical questions, biomechanics, human performance engineering, biomaterials and tissue engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 122 [Min Grade: D] and CHEM 102 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and MEM 202 [Min Grade: D] and ENGR 220 [Min Grade: D] and ENGR 232 [Min Grade: D]

BMES 326 Principles of Biomedical Engineering II 3.0 Credits
This course is the second part of a two-term sequence which introduces biomedical engineering students to engineering principles applied to biological and physiological systems. This course focuses on bioinformatics, neuroengineering, biosignal processing, biosensors, and medical imaging.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 325 [Min Grade: D] and BIO 201 [Min Grade: D] and (BMES 202 [Min Grade: D] or ENGR 202 [Min Grade: D])

BMES 330 Biological Rhythm in Pharmacology and Toxicology 3.0 Credits
This course covers the fundamentals of biological rhythms with particular emphasis on the influence these cycles have on the susceptibility of organism to physical, chemical, and /or toxic agents.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman
Prerequisites: BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]

BMES 331 Computers in Health Systems I 3.0 Credits
Introduces the allied health professional to basic computer applications on personal computers. Includes word processing, spreadsheets, databases, and networking (e.g., e-mail and information search and retrieval) in a primarily Windows environment. Designed for individuals with little or no computer background. Students are encouraged to bring in their own work-related problems or projects to provide immediate application of knowledge learned to the student's professional healthcare environment.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 332 Computers in Health Systems II 3.0 Credits
Continues the general overview of computers for people in the allied health professions, using specific examples from health care. Offers further study of and practice with special scientific (e.g., statistics, graphing) and medical clinical decision-support software. Introduces algorithms and formal programming methods.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman

BMES 335 Biomedical Informatics I 3.0 Credits
Introduces information and information handling systems for people in the allied health professions, with specific examples drawn from health care. Covers locating, manipulating, and displaying information in the health system setting.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore

BMES 336 Biomedical Informatics II: Hospital and Patient Information 3.0 Credits
Continues BMES 335. Emphasizes medical records and hospital and patient information handling. Examines the problems of patient information flow within the health care system. Introduces conventional and proposed patient and hospital information systems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 335 [Min Grade: D]

BMES 338 Biomedical Ethics and Law 3.0 Credits
Introduces the wide spectrum of ethical, regulatory, and legal issues facing health care practitioners and health-related research workers. Helps students become aware of the ethical and legal issues involved in their work. Helps students understand how legal and ethical decisions should be made in health-related matters, as well as what sources of help and guidance are available.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman

BMES 340 Health Care Administration 3.0 Credits
This course provides students with an analysis of health care administration process, including: planning, organizing, designing, decision-making, leading, and controlling. Presents methods and techniques that can contribute to the effective performance of administrative duties.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman

BMES 345 Mechanics of Biological Systems 3.0 Credits
This course introduces the fundamentals of mechanics of deformable bodies as they relevant to biologicaltissues and biomaterials. Major topics include stress and strain, mechanical properties of biologicaltissues and biomaterials, axial loading, torsion, bending, and viscoelasticity, These concepts will be applied to biological examples such as long bones, the heart, blood vessels, and orthopaedic implants.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MEM 202 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D])

BMES 350 Med & Bio Effects Of Light 3.0 Credits
Examines the role of environmental lighting in human physiological and psychological processes. Topics include vitamin D synthesis and calcium regulation; light effects on bilirubin in newborns; photoactivation and DNA in skin; effects of nonionizing radiation on the immune systems; environmental lighting and human vision; light effects on biological rhythms and sleep; photosensitivity diseases related to interior lighting; the therapeutic uses of light; and light and the aging eye.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman
Prerequisites: BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]

BMES 363 Robotics in Medicine I 3.0 Credits
This course provides an introduction to the use of haptics (the use of somtaosensory information) in the design of robotic devices in surgery. Topics covered include actuators, sensors, nonportable feedback, portable force feedback, tactile feedback interfaces, haptic sensing and control systems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MEM 238 [Min Grade: D]

BMES 365 Robotics in Medicine II 3.0 Credits
This course covers the use of robots in surgery and included aspects of safety, robot kinematics, analysis of surgical performance using robotic devices, inverse kinematics, velocity analysis and acceleration analysis. Various types of surgeries in which robotic devices are or could be used are presented on a case study basis.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 363 [Min Grade: D]

BMES 372 Biosimulation 3.0 Credits
This course provides the foundation for the mathematical analysis of biomedical engineering systems. It focuses on the essential mathematical methods necessary for further development of modeling and simulation skills in other courses (materials, mechanics, fluids/transport, signals/control system, etc). The course applies the skills in calculus, differential equations and linear algebra gained in ENGR 231 and ENGR 232 to developing analytical techniques for biomedical applications.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and ENGR 231 [Min Grade: D] and ENGR 232 [Min Grade: D] and (BMES 201 [Min Grade: D] and BMES 202 [Min Grade: D]) or (ENGR 201 [Min Grade: D] and ENGR 202 [Min Grade: D])

BMES 375 Computational Bioengineering 4.0 Credits
This course introduces undergraduate students to the mathematical and computational analysis of biological systems. The systems analyzed include the genome, protein and gene networks, cell division cycles, and cellular level disease. Mathematical tools include matrix algebra, differential equations, cellular automata, cluster analysis, etc.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and BMES 325 [Min Grade: D] and BMES 372 [Min Grade: D] and ENGR 231 [Min Grade: D] and (TDEC 221 [Min Grade: D] or ENGR 232 [Min Grade: D])

BMES 381 Junior Design Seminar I 2.0 Credits
This is the first course in a two-course sequence intended to present the basics of engineering design, project management, product development and translational research. This first course focuses on engineering design and product development. A case-study approach is used to illustrate best practices and common mistakes in engineering design.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore

BMES 382 Junior Design Seminar II 2.0 Credits
This is the second course in a two-course sequence intended to present the basics of engineering design, project management, product development and translational research. This second course focuses on project management and quality control. A case-study approach is used to illustrate best practices and common mistakes in management and evaluation of engineering projects.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: BMES 381 [Min Grade: D]

BMES 391 Biomedical Instrumentation I 3.0 Credits
This course introduces the student to the medical instrumentation and provides background on the physical, chemical, electronic and computational fundamentals by which medical instrumentation operates. It is an analytical course exploring the design, operation, safety aspects and calibration of primary electronic instruments.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: ECE 201 [Min Grade: D] and (TDEC 202 [Min Grade: D] or ENGR 210 [Min Grade: D]) and (TDEC 221 [Min Grade: D] or ENGR 231 [Min Grade: D]) and ENGR 232 [Min Grade: D] and (BMES 235 [Min Grade: D] or BIO 203 [Min Grade: D])

BMES 392 Biomedical Instrumentation II 3.0 Credits
Continues BMES 391. Explores the operation, safety aspects, and calibration of primarily optical and acoustical instruments, as well as those involving ionizing radiation. Also examines instrumentation primarily intended for particular departments and areas, such as anesthesia and infusion.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: BMES 391 [Min Grade: D]

BMES 401 Biosensors I 4.0 Credits
Introduces the general topic of microsensors, discusses basic sensing mechanisms for microsensors, and presents various types of conductometric, acoustic, silicon, and optical microsensors. Uses two case studies that include an acoustic immunosensor and silicon glucose sensor to provide students with in-depth knowledge and hands-on experience. Provides additional experience through three laboratory sessions that support the lectures and familiarize students with practical aspects of microsensors. Also discusses applications of microsensors in the medical, chemical, pharmaceutical, environmental, aeronautical, and automotive industries.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D]) and (TDEC 202 [Min Grade: D] or ENGR 210 [Min Grade: D]) and (TDEC 221 [Min Grade: D] or ENGR 231 [Min Grade: D]) and ECE 201 [Min Grade: D] and ENGR 232 [Min Grade: D]

BMES 402 Biosensors II 4.0 Credits
Investigates modern biosensor design methods and addresses the challenges associated with fabrication technologies and instrumentation techniques. Topics include theory and modeling of biosensors, biosensor fabrication steps, and electronic and clinical testing methods. Discusses local and distant sensor data acquisition techniques. Students will design, fabricate and test a biosensor. Essential stages of biosensor manufacturing processes will be outlined. Some or all pre-requisites may be taken as either a pre-requisite or co-requisite. Please see the department for more information.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: BMES 401 [Min Grade: D] (Can be taken Concurrently)

BMES 403 Biosensors III 4.0 Credits
Covers recent advances in biosensor technology and applications, business aspects, and technology transfer issues. Topics include new sensing mechanisms, new technologies, new biomedical applications, the starting of small sensor companies, and the introduction of new sensor technologies into industrial settings. Requires students to develop a technical proposal in the area of biosensors and to review proposals written by their peers. Presentations by regular faculty and industrial and government researchers form an integral part of the course.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: BMES 402 [Min Grade: D]

BMES 405 Physiological Control Systems 3.0 Credits
Introduces the basic concepts of feedback and feed forward controls systems, including characterizations in terms of prescribed constraints, study of input and output relationships for various types of physiological systems, and stability and time-delay problems. Covers mathematical models of physiological systems, with emphasis on non-linear and adaptive systems study.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and ECES 356 [Min Grade: D] and BMES 372 [Min Grade: D]

BMES 409 Entrepreneurship for BMES 3.0 Credits
This course serves as the foundation course in entrepreneurship and is designed to provide students with a complete working knowledge of the modern entrepreneurial and business planning process.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 411 Chronoengineering I: Biological Rhythms in Health and Performance 3.0 Credits
Introduces students to the concepts of biological, and especially circadian, rhythmicity. Advances students' knowledge of biological time-keeping and adaptive functions of biological clocks. Topics include biochemical and physiological models of biological clocks, adjustment to environmental cycles, rhythms in behavior and physiological functions, sleep-wake cyclicity, adaptability of circadian systems, and influences of rhythms on human physiology and behavior. Designed to give students a thorough understanding of the role rhythms play in animal and human behavior, physiology, and medicine.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D])

BMES 412 Chronoengineering II: Sleep Functions in Health and Performance 3.0 Credits
Continues BMES 411. Enhances students' education in the concepts of biological, and especially circadian, rhythmicity. Focuses on sleep patterns, rhythms, evolution, neurology, psychology, and overall function.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: BMES 411 [Min Grade: D]

BMES 421 Biomedical Imaging Systems I: Images 4.0 Credits
Provides an overview of the field of medical imaging. Covers aspects of light imaging; systems theory, convolutions, and transforms; photometry, lenses, and depth of field; image perception and roc theory; three-dimensional imaging; image acquisition and display; and image processing operations, including scanning and segmentation.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: (TDEC 115 [Min Grade: D] and ECES 302 [Min Grade: D] and ECES 304 [Min Grade: D] and BMES 325 [Min Grade: D] and BMES 326 [Min Grade: D]) or PHYS 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (MATH 311 [Min Grade: D] or BMES 310 [Min Grade: D]) and (TDEC 222 [Min Grade: D] or ENGR 231 [Min Grade: D]) and ENGR 232 [Min Grade: D]

BMES 422 Biomedical Imaging Systems II: Ultrasound 4.0 Credits
Intended for students who would like to gain an adequate understanding of diagnostic ultrasound imaging principles and become familiar with developments in this rapidly expanding field. Introduces medical visualization techniques based on ultrasound propagation in biological tissues. Topics include generation and reception of ultrasound, imaging techniques (A-mode, B-mode, M-mode, and Doppler), typical and emerging diagnostic applications, elements of ultrasound exposimetry, and safety aspects from the clinical point of view.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 421 [Min Grade: D]

BMES 423 Biomedical Imaging Systems III 4.0 Credits
Covers volumetric and functional imaging systems. Discusses the principles and algorithms of projection tomography, XCAT, SPECT, PET; the principles of MRI: Bloch equation, slice selection, K-space scanning, volumetric MRI; biochemical imaging; chemical equilibrium equations and Scatchard plots, specific and nonspecific labeling; autoradiography; and flow and dynamical systems: Doppler, mass transport, and phase (MRI) measurement of flow.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 422 [Min Grade: D]

BMES 430 Neural Aspects of Posture and Locomotion 3.0 Credits
Students will study the physiology of ensory/motor systems, with emphasis on modeling of neural systems and biomechanical aspects of functional tasks. Combines information on basic nerve cell activities, synaptic communication and structure/function relationships of skeletal muscle with basic mechanics to study spinal, vestibular and ocular reflexes. Culminates with the study of the control of motor systems with respect to bipedal motion.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (BMES 201 [Min Grade: D] and BMES 202 [Min Grade: D]) or (ENGR 201 [Min Grade: D] and ENGR 202 [Min Grade: D]) and MEM 202 [Min Grade: D]

BMES 432 Biomedical Systems and Signals 3.0 Credits
Introduces various aspects of biomedical signals, systems, and signal processing. Covers topics in the origin and acquisition of biomedical signals; discrete-time signals and linear systems; frequency analysis of discrete-time signals, spectral estimation, data records and digital filters; and compression of biomedical signals through time-domain and frequency-domain coding.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: ECES 302 [Min Grade: D] and ECES 304 [Min Grade: D]

BMES 440 Introduction to Biodynamics 3.0 Credits
The objective of the course is to prepare students for biomechanical modeling, modeling methods, formulation of equations of motion and methods of determination of strength will be applied to human body dynamics. Particular emphasis is placed on the use of Rigid Body and Multi-Body Dynamics.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MEM 202 [Min Grade: D] and (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D]) and MEM 238 [Min Grade: D] and (BMES 235 [Min Grade: D] or BIO 203 [Min Grade: D])

BMES 441 Biomechanics I: Introduction to Biomechanics 4.0 Credits
Teaches students to use mechanical tools to get an introductory appreciation for solving biomechanical problems. Models human performance by using static, quasi-static, and dynamic approaches. Assesses overall loading of the musculoskeletal system during functional activities. Demonstrates introductory methods of estimation of forces in the joints and muscles and evaluates the endurance of the human tissues under traumatic loading conditions. Builds on existing knowledge in mechanics to illustrate the practical application of mechanical tools in the determination of human systems performance.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: MEM 202 [Min Grade: D] and (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D]) and MEM 238 [Min Grade: D] and (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D]) and BIO 203 [Min Grade: D]
Corequisite: BMES 440

BMES 442 Biomechanics II: Musculoskeletal Modeling and Human Performance 4.0 Credits
Teaches students to think biomechanically. Reviews and categorizes the various functional components (tissues) of the musculoskeletal system. Considers constraints of the joints and action of the soft and hard tissues, along with corresponding models. Computes joint and muscle forces. Discusses some aspect of postural stability of the whole musculoskeletal structure and reviews various methods of task performance.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 441 [Min Grade: D]

BMES 443 Biomechanics III: Mechanics of Biological Tissues, Implant Technology and Prosthetics 4.0 Credits
Provides more advanced knowledge of mechanics of materials and offers a general description of mechanical behavior of the variety of the soft and hard tissues of the human body. Considers some prosthetic replacements of tissues as well as entire bone, joint, soft tissue, and system prosthetics. Reviews some specific orthopedic appliances and covers limb prosthetics if time permits. Students plan design projects.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 442 [Min Grade: D]

BMES 444 Biofluid Mechanics 3.0 Credits
This course introduces flow-related anatomy and pathophysiology, and biomedical flow devices and their design challenges. Analysis methods to solve biological fluid mechanics design problems will be introduced and several interdisciplinary team projects will be assigned to apply fluid mechanics to practical biological or medical problems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 451 [Min Grade: D]

BMES 451 Transport Phenomena in Living Systems 4.0 Credits
Introduces students to applications of chemical engineering concepts in biological systems. Shows that chemical engineering approaches to problem solving are ideally suited to investigation of biology. Approaches include material and energy balances, transport phenomena, and kinetics.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: (TDEC 115 [Min Grade: D] or PHYS 201 [Min Grade: D]) and (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D]) and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (TDEC 202 [Min Grade: D] or ENGR 210 [Min Grade: D]) and ENGR 232 [Min Grade: D]

BMES 452 Transport Phenomena in Living Systems II 3.0 Credits
Continues BMES 451. Advances students' understanding of the engineering principles of membrane transport and its consequences at the subcellular (mitochondria), cellular (neuron), and organ (kidney) level. Introduces concepts associated with pharmacokinetics. Provides students with a kinetic approach to analysis of receptors, including the kinetics of ligand-receptor binding, rate constants, and signal transduction.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: BMES 451 [Min Grade: D]

BMES 460 Biomaterials I 4.0 Credits
First course in a three-quarter sequence designed to acquaint students with the behavior of materials used in biomedical application under load (i.e., mechanical properties), their modes of failure and as a function of their environment. This course provides students with the fundamentals needed to proceed with Biomaterials II.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D]) and CHEM 241 [Min Grade: D] and CHEM 242 [Min Grade: D]

BMES 461 Biomaterials II 4.0 Credits
Second course in a three-quarter sequence in biomaterials. The goal of this course is with an understanding of, and ability to select, appropriate materials for specific applications taking into account mechanical, thermal, and rheological properties taught in Biomaterials I and combining them with the biocompatibility issues covered in the present course.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 460 [Min Grade: D]

BMES 466 Robotics in Medicine III 3.0 Credits
This course covers topics in the design of medical robotic systems, including force and movement analysis for robotic arms, dynamics, computer vision and vision-based control. Thus use of haptics, vision systems and robot dynamics are examined in a cohesive framework.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 365 [Min Grade: D]

BMES 471 Cellular and Molecular Foundations of Tissue Engineering 4.0 Credits
Course is designed to familiarize students with the advanced concepts of cellular and molecular biology and physiology relevant to tissue engineering. The initial part of a two-quarter sequence combining material from cellular/molecular biology, evolutionary/developmental biology with engineering design and biomaterials to educate students in the principles, methods, and technology of tissue engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BIO 218 [Min Grade: D] and BIO 122 [Min Grade: D] and BIO 219 [Min Grade: D] and CHEM 242 [Min Grade: D] and (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D])

BMES 472 Developmental and Evolutionary Foundations of Tissue Engineering 4.0 Credits
Familiarizes students with advanced concepts of developmental and evolutionary biology relevant to tissue engineering. This second part of the two-quarter sequence combines material from cellular/molecular biology and evolutionary design and biomaterials to educate students in the principles, methods, and technology of tissue engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 471 [Min Grade: D]

BMES 475 Biomaterials and Tissue Engineering III 4.0 Credits
This course provides students with in-depth knowledge of factor-mediated tissue engineering and regenerative medicine. Students learn about fundamental repair and regenerative processes and gain an understanding of specific biomaterials being used to mimic and/or enhance such processes. Students also learn about the delivery methods of agents which promote the proper functional development of specialized tissues.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 460 [Min Grade: D] and BMES 461 [Min Grade: D] and BMES 471 [Min Grade: D] and BMES 472 [Min Grade: D]

BMES 477 Neuroengineering I: Neural Signals 3.0 Credits
Introduces the theory of neural signaling. Students will learn the fundamental theory of cellular potentials and chemical signaling, the Hodgkin Huxeley description of action potential generation, circuit representations of neurons and be able to derive and integrate equations describing the circuit as well as design computer models.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: ECES 302 [Min Grade: D] and ECES 304 [Min Grade: D] and ECES 356 [Min Grade: D] and BIO 203 [Min Grade: D] and BMES 405 [Min Grade: D] and BMES 430 [Min Grade: D]

BMES 478 Neuroengineering II: Principles of Neuroengineering 3.0 Credits
This course investigates cutting edge technologies in neuroengineering in a seminar-style format with faculty from the School of Biomedical Engineering and College of Medicine. Three modules cover topics, which vary from year to year. Students are expected to submit written and oral presentations covering each topic.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 477 [Min Grade: D]

BMES 480 Special Topics in Biomedical Engineering & Sciences 12.0 Credits
Covers topics related to the field of health care, systems, and technology. Past topics include health care administration.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit

BMES 483 Quantitative Systems Biology 4.5 Credits
This course uses a systems engineering approach to provide a foundation in systems biology and pathology informatics. Topics covered include the robust complex network of genes and proteins; cell as basic units of life; communication of cells with other cells and the environment; and gene circuits governing development.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: (TDEC 222 [Min Grade: D] or ENGR 232 [Min Grade: D]) and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (BMES 202 [Min Grade: D] or ENGR 202 [Min Grade: D]) and BMES 372 [Min Grade: D] and BMES 375 [Min Grade: D] and CS 172 [Min Grade: D]

BMES 484 Genome Information Engineering 4.5 Credits
This course is designed to provide students with hands-on experience in the application of genomic, proteomic, and other large-scale information to biomedical engineering. The underlying goal is to develop an understanding of highthrough underlying technologies, biological challenges, and key mathematical and computational methods relevant to biomedical engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 483 [Min Grade: D]

BMES 488 Medical Device Development 3.0 Credits
Medical device product development must take into account a diverse set of disciplines to achieve a safe and successful product. This course exposes the student to several of these disciplines with the objective of raising the student¿s awareness of safety throughout the product development life cycle. Students will learn to appreciate the complex engineering decisions that support development of a safe medical device through an examination of risk management, regulatory processes, human factors and clinical studies.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 391 [Min Grade: D] and BMES 392 [Min Grade: D]

BMES 491 [WI] Senior Design Project I 3.0 Credits
This is the first course in a three-quarter capstone design experience for senior biomedical engineering students.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.

BMES 492 Senior Design Project II 2.0 Credits
Continues senior design activities begun in BMES 492.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.

BMES 493 Senior Design Project III 3.0 Credits
Continues the design project begun in BMES 491 and continued through BMES 492.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.

BMES 494 Clinical Practicum I 3.0 Credits
This course provides biomedical engineering students with an extensive exposure to live clinical cardiology procedures, including cardiac catheterization, electrophysiology, echocardiography and nuclear stress testing. Emphasis is placed on identifying important interfaces between engineering and clinical medicine, particularly in areas where clinical needs may be addressed by advances in biomedical engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if major is BME.

BMES 495 Clinical Practicum II 3.0 Credits
This course provides biomedical engineering students with an extensive exposure to live operations in an emergency department and intensive care unit. The students are expected to analyze specific operations within these environments and develop a solution to a process problem within one of these environments. System analysis, design and evaluation are emphasized.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if major is BME.

BMES 496 Clinical Practicum III 3.0 Credits
This course provides biomedical engineering students with an opportunity to observe basic operative and postoperative procedures with the idea of both learning about such procedures and identifying the role of biomedical engineering in these clinical settings.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if major is BME.

BMES 499 Independent Study in Biomedical Engineering and Science 0.5-6.0 Credits
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit

Biomedical Devices and Imaging Concentration

About the Program

Bachelor of Science in Biomedical Engineering (BMES) 199.0 credits
Biomedical imaging focuses on the theoretical and practical issues related to machine vision, image processing and analysis, and signal processing associated with such medical applications as ultrasound, optics, magnetic resonance, and autoradiographic imaging.

The concentration in biomedical devices and imaging is for those individuals interested in careers in medical imaging, medical device development, and clinical engineering. The concentration covers the fundamentals of modern imaging methodologies, covering aspects of light imaging, ultrasound imaging, and volumetric and functional imaging systems, and the principles of magnetic resonance imaging (MRI).

Upon graduation, students will be able to:

- understand the multi-disciplinary background and limitations of current and emerging instrumentation, imaging and internet technologies used in clinical, pharmaceutical and research environments;
- select and evaluate sensors and imaging modalities for specific biomedical research, diagnostic and theragnostic applications;
- analyze the performance of different systems including microscopical and medical imaging methodologies in terms of safety, resolution and the trade-offs important for a given application;
- optimize digital acquisition, enhancement, visualization and analysis of signals from biomedical instruments in multidimensions;
- understand the impact of compliance with the standards and guidelines of regulatory agencies such as FDA on the design and application of devices in clinical practice and knowledge of basic quality assurance tools.

The School maintains extensive facilities and laboratories devoted to areas of research. Visit the School's BIOMED Research Facilities and Laboratory Map (http://www.biomed.drexel.edu/new04/Content/research/facilities) page for more details about the laboratories and equipment available.

For more information about this concentration, see Drexel's School of Biomedical Engineering, Science, and Health Systems (http://www.biomed.drexel.edu/new04) website.

