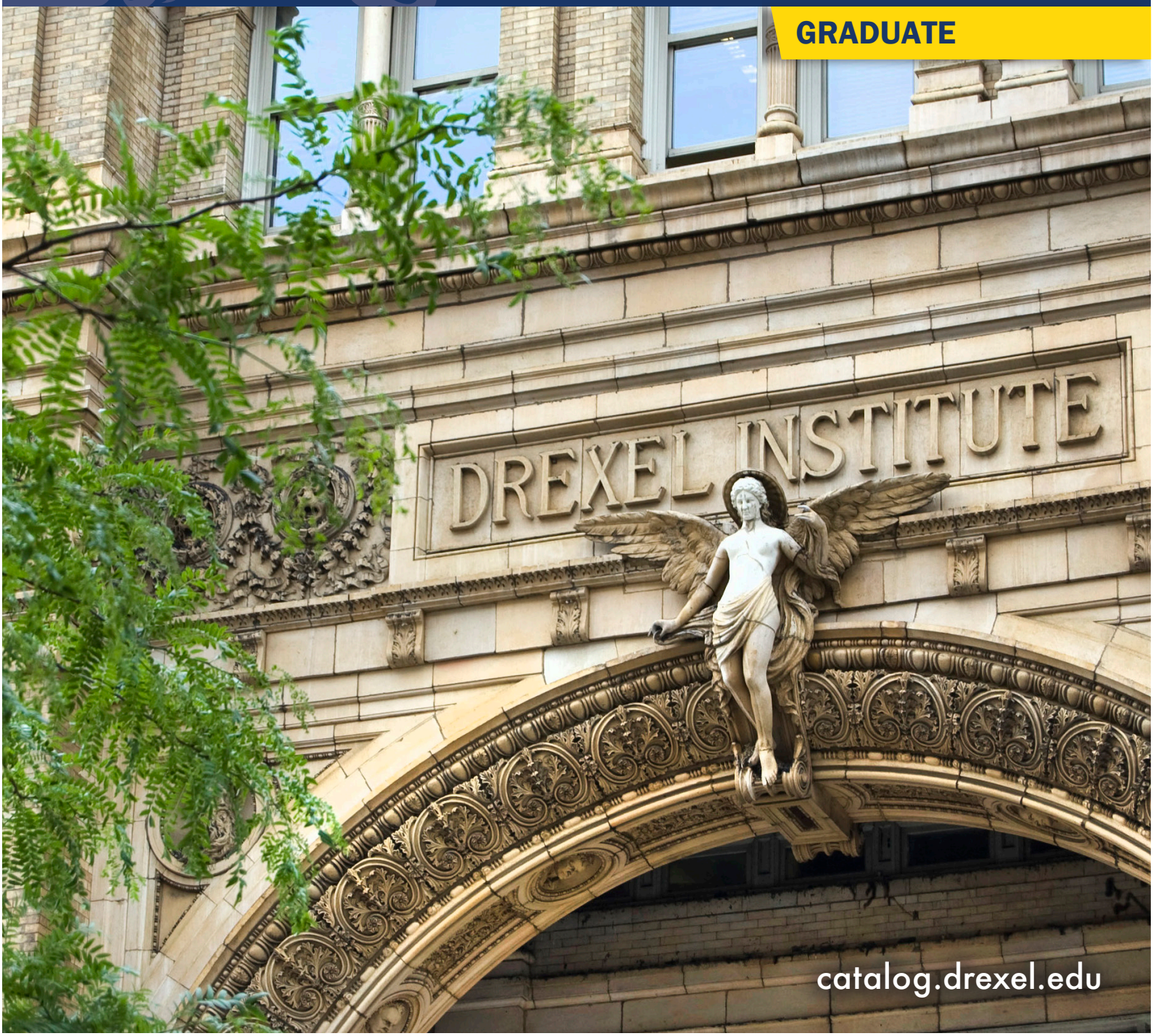
DREXEL UNIVERSITY
School of
Biomedical Engineering,
Science and Health Systems

CATALOG
2021-2022

GRADUATE



catalog.drexel.edu

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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://drexel.edu/biomed/) 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 and translational research is carried out through collaboration among Drexel University faculty members and with medical schools and hospitals in the Philadelphia area.

The School offers MS programs in biomedical engineering, integrated biomedical engineering and business, and biomedical science. PhD programs are offered in biomedical engineering and biomedical science. Areas of specialization available include biomaterials and tissue engineering, neuroengineering, biosensors and devices, biomedical imaging, biostatistics, genome science and bioinformatics, systems biology, biomechanics, human factors and performance engineering.

The School offers certificate programs in bioinformatics, medical product design, and tissue engineering for professionals continuing their education.

Majors

- Bioinformatics (MS) (http://catalog.drexel.edu/graduate/schoolofbiomedicalengineeringscienceandhealthsystems/bioinformatics)
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- Medical Product Design and Device Development (p. 29)
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About the School

The vision of the School of Biomedical Engineering, Science and Health Systems (the School) is to accelerate its role as the University's incubator for developing cutting-edge programs that enhance the University's position as a national leader in education and research. The School is a leader at Drexel University, regionally, and nationally in research and translation of discoveries that impact human health and well-being. It engages students across Drexel's campus in a unique combination of cooperative (Co-op) and experiential learning, multi-disciplinary research, entrepreneurship and international exposure. Faculty and students within School possess a spirit of innovation that is built on a deep understanding of fundamental scientific principles; hand-on experience both in the laboratory and in service to others; and recognition of the synergistic impact that occurs through partnerships, globally and locally, with industry, academia, policymakers, clinicians and social-service providers. The School will cultivate "Renaissance Biomedical Scientists and Engineers" who adapt easily to changing technologies, environments and problems.

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. The School's multidisciplinary programs are built around a core curriculum with research opportunities in specialized areas. The core curriculum provides the technical and analytical training students need to apply their engineering skills or knowledge of the life sciences to current problems in biology and medicine. Various units at Drexel, such as the College of Engineering, the Dornsife School of Public Health, and the College of Arts and Sciences offer courses relevant to graduate students in biomedical engineering and biomedical science.

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 (https://drexel.edu/biomed/research-and-design/overview/) webpage 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.

An agreement with 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 Medical Science.

The School also offers an integrated master's degree in biomedical engineering and business, a collaboration with the LeBow College of Business and the Close School of Entrepreneurship, which offers early-career engineers a tech-savvy alternative to an MBA. Through this cross-disciplinary approach, students are able to acquire the advanced knowledge and skills necessary for graduate-level research and career specialization.

Programs are revised regularly to met industry needs. For the most up-to-date list, please visit the School of Biomedical Engineering, Science and Health Systems Graduate Admissions webpage (http://drexel.edu/grad/programs/biomed/).

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.

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.

Dean's Fellowships are available for outstanding applicants to the School's Master programs and are 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 the student's 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 Admission Information (http://www.drexel.edu/grad/resources/international/) page.

Calhoun Graduate Assistantships are supported by the School's Calhoun Endowment and are available to outstanding applicants to the PhD program. 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 further assistance, students should contact the Office of Graduate Admissions (https://drexel.edu/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/), 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 24.0 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 3.0 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/)

Bioinformatics

Major: Bioinformatics
Degree Awarded: Master of Science
Calendar Type: Quarter
Total Credit Hours: 45.0
Co-op Option: None
Classification of Instructional Programs (CIP) code: 26.1103
Standard Occupational Classification (SOC) code: 15-1221; 15-1299; 15-2051; 19-4021; 15-1252

About the Program

The Bioinformatics program aims to train professional graduates for bioinformatics specialist roles in healthcare, biomedical research, pharmaceutical, and biotechnology industries by providing them with interdisciplinary knowledge and experience to develop and apply sophisticated computational methods for the analysis of biomedical data. The program consists of classes and electives included in certificates offered by the School of Biomedical Engineering, Science and Health Systems (Bioinformatics, Neurotechnologies and Neurosystems), the College of Computing and Informatics (Computational Data Science), and the Graduate School of Biomedical Science and Professional Studies (Drug Discovery and Development).

Additional Information

For questions about how to apply to the program, please contact:

Natalia Broz
Associate Director for Graduate Programs
School of Biomedical Engineering, Science and Health Systems
Email: njb33@drexel.edu

Andres Kriete, PhD
Associate Dean for Academic Affairs
School of Biomedical Engineering, Science and Health Systems
Email: ak3652@drexel.edu

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

Admission Requirements

Acceptance into the MS in Bioinformatics program requires a four-year bachelor's degree in sciences or engineering from a regionally accredited institution in the United States or an equivalent international institution. Regular acceptance typically requires a minimum cumulative grade point average of 3.0. The average for any graduate work must be at least 3.0.

