DREXEL UNIVERSITY
School of
Biomedical Engineering,
Science and Health Systems

CATALOG
2020-2021

UNDERGRADUATE

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 offering multi-disciplinary instruction on a full- and part-time basis at the graduate and undergraduate levels.

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

Major

- Biomedical Engineering (BSBE) (p. 3)

Accelerated Degree Programs

- ***NEW:*** Biomedical Engineering BSBE / Biomedical Engineering MSBE

About the School

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

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

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

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

Metropolitan Philadelphia has one of the nation’s highest concentrations of medical institutions and pharmaceutical, biotechnology, medical device and systems industry. The School has forged strategic partnerships with select universities, research institutes, health care institutions and industries in the region. The School enjoys a close working relationship with our Drexel College of Medicine as well as alliances with prominent medical institutions in the region to develop joint research and educational programs. These include the 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.

Co-operative Education

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

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

Special Programs

Accelerated Bachelor’s/Master’s Dual Degree Program

The Accelerated BS/MS degree program provides opportunities for strongly motivated students with high ability to progress toward their educational goals at an accelerated pace. The program makes it possible for top engineering students to obtain both a bachelor's and master's

degree in the same time period that it takes most Drexel students to obtain a bachelor's degree.

Preprofessional Programs

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

University Honors

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

BME Learning Community

The mission of the Biomedical Engineering Learning Community (BLC) is to promote a dynamic and collaborative environment by forming a close-knit community living together on the same floor in Millennium Hall. Members of the BLC are not only housed together, but also attend classes together, participate in team building activities, and attend various academic and social events. These events and activities actively promote academic success and a sense of community among students. BLC students will build life-long friendships, networking connections, and make lasting college memories.

Study Abroad Programs

The School enjoys a robust association and participation in the Drexel University Study Abroad Program. Multiple programs afford the BME student an opportunity to travel and experience new places and cultures in ways that fit their objectives.

Free standing programs are designed specifically for study abroad purposes. Courses are taken by students from Drexel and other American universities. Because the programs are catered specifically for study abroad students (rather than local students), courses usually include field trips and site visits to utilize the city as an integral part of the learning experience. Some programs only have a select list of courses while others have more extensive courses available.

Intensive Courses Abroad (ICAs) offer the opportunity to have an international academic experience in a short period of time (generally 7 - 10 days during break weeks). ICAs are normally led by a Drexel faculty director, in conjunction with an on campus course before and/or after the tour. They include activities such as guest lectures, industry visits, and other hands on events that transform the city into a living laboratory. The Drexel BME program regards the study abroad experience as a significant part of becoming a global leader in the field

Biomedical Engineering

Major: Biomedical Engineering
Degree Awarded: Bachelor of Science in Biomedical Engineering (BSBE)
Calendar Type: Quarter
Total Credit Hours: 187.5
Co-op Options: Three Co-op (Five years); One Co-op (Four years)
Classification of Instructional Programs (CIP) code: 14.0501
Standard Occupational Classification (SOC) code: 17-2031

About the Program

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

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

Concentrations

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

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

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

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

Additional Information

More information about the School’s undergraduate program can be found at the School of Biomedical Engineering, Sciences and Health Systems' Academic Program (http://drexel.edu/biomed/academics/undergraduate-programs/) webpage.

Students are also encouraged to contact the School's director for student services:

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

Career and professional counseling is provided independently by the student's professional academic advisors and faculty advisors. Information regarding undergraduate professional academic advisors is available on the School's Undergraduate Advising (http://drexel.edu/biomed/resources/current-undergraduate/advising/) webpage.

Program Educational Objectives

PEO - Graduates Whose Careers Effectively Leverage Their Education in Biomedical Engineering

As a result, graduates will be able to recognize and/or create opportunities, adjust to new conditions, and take advantage of opportunities across multiple boundaries: disciplinary, geographic, social and cultural. Graduates may demonstrate success through professional/personal recognition and/or advancement.