Degree Requirements

General education requirements		
HIST 285	Technology in Historical Perspective	3.0
ENGL 101	Composition and Rhetoric I: Inquiry and Exploratory Research	3.0
ENGL 102	Composition and Rhetoric II: The Craft of Persuasion	3.0
ENGL 103	Composition and Rhetoric III: Thematic Analysis Across Genres	3.0
UNIV R101	The Drexel Experience	2.0
Liberal and General Studies Electives (5)		15.0
Engineering core courses		
MATH 121	Calculus I	4.0
MATH 122	Calculus II	4.0
MATH 200	Multivariate Calculus	4.0
PHYS 101	Fundamentals of Physics I	4.0
PHYS 102	Fundamentals of Physics II	4.0
PHYS 201	Fundamentals of Physics III	4.0
CHEM 101	General Chemistry I	3.5
CHEM 102	General Chemistry II	4.5
BIO 122	Cells and Genetics	4.5
ENGR 100	Beginning Computer Aided Drafting for Design	1.0
ENGR 101	Engineering Design Laboratory I	2.0
ENGR 102	Engineering Design Laboratory II	2.0
ENGR 103	Engineering Design Laboratory III	2.0
ENGR 210	Introduction to Thermodynamics	3.0
ENGR 220	Fundamentals of Materials	4.0
ENGR 231	Linear Engineering Systems	3.0
ENGR 232	Dynamic Engineering Systems	3.0
MEM 202	Statics	3.0
Required Biomedical Engineering courses		
BIO 201	Human Physiology I	4.0
BIO 203	Human Physiology II	4.0
BMES 124	Biomedical Engineering Freshman Seminar I	1.0
BMES 126	Biomedical Engineering Freshman Seminar II	1.0
BMES 130	Problem Solving in Biomedical Engineering	2.0
BMES 201	Programming and Modeling for Biomedical Engineers I	3.0
BMES 202	Programming and Modeling for Biomedical Engineers ll	3.0
BMES 212	The Body Synthetic	3.0
BMES 302	Laboratory II: Biomeasurements	2.0
BMES 303	Laboratory III: Biomedical Electronics	2.0
BMES 310	Biomedical Statistics	4.0
BMES 325	Principles of Biomedical Engineering I	3.0
BMES 326	Principles of Biomedical Engineering II	3.0
BMES 338	Biomedical Ethics and Law	3.0
BMES 372	Biosimulation	3.0
BMES 381	Junior Design Seminar I	2.0
BMES 382	Junior Design Seminar II	2.0
BMES 491 [WI]	Senior Design Project I	3.0
BMES 492	Senior Design Project II	2.0
BMES 493	Senior Design Project III	3.0
ECE 201	Foundations of Electric Circuits	3.0
Biomedical Devices and Imaging concentration courses		
BIO 202	Human Physiology Laboratory	2.0
BMES 301	Laboratory I: Experimental Biomechanics	2.0
BMES 304	Laboratory IV: Ultrasound Images	2.0
BMES 315	Experimental Design in Biomedical Research	4.0
BMES 391	Biomedical Instrumentation I	3.0
BMES 392	Biomedical Instrumentation II	3.0
BMES 375	Computational Bioengineering	4.0
BMES 401	Biosensors I	4.0
BMES 421	Biomedical Imaging Systems I: Images	4.0
BMES 422	Biomedical Imaging Systems II: Ultrasound	4.0
BMES 423	Biomedical Imaging Systems III	4.0
ECES 304	Dynamic Systems and Stability	4.0
ECES 352	Introduction to Digital Signal Process	4.0
Biomedical Systems and Imaging Elective		3.0
Select one of the following:		
BMES 488	Medical Device Development	
BMES 494	Clinical Practicum I	
BMES 495	Clinical Practicum II	
BMES 496	Clinical Practicum III	
Total Credits		**191.5**

Sample Plan of Study

Term 1		**Credits**
BMES 124	Biomedical Engineering Freshman Seminar I	1.0
CHEM 101	General Chemistry I	3.5
ENGL 101	Composition and Rhetoric I: Inquiry and Exploratory Research	3.0
ENGR 100	Beginning Computer Aided Drafting for Design	1.0

ENGR 101	Engineering Design Laboratory I	2.0
MATH 121	Calculus I	4.0
UNIV R101	The Drexel Experience	1.0
	Term Credits	**15.5**
Term 2		
BMES 126	Biomedical Engineering Freshman Seminar II	1.0
CHEM 102	General Chemistry II	4.5
ENGL 102	Composition and Rhetoric II: The Craft of Persuasion	3.0
ENGR 102	Engineering Design Laboratory II	2.0
MATH 122	Calculus II	4.0
PHYS 101	Fundamentals of Physics I	4.0
UNIV R101	The Drexel Experience	0.5
	Term Credits	**19.0**
Term 3		
BIO 122	Cells and Genetics	4.5
BMES 130	Problem Solving in Biomedical Engineering	2.0
ENGL 103	Composition and Rhetoric III: Thematic Analysis Across Genres	3.0
ENGR 103	Engineering Design Laboratory III	2.0
MATH 200	Multivariate Calculus	4.0
PHYS 102	Fundamentals of Physics II	4.0
UNIV R101	The Drexel Experience	0.5
	Term Credits	**20.0**
Term 4		
BIO 201	Human Physiology I	4.0
BMES 201	Programming and Modeling for Biomedical Engineers I	3.0
ENGR 220	Fundamentals of Materials	4.0
ENGR 231	Linear Engineering Systems	3.0
PHYS 201	Fundamentals of Physics III	4.0
	Term Credits	**18.0**
Term 5		
BMES 202	Programming and Modeling for Biomedical Engineers ll	3.0
BMES 212	The Body Synthetic	3.0
BMES 235	Living Systems Engineering	4.0
ENGR 210	Introduction to Thermodynamics	3.0
ENGR 232	Dynamic Engineering Systems	3.0
MEM 202	Statics	3.0
	Term Credits	**19.0**
Term 6		
BMES 301	Laboratory I: Experimental Biomechanics	2.0
BMES 302	Laboratory II: Biomeasurements	2.0
BMES 325	Principles of Biomedical Engineering I	3.0
BMES 372	Biosimulation	3.0
ECE 201	Foundations of Electric Circuits	3.0
HIST 285	Technology in Historical Perspective	3.0
	Term Credits	**16.0**
Term 7		
BMES 303	Laboratory III: Biomedical Electronics	2.0
BMES 310	Biomedical Statistics	4.0
BMES 326	Principles of Biomedical Engineering II	3.0
ECES 302	Transform Methods I	4.0
Liberal Studies Elective		3.0
	Term Credits	**16.0**
Term 8		
BIO 202	Human Physiology Laboratory	2.0
BMES 304	Laboratory IV: Ultrasound Images	2.0
BMES 315	Experimental Design in Biomedical Research	4.0
BMES 338	Biomedical Ethics and Law	3.0
BMES 381	Junior Design Seminar I	2.0
BMES 401	Biosensors I	4.0
	Term Credits	**17.0**
Term 9		
BMES 375	Computational Bioengineering	4.0
BMES 382	Junior Design Seminar II	2.0
ECES 304	Dynamic Systems and Stability	4.0
ECES 352	Introduction to Digital Signal Process	4.0
	Term Credits	**14.0**
Term 10		
BMES 391	Biomedical Instrumentation I	3.0
BMES 421	Biomedical Imaging Systems I: Images	4.0
BMES 432	Biomedical Systems and Signals	3.0
BMES 491 [WI]	Senior Design Project I	3.0
Liberal Studies Elective		3.0
	Term Credits	**16.0**
Term 11		
BMES 392	Biomedical Instrumentation II	3.0
BMES 422	Biomedical Imaging Systems II: Ultrasound	4.0
BMES 492	Senior Design Project II	2.0
General Studies Electives		6.0
	Term Credits	**15.0**
Term 12		
BMES 423	Biomedical Imaging Systems III	4.0
BMES 493	Senior Design Project III	3.0
Biomedical Devices and Imaging Concentration Elective*		3.0
Liberal Studies Elective		3.0
	Term Credits	**13.0**
Total Credit: 198.5		

* See degree requirements.

Opportunities

Metropolitan Philadelphia has one of the highest concentrations of medical institutions and pharmaceutical and biotechnology industries in the nation.The bachelor of science degree in biomedical engineering gives students access to a broad spectrum of career opportunities in medical device and equipment industry; prosthetics and assist devices industry; biomaterials and implants industry; and the telemedicine, pharmaceutical, biotechnology, and agricultural sectors.

Biomedical engineering graduates are also ideally prepared for professional education in medicine, dentistry, veterinary medicine, and law. Those who choose to pursue graduate education can aim for careers

in research and development, biomedical technology innovation and transfer, as well as health care technology management.

Visit the Drexel Steinbright Career Development Center (http://www.drexel.edu/scdc) page for more detailed information on co-op and post-graduate opportunities.

Biomedical Engineering, Science and Health Systems Faculty

Fred D. Allen, PhD *(University of Pennsylvania)*. Assistant Professor. Tissue engineering, cell engineering, orthopedics, bone remodeling, wound healing, mechanotransduction, signal transduction, adhesion, migration.

Sriram Balasubramanian, PhD *(Wayne State University)*. Assistant Professor. Structural characteristics of the pediatric thoracic cage using CT scans and developing an age-equivalent animal model for pediatric long bones.

Kenneth A. Barbee, PhD *(University of Pennsylvania)*. Professor. Cellular biomechanics of neural and vascular injury, mechanotransduction in the cardiovascular system, mechanical control of growth and development for wound healing and tissue engineering.

Lin Han, PhD *(Massachusetts Institute of Technology)*. Assistant Professor. Nanoscale structure-property relationships of biological materials, genetic and molecular origins soft joint tissue diseases, biomaterials under extreme conditions, coupling between stimulus-responsiveness and geometry.

Uri Hershberg, PhD *(Hebrew University of Jerusalem, Israel)*. Assistant Professor. Bioinformatics, immunology, neural computation, system biology, somatic selection, autoimmunity, genetic stability, germline diversity, dendritic cell, transcription elements, pathogens, computational and mathematical modeling, complex systems, cognition and inflammation.

Joshua Jacobs, PhD *(University of Pennsylvania)*. Assistant Professor. Neuroengineering, electrocorticography (ECoG), electroencephalography (EEG), single-neuron spiking, brain oscillations, episodic memory, working memory, spatial navigation, conceptual representations.

Dov Jaron, PhD *(University of Pennsylvania) Calhoun Distinguished Professor of Engineering in Medicine*. Professor. Mathematical, computer and electromechanical simulations of the cardiovascular system.

Andres Kriete, PhD *(University in Bremen Germany) Associate Director for Graduate Studies and Academic Operations*. Systems biology, bioimaging, control theory, biology of aging, skin cancer.

Ryszard Lec, PhD *(University of Warsaw Engineering College)*. Professor. Biomedical applications of visoelastic, acoustoptic and ultrasonic properties of liquid and solid media.

Peter Lewin, PhD *(University of Denmark, Copenhagen-Lyngby) Richard B. Beard Professor, School Of Biomedical Engineering, Science & Health Systems*. Professor. Biomedical ultrasonics, piezoelectric and polymer transducers and hydrophones; shock wave sensors.

Hualou Liang, PhD *(Chinese Academy of Sciences)*. Associate Professor. Neuroengineering, neuroinformatics, cognitive and computational neuroscience, neural data analysis and computational modeling, biomedical signal processing.

Donald L. McEachron, PhD *(University of California at San Diego) Associate Director*. Research Professor. Animal behavior, autoradiography, biological rhythms, cerebral metabolism, evolutionary theory, image processing, neuroendocrinology.

Karen Moxon, PhD *(University of Colorado)*. Associate Professor. Cortico-thalamic interactions; neurobiological perspectives on design of humanoid robots.

Banu Onaral, Ph.D. *(University of Pennsylvania) H.H. Sun Professor / Director, School of Biomedical Engineering Science and Health Systems*. Professor. Biomedical signal processing; complexity and scaling in biomedical signals and systems.

Kambiz Pourrezaei, PhD *(Rensselaer Polytechnic University)*. Professor. Thin film technology; nanotechnology; near infrared imaging; power electronics.

Arye Rosen, PhD *(Drexel University) Biomedical Engineering and Electrical Engineering*. Microwave components and subsystems; utilization of RF/microwaves and lasers in therapeutic medicine.

Ahmet Sacan, PhD *(Middle East Technical University)*. Assistant Professor. Indexing and data mining in biological databases; protein sequence and structure; similarity search; protein structure modeling; protein-protein interaction; automated cell tracking.

Joseph J. Sarver, PhD *(Drexel University)*. Teaching Professor. Neuromuscular adaptation to changes in the myo-mechanical environment.

Rahamim Seliktar, PhD *(University of Strathclyde, Glasgow) Vice Director, School of Biomedical Engineering, Science & Health Systems*. Professor. Limb prostheses, biomechanics of human motion, orthopedic biomechanics.

Adrian C. Shieh, PhD *(Rice University)*. Assistant Professor. Contribution of mechanical forces to tumor invasion and metastasis, with a particular emphasis on how biomechanical signals may drive the invasive switch, and how the biomechanical microenvironment interacts with cytokine signaling and the extracellular matrix to influence tumor and stromal cell behavior.

Wan Young Shih, PhD *(Ohio State University) School of Biomedical Engineering, Science and Health Systems*. Associate Professor. Piezoelectric microcantilever biosensors development, piezoelectric finger development, quantum dots development, tissue elasticity imaging, piezoelectric microcantilever force probes.

Kara Spiller, PhD *(Drexel University)*. Assistant Professor. Cell-biomaterial interactions, biomaterial design, and international engineering education.

Margaret Wheatley, PhD *(University of Toronto) School of Biomedical Engineering, Science and Health Systems, John M. Reid Professor*. Ultrasound contrast agent development (tumor targeting and triggered drug delivery), controlled release technology (bioactive compounds), microencapsulated allografts (*ex vivo* gene therapy) for spinal cord repair.

Yinghui Zhong, PhD *(Georgia Institute of Technology)*. Assistant Professor. Spinal cord repair, and engineering neural prosthesis/brain interface using biomaterials, drug delivery, and stem cell therapy.

Interdepartmental Faculty

Douglas L. Chute, PhD *(University of Missouri) Louis and Bessie Stein Fellow*. Professor. Neuropsychology and rehabilitation; technological applications for the cognitively compromised and those with acquired brain injuries.

Patricia A. Shewokis, PhD *(University of Georgia)*. Professor. Roles of cognition and motor function during motor skill learning; role of information feedback frequency on the memory of motor skills, noninvasive neural imaging techniques of functional near infrared spectroscopy(fNIR) and electroencephalograpy (EEG) and methodology and research design.

Emeritus Faculty

William Freedman, PhD *(Drexel University)*. Professor Emeritus. Motor control; sensory and motor systems; reflexes; eye movements; neural networks.

John M. Reid, PhD *(University of Pennsylvania) Calhoun Professor Emeritus*. Professor Emeritus. Diagnostic ultrasound, wave propagation and scattering in inhomogeneous media, imaging, instrumentation.

Hun H. Sun, PhD *(Cornell University)*. Professor Emeritus. Biological control systems, physiological modeling, systems analysis.

Aydin Tozeren, PhD *(Columbia University) Distinguished Professor and Director, Center for Integrated Bioinformatics, School of Biomedical Engineering, Science & Health Systems*. Professor Emeritus. Breast cell adhesion and communication, signal transduction networks in cancer and epithelial cells; integrated bioinformatics, molecular profiling, 3D-tumors, bioimaging.

Courses

BMES 124 Biomedical Engineering Freshman Seminar I 1.0 Credit
This course is intended to introduce freshman biomedical engineering students in the School of biomedical Engineering, Science and Health Systems at Drexel University to academic programs and opportunities, ongoing research projects and University resources to ensure a successful educational experience at Drexel and beyond. Through class discussions and guest lecture presentations, the students are provided with information and contacts necessary to begin a plan of academic study.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 125 Foundations of Biomedical Engineering 2.0 Credits
This course is intended to introduce new transfer biomedical engineering students in the School of biomedical Engineering, Science and Health Systems at Drexel University academic programs and opportunities, ongoing research projects and University resources to ensure a successful educational experience at Drexel and beyond. Through class discussions and guest lecture presentations, the students are provided with information and contact necessary to begin a plan of academic study.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 126 Biomedical Engineering Freshman Seminar II 1.0 Credit
This course is intended to introduce freshman biomedical engineering students to the career embodied by the School's current concentration areas. Each area will be discussed in terms of the current state of the art, research possibilities and career opportunities. The curricula for each concentration will be discussed in detail so as to facilitate students' knowledge of how each curriculum relates to the research and employment opportunities in that field.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 130 Problem Solving in Biomedical Engineering 2.0 Credits
This course integrates fundamental principles of biology, chemistry, engineering, mathematics and physics into a framework for the study of biomedical engineering. In this course, students will use both engineering and scientific approaches to problem-solving. They will learn about the differences between engineering design and biological evolution. They will also learn to apply basic principles of chemistry, physics and mathematics to specific biological and physiological problems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MATH 122 [Min Grade: D] and CHEM 102 [Min Grade: D] and PHYS 101 [Min Grade: D]

BMES 201 Programming and Modeling for Biomedical Engineers I 3.0 Credits
This course aims to introduce students with some fundamental concepts about programming in MATLAB to give the ability to solve basic bioengineering problems. The course introduces the basics of programming using Matlab, including programming environment and tools. Fundamental programming techniques and concepts such as loops, switches and logical operators, functions and file handling are covered. Applications in bioengineering for basic numerical problem solving are discussed.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MATH 200 [Min Grade: D] and PHYS 102 [Min Grade: D] and BIO 122 [Min Grade: D] and (BMES 130 [Min Grade: D] or BMES 125 [Min Grade: D])

BMES 202 Programming and Modeling for Biomedical Engineers II 3.0 Credits
The course aims to introduce students to advanced programming concepts and tools to solve numerical problems in bioengineering. It provides the foundation for biosimulation and biocomputation classes. This course introduces advanced programming methods and computational tools for numerical analysis, model design and graphics. Higher level level lunctionality in Matlab such as SIMULINK, symbolic processing and CAD related tools are discussed.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 201 [Min Grade: D]

BMES 212 The Body Synthetic 3.0 Credits
The Body Synthetic introduces concepts underlying biological and engineering principles involved in the design and construction of prosthetic devices used to replace various parts of the human body.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: (TDEC 122 [Min Grade: D] or BIO 122 [Min Grade: D]) and (BMES 130 [Min Grade: D] or BMES 125 [Min Grade: D])

BMES 235 Living Systems Engineering 4.0 Credits
This course introduces the biomedical engineering students to engineering principles applied to biological and physiological systeTs. This course focuses.on evolution, adaptation, energy, thermodynamics, fluid dynamics and control systems in living organrsms.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 122 [Min Grade: D] and CHEM 102 [Min Grade: D] and MATH 200 [Min Grade: D] and PHYS 102 [Min Grade: D] and BMES 130 [Min Grade: D] and BIO 201 [Min Grade: D]

BMES 301 Laboratory I: Experimental Biomechanics 2.0 Credits
This course deals with experimental aspects of biomechanics, specifically with the testing mechanical properties of biological tissues.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (TDEC 114 [Min Grade: D] or MATH 200 [Min Grade: D]) and (TDEC 115 [Min Grade: D] or PHYS 201 [Min Grade: D]) and (TDEC 211 [Min Grade: D] or ENGR 231 [Min Grade: D]) and MEM 202 [Min Grade: D]

BMES 302 Laboratory II: Biomeasurements 2.0 Credits
This course introduces students to the measurement of physiological/biological/functional signals. Four specific signals will be collected and analyzed. Students are expected to analyze type of signal to be collected, possible measurement techniques and potential data analysis and then collect and analyze each signal.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: ECE 201 [Min Grade: D] (Can be taken Concurrently) (BMES 222 [Min Grade: D] or BIO 201 [Min Grade: D]) and (TDEC 231 [Min Grade: D] or ENGR 103 [Min Grade: D])

BMES 303 Laboratory III: Biomedical Electronics 2.0 Credits
This course introduces students to the widespread application of electronics and electronic devices in biomedical engineering. The course reinforces concepts learned in ECE 201 with hands-on experimentation related to biomedical applications such as telemedicine and medical devices.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (ECE 201 [Min Grade: D] and TDEC 231 [Min Grade: D]) or ENGR 232 [Min Grade: D]

BMES 304 Laboratory IV: Ultrasound Images 2.0 Credits
This course introduces students to the engineering principles of acoustical measurements by combining hands-on laboratory experiences with lectures. Students will learn the engineering/physical principles of measuring sound velocity in different materials, attenuation, and directivity of a circular transducers.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (BIO 201 [Min Grade: D] or BMES 235 [Min Grade: D]) and ECE 201 [Min Grade: D] and (TDEC 231 [Min Grade: D] or ENGR 103 [Min Grade: D])

BMES 305 Laboratory V: Musculoskeletal Anatomy for Biomedical Engineers 2.0 Credits
This course provides an opportunity for students to study the anatomy and biomechanics of select articulations of the human body. While the main emphasis will be on the musculoskeletal structures associated with each articulation, major neural and vascular structures will be studied as well.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: (BIO 201 [Min Grade: D] or BMES 235 [Min Grade: D]) and MEM 202 [Min Grade: D]

BMES 310 Biomedical Statistics 4.0 Credits
This course is designed to introduce biomedical engineering students to the fundamentals of biostatistics necessary for medical research. Topics covered include measurements, sampling, basic hypothesis testing, analysis of variance and regression. Medical applications are emphasized.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: ENGR 231 [Min Grade: D]

BMES 315 Experimental Design in Biomedical Research 4.0 Credits
This course is designed to introduce students to the fundamental principles of experimental design and statistical analysis as applied to biomedical research with animals and humans. Topics to be covered include experimental design, clinical design, and protocol submission and review.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 310 [Min Grade: D]

BMES 325 Principles of Biomedical Engineering I 3.0 Credits
This course is the first part of a two-term sequence which introduces biomedical engineering students to engineering principles applied to biological and physiological systems. This course focuses on bioethical questions, biomechanics, human performance engineering, biomaterials and tissue engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 122 [Min Grade: D] and CHEM 102 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and MEM 202 [Min Grade: D] and ENGR 220 [Min Grade: D] and ENGR 232 [Min Grade: D]

BMES 326 Principles of Biomedical Engineering II 3.0 Credits
This course is the second part of a two-term sequence which introduces biomedical engineering students to engineering principles applied to biological and physiological systems. This course focuses on bioinformatics, neuroengineering, biosignal processing, biosensors, and medical imaging.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 325 [Min Grade: D] and BIO 201 [Min Grade: D] and (BMES 202 [Min Grade: D] or ENGR 202 [Min Grade: D])

BMES 330 Biological Rhythm in Pharmacology and Toxicology 3.0 Credits
This course covers the fundamentals of biological rhythms with particular emphasis on the influence these cycles have on the susceptibility of organism to physical, chemical, and /or toxic agents.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman
Prerequisites: BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]

BMES 331 Computers in Health Systems I 3.0 Credits
Introduces the allied health professional to basic computer applications on personal computers. Includes word processing, spreadsheets, databases, and networking (e.g., e-mail and information search and retrieval) in a primarily Windows environment. Designed for individuals with little or no computer background. Students are encouraged to bring in their own work-related problems or projects to provide immediate application of knowledge learned to the student's professional healthcare environment.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 332 Computers in Health Systems II 3.0 Credits
Continues the general overview of computers for people in the allied health professions, using specific examples from health care. Offers further study of and practice with special scientific (e.g., statistics, graphing) and medical clinical decision-support software. Introduces algorithms and formal programming methods.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman

BMES 335 Biomedical Informatics I 3.0 Credits
Introduces information and information handling systems for people in the allied health professions, with specific examples drawn from health care. Covers locating, manipulating, and displaying information in the health system setting.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore

BMES 336 Biomedical Informatics II: Hospital and Patient Information 3.0 Credits
Continues BMES 335. Emphasizes medical records and hospital and patient information handling. Examines the problems of patient information flow within the health care system. Introduces conventional and proposed patient and hospital information systems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 335 [Min Grade: D]

BMES 338 Biomedical Ethics and Law 3.0 Credits
Introduces the wide spectrum of ethical, regulatory, and legal issues facing health care practitioners and health-related research workers. Helps students become aware of the ethical and legal issues involved in their work. Helps students understand how legal and ethical decisions should be made in health-related matters, as well as what sources of help and guidance are available.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman

BMES 340 Health Care Administration 3.0 Credits
This course provides students with an analysis of health care administration process, including: planning, organizing, designing, decision-making, leading, and controlling. Presents methods and techniques that can contribute to the effective performance of administrative duties.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman

BMES 345 Mechanics of Biological Systems 3.0 Credits
This course introduces the fundamentals of mechanics of deformable bodies as they relevant to biologicaltissues and biomaterials. Major topics include stress and strain, mechanical properties of biologicaltissues and biomaterials, axial loading, torsion, bending, and viscoelasticity, These concepts will be applied to biological examples such as long bones, the heart, blood vessels, and orthopaedic implants.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MEM 202 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D])

BMES 350 Med & Bio Effects Of Light 3.0 Credits
Examines the role of environmental lighting in human physiological and psychological processes. Topics include vitamin D synthesis and calcium regulation; light effects on bilirubin in newborns; photoactivation and DNA in skin; effects of nonionizing radiation on the immune systems; environmental lighting and human vision; light effects on biological rhythms and sleep; photosensitivity diseases related to interior lighting; the therapeutic uses of light; and light and the aging eye.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman
Prerequisites: BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]

BMES 363 Robotics in Medicine I 3.0 Credits
This course provides an introduction to the use of haptics (the use of somtaosensory information) in the design of robotic devices in surgery. Topics covered include actuators, sensors, nonportable feedback, portable force feedback, tactile feedback interfaces, haptic sensing and control systems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MEM 238 [Min Grade: D]

BMES 365 Robotics in Medicine II 3.0 Credits
This course covers the use of robots in surgery and included aspects of safety, robot kinematics, analysis of surgical performance using robotic devices, inverse kinematics, velocity analysis and acceleration analysis. Various types of surgeries in which robotic devices are or could be used are presented on a case study basis.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 363 [Min Grade: D]

BMES 372 Biosimulation 3.0 Credits
This course provides the foundation for the mathematical analysis of biomedical engineering systems. It focuses on the essential mathematical methods necessary for further development of modeling and simulation skills in other courses (materials, mechanics, fluids/transport, signals/control system, etc). The course applies the skills in calculus, differential equations and linear algebra gained in ENGR 231 and ENGR 232 to developing analytical techniques for biomedical applications.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and ENGR 231 [Min Grade: D] and ENGR 232 [Min Grade: D] and (BMES 201 [Min Grade: D] and BMES 202 [Min Grade: D]) or (ENGR 201 [Min Grade: D] and ENGR 202 [Min Grade: D])

BMES 375 Computational Bioengineering 4.0 Credits
This course introduces undergraduate students to the mathematical and computational analysis of biological systems. The systems analyzed include the genome, protein and gene networks, cell division cycles, and cellular level disease. Mathematical tools include matrix algebra, differential equations, cellular automata, cluster analysis, etc.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and BMES 325 [Min Grade: D] and BMES 372 [Min Grade: D] and ENGR 231 [Min Grade: D] and (TDEC 221 [Min Grade: D] or ENGR 232 [Min Grade: D])

BMES 381 Junior Design Seminar I 2.0 Credits
This is the first course in a two-course sequence intended to present the basics of engineering design, project management, product development and translational research. This first course focuses on engineering design and product development. A case-study approach is used to illustrate best practices and common mistakes in engineering design.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore

BMES 382 Junior Design Seminar II 2.0 Credits
This is the second course in a two-course sequence intended to present the basics of engineering design, project management, product development and translational research. This second course focuses on project management and quality control. A case-study approach is used to illustrate best practices and common mistakes in management and evaluation of engineering projects.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: BMES 381 [Min Grade: D]

BMES 391 Biomedical Instrumentation I 3.0 Credits
This course introduces the student to the medical instrumentation and provides background on the physical, chemical, electronic and computational fundamentals by which medical instrumentation operates. It is an analytical course exploring the design, operation, safety aspects and calibration of primary electronic instruments.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: ECE 201 [Min Grade: D] and (TDEC 202 [Min Grade: D] or ENGR 210 [Min Grade: D]) and (TDEC 221 [Min Grade: D] or ENGR 231 [Min Grade: D]) and ENGR 232 [Min Grade: D] and (BMES 235 [Min Grade: D] or BIO 203 [Min Grade: D])

BMES 392 Biomedical Instrumentation II 3.0 Credits
Continues BMES 391. Explores the operation, safety aspects, and calibration of primarily optical and acoustical instruments, as well as those involving ionizing radiation. Also examines instrumentation primarily intended for particular departments and areas, such as anesthesia and infusion.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: BMES 391 [Min Grade: D]

BMES 401 Biosensors I 4.0 Credits
Introduces the general topic of microsensors, discusses basic sensing mechanisms for microsensors, and presents various types of conductometric, acoustic, silicon, and optical microsensors. Uses two case studies that include an acoustic immunosensor and silicon glucose sensor to provide students with in-depth knowledge and hands-on experience. Provides additional experience through three laboratory sessions that support the lectures and familiarize students with practical aspects of microsensors. Also discusses applications of microsensors in the medical, chemical, pharmaceutical, environmental, aeronautical, and automotive industries.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D]) and (TDEC 202 [Min Grade: D] or ENGR 210 [Min Grade: D]) and (TDEC 221 [Min Grade: D] or ENGR 231 [Min Grade: D]) and ECE 201 [Min Grade: D] and ENGR 232 [Min Grade: D]