Applicants must also fulfill the following requirements for consideration:

- Official transcripts from all colleges and universities attended
- References from at least two instructors or professionals;\
- Essay
- Resume

International applicants (non-United States citizens) must meet the same requirements for admission as students from the United States. Applicants whose native language is not English must demonstrate the ability to speak, write, and understand the English language by submitting an acceptable score on the Test of English as a Foreign Language (TOEFL). An evaluation by World Education Services (WES) is required for transcripts from institutions outside the United States.

Online applications are accepted all year-round, but all admitted students initiate their studies in the following fall term. Students are encouraged to apply no later than July 1 for consideration for admission the following fall term. Students may defer admission by one year.

Degree Requirements

Core Required Courses		
BMES 546	Biocomputational Languages	4.0
or BMES 550	Advanced Biocomputational Languages	
BMES 544	Genome Information Engineering	4.0
Core Elective Courses (Choose 7-9 credits)		**7.0-9.0**
BMES 543	Quantitative Systems Biology	
BMES 548	Structural Bioinformatics and Drug Design	
BMES 547	Machine Learning in Biomedical Applications	

BMES 545	Biosystems Modeling	
BMES 549	Genomic and Sequencing Technologies	
BMES 551	Biomedical Signal Processing	
BMES 604	Pharmacogenomics	
[Option 1] Computational Data Sciences (Choose 2 out of 3 options)		
Required Courses for Option 1		0.0-6.0
DSCI 511	Data Acquisition and Pre-Processing	
DSCI 521	Data Analysis and Interpretation	
Elective Courses for Option 1 (Choose 9 credits)		0.0-9.0
CS 500	Fundamentals of Databases	
CS 510	Introduction to Artificial Intelligence	
CS 583	Introduction to Computer Vision	
CS 613	Machine Learning	
CS 615	Deep Learning	
CS 660	Data Analysis at Scale	
CS 661	Responsible Data Analysis	
[Option 2] Drug Discovery and Development (Choose 2 out of 3 options)		
Required courses for Option 2		0.0-6.0
PHRM 525S	Drug Discovery and Development I	
PHRM 526S	Drug Discovery and Development II	
Elective courses for Option 2 (Choose 9 credits)		0.0-9.0
CBIO 510S	Cancer Biology	
CR 500S	Epidemiology	
CR 505S	Ethical Issues in Research	
CR 513S	Business Processes and Contemporary Concerns in Pharmaceutical R & D	
CR 514S	World Wide Regulatory Submissions	
CR 515S	Intro to Clinical Trials	
CR 520S	Applications of Clinical Research Biostatistics	
CR 525S	Scientific Writing and Medical Literature	
CR 535S	Current Federal Regulatory Issues in Biomedical Research	
CR 545S	Pharmaceutical Law	
CR 550S	Leadership Skills	
CR 555S	Compliance & Monitoring Issues	
CR 570S	Principles and Practice of Pharmacovigilance	
CR 600S	Designing the Clinical Trial	
CR 609S	Innovative Product Development	
CR 612S	Fundamentals of Compliance	
CR 614S	Introduction to Clinical Pharmacology	
CR 617S	Informatics in Pharm Res & Development	
CR 620S	Regulatory, Scientific and Social Issues Affecting Biotech Research	
CR 625S	Health Policy and Economics	
CR 635S	Strategic Planning	
CR T980S	Special Topics in Clinical Research	
IDPT 500S	Responsible Conduct of Research	
MIIM 508S	Immunology I	
MIIM 521S	Biotechniques I: Molecular and Genomic Methods	
MIIM 524S	Vaccines and Vaccine Development	
MIIM 530S	Fundamentals of Molecular Medicine I	
MIIM 531S	Fundamentals of Molecular Medicine II	
MLAS 536S	Animal Models for Biomedical Research	
NEUR 500S	Statistics for Neuro/Pharm Research	
NEUR 508S	Graduate Neuroscience I	
PHGY 503S	Graduate Physiology	
PHRM 502S	Current Topics in Pharmacology & Physiology	
PHRM 503S	Pharm & Phys 1st Lab Rotation	
PHRM 507S	Prin of Neuropharmacology	
PHRM 512S	Graduate Pharmacology	
PHRM 516S	Advanced Topics in Physiology	
PHRM 517S	Advanced Topics in Pharmacology	
PHRM 518S	New Frontiers in Therapy	
PHRM 519S	Methods in Biomedical Research	
PHRM 520S	Internship in Drug Discovery and Development	

PHRM 521S	Intensive Internship in Drug Discovery and Development	
PHRM 527S	Current Topics in Drug Discovery and Development	
PHRM 605S	Research in Drug Discovery and Development	
[Option 3] Neurotechnologies and Neurosystems (Choose 2 out of 3 options)		
Required courses for Option 3		0.0-6.0
BMES 710	Neural Signals	
BMES 711	Principles in Neuroengineering	
Elective courses for Option 3 (Choose 9 credits)		0.0-9.0
BMES 685	Experimental Methods in Neuroengineering	
BMES 715	Systems Neuroscience and Applications I	
BMES 718	Brain Computer Interfaces	
BMES 725	Neural Networks	

Total Credits: 45.0

Sample Plan of Study

Sample Curriculum Schedule without Co-Op

First Year

Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
BMES 546 or 550	4.0	BMES 547	3.0	BMES 543	4.0	VACATION	
BMES 718	3.0	BMES 551	3.0	BMES 711	3.0		
		BMES 710	3.0	BMES 725	3.0		
	7		**9**		**10**		**0**

Second Year

Fall	Credits	Winter	Credits	Spring	Credits
CS 500	3.0	BMES 544	4.0	CS 510	3.0
DSCI 511	3.0	DSCI 521	3.0	CS 615	3.0
	6		**7**		**6**

Total Credits 45

Biomedical Engineering, Science and Health Systems Faculty

Fred D. Allen, PhD *(University of Pennsylvania) Associate Dean for Undergraduate Education.* . Teaching Professor. Tissue engineering, cell engineering, orthopedics, bone remodeling, wound healing, mechanotransduction, signal transduction, adhesion, migration.

Hasan Ayaz, PhD *(Drexel University) School of Biomedical Engineering, Science and Health Systems*. Associate Professor. Neuroergonomics for Brain Health and Performance, Functional Neuroimaging, Biomedical Signal Processing, Biomedical Optics, Cognitive Neuroengineering, Brain Computer Interfaces, Neurotechnology, Clinical Neuroergonomics, Systems and Applied Neuroscience, Functional Near Infrared spectroscopy (fNIRS), Electroencephalogram (EEG), Brain Computer Interfaces (BCI), Mobile Brain/Body Imaging (MoBI)

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) Senior Associate Dean, Associate Dean for Research*. 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.

Paul Brandt-Rauf, MD, DrPH *(Columbia University) Dean*. Distinguished University Professor. Environmental health, particularly the molecular biology and molecular epidemiology of environmental carcinogenesis, and protein engineering for the development of novel peptide therapies for the treatment and prevention of cancer.

Donald Buerk, PhD *(Northwestern University)*. Research Professor. Biotechnology, physiology, systems biology, blood flow, microcirculation, nitric oxide, oxygen transport

Jaimie Dougherty, PhD *(Drexel University)*. Associate Teaching Professor. Brain-computer interface, neural encoding, electrophysiological signal acquisition and processing.

Lin Han, PhD *(Massachusetts Institute of Technology)*. Associate 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.

Kurtulus Izzetoglu, PhD *(Drexel University)*. Associate Professor. Biomedical optics, biomedical signal processing, medical sensor design, functional brain imaging, cognitive neuro engineering, cognitive performance, anesthesia monitoring, brain injury models and assessment.

Andres Kriete, PhD *(University in Bremen Germany) Associate Dean of Academic Affairs*. Teaching Professor. Systems biology, bioimaging, control theory, biology of aging.

Steven Kurtz, PhD *(Cornell University)*. Part-time Research Professor. Computational biomechanics of bone-implant systems and impact-related injuries, orthopaedic biomechanics, contact mechanics, orthopaedic biomaterials, large-deformation mechanical behavior and wear of polymers, and degradation and crosslinking of polyolefins in implant applications.

Peter A. Lewin, PhD *(University of Denmark, Copenhagen-Lyngby) Richard B. Beard Professor*. Distinguished University Professor. Biomedical ultrasonics, piezoelectric and polymer transducers and hydrophones; shock wave sensors., power ultrasonics, ultrasonic metrology, tissue characterization using nonlinear acoustics, biological effects of ultrasound (chronic wound healing and noninvasive drug delivery), applications of shock waves in medicine and image reconstruction and processing.