PEO - Graduates Competent to Obtain Additional Knowledge and/or Skills

As a result, graduates will continue to learn and enhance their skills through professional development and/or research activities. Graduates may use this new knowledge and/or additional skills to enhance current activities or move in a new direction. Graduates may also pursue further education in the form of graduate and professional degrees.

PEO - Graduates Who Make Contributions in Research, Innovation, Design and/or Technological Development.

As a result, graduates will make significant or meaningful contributions in their chosen fields either through publications and/or presentations, the development of a product or process, obtaining patents for new products and/or processes, or other evidence of contributing to the advancement of knowledge, particularly in fields integrating engineering and the life sciences.

PEO - Graduates Who Contribute to Their Communities

As a result, graduates will work independently and in diverse groups to effectively and efficiently achieve personal and organizational goals, manage projects, foster collaborative effort among co-workers, mentor individuals within the organization or in the community, engage in community or public service, create a product or process that fills a social need, and/or participate in educating individuals about an issue of societal concern.

PEO - Graduates Who Practice Ethical Reasoning, Behavior, and Professionalism

As a result, graduates will work in the global environment respecting cultural and social differences, managing risk and accepting responsibility, and adhering to the professional codes of conduct appropriate to his or her field of study and/or practice.

Student Learning Outcomes

By participating in the Biomedical Engineering undergraduate curriculum at the School of Biomedical Engineering, Science and Health Systems and graduating with the Bachelor of Science (BS) degree in Biomedical Engineering from Drexel University, students will be able to:

- Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
- Apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
- Communicate effectively with a range of audiences
- Recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
- Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
- Develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
- Acquire and apply new knowledge, as needed, using appropriate learning strategies
- Apply knowledge and skills gained from a program of study to the achievement of goals in a work, clinical, or other professional setting

Core Courses		
BIO 122	Cells and Genetics	4.5
BIO 201	Human Physiology I	4.0
BIO 218	Principles of Molecular Biology	4.0
BMES 101	Introduction to BMES Design I: Defining Medical Problems	2.0
BMES 102	Introduction to BMES Design II: Evaluating Design Solutions	2.0
BMES 124	Biomedical Engineering Freshman Seminar I	2.0
BMES 201	Programming and Modeling for Biomedical Engineers I	3.0
BMES 202	Programming and Modeling for Biomedical Engineers II	3.0
MEM 238	Dynamics	4.0
BMES 241	Modeling in Biomedical Design I	2.0
BMES 302	Laboratory II: Biomeasurements	2.0
BMES 303	Laboratory III: Biomedical Electronics	2.0
BMES 310	Biomedical Statistics	4.0
BMES 315	Experimental Design in Biomedical Research	4.0
BMES 337	Introduction to Physiological Control Systems	3.0
BMES 338	Biomedical Ethics and Law	3.0
BMES 341	Modeling in Biomedical Design II	2.0
BMES 345	Mechanics of Biological Systems	3.0
BMES 375	Computational Bioengineering	4.0
BMES 381	Junior Design Seminar I	2.0
BMES 382	Junior Design Seminar II	2.0
BMES 432	Biomedical Systems and Signals	3.0
BMES 444	Biofluid Mechanics	3.0
BMES 451	Transport Phenomena in Living Systems	4.0
BMES 491 [WI]	Senior Design Project I	3.0
BMES 492	Senior Design Project II	2.0
BMES 493	Senior Design Project III	3.0
CHEM 101	General Chemistry I	3.5
CHEM 102	General Chemistry II	4.5
CHEM 253	Thermodynamics and Kinetics	3.0-4.0
or ENGR 210	Introduction to Thermodynamics	
CIVC 101	Introduction to Civic Engagement	1.0
ECE 201	Foundations of Electric Circuits I	4.0
ENGL 101	Composition and Rhetoric I: Inquiry and Exploratory Research	3.0
or ENGL 111	English Composition I	
ENGL 102	Composition and Rhetoric II: Advanced Research and Evidence-Based Writing	3.0
or ENGL 112	English Composition II	
ENGL 103	Composition and Rhetoric III: Themes and Genres	3.0
or ENGL 113	English Composition III	
ENGR 220	Fundamentals of Materials	4.0
MATH 121	Calculus I	4.0
MATH 122	Calculus II	4.0
MATH 200	Multivariate Calculus	4.0
MATH 201	Linear Algebra	4.0
MATH 210	Differential Equations	4.0
MEM 202	Statics	3.0
PHYS 101	Fundamentals of Physics I	4.0
PHYS 102	Fundamentals of Physics II	4.0
UNIV R101	The Drexel Experience	1.0
COOP 101	Career Management and Professional Development	1.0
Electives		
Bioscience Elective: Choose any BIO course, 200-level or higher		3.0
Bioscience Restricted Elective: Choose 1		3.0