BMES 402 Biosensors II 4.0 Credits
Investigates modern biosensor design methods and addresses the challenges associated with fabrication technologies and instrumentation techniques. Topics include theory and modeling of biosensors, biosensor fabrication steps, and electronic and clinical testing methods. Discusses local and distant sensor data acquisition techniques. Students will design, fabricate and test a biosensor. Essential stages of biosensor manufacturing processes will be outlined. Some or all pre-requisites may be taken as either a pre-requisite or co-requisite. Please see the department for more information.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: BMES 401 [Min Grade: D] (Can be taken Concurrently)

BMES 403 Biosensors III 4.0 Credits
Covers recent advances in biosensor technology and applications, business aspects, and technology transfer issues. Topics include new sensing mechanisms, new technologies, new biomedical applications, the starting of small sensor companies, and the introduction of new sensor technologies into industrial settings. Requires students to develop a technical proposal in the area of biosensors and to review proposals written by their peers. Presentations by regular faculty and industrial and government researchers form an integral part of the course.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: BMES 402 [Min Grade: D]

BMES 405 Physiological Control Systems 3.0 Credits
Introduces the basic concepts of feedback and feed forward controls systems, including characterizations in terms of prescribed constraints, study of input and output relationships for various types of physiological systems, and stability and time-delay problems. Covers mathematical models of physiological systems, with emphasis on non-linear and adaptive systems study.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and ECES 356 [Min Grade: D] and BMES 372 [Min Grade: D]

BMES 409 Entrepreneurship for BMES 3.0 Credits
This course serves as the foundation course in entrepreneurship and is designed to provide students with a complete working knowledge of the modern entrepreneurial and business planning process.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 411 Chronoengineering I: Biological Rhythms in Health and Performance 3.0 Credits
Introduces students to the concepts of biological, and especially circadian, rhythmicity. Advances students' knowledge of biological time-keeping and adaptive functions of biological clocks. Topics include biochemical and physiological models of biological clocks, adjustment to environmental cycles, rhythms in behavior and physiological functions, sleep-wake cyclicity, adaptability of circadian systems, and influences of rhythms on human physiology and behavior. Designed to give students a thorough understanding of the role rhythms play in animal and human behavior, physiology, and medicine.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D])

BMES 412 Chronoengineering II: Sleep Functions in Health and Performance 3.0 Credits
Continues BMES 411. Enhances students' education in the concepts of biological, and especially circadian, rhythmicity. Focuses on sleep patterns, rhythms, evolution, neurology, psychology, and overall function.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: BMES 411 [Min Grade: D]

BMES 421 Biomedical Imaging Systems I: Images 4.0 Credits
Provides an overview of the field of medical imaging. Covers aspects of light imaging; systems theory, convolutions, and transforms; photometry, lenses, and depth of field; image perception and roc theory; three-dimensional imaging; image acquisition and display; and image processing operations, including scanning and segmentation.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: (TDEC 115 [Min Grade: D] and ECES 302 [Min Grade: D] and ECES 304 [Min Grade: D] and BMES 325 [Min Grade: D] and BMES 326 [Min Grade: D]) or PHYS 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (MATH 311 [Min Grade: D] or BMES 310 [Min Grade: D]) and (TDEC 222 [Min Grade: D] or ENGR 231 [Min Grade: D]) and ENGR 232 [Min Grade: D]

BMES 422 Biomedical Imaging Systems II: Ultrasound 4.0 Credits
Intended for students who would like to gain an adequate understanding of diagnostic ultrasound imaging principles and become familiar with developments in this rapidly expanding field. Introduces medical visualization techniques based on ultrasound propagation in biological tissues. Topics include generation and reception of ultrasound, imaging techniques (A-mode, B-mode, M-mode, and Doppler), typical and emerging diagnostic applications, elements of ultrasound exposimetry, and safety aspects from the clinical point of view.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 421 [Min Grade: D]

BMES 423 Biomedical Imaging Systems III 4.0 Credits
Covers volumetric and functional imaging systems. Discusses the principles and algorithms of projection tomography, XCAT, SPECT, PET; the principles of MRI: Bloch equation, slice selection, K-space scanning, volumetric MRI; biochemical imaging; chemical equilibrium equations and Scatchard plots, specific and nonspecific labeling; autoradiography; and flow and dynamical systems: Doppler, mass transport, and phase (MRI) measurement of flow.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 422 [Min Grade: D]

BMES 430 Neural Aspects of Posture and Locomotion 3.0 Credits
Students will study the physiology of ensory/motor systems, with emphasis on modeling of neural systems and biomechanical aspects of functional tasks. Combines information on basic nerve cell activities, synaptic communication and structure/function relationships of skeletal muscle with basic mechanics to study spinal, vestibular and ocular reflexes. Culminates with the study of the control of motor systems with respect to bipedal motion.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (BMES 201 [Min Grade: D] and BMES 202 [Min Grade: D]) or (ENGR 201 [Min Grade: D] and ENGR 202 [Min Grade: D]) and MEM 202 [Min Grade: D]

BMES 432 Biomedical Systems and Signals 3.0 Credits
Introduces various aspects of biomedical signals, systems, and signal processing. Covers topics in the origin and acquisition of biomedical signals; discrete-time signals and linear systems; frequency analysis of discrete-time signals, spectral estimation, data records and digital filters; and compression of biomedical signals through time-domain and frequency-domain coding.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: ECES 302 [Min Grade: D] and ECES 304 [Min Grade: D]

BMES 440 Introduction to Biodynamics 3.0 Credits
The objective of the course is to prepare students for biomechanical modeling, modeling methods, formulation of equations of motion and methods of determination of strength will be applied to human body dynamics. Particular emphasis is placed on the use of Rigid Body and Multi-Body Dynamics.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MEM 202 [Min Grade: D] and (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D]) and MEM 238 [Min Grade: D] and (BMES 235 [Min Grade: D] or BIO 203 [Min Grade: D])

BMES 441 Biomechanics I: Introduction to Biomechanics 4.0 Credits
Teaches students to use mechanical tools to get an introductory appreciation for solving biomechanical problems. Models human performance by using static, quasi-static, and dynamic approaches. Assesses overall loading of the musculoskeletal system during functional activities. Demonstrates introductory methods of estimation of forces in the joints and muscles and evaluates the endurance of the human tissues under traumatic loading conditions. Builds on existing knowledge in mechanics to illustrate the practical application of mechanical tools in the determination of human systems performance.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: MEM 202 [Min Grade: D] and (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D]) and MEM 238 [Min Grade: D] and (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D]) and BIO 203 [Min Grade: D]
Corequisite: BMES 440

BMES 442 Biomechanics II: Musculoskeletal Modeling and Human Performance 4.0 Credits
Teaches students to think biomechanically. Reviews and categorizes the various functional components (tissues) of the musculoskeletal system. Considers constraints of the joints and action of the soft and hard tissues, along with corresponding models. Computes joint and muscle forces. Discusses some aspect of postural stability of the whole musculoskeletal structure and reviews various methods of task performance.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 441 [Min Grade: D]

BMES 443 Biomechanics III: Mechanics of Biological Tissues, Implant Technology and Prosthetics 4.0 Credits
Provides more advanced knowledge of mechanics of materials and offers a general description of mechanical behavior of the variety of the soft and hard tissues of the human body. Considers some prosthetic replacements of tissues as well as entire bone, joint, soft tissue, and system prosthetics. Reviews some specific orthopedic appliances and covers limb prosthetics if time permits. Students plan design projects.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 442 [Min Grade: D]

BMES 444 Biofluid Mechanics 3.0 Credits
This course introduces flow-related anatomy and pathophysiology, and biomedical flow devices and their design challenges. Analysis methods to solve biological fluid mechanics design problems will be introduced and several interdisciplinary team projects will be assigned to apply fluid mechanics to practical biological or medical problems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 451 [Min Grade: D]

BMES 451 Transport Phenomena in Living Systems 4.0 Credits
Introduces students to applications of chemical engineering concepts in biological systems. Shows that chemical engineering approaches to problem solving are ideally suited to investigation of biology. Approaches include material and energy balances, transport phenomena, and kinetics.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: (TDEC 115 [Min Grade: D] or PHYS 201 [Min Grade: D]) and (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D]) and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (TDEC 202 [Min Grade: D] or ENGR 210 [Min Grade: D]) and ENGR 232 [Min Grade: D]

BMES 452 Transport Phenomena in Living Systems II 3.0 Credits
Continues BMES 451. Advances students' understanding of the engineering principles of membrane transport and its consequences at the subcellular (mitochondria), cellular (neuron), and organ (kidney) level. Introduces concepts associated with pharmacokinetics. Provides students with a kinetic approach to analysis of receptors, including the kinetics of ligand-receptor binding, rate constants, and signal transduction.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: BMES 451 [Min Grade: D]

BMES 460 Biomaterials I 4.0 Credits
First course in a three-quarter sequence designed to acquaint students with the behavior of materials used in biomedical application under load (i.e., mechanical properties), their modes of failure and as a function of their environment. This course provides students with the fundamentals needed to proceed with Biomaterials II.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D]) and CHEM 241 [Min Grade: D] and CHEM 242 [Min Grade: D]

BMES 461 Biomaterials II 4.0 Credits
Second course in a three-quarter sequence in biomaterials. The goal of this course is with an understanding of, and ability to select, appropriate materials for specific applications taking into account mechanical, thermal, and rheological properties taught in Biomaterials I and combining them with the biocompatibility issues covered in the present course.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 460 [Min Grade: D]

BMES 466 Robotics in Medicine III 3.0 Credits
This course covers topics in the design of medical robotic systems, including force and movement analysis for robotic arms, dynamics, computer vision and vision-based control. Thus use of haptics, vision systems and robot dynamics are examined in a cohesive framework.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 365 [Min Grade: D]

BMES 471 Cellular and Molecular Foundations of Tissue Engineering 4.0 Credits
Course is designed to familiarize students with the advanced concepts of cellular and molecular biology and physiology relevant to tissue engineering. The initial part of a two-quarter sequence combining material from cellular/molecular biology, evolutionary/developmental biology with engineering design and biomaterials to educate students in the principles, methods, and technology of tissue engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BIO 218 [Min Grade: D] and BIO 122 [Min Grade: D] and BIO 219 [Min Grade: D] and CHEM 242 [Min Grade: D] and (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D])

BMES 472 Developmental and Evolutionary Foundations of Tissue Engineering 4.0 Credits
Familiarizes students with advanced concepts of developmental and evolutionary biology relevant to tissue engineering. This second part of the two-quarter sequence combines material from cellular/molecular biology and evolutionary design and biomaterials to educate students in the principles, methods, and technology of tissue engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 471 [Min Grade: D]

BMES 475 Biomaterials and Tissue Engineering III 4.0 Credits
This course provides students with in-depth knowledge of factor-mediated tissue engineering and regenerative medicine. Students learn about fundamental repair and regenerative processes and gain an understanding of specific biomaterials being used to mimic and/or enhance such processes. Students also learn about the delivery methods of agents which promote the proper functional development of specialized tissues.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 460 [Min Grade: D] and BMES 461 [Min Grade: D] and BMES 471 [Min Grade: D] and BMES 472 [Min Grade: D]

BMES 477 Neuroengineering I: Neural Signals 3.0 Credits
Introduces the theory of neural signaling. Students will learn the fundamental theory of cellular potentials and chemical signaling, the Hodgkin Huxeley description of action potential generation, circuit representations of neurons and be able to derive and integrate equations describing the circuit as well as design computer models.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: ECES 302 [Min Grade: D] and ECES 304 [Min Grade: D] and ECES 356 [Min Grade: D] and BIO 203 [Min Grade: D] and BMES 405 [Min Grade: D] and BMES 430 [Min Grade: D]

BMES 478 Neuroengineering II: Principles of Neuroengineering 3.0 Credits
This course investigates cutting edge technologies in neuroengineering in a seminar-style format with faculty from the School of Biomedical Engineering and College of Medicine. Three modules cover topics, which vary from year to year. Students are expected to submit written and oral presentations covering each topic.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 477 [Min Grade: D]

BMES 480 Special Topics in Biomedical Engineering & Sciences 12.0 Credits
Covers topics related to the field of health care, systems, and technology. Past topics include health care administration.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit

BMES 483 Quantitative Systems Biology 4.5 Credits
This course uses a systems engineering approach to provide a foundation in systems biology and pathology informatics. Topics covered include the robust complex network of genes and proteins; cell as basic units of life; communication of cells with other cells and the environment; and gene circuits governing development.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: (TDEC 222 [Min Grade: D] or ENGR 232 [Min Grade: D]) and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (BMES 202 [Min Grade: D] or ENGR 202 [Min Grade: D]) and BMES 372 [Min Grade: D] and BMES 375 [Min Grade: D] and CS 172 [Min Grade: D]

BMES 484 Genome Information Engineering 4.5 Credits
This course is designed to provide students with hands-on experience in the application of genomic, proteomic, and other large-scale information to biomedical engineering. The underlying goal is to develop an understanding of highthrough underlying technologies, biological challenges, and key mathematical and computational methods relevant to biomedical engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 483 [Min Grade: D]

BMES 488 Medical Device Development 3.0 Credits
Medical device product development must take into account a diverse set of disciplines to achieve a safe and successful product. This course exposes the student to several of these disciplines with the objective of raising the student¿s awareness of safety throughout the product development life cycle. Students will learn to appreciate the complex engineering decisions that support development of a safe medical device through an examination of risk management, regulatory processes, human factors and clinical studies.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 391 [Min Grade: D] and BMES 392 [Min Grade: D]

BMES 491 [WI] Senior Design Project I 3.0 Credits
This is the first course in a three-quarter capstone design experience for senior biomedical engineering students.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.

BMES 492 Senior Design Project II 2.0 Credits
Continues senior design activities begun in BMES 492.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.

BMES 493 Senior Design Project III 3.0 Credits
Continues the design project begun in BMES 491 and continued through BMES 492.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.

BMES 494 Clinical Practicum I 3.0 Credits
This course provides biomedical engineering students with an extensive exposure to live clinical cardiology procedures, including cardiac catheterization, electrophysiology, echocardiography and nuclear stress testing. Emphasis is placed on identifying important interfaces between engineering and clinical medicine, particularly in areas where clinical needs may be addressed by advances in biomedical engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if major is BME.

BMES 495 Clinical Practicum II 3.0 Credits
This course provides biomedical engineering students with an extensive exposure to live operations in an emergency department and intensive care unit. The students are expected to analyze specific operations within these environments and develop a solution to a process problem within one of these environments. System analysis, design and evaluation are emphasized.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if major is BME.

BMES 496 Clinical Practicum III 3.0 Credits
This course provides biomedical engineering students with an opportunity to observe basic operative and postoperative procedures with the idea of both learning about such procedures and identifying the role of biomedical engineering in these clinical settings.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if major is BME.

BMES 499 Independent Study in Biomedical Engineering and Science 0.5-6.0 Credits
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit

Biomedical Devices and Imaging Concentration

About the Program

Bachelor of Science in Biomedical Engineering (BMES) 199.0 credits
Biomedical imaging focuses on the theoretical and practical issues related to machine vision, image processing and analysis, and signal processing associated with such medical applications as ultrasound, optics, magnetic resonance, and autoradiographic imaging.

The concentration in biomedical devices and imaging is for those individuals interested in careers in medical imaging, medical device development, and clinical engineering. The concentration covers the fundamentals of modern imaging methodologies, covering aspects of light imaging, ultrasound imaging, and volumetric and functional imaging systems, and the principles of magnetic resonance imaging (MRI).

Upon graduation, students will be able to:

- understand the multi-disciplinary background and limitations of current and emerging instrumentation, imaging and internet technologies used in clinical, pharmaceutical and research environments;
- select and evaluate sensors and imaging modalities for specific biomedical research, diagnostic and theragnostic applications;
- analyze the performance of different systems including microscopical and medical imaging methodologies in terms of safety, resolution and the trade-offs important for a given application;
- optimize digital acquisition, enhancement, visualization and analysis of signals from biomedical instruments in multidimensions;
- understand the impact of compliance with the standards and guidelines of regulatory agencies such as FDA on the design and application of devices in clinical practice and knowledge of basic quality assurance tools.

The School maintains extensive facilities and laboratories devoted to areas of research. Visit the School's BIOMED Research Facilities and Laboratory Map (http://www.biomed.drexel.edu/new04/Content/research/facilities) page for more details about the laboratories and equipment available.

For more information about this concentration, see Drexel's School of Biomedical Engineering, Science, and Health Systems (http://www.biomed.drexel.edu/new04) website.

Degree Requirements

General education requirements		
HIST 285	Technology in Historical Perspective	3.0
ENGL 101	Composition and Rhetoric I: Inquiry and Exploratory Research	3.0
ENGL 102	Composition and Rhetoric II: The Craft of Persuasion	3.0
ENGL 103	Composition and Rhetoric III: Thematic Analysis Across Genres	3.0
UNIV R101	The Drexel Experience	2.0
Liberal and General Studies Electives (5)		15.0
Engineering core courses		
MATH 121	Calculus I	4.0
MATH 122	Calculus II	4.0
MATH 200	Multivariate Calculus	4.0
PHYS 101	Fundamentals of Physics I	4.0
PHYS 102	Fundamentals of Physics II	4.0
PHYS 201	Fundamentals of Physics III	4.0
CHEM 101	General Chemistry I	3.5
CHEM 102	General Chemistry II	4.5
BIO 122	Cells and Genetics	4.5
ENGR 100	Beginning Computer Aided Drafting for Design	1.0
ENGR 101	Engineering Design Laboratory I	2.0
ENGR 102	Engineering Design Laboratory II	2.0
ENGR 103	Engineering Design Laboratory III	2.0
ENGR 210	Introduction to Thermodynamics	3.0
ENGR 220	Fundamentals of Materials	4.0
ENGR 231	Linear Engineering Systems	3.0
ENGR 232	Dynamic Engineering Systems	3.0
MEM 202	Statics	3.0
Required Biomedical Engineering courses		
BIO 201	Human Physiology I	4.0
BIO 203	Human Physiology II	4.0
BMES 124	Biomedical Engineering Freshman Seminar I	1.0
BMES 126	Biomedical Engineering Freshman Seminar II	1.0
BMES 130	Problem Solving in Biomedical Engineering	2.0
BMES 201	Programming and Modeling for Biomedical Engineers I	3.0
BMES 202	Programming and Modeling for Biomedical Engineers ll	3.0
BMES 212	The Body Synthetic	3.0
BMES 302	Laboratory II: Biomeasurements	2.0
BMES 303	Laboratory III: Biomedical Electronics	2.0
BMES 310	Biomedical Statistics	4.0
BMES 325	Principles of Biomedical Engineering I	3.0
BMES 326	Principles of Biomedical Engineering II	3.0
BMES 338	Biomedical Ethics and Law	3.0
BMES 372	Biosimulation	3.0
BMES 381	Junior Design Seminar I	2.0
BMES 382	Junior Design Seminar II	2.0
BMES 491 [WI]	Senior Design Project I	3.0
BMES 492	Senior Design Project II	2.0
BMES 493	Senior Design Project III	3.0
ECE 201	Foundations of Electric Circuits	3.0
Biomedical Devices and Imaging concentration courses		
BIO 202	Human Physiology Laboratory	2.0
BMES 301	Laboratory I: Experimental Biomechanics	2.0
BMES 304	Laboratory IV: Ultrasound Images	2.0
BMES 315	Experimental Design in Biomedical Research	4.0
BMES 391	Biomedical Instrumentation I	3.0
BMES 392	Biomedical Instrumentation II	3.0
BMES 375	Computational Bioengineering	4.0
BMES 401	Biosensors I	4.0
BMES 421	Biomedical Imaging Systems I: Images	4.0
BMES 422	Biomedical Imaging Systems II: Ultrasound	4.0
BMES 423	Biomedical Imaging Systems III	4.0
ECES 304	Dynamic Systems and Stability	4.0
ECES 352	Introduction to Digital Signal Process	4.0
Biomedical Systems and Imaging Elective		3.0
Select one of the following:		
BMES 488	Medical Device Development	
BMES 494	Clinical Practicum I	
BMES 495	Clinical Practicum II	
BMES 496	Clinical Practicum III	
Total Credits		**191.5**

Sample Plan of Study

Term 1		**Credits**
BMES 124	Biomedical Engineering Freshman Seminar I	1.0
CHEM 101	General Chemistry I	3.5
ENGL 101	Composition and Rhetoric I: Inquiry and Exploratory Research	3.0
ENGR 100	Beginning Computer Aided Drafting for Design	1.0

ENGR 101	Engineering Design Laboratory I	2.0
MATH 121	Calculus I	4.0
UNIV R101	The Drexel Experience	1.0
	Term Credits	**15.5**
Term 2		
BMES 126	Biomedical Engineering Freshman Seminar II	1.0
CHEM 102	General Chemistry II	4.5
ENGL 102	Composition and Rhetoric II: The Craft of Persuasion	3.0
ENGR 102	Engineering Design Laboratory II	2.0
MATH 122	Calculus II	4.0
PHYS 101	Fundamentals of Physics I	4.0
UNIV R101	The Drexel Experience	0.5
	Term Credits	**19.0**
Term 3		
BIO 122	Cells and Genetics	4.5
BMES 130	Problem Solving in Biomedical Engineering	2.0
ENGL 103	Composition and Rhetoric III: Thematic Analysis Across Genres	3.0
ENGR 103	Engineering Design Laboratory III	2.0
MATH 200	Multivariate Calculus	4.0
PHYS 102	Fundamentals of Physics II	4.0
UNIV R101	The Drexel Experience	0.5
	Term Credits	**20.0**
Term 4		
BIO 201	Human Physiology I	4.0
BMES 201	Programming and Modeling for Biomedical Engineers I	3.0
ENGR 220	Fundamentals of Materials	4.0
ENGR 231	Linear Engineering Systems	3.0
PHYS 201	Fundamentals of Physics III	4.0
	Term Credits	**18.0**
Term 5		
BMES 202	Programming and Modeling for Biomedical Engineers ll	3.0
BMES 212	The Body Synthetic	3.0
BMES 235	Living Systems Engineering	4.0
ENGR 210	Introduction to Thermodynamics	3.0
ENGR 232	Dynamic Engineering Systems	3.0
MEM 202	Statics	3.0
	Term Credits	**19.0**
Term 6		
BMES 301	Laboratory I: Experimental Biomechanics	2.0
BMES 302	Laboratory II: Biomeasurements	2.0
BMES 325	Principles of Biomedical Engineering I	3.0
BMES 372	Biosimulation	3.0
ECE 201	Foundations of Electric Circuits	3.0
HIST 285	Technology in Historical Perspective	3.0
	Term Credits	**16.0**
Term 7		
BMES 303	Laboratory III: Biomedical Electronics	2.0
BMES 310	Biomedical Statistics	4.0
BMES 326	Principles of Biomedical Engineering II	3.0
ECES 302	Transform Methods I	4.0
Liberal Studies Elective		3.0
	Term Credits	**16.0**
Term 8		
BIO 202	Human Physiology Laboratory	2.0
BMES 304	Laboratory IV: Ultrasound Images	2.0
BMES 315	Experimental Design in Biomedical Research	4.0
BMES 338	Biomedical Ethics and Law	3.0
BMES 381	Junior Design Seminar I	2.0
BMES 401	Biosensors I	4.0
	Term Credits	**17.0**
Term 9		
BMES 375	Computational Bioengineering	4.0
BMES 382	Junior Design Seminar II	2.0
ECES 304	Dynamic Systems and Stability	4.0
ECES 352	Introduction to Digital Signal Process	4.0
	Term Credits	**14.0**
Term 10		
BMES 391	Biomedical Instrumentation I	3.0
BMES 421	Biomedical Imaging Systems I: Images	4.0
BMES 432	Biomedical Systems and Signals	3.0
BMES 491 [WI]	Senior Design Project I	3.0
Liberal Studies Elective		3.0
	Term Credits	**16.0**
Term 11		
BMES 392	Biomedical Instrumentation II	3.0
BMES 422	Biomedical Imaging Systems II: Ultrasound	4.0
BMES 492	Senior Design Project II	2.0
General Studies Electives		6.0
	Term Credits	**15.0**
Term 12		
BMES 423	Biomedical Imaging Systems III	4.0
BMES 493	Senior Design Project III	3.0
Biomedical Devices and Imaging Concentration Elective*		3.0
Liberal Studies Elective		3.0
	Term Credits	**13.0**
Total Credit: 198.5		

* See degree requirements.

Opportunities

Metropolitan Philadelphia has one of the highest concentrations of medical institutions and pharmaceutical and biotechnology industries in the nation.The bachelor of science degree in biomedical engineering gives students access to a broad spectrum of career opportunities in medical device and equipment industry; prosthetics and assist devices industry; biomaterials and implants industry; and the telemedicine, pharmaceutical, biotechnology, and agricultural sectors.

Biomedical engineering graduates are also ideally prepared for professional education in medicine, dentistry, veterinary medicine, and law. Those who choose to pursue graduate education can aim for careers

in research and development, biomedical technology innovation and transfer, as well as health care technology management.

Visit the Drexel Steinbright Career Development Center (http://www.drexel.edu/scdc) page for more detailed information on co-op and post-graduate opportunities.

Biomedical Engineering, Science and Health Systems Faculty

Fred D. Allen, PhD *(University of Pennsylvania)*. Assistant Professor. Tissue engineering, cell engineering, orthopedics, bone remodeling, wound healing, mechanotransduction, signal transduction, adhesion, migration.

Sriram Balasubramanian, PhD *(Wayne State University)*. Assistant Professor. Structural characteristics of the pediatric thoracic cage using CT scans and developing an age-equivalent animal model for pediatric long bones.

Kenneth A. Barbee, PhD *(University of Pennsylvania)*. Professor. Cellular biomechanics of neural and vascular injury, mechanotransduction in the cardiovascular system, mechanical control of growth and development for wound healing and tissue engineering.

Lin Han, PhD *(Massachusetts Institute of Technology)*. Assistant Professor. Nanoscale structure-property relationships of biological materials, genetic and molecular origins soft joint tissue diseases, biomaterials under extreme conditions, coupling between stimulus-responsiveness and geometry.

Uri Hershberg, PhD *(Hebrew University of Jerusalem, Israel)*. Assistant Professor. Bioinformatics, immunology, neural computation, system biology, somatic selection, autoimmunity, genetic stability, germline diversity, dendritic cell, transcription elements, pathogens, computational and mathematical modeling, complex systems, cognition and inflammation.

Joshua Jacobs, PhD *(University of Pennsylvania)*. Assistant Professor. Neuroengineering, electrocorticography (ECoG), electroencephalography (EEG), single-neuron spiking, brain oscillations, episodic memory, working memory, spatial navigation, conceptual representations.

Dov Jaron, PhD *(University of Pennsylvania) Calhoun Distinguished Professor of Engineering in Medicine*. Professor. Mathematical, computer and electromechanical simulations of the cardiovascular system.

Andres Kriete, PhD *(University in Bremen Germany) Associate Director for Graduate Studies and Academic Operations*. Systems biology, bioimaging, control theory, biology of aging, skin cancer.

Ryszard Lec, PhD *(University of Warsaw Engineering College)*. Professor. Biomedical applications of visoelastic, acoustoptic and ultrasonic properties of liquid and solid media.