Hualou Liang, PhD *(Chinese Academy of Sciences)*. 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) Coordinator, Academic Assessment and Improvement*. Teaching Professor. Animal behavior, autoradiography, biological rhythms, cerebral metabolism, evolutionary theory, image processing, neuroendocrinology.

Banu Onaral, PhD *(University of Pennsylvania) H.H. Sun Professor; Senior Advisor to the President, Global Partnerships*. 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.

Christopher Rodell, PhD *(University of Pennsylvania)*. Assistant Professor. Biomaterials, supramolecular chemistry, and drug delivery. Therapeutic applications including the etiology of disease, organ injury, cardiovascular engineering, immune engineering, and biomedical imaging.

Ahmet Sacan, PhD *(Middle East Technical University)*. Associate Teaching 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.

Mark E. Schafer, PhD *(Drexel University)*. Research Professor. Diagnostic, therapeutic, and surgical ultrasound.

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(fNIRS) and electroencephalography (EEG) and methodology and research design.

Adrian C. Shieh, PhD *(Rice University)*. Associate Teaching Professor. Mechanobiology, mechanotransduction, tumor microenvironment, cell and tissue biomechanics.

Wan Y. Shih, PhD *(Ohio State University)*. Professor. Piezoelectric microcantilever biosensors development, piezoelectric finger development, quantum dots development, tissue elasticity imaging, piezoelectric microcantilever force probes.

Kara Spiller, PhD *(Drexel University)*. Professor. Macrophage-biometerial interactions, drug delivery systems, and chronic would healing. Cell-biomaterial interactions, biomaterial design, and international engineering education.

Marek Swoboda, PhD *(Drexel University)*. Assistant Teaching Professor. Cardiovascular engineering, cardiovascular system, diagnostic devices in cardiology, piezoelectric biosensors, and pathogen detection.

Amy Throckmorton, PhD *(University of Virginia)*. Professor. Computational and experimental fluid dynamics; cardiovascular modeling, including steady, transient, fluid-structure interaction, lumped parameter, microelectromechanical systems, and patient-specific anatomical studies; artificial organs research; and engineering.

Bhandawat Vikas, PhD *(Johns Hopkins School of Medicine)*. Associate Professor. Sensorimotor integration, whole-cell patch clamp and imaging in behaving animals, optogenetics, neuromechanics, locomotion.

Margaret Wheatley, PhD *(University of Toronto) 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.

Ming Xiao, PhD *(Baylor University)*. Associate Professor. Nanotechnology, single molecule detection, single molecule fluorescent imaging, genomics, genetics, genome mapping, DNA sequencing, DNA biochemistry, and biophysics.

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.

Leonid Zubkov, PhD, DSc *(St. Petersburg State University, Russia)*. Research Professor. Physiology, wound healing, physiologic neovascularization, near-infrared spectroscopy, optical tomography, histological techniques, computer-assisted diagnosis, infrared spectrophotometry, physiologic monitoring, experimental diabetes mellitus, penetrating wounds, diabetes complications, skin, animal models, radiation scattering, failure analysis

Catherin von Reyn, PhD *(University of Pennsylvania)*. Assistant Professor. Cell type-specific genetic engineering, whole-cell patch clamp in behaving animals, modeling, and detailed behavioral analysis to identify and characterize sensorimotor circuits.

Emeritus Faculty

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

Rahamim Seliktar, PhD *(University of Strathclyde, Glasgow)*. Professor Emeritus. Limb prostheses, biomechanics of human motion, orthopedic biomechanics.

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

Biomedical Engineering

Major: Biomedical Engineering
Degree Awarded: Master of Science (MS) or Doctor of Philosophy (PhD)
Calendar Type: Quarter
Total Credit Hours: 45.0 (MS) or 90.0 (PhD)
Co-op Option: Available for full-time, on-campus master's-level students
Classification of Instructional Programs (CIP) code: 14.0501
Standard Occupational Classification (SOC) code: 17-2031

About the Program

The curriculum develops graduates who can identify and address unmet clinical, diagnostic, and healthcare needs by using their knowledge of modern theories, engineering systems, and mathematical and engineering tools. Biomedical engineers require the analytical tools and broad knowledge of modern engineering and science, fundamental understanding of the biological or physiological system, and familiarity with recent technological breakthroughs.

Master students can choose to include a six-month graduate co-op cycle as part of their studies. Students may also choose to enroll in a concentration in Biomedical Device Development or specialize in biomaterials and tissue engineering, biomechanics, neuroengineering, imaging and devices, or bioinformatics, or may pursue a dual-degree MS option. Graduating students work in industry in such fields as medical devices, healthcare, pharmaceuticals and biotechnology, continue academic careers (PhD), or continue to medical schools.

Additional Information

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Andres Kriete, PhD
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For more information, visit the the School of Biomedical Engineering, Science and Health Systems (https://drexel.edu/biomed/) website.

Degree Requirements (MS)

The core requirements for the Master in Biomedical Engineering encompass approximately 45.0 course credits (most courses carry 3.0 credits each). Students who choose the non-thesis option cannot register for thesis or research credits.

The curriculum includes room for specialization in several areas of biomedical engineering, as well as a concentration in Biomedical Technology Development.

Concentrations

Four 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, machine learning, 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.
- **Pediatric Engineering**
  This concentration provides a foundation for future scientific and technical careers in pediatric engineering, healthcare, entrepreneurship, and innovation.

The sum of electives, core credits, and/or thesis credits must total 45.0 credits. Elective choices would depend upon the student's area(s) of focus or concentration but must be within the fields of science, engineering, or medicine. A concentration may substitute for elective credits.

Core Courses		
BMES 501	Medical Sciences I	3.0
BMES 502	Medical Sciences II	3.0
BMES 510	Biomedical Statistics	4.0
BMES 538	Biomedical Ethics and Law	3.0
BMES 546	Biocomputational Languages	4.0
or BMES 550	Advanced Biocomputational Languages	
BMES 864	Seminar (Must be taken 3 times)	0.0
Modeling-Intensive Courses		
Select two:		6.0
BMES 611	Biological Control Systems	
BMES 651	Transport Phenomena in Living Systems I	
BMES 672	Biosimulation I	
BMES 673	Biosimulation II	
BMES 677	Mathematical Modeling of Cellular Behavior	
BMES 678	Biocomputational Modeling and Simulation	
BMES 710	Neural Signals	
BMES Electives		**13.0**
BMES 503	Medical Sciences III	
BMES 508	Cardiovascular Engineering	
BMES 509	Entrepreneurship for Biomedical Engineering and Science	
BMES 515	Experimental Design in Biomedical Research	
BMES 517	Intermediate Biostatistics	
BMES 518	Interpretation of Biomedical Data	
BMES 524	Introduction to Biosensors	
BMES 528	Pediatric Engineering I	
BMES 529	Pediatric Engineering II	
BMES 531	Chronobioengineering I	
BMES 532	Chronobioengineering II	
BMES 534	Design Thinking for Biomedical Engineers	
BMES 535	Introduction to Product Design for Biomedical Engineers	
BMES 541	Nano and Molecular Mechanics of Biological Materials	
BMES 543	Quantitative Systems Biology	
BMES 544	Genome Information Engineering	
BMES 548	Structural Bioinformatics and Drug Design	
BMES 549	Genomic and Sequencing Technologies	
BMES 551	Biomedical Signal Processing	
BMES 588	Medical Device Development	
BMES 604	Pharmacogenomics	
BMES 611	Biological Control Systems	

BMES 621	Medical Imaging Systems I	
BMES 622	Medical Imaging Systems II	
BMES 623	Medical Imaging Systems III	
BMES 631	Tissue Engineering I	
BMES 632	Tissue Engineering II	
BMES 641	Biomedical Mechanics I	
BMES 642	Biomedical Mechanics II	
BMES 651	Transport Phenomena in Living Systems I	
BMES 660	Biomaterials I	
BMES 661	Biomaterials II	
BMES 672	Biosimulation I	
BMES 673	Biosimulation II	
BMES 675	Biomaterials and Tissue Engineering III	
BMES 677	Mathematical Modeling of Cellular Behavior	
BMES 678	Biocomputational Modeling and Simulation	
BMES 685	Experimental Methods in Neuroengineering	
BMES 710	Neural Signals	
BMES 711	Principles in Neuroengineering	
BMES 722	Neural Aspects of Posture and Locomotion I	
BMES 725	Neural Networks	
BMES 821	Medical Instrumentation	
BMES 822	Medical Instrumentation II	
BMES 825	Hospital Administration	
Science, Engineering, and Medicine Electives *		**9.0**
Thesis Option **		
BMES 897	Research	
BMES 898	Master's Thesis	
Total Credits		**45.0**

* Science, engineering, and medicine electives may include graduate-level courses from appropriate disciplines and departments, including Biomedical Engineering. Please consult with your graduate advisor when formulating your plan of study and choosing electives.