BIO 203	Human Physiology II	
BIO 214	Principles of Cell Biology	
BIO 224	Form, Function & Evolution of Vertebrates	
BIO 244	Genetics I	
BIO 311	Biochemistry	
General Studies Electives (5) *		15.0
Laboratory Electives: Choose 2		4.0
BIO 202	Human Physiology Laboratory	
BIO 215	Techniques in Cell Biology	
BIO 219 [WI]	Techniques in Molecular Biology	
BIO 306	Biochemistry Laboratory	
BMES 301	Laboratory I: Experimental Biomechanics	
BMES 304	Laboratory IV: Ultrasound Images	
BMES 305	Laboratory V: Musculoskeletal Anatomy for Biomedical Engineers	
BMES 485	Brain Computer Interface Laboratory	
HSCI 305	Laboratory V: Musculoskeletal Anatomy for Biomedical Engineers	
CHEM 244	Organic Chemistry Laboratory I	
CHEM 245	Organic Chemistry Laboratory II	
Concentration Requirements and STEM Electives		**21.0**
Concentration Required Courses (3)		
STEM Electives (up to the 21 credit total)**		
Total Credits		**187.5-188.5**

* General studies electives include all liberal arts electives plus additional subjects, such as business, which do not fall under the subject areas of science, math or engineering. See the Biomedical Engineering General Studies List (https://drexel.edu/biomed/resources/current-undergraduate/general-studies/) for approved courses. A certain number of General Studies credits are required for graduation with this major.

** STEM electives include courses offered by the School of Biomedical Engineering, Science and Health Systems, as well as, select science, technology, and math courses from other academic units. See the Biomedical Engineering STEM Elective List (https://drexel.edu/biomed/resources/current-undergraduate/) for approved courses.

Concentration Course Requirements

Students must select one concentration and complete the listed required courses. The student also needs to take additional STEM electives, as described above. The credit total of the concentration required courses and the STEM electives must be at least 21.0 credits.

Biomaterials

CHEM 241	Organic Chemistry I (* P/R for BMES 460)	4.0
BMES 460	Biomaterials I	4.0
BMES 461	Biomaterials II	4.0
Total Credits		**12.0**

Biomechanics

MEM 201	Foundations of Computer Aided Design	3.0
BMES 441	Biomechanics I: Introduction to Biomechanics	4.0
BMES 442	Biomechanics II: Musculoskeletal Modeling and Human Performance	4.0
Total Credits		**11.0**

Biomedical Imaging

PHYS 201	Fundamentals of Physics III *	4.0
BMES 421	Biomedical Imaging Systems I: Images	4.0
BMES 422	Biomedical Imaging Systems II: Ultrasound	4.0
Total Credits		**12.0**

* PHYS 201 is a pre-req for BMES 421.

Biomedical Informatics

BIO 219 [WI]	Techniques in Molecular Biology	3.0
BMES 483	Quantitative Systems Biology	4.0
BMES 484	Genome Information Engineering	4.0
Total Credits		**11.0**

Neuroengineering

BIO 462	Biology of Neuron Function *	3.0
BMES 477	Neuroengineering I: Neural Signals	3.0
BMES 478	Neuroengineering II: Principles of Neuroengineering	3.0
Total Credits		**9.0**

* BIO 462 is a pre-req for BMES 477.