Peter Lewin, PhD *(University of Denmark, Copenhagen-Lyngby) Richard B. Beard Professor, School Of Biomedical Engineering, Science & Health Systems*. Professor. Biomedical ultrasonics, piezoelectric and polymer transducers and hydrophones; shock wave sensors.

Hualou Liang, PhD *(Chinese Academy of Sciences)*. Associate Professor. Neuroengineering, neuroinformatics, cognitive and computational neuroscience, neural data analysis and computational modeling, biomedical signal processing.

Donald L. McEachron, PhD *(University of California at San Diego) Associate Director*. Research Professor. Animal behavior, autoradiography, biological rhythms, cerebral metabolism, evolutionary theory, image processing, neuroendocrinology.

Karen Moxon, PhD *(University of Colorado)*. Associate Professor. Cortico-thalamic interactions; neurobiological perspectives on design of humanoid robots.

Banu Onaral, Ph.D. *(University of Pennsylvania) H.H. Sun Professor / Director, School of Biomedical Engineering Science and Health Systems*. Professor. Biomedical signal processing; complexity and scaling in biomedical signals and systems.

Kambiz Pourrezaei, PhD *(Rensselaer Polytechnic University)*. Professor. Thin film technology; nanotechnology; near infrared imaging; power electronics.

Arye Rosen, PhD *(Drexel University) Biomedical Engineering and Electrical Engineering*. Microwave components and subsystems; utilization of RF/microwaves and lasers in therapeutic medicine.

Ahmet Sacan, PhD *(Middle East Technical University)*. Assistant Professor. Indexing and data mining in biological databases; protein sequence and structure; similarity search; protein structure modeling; protein-protein interaction; automated cell tracking.

Joseph J. Sarver, PhD *(Drexel University)*. Teaching Professor. Neuromuscular adaptation to changes in the myo-mechanical environment.

Rahamim Seliktar, PhD *(University of Strathclyde, Glasgow) Vice Director, School of Biomedical Engineering, Science & Health Systems*. Professor. Limb prostheses, biomechanics of human motion, orthopedic biomechanics.

Adrian C. Shieh, PhD *(Rice University)*. Assistant Professor. Contribution of mechanical forces to tumor invasion and metastasis, with a particular emphasis on how biomechanical signals may drive the invasive switch, and how the biomechanical microenvironment interacts with cytokine signaling and the extracellular matrix to influence tumor and stromal cell behavior.

Wan Young Shih, PhD *(Ohio State University) School of Biomedical Engineering, Science and Health Systems*. Associate Professor. Piezoelectric microcantilever biosensors development, piezoelectric finger development, quantum dots development, tissue elasticity imaging, piezoelectric microcantilever force probes.

Kara Spiller, PhD *(Drexel University)*. Assistant Professor. Cell-biomaterial interactions, biomaterial design, and international engineering education.

Margaret Wheatley, PhD *(University of Toronto) School of Biomedical Engineering, Science and Health Systems, John M. Reid Professor*. Ultrasound contrast agent development (tumor targeting and triggered drug delivery), controlled release technology (bioactive compounds), microencapsulated allografts (*ex vivo* gene therapy) for spinal cord repair.

Yinghui Zhong, PhD *(Georgia Institute of Technology)*. Assistant Professor. Spinal cord repair, and engineering neural prosthesis/brain interface using biomaterials, drug delivery, and stem cell therapy.

Interdepartmental Faculty

Douglas L. Chute, PhD *(University of Missouri) Louis and Bessie Stein Fellow*. Professor. Neuropsychology and rehabilitation; technological applications for the cognitively compromised and those with acquired brain injuries.

Patricia A. Shewokis, PhD *(University of Georgia)*. Professor. Roles of cognition and motor function during motor skill learning; role of information feedback frequency on the memory of motor skills, noninvasive neural imaging techniques of functional near infrared spectroscopy(fNIR) and electroencephalograpy (EEG) and methodology and research design.

Emeritus Faculty

William Freedman, PhD *(Drexel University)*. Professor Emeritus. Motor control; sensory and motor systems; reflexes; eye movements; neural networks.

John M. Reid, PhD *(University of Pennsylvania) Calhoun Professor Emeritus*. Professor Emeritus. Diagnostic ultrasound, wave propagation and scattering in inhomogeneous media, imaging, instrumentation.

Hun H. Sun, PhD *(Cornell University)*. Professor Emeritus. Biological control systems, physiological modeling, systems analysis.

Aydin Tozeren, PhD *(Columbia University) Distinguished Professor and Director, Center for Integrated Bioinformatics, School of Biomedical Engineering, Science & Health Systems*. Professor Emeritus. Breast cell adhesion and communication, signal transduction networks in cancer and epithelial cells; integrated bioinformatics, molecular profiling, 3D-tumors, bioimaging.

Courses

BMES 124 Biomedical Engineering Freshman Seminar I 1.0 Credit
This course is intended to introduce freshman biomedical engineering students in the School of biomedical Engineering, Science and Health Systems at Drexel University to academic programs and opportunities, ongoing research projects and University resources to ensure a successful educational experience at Drexel and beyond. Through class discussions and guest lecture presentations, the students are provided with information and contacts necessary to begin a plan of academic study.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 125 Foundations of Biomedical Engineering 2.0 Credits
This course is intended to introduce new transfer biomedical engineering students in the School of biomedical Engineering, Science and Health Systems at Drexel University academic programs and opportunities, ongoing research projects and University resources to ensure a successful educational experience at Drexel and beyond. Through class discussions and guest lecture presentations, the students are provided with information and contact necessary to begin a plan of academic study.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 126 Biomedical Engineering Freshman Seminar II 1.0 Credit
This course is intended to introduce freshman biomedical engineering students to the career embodied by the School's current concentration areas. Each area will be discussed in terms of the current state of the art, research possibilities and career opportunities. The curricula for each concentration will be discussed in detail so as to facilitate students' knowledge of how each curriculum relates to the research and employment opportunities in that field.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 130 Problem Solving in Biomedical Engineering 2.0 Credits
This course integrates fundamental principles of biology, chemistry, engineering, mathematics and physics into a framework for the study of biomedical engineering. In this course, students will use both engineering and scientific approaches to problem-solving. They will learn about the differences between engineering design and biological evolution. They will also learn to apply basic principles of chemistry, physics and mathematics to specific biological and physiological problems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MATH 122 [Min Grade: D] and CHEM 102 [Min Grade: D] and PHYS 101 [Min Grade: D]

BMES 201 Programming and Modeling for Biomedical Engineers I 3.0 Credits
This course aims to introduce students with some fundamental concepts about programming in MATLAB to give the ability to solve basic bioengineering problems. The course introduces the basics of programming using Matlab, including programming environment and tools. Fundamental programming techniques and concepts such as loops, switches and logical operators, functions and file handling are covered. Applications in bioengineering for basic numerical problem solving are discussed.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MATH 200 [Min Grade: D] and PHYS 102 [Min Grade: D] and BIO 122 [Min Grade: D] and (BMES 130 [Min Grade: D] or BMES 125 [Min Grade: D])

BMES 202 Programming and Modeling for Biomedical Engineers II 3.0 Credits
The course aims to introduce students to advanced programming concepts and tools to solve numerical problems in bioengineering. It provides the foundation for biosimulation and biocomputation classes. This course introduces advanced programming methods and computational tools for numerical analysis, model design and graphics. Higher level level lunctionality in Matlab such as SIMULINK, symbolic processing and CAD related tools are discussed.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 201 [Min Grade: D]

BMES 212 The Body Synthetic 3.0 Credits
The Body Synthetic introduces concepts underlying biological and engineering principles involved in the design and construction of prosthetic devices used to replace various parts of the human body.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: (TDEC 122 [Min Grade: D] or BIO 122 [Min Grade: D]) and (BMES 130 [Min Grade: D] or BMES 125 [Min Grade: D])

BMES 235 Living Systems Engineering 4.0 Credits
This course introduces the biomedical engineering students to engineering principles applied to biological and physiological systeTs. This course focuses.on evolution, adaptation, energy, thermodynamics, fluid dynamics and control systems in living organrsms.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 122 [Min Grade: D] and CHEM 102 [Min Grade: D] and MATH 200 [Min Grade: D] and PHYS 102 [Min Grade: D] and BMES 130 [Min Grade: D] and BIO 201 [Min Grade: D]

BMES 301 Laboratory I: Experimental Biomechanics 2.0 Credits
This course deals with experimental aspects of biomechanics, specifically with the testing mechanical properties of biological tissues.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (TDEC 114 [Min Grade: D] or MATH 200 [Min Grade: D]) and (TDEC 115 [Min Grade: D] or PHYS 201 [Min Grade: D]) and (TDEC 211 [Min Grade: D] or ENGR 231 [Min Grade: D]) and MEM 202 [Min Grade: D]

BMES 302 Laboratory II: Biomeasurements 2.0 Credits
This course introduces students to the measurement of physiological/biological/functional signals. Four specific signals will be collected and analyzed. Students are expected to analyze type of signal to be collected, possible measurement techniques and potential data analysis and then collect and analyze each signal.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: ECE 201 [Min Grade: D] (Can be taken Concurrently) (BMES 222 [Min Grade: D] or BIO 201 [Min Grade: D]) and (TDEC 231 [Min Grade: D] or ENGR 103 [Min Grade: D])

BMES 303 Laboratory III: Biomedical Electronics 2.0 Credits
This course introduces students to the widespread application of electronics and electronic devices in biomedical engineering. The course reinforces concepts learned in ECE 201 with hands-on experimentation related to biomedical applications such as telemedicine and medical devices.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (ECE 201 [Min Grade: D] and TDEC 231 [Min Grade: D]) or ENGR 232 [Min Grade: D]

BMES 304 Laboratory IV: Ultrasound Images 2.0 Credits
This course introduces students to the engineering principles of acoustical measurements by combining hands-on laboratory experiences with lectures. Students will learn the engineering/physical principles of measuring sound velocity in different materials, attenuation, and directivity of a circular transducers.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (BIO 201 [Min Grade: D] or BMES 235 [Min Grade: D]) and ECE 201 [Min Grade: D] and (TDEC 231 [Min Grade: D] or ENGR 103 [Min Grade: D])

BMES 305 Laboratory V: Musculoskeletal Anatomy for Biomedical Engineers 2.0 Credits
This course provides an opportunity for students to study the anatomy and biomechanics of select articulations of the human body. While the main emphasis will be on the musculoskeletal structures associated with each articulation, major neural and vascular structures will be studied as well.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: (BIO 201 [Min Grade: D] or BMES 235 [Min Grade: D]) and MEM 202 [Min Grade: D]

BMES 310 Biomedical Statistics 4.0 Credits
This course is designed to introduce biomedical engineering students to the fundamentals of biostatistics necessary for medical research. Topics covered include measurements, sampling, basic hypothesis testing, analysis of variance and regression. Medical applications are emphasized.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: ENGR 231 [Min Grade: D]

BMES 315 Experimental Design in Biomedical Research 4.0 Credits
This course is designed to introduce students to the fundamental principles of experimental design and statistical analysis as applied to biomedical research with animals and humans. Topics to be covered include experimental design, clinical design, and protocol submission and review.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 310 [Min Grade: D]

BMES 325 Principles of Biomedical Engineering I 3.0 Credits
This course is the first part of a two-term sequence which introduces biomedical engineering students to engineering principles applied to biological and physiological systems. This course focuses on bioethical questions, biomechanics, human performance engineering, biomaterials and tissue engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 122 [Min Grade: D] and CHEM 102 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and MEM 202 [Min Grade: D] and ENGR 220 [Min Grade: D] and ENGR 232 [Min Grade: D]

BMES 326 Principles of Biomedical Engineering II 3.0 Credits
This course is the second part of a two-term sequence which introduces biomedical engineering students to engineering principles applied to biological and physiological systems. This course focuses on bioinformatics, neuroengineering, biosignal processing, biosensors, and medical imaging.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 325 [Min Grade: D] and BIO 201 [Min Grade: D] and (BMES 202 [Min Grade: D] or ENGR 202 [Min Grade: D])

BMES 330 Biological Rhythm in Pharmacology and Toxicology 3.0 Credits
This course covers the fundamentals of biological rhythms with particular emphasis on the influence these cycles have on the susceptibility of organism to physical, chemical, and /or toxic agents.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman
Prerequisites: BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]

BMES 331 Computers in Health Systems I 3.0 Credits
Introduces the allied health professional to basic computer applications on personal computers. Includes word processing, spreadsheets, databases, and networking (e.g., e-mail and information search and retrieval) in a primarily Windows environment. Designed for individuals with little or no computer background. Students are encouraged to bring in their own work-related problems or projects to provide immediate application of knowledge learned to the student's professional healthcare environment.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 332 Computers in Health Systems II 3.0 Credits
Continues the general overview of computers for people in the allied health professions, using specific examples from health care. Offers further study of and practice with special scientific (e.g., statistics, graphing) and medical clinical decision-support software. Introduces algorithms and formal programming methods.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman

BMES 335 Biomedical Informatics I 3.0 Credits
Introduces information and information handling systems for people in the allied health professions, with specific examples drawn from health care. Covers locating, manipulating, and displaying information in the health system setting.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore

BMES 336 Biomedical Informatics II: Hospital and Patient Information 3.0 Credits
Continues BMES 335. Emphasizes medical records and hospital and patient information handling. Examines the problems of patient information flow within the health care system. Introduces conventional and proposed patient and hospital information systems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 335 [Min Grade: D]

BMES 338 Biomedical Ethics and Law 3.0 Credits
Introduces the wide spectrum of ethical, regulatory, and legal issues facing health care practitioners and health-related research workers. Helps students become aware of the ethical and legal issues involved in their work. Helps students understand how legal and ethical decisions should be made in health-related matters, as well as what sources of help and guidance are available.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman

BMES 340 Health Care Administration 3.0 Credits
This course provides students with an analysis of health care administration process, including: planning, organizing, designing, decision-making, leading, and controlling. Presents methods and techniques that can contribute to the effective performance of administrative duties.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman

BMES 345 Mechanics of Biological Systems 3.0 Credits
This course introduces the fundamentals of mechanics of deformable bodies as they relevant to biologicaltissues and biomaterials. Major topics include stress and strain, mechanical properties of biologicaltissues and biomaterials, axial loading, torsion, bending, and viscoelasticity, These concepts will be applied to biological examples such as long bones, the heart, blood vessels, and orthopaedic implants.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MEM 202 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D])

BMES 350 Med & Bio Effects Of Light 3.0 Credits
Examines the role of environmental lighting in human physiological and psychological processes. Topics include vitamin D synthesis and calcium regulation; light effects on bilirubin in newborns; photoactivation and DNA in skin; effects of nonionizing radiation on the immune systems; environmental lighting and human vision; light effects on biological rhythms and sleep; photosensitivity diseases related to interior lighting; the therapeutic uses of light; and light and the aging eye.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman
Prerequisites: BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]

BMES 363 Robotics in Medicine I 3.0 Credits
This course provides an introduction to the use of haptics (the use of somtaosensory information) in the design of robotic devices in surgery. Topics covered include actuators, sensors, nonportable feedback, portable force feedback, tactile feedback interfaces, haptic sensing and control systems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MEM 238 [Min Grade: D]

BMES 365 Robotics in Medicine II 3.0 Credits
This course covers the use of robots in surgery and included aspects of safety, robot kinematics, analysis of surgical performance using robotic devices, inverse kinematics, velocity analysis and acceleration analysis. Various types of surgeries in which robotic devices are or could be used are presented on a case study basis.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 363 [Min Grade: D]

BMES 372 Biosimulation 3.0 Credits
This course provides the foundation for the mathematical analysis of biomedical engineering systems. It focuses on the essential mathematical methods necessary for further development of modeling and simulation skills in other courses (materials, mechanics, fluids/transport, signals/control system, etc). The course applies the skills in calculus, differential equations and linear algebra gained in ENGR 231 and ENGR 232 to developing analytical techniques for biomedical applications.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and ENGR 231 [Min Grade: D] and ENGR 232 [Min Grade: D] and (BMES 201 [Min Grade: D] and BMES 202 [Min Grade: D]) or (ENGR 201 [Min Grade: D] and ENGR 202 [Min Grade: D])

BMES 375 Computational Bioengineering 4.0 Credits
This course introduces undergraduate students to the mathematical and computational analysis of biological systems. The systems analyzed include the genome, protein and gene networks, cell division cycles, and cellular level disease. Mathematical tools include matrix algebra, differential equations, cellular automata, cluster analysis, etc.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and BMES 325 [Min Grade: D] and BMES 372 [Min Grade: D] and ENGR 231 [Min Grade: D] and (TDEC 221 [Min Grade: D] or ENGR 232 [Min Grade: D])

BMES 381 Junior Design Seminar I 2.0 Credits
This is the first course in a two-course sequence intended to present the basics of engineering design, project management, product development and translational research. This first course focuses on engineering design and product development. A case-study approach is used to illustrate best practices and common mistakes in engineering design.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore

BMES 382 Junior Design Seminar II 2.0 Credits
This is the second course in a two-course sequence intended to present the basics of engineering design, project management, product development and translational research. This second course focuses on project management and quality control. A case-study approach is used to illustrate best practices and common mistakes in management and evaluation of engineering projects.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: BMES 381 [Min Grade: D]

BMES 391 Biomedical Instrumentation I 3.0 Credits
This course introduces the student to the medical instrumentation and provides background on the physical, chemical, electronic and computational fundamentals by which medical instrumentation operates. It is an analytical course exploring the design, operation, safety aspects and calibration of primary electronic instruments.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: ECE 201 [Min Grade: D] and (TDEC 202 [Min Grade: D] or ENGR 210 [Min Grade: D]) and (TDEC 221 [Min Grade: D] or ENGR 231 [Min Grade: D]) and ENGR 232 [Min Grade: D] and (BMES 235 [Min Grade: D] or BIO 203 [Min Grade: D])

BMES 392 Biomedical Instrumentation II 3.0 Credits
Continues BMES 391. Explores the operation, safety aspects, and calibration of primarily optical and acoustical instruments, as well as those involving ionizing radiation. Also examines instrumentation primarily intended for particular departments and areas, such as anesthesia and infusion.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: BMES 391 [Min Grade: D]

BMES 401 Biosensors I 4.0 Credits
Introduces the general topic of microsensors, discusses basic sensing mechanisms for microsensors, and presents various types of conductometric, acoustic, silicon, and optical microsensors. Uses two case studies that include an acoustic immunosensor and silicon glucose sensor to provide students with in-depth knowledge and hands-on experience. Provides additional experience through three laboratory sessions that support the lectures and familiarize students with practical aspects of microsensors. Also discusses applications of microsensors in the medical, chemical, pharmaceutical, environmental, aeronautical, and automotive industries.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D]) and (TDEC 202 [Min Grade: D] or ENGR 210 [Min Grade: D]) and (TDEC 221 [Min Grade: D] or ENGR 231 [Min Grade: D]) and ECE 201 [Min Grade: D] and ENGR 232 [Min Grade: D]

BMES 402 Biosensors II 4.0 Credits
Investigates modern biosensor design methods and addresses the challenges associated with fabrication technologies and instrumentation techniques. Topics include theory and modeling of biosensors, biosensor fabrication steps, and electronic and clinical testing methods. Discusses local and distant sensor data acquisition techniques. Students will design, fabricate and test a biosensor. Essential stages of biosensor manufacturing processes will be outlined. Some or all pre-requisites may be taken as either a pre-requisite or co-requisite. Please see the department for more information.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: BMES 401 [Min Grade: D] (Can be taken Concurrently)

BMES 403 Biosensors III 4.0 Credits
Covers recent advances in biosensor technology and applications, business aspects, and technology transfer issues. Topics include new sensing mechanisms, new technologies, new biomedical applications, the starting of small sensor companies, and the introduction of new sensor technologies into industrial settings. Requires students to develop a technical proposal in the area of biosensors and to review proposals written by their peers. Presentations by regular faculty and industrial and government researchers form an integral part of the course.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Junior or Senior.
Prerequisites: BMES 402 [Min Grade: D]

BMES 405 Physiological Control Systems 3.0 Credits
Introduces the basic concepts of feedback and feed forward controls systems, including characterizations in terms of prescribed constraints, study of input and output relationships for various types of physiological systems, and stability and time-delay problems. Covers mathematical models of physiological systems, with emphasis on non-linear and adaptive systems study.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and ECES 356 [Min Grade: D] and BMES 372 [Min Grade: D]

BMES 409 Entrepreneurship for BMES 3.0 Credits
This course serves as the foundation course in entrepreneurship and is designed to provide students with a complete working knowledge of the modern entrepreneurial and business planning process.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 411 Chronoengineering I: Biological Rhythms in Health and Performance 3.0 Credits
Introduces students to the concepts of biological, and especially circadian, rhythmicity. Advances students' knowledge of biological time-keeping and adaptive functions of biological clocks. Topics include biochemical and physiological models of biological clocks, adjustment to environmental cycles, rhythms in behavior and physiological functions, sleep-wake cyclicity, adaptability of circadian systems, and influences of rhythms on human physiology and behavior. Designed to give students a thorough understanding of the role rhythms play in animal and human behavior, physiology, and medicine.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D])

BMES 412 Chronoengineering II: Sleep Functions in Health and Performance 3.0 Credits
Continues BMES 411. Enhances students' education in the concepts of biological, and especially circadian, rhythmicity. Focuses on sleep patterns, rhythms, evolution, neurology, psychology, and overall function.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Sophomore
Prerequisites: BMES 411 [Min Grade: D]

BMES 421 Biomedical Imaging Systems I: Images 4.0 Credits
Provides an overview of the field of medical imaging. Covers aspects of light imaging; systems theory, convolutions, and transforms; photometry, lenses, and depth of field; image perception and roc theory; three-dimensional imaging; image acquisition and display; and image processing operations, including scanning and segmentation.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: (TDEC 115 [Min Grade: D] and ECES 302 [Min Grade: D] and ECES 304 [Min Grade: D] and BMES 325 [Min Grade: D] and BMES 326 [Min Grade: D]) or PHYS 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (MATH 311 [Min Grade: D] or BMES 310 [Min Grade: D]) and (TDEC 222 [Min Grade: D] or ENGR 231 [Min Grade: D]) and ENGR 232 [Min Grade: D]

BMES 422 Biomedical Imaging Systems II: Ultrasound 4.0 Credits
Intended for students who would like to gain an adequate understanding of diagnostic ultrasound imaging principles and become familiar with developments in this rapidly expanding field. Introduces medical visualization techniques based on ultrasound propagation in biological tissues. Topics include generation and reception of ultrasound, imaging techniques (A-mode, B-mode, M-mode, and Doppler), typical and emerging diagnostic applications, elements of ultrasound exposimetry, and safety aspects from the clinical point of view.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 421 [Min Grade: D]

BMES 423 Biomedical Imaging Systems III 4.0 Credits
Covers volumetric and functional imaging systems. Discusses the principles and algorithms of projection tomography, XCAT, SPECT, PET; the principles of MRI: Bloch equation, slice selection, K-space scanning, volumetric MRI; biochemical imaging; chemical equilibrium equations and Scatchard plots, specific and nonspecific labeling; autoradiography; and flow and dynamical systems: Doppler, mass transport, and phase (MRI) measurement of flow.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 422 [Min Grade: D]

BMES 430 Neural Aspects of Posture and Locomotion 3.0 Credits
Students will study the physiology of ensory/motor systems, with emphasis on modeling of neural systems and biomechanical aspects of functional tasks. Combines information on basic nerve cell activities, synaptic communication and structure/function relationships of skeletal muscle with basic mechanics to study spinal, vestibular and ocular reflexes. Culminates with the study of the control of motor systems with respect to bipedal motion.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BIO 201 [Min Grade: D] and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (BMES 201 [Min Grade: D] and BMES 202 [Min Grade: D]) or (ENGR 201 [Min Grade: D] and ENGR 202 [Min Grade: D]) and MEM 202 [Min Grade: D]

BMES 432 Biomedical Systems and Signals 3.0 Credits
Introduces various aspects of biomedical signals, systems, and signal processing. Covers topics in the origin and acquisition of biomedical signals; discrete-time signals and linear systems; frequency analysis of discrete-time signals, spectral estimation, data records and digital filters; and compression of biomedical signals through time-domain and frequency-domain coding.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: ECES 302 [Min Grade: D] and ECES 304 [Min Grade: D]

BMES 440 Introduction to Biodynamics 3.0 Credits
The objective of the course is to prepare students for biomechanical modeling, modeling methods, formulation of equations of motion and methods of determination of strength will be applied to human body dynamics. Particular emphasis is placed on the use of Rigid Body and Multi-Body Dynamics.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MEM 202 [Min Grade: D] and (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D]) and MEM 238 [Min Grade: D] and (BMES 235 [Min Grade: D] or BIO 203 [Min Grade: D])

BMES 441 Biomechanics I: Introduction to Biomechanics 4.0 Credits
Teaches students to use mechanical tools to get an introductory appreciation for solving biomechanical problems. Models human performance by using static, quasi-static, and dynamic approaches. Assesses overall loading of the musculoskeletal system during functional activities. Demonstrates introductory methods of estimation of forces in the joints and muscles and evaluates the endurance of the human tissues under traumatic loading conditions. Builds on existing knowledge in mechanics to illustrate the practical application of mechanical tools in the determination of human systems performance.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: MEM 202 [Min Grade: D] and (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D]) and MEM 238 [Min Grade: D] and (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D]) and BIO 203 [Min Grade: D]
Corequisite: BMES 440

BMES 442 Biomechanics II: Musculoskeletal Modeling and Human Performance 4.0 Credits
Teaches students to think biomechanically. Reviews and categorizes the various functional components (tissues) of the musculoskeletal system. Considers constraints of the joints and action of the soft and hard tissues, along with corresponding models. Computes joint and muscle forces. Discusses some aspect of postural stability of the whole musculoskeletal structure and reviews various methods of task performance.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 441 [Min Grade: D]

BMES 443 Biomechanics III: Mechanics of Biological Tissues, Implant Technology and Prosthetics 4.0 Credits
Provides more advanced knowledge of mechanics of materials and offers a general description of mechanical behavior of the variety of the soft and hard tissues of the human body. Considers some prosthetic replacements of tissues as well as entire bone, joint, soft tissue, and system prosthetics. Reviews some specific orthopedic appliances and covers limb prosthetics if time permits. Students plan design projects.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 442 [Min Grade: D]

BMES 444 Biofluid Mechanics 3.0 Credits
This course introduces flow-related anatomy and pathophysiology, and biomedical flow devices and their design challenges. Analysis methods to solve biological fluid mechanics design problems will be introduced and several interdisciplinary team projects will be assigned to apply fluid mechanics to practical biological or medical problems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 451 [Min Grade: D]

BMES 451 Transport Phenomena in Living Systems 4.0 Credits
Introduces students to applications of chemical engineering concepts in biological systems. Shows that chemical engineering approaches to problem solving are ideally suited to investigation of biology. Approaches include material and energy balances, transport phenomena, and kinetics.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: (TDEC 115 [Min Grade: D] or PHYS 201 [Min Grade: D]) and (BMES 222 [Min Grade: D] or BMES 326 [Min Grade: D]) and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (TDEC 202 [Min Grade: D] or ENGR 210 [Min Grade: D]) and ENGR 232 [Min Grade: D]