** Up to 9.0 credits of research and thesis may be applied toward the MS degree requirements. The research for the thesis may include work carried out during an internship.

Biomedical Technology Development Concentration (Optional)

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 596	Clinical Practicum	3.0
Total Credits		**15.0**

Biomaterials and Tissue Engineering Concentration (Optional)

This concentration 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

Core 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**

Bioinformatics Concentration (Optional)

This concentration 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.

BMES 543	Quantitative Systems Biology	4.0
BMES 544	Genome Information Engineering	4.0
BMES 547	Machine Learning in Biomedical Applications	3.0
or BMES 549	Genomic and Sequencing Technologies	
BMES 551	Biomedical Signal Processing	3.0
BMES 604	Pharmacogenomics	3.0
Total Credits		**17.0**

Pediatric Engineering Concentration (Optional)

This concentration aims to train students: 1) to develop a fundamental understanding of childhood injury and disease, healthcare, and treatment, and 2) to apply scientific and engineering concepts, methods, and approaches to address healthcare challenges with direct relevance to pediatric patients.

BMES 528	Pediatric Engineering I	3.0
BMES 529	Pediatric Engineering II	3.0
BMES 538	Biomedical Ethics and Law	3.0
BMES 509	Entrepreneurship for Biomedical Engineering and Science	3.0
Total Credits		**12.0**

Sample Plan of Study (MS)

First Year

Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
BMES 501	3.0	BMES 502	3.0	BMES 538*	3.0	VACATION	
BMES 510	4.0	BMES 864	0.0	BMES 864	0.0		
BMES 546 or 550	4.0	Modeling-Intensive Course	3.0	Modeling-Intensive Course	3.0		
BMES 864	0.0	BMES Elective	3.0	BMES Elective	3.0		
	11		**9**		**9**		**0**

Second Year

Fall	Credits	Winter	Credits
Elective Courses and/or Thesis**	9.0	Elective Courses and/or Thesis***	7.0
	9		**7**

Total Credits 45

* Can be taken in any term.

** Can include BMES 897.

*** Can include BMES 897 and BMES 898.

Degree Requirements (PhD)

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 864	Seminar	0.0
BMES 870	Graduate Research Talks (must be taken 9 times) *	9.0
Modeling-Intensive Courses: Select two		6.0
BMES 611	Biological Control Systems	
BMES 651	Transport Phenomena in Living Systems I	
BMES 672	Biosimulation I	
BMES 673	Biosimulation II	
BMES 677	Mathematical Modeling of Cellular Behavior	
BMES 678	Biocomputational Modeling and Simulation	
BMES 710	Neural Signals	
Additional Courses **		
BMES 510	Biomedical Statistics	4.0
BMES 538	Biomedical Ethics and Law	3.0
BMES 546	Biocomputational Languages	4.0
or BMES 550	Advanced Biocomputational Languages	
BMES Electives		**10.0**
BMES 503	Medical Sciences III	
BMES 508	Cardiovascular Engineering	
BMES 509	Entrepreneurship for Biomedical Engineering and Science	
BMES 515	Experimental Design in Biomedical Research	
BMES 517	Intermediate Biostatistics	
BMES 518	Interpretation of Biomedical Data	
BMES 524	Introduction to Biosensors	
BMES 528	Pediatric Engineering I	
BMES 529	Pediatric Engineering II	
BMES 531	Chronobioengineering I	
BMES 532	Chronobioengineering II	
BMES 534	Design Thinking for Biomedical Engineers	
BMES 535	Introduction to Product Design for Biomedical Engineers	
BMES 541	Nano and Molecular Mechanics of Biological Materials	
BMES 543	Quantitative Systems Biology	
BMES 544	Genome Information Engineering	
BMES 548	Structural Bioinformatics and Drug Design	
BMES 549	Genomic and Sequencing Technologies	
BMES 551	Biomedical Signal Processing	
BMES 588	Medical Device Development	
BMES 604	Pharmacogenomics	
BMES 611	Biological Control Systems	
BMES 621	Medical Imaging Systems I	
BMES 622	Medical Imaging Systems II	
BMES 623	Medical Imaging Systems III	
BMES 631	Tissue Engineering I	
BMES 632	Tissue Engineering II	
BMES 641	Biomedical Mechanics I	
BMES 642	Biomedical Mechanics II	
BMES 651	Transport Phenomena in Living Systems I	
BMES 660	Biomaterials I	
BMES 661	Biomaterials II	
BMES 672	Biosimulation I	
BMES 673	Biosimulation II	
BMES 675	Biomaterials and Tissue Engineering III	
BMES 677	Mathematical Modeling of Cellular Behavior	
BMES 678	Biocomputational Modeling and Simulation	
BMES 685	Experimental Methods in Neuroengineering	
BMES 710	Neural Signals	
BMES 711	Principles in Neuroengineering	

BMES 722	Neural Aspects of Posture and Locomotion I	
BMES 725	Neural Networks	
BMES 821	Medical Instrumentation	
BMES 822	Medical Instrumentation II	
BMES 825	Hospital Administration	
Research		
BMES 897	Research	48.0
Total Credits		**90.0**

* PHD students in the 2nd through 4th years are required to enroll in BMES 870 for the Fall, Winter, and Spring quarters (thus taking the course 9 times). Students with extenuating circumstances (e.g., study or research abroad, leave of absence) may petition the graduate advisor to waive the requirement for a given term.

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

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. 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. 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, they 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.

Additional Information

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, Science and Health Systems (http://drexel.edu/biomed/) website.

Sample Plan of Study (PhD)

First Year

Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
BMES 501	3.0	BMES 502	3.0	BMES 538	3.0	BMES 897	5.0
BMES 510	4.0	BMES 864	0.0	BMES 864	0.0	BMES Elective	4.0
BMES 546 or 550	4.0	Modeling-Intensive Course	3.0	Modeling-Intensive Course	3.0		
BMES 864	0.0	BMES Elective	3.0	BMES Elective	3.0		
	11		**9**		**9**		**9**

Second Year

Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
BMES 870	1.0	BMES 870	1.0	BMES 870	1.0	VACATION	
BMES 897	8.0	BMES 897	8.0	BMES 897	8.0		
	9		**9**		**9**		**0**

Third Year

Fall	Credits	Winter	Credits	Spring	Credits
BMES 870	1.0	BMES 870	1.0	BMES 870	1.0

BMES 897	8.0	BMES 897	8.0	BMES 897	6.0		
	9		**9**		**7**		

Total Credits 90

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) Associate Dean for Undergraduate Education.* . Teaching Professor. Tissue engineering, cell engineering, orthopedics, bone remodeling, wound healing, mechanotransduction, signal transduction, adhesion, migration.

Hasan Ayaz, PhD *(Drexel University) School of Biomedical Engineering, Science and Health Systems*. Associate Professor. Neuroergonomics for Brain Health and Performance, Functional Neuroimaging, Biomedical Signal Processing, Biomedical Optics, Cognitive Neuroengineering, Brain Computer Interfaces, Neurotechnology, Clinical Neuroergonomics, Systems and Applied Neuroscience, Functional Near Infrared spectroscopy (fNIRS), Electroencephalogram (EEG), Brain Computer Interfaces (BCI), Mobile Brain/Body Imaging (MoBI)

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) Senior Associate Dean, Associate Dean for Research*. 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.

Paul Brandt-Rauf, MD, DrPH *(Columbia University) Dean*. Distinguished University Professor. Environmental health, particularly the molecular biology and molecular epidemiology of environmental carcinogenesis, and protein engineering for the development of novel peptide therapies for the treatment and prevention of cancer.

Donald Buerk, PhD *(Northwestern University)*. Research Professor. Biotechnology, physiology, systems biology, blood flow, microcirculation, nitric oxide, oxygen transport

Jaimie Dougherty, PhD *(Drexel University)*. Associate Teaching Professor. Brain-computer interface, neural encoding, electrophysiological signal acquisition and processing.

Lin Han, PhD *(Massachusetts Institute of Technology)*. Associate 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.