Tissue Engineering

BIO 219 [WI]	Techniques in Molecular Biology *	3.0
BMES 471	Cellular and Molecular Foundations of Tissue Engineering	4.0
BMES 472	Developmental and Evolutionary Foundations of Tissue Engineering	4.0
Total Credits		**11.0**

* BIO 219 [WI] is a pre-req for BMES 471.

Writing-Intensive Course Requirements

In order to graduate, all students must pass three writing-intensive courses after their freshman year. Two writing-intensive courses must be in a student's major. The third can be in any discipline. Students are advised to take one writing-intensive class each year, beginning with the sophomore year, and to avoid “clustering” these courses near the end of their matriculation. Transfer students need to meet with an academic advisor to review the number of writing-intensive courses required to graduate.

A "WI" next to a course in this catalog may indicate that this course can fulfill a writing-intensive requirement. For the most up-to-date list of writing-intensive courses being offered, students should check the Writing Intensive Course List (http://drexel.edu/coas/academics/departments-centers/english-philosophy/university-writing-program/writing-intensive-courses/) at the University Writing Program (http://drexel.edu/coas/academics/departments-centers/english-philosophy/university-writing-program/). (http://drexel.edu/coas/academics/departments-centers/english-philosophy/university-writing-program/drexel-writing-center/) Students scheduling their courses can also conduct a search for courses with the attribute "WI" to bring up a list of all writing-intensive courses available that term.

Sample Plan of Study

4 year, 1 co-op

Co-op cycles may vary. Students are assigned a co-op cycle (fall/winter, spring/summer, summer-only) based on their co-op program (4-year, 5-year) and major.

First Year

Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
BMES 101	2.0	BMES 102	2.0	BIO 122	4.5	VACATION	
BMES 124	2.0	CHEM 102	4.5	BMES 201	3.0		

CHEM 101	3.5	ENGL 102 or 112	3.0	COOP 101*	1.0		
CIVC 101	1.0	MATH 122	4.0	ENGL 103 or 113	3.0		
ENGL 101 or 111	3.0	PHYS 101	4.0	MATH 200	4.0		
MATH 121	4.0			PHYS 102	4.0		
UNIV R101	1.0						
	16.5		**17.5**		**19.5**		**0**

Second Year

Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
BMES 202	3.0	BIO 218	4.0	BIO 201	4.0	BMES 303	2.0
ECE 201	4.0	BMES 338	3.0	BMES 345	3.0	BMES 310	4.0
ENGR 220	4.0	BMES 241	2.0	BMES 375	4.0	BMES 341	2.0
MATH 201	4.0	MATH 210	4.0	BMES 432	3.0	BMES 451	4.0
MEM 202	3.0	MEM 238	4.0	CHEM 253 or ENGR 210	3.0-4.0	Bioscience Restricted elective	3.0
	18		**17**		**17-18**		**15**

Third Year

Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
BMES 315	4.0	BMES 302	2.0	COOP EXPERIENCE		COOP EXPERIENCE	
BMES 381	2.0	BMES 337	3.0				
General Studies electives	6.0	BMES 382	2.0				
		BMES 444	3.0				
		Bioscience elective	3.0				
		Concentration required course	3.0				
	12		**16**		**0**		**0**

Fourth Year

Fall	Credits	Winter	Credits	Spring	Credits
BMES 491	3.0	BMES 492	2.0	BMES 493	3.0
Concentration required course	3.0	Concentration required course	3.0	General Studies elective	3.0
General Studies elective	3.0	General Studies elective	3.0	STEM electives	6.0
Lab elective	2.0	Lab elective	2.0		
STEM elective	3.0	STEM elective	3.0		
	14		**13**		**12**

Total Credits 187.5-188.5

* COOP 101 registration is determined by the co-op cycle assigned and may be scheduled in a different term. Select students may be eligible to take COOP 001 in place of COOP 101.

5 year, 3 co-ops

Co-op cycles may vary. Students are assigned a co-op cycle (fall/winter, spring/summer, summer-only) based on their co-op program (4-year, 5-year) and major.