BMES 452 Transport Phenomena in Living Systems II 3.0 Credits
Continues BMES 451. Advances students' understanding of the engineering principles of membrane transport and its consequences at the subcellular (mitochondria), cellular (neuron), and organ (kidney) level. Introduces concepts associated with pharmacokinetics. Provides students with a kinetic approach to analysis of receptors, including the kinetics of ligand-receptor binding, rate constants, and signal transduction.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
Prerequisites: BMES 451 [Min Grade: D]

BMES 460 Biomaterials I 4.0 Credits
First course in a three-quarter sequence designed to acquaint students with the behavior of materials used in biomedical application under load (i.e., mechanical properties), their modes of failure and as a function of their environment. This course provides students with the fundamentals needed to proceed with Biomaterials II.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D]) and CHEM 241 [Min Grade: D] and CHEM 242 [Min Grade: D]

BMES 461 Biomaterials II 4.0 Credits
Second course in a three-quarter sequence in biomaterials. The goal of this course is with an understanding of, and ability to select, appropriate materials for specific applications taking into account mechanical, thermal, and rheological properties taught in Biomaterials I and combining them with the biocompatibility issues covered in the present course.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 460 [Min Grade: D]

BMES 466 Robotics in Medicine III 3.0 Credits
This course covers topics in the design of medical robotic systems, including force and movement analysis for robotic arms, dynamics, computer vision and vision-based control. Thus use of haptics, vision systems and robot dynamics are examined in a cohesive framework.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 365 [Min Grade: D]

BMES 471 Cellular and Molecular Foundations of Tissue Engineering 4.0 Credits
Course is designed to familiarize students with the advanced concepts of cellular and molecular biology and physiology relevant to tissue engineering. The initial part of a two-quarter sequence combining material from cellular/molecular biology, evolutionary/developmental biology with engineering design and biomaterials to educate students in the principles, methods, and technology of tissue engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BIO 218 [Min Grade: D] and BIO 122 [Min Grade: D] and BIO 219 [Min Grade: D] and CHEM 242 [Min Grade: D] and (MEM 230 [Min Grade: D] or BMES 345 [Min Grade: D])

BMES 472 Developmental and Evolutionary Foundations of Tissue Engineering 4.0 Credits
Familiarizes students with advanced concepts of developmental and evolutionary biology relevant to tissue engineering. This second part of the two-quarter sequence combines material from cellular/molecular biology and evolutionary design and biomaterials to educate students in the principles, methods, and technology of tissue engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 471 [Min Grade: D]

BMES 475 Biomaterials and Tissue Engineering III 4.0 Credits
This course provides students with in-depth knowledge of factor-mediated tissue engineering and regenerative medicine. Students learn about fundamental repair and regenerative processes and gain an understanding of specific biomaterials being used to mimic and/or enhance such processes. Students also learn about the delivery methods of agents which promote the proper functional development of specialized tissues.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 460 [Min Grade: D] and BMES 461 [Min Grade: D] and BMES 471 [Min Grade: D] and BMES 472 [Min Grade: D]

BMES 477 Neuroengineering I: Neural Signals 3.0 Credits
Introduces the theory of neural signaling. Students will learn the fundamental theory of cellular potentials and chemical signaling, the Hodgkin Huxeley description of action potential generation, circuit representations of neurons and be able to derive and integrate equations describing the circuit as well as design computer models.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: ECES 302 [Min Grade: D] and ECES 304 [Min Grade: D] and ECES 356 [Min Grade: D] and BIO 203 [Min Grade: D] and BMES 405 [Min Grade: D] and BMES 430 [Min Grade: D]

BMES 478 Neuroengineering II: Principles of Neuroengineering 3.0 Credits
This course investigates cutting edge technologies in neuroengineering in a seminar-style format with faculty from the School of Biomedical Engineering and College of Medicine. Three modules cover topics, which vary from year to year. Students are expected to submit written and oral presentations covering each topic.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 477 [Min Grade: D]

BMES 480 Special Topics in Biomedical Engineering & Sciences 12.0 Credits
Covers topics related to the field of health care, systems, and technology. Past topics include health care administration.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit

BMES 483 Quantitative Systems Biology 4.5 Credits
This course uses a systems engineering approach to provide a foundation in systems biology and pathology informatics. Topics covered include the robust complex network of genes and proteins; cell as basic units of life; communication of cells with other cells and the environment; and gene circuits governing development.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: (TDEC 222 [Min Grade: D] or ENGR 232 [Min Grade: D]) and (BIO 203 [Min Grade: D] or BMES 235 [Min Grade: D]) and (BMES 202 [Min Grade: D] or ENGR 202 [Min Grade: D]) and BMES 372 [Min Grade: D] and BMES 375 [Min Grade: D] and CS 172 [Min Grade: D]

BMES 484 Genome Information Engineering 4.5 Credits
This course is designed to provide students with hands-on experience in the application of genomic, proteomic, and other large-scale information to biomedical engineering. The underlying goal is to develop an understanding of highthrough underlying technologies, biological challenges, and key mathematical and computational methods relevant to biomedical engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.
Prerequisites: BMES 483 [Min Grade: D]

BMES 488 Medical Device Development 3.0 Credits
Medical device product development must take into account a diverse set of disciplines to achieve a safe and successful product. This course exposes the student to several of these disciplines with the objective of raising the student¿s awareness of safety throughout the product development life cycle. Students will learn to appreciate the complex engineering decisions that support development of a safe medical device through an examination of risk management, regulatory processes, human factors and clinical studies.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 391 [Min Grade: D] and BMES 392 [Min Grade: D]

BMES 491 [WI] Senior Design Project I 3.0 Credits
This is the first course in a three-quarter capstone design experience for senior biomedical engineering students.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.

BMES 492 Senior Design Project II 2.0 Credits
Continues senior design activities begun in BMES 492.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.

BMES 493 Senior Design Project III 3.0 Credits
Continues the design project begun in BMES 491 and continued through BMES 492.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if classification is Senior.

BMES 494 Clinical Practicum I 3.0 Credits
This course provides biomedical engineering students with an extensive exposure to live clinical cardiology procedures, including cardiac catheterization, electrophysiology, echocardiography and nuclear stress testing. Emphasis is placed on identifying important interfaces between engineering and clinical medicine, particularly in areas where clinical needs may be addressed by advances in biomedical engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if major is BME.

BMES 495 Clinical Practicum II 3.0 Credits
This course provides biomedical engineering students with an extensive exposure to live operations in an emergency department and intensive care unit. The students are expected to analyze specific operations within these environments and develop a solution to a process problem within one of these environments. System analysis, design and evaluation are emphasized.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if major is BME.

BMES 496 Clinical Practicum III 3.0 Credits
This course provides biomedical engineering students with an opportunity to observe basic operative and postoperative procedures with the idea of both learning about such procedures and identifying the role of biomedical engineering in these clinical settings.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if major is BME.

BMES 499 Independent Study in Biomedical Engineering and Science 0.5-6.0 Credits
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit

The School of Biomedical Engineering, Science, and Health Systems

Mission Statement

The mission of the School of Biomedical Engineering, Science and Health Systems is to promote health and quality of life through education, research and innovation that integrates engineering and life sciences in a global context.

The School of Biomedical Engineering, Science, and Health Systems (http://www.biomed.drexel.edu/new04/default.cfm) is a nationally recognized center for research in biomedical engineering and science. The School offers multidisciplinary instruction on a full- and part-time basis at the graduate level and full-time instruction at the undergraduate level.
The faculty includes individuals with engineering, physics, mathematics, biostatistics, life science, medical, and clinical specialties. Multidisciplinary research is carried out through collaboration among Drexel University faculty members and with several medical schools and hospitals in the Philadelphia area.
The School offers MS and PhD programs in biomedical engineering and biomedical science. Areas of specialization available or under development include biomechanics, rehabilitation, biomaterials and tissue engineering, biosensors and biomedical imaging, biostatistics, genome science and bioinformatics, human factors and performance engineering, neuroengineering, and systems biology.

Majors

- Biomedical Engineering (MS, PhD)
- Biomedical Science (MS, PhD)

Certificates

- Bioinformatics
- Biomedical Technology Development
- Medical Product Design and Device Development
- Tissue Engineering

About the School

The School of Biomedical Engineering, Science, and Health Systems (http://www.biomed.drexel.edu) (formerly the Biomedical Engineering and Science Institute, founded in 1961) is a leader in biomedical engineering and biomedical science research and education. The undergraduate program was inaugurated in September 1998 and has steadily grown to attract the highest ability students at the University.

The School's areas of academic thrust, both in research and education, are at the forefront of biosensing, bioimaging, bioinformation engineering and integrated bioinformatics, drug delivery, biomedical ultrasound & optics, bionanotechnology, cellular tissue engineering, neuroengineering and human performance. Emerging initiatives include skin bioengineering, pediatric engineering and homeland security technologies. Various departments at Drexel University offer courses that are suited for students in biomedical engineering and biomedical science. The School of Biomedical Engineering, Science and Health Systems' curriculum complements the strengths of the Colleges of Arts & Sciences, Business, Engineering, Computing and Informatics, Law and Medicine.

The marriage of technology with biology and medicine drives the 21st Century industrial enterprise. Consistent with this mission, the School strives for clinical and industrial relevance in academic pursuits, and enjoys a strong entrepreneurship program in biomedical technologies. The School's alliance with regional economic development agencies and corporations together with advisors from business development, legal, and investment communities sustains the growth of this program. The students and faculty of the School are committed to move their discoveries from our laboratories to clinical practice or home use. The success of Drexel's Translational Research in Biomedical Technologies program has been recognized and funded regionally as well as nationally.

The School has experienced remarkable growth in recent years thanks to outstanding research portfolio, high quality and innovative undergraduate program, and a multidisciplinary approach to education and research. Another competitive advantage is the unique free-standing university-level administrative structure with its own tenure-track faculty lines, budget and space. This helps transcend the traditional organizational boundaries of engineering, sciences and medicine. The School of Biomedical Engineering, Science and Health Systems' independence allows for the pursuit of growth and collaborations in various disciplines. Its small size provides agility to reconfigure and reorganize in response to emerging opportunities. The University Strategic Plan recognizes the School of Biomedical Engineering, Science and Health Systems as “Drexel’s prototype of academic integration. ”

Metropolitan Philadelphia has one of the nation’s highest concentrations of medical institutions and pharmaceutical, biotechnology, medical device and systems industry. The School has forged strategic partnerships with select universities, research institutes, health care institutions and industries in the region. The School enjoys a close working relationship with Drexel's College of Medicine as well as alliances with prominent medical institutions in the region to develop joint research and educational programs. These include University of Pennsylvania, Thomas Jefferson University, the Fox Chase Cancer Center and the Wistar Institute. These collaborative initiatives provide students with ample opportunities in basic and clinical research as well as innovative academic programs.

The School maintains extensive facilities and laboratories devoted to areas of research. Visit the School's BIOMED Research Facilities and Laboratory Map (http://www.biomed.drexel.edu/new04/Content/research/facilities) web page for more details about the laboratories and equipment available.

Applicants to the graduate program must meet the requirements for admission to graduate studies at Drexel University. Candidates for degrees in the School of Biomedical Engineering, Science and Health Systems are required to maintain academics standards applicable to all graduate students at Drexel University.

Program Objectives

The overall objective of the graduate programs offered by the School of Biomedical Engineering, Science, and Health Systems is to provide multidisciplinary curricula with an instructional core and research opportunities for students. Graduate biomedical engineering students are typically individuals with undergraduate degrees in engineering, physical sciences, or mathematics. The core curriculum provides the

necessary training in life and medical sciences, modeling and simulation, and biomedical engineering applications to allow students to apply their engineering skills and perspective to solve current problems in biology and medicine. Areas in which students may focus their advanced studies and research attention include biomechanics and biomaterials, cellular and tissue engineering, biomedical sensing and imaging, human factors and performance engineering, neuroengineering, and bioinformatics. Students without an academic background in engineering or physical science who wish to enter the biomedical engineering program may enroll in the Crossover Program.

The core courses in the Biomedical Science program are designed to educate life-science students in quantitative analysis, mathematical modeling, systems analysis, and fundamental computational and informatics skills. Students are then encouraged to combine their knowledge of the life sciences with their newly acquired analytical skills to focus in such areas as tissue engineering and/or bioinformatics.

A recent agreement with the Interdepartmental Medical Science Program (http://www.drexelmed.edu/Home/AcademicPrograms/ProfessionalStudiesintheHealthSciences/Programs/PreMedicalPrograms/InterdepartmentalMedicalScienceIMSProgram.aspx) at the Drexel College of Medicine allows students to spend one year taking courses at the College of Medicine and their second year at the School of Biomedical Engineering, Science and Health Systems—leading to a Master's degree in Biomedical Science.

A non-thesis MS degree is available to non-traditional students seeking advanced studies in biomedical engineering and biomedical science to enhance their careers.

Admission Requirements

Acceptance for graduate study at Drexel's School of Biomedical Engineering, Science and Health Systems requires a four-year bachelor's degree from an accredited institution in the United States or equivalent international institution. Regular acceptance requires a minimal cumulative grade point average of 3.0 (B) on a 4.0 scale for the last two years of undergraduate work, and for any graduate level work undertaken.

Drexel's School of Biomedical Engineering, Science and Health Systems normally requires a TOEFL score of at least 260. Verbal, analytical, and quantitative scores on the GRE General Test are recommended for admission and are required for financial assistantship consideration.

The School practices a rolling admissions policy--students are able to apply at any term during the year, but students are encouraged to matriculate in the fall to ensure proper sequence of coursework.

In addition to the School's requirements, students must satisfy the requirements of the Office of Research and Graduate Studies in matters such as academic standing, thesis, examinations, and time limits.

Students without an academic background in engineering or physical science should review information about the Crossover Program. (http://www.biomed.drexel.edu/content_frame_v2.cfm?DISPLAYED_CONTENT=academics&DISPLAYED_SUBCONTENT=academic_programs#crossover)

Financial Assistance

Financial support for qualified students pursuing studies toward the MS and PhD degrees is available in the form of research assistantships, teaching assistantships, graduate assistantships, and fellowships.

Calhoun Graduate Assistantships are supported by the School's Calhoun Endowment. To be considered for a fellowship, students must submit GRE scores along with all their application materials. The application deadline is February 28 for the following academic year. For more information, please contact Dr. Rami Seliktar (seliktar@coe.drexel.edu) .

Dean's Fellowships are available for outstanding applicants to the School when other forms of financial assistance are not available. This Fellowship provides approximately 40% of a student's tuition for the first year and is renewable depending on the student's academic performance. Fellowship applicants must be seeking full-time study only at the master's level. Other requirements include a GPA of 3.5 or better in their bachelor's program and submission of GRE scores. For international students, a TOEFL score of 260 or better is required. For more information regarding international applicant requirements, view the International Students Admissions Information (http://drexel.edu/isss/NewStudent.html) page.

For further assistance, students should contact the Office of Graduate Admissions (http://www.drexel.edu/em/grad) .

All applicants will automatically be considered for departmental assistantships. There is no additional paperwork to apply. Applicants interested in graduate assistantships must submit GRE scores. These awards are based on academic merit.

About Graduate Co-op

Drexel University's long tradition in the field of experiential learning has now been extended into many of its master's programs in science, business, and engineering.

This option, called Graduate Co-op (http://www.drexel.edu/scdc/co-op/graduate/requirements) , provides students with the opportunity to gain work experience directly related to their career goals while earning academic credit. Students who have earned a minimum of 24 credits with a GPA of at least 3.0 are eligible to participate. Employment typically lasts six months, during which students enroll in a special 3 credit GCP course coinciding with their term of employment. Students gain work experience while earning salaries. It is important to note that the GCP program does not guarantee a job. It is a market-driven process for the candidates as well as employers. GCP provides the tools and contacts; the student must qualify for the job on the basis of merit, qualifications, and skills.

Further information on the GCP program is available at the Drexel Steinbright Career Development Center. (http://www.drexel.edu/scdc)

Advanced Certificate in Bioinformatics

Certificate Level: Graduate
Admission Requirements: Bachelor's degree
Certificate Type: Certificate
Number of Credits to Completion: 23.5
Instructional Delivery: Campus
Calendar Type: Quarter
Expected Time to Completion: 2 years
Financial Aid Eligibility: Not aid eligible

The certificate in bioinformatics program emphasizes a systems engineering approach to provide a foundation in systems biology and pathology informatics. Students are provided with hands-on experience in the application of genomic, proteomic, and other large-scale information to biomedical engineering as well as experience in advanced computational

methods used in systems biology: pathway and circuitry, feedback and control, cellular automata, sets of partial differential equations, stochastic analysis, and biostatistics.

Required Courses		
BMES 543	Quantitative Systems Biology	4.5
BMES 544	Genome Information Engineering	4.5
BMES 545	Biosystems Modeling	4.5
BMES 546	Biocomputational Languages	4.0
BMES 551	Biomedical Signal Processing	3.0
BMES 604	Pharmacogenomics	3.0
Total Credits		**23.5**

Advanced Certificate in Biomedical Technology Development

Certificate Level: Graduate
Admission Requirements: Bachelor's degree
Certificate Type: Certificate
Number of Credits to Completion: 24.0
Instructional Delivery: Campus
Calendar Type: Quarter
Expected Time to Completion: 2 years
Financial Aid Eligibility: Not aid eligible

This certificate program is designed for working engineers interested in medical devices and technology. Students enrolled in this program will develop an understanding of the critical regulatory, economic, and legal issues in addition to the project management skills that facilitate the development of new medical devices.

Required Courses		
BMES 501	Medical Sciences I	3.0
BMES 502	Medical Sciences II	3.0
BMES 503	Medical Sciences III	3.0
BMES 509	Entrepreneurship for Biomedical Engineering and Science	3.0
BMES 534	Design Thinking for Biomedical Engineers	3.0
BMES 538	Biomedical Ethics and Law	3.0
BMES 588	Medical Device Development	3.0
BMES 590	Clinical Rotation	3.0
Total Credits		**24.0**

Advanced Certificate in Tissue Engineering

Certificate Level: Graduate
Admission Requirements: Bachelor's degree
Certificate Type: Certificate
Number of Credits to Completion: 20.0
Instructional Delivery: Campus
Calendar Type: Quarter
Estimated Time to Completion: 2 years
Financial Aid Eligibility: Not aid eligible

The certificate in tissue engineering is designed to provide advanced training in cellular and molecular biology relevant to tissue engineering and behavior of materials used in biomedical applications.

Required Courses		
BMES 631	Tissue Engineering I	4.0
BMES 632	Tissue Engineering II	4.0
BMES 660	Biomaterials I	4.0
BMES 661	Biomaterials II	4.0
BMES 675	Biomaterials and Tissue Engineering III	4.0
Total Credits		**20.0**

Biomedical Engineering

Master of Science in Biomedical Engineering (MSBE): 45.0 quarter credits
Doctor of Philosophy: 90.0 quarter credits

About the Program

Biomedical engineering applies engineering and science methodologies to the analysis of biological and physiological problems and to the delivery of health care. The biomedical engineer requires the analytical tools and broad physical knowledge of modern engineering and science, fundamental understanding of the biological or physiological system, and familiarity with recent technological breakthroughs.

The biomedical engineer serves as an interface between traditional engineering disciplines and living systems and may work in either direction, applying the patterns of living organisms to engineering design or engineering new approaches to human health. The biomedical engineer may use his/her knowledge of physiological systems to reverse engineer nature, creating, for example, artificial tissues and neural networks. On the other hand, a biomedical engineer may use his/her knowledge of engineering to create new equipment or environments for such purposes as maximizing human performance, accelerating wound healing, or providing non-invasive diagnostic tools.

The master's program in biomedical engineering emphasizes engineering design and scientific analysis. The curriculum develops graduates who can solve problems in the fields of chemical, environmental, biochemical, and materials process engineering, using their knowledge of modern theories, engineering systems, and mathematical and engineering tools.

Superior students with training in engineering, natural science, or physical science will be considered for admission to the doctoral program.

Master students can choose to include a 6 month co-op cycle in to their studies. Students may also choose to complete specialized advanced certificates as part of their studies in either: biomedical technology development; biomaterials and tissue engineering; bioinformatics**;** or may pursue a dual-degree MS option.

Additional Information

Andres Kriete, PhD
Associate Director for Graduate Studies
School of Biomedical Engineering, Science and Health Systems
ak3652@drexel.edu

Rami Seliktar, PhD
Vice President
School of Biomedical Engineering, Science and Health Systems

seliktar@drexel.edu

For more information, visit the The School of Biomedical Engineering, Science, and Health Systems (http://www.biomed.drexel.edu) website.

Master of Science Degree Requirements

The core requirements for the master's in biomedical engineering encompass approximately 45.0 course credits. (Most courses carry three credits each.) A thesis is highly recommended. A non-thesis option is also offered. Students who choose the non-thesis option must take 51.0 credits of coursework and cannot register for thesis or research credits.

The curriculum includes room for specialization in several focus areas of biomedical engineering, as well as a concentration in biomedical technology development.

Core Courses		
BMES 501	Medical Sciences I	3.0
BMES 502	Medical Sciences II	3.0
BMES 503	Medical Sciences III	3.0
BMES 672	Biosimulation I	3.0
BMES 673	Biosimulation II	3.0
BMES 864	Seminar	0.0
Electives		
The sum of electives, core credits, and/or thesis credits must total 45.0 for thesis students and and 51.0 for non-thesis students. Elective choices would depend upon the student's area(s) of focus or concentration.		
Thesis		
BMES 897	Research	1.0-12.0
BMES 898	Master's Thesis *	0.5-20.0

* The research for the thesis may include work carried out during an internship.

Biomedical Technology Development Concentration

Students enrolled in this concentration will develop an understanding of critical regulatory, economic, and legal issues in addition to the project management skills that facilitate the development of new medical devices and positive working relationships with intellectual property lawyers, insurance companies, and the federal government.

Core Courses		
BMES 509	Entrepreneurship for Biomedical Engineering and Science	3.0
BMES 534	Design Thinking for Biomedical Engineers	3.0
BMES 538	Biomedical Ethics and Law	3.0
BMES 588	Medical Device Development	3.0
BMES 590	Clinical Rotation	3.0
Total Credits		**15.0**

PhD in Biomedical Engineering Degree Requirements

To be awarded the PhD degree, students must complete 90.0 required credits and fulfill the one-year residency requirement.

The following milestones have to be satisfied during the course of the program:

- Students must successfully pass the candidacy examination.
- Students must submit a PhD dissertation proposal and successfully defend it.
- Students must write a dissertation and successfully pass final oral defense.

Post-Baccalaureate Requirements and Post-Master's Requirements
Both post-baccalaureate and post-master's students are admitted into the doctoral program in Biomedical Engineering, but have slightly differing sets of requirements.

For **post-master's students**, 45.0 of the credits that they earned toward their Master's degree may be applied toward the PhD. If coming from the Master's program in Biomedical Engineering at Drexel University, those courses they took would apply. For non-Drexel students who have completed their master's elsewhere, there may be exceptions made. If these students believe that they have covered the material of the required courses in another program, they must show evidence of such material and obtain a formal waiver of this requirement from the Graduate Advisor.

For **post-baccalaureate students**, students must complete a minimum of 90.0 credits and a research thesis. These 90.0 credits include the core courses required by Drexel's MS in Biomedical Engineering.

Core Courses		
BMES 501	Medical Sciences I	3.0
BMES 502	Medical Sciences II	3.0
BMES 503	Medical Sciences III	3.0
BMES 672	Biosimulation I	3.0
BMES 673	Biosimulation II	3.0
BMES 864	Seminar	0.0

In addition to the required courses, post-baccalaureate PhD students must take at least 21.0 more credits in courses. This balance may be taken as research and/or thesis/dissertation credits.

Thesis Advisor/Plan of Study
During the first year of the program all Doctoral students are required to identify a Thesis Advisor and complete a plan of study. The student's Thesis Advisor and the Graduate Advisor will guide the student in developing this plan of study. Each plan of study is individually tailored to the student, and includes a combination of research and course credits most beneficial and complimentary to the student's chosen thesis topic.

The Candidacy Examination
Doctoral students must successfully pass a candidacy examination, preferably at the end of the first year of their study, but no later than the end of the second year.

The overall objective of the candidacy examination is to test the student's basic knowledge and preparedness to proceed toward a PhD in Biomedical Engineering. The candidacy examination contains two parts: a written portion and a pre-proposal. In the written portion of the candidacy examination, students are expected to demonstrate physical

science aptitude and a preparation to formulate and model biomedical problems. The pre-proposal portion focuses on the formulation of a brief research protocol of a specific study, its presentation to a committee of five faculty members, an the student's ability to successfully answer relevant questions.

After a satisfactory performance on the candidacy examination the student is awarded the Doctoral Candidate status. Candidates must submit a Thesis Proposal by the end of the second year and defend it in an oral presentation to a committee of five faculty members.

Thesis Defense
After the student has successfully completed all the necessary research and composed a thesis manuscript, in accordance with the guidelines specified by the Office of Research and Graduate Studies, he or she then must formally defend their thesis. A formal thesis defense includes an oral presentation of research accomplishments in front of a committee of faculty members. The thesis defense is open to the general public.

Prospective PhD students are welcome to contact the school to discuss their research interests. For a more detailed description of the PhD requirements, please visit the School of Biomedical Engineering and Health Systems' Biomedical Engineering (http://www.biomed.drexel.edu/new04) web site.

Areas of Specialization

Areas of specialization can be pursued within the Biomedical Engineering graduate program. Students can plan their own focus area that will give them strength in a particular sub-discipline. Alternatively, the student can specialize by conducting research and writing a thesis.

Biomaterials and Tissue Engineering
Biomaterials and tissue engineering is designed to provide students with advanced training in cellular and molecular biology relevant to tissue engineering and behavior of materials used in biomedical applications.

Biomedical Technology Development
Students pursuing the concentration will develop an understanding of critical regulatory, economic, and legal issues in addition to the project management skills that facilitate the development of new medical devices and positive working relationships with intellectual property lawyers, insurance companies, and the federal government. (This is a formal concentration with specific course requirements.)

Bioinformatics
Bioinformatics emphasizes a systems engineering approach to provide a foundation in systems biology and pathology informatics. Students are provided with hands-on experience in the application of genomic, proteomic, and other large-scale information to biomedical engineering as well as experience in advanced computational methods used in systems biology: pathway and circuitry, feedback and control, cellular automata, sets of partial differential equations, stochastic analysis, and biostatistics.

Biomechanics and Human Performance Engineering
Biomechanics and human performance engineering is designed to meet two objectives: to acquaint students with the responses of biological tissues to mechanical loads as well as with the mechanical properties of living systems and to provide students with the background and skills needed to create work and living environments which improve human health and enhance performance. Biomechanics and human performance also involves the study of orthopedic appliances and the broader aspect of rehabilitation engineering and the management of disability.