Kurtulus Izzetoglu, PhD *(Drexel University)*. Associate Professor. Biomedical optics, biomedical signal processing, medical sensor design, functional brain imaging, cognitive neuro engineering, cognitive performance, anesthesia monitoring, brain injury models and assessment.

Andres Kriete, PhD *(University in Bremen Germany) Associate Dean of Academic Affairs*. Teaching Professor. Systems biology, bioimaging, control theory, biology of aging.

Steven Kurtz, PhD *(Cornell University)*. Part-time Research Professor. Computational biomechanics of bone-implant systems and impact-related injuries, orthopaedic biomechanics, contact mechanics, orthopaedic biomaterials, large-deformation mechanical behavior and wear of polymers, and degradation and crosslinking of polyolefins in implant applications.

Peter A. Lewin, PhD *(University of Denmark, Copenhagen-Lyngby) Richard B. Beard Professor*. Distinguished University Professor. Biomedical ultrasonics, piezoelectric and polymer transducers and hydrophones; shock wave sensors., power ultrasonics, ultrasonic metrology, tissue characterization using nonlinear acoustics, biological effects of ultrasound (chronic wound healing and noninvasive drug delivery), applications of shock waves in medicine and image reconstruction and processing.

Hualou Liang, PhD *(Chinese Academy of Sciences)*. 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) Coordinator, Academic Assessment and Improvement*. Teaching Professor. Animal behavior, autoradiography, biological rhythms, cerebral metabolism, evolutionary theory, image processing, neuroendocrinology.

Banu Onaral, PhD *(University of Pennsylvania) H.H. Sun Professor; Senior Advisor to the President, Global Partnerships*. 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.

Christopher Rodell, PhD *(University of Pennsylvania)*. Assistant Professor. Biomaterials, supramolecular chemistry, and drug delivery. Therapeutic applications including the etiology of disease, organ injury, cardiovascular engineering, immune engineering, and biomedical imaging.

Ahmet Sacan, PhD *(Middle East Technical University)*. Associate Teaching 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.

Mark E. Schafer, PhD *(Drexel University)*. Research Professor. Diagnostic, therapeutic, and surgical ultrasound.

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(fNIRS) and electroencephalography (EEG) and methodology and research design.

Adrian C. Shieh, PhD *(Rice University)*. Associate Teaching Professor. Mechanobiology, mechanotransduction, tumor microenvironment, cell and tissue biomechanics.

Wan Y. Shih, PhD *(Ohio State University)*. Professor. Piezoelectric microcantilever biosensors development, piezoelectric finger development, quantum dots development, tissue elasticity imaging, piezoelectric microcantilever force probes.

Kara Spiller, PhD *(Drexel University)*. Professor. Macrophage-biometerial interactions, drug delivery systems, and chronic would healing. Cell-biomaterial interactions, biomaterial design, and international engineering education.

Marek Swoboda, PhD *(Drexel University)*. Assistant Teaching Professor. Cardiovascular engineering, cardiovascular system, diagnostic devices in cardiology, piezoelectric biosensors, and pathogen detection.

Amy Throckmorton, PhD *(University of Virginia)*. Professor. Computational and experimental fluid dynamics; cardiovascular modeling, including steady, transient, fluid-structure interaction, lumped parameter, microelectromechanical systems, and patient-specific anatomical studies; artificial organs research; and engineering.

Bhandawat Vikas, PhD *(Johns Hopkins School of Medicine)*. Associate Professor. Sensorimotor integration, whole-cell patch clamp and imaging in behaving animals, optogenetics, neuromechanics, locomotion.

Margaret Wheatley, PhD *(University of Toronto) 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.

Ming Xiao, PhD *(Baylor University)*. Associate Professor. Nanotechnology, single molecule detection, single molecule fluorescent imaging, genomics, genetics, genome mapping, DNA sequencing, DNA biochemistry, and biophysics.

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.

Leonid Zubkov, PhD, DSc *(St. Petersburg State University, Russia)*. Research Professor. Physiology, wound healing, physiologic neovascularization, near-infrared spectroscopy, optical tomography, histological techniques, computer-assisted diagnosis, infrared spectrophotometry, physiologic monitoring, experimental diabetes mellitus, penetrating wounds, diabetes complications, skin, animal models, radiation scattering, failure analysis

Catherin von Reyn, PhD *(University of Pennsylvania)*. Assistant Professor. Cell type-specific genetic engineering, whole-cell patch clamp in behaving animals, modeling, and detailed behavioral analysis to identify and characterize sensorimotor circuits.

Emeritus Faculty

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

Rahamim Seliktar, PhD *(University of Strathclyde, Glasgow)*. Professor Emeritus. Limb prostheses, biomechanics of human motion, orthopedic biomechanics.

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

Biomedical Science

Major: Biomedical Science
Degree Awarded: Master of Science (MS) or Doctor of Philosophy (PhD)
Calendar Type: Quarter
Total Credit Hours: 45.0 (MS) or 90.0 (PhD)
Co-op Option: Available for full-time, on-campus master's-level students
Classification of Instructional Programs (CIP) code: 26.0102
Standard Occupational Classification (SOC) code: 19-1042

About the Program

The Biomedical Science program at the School of Biomedical Engineering, Science and Health Systems applies fundamental biological research, analysis and technology to human health. The program educates students whose undergraduate education is in basic life sciences (e.g., biology) or paramedical disciplines in quantitative data analysis, mathematical modeling, systems analysis 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.

Master students can choose to include a 6 months co-op cycle as part of their studies. Students may also choose to enroll in concentrations such as biomedical technology development, biomaterials and tissue engineering, or bioinformatics. They can also specialize in neuroengineering, biomechanics or imaging and devices. 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 Intensive Medical Sciences (IMS) program at the Drexel College of Medicine, which can be pursued after taking one year of required classes. The IMS program is a rigorous one-year graduate program designed to help students develop strong academic portfolios and become attractive candidates for medical school.

Additional Information

Natalia Broz
Associate Director for Graduate Programs
School of Biomedical Engineering, Science and Health Systems
Email: njb33@drexel.edu

Andres Kriete, PhD
Associate Dean for Academic Affairs
School of Biomedical Engineering, Science and Health Systems
Email: ak3652@drexel.edu

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

Degree Requirements (MS)

The core requirements for the master's in biomedical science encompass approximately 45.0 course credits (most courses carry three credits each). Students who choose the non-thesis option cannot register for thesis or research credits.

The curriculum includes room for specialization in several areas in biomedical engineering, as well as concentrations in biomaterials and tissue engineering, bioinformatics and biomedical technology development.

Concentrations

Four 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, machine learning, 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.
- **Pediatric Engineering**
  This concentration provides a foundation for future scientific and technical careers in pediatric engineering, healthcare, entrepreneurship, and innovation.

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	3.0-4.0
or BMES 543	Quantitative Systems Biology	
or BMES 611	Biological Control Systems	
BMES 515	Experimental Design in Biomedical Research	4.0
BMES 538	Biomedical Ethics and Law	3.0
BMES 546	Biocomputational Languages	4.0
or BMES 550	Advanced Biocomputational Languages	
BMES 864	Seminar (Must be taken 3 times)	0.0
BMES Electives - Select a minimum of 9.0 credits from the list below		**9.0-15.0**
BMES 508	Cardiovascular Engineering	
BMES 509	Entrepreneurship for Biomedical Engineering and Science	
BMES 517	Intermediate Biostatistics	
BMES 518	Interpretation of Biomedical Data	
BMES 524	Introduction to Biosensors	
BMES 525	Advanced Biosensors	
BMES 528	Pediatric Engineering I	
BMES 529	Pediatric Engineering II	
BMES 531	Chronobioengineering I	
BMES 532	Chronobioengineering II	
BMES 534	Design Thinking for Biomedical Engineers	
BMES 535	Introduction to Product Design for Biomedical Engineers	
BMES 541	Nano and Molecular Mechanics of Biological Materials	
BMES 543	Quantitative Systems Biology	
BMES 544	Genome Information Engineering	
BMES 547	Machine Learning in Biomedical Applications	
BMES 548	Structural Bioinformatics and Drug Design	
BMES 549	Genomic and Sequencing Technologies	
BMES 551	Biomedical Signal Processing	
BMES 588	Medical Device Development	
BMES 604	Pharmacogenomics	

BMES 621	Medical Imaging Systems I	
BMES 622	Medical Imaging Systems II	
BMES 623	Medical Imaging Systems III	
BMES 631	Tissue Engineering I	
BMES 632	Tissue Engineering II	
BMES 641	Biomedical Mechanics I	
BMES 642	Biomedical Mechanics II	
BMES 651	Transport Phenomena in Living Systems I	
BMES 660	Biomaterials I	
BMES 661	Biomaterials II	
BMES 672	Biosimulation I	
BMES 673	Biosimulation II	
BMES 685	Experimental Methods in Neuroengineering	
BMES 710	Neural Signals	
BMES 711	Principles in Neuroengineering	
BMES 722	Neural Aspects of Posture and Locomotion I	
BMES 821	Medical Instrumentation	
BMES 822	Medical Instrumentation II	
BMES 825	Hospital Administration	
General Electives in the fields of science, engineering, or medicine including additional BMES classes		**6.0-12.0**
The sum of electives, core credits, and/or thesis credits must total 45.0 credits. Elective choices would depend upon the student's area(s) of focus or concentration but must be within the fields of science, engineering, or medicine. A concentration may substitute for elective credits. A minimum of 15 credits of BMES elective courses are required.		
Thesis		**0.0-9.0**
BMES 897	Research	
BMES 898	Master's Thesis	
Total Credits		**45.0-67.0**

Biomedical Technology Development Concentration (Optional)

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.