First Year

Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
BMES 101	2.0	BMES 102	2.0	BIO 122	4.5	VACATION	
BMES 124	2.0	CHEM 102	4.5	BMES 201	3.0		
CHEM 101	3.5	ENGL 102 or 112	3.0	COOP 101*	1.0		
CIVC 101	1.0	MATH 122	4.0	ENGL 103 or 113	3.0		
ENGL 101 or 111	3.0	PHYS 101	4.0	MATH 200	4.0		
MATH 121	4.0			PHYS 102	4.0		
UNIV R101	1.0						
	16.5		**17.5**		**19.5**		**0**

Second Year

Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
BMES 202	3.0	BIO 218	4.0	COOP EXPERIENCE		COOP EXPERIENCE	
ECE 201	4.0	BMES 338	3.0				
ENGR 220	4.0	BMES 241	2.0				
MATH 201	4.0	MATH 210	4.0				
MEM 202	3.0	MEM 238	4.0				
	18		**17**		**0**		**0**

Third Year

Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
BIO 201	4.0	BMES 303	2.0	COOP EXPERIENCE		COOP EXPERIENCE	
BMES 345	3.0	BMES 310	4.0				
BMES 375	4.0	BMES 341	2.0				
BMES 432	3.0	BMES 451	4.0				
CHEM 253 or ENGR 210	3.0-4.0	Bioscience restricted elective	3.0				
	17-18		**15**		**0**		**0**

Fourth Year

Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
BMES 315	4.0	BMES 302	2.0	COOP EXPERIENCE		COOP EXPERIENCE	
BMES 381	2.0	BMES 382	2.0				
General Studies electives	6.0	BMES 337	3.0				
		BMES 444	3.0				
		Bioscience elective	3.0				
		Concentration required course	3.0				
	12		**16**		**0**		**0**

Fifth Year

Fall	Credits	Winter	Credits	Spring	Credits
BMES 491	3.0	BMES 492	2.0	BMES 493	3.0
Concentration required course	3.0	Concentration required course	3.0	General Studies elective	3.0
General Studies elective	3.0	General Studies elective	3.0	STEM electives	6.0
Lab elective	2.0	Lab elective	2.0		
STEM elective	3.0	STEM elective	3.0		
	14		**13**		**12**

Total Credits 187.5-188.5

* COOP 101 registration is determined by the co-op cycle assigned and may be scheduled in a different term. Select students may be eligible to take COOP 001 in place of COOP 101.

Co-op/Career Opportunities

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

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

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

Biomedical Engineering, Science and Health Systems Faculty

Fred D. Allen, PhD *(University of Pennsylvania) 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. Optical brain imaging, cognitive neuroengineering, brain computer interface (BCI), functional ner infrared (fNIR), and near infrared spectroscopy (NIRS).

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

Jamie 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 Research Professor. Cognitive neuroengineering, functional brain imaging, near infrared spectroscopy, medical sensor development, biomedical signal processing, human performance assessment, and cognitive aging

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

Hualou Liang, PhD *(Chinese Academy of Sciences)*. 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.

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Biomedical Engineering BS / Biomedical Engineering MS

Major: Biomedical Engineering
Degree Awarded: Bachelor of Science in Biomedical Engineering (BSBE) and Master of Science in Biomedical Engineering (MSBE)
Calendar Type: Quarter
Total Credit Hours: 228.5
Co-op Options: Three Co-ops (Five years)
Classification of Instructional Programs (CIP) code: 14.0501
Standard Occupational Classification (SOC) code: 17-2031

About the Program

The Biomedical Engineering BS/MS dual degree is an accelerated program providing the academically qualified student an opportunity to simultaneously earn both BS and MS degrees (two diplomas are awarded) in the biomedical engineering program areas of his/her/their choice in five years, the time normally required to finish a bachelor's degree alone.

The program combines the practical work experience of Drexel undergraduate cooperative education with the graduate credentials of an advanced degree. With both an undergraduate and graduate degree and practical work experience, BS/MS graduates enter the work force with specialized knowledge and training.