Biomedical Systems and Imaging
Biomedical systems and imaging focuses on the theoretical and practical issues related to machine vision, image processing and analysis, and signal processing associated with such medical applications as well biomedical instrumentation and product development.

Neuroengineering
Neuroengineering is broadly defined to include the modeling of neural and endocrine systems, neural networks, complexity in physiological systems, evolutionary influences in biological control systems, neurocontrol, neurorobotics, and neuroprosthetics.

Biomedical Engineering, Science and Health Systems Faculty

Fred D. Allen, PhD *(University of Pennsylvania)*. Assistant Professor. Tissue engineering, cell engineering, orthopedics, bone remodeling, wound healing, mechanotransduction, signal transduction, adhesion, migration.

Sriram Balasubramanian, PhD *(Wayne State University)*. Assistant Professor. Structural characteristics of the pediatric thoracic cage using CT scans and developing an age-equivalent animal model for pediatric long bones.

Kenneth A. Barbee, PhD *(University of Pennsylvania)*. Professor. Cellular biomechanics of neural and vascular injury, mechanotransduction in the cardiovascular system, mechanical control of growth and development for wound healing and tissue engineering.

Lin Han, PhD *(Massachusetts Institute of Technology)*. Assistant Professor. Nanoscale structure-property relationships of biological materials, genetic and molecular origins soft joint tissue diseases, biomaterials under extreme conditions, coupling between stimulus-responsiveness and geometry.

Uri Hershberg, PhD *(Hebrew University of Jerusalem, Israel)*. Assistant Professor. Bioinformatics, immunology, neural computation, system biology, somatic selection, autoimmunity, genetic stability, germline diversity, dendritic cell, transcription elements, pathogens, computational and mathematical modeling, complex systems, cognition and inflammation.

Joshua Jacobs, PhD *(University of Pennsylvania)*. Assistant Professor. Neuroengineering, electrocorticography (ECoG), electroencephalography (EEG), single-neuron spiking, brain oscillations, episodic memory, working memory, spatial navigation, conceptual representations.

Dov Jaron, PhD *(University of Pennsylvania) Calhoun Distinguished Professor of Engineering in Medicine*. Professor. Mathematical, computer and electromechanical simulations of the cardiovascular system.

Andres Kriete, PhD *(University in Bremen Germany) Associate Director for Graduate Studies and Academic Operations*. Systems biology, bioimaging, control theory, biology of aging, skin cancer.

Ryszard Lec, PhD *(University of Warsaw Engineering College)*. Professor. Biomedical applications of visoelastic, acoustoptic and ultrasonic properties of liquid and solid media.

Peter Lewin, PhD *(University of Denmark, Copenhagen-Lyngby) Richard B. Beard Professor, School Of Biomedical Engineering, Science & Health Systems*. Professor. Biomedical ultrasonics, piezoelectric and polymer transducers and hydrophones; shock wave sensors.

Hualou Liang, PhD *(Chinese Academy of Sciences)*. Associate Professor. Neuroengineering, neuroinformatics, cognitive and computational neuroscience, neural data analysis and computational modeling, biomedical signal processing.

Donald L. McEachron, PhD *(University of California at San Diego) Associate Director*. Research Professor. Animal behavior, autoradiography, biological rhythms, cerebral metabolism, evolutionary theory, image processing, neuroendocrinology.

Karen Moxon, PhD *(University of Colorado)*. Associate Professor. Cortico-thalamic interactions; neurobiological perspectives on design of humanoid robots.

Banu Onaral, Ph.D. *(University of Pennsylvania) H.H. Sun Professor / Director, School of Biomedical Engineering Science and Health Systems*. Professor. Biomedical signal processing; complexity and scaling in biomedical signals and systems.

Kambiz Pourrezaei, PhD *(Rensselaer Polytechnic University)*. Professor. Thin film technology; nanotechnology; near infrared imaging; power electronics.

Arye Rosen, PhD *(Drexel University) Biomedical Engineering and Electrical Engineering*. Microwave components and subsystems; utilization of RF/microwaves and lasers in therapeutic medicine.

Ahmet Sacan, PhD *(Middle East Technical University)*. Assistant Professor. Indexing and data mining in biological databases; protein sequence and structure; similarity search; protein structure modeling; protein-protein interaction; automated cell tracking.

Joseph J. Sarver, PhD *(Drexel University)*. Teaching Professor. Neuromuscular adaptation to changes in the myo-mechanical environment.

Rahamim Seliktar, PhD *(University of Strathclyde, Glasgow) Vice Director, School of Biomedical Engineering, Science & Health Systems*. Professor. Limb prostheses, biomechanics of human motion, orthopedic biomechanics.

Adrian C. Shieh, PhD *(Rice University)*. Assistant Professor. Contribution of mechanical forces to tumor invasion and metastasis, with a particular emphasis on how biomechanical signals may drive the invasive switch, and how the biomechanical microenvironment interacts with cytokine signaling and the extracellular matrix to influence tumor and stromal cell behavior.

Wan Young Shih, PhD *(Ohio State University) School of Biomedical Engineering, Science and Health Systems*. Associate Professor. Piezoelectric microcantilever biosensors development, piezoelectric finger development, quantum dots development, tissue elasticity imaging, piezoelectric microcantilever force probes.

Kara Spiller, PhD *(Drexel University)*. Assistant Professor. Cell-biomaterial interactions, biomaterial design, and international engineering education.

Margaret Wheatley, PhD *(University of Toronto) School of Biomedical Engineering, Science and Health Systems, John M. Reid Professor*. Ultrasound contrast agent development (tumor targeting and triggered drug delivery), controlled release technology (bioactive compounds), microencapsulated allografts (*ex vivo* gene therapy) for spinal cord repair.

Yinghui Zhong, PhD *(Georgia Institute of Technology)*. Assistant Professor. Spinal cord repair, and engineering neural prosthesis/brain interface using biomaterials, drug delivery, and stem cell therapy.

Interdepartmental Faculty

Douglas L. Chute, PhD *(University of Missouri) Louis and Bessie Stein Fellow*. Professor. Neuropsychology and rehabilitation; technological applications for the cognitively compromised and those with acquired brain injuries.

Patricia A. Shewokis, PhD *(University of Georgia)*. Professor. Roles of cognition and motor function during motor skill learning; role of information feedback frequency on the memory of motor skills, noninvasive neural imaging techniques of functional near infrared spectroscopy(fNIR) and electroencephalograpy (EEG) and methodology and research design.

Emeritus Faculty

William Freedman, PhD *(Drexel University)*. Professor Emeritus. Motor control; sensory and motor systems; reflexes; eye movements; neural networks.

John M. Reid, PhD *(University of Pennsylvania) Calhoun Professor Emeritus*. Professor Emeritus. Diagnostic ultrasound, wave propagation and scattering in inhomogeneous media, imaging, instrumentation.

Hun H. Sun, PhD *(Cornell University)*. Professor Emeritus. Biological control systems, physiological modeling, systems analysis.

Aydin Tozeren, PhD *(Columbia University) Distinguished Professor and Director, Center for Integrated Bioinformatics, School of Biomedical Engineering, Science & Health Systems*. Professor Emeritus. Breast cell adhesion and communication, signal transduction networks in cancer and epithelial cells; integrated bioinformatics, molecular profiling, 3D-tumors, bioimaging.

Courses

BMES 501 Medical Sciences I 3.0 Credits
First course in a three-course sequence designed to acquaint students with the fundamentals of biology and physiology from an engineering perspective. This first course covers evolution, genetics, molecular biology and basic cellular physiology.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 502 Medical Sciences II 3.0 Credits
Second course in a three-course sequence designed to acquaint students with the fundamentals of biology and physiology from an engineering perspective. This second course covers tissues, muscle and nerve function, cardiovascular systems and respiration.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 501 [Min Grade: C]

BMES 503 Medical Sciences III 3.0 Credits
Third course in a three-course sequence designed to acquaint students with the fundamentals of biology and physiology from an engineering perspective. This third course covers renal and digestive systems. However, the major emphasis is on biological control systems ? nervous, endocrine and immune system structure and function.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 502 [Min Grade: C]

BMES 504 Medical Sciences IV 4.0 Credits
Mechanical, physical, electrical, and mathematical models of living systems, including feedback control systems. The laboratory part includes computer simulation so that data obtained from laboratory experiments may be compared with those predicted from models.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 505 Mathematics for Biomedical Sciences I 3.0 Credits
This course is for students of biology and related medical fields aimed at bridging the gap between qualitative and quantitative approaches in the study of biological processes. Topics include single and multivariable calculus infinte series, etc.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 506 Mathematics for Biomedical Sciences II 3.0 Credits
This course for students of biomedical sicence or biomedical engineering is designed to permit the student to go on to advanced studies in engineering and science in which differential equations are needed. Biological applications are emphasized.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 505 [Min Grade: C]

BMES 507 Mathematics for Biomedical Sciences III 3.0 Credits
This course covers topics in Fourier series and orthogobnal functions, partial differential equations, and boundary value problems Applications are made to problems in neuro-physiology, cellular transport, and biological oscillations.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 506 [Min Grade: C]

BMES 508 Cardiovascular Engineering 3.0 Credits
This course emphasizes engineering approaches to the analysis of the cardiovascular system focusing on fundamental mechanics and emerging technologies.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 501 [Min Grade: B] and BMES 502 [Min Grade: B] and BMES 503 [Min Grade: B]

BMES 509 Entrepreneurship for Biomedical Engineering and Science 3.0 Credits
This course serves as the foundation course in entrepreneurship and is designed to provide students with a complete working knowledge of the modern entrepreneurial and business planning process.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 510 Biomedical Statistics 4.0 Credits
This course introduces the graduate student to the fundamentals of inferential statistics with biomedical applications. It covers topics in data presentation, sampling, experimental design, probability and probability distributions, significance tests, and clinical trials.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 511 Principles of Systems Analysis Applied to Biomedicine I 3.0 Credits
Covers formulation of biological problems by rigorous mathematical techniques, including application of conservation laws, network theorems, and mesh and nodal analysis.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 512 Principles of Systems Analysis Applied to Biomedicine II 3.0 Credits
Continues BMES 511. Emphasizes input/output transfer function problems, linear systems and linear operations, and impulse response.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 513 Biomedical Electronics 3.0 Credits
Physical principles in the operation of both integrated circuits and discrete components. Analysis and design of transducers, amplifiers, oscillators, logic circuits, etc., with particular application to biomedical problems. (BMS).
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 514 Computer Applications in Biomedical Research 3.0 Credits
This course is intended to familiarize students with at least one computer language and to demonstrate computer applications in diagnosis, monitoring, and biomedical signal processing. (BMS).
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 515 Experimental Design in Biomedical Research 4.0 Credits
This course is designed to introduce students to the fundamental principles of experimental design and statistical analysis as applied to biomedical research with animals and humans. Topics to be covered include experimental design, clinical design, and protocol submission and review.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 510 [Min Grade: B]

BMES 517 Intermediate Biostatistics 3.0 Credits
The purpose of this course is to acquaint students with some of the statistical tools commonly used in biomedical and health sciences research. The course will provide the student with a basic theoretical background on the procedures of repeated measures ANOVA and selected multivariate statistical tests. It will familiarize students with the use of computer-based statistical analyses.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 510 [Min Grade: C]

BMES 518 Interpretation of Biomedical Data 3.0 Credits
The focus of this course is on understanding the methods used to analyze and interpret the results of quantitative data analyses in the biomedical and health sciences and determine their meaningfulness (clinical significance). Fundamental to this process is an understanding of the interrelatedness of statistical power, effect size, sample size and alpha.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 510 [Min Grade: C]

BMES 520 Introduction to Medical Science 3.0 Credits
The course is designed to acquaint professionals with the fundamentals of structure and function of biomedical systems from an engineering perspective. The course introduces the basics of molecular biology, cellular biology, anatomy and physiology.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if major is CMPD.

BMES 521 Principles of Bioengineering 3.0 Credits
Principles of transduction and measurement, including characterization of the measurements systems, and invasive vs. noninvasive methods. (BME).
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 522 Principles of Bioengineering II 3.0 Credits
In-depth analysis of selected electromechanical transducer principles; review of important transduction methods in bioengineering; biopotential electrodes and chemical electrodes. (BME).
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 523 Principles of Bioengineering III 3.0 Credits
Microprocessor applications in biomedical engineering, including interfacing, data processing, display, and storage. (BME).
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 524 Introduction to Biosensors 4.0 Credits
An introductory course in the general area of microsensors covering basic sensing mechanisms and various types of conductometric, acoustic, silicon, optical and MEMS microsensors. Two case studies involving biosensors and acoustics sensors allow students to acquire in-depth knowledge in the theory and design of microsensors.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 525 Advanced Biosensors 4.0 Credits
The second course in a two-course sequence, this course covers aspects of modern biosensor design methods and addresses challenges associated with fabrication technologies and instrumentation techniques. Topics covered include the theory and modeling of biosensors, fabrication steps, and testing methods.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 531 Chronobioengineering I 3.0 Credits
This course advances the student's knowledge of biological time-keeping and adaptive functions of biological clocks. It includes such topics as biochemical and physiological models of biological blocks, adjustment to environmental cycles and rhythms in behavior and models.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 503 [Min Grade: C]

BMES 532 Chronobioengineering II 3.0 Credits
This course continues BMES 531. It covers topics in the patterns, rhythms, evolution, neurology, psychology and overall functions of sleep.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 531 [Min Grade: C]

BMES 534 Design Thinking for Biomedical Engineers 3.0 Credits
This course is a studio-seminar exploring principles and theories of product design, systematic design process, problem-solving, decision-makingand design as authorship. The course uses design research methods and topical design issues to explore and experience design thinking.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 535 Introduction to Product Design for Biomedical Engineers 3.0 Credits
This course introduces students to basic product design techniques. It combines lectures, demonstrations, discussions and problem solving exercises exploring product design as a creative process in the production of simple objects. Students develop a command of product development, skills in modeling and communication of their novel solutions.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 534 [Min Grade: D] or PROD 101 [Min Grade: C]

BMES 538 Biomedical Ethics and Law 3.0 Credits
Introduces a wide spectrum of ethical, regulatory, and legal issues facing health care practitioners and biomedical researchers. The course helps students become aware of the ethical and legal issues involved in their work while increasing the student's understanding of how legal and ethical decisions should be made in biomedical research, as well as what sources of help and guidance are available.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 541 Nano and Molecular Mechanics of Biological Materials 3.0 Credits
This course aims to provide students with the fundamental knowledge and latest scientific developments in molecular mechanics of biological materials. The first half of the course will introduce interdisciplinary theoretical background including molecular physics, electrostatics, colloidal science, biocompatibility and polymer mechanics. The second half will describe the most recent advances in nanotechnology and nanomechanics-related biomechanical and biomedical research. Students are expected to understand the fundamental knowledge of the molecular-level phenomena in biological systems, and to grasp the basic design and operation principles of nanomechanical instruments.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 543 Quantitative Systems Biology 4.5 Credits
This course uses a systems engineering approach to provide a foundation in systems biology and pathology informatics. Topics covered include the robust complex network of genes and proteins; cell as basic units of life; communication of cells with other cells and the environment; and gene circuits governing development.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 544 Genome Information Engineering 4.5 Credits
This course is designed to provide students with hands-on experience in the application of genomic, proteomic, and other large-scale information to biomedical engineering. The underlying goal is to develop an understanding of highthrough experimental technologies, biological challenges, and key mathematical and computational methods relevant to biomedical engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 543 [Min Grade: B]

BMES 545 Biosystems Modeling 4.5 Credits
This course provides hands-on experience in advanced computational methods used in systems biology: pathway and circuitry, feedback and control, cellular automata, sets of partial differential equations, stochastic analysis, and biostatistics.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 503 [Min Grade: C] and (BMES 512 [Min Grade: C] or BMES 561 [Min Grade: C])

BMES 546 Biocomputational Languages 4.0 Credits
This course provides hands-on education in C/C++, MATLAB, Java, and Perl languages used in biomedical applications. The principle application areas to be investigated include image analysis, feedback and control systems, algorithms on strings and sequences, database interactions, Web interactions, and biostatistics.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 551 Biomedical Signal Processing 3.0 Credits
Introduces discrete time signals and systems; origin and classification of biomedical signals; data acquisition, filtering, and spectral estimation of medical signals; compression of medical signals; new processing approaches and time-frequency representation and wavelets.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 552 Introduction to Bioacoustics 3.0 Credits
This course covers essential materials for anyone who is interested in the application of acoustical waves in biomedical and material science. The main objective is to familiarize students with the propagation of acoustic waves in different media, with particular emphasis on biomedical applications.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 561 Introduction to Systems Analysis in Biomedical Engineering & Science 3.0 Credits
This course acquaints students with the methods of dynamical systems analysis as used to understand biological phenomena. Uses mathematical/engineering models from several areas of biological/medical research to describe the function of systems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 563 Robotics in Medicine I 3.0 Credits
This course provides an introduction to the use of haptics (the use of somtaosensory information) in the design of robotic devices in surgery. Topics covered include actuators, sensors, nonportable feedback, portable force feedback, tactile feedback interfaces, haptic sensing and control systems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 565 Robotics in Medicine II 3.0 Credits
This course covers the use of robots in surgery and included aspects of safety, robot kinematics, analysis of surgical performance using robotic devices, inverse kinematics, velocity analysis and acceleration analysis. Various types of surgeries in which robotic devices are or could be used are presented on a case study basis.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 563 [Min Grade: B]

BMES 566 Robotics in Medicine III 3.0 Credits
This course covers topics in the design of medical robotic systems, including force and movement analysis for robotic arms, dynamics, computer vision and vision-based control. Thus use of haptics, vision systems and robot dynamics are examined in a cohesive framework.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 565 [Min Grade: B]

BMES 571 Biological Evolution: Applications to Human Health and Performance 4.0 Credits
This course is designed to provide students with an evolutionary perspective on health and disease. The focus is on humans as products of evolution by natural selection and as such, subject to the same relationships and historical precedents that govern the rest of the natural world. Topics to be covered include ecological damage and emerging diseases, sociobiological perspectives on behavioral disorders, the development of resistance in pathogens, and adaptation and maladaptation of humans to urban environments.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 588 Medical Device Development 3.0 Credits
Medical device product development must take into account a diverse set of disciplines to achieve a safe and successful product. This course exposes the student to several of these disciplines with the objective of raising the student¿s awareness of safety throughout the product development life cycle. Students will learn to appreciate the complex engineering decisions that support development of a safe medical device through an examination of risk management, regulatory processes, human factors and clinical studies.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 821 [Min Grade: C-]

BMES 590 Clinical Rotation 3.0 Credits
Students are exposed to the problems and issues surrounding the practice of medicine in a modern hospital. Every 2 weeks students will be paired with a medical professional and observe clinical applications and procedures as well as other administrative functions. Actual topics covered vary from offering to offering. Course is run off campus at local hospitals.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated 2 times for 6 credits

BMES 594 Clinical Practicum I 3.0 Credits
This course provides biomedical engineering students with an extensive exposure to live clinical cardiology procedures, including cardiac catheterization, electrophysiology, echocardiography and nuclear stress testing. Emphasis is placed on identifying important interfaces between engineering and clinical medicine, particularly in areas where clinical needs may be addressed by advances in biomedical engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 595 Clinical Practicum II 3.0 Credits
This course provides biomedical engineering students with an extensive exposure to live operations in an emergency department an intensive care until. The students are expected to analyze specific operations within these environments and develop a solution to a process problem within one of these environments. System analysis, design and evaluation are emphasized.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 596 Clinical Practicum III 3.0 Credits
This course provides biomedical engineering students with an opportunity to observe basic operative and postoperative procedures with the idea of both learning about such procedures and identifying the role of biomedical engineering in these clinical settings.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 601 Anatomy I 2.0 Credits
The anatomy sequence surveys the gross and microscopic structure of the human body with emphasis on the structure-function relationship. This course is concerned with cell structure, histology, and tissues.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 602 Anatomy II 2.0 Credits
Continues BMES 601. Functional gross anatomy.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 603 Anatomy III 2.0 Credits
Continues BMES 602. Neuroanatomy.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 604 Pharmacogenomics 3.0 Credits
Covers the interaction between chemical agents and biological systems at all levels of integration. Discusses general classes of drugs, with particular emphasis on general concepts and problems of medical importance.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 611 Biological Control Systems I 3.0 Credits
Introduces the basic concepts of feedback control systems, including characterization in terms of prescribed constraints, study of input and output relationship for various types of biological systems, and stability and time delay problems in the pupillary reflex/eye-hand coordination system.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 612 Biological Control Systems II 3.0 Credits
Covers receptors, skeletal-muscle control systems, vestibular feedback, and sampled-data models.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 613 Biological Control Systems III 3.0 Credits
Covers mathematical models of biological systems, with emphasis on non-linear and adaptive systems study.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 621 Medical Imaging Systems I 4.0 Credits
Provides an overview of the field of medical imaging. Covers aspects of light imaging; systems theory, convolutions, and transforms; photometry, lenses, and depth of field; image perception and roc theory; three-dimensional imaging; image acquisition and display; and image processing operations, including scanning and segmentation.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 622 Medical Imaging Systems II 4.0 Credits
Introduces medical visualization techniques based on ultrasound propagation in biological tissues. Includes generation and reception of ultrasound, imaging techniques (A-mode, B-mode, M-mode, and Doppler), typical and emerging diagnostic applications, elements of ultrasound exposimetry, and safety aspects from the clinical point of view.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 621 [Min Grade: C]

BMES 623 Medical Imaging Systems III 4.0 Credits
Introduces elements of wave imaging, including wave propagation, Fourier optics and acoustics, limitations on resolution, ultrasound transducer characterization, and synthetic aperture systems. Examines MRI imaging in detail, including physical principles and scanning methodologies. Includes aspects of the psychophysics of human vision.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 622 [Min Grade: C]

BMES 625 Biomedical Ultrasound I 3.0 Credits
Focuses on the propagation of ultrasound in inhomogeneous media such as tissue, and discusses imaging principles and basics of tissue characterization. Discusses ultrasound instrumentation, including A-and B-mode scanners. Presents simple tissue models based on ultrasound wave absorption and scattering, and examines properties of tissue-mimicking materials and tissue phantoms. Covers ultrasound transducer models and discusses advantages and disadvantages of various transducer configurations. Outlines the principles of acoustic output measurements and discusses instrumentation requirements. Includes ultrasound exposimetry and biological effects of ultrasound.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 626 Biomedical Ultrasound II 3.0 Credits
Covers the theory and construction of array transducers for imaging, Doppler ultrasound systems and their application to the study of blood flow, and continuous wave and pulsed systems and Doppler imaging. Discusses the mechanisms for biological effects of ultrasound, including thermal and mechanical interaction of ultrasound energy and tissue.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 628 Ultrasound Wave Motion in Solids and Piezoelectrics 3.0 Credits
This course provides an introduction to the physics of wave propagation in solids, acquainting the student along the way with the necessary tensor formalism. The origin and behavior of longitudinal and shear bulk waves, surface waves, and plate waves are derived. The ultrasound behavior of piezoelectrics is analyzed and the results are applied to the analysis of piezoelectric transducers and ultrasound signal-processing devices.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 631 Tissue Engineering I 4.0 Credits
This course is designed to familiarize students with advanced concepts of cellular and molecular biology relevant to tissue engineering. This is the initial course in a three-course sequence combining materials from life science, engineering design and biomaterials to educate students in the principles, methods and technology of tissue engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 503 [Min Grade: B]

BMES 632 Tissue Engineering II 4.0 Credits
This course familiarizes students with advanced concepts of developmental and evolutionary biology relevant to tissue engineering. The second part of a three-course sequence combines materials from cellular/molecular biology, evolutionary design, and biomaterials to education students in the principles and methods of tissue engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 631 [Min Grade: B]
Corequisite: BMES 661

BMES 641 Biomedical Mechanics I 4.0 Credits
Designed to acquaint students with the response of biological tissues to mechanical loads and with the mechanical properties of living systems. Covers topics in musculoskeletal anatomy and functional mechanics; a review of mechanical principles, statics, dynamics, and materials; soft and hard tissue mechanics; mechano-pathological conditions in biological tissues and their correction; and prosthetics.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 642 Biomedical Mechanics II 4.0 Credits
Continues BMES 641.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 643 Biomedical Mechanics III 4.0 Credits
Continues BMES 642.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 644 Cellular Biomechanics 3.0 Credits
This course of cellular bioengineering focuses on mechanics and transport. Material builds upon undergraduate engineering education to place engineering mechanics into the context of biological function at the cellular level.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 651 Transport Phenomena in Living Systems I 3.0 Credits
Covers physical principles of momentum, energy, and mass transport phenomena in blood and other biological fluids; diffusion and convection at the microcirculatory level; physiology of arteries and veins; and local and systemic blood flow regulation and vascular disease.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 503 [Min Grade: C] and BMES 681 [Min Grade: C]

BMES 660 Biomaterials I 4.0 Credits
First course in a three-quarter sequence designed to acquaint students with the behavior of materials used in biomedical application under load (i.e., mechanical properties), their modes of failure and as a function of their environment. This course provides students with the fundamentals needed to proceed with Biomaterials II.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 661 Biomaterials II 4.0 Credits
Second course in a three-quarter sequence in biomaterials. The goal of this course is with an understanding of, and ability to select, appropriate materials for specific applications taking into account mechanical, thermal, and rheological properties taught in Biomaterials I and combining them with the biocompatibility issues covered in the present course.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Junior or Pre-Junior or Sophomore

BMES 672 Biosimulation I 3.0 Credits
This course focuses upon the mathematical analysis of biomedical engineering systems. As the first course in the biosimulation sequence, the course is a blend of analytical and numerical methods with strong emphasis on analytical approaches. The class concentrates on the application of mathematical concepts to biomedical problems drawn from physiological systems, cellular and molecular systems, bioimaging and biomedical device design.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 673 Biosimulation II 3.0 Credits
The second in a two-course sequence, this course focuses upon the mathematical modeling and subsequent computational analysis of complex biological systems. Specific examples are drawn physiological systems, cellular and molecular systems, bioimaging and biomedical device design and analysis. Topics covered include: modeling of complex bioengineering systems; parameter estimation and optimization of such models; and application of probability and statistical approaches as required.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 672 [Min Grade: C]

BMES 675 Biomaterials and Tissue Engineering III 4.0 Credits
This course provides students with in-depth knowledge of factor-mediated tissue engineering and regenerative medicine. Students learn about fundamental repair and regenerative processes and gain an understanding of specific biomaterials being used to mimic and/or enhance such processes. Students also learn about the delivery methods of agents which promote the proper functional development of specialized tissues.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 660 [Min Grade: C-] and BMES 661 [Min Grade: C-] and BMES 631 [Min Grade: C-] and BMES 632 [Min Grade: C-]

BMES 676 Software Development for Health Science Instruction 3.0 Credits
This course presents the planning, development and evaluation of computer software for instruction and clinical decision support in the area of health care. Particular emphasis is given to the Macintosh computer and the preparation of compiled "stand-alone" programs.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 680 Special Topics 9.0 Credits
Covers topics of particular interest that may not be offered every term or every year. Also included in this category are courses under development.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit