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 596	Clinical Practicum	3.0
Total Credits		**15.0**

Biomaterials and Tissue Engineering Concentration (Optional)

This concentration 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

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**

Bioinformatics Concentration (Optional)

This concentration 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.

BMES 543	Quantitative Systems Biology	4.0
BMES 544	Genome Information Engineering	4.0
BMES 547	Machine Learning in Biomedical Applications	3.0
or BMES 549	Genomic and Sequencing Technologies	
BMES 551	Biomedical Signal Processing	3.0

BMES 604	Pharmacogenomics	3.0
Total Credits		**17.0**

Pediatric Engineering Concentration (Optional)

This concentration aims to train students: 1) to develop a fundamental understanding of childhood injury and disease, healthcare, and treatment, and 2) to apply scientific and engineering concepts, methods, and approaches to address healthcare challenges with direct relevance to pediatric patients.

BMES 509	Entrepreneurship for Biomedical Engineering and Science	3.0
BMES 528	Pediatric Engineering I	3.0
BMES 529	Pediatric Engineering II	3.0
BMES 538	Biomedical Ethics and Law	3.0
Total Credits		**12.0**

Sample Plan of Study (MS)

First Year				
Fall	**Credits Winter**		**Credits Spring**	**Credits**
BMES 505	3.0 BMES 506	3.0 BMES 507		3.0
BMES 510	4.0 BMES 511	3.0 BMES 538		3.0
BMES 546 or 550	4.0 BMES 515	4.0 BMES 864		0.0
BMES 864	0.0 BMES 864	0.0 Choose one of the following courses		3.0
			BMES 512	
			BMES 543	
			BMES 611	
	11	**10**		**9**
Second Year				
Fall	**Credits Winter**		**Credits**	
Elective Courses and/or Research*	9.0-12.0 Elective Courses and/or Thesis**		6.0-9.0	
	9-12		**6-9**	
Total Credits 45-51				

* Can include BMES 897.

** Can include BMES 897 and BMES 898.

Degree Requirements (PhD)

Students with training in natural science or engineering, 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 degree, students must complete 90.0 required credits and fulfill a 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 Science, 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 Science at the School of Biomedical Engineering, those courses they took would apply.

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 Science.

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.

The overall objective of the candidacy examination is to test the student's basic knowledge and preparedness to proceed toward a PhD in Biomedical Science. 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.

Additional Information

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, Science and Health Systems' Biomedical Science (http://drexel.edu/biomed/) website.

For more information, visit the School's Graduate Programs (http://drexel.edu/biomed/academics/graduate-programs/) webpage.

Intensive Medical Sciences 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 Intensive Medical Sciences program (IMS), to offer a unique pathway to a master's in Biomedical Science degree. Students take one year of studies in the MS Biomedical Science program and another year in the IMS program (described below). This involves completing the core sequence and a thesis or taking a non-thesis option with additional coursework.

Intensive Medical Sciences Program Curriculum

The IMS curriculum involves a full-time commitment to rigorous coursework with strong academic requirements. Six major medical school equivalent courses are taken over two semesters. These include Medical Biochemistry, Medical Physiology, Medical Microanatomy, Medical Immunology, Medical Neuroanatomy, and Medical Nutrition. The courses are taught by the medical school faculty and students are guided by advisors when completing their medical school applications.

In addition to rigorous science courses, students also take a medical ethics course in the fall semester, followed by a professionalism course in the spring. 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.

Additional Information

For more information, visit Drexel's College of Medicine's Intensive Medical Sciences program (https://drexel.edu/medicine/academics/graduate-school/intensive-medical-sciences/) webpage.

Biomedical Engineering, Science and Health Systems Faculty

Fred D. Allen, PhD *(University of Pennsylvania) Associate Dean for Undergraduate Education.* . Teaching Professor. Tissue engineering, cell engineering, orthopedics, bone remodeling, wound healing, mechanotransduction, signal transduction, adhesion, migration.

Hasan Ayaz, PhD *(Drexel University) School of Biomedical Engineering, Science and Health Systems*. Associate Professor. Neuroergonomics for Brain Health and Performance, Functional Neuroimaging, Biomedical Signal Processing, Biomedical Optics, Cognitive Neuroengineering, Brain Computer Interfaces, Neurotechnology, Clinical Neuroergonomics, Systems and Applied Neuroscience, Functional Near Infrared spectroscopy (fNIRS), Electroencephalogram (EEG), Brain Computer Interfaces (BCI), Mobile Brain/Body Imaging (MoBI)

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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Lin Han, PhD *(Massachusetts Institute of Technology)*. Associate 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.

Kurtulus Izzetoglu, PhD *(Drexel University)*. Associate Professor. Biomedical optics, biomedical signal processing, medical sensor design, functional brain imaging, cognitive neuro engineering, cognitive performance, anesthesia monitoring, brain injury models and assessment.

Andres Kriete, PhD *(University in Bremen Germany) Associate Dean of Academic Affairs*. Teaching Professor. Systems biology, bioimaging, control theory, biology of aging.

Steven Kurtz, PhD *(Cornell University)*. Part-time Research Professor. Computational biomechanics of bone-implant systems and impact-related injuries, orthopaedic biomechanics, contact mechanics, orthopaedic biomaterials, large-deformation mechanical behavior and wear of polymers, and degradation and crosslinking of polyolefins in implant applications.

Peter A. Lewin, PhD *(University of Denmark, Copenhagen-Lyngby) Richard B. Beard Professor*. Distinguished University Professor. Biomedical ultrasonics, piezoelectric and polymer transducers and hydrophones; shock wave sensors., power ultrasonics, ultrasonic metrology, tissue characterization using nonlinear acoustics, biological effects of ultrasound (chronic wound healing and noninvasive drug delivery), applications of shock waves in medicine and image reconstruction and processing.

Hualou Liang, PhD *(Chinese Academy of Sciences)*. 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) Coordinator, Academic Assessment and Improvement*. Teaching Professor. Animal behavior, autoradiography, biological rhythms, cerebral metabolism, evolutionary theory, image processing, neuroendocrinology.

Banu Onaral, PhD *(University of Pennsylvania) H.H. Sun Professor; Senior Advisor to the President, Global Partnerships*. 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.

Christopher Rodell, PhD *(University of Pennsylvania)*. Assistant Professor. Biomaterials, supramolecular chemistry, and drug delivery. Therapeutic applications including the etiology of disease, organ injury, cardiovascular engineering, immune engineering, and biomedical imaging.

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

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Wan Y. Shih, PhD *(Ohio State University)*. Professor. Piezoelectric microcantilever biosensors development, piezoelectric finger development, quantum dots development, tissue elasticity imaging, piezoelectric microcantilever force probes.

Kara Spiller, PhD *(Drexel University)*. Professor. Macrophage-biometerial interactions, drug delivery systems, and chronic would healing. Cell-biomaterial interactions, biomaterial design, and international engineering education.

Marek Swoboda, PhD *(Drexel University)*. Assistant Teaching Professor. Cardiovascular engineering, cardiovascular system, diagnostic devices in cardiology, piezoelectric biosensors, and pathogen detection.

Amy Throckmorton, PhD *(University of Virginia)*. Professor. Computational and experimental fluid dynamics; cardiovascular modeling, including steady, transient, fluid-structure interaction, lumped parameter, microelectromechanical systems, and patient-specific anatomical studies; artificial organs research; and engineering.

Bhandawat Vikas, PhD *(Johns Hopkins School of Medicine)*. Associate Professor. Sensorimotor integration, whole-cell patch clamp and imaging in behaving animals, optogenetics, neuromechanics, locomotion.