Admission Requirements

In addition to meeting the University requirements, students applying into the Biomedical BS/MS program must:

- Be an undergraduate in Biomedical Engineering in the 5 year, 3 co-op plan of study
- Have an approved plan to study that includes master's degree in Biomedical Engineering
- Have a minimum cumulative GPA of at least 3.4

For those interested in pursuing a MS thesis, there is an additional requirement:

- Students must submit a research petition no later than April 1 of junior year*

*If the petition is not submitted or accepted, the student will not be able to pursue a thesis option

Degree Requirements

Core Courses		
BIO 122	Cells and Genetics	4.5
BIO 201	Human Physiology I	4.0
BIO 218	Principles of Molecular Biology	4.0
BMES 101	Introduction to BMES Design I: Defining Medical Problems	2.0

BMES 102	Introduction to BMES Design II: Evaluating Design Solutions	2.0
BMES 124	Biomedical Engineering Freshman Seminar I	2.0
BMES 201	Programming and Modeling for Biomedical Engineers I	3.0
BMES 202	Programming and Modeling for Biomedical Engineers ll	3.0
BMES 241	Modeling in Biomedical Design I	2.0
BMES 302	Laboratory II: Biomeasurements	2.0
BMES 303	Laboratory III: Biomedical Electronics	2.0
BMES 310	Biomedical Statistics	4.0
BMES 315	Experimental Design in Biomedical Research	4.0
BMES 337	Introduction to Physiological Control Systems	3.0
BMES 338	Biomedical Ethics and Law	3.0
BMES 341	Modeling in Biomedical Design II	2.0
BMES 345	Mechanics of Biological Systems	3.0
BMES 375	Computational Bioengineering	4.0
BMES 381	Junior Design Seminar I	2.0
BMES 382	Junior Design Seminar II	2.0
BMES 432	Biomedical Systems and Signals	3.0
BMES 444	Biofluid Mechanics	3.0
BMES 451	Transport Phenomena in Living Systems	4.0
BMES 491 [WI]	Senior Design Project I	3.0
BMES 492	Senior Design Project II	2.0
BMES 493	Senior Design Project III	3.0
CHEM 101	General Chemistry I	3.5
CHEM 102	General Chemistry II	4.5
CHEM 253	Thermodynamics and Kinetics	4.0
or ENGR 210	Introduction to Thermodynamics	
CIVC 101	Introduction to Civic Engagement	1.0
COOP 101	Career Management and Professional Development	1.0
ECE 201	Foundations of Electric Circuits I	4.0
ENGL 101	Composition and Rhetoric I: Inquiry and Exploratory Research	3.0
ENGL 102	Composition and Rhetoric II: Advanced Research and Evidence-Based Writing	3.0
ENGL 103	Composition and Rhetoric III: Themes and Genres	3.0
ENGR 220	Fundamentals of Materials	4.0
MATH 121	Calculus I	4.0
MATH 122	Calculus II	4.0
MATH 200	Multivariate Calculus	4.0
MATH 201	Linear Algebra	4.0
MATH 210	Differential Equations	4.0
MEM 202	Statics	3.0
MEM 238	Dynamics	4.0
PHYS 101	Fundamentals of Physics I	4.0
PHYS 102	Fundamentals of Physics II	4.0
UNIV R101	The Drexel Experience	1.0
Electives		
Bioscience Elective: Choose any BIO course (200-level or higher)		3.0
Bioscience Restricted Elective (Choose 1)		3.0
BIO 203	Human Physiology II	
BIO 214	Principles of Cell Biology	
BIO 224	Form, Function & Evolution of Vertebrates	
BIO 311	Biochemistry	
General Studies Electives (Choose 5) *		15.0
Laboratory Electives (Choose 2)		4.0
BIO 202	Human Physiology Laboratory	
BIO 215	Techniques in Cell Biology	
BIO 219 [WI]	Techniques in Molecular Biology	
BIO 306	Biochemistry Laboratory	
BMES 301	Laboratory I: Experimental Biomechanics	
BMES 304	Laboratory IV: Ultrasound Images	
BMES 305	Laboratory V: Musculoskeletal Anatomy for Biomedical Engineers	
BMES 485	Brain Computer Interface Laboratory	
HSCI 305	Laboratory V: Musculoskeletal Anatomy for Biomedical Engineers	
Concentration Requirements and STEM Electives (22 credits total; 6 of which are satisfied by GR SEM electives)		16.0
Concentration Required Courses (3 Courses)		
STEM Electives (9 - 12 credits depending on concentration) (Graduate SEM electives satifies 6 credits of UG STEM electives) **		
Graduate 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 550	Advanced Biocomputational Languages	4.0
or BMES 546	Biocomputational Languages	
Modeling Intensive Courses (choose 2)		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 (Can include up to 9.0 credit of Thesis)		16.0
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 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 (Satisfies both UG and GR degree requirements) ***		6.0
Thesis Option †		
BMES 897	Research	
BMES 898	Master's Thesis	
Total Credits		**228.5**