BMES 681 Physics of Living Systems I 3.0 Credits
Designed for the biomedical science student with a background in life sciences. Reviews and expands on basic concepts in physics as applied in biological systems. Topics include mechanics, exponential growth and decay, thermodynamics, and diffusion and membrane transport.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 682 Physics of Living Systems II 3.0 Credits
Covers advanced topics in biophysics for both biomedical science and biomedical engineering students.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 683 Physics of Living Systems III 3.0 Credits
Covers advanced topics of current interest in biomedical engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 710 Neural Signals 3.0 Credits
This course covers aspects of neural signaling, including fundamentals of action potential generation, generator potentials, synaptic potentials, and second messenger signals. Students learn Hodgkin-Huxeley descriptions, equivalent circuit representations and be able to derive and integrate descriptive equations and generate computer simulations.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 711 Principles in Neuroengineering 3.0 Credits
This course is an in-depth student of some of the cutting-edge technologies in neuroengineering. The course draws on faculty in the College of Medicine and School of Biomedical Engineering, Science and Health Systems to present and investigate three topics in neuroengineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 710 [Min Grade: B]

BMES 722 Neural Aspects of Posture and Locomotion I 3.0 Credits
Studies physiology of sensory/motor systems, with emphasis on modeling of neural systems and biomechanical aspects of functional tasks. Begins with an analysis of the transportation of materials in and out of cells, followed by an examination of the origin and maintenance of membrane potentials. Discusses intra-and extracellular and surface measurement of potentials, generation and transmission of action potentials, synaptic processes, and the structure/function of muscle. Combines these elements to study reflex systems as well as vestibular and ocular effects on posture. Culminates in the study of the control of motor systems with respect to bipedal locomotion.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 725 Neural Networks 3.0 Credits
Explores the mathematical and biological bases for neurocomputing. Involves construction by students of computer simulations of important models and learning algorithms. Discusses applications to pattern recognition, vision, speech, control, and psychological modeling.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MATH 210 [Min Grade: C]

BMES 731 Advanced Topics in Ultrasound Research I 3.0 Credits
Explores subjects of current interest through review of the literature by faculty, students, or invited lecturers.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit

BMES 732 Advanced Topics in Ultrasound Research II 3.0 Credits
Continues BMES 731. Discusses current developments and research in medical and industrial ultrasound, and geophysical and underwater signal processing.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit
Prerequisites: BMES 731 [Min Grade: C]

BMES 799 Independent & Supervised Study 9.0 Credits
Course and credits arranged with individual advisers.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit

BMES 821 Medical Instrumentation 3.0 Credits
Provides a broad overview of the applications of health care technology in diagnosis and therapy. Reflects the persuasiveness of biomedical engineering in medicine by describing medical instrumentation and engineering technology used in most of the main areas of specialization in medicine.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 822 Medical Instrumentation II 3.0 Credits
The objective of this course is to prepare the student for following an industry-accepted standard for designing a medical device. Students will work in teams to identify and design a response to medical need. The resulting design will either address an unmet medical need or present an improved approach to an existing solution. After identifying a particular project, the students will learn and implement particular processes for both design and dcoumentation.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated 2 times for 6 credits
Prerequisites: BMES 821 [Min Grade: C] or (BMES 391 [Min Grade: C] and BMES 392 [Min Grade: C])

BMES 823 Medical Instrument Laboratory 2.0 Credits
Provides laboratory exercises, including pulmonary function testing, stress testing, EKG, electrosurgery, and x-ray.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 821 [Min Grade: C]

BMES 825 Hospital Administration 3.0 Credits
Provides an analysis of the administrative process, including planning, organization, design, decision-making, leadership, and control. Presents methodologies and techniques that can contribute to the effective performance of administrative responsibilities examined in the light of significant and unique factors in hospital health care administration.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 826 Hospital Engineering Management 3.0 Credits
Covers the wide range of responsibilities of a clinical engineer, including managing a clinical engineering department, setting up an electrical safety program, establishing an equipment maintenance program, approaches for equipment acquisition, pre-purchase evaluation, and incoming inspection. Includes medical legislation, liability, and risk management.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 825 [Min Grade: C]

BMES 864 Seminar 0.0 Credits
An invitation seminar for discussion of research topics in biomedical engineering and science. Attendance of all graduate students in the institute is required. (None may be repeated for credit.).
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 866 Seminar II 2.0 Credits
Continues BMES 865.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 867 Seminar III 2.0 Credits
Continues BMES 866.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 897 Research 1.0-12.0 Credit
Requires investigation of a biomedical problem under the direction of a faculty adviser.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit

BMES 898 Master's Thesis 0.5-20.0 Credits
Requires the study and investigation of a research or development problem. Requires results to be reported in a thesis under the direction of a faculty adviser. No credit granted until the thesis is completed and approved.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 998 Ph.D. Dissertation 1.0-12.0 Credit
Requires the study and investigation of a research or development problem. Requires results to be reported in a dissertation under the direction of a faculty adviser. No credit granted until the dissertation is completed and approved.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit

Biomedical Science

Master of Science in Biomedical Science (MSBS): 45.0 quarter credits
Doctor of Philosophy: 90.0 quarter credits

About the Program

The Biomedical Science program at the School of Biomedical Engineering, Science and Health Systems applies fundamental biological research and quantitative analysis to human health. The overall objective of the School of Biomedical Engineering, Science and Health Systems is to provide multidisciplinary programs offering an instructional core curriculum and research in selected areas. Students in biomedical science achieve depth in the modeling of living systems and biomedical information processing and display

The master's program in biomedical science educates students whose undergraduate education is in basic life sciences (e.g., biology or biochemistry) or paramedical disciplines (e.g., nursing, physical therapy, or medical technology) in quantitative analysis, mathematical modeling, fundamental computing skills, and informatics.

For students entering with degrees in physics, mathematics, and/or computer science, the School, in close collaboration with the Department of Biology, provides the coursework needed to acquire proficiency in the life sciences.

Superior students with training in natural science or physical science -- as well as individuals with academic or professional degrees in the medical

science disciplines -- will be considered for admission to the doctoral program.

Master students can choose to include a 6 months co-op cycle in their studies. Students may also choose to complete specialized advanced certificates as part of their studies in either: biomedical technology development; biomaterials and tissue engineering; or bioinformatics. Students who graduate with a master's degree from the biomedical science program often continue clinical training in medicine, dentistry, or veterinary medicine; pursue further graduate study toward the PhD degree; or work in industry in such fields as health care, pharmaceuticals, biotechnology, medical devices, etc.

The Biomedical Science program has an articulation with Interdepartmental Medical Science (IMS) at the Drexel College of Medicine, which can be pursued after taking one year of required classes. Applicants to the IMS program include students who are late in their decision to apply to medical school, students interested in improving their academic record before applying or re-applying to medical schools, or students who would like a year in a medical school setting before deciding whether medicine is the career for them.

Additional Information

Andres Kriete, PhD
Associate Director for Graduate Studies
School of Biomedical Engineering, Science and Health Systems
ak3652@drexel.edu

Rami Seliktar, PhD
Vice President
School of Biomedical Engineering, Science and Health Systems
seliktar@drexel.edu

For more information, visit the The School of Biomedical Engineering, Science, and Health Systems (http://www.biomed.drexel.edu) website.

Master of Science in Biomedical Science Degree Requirements

The core requirements for the master's in biomedical science encompass approximately 45.0 course credits (most courses carry three credits each). A thesis is highly recommended. A non-thesis option is also offered. The School of Biomedical Engineering, Science and Health Systems has recently decided to eliminate the comprehensive exam as a part of the requirements for the non-thesis master's degree.

A unique aspect of the School's biomedical sciences program is its ability to integrate aspects of physiology and molecular biology with quantitative analysis, mathematical modeling, and computer processing to create a systems approach to biomedical research and applications. Elective courses such as Biological Control Systems; Applied Evolution; and Chronobioengineering reflect the School's emphasis on multidisciplinary approaches to the most current research in biology and medicine.

Concentrations

Three concentrations are available:

- **Biomaterials and Tissue Engineering**
  Biomaterials and tissue engineering is designed to provide students with advanced training in cellular and molecular biology relevant to tissue engineering and behavior of materials used in biomedical applications.
- **Bioinformatics**
  This specialization emphasized a systems engineering approach to provide a foundation in systems biology and pathology informatics. Students are provided with hands-on experience in the application of genomic, proteomic, and other large-scale information to biomedical engineering as well as experience in advanced computational methods used in systems biology: pathway and circuitry, feedback and control, cellular automata, sets of partial differential equations, stochastic analysis, and biostatistics.
- **Biomedical Technology Development**
  This concentration area aims to provide engineers with the comprehensive education and training necessary to succeed in careers in business, industry, non-profit organizations, and government agencies involving biomedical technology development.

Required Courses

BMES 505	Mathematics for Biomedical Sciences I	3.0
BMES 506	Mathematics for Biomedical Sciences II	3.0
BMES 507	Mathematics for Biomedical Sciences III	3.0
BMES 510	Biomedical Statistics	4.0
BMES 511	Principles of Systems Analysis Applied to Biomedicine I	3.0
BMES 512	Principles of Systems Analysis Applied to Biomedicine II	3.0
BMES 515	Experimental Design in Biomedical Research	4.0
BMES 538	Biomedical Ethics and Law	3.0
BMES 546	Biocomputational Languages	4.0
Electives		15.0-21.0
BMES 897	Research	
BMES 898	Master's Thesis	
Total Credits		**45.0-51.0**

PhD in Biomedical Science Degree Requirements

Superior students with training in engineering, natural science, or physical science as well as individuals with academic or professional degrees in the medical science disciplines will be considered for admission to the doctoral program.

To be awarded the PhD, students must complete 90.0 credits (credits earned toward a master's degree may apply toward the 90.0 credits), fulfill a one-year residency requirement, and successfully pass the qualifying examination, the candidacy examination, and a PhD dissertation and oral defense. Prospective PhD students are welcome to contact the school to discuss their research interests.

Concentration Areas

Biomaterials and Tissue Engineering
Biomaterials and Tissue Engineering is designed to provide students with advanced training in cellular and molecular biology relevant to tissue engineering and behavior of materials used in biomedical applications.

Bioinformatics
Bioinformations emphasizes a systems engineering approach to provide a foundation in systems biology and pathology informatics. Students are provided students with hands-on experience in the application of genomic, proteomic, and other large-scale information to biomedical engineering as well as experience in advanced computational methods used in systems

biology: pathway and circuitry, feedback and control, cellular automata, sets of partial differential equations, stochastic analysis, and biostatistics.

Biomedical Technology Development
This concentration aims to provide engineers with the comprehensive education and training necessary to succeed in careers in business, industry, non-profit organizations, and government agencies involving biomedical technology development. The concentration area in Biomedical Technology Development is a professional degree program and follows the School of Biomedical Engineering, Science and Health Systems' established procedures for a non-thesis option master's degree.

For more information, visit the School's web site and click on Graduate Programs (http://www.biomed.drexel.edu/new04/Content/grad_prog/academic_programs) .

Interdepartmental Medical Science Pathway to the MS in Biomedical Science

The School of Biomedical Engineering, Science and Health Systems collaborates with the Drexel College of Medicine, specifically with the Interdepartmental Medical Science Program (IMSP) (https://nextcatalog.drexel.edu/graduate/schoolofbiomedicalsciences/interdepartmentalmedicalsciencecert) , to offer a unique pathway to a Masters in Biomedical Science. Students complete 1 year in the IMS program (described below) and then complete their second year at the School. This involves completing the core sequence and a thesis or taking a non-thesis option with additional coursework. Student may elect to pursue certificates of advanced study in either Tissue Engineering or Bioinformatics .

Interdeparmental Medial Science Program Curriculum
The IMS curriculum involves a full-time commitment to rigorous coursework with strong academic requirements. Six major medical school courses are taken simultaneously with the College of Medicine first-year class. These include Medical Biochemistry, Cell Biology & Microanatomy, Medical Physiology, Medical Nutrition, Medical Immunology, and Medical Neuroscience.

The medical school lectures are simulcast to the Health Sciences Campus (located in Center City, Philadelphia) from the Drexel University College of Medicine campus (located in East Falls, Philadelphia). The lectures are also videotaped and available in the Health Sciences library as well as being accessible via streaming video on the web. The students take the exact same courses and exams as the medical students and are evaluated based on their performance in comparison to our medical school students. Performance on tests, quizzes, and assignments equal to the mean grade of the medical school class signifies a letter grade of "B" for the IMS students. Thus, IMS students receiving A's and B's are performing at the top 50% of the medical school class and can then present themselves with strong academic credentials before the admissions committee. This permits medical school admissions committees to directly evaluate the student's competence compared with their own first year medical school class. This allows students an opportunity to test their preparation, motivation, and commitment to medicine.

In addition to the medical school courses, students take a medical ethics course each semester. The campuses are approximately five miles apart and a University shuttle provides free transportation between the two.

Additionally, course conferences and laboratory components for IMS students are conducted at the Health Sciences Campus where the program is based. The IMS curriculum allows exposure to both medical school lectures and individual attention from medical school professors in small group conferences.

For more information, visit Drexel's College of Medicine's Interdepartmental Medical Science Program (http://www.drexelmed.edu/Home/AcademicPrograms/ProfessionalStudiesintheHealthSciences/PremedicalPrograms/InterdepartmentalMedicalScienceIMSProgram/Curriculum.aspx) web page.

Biomedical Engineering, Science and Health Systems Faculty

Fred D. Allen, PhD *(University of Pennsylvania)*. Assistant Professor. Tissue engineering, cell engineering, orthopedics, bone remodeling, wound healing, mechanotransduction, signal transduction, adhesion, migration.

Sriram Balasubramanian, PhD *(Wayne State University)*. Assistant Professor. Structural characteristics of the pediatric thoracic cage using CT scans and developing an age-equivalent animal model for pediatric long bones.

Kenneth A. Barbee, PhD *(University of Pennsylvania)*. Professor. Cellular biomechanics of neural and vascular injury, mechanotransduction in the cardiovascular system, mechanical control of growth and development for wound healing and tissue engineering.

Lin Han, PhD *(Massachusetts Institute of Technology)*. Assistant Professor. Nanoscale structure-property relationships of biological materials, genetic and molecular origins soft joint tissue diseases, biomaterials under extreme conditions, coupling between stimulus-responsiveness and geometry.

Uri Hershberg, PhD *(Hebrew University of Jerusalem, Israel)*. Assistant Professor. Bioinformatics, immunology, neural computation, system biology, somatic selection, autoimmunity, genetic stability, germline diversity, dendritic cell, transcription elements, pathogens, computational and mathematical modeling, complex systems, cognition and inflammation.

Joshua Jacobs, PhD *(University of Pennsylvania)*. Assistant Professor. Neuroengineering, electrocorticography (ECoG), electroencephalography (EEG), single-neuron spiking, brain oscillations, episodic memory, working memory, spatial navigation, conceptual representations.

Dov Jaron, PhD *(University of Pennsylvania) Calhoun Distinguished Professor of Engineering in Medicine*. Professor. Mathematical, computer and electromechanical simulations of the cardiovascular system.

Andres Kriete, PhD *(University in Bremen Germany) Associate Director for Graduate Studies and Academic Operations*. Systems biology, bioimaging, control theory, biology of aging, skin cancer.

Ryszard Lec, PhD *(University of Warsaw Engineering College)*. Professor. Biomedical applications of visoelastic, acoustoptic and ultrasonic properties of liquid and solid media.

Peter Lewin, PhD *(University of Denmark, Copenhagen-Lyngby) Richard B. Beard Professor, School Of Biomedical Engineering, Science & Health Systems*. Professor. Biomedical ultrasonics, piezoelectric and polymer transducers and hydrophones; shock wave sensors.

Hualou Liang, PhD *(Chinese Academy of Sciences)*. Associate Professor. Neuroengineering, neuroinformatics, cognitive and computational

neuroscience, neural data analysis and computational modeling, biomedical signal processing.

Donald L. McEachron, PhD *(University of California at San Diego) Associate Director*. Research Professor. Animal behavior, autoradiography, biological rhythms, cerebral metabolism, evolutionary theory, image processing, neuroendocrinology.

Karen Moxon, PhD *(University of Colorado)*. Associate Professor. Cortico-thalamic interactions; neurobiological perspectives on design of humanoid robots.

Banu Onaral, Ph.D. *(University of Pennsylvania) H.H. Sun Professor / Director, School of Biomedical Engineering Science and Health Systems*. Professor. Biomedical signal processing; complexity and scaling in biomedical signals and systems.

Kambiz Pourrezaei, PhD *(Rensselaer Polytechnic University)*. Professor. Thin film technology; nanotechnology; near infrared imaging; power electronics.

Arye Rosen, PhD *(Drexel University) Biomedical Engineering and Electrical Engineering*. Microwave components and subsystems; utilization of RF/microwaves and lasers in therapeutic medicine.

Ahmet Sacan, PhD *(Middle East Technical University)*. Assistant Professor. Indexing and data mining in biological databases; protein sequence and structure; similarity search; protein structure modeling; protein-protein interaction; automated cell tracking.

Joseph J. Sarver, PhD *(Drexel University)*. Teaching Professor. Neuromuscular adaptation to changes in the myo-mechanical environment.

Rahamim Seliktar, PhD *(University of Strathclyde, Glasgow) Vice Director, School of Biomedical Engineering, Science & Health Systems*. Professor. Limb prostheses, biomechanics of human motion, orthopedic biomechanics.

Adrian C. Shieh, PhD *(Rice University)*. Assistant Professor. Contribution of mechanical forces to tumor invasion and metastasis, with a particular emphasis on how biomechanical signals may drive the invasive switch, and how the biomechanical microenvironment interacts with cytokine signaling and the extracellular matrix to influence tumor and stromal cell behavior.

Wan Young Shih, PhD *(Ohio State University) School of Biomedical Engineering, Science and Health Systems*. Associate Professor. Piezoelectric microcantilever biosensors development, piezoelectric finger development, quantum dots development, tissue elasticity imaging, piezoelectric microcantilever force probes.

Kara Spiller, PhD *(Drexel University)*. Assistant Professor. Cell-biomaterial interactions, biomaterial design, and international engineering education.

Margaret Wheatley, PhD *(University of Toronto) School of Biomedical Engineering, Science and Health Systems, John M. Reid Professor*. Ultrasound contrast agent development (tumor targeting and triggered drug delivery), controlled release technology (bioactive compounds), microencapsulated allografts (*ex vivo* gene therapy) for spinal cord repair.

Yinghui Zhong, PhD *(Georgia Institute of Technology)*. Assistant Professor. Spinal cord repair, and engineering neural prosthesis/brain interface using biomaterials, drug delivery, and stem cell therapy.

Interdepartmental Faculty

Douglas L. Chute, PhD *(University of Missouri) Louis and Bessie Stein Fellow*. Professor. Neuropsychology and rehabilitation; technological applications for the cognitively compromised and those with acquired brain injuries.

Patricia A. Shewokis, PhD *(University of Georgia)*. Professor. Roles of cognition and motor function during motor skill learning; role of information feedback frequency on the memory of motor skills, noninvasive neural imaging techniques of functional near infrared spectroscopy(fNIR) and electroencephalograpy (EEG) and methodology and research design.

Emeritus Faculty

William Freedman, PhD *(Drexel University)*. Professor Emeritus. Motor control; sensory and motor systems; reflexes; eye movements; neural networks.

John M. Reid, PhD *(University of Pennsylvania) Calhoun Professor Emeritus*. Professor Emeritus. Diagnostic ultrasound, wave propagation and scattering in inhomogeneous media, imaging, instrumentation.

Hun H. Sun, PhD *(Cornell University)*. Professor Emeritus. Biological control systems, physiological modeling, systems analysis.

Aydin Tozeren, PhD *(Columbia University) Distinguished Professor and Director, Center for Integrated Bioinformatics, School of Biomedical Engineering, Science & Health Systems*. Professor Emeritus. Breast cell adhesion and communication, signal transduction networks in cancer and epithelial cells; integrated bioinformatics, molecular profiling, 3D-tumors, bioimaging.

Courses

BMES 501 Medical Sciences I 3.0 Credits
First course in a three-course sequence designed to acquaint students with the fundamentals of biology and physiology from an engineering perspective. This first course covers evolution, genetics, molecular biology and basic cellular physiology.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 502 Medical Sciences II 3.0 Credits
Second course in a three-course sequence designed to acquaint students with the fundamentals of biology and physiology from an engineering perspective. This second course covers tissues, muscle and nerve function, cardiovascular systems and respiration.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 501 [Min Grade: C]

BMES 503 Medical Sciences III 3.0 Credits
Third course in a three-course sequence designed to acquaint students with the fundamentals of biology and physiology from an engineering perspective. This third course covers renal and digestive systems. However, the major emphasis is on biological control systems ? nervous, endocrine and immune system structure and function.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 502 [Min Grade: C]

BMES 504 Medical Sciences IV 4.0 Credits
Mechanical, physical, electrical, and mathematical models of living systems, including feedback control systems. The laboratory part includes computer simulation so that data obtained from laboratory experiments may be compared with those predicted from models.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 505 Mathematics for Biomedical Sciences I 3.0 Credits
This course is for students of biology and related medical fields aimed at bridging the gap between qualitative and quantitative approaches in the study of biological processes. Topics include single and multivariable calculus infinte series, etc.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 506 Mathematics for Biomedical Sciences II 3.0 Credits
This course for students of biomedical sicence or biomedical engineering is designed to permit the student to go on to advanced studies in engineering and science in which differential equations are needed. Biological applications are emphasized.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 505 [Min Grade: C]

BMES 507 Mathematics for Biomedical Sciences III 3.0 Credits
This course covers topics in Fourier series and orthogobnal functions, partial differential equations, and boundary value problems Applications are made to problems in neuro-physiology, cellular transport, and biological oscillations.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 506 [Min Grade: C]

BMES 508 Cardiovascular Engineering 3.0 Credits
This course emphasizes engineering approaches to the analysis of the cardiovascular system focusing on fundamental mechanics and emerging technologies.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 501 [Min Grade: B] and BMES 502 [Min Grade: B] and BMES 503 [Min Grade: B]

BMES 509 Entrepreneurship for Biomedical Engineering and Science 3.0 Credits
This course serves as the foundation course in entrepreneurship and is designed to provide students with a complete working knowledge of the modern entrepreneurial and business planning process.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 510 Biomedical Statistics 4.0 Credits
This course introduces the graduate student to the fundamentals of inferential statistics with biomedical applications. It covers topics in data presentation, sampling, experimental design, probability and probability distributions, significance tests, and clinical trials.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 511 Principles of Systems Analysis Applied to Biomedicine I 3.0 Credits
Covers formulation of biological problems by rigorous mathematical techniques, including application of conservation laws, network theorems, and mesh and nodal analysis.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 512 Principles of Systems Analysis Applied to Biomedicine II 3.0 Credits
Continues BMES 511. Emphasizes input/output transfer function problems, linear systems and linear operations, and impulse response.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 513 Biomedical Electronics 3.0 Credits
Physical principles in the operation of both integrated circuits and discrete components. Analysis and design of transducers, amplifiers, oscillators, logic circuits, etc., with particular application to biomedical problems. (BMS).
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 514 Computer Applications in Biomedical Research 3.0 Credits
This course is intended to familiarize students with at least one computer language and to demonstrate computer applications in diagnosis, monitoring, and biomedical signal processing. (BMS).
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 515 Experimental Design in Biomedical Research 4.0 Credits
This course is designed to introduce students to the fundamental principles of experimental design and statistical analysis as applied to biomedical research with animals and humans. Topics to be covered include experimental design, clinical design, and protocol submission and review.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 510 [Min Grade: B]

BMES 517 Intermediate Biostatistics 3.0 Credits
The purpose of this course is to acquaint students with some of the statistical tools commonly used in biomedical and health sciences research. The course will provide the student with a basic theoretical background on the procedures of repeated measures ANOVA and selected multivariate statistical tests. It will familiarize students with the use of computer-based statistical analyses.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 510 [Min Grade: C]

BMES 518 Interpretation of Biomedical Data 3.0 Credits
The focus of this course is on understanding the methods used to analyze and interpret the results of quantitative data analyses in the biomedical and health sciences and determine their meaningfulness (clinical significance). Fundamental to this process is an understanding of the interrelatedness of statistical power, effect size, sample size and alpha.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 510 [Min Grade: C]

BMES 520 Introduction to Medical Science 3.0 Credits
The course is designed to acquaint professionals with the fundamentals of structure and function of biomedical systems from an engineering perspective. The course introduces the basics of molecular biology, cellular biology, anatomy and physiology.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Can enroll if major is CMPD.