Margaret Wheatley, PhD *(University of Toronto) 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.

Ming Xiao, PhD *(Baylor University)*. Associate Professor. Nanotechnology, single molecule detection, single molecule fluorescent imaging, genomics, genetics, genome mapping, DNA sequencing, DNA biochemistry, and biophysics.

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.

Leonid Zubkov, PhD, DSc *(St. Petersburg State University, Russia)*. Research Professor. Physiology, wound healing, physiologic neovascularization, near-infrared spectroscopy, optical tomography, histological techniques, computer-assisted diagnosis, infrared spectrophotometry, physiologic monitoring, experimental diabetes mellitus, penetrating wounds, diabetes complications, skin, animal models, radiation scattering, failure analysis

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Rahamim Seliktar, PhD *(University of Strathclyde, Glasgow)*. Professor Emeritus. Limb prostheses, biomechanics of human motion, orthopedic biomechanics.

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

Integrated Biomedical Engineering and Business

Major: Integrated Biomedical Engineering and Business
Degree Awarded: Master of Science (MS)
Calendar Type: Quarter
Total Credit Hours: 46.0
Co-op Option: Available for full-time, on-campus master's-level students
Classification of Instructional Programs (CIP) code: 14.0501
Standard Occupational Classification (SOC) code: 17-2031

About the Program

The Master of Science in Integrated Biomedical Engineering and Business is designed for engineers pursuing business/management-oriented careers in biomedical engineering. The program is open for students with previous undergraduate degrees in an engineering discipline. The program provides participants with a biomedical engineering training, but combines it with a multifaceted and transferable skillset of a manager and technology entrepreneur. Participants will complete specific courses and have experiences that promote the development of their business skills in terms of management, finance, leadership, communications, and marketing skills, thus helping to ensure graduates' professional success.

In addition, the program requires a minimum of 46.0 quarter credits (40.0 credits in class; 3.0 or 6.0 co-op and/or 3.0-6.0 elective credits). It is a non-thesis program and can be completed in 1.5 years as a full time student, or it can be taken on a part-time basis.

Additional Information

Natalia Broz
Associate Director for Graduate Programs
School of Biomedical Engineering, Science and Health Systems
Email: njb33@drexel.edu

Andres Kriete, PhD
Associate Dean for Academic Affairs

School of Biomedical Engineering, Science and Health Systems
Email: ak3652@drexel.edu

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

Admission Requirements

Acceptance into the MS in Integrated Biomedical Engineering and Business program requires a four-year bachelor's degree in engineering from a regionally accredited institution in the United States or an equivalent international institution. Regular acceptance typically requires a minimum cumulative grade point average of 3.0 for the last two years of undergraduate work. The average for any graduate work must be at least 3.0.

Applicants must also fulfill the following requirements for consideration:

- Official transcripts from all colleges and universities attended
- Official test scores from Graduate Record Examination (GRE)
- References from at least two instructors or professionals
- Essay and resume

International applicants (non-United States citizens) must meet the same requirements for admission as students from the United States. Applicants whose native language is not English must demonstrate the ability to speak, write, and understand the English language by submitting an acceptable score on the Test of English as a Foreign Language (TOEFL). An evaluation by World Education Services (WES) is required for transcripts from institutions outside the United States.

Online applications are accepted all year-round, but all admitted students initiate their studies in the following fall term. Students are encouraged to apply no later than July 1 for consideration for admission the following fall term. Students may defer admission by one year.

Program Contact Information:

For questions about how to apply to the program, please contact:

Carolyn Riley
Associate Director of Professional Programs and Graduate Advising
School of Biomedical Engineering, Science and Health Systems
Email: cr63@drexel.edu

Andres Kriete, PhD
Associate Dean for Academic Operations
School of Biomedical Engineering, Science and Health Systems
Email: ak3652@drexel.edu

Degree Requirements

Required Biomedical Engineering Core		
BMES 501	Medical Sciences I	3.0
BMES 510	Biomedical Statistics	4.0
BMES 511	Principles of Systems Analysis Applied to Biomedicine I	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
Required Business Classes		
BUSN 501	Measuring and Maximizing Financial Performance	3.0
BUSN 502	Essentials of Economics	3.0
MGMT 601	Managing the Total Enterprise	3.0
MKTG 601	Marketing Strategy & Planning	3.0
ORGB 625	Leadership and Professional Development	3.0
Required Entrepreneurial Classes		
BMES 509	Entrepreneurship for Biomedical Engineering and Science	3.0
ENTP 540	Approaches to Entrepreneurship	3.0
Biomedical Engineering Elective Courses (Choose 6-10 credits)		**6.0-10.0**
BMES 604	Pharmacogenomics	
BMES 631	Tissue Engineering I	
BMES 641	Biomedical Mechanics I	
BMES 660	Biomaterials I	
BMES 710	Neural Signals	
BMES 821	Medical Instrumentation	

BMES 825	Hospital Administration
BMES I799	Independent Study in BMES
Total Credits	**46.0-50.0**

Sample Plan of Study

First Year

Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
BMES 501	3.0	BMES 511	3.0	BMES 538	3.0	BMES I799, COOP 501, or COOP 601	3.0-6.0
BMES 510	4.0	BMES 534	3.0	BMES 588	3.0		
MGMT 601	3.0	BUSN 501	3.0	BUSN 502	3.0		
	10		**9**		**9**		**3-6**

Second Year

Fall	Credits	Winter	Credits
BMES 509	3.0	ENTP 540	3.0
ORGB 625	3.0	MKTG 601	3.0
BMES Elective / Specialization Course (Choose One)	3.0-4.0		
BMES 631			
BMES 641			
BMES 660			
BMES 821			
	9-10		**6**

Total Credits 46-50

First Year

Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
BMES 501	3.0	BMES 511	3.0	BMES 538	3.0	COOP 501	0.0
BMES 510	4.0	BMES 534	3.0	BMES 588	3.0		
MGMT 601	3.0	BUSN 501	3.0	BUSN 502	3.0		
	10		**9**		**9**		**0**

Second Year

Fall	Credits	Winter	Credits	Spring	Credits
BMES I799	3.0	ENTP 540	3.0	BMES 509	3.0
		MKTG 601	3.0	ORGB 625	3.0
		BMES Elective / Specialization Course (Choose One)	3.0		
		BMES 604			
		BMES 710			
		BMES 825			
	3		**9**		**6**

Total Credits 46

Note: Some terms are less than the 4.5-credit minimum required (considered half-time status) of graduate programs to be considered financial aid eligible. As a result, aid will not be disbursed to students these terms.

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

Graduate Minor in Bioinformatics

About the Graduate Minor

The graduate minor in Bioinformatics aims to train graduate students in core areas of bioinformatics through an interdisciplinary approach. Students are introduced to biocomputational programming languages and bioinformatics data analysis tasks. Students pursue further in-depth training in genomic data science topics, including systems biology, molecular analyses, and genomic technologies.

Key characteristics of the Bioinformatics graduate minor are:

- Designed for graduate students in programs related to science, health, engineering, and mathematics
- Requires courses in programming, machine learning, and genomics (12.0-15.0 credits)
- Can be completed in three quarters
- Requires interdisciplinary study

Drexel graduate students in STEM- or Health-Science-related disciplines are eligible to enroll.

Program Requirements

Depending on their background, students may find one of the following courses to be helpful in preparation for this graduate minor		0.0
BMES 510	Biomedical Statistics	
BST 555	Introduction to Statistical Computing	
CS 502	Data Structures and Algorithms	
CS 510	Introduction to Artificial Intelligence	
ECES 631	Fundamentals of Deterministic Digital Signal Processing	
ECES 632	Fundamentals of Statistical Digital Signal Processing	
ENVS 501	Chemistry of the Environment	
MATH 510	Applied Probability and Statistics I	

PHYS 561	Biophysics	
Program Requirements *		
Programming. Select One from the list below:		3.0-4.0
BMES 546	Biocomputational Languages	
BMES 550	Advanced Biocomputational Languages	
CS 501	Introduction to Programming	
CS 503	Systems Basics	
Machine Learning. Select one from the list below:		3.0
BMES 547	Machine Learning in Biomedical Applications	
CS 613	Machine Learning	
Introductory Genomics. Select one course from the list below:		3.0-4.0
BIO 534	Bioinformatics I	
BMES 544	Genome Information Engineering	
ECES 640	Genomic Signal Processing	
ECES 641	Bioinformatics	
Advanced Genomics. Select one course from the list below:		3.0-4.0
BMES 543	Quantitative Systems Biology	
BIO 613	Genomics	
BMES 548	Structural Bioinformatics and Drug Design	
BMES 549	Genomic and Sequencing Technologies	
ECES 650	Statistical Analysis of Genomics	
PHYS 562	Computational Biophysics	
Total Credits		**12.0-15.0**

* Students may take a maximum of one course in their home department

Graduate Minor in Pediatric Engineering

About the Graduate Minor

This minor in Pediatric Engineering aims to train graduate students in related science, mathematics, technology, health, and engineering fields: 1) to develop a fundamental understanding of childhood injury and disease, healthcare, and treatment, and 2) to apply scientific and engineering concepts, methods, and approaches to address healthcare challenges with direct relevance to pediatric patients. Pediatric patients suffer from injuries and diseases that are congenital due to genetic factors and that are acquired due to exposure to environmental or biological factors, such as trauma, bacteria or viruses. Infants and children have unique physiology that dramatically changes during growth and development, and the substantial heterogeneity of complex pediatric illnesses and rare childhood diseases is distinct from adult diseases.