* **General studies electives** include all liberal arts electives plus additional subjects, such as business, which do not fall under the subject areas of science, math or engineering. See the Biomedical Engineering General Studies List (https://drexel.edu/biomed/resources/current-undergraduate/general-studies/) for approved courses. A certain number of General Studies credits are required for graduation with this major.

** **STEM electives** include courses offered by the School of Biomedical Engineering, Science and Health Systems, as well as, select science, technology, and math courses from other academic units. See the Biomedical Engineering STEM Elective List (https://drexel.edu/biomed/resources/current-undergraduate/) for approved courses.

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

Concentration Requirements

Students must select one concentration and complete the listed required courses. The student also needs to take additional STEM electives, as described above. The credit total of the concentration required courses and the STEM electives must be at least 22.0 credits.

Biomaterials Required Courses

BMES 460	Biomaterials I (term 10)	4.0
BMES 461	Biomaterials II (term 11)	4.0
CHEM 241	Organic Chemistry I	4.0
Total Credits		**12.0**

Biomechanics Required Courses

BMES 441	Biomechanics I: Introduction to Biomechanics (term 10)	4.0
BMES 442	Biomechanics II: Musculoskeletal Modeling and Human Performance (term 11)	4.0
MEM 201	Foundations of Computer Aided Design	3.0
Total Credits		**11.0**

Biomedical Imaging Required Courses

BMES 421	Biomedical Imaging Systems I: Images (term 10)	4.0
BMES 422	Biomedical Imaging Systems II: Ultrasound (term 11)	4.0
PHYS 201	Fundamentals of Physics III	4.0
Total Credits		**12.0**

Biomedical Informatics Required Courses

BIO 219 [WI]	Techniques in Molecular Biology	3.0
BMES 483	Quantitative Systems Biology (term 11)	4.0
BMES 484	Genome Information Engineering (term 12)	4.0
Total Credits		**11.0**

Neuroengineering Required Courses

BIO 462	Biology of Neuron Function	3.0
BMES 477	Neuroengineering I: Neural Signals (term 11)	3.0
BMES 478	Neuroengineering II: Principles of Neuroengineering (term 12)	3.0
Total Credits		**9.0**

Tissue Engineering Required Courses

BIO 219 [WI]	Techniques in Molecular Biology	3.0
BMES 471	Cellular and Molecular Foundations of Tissue Engineering (term 10)	4.0
BMES 472	Developmental and Evolutionary Foundations of Tissue Engineering (term 11)	4.0
Total Credits		**11.0**

Writing-Intensive Course Requirements

In order to graduate, all students must pass three writing-intensive courses after their freshman year. Two writing-intensive courses must be in a student's major. The third can be in any discipline. Students are advised to take one writing-intensive class each year, beginning with the sophomore year, and to avoid “clustering” these courses near the end of their matriculation. Transfer students need to meet with an academic advisor to review the number of writing-intensive courses required to graduate.