BMES 521 Principles of Bioengineering 3.0 Credits
Principles of transduction and measurement, including characterization of the measurements systems, and invasive vs. noninvasive methods. (BME).
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 522 Principles of Bioengineering II 3.0 Credits
In-depth analysis of selected electromechanical transducer principles; review of important transduction methods in bioengineering; biopotential electrodes and chemical electrodes. (BME).
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 523 Principles of Bioengineering III 3.0 Credits
Microprocessor applications in biomedical engineering, including interfacing, data processing, display, and storage. (BME).
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 524 Introduction to Biosensors 4.0 Credits
An introductory course in the general area of microsensors covering basic sensing mechanisms and various types of conductometric, acoustic, silicon, optical and MEMS microsensors. Two case studies involving biosensors and acoustics sensors allow students to acquire in-depth knowledge in the theory and design of microsensors.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 525 Advanced Biosensors 4.0 Credits
The second course in a two-course sequence, this course covers aspects of modern biosensor design methods and addresses challenges associated with fabrication technologies and instrumentation techniques. Topics covered include the theory and modeling of biosensors, fabrication steps, and testing methods.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 531 Chronobioengineering I 3.0 Credits
This course advances the student's knowledge of biological time-keeping and adaptive functions of biological clocks. It includes such topics as biochemical and physiological models of biological blocks, adjustment to environmental cycles and rhythms in behavior and models.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 503 [Min Grade: C]

BMES 532 Chronobioengineering II 3.0 Credits
This course continues BMES 531. It covers topics in the patterns, rhythms, evolution, neurology, psychology and overall functions of sleep.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 531 [Min Grade: C]

BMES 534 Design Thinking for Biomedical Engineers 3.0 Credits
This course is a studio-seminar exploring principles and theories of product design, systematic design process, problem-solving, decision-makingand design as authorship. The course uses design research methods and topical design issues to explore and experience design thinking.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 535 Introduction to Product Design for Biomedical Engineers 3.0 Credits
This course introduces students to basic product design techniques. It combines lectures, demonstrations, discussions and problem solving exercises exploring product design as a creative process in the production of simple objects. Students develop a command of product development, skills in modeling and communication of their novel solutions.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 534 [Min Grade: D] or PROD 101 [Min Grade: C]

BMES 538 Biomedical Ethics and Law 3.0 Credits
Introduces a wide spectrum of ethical, regulatory, and legal issues facing health care practitioners and biomedical researchers. The course helps students become aware of the ethical and legal issues involved in their work while increasing the student's understanding of how legal and ethical decisions should be made in biomedical research, as well as what sources of help and guidance are available.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 541 Nano and Molecular Mechanics of Biological Materials 3.0 Credits
This course aims to provide students with the fundamental knowledge and latest scientific developments in molecular mechanics of biological materials. The first half of the course will introduce interdisciplinary theoretical background including molecular physics, electrostatics, colloidal science, biocompatibility and polymer mechanics. The second half will describe the most recent advances in nanotechnology and nanomechanics-related biomechanical and biomedical research. Students are expected to understand the fundamental knowledge of the molecular-level phenomena in biological systems, and to grasp the basic design and operation principles of nanomechanical instruments.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 543 Quantitative Systems Biology 4.5 Credits
This course uses a systems engineering approach to provide a foundation in systems biology and pathology informatics. Topics covered include the robust complex network of genes and proteins; cell as basic units of life; communication of cells with other cells and the environment; and gene circuits governing development.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 544 Genome Information Engineering 4.5 Credits
This course is designed to provide students with hands-on experience in the application of genomic, proteomic, and other large-scale information to biomedical engineering. The underlying goal is to develop an understanding of highthrough experimental technologies, biological challenges, and key mathematical and computational methods relevant to biomedical engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 543 [Min Grade: B]

BMES 545 Biosystems Modeling 4.5 Credits
This course provides hands-on experience in advanced computational methods used in systems biology: pathway and circuitry, feedback and control, cellular automata, sets of partial differential equations, stochastic analysis, and biostatistics.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 503 [Min Grade: C] and (BMES 512 [Min Grade: C] or BMES 561 [Min Grade: C])

BMES 546 Biocomputational Languages 4.0 Credits
This course provides hands-on education in C/C++, MATLAB, Java, and Perl languages used in biomedical applications. The principle application areas to be investigated include image analysis, feedback and control systems, algorithms on strings and sequences, database interactions, Web interactions, and biostatistics.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 551 Biomedical Signal Processing 3.0 Credits
Introduces discrete time signals and systems; origin and classification of biomedical signals; data acquisition, filtering, and spectral estimation of medical signals; compression of medical signals; new processing approaches and time-frequency representation and wavelets.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 552 Introduction to Bioacoustics 3.0 Credits
This course covers essential materials for anyone who is interested in the application of acoustical waves in biomedical and material science. The main objective is to familiarize students with the propagation of acoustic waves in different media, with particular emphasis on biomedical applications.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 561 Introduction to Systems Analysis in Biomedical Engineering & Science 3.0 Credits
This course acquaints students with the methods of dynamical systems analysis as used to understand biological phenomena. Uses mathematical/engineering models from several areas of biological/medical research to describe the function of systems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 563 Robotics in Medicine I 3.0 Credits
This course provides an introduction to the use of haptics (the use of somtaosensory information) in the design of robotic devices in surgery. Topics covered include actuators, sensors, nonportable feedback, portable force feedback, tactile feedback interfaces, haptic sensing and control systems.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 565 Robotics in Medicine II 3.0 Credits
This course covers the use of robots in surgery and included aspects of safety, robot kinematics, analysis of surgical performance using robotic devices, inverse kinematics, velocity analysis and acceleration analysis. Various types of surgeries in which robotic devices are or could be used are presented on a case study basis.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 563 [Min Grade: B]

BMES 566 Robotics in Medicine III 3.0 Credits
This course covers topics in the design of medical robotic systems, including force and movement analysis for robotic arms, dynamics, computer vision and vision-based control. Thus use of haptics, vision systems and robot dynamics are examined in a cohesive framework.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 565 [Min Grade: B]

BMES 571 Biological Evolution: Applications to Human Health and Performance 4.0 Credits
This course is designed to provide students with an evolutionary perspective on health and disease. The focus is on humans as products of evolution by natural selection and as such, subject to the same relationships and historical precedents that govern the rest of the natural world. Topics to be covered include ecological damage and emerging diseases, sociobiological perspectives on behavioral disorders, the development of resistance in pathogens, and adaptation and maladaptation of humans to urban environments.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 588 Medical Device Development 3.0 Credits
Medical device product development must take into account a diverse set of disciplines to achieve a safe and successful product. This course exposes the student to several of these disciplines with the objective of raising the student¿s awareness of safety throughout the product development life cycle. Students will learn to appreciate the complex engineering decisions that support development of a safe medical device through an examination of risk management, regulatory processes, human factors and clinical studies.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 821 [Min Grade: C-]

BMES 590 Clinical Rotation 3.0 Credits
Students are exposed to the problems and issues surrounding the practice of medicine in a modern hospital. Every 2 weeks students will be paired with a medical professional and observe clinical applications and procedures as well as other administrative functions. Actual topics covered vary from offering to offering. Course is run off campus at local hospitals.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated 2 times for 6 credits

BMES 594 Clinical Practicum I 3.0 Credits
This course provides biomedical engineering students with an extensive exposure to live clinical cardiology procedures, including cardiac catheterization, electrophysiology, echocardiography and nuclear stress testing. Emphasis is placed on identifying important interfaces between engineering and clinical medicine, particularly in areas where clinical needs may be addressed by advances in biomedical engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 595 Clinical Practicum II 3.0 Credits
This course provides biomedical engineering students with an extensive exposure to live operations in an emergency department an intensive care until. The students are expected to analyze specific operations within these environments and develop a solution to a process problem within one of these environments. System analysis, design and evaluation are emphasized.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 596 Clinical Practicum III 3.0 Credits
This course provides biomedical engineering students with an opportunity to observe basic operative and postoperative procedures with the idea of both learning about such procedures and identifying the role of biomedical engineering in these clinical settings.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 601 Anatomy I 2.0 Credits
The anatomy sequence surveys the gross and microscopic structure of the human body with emphasis on the structure-function relationship. This course is concerned with cell structure, histology, and tissues.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 602 Anatomy II 2.0 Credits
Continues BMES 601. Functional gross anatomy.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 603 Anatomy III 2.0 Credits
Continues BMES 602. Neuroanatomy.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 604 Pharmacogenomics 3.0 Credits
Covers the interaction between chemical agents and biological systems at all levels of integration. Discusses general classes of drugs, with particular emphasis on general concepts and problems of medical importance.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 611 Biological Control Systems I 3.0 Credits
Introduces the basic concepts of feedback control systems, including characterization in terms of prescribed constraints, study of input and output relationship for various types of biological systems, and stability and time delay problems in the pupillary reflex/eye-hand coordination system.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 612 Biological Control Systems II 3.0 Credits
Covers receptors, skeletal-muscle control systems, vestibular feedback, and sampled-data models.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 613 Biological Control Systems III 3.0 Credits
Covers mathematical models of biological systems, with emphasis on non-linear and adaptive systems study.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 621 Medical Imaging Systems I 4.0 Credits
Provides an overview of the field of medical imaging. Covers aspects of light imaging; systems theory, convolutions, and transforms; photometry, lenses, and depth of field; image perception and roc theory; three-dimensional imaging; image acquisition and display; and image processing operations, including scanning and segmentation.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 622 Medical Imaging Systems II 4.0 Credits
Introduces medical visualization techniques based on ultrasound propagation in biological tissues. Includes generation and reception of ultrasound, imaging techniques (A-mode, B-mode, M-mode, and Doppler), typical and emerging diagnostic applications, elements of ultrasound exposimetry, and safety aspects from the clinical point of view.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 621 [Min Grade: C]

BMES 623 Medical Imaging Systems III 4.0 Credits
Introduces elements of wave imaging, including wave propagation, Fourier optics and acoustics, limitations on resolution, ultrasound transducer characterization, and synthetic aperture systems. Examines MRI imaging in detail, including physical principles and scanning methodologies. Includes aspects of the psychophysics of human vision.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 622 [Min Grade: C]

BMES 625 Biomedical Ultrasound I 3.0 Credits
Focuses on the propagation of ultrasound in inhomogeneous media such as tissue, and discusses imaging principles and basics of tissue characterization. Discusses ultrasound instrumentation, including A-and B-mode scanners. Presents simple tissue models based on ultrasound wave absorption and scattering, and examines properties of tissue-mimicking materials and tissue phantoms. Covers ultrasound transducer models and discusses advantages and disadvantages of various transducer configurations. Outlines the principles of acoustic output measurements and discusses instrumentation requirements. Includes ultrasound exposimetry and biological effects of ultrasound.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 626 Biomedical Ultrasound II 3.0 Credits
Covers the theory and construction of array transducers for imaging, Doppler ultrasound systems and their application to the study of blood flow, and continuous wave and pulsed systems and Doppler imaging. Discusses the mechanisms for biological effects of ultrasound, including thermal and mechanical interaction of ultrasound energy and tissue.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 628 Ultrasound Wave Motion in Solids and Piezoelectrics 3.0 Credits
This course provides an introduction to the physics of wave propagation in solids, acquainting the student along the way with the necessary tensor formalism. The origin and behavior of longitudinal and shear bulk waves, surface waves, and plate waves are derived. The ultrasound behavior of piezoelectrics is analyzed and the results are applied to the analysis of piezoelectric transducers and ultrasound signal-processing devices.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 631 Tissue Engineering I 4.0 Credits
This course is designed to familiarize students with advanced concepts of cellular and molecular biology relevant to tissue engineering. This is the initial course in a three-course sequence combining materials from life science, engineering design and biomaterials to educate students in the principles, methods and technology of tissue engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 503 [Min Grade: B]

BMES 632 Tissue Engineering II 4.0 Credits
This course familiarizes students with advanced concepts of developmental and evolutionary biology relevant to tissue engineering. The second part of a three-course sequence combines materials from cellular/molecular biology, evolutionary design, and biomaterials to education students in the principles and methods of tissue engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 631 [Min Grade: B]
Corequisite: BMES 661

BMES 641 Biomedical Mechanics I 4.0 Credits
Designed to acquaint students with the response of biological tissues to mechanical loads and with the mechanical properties of living systems. Covers topics in musculoskeletal anatomy and functional mechanics; a review of mechanical principles, statics, dynamics, and materials; soft and hard tissue mechanics; mechano-pathological conditions in biological tissues and their correction; and prosthetics.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 642 Biomedical Mechanics II 4.0 Credits
Continues BMES 641.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 643 Biomedical Mechanics III 4.0 Credits
Continues BMES 642.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 644 Cellular Biomechanics 3.0 Credits
This course of cellular bioengineering focuses on mechanics and transport. Material builds upon undergraduate engineering education to place engineering mechanics into the context of biological function at the cellular level.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 651 Transport Phenomena in Living Systems I 3.0 Credits
Covers physical principles of momentum, energy, and mass transport phenomena in blood and other biological fluids; diffusion and convection at the microcirculatory level; physiology of arteries and veins; and local and systemic blood flow regulation and vascular disease.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 503 [Min Grade: C] and BMES 681 [Min Grade: C]

BMES 660 Biomaterials I 4.0 Credits
First course in a three-quarter sequence designed to acquaint students with the behavior of materials used in biomedical application under load (i.e., mechanical properties), their modes of failure and as a function of their environment. This course provides students with the fundamentals needed to proceed with Biomaterials II.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 661 Biomaterials II 4.0 Credits
Second course in a three-quarter sequence in biomaterials. The goal of this course is with an understanding of, and ability to select, appropriate materials for specific applications taking into account mechanical, thermal, and rheological properties taught in Biomaterials I and combining them with the biocompatibility issues covered in the present course.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Restrictions: Cannot enroll if classification is Freshman or Junior or Pre-Junior or Sophomore

BMES 672 Biosimulation I 3.0 Credits
This course focuses upon the mathematical analysis of biomedical engineering systems. As the first course in the biosimulation sequence, the course is a blend of analytical and numerical methods with strong emphasis on analytical approaches. The class concentrates on the application of mathematical concepts to biomedical problems drawn from physiological systems, cellular and molecular systems, bioimaging and biomedical device design.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 673 Biosimulation II 3.0 Credits
The second in a two-course sequence, this course focuses upon the mathematical modeling and subsequent computational analysis of complex biological systems. Specific examples are drawn physiological systems, cellular and molecular systems, bioimaging and biomedical device design and analysis. Topics covered include: modeling of complex bioengineering systems; parameter estimation and optimization of such models; and application of probability and statistical approaches as required.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 672 [Min Grade: C]

BMES 675 Biomaterials and Tissue Engineering III 4.0 Credits
This course provides students with in-depth knowledge of factor-mediated tissue engineering and regenerative medicine. Students learn about fundamental repair and regenerative processes and gain an understanding of specific biomaterials being used to mimic and/or enhance such processes. Students also learn about the delivery methods of agents which promote the proper functional development of specialized tissues.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 660 [Min Grade: C-] and BMES 661 [Min Grade: C-] and BMES 631 [Min Grade: C-] and BMES 632 [Min Grade: C-]

BMES 676 Software Development for Health Science Instruction 3.0 Credits
This course presents the planning, development and evaluation of computer software for instruction and clinical decision support in the area of health care. Particular emphasis is given to the Macintosh computer and the preparation of compiled "stand-alone" programs.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 680 Special Topics 9.0 Credits
Covers topics of particular interest that may not be offered every term or every year. Also included in this category are courses under development.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit

BMES 681 Physics of Living Systems I 3.0 Credits
Designed for the biomedical science student with a background in life sciences. Reviews and expands on basic concepts in physics as applied in biological systems. Topics include mechanics, exponential growth and decay, thermodynamics, and diffusion and membrane transport.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 682 Physics of Living Systems II 3.0 Credits
Covers advanced topics in biophysics for both biomedical science and biomedical engineering students.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 683 Physics of Living Systems III 3.0 Credits
Covers advanced topics of current interest in biomedical engineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 710 Neural Signals 3.0 Credits
This course covers aspects of neural signaling, including fundamentals of action potential generation, generator potentials, synaptic potentials, and second messenger signals. Students learn Hodgkin-Huxeley descriptions, equivalent circuit representations and be able to derive and integrate descriptive equations and generate computer simulations.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 711 Principles in Neuroengineering 3.0 Credits
This course is an in-depth student of some of the cutting-edge technologies in neuroengineering. The course draws on faculty in the College of Medicine and School of Biomedical Engineering, Science and Health Systems to present and investigate three topics in neuroengineering.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 710 [Min Grade: B]

BMES 722 Neural Aspects of Posture and Locomotion I 3.0 Credits
Studies physiology of sensory/motor systems, with emphasis on modeling of neural systems and biomechanical aspects of functional tasks. Begins with an analysis of the transportation of materials in and out of cells, followed by an examination of the origin and maintenance of membrane potentials. Discusses intra-and extracellular and surface measurement of potentials, generation and transmission of action potentials, synaptic processes, and the structure/function of muscle. Combines these elements to study reflex systems as well as vestibular and ocular effects on posture. Culminates in the study of the control of motor systems with respect to bipedal locomotion.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 725 Neural Networks 3.0 Credits
Explores the mathematical and biological bases for neurocomputing. Involves construction by students of computer simulations of important models and learning algorithms. Discusses applications to pattern recognition, vision, speech, control, and psychological modeling.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: MATH 210 [Min Grade: C]

BMES 731 Advanced Topics in Ultrasound Research I 3.0 Credits
Explores subjects of current interest through review of the literature by faculty, students, or invited lecturers.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit

BMES 732 Advanced Topics in Ultrasound Research II 3.0 Credits
Continues BMES 731. Discusses current developments and research in medical and industrial ultrasound, and geophysical and underwater signal processing.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit
Prerequisites: BMES 731 [Min Grade: C]

BMES 799 Independent & Supervised Study 9.0 Credits
Course and credits arranged with individual advisers.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit

BMES 821 Medical Instrumentation 3.0 Credits
Provides a broad overview of the applications of health care technology in diagnosis and therapy. Reflects the persuasiveness of biomedical engineering in medicine by describing medical instrumentation and engineering technology used in most of the main areas of specialization in medicine.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 822 Medical Instrumentation II 3.0 Credits
The objective of this course is to prepare the student for following an industry-accepted standard for designing a medical device. Students will work in teams to identify and design a response to medical need. The resulting design will either address an unmet medical need or present an improved approach to an existing solution. After identifying a particular project, the students will learn and implement particular processes for both design and dcoumentation.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated 2 times for 6 credits
Prerequisites: BMES 821 [Min Grade: C] or (BMES 391 [Min Grade: C] and BMES 392 [Min Grade: C])

BMES 823 Medical Instrument Laboratory 2.0 Credits
Provides laboratory exercises, including pulmonary function testing, stress testing, EKG, electrosurgery, and x-ray.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 821 [Min Grade: C]

BMES 825 Hospital Administration 3.0 Credits
Provides an analysis of the administrative process, including planning, organization, design, decision-making, leadership, and control. Presents methodologies and techniques that can contribute to the effective performance of administrative responsibilities examined in the light of significant and unique factors in hospital health care administration.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 826 Hospital Engineering Management 3.0 Credits
Covers the wide range of responsibilities of a clinical engineer, including managing a clinical engineering department, setting up an electrical safety program, establishing an equipment maintenance program, approaches for equipment acquisition, pre-purchase evaluation, and incoming inspection. Includes medical legislation, liability, and risk management.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit
Prerequisites: BMES 825 [Min Grade: C]

BMES 864 Seminar 0.0 Credits
An invitation seminar for discussion of research topics in biomedical engineering and science. Attendance of all graduate students in the institute is required. (None may be repeated for credit.).
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 866 Seminar II 2.0 Credits
Continues BMES 865.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 867 Seminar III 2.0 Credits
Continues BMES 866.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 897 Research 1.0-12.0 Credit
Requires investigation of a biomedical problem under the direction of a faculty adviser.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit

BMES 898 Master's Thesis 0.5-20.0 Credits
Requires the study and investigation of a research or development problem. Requires results to be reported in a thesis under the direction of a faculty adviser. No credit granted until the thesis is completed and approved.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Not repeatable for credit

BMES 998 Ph.D. Dissertation 1.0-12.0 Credit
Requires the study and investigation of a research or development problem. Requires results to be reported in a dissertation under the direction of a faculty adviser. No credit granted until the dissertation is completed and approved.
College/Department: School of Biomedical Engineering, Science Health Systems
Repeat Status: Can be repeated multiple times for credit

Certificate in Medical Product Design and Device Development

Certificate Level: Graduate
Admission Requirements: Bachelor's degree
Certificate Type: Graduate Certificate
Number of Credits to Completion: 15.0
Instructional Delivery: Online
Calendar Type: Quarter
Expected Time to Completion: 1 year
Financial Aid Eligibility: Not aid eligible

Over the past 50 years, the practice of medicine has become increasingly driven by technological innovations. However, simply being able to design and develop a new technology is no guarantee that the technology will reach its intended audience, whether that audience be made of medical professionals or patients. To reach the goal of introducing a medical technology into the marketplace, a biomedical engineer must run the gauntlet of regulations, attitudes, and financial considerations that make up the United States health care system.

Medical devices are subject to extensive FDA regulations. Thus, biomedical engineers who design medical technologies must be proficient in the regulatory and economic components of introducing a new medical device into the US health market. Knowledge of intellectual property law is also a prerequisite for those who plan to develop novel medical technologies. Because the cost of obtaining FDA is steep, obtaining intellectual property protection for extended periods of time is necessary to recovering project costs. Along similar lines, biomedical engineers

must also appreciate the role of Medicare and other insurers and their requirements for reimbursement.

This certificate program is designed to prepare biomedical engineers to understand the environment into which their innovations will be placed and the users who will interact with them. Professionals enrolled in the certificate will develop an understanding of critical regulatory, economic, and legal issues in addition to the project management skills that facilitate the development of new medical devices and positive working relationships with intellectual property lawyers, insurance companies, and the federal government.

Required Courses

BMES 509	Entrepreneurship for Biomedical Engineering and Science	3.0
BMES 538	Biomedical Ethics and Law	3.0
BMES 588	Medical Device Development	3.0
BMES 821	Medical Instrumentation	3.0
Select one of the following:		3.0
BMES 520	Introduction to Medical Science	
BMES 822	Medical Instrumentation II	
Total Credits		**15.0**

Additional Information

For addition information, please contact Carolyn Riley (Professional Programs, cr63@drexel.edu) or Professor Kambiz Pourrezaei (Program Coordinator, pourrezk@drexel.edu).

Biomedical Engineering, Science and Health Systems Faculty

Fred D. Allen, PhD *(University of Pennsylvania)*. Assistant Professor. Tissue engineering, cell engineering, orthopedics, bone remodeling, wound healing, mechanotransduction, signal transduction, adhesion, migration.

Sriram Balasubramanian, PhD *(Wayne State University)*. Assistant Professor. Structural characteristics of the pediatric thoracic cage using CT scans and developing an age-equivalent animal model for pediatric long bones.

Kenneth A. Barbee, PhD *(University of Pennsylvania)*. Professor. Cellular biomechanics of neural and vascular injury, mechanotransduction in the cardiovascular system, mechanical control of growth and development for wound healing and tissue engineering.

Lin Han, PhD *(Massachusetts Institute of Technology)*. Assistant Professor. Nanoscale structure-property relationships of biological materials, genetic and molecular origins soft joint tissue diseases, biomaterials under extreme conditions, coupling between stimulus-responsiveness and geometry.

Uri Hershberg, PhD *(Hebrew University of Jerusalem, Israel)*. Assistant Professor. Bioinformatics, immunology, neural computation, system biology, somatic selection, autoimmunity, genetic stability, germline diversity, dendritic cell, transcription elements, pathogens, computational and mathematical modeling, complex systems, cognition and inflammation.

Joshua Jacobs, PhD *(University of Pennsylvania)*. Assistant Professor. Neuroengineering, electrocorticography (ECoG), electroencephalography (EEG), single-neuron spiking, brain oscillations, episodic memory, working memory, spatial navigation, conceptual representations.

Dov Jaron, PhD *(University of Pennsylvania) Calhoun Distinguished Professor of Engineering in Medicine*. Professor. Mathematical, computer and electromechanical simulations of the cardiovascular system.

Andres Kriete, PhD *(University in Bremen Germany) Associate Director for Graduate Studies and Academic Operations*. Systems biology, bioimaging, control theory, biology of aging, skin cancer.

Ryszard Lec, PhD *(University of Warsaw Engineering College)*. Professor. Biomedical applications of visoelastic, acoustoptic and ultrasonic properties of liquid and solid media.

Peter Lewin, PhD *(University of Denmark, Copenhagen-Lyngby) Richard B. Beard Professor, School Of Biomedical Engineering, Science & Health Systems*. Professor. Biomedical ultrasonics, piezoelectric and polymer transducers and hydrophones; shock wave sensors.

Hualou Liang, PhD *(Chinese Academy of Sciences)*. Associate Professor. Neuroengineering, neuroinformatics, cognitive and computational neuroscience, neural data analysis and computational modeling, biomedical signal processing.

Donald L. McEachron, PhD *(University of California at San Diego) Associate Director*. Research Professor. Animal behavior, autoradiography, biological rhythms, cerebral metabolism, evolutionary theory, image processing, neuroendocrinology.

Karen Moxon, PhD *(University of Colorado)*. Associate Professor. Cortico-thalamic interactions; neurobiological perspectives on design of humanoid robots.

Banu Onaral, Ph.D. *(University of Pennsylvania) H.H. Sun Professor / Director, School of Biomedical Engineering Science and Health Systems*. Professor. Biomedical signal processing; complexity and scaling in biomedical signals and systems.

Kambiz Pourrezaei, PhD *(Rensselaer Polytechnic University)*. Professor. Thin film technology; nanotechnology; near infrared imaging; power electronics.

Arye Rosen, PhD *(Drexel University) Biomedical Engineering and Electrical Engineering*. Microwave components and subsystems; utilization of RF/microwaves and lasers in therapeutic medicine.

Ahmet Sacan, PhD *(Middle East Technical University)*. Assistant Professor. Indexing and data mining in biological databases; protein sequence and structure; similarity search; protein structure modeling; protein-protein interaction; automated cell tracking.

Joseph J. Sarver, PhD *(Drexel University)*. Teaching Professor. Neuromuscular adaptation to changes in the myo-mechanical environment.

Rahamim Seliktar, PhD *(University of Strathclyde, Glasgow) Vice Director, School of Biomedical Engineering, Science & Health Systems*. Professor. Limb prostheses, biomechanics of human motion, orthopedic biomechanics.

Adrian C. Shieh, PhD *(Rice University)*. Assistant Professor. Contribution of mechanical forces to tumor invasion and metastasis, with a particular emphasis on how biomechanical signals may drive the invasive switch, and how the biomechanical microenvironment interacts with cytokine

signaling and the extracellular matrix to influence tumor and stromal cell behavior.

Wan Young Shih, PhD *(Ohio State University) School of Biomedical Engineering, Science and Health Systems*. Associate Professor. Piezoelectric microcantilever biosensors development, piezoelectric finger development, quantum dots development, tissue elasticity imaging, piezoelectric microcantilever force probes.

Kara Spiller, PhD *(Drexel University)*. Assistant Professor. Cell-biomaterial interactions, biomaterial design, and international engineering education.

Margaret Wheatley, PhD *(University of Toronto) School of Biomedical Engineering, Science and Health Systems, John M. Reid Professor*. Ultrasound contrast agent development (tumor targeting and triggered drug delivery), controlled release technology (bioactive compounds), microencapsulated allografts (*ex vivo* gene therapy) for spinal cord repair.

Yinghui Zhong, PhD *(Georgia Institute of Technology)*. Assistant Professor. Spinal cord repair, and engineering neural prosthesis/brain interface using biomaterials, drug delivery, and stem cell therapy.

Interdepartmental Faculty

Douglas L. Chute, PhD *(University of Missouri) Louis and Bessie Stein Fellow*. Professor. Neuropsychology and rehabilitation; technological applications for the cognitively compromised and those with acquired brain injuries.

Patricia A. Shewokis, PhD *(University of Georgia)*. Professor. Roles of cognition and motor function during motor skill learning; role of information feedback frequency on the memory of motor skills, noninvasive neural imaging techniques of functional near infrared spectroscopy(fNIR) and electroencephalograpy (EEG) and methodology and research design.

Emeritus Faculty

William Freedman, PhD *(Drexel University)*. Professor Emeritus. Motor control; sensory and motor systems; reflexes; eye movements; neural networks.

John M. Reid, PhD *(University of Pennsylvania) Calhoun Professor Emeritus*. Professor Emeritus. Diagnostic ultrasound, wave propagation and scattering in inhomogeneous media, imaging, instrumentation.

Hun H. Sun, PhD *(Cornell University)*. Professor Emeritus. Biological control systems, physiological modeling, systems analysis.

Aydin Tozeren, PhD *(Columbia University) Distinguished Professor and Director, Center for Integrated Bioinformatics, School of Biomedical Engineering, Science & Health Systems*. Professor Emeritus. Breast cell adhesion and communication, signal transduction networks in cancer and epithelial cells; integrated bioinformatics, molecular profiling, 3D-tumors, bioimaging.