Select topics in courses include pediatric trauma or injury, congenital or acquired cardiovascular diseases, cancer, cerebral palsy, infectious diseases, autism, musculoskeletal diseases, neurological illness and defects, anxiety, ADHD, learning disabilities, and medical devices for pediatric usage. The long-term goal of this minor is to train the next-generation of students for future scientific and technical careers in pediatric engineering, healthcare, entrepreneurship, and innovation that will have a lasting impact on global health.

This minor is divided among courses in biomedical engineering, entrepreneurship, clinical treatment, healthcare, psychology, biomedical ethics, and statistics. Key characteristics are:

- Designed for graduate students in science, mathematics, technology, health, and engineering program 1) to gain a fundamental understanding of childhood disease, healthcare, and treatment, and 2) to apply scientific and engineering concepts, methods, and approaches to address healthcare challenges with direct relevance to pediatric patients
- Requires 3 core and 2 elective courses (15.0-17.5 credits)
- Can be completed in 4 quarters

Admission Requirements

Requires that students have a minimum mathematical skill level equivalent to Calculus I.

Program Requirements

Required Courses		
BMES 509	Entrepreneurship for Biomedical Engineering and Science	3.0
BMES 528	Pediatric Engineering I	3.0
BMES 529	Pediatric Engineering II	3.0
Elective Courses		
Complete 2 of the following courses		6.0-8.5

BMES 508	Cardiovascular Engineering
BMES 510	Biomedical Statistics
BMES 515	Experimental Design in Biomedical Research
BMES 517	Intermediate Biostatistics
BMES 538	Biomedical Ethics and Law
BMES 571	Biological Evolution: Applications to Human Health and Performance
BMES 588	Medical Device Development
BMES 609	Emerging Technologies in the Healthcare System
BMES 641	Biomedical Mechanics I
BMES 642	Biomedical Mechanics II
BMES 710	Neural Signals
BMES T580	Special Topics in BMES (Brain Computer Interfaces)
PTRS 664	Pediatric Physical Therapy *
RHAB I899	Independent Study (Pediatric Rehabilitation)
Total Credits	**15.0-17.5**

* CNHP students only.

Additional Information

Carolyn Riley
Associate Director of Professional Programs
215-895-2215
cr63@drexel.edu

Advanced Certificate in Bioinformatics

Certificate Level: Graduate
Admission Requirements: Bachelor's degree
Certificate Type: Post-Baccalaureate
Number of Credits to Completion: 14.0
Instructional Delivery: Campus
Calendar Type: Quarter
Expected Time to Completion: 1 year
Financial Aid Eligibility: Not aid eligible
Classification of Instructional Program (CIP) Code: 26.1103
Standard Occupational Classification (SOC) Code: 15-1111

About the Program

The certificate in 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, machine learning, and biostatistics.

Program Requirements

Required Courses		
BMES 546	Biocomputational Languages	4.0
or BMES 550	Advanced Biocomputational Languages	
BMES 544	Genome Information Engineering	4.0
Select Two of the Following Electives		**6.0-9.0**
BMES 543	Quantitative Systems Biology	
BMES 548	Structural Bioinformatics and Drug Design	
BMES 547	Machine Learning in Biomedical Applications	
BMES 545	Biosystems Modeling	
BMES 549	Genomic and Sequencing Technologies	
BMES 551	Biomedical Signal Processing	
BMES 604	Pharmacogenomics	
Total Credits		**14.0-17.0**

Additional Information

Carolyn Riley
Associate Director of Professional Programs
215-895-2215
cr63@drexel.edu

Medical Product Design and Device Development

Certificate Level: Graduate
Admission Requirements: Bachelor's degree
Certificate Type: Post-baccalaureate 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
Classification of Instructional Programs (CIP) code: 14.0501
Standard Occupational Classification (SOC) code: 17-2031

About the Program

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 healthcare 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.

Program Requirements

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
or BMES 534	Design Thinking for Biomedical Engineers	
BMES 822	Medical Instrumentation II	3.0
Total Credits		**15.0**

Sample Plan of Study

First Year				
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
BMES 821	3.0	BMES 822	3.0	BMES 588	3.0
	3		**3**		**3**
Second Year					
Fall	**Credits**	**Winter**	**Credits**		
BMES 538	3.0	BMES 509	3.0		
	3		**3**		

Total Credits 15

Additional Information

For more information, contact:

Carolyn Riley
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215-895-2215
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Neurotechnologies and Neurosystems Post-Baccalaureate Certificate

Certificate Level: Graduate
Admission Requirements: Bachelor's degree
Certificate Type: Post-Baccalaureate
Number of Credits to Completion: 12.0
Instructional Delivery: Campus
Calendar Type: Quarter
Expected Time to Completion: 1 year
*Financial Aid Eligibility: Aid eligible**
Classification of Instructional Program (CIP) Code: 26.1501
Standard Occupational Classification (SOC) Code: 11-9121

The current plan of study for this program would only allow for federal financial aid (including Federal Direct Student Loans) for terms that are at least a minimum of 4.5 credits for graduate courses and 6.0 credits for undergraduate courses. This is based on current regulations from the U.S. Department of Education.

About the Program

The certificate in Neurotechnologies and Neurosystems is designed for engineers pursuing careers at the intersection of device development and neuroscience. The program is open for all students with previous undergraduate degrees in an engineering discipline. The program is based on recent technological and scientific advances and provides participants with specific courses and experiences promoting the development of their skills, with the option to specialize either in the neuro-device and -technology sector, or specialize in neuroscience to decipher a better understanding of neuronal systems. This also includes skills at the interface of both technologies and science, such as analysis of complex neural data sets, understanding of how the nervous system interacts with technology, and demonstrate how it is being applied in clinical and research settings. Students will complete a sequence of two required introductory courses and at least two elective course to focus their education on their interests, helping to ensure the graduate's professional success.

Admission Requirements

The applicant must have completed a four-year bachelor's engineering degree or equivalent program in a relevant subject area with a preferred GPA of at least 3.0. All students must submit two confidential letters of recommendation, a personal statement explaining their interest in the program and all previous official educational transcripts. No standardized test is required. The merit of each applicant will be evaluated by the admissions committee of the program and all qualifications, including professional experience, will be taken into consideration.

Program Requirements

Required courses		
BMES 710	Neural Signals	3.0
BMES 711	Principles in Neuroengineering	3.0
Elective courses (6 or more credits)		**6.0**
BMES 685	Experimental Methods in Neuroengineering	
BMES 715	Systems Neuroscience and Applications I	
BMES 718	Brain Computer Interfaces	
BMES 725	Neural Networks	
Total Credits		**12.0**

Sample Plan of Study

First Year			
Fall	**Credits Winter**	**Credits Spring**	**Credits**
BMES 718	3.0 BMES 710	3.0 BMES 711	3.0
		BMES 725	3.0
	3	**3**	**6**

Total Credits 12

Advanced Certificate in Tissue Engineering

Certificate Level: Graduate

Admission Requirements: Bachelor's degree
Certificate Type: Post-Baccalaureate
Number of Credits to Completion: 12.0
Instructional Delivery: Campus
Calendar Type: Quarter
Expected Time to Completion: 1 year
Financial Aid Eligibility: Not aid eligible
Classification of Instructional Program (CIP) Code: 14.0501
Standard Occupational Classification (SOC) Code: 17-2031

About the Program

Program Requirements

Required Courses		
BMES 631	Tissue Engineering I	4.0
BMES 632	Tissue Engineering II	4.0
BMES 660	Biomaterials I	4.0
Total Credits		**12.0**

Additional Information

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