A "WI" next to a course in this catalog may indicate that this course can fulfill a writing-intensive requirement. For the most up-to-date list of writing-intensive courses being offered, students should check the Writing Intensive Course List (http://drexel.edu/coas/academics/departments-centers/english-philosophy/university-writing-program/writing-intensive-courses/) at the University Writing Program (http://drexel.edu/coas/academics/departments-centers/english-philosophy/university-writing-program/). (http://drexel.edu/coas/academics/departments-centers/english-philosophy/university-writing-program/drexel-writing-center/) Students scheduling their courses can also conduct a search for courses with the attribute "WI" to bring up a list of all writing-intensive courses available that term.

Sample Plan of Study

First Year

Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
BMES 101	2.0	BMES 102	2.0	BIO 122	4.5	VACATION	
BMES 124	2.0	CHEM 102	4.5	BMES 201	3.0		
CHEM 101	3.5	ENGL 102 or 112	3.0	COOP 101	1.0		
CIVC 101	1.0	MATH 122	4.0	ENGL 103 or 113	3.0		
ENGL 101 or 111	3.0	PHYS 101	4.0	MATH 200	4.0		
MATH 121	4.0			PHYS 102	4.0		
UNIV R101	1.0						
	16.5		**17.5**		**19.5**		**0**

Second Year

Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
BMES 202	3.0	BIO 218	4.0	COOP EXPERIENCE		COOP EXPERIENCE	
ECE 201	4.0	MEM 238	4.0				
ENGR 220	4.0	BMES 241	2.0				
MATH 201	4.0	BMES 338	3.0				
MEM 202	3.0	MATH 210	4.0				

		(UG) Bioscience Restricted Elective	3.0				
	18		**20**		**0**		**0**

Third Year

Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
BIO 201	4.0	BMES 303	2.0	COOP EXPERIENCE		COOP EXPERIENCE	
BMES 345	3.0	BMES 310	4.0				
BMES 375	4.0	BMES 341	2.0				
BMES 432	3.0	BMES 451	4.0				
CHEM 253 or ENGR 220	4.0	(UG) Bioscience Elective 200+ level or higher	3.0				
(UG) Laboratory Elective	2.0	(UG) Laboratory Elective	2.0				
		BMES 538	3.0				
	20		**20**		**0**		**0**

Fourth Year

Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
BMES 315	4.0	BMES 302	2.0	COOP EXPERIENCE		COOP EXPERIENCE	
BMES 381	2.0	BMES 337	3.0				
(UG) General Studies Electives	6.0	BMES 382	2.0				
BMES 550	4.0	BMES 444	3.0				
BMES 510	4.0	(UG) Concentration Requirement	3.0				
		(GR) Modeling Intensive Elective	3.0				
		(GR) BMES Elective	4.0				
	20		**20**		**0**		**0**

Fifth Year

Fall	Credits	Winter	Credits	Spring	Credits
BMES 491	3.0	BMES 492	2.0	BMES 493	3.0
(UG) Concentration Requirement	3.0	(UG) Concentration Requirement	3.0	(UG) Gen Studies Elective	3.0
(UG) Gen Studies Elective	3.0	(UG) Gen Studies Elective	3.0	(GR) SEM Elective / (UG) STEM Elective*	3.0
(UG) STEM Elective	3.0	(UG) STEM Elective	4.0	(GR) SEM Elective / (UG) STEM Elective*	3.0
BMES 501	3.0	BMES 502	3.0	(GR) Modeling Intensive Elective	3.0
(GR) BMES Elective	4.0	(GR) BMES Elective	4.0	(GR) BMES Elective	4.0
	19		**19**		**19**

Total Credits 228.5

* GR credits shared with BSE program.

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. Optical brain imaging, cognitive neuroengineering, brain computer interface (BCI), functional ner infrared (fNIR), and near infrared spectroscopy (NIRS).

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

Jamie 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 Research Professor. Cognitive neuroengineering, functional brain imaging, near infrared spectroscopy, medical sensor development, biomedical signal processing, human performance assessment, and cognitive aging

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

Hualou Liang, PhD *(Chinese Academy of Sciences)*. 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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