Drexel University
Catalog 2008/2009

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The School of Biomedical Engineering, Science and Health Systems Undergraduate and Graduate Programs

The School of Biomedical Engineering, Science and Health Systems

The School of Biomedical Engineering, Science, and Health Systems (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 program has received accreditation by the Accreditation Board of Engineering Technology (ABET) in 2002.

Our academic thrust areas, both in research and education, are at the forefront of biosensing, bioimaging, bioinformation engineering and integrated bioinformatics, drug delivery, biomedical ultrasound & optics, bionanotechnology, cellular tissue engineering, neuroengineering and human performance. Emerging initiatives include skin bioengineering, pediatric engineering and homeland security technologies. Various departments at Drexel University offer courses that are suited for students in biomedical engineering and biomedical science. Our curriculum complements the strengths of the Colleges of Arts & Sciences, Business, Engineering, Information Science, Law and Medicine. As a whole, our 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, we strive for clinical and industrial relevance in our academic pursuits. We enjoy a strong entrepreneurship program in biomedical technologies. Our alliance with regional economic development agencies and corporations together with our advisors from business development, legal, and investment communities sustains the growth of this program. The students and faculty of the School are committed to move their discoveries from our laboratories to clinical practice or home use. The success of our Translational Research in Biomedical Technologies Program has been recognized and funded regionally as well as nationally.

Our School has experienced remarkable growth in recent years thanks to our outstanding research portfolio, high quality and innovative undergraduate program, and our multidisciplinary approach to education and research. Another competitive advantage of our School is the unique free-standing university-level administrative structure with its own tenure-track faculty lines, budget and space. This helps us transcend the traditional organizational boundaries of engineering, sciences and medicine. Our independence allows us to pursue growth and collaborations in various disciplines. Our small size gives us 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. We enjoy a

close working relationship with our Drexel College of Medicine as well as alliances with prominent medical institutions in the region to develop joint research and educational programs. These include University of Pennsylvania, Thomas Jefferson University, the Fox Chase Cancer Center and the Wistar Institute. These collaborative initiatives provide students with ample opportunities in basic and clinical research as well as innovative academic programs.

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

The School of Biomedical Engineering, Science, and Health Systems

Program Objectives
The overall objective of the graduate programs offered by the School of Biomedical Engineering, Science, and Health Systems is to provide multidisciplinary curricula with an instructional core and research opportunities for students. Graduate biomedical engineering students are typically individuals with undergraduate degrees in engineering, physical sciences, or mathematics. The core curriculum provides the necessary training in life and medical sciences, modeling and simulation, and biomedical engineering applications to allow students to apply their engineering skills and perspective to solve current problems in biology and medicine. Areas in which students may focus their advanced studies and research attention include biomechanics and biomaterials, cellular and tissue engineering, biomedical sensing and imaging, human factors and performance engineering, neuroengineering, and bioinformatics. Students without an academic background in engineering or physical science who wish to enter the biomedical engineering program may enroll in the Crossover Program.

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

A recent agreement with the Interdepartmental Medical Science Program at the Drexel College of Medicine allows students to spend one year taking courses at the College of Medicine and their second year at the School of Biomedical Engineering, Science and Health Systems—leading to a Master's degree in Biomedical Science.

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

Admission Requirements

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

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

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

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

Students without an academic background in engineering or physical science should review information about the Crossover Program.

Financial Assistance

Financial support for qualified students pursuing studies toward the M.S. and Ph.D. degrees is available in the form of research assistantships, teaching assistantships, graduate assistantships, and fellowships.

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

Dean's Fellowships are available for outstanding applicants to the School when other forms of financial assistance are not available. This Fellowship provides approximately 40% of a student's tuition for the first year and is renewable depending on the student's academic performance. Fellowship applicants must be seeking full-time study only at the master's level. Other requirements include a GPA of 3.5 or better in their bachelor's program and submission of GRE scores. For international students, a TOEFL score of 260 or better is required.

For further assistance, students should contact the Office of Graduate Admissions.

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.

Crossover Program

Students without an academic background in engineering or physical science who wish to enter the biomedical engineering program will be enrolled in the Crossover Program, an accelerated curriculum designed to fulfill the requirements for admission to a Drexel graduate engineering program. Classes in the program do not count toward the MS. degree, and they may entail one to two years of additional full-time study. For specific course requirements, students should contact Dr. Rami Seliktar, the graduate advisor for biomedical engineering.

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 academic standards applicable to all graduate students at Drexel University.

Graduate Co-op Program (GCP)

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

Further information on the GCP program is available at the Drexel Steinbright Career Development Center.

Biomedical Engineering

Bachelor of Science Degree

About the major

Biomedical engineering is an innovative Bachelor of Science degree program developed and delivered in collaboration with the College of Engineering, the College of Arts and Sciences and the College of Information Science and Technology. 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.

As preparation for the major in biomedical engineering, students are strongly encouraged to take AP biology courses in high school.

Biomedical Engineering Program Outcomes

Graduates of the Biomedical Engineering program will attain the following skills:

- an understanding of advanced mathematics, physical science, biology and physiology;
- the ability to apply knowledge of mathematics, science and engineering to solve problems at the interface of engineering and biology;
- the ability to design and conduct experiments as well as to analyze and interpret data using statistical, computational or mathematical methods;
- the ability to make measurements on, and interpret data from, living systems addressing the problems associated with the interactions between living and non-living materials and systems;
- the ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, entrepreneurial, environmental, intellectual property rights, social, political, health and safety, manufacturability and sustainability;
- the ability to function on multi-disciplinary teams;
- the ability to identify, formulate, and solve engineering problems;
- an understanding of professional and ethical responsibilities;
- the ability to communicate effectively;
- the ability to understand the impact of engineering solutions in global, economic, environmental and societal contexts;
- a recognition of the need for, and ability to engage in, life-long learning;
- knowledge of contemporary issues;
- the ability to use the techniques, skills, and modern engineering tools necessary for engineering practice; and
- knowledge of interdisciplinary concepts within a biomedical perspective.

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Areas of Specialization

The undergraduate biomedical engineering curriculum is designed to strike a balance between academic breadth in biomedical engineering and specialization in an area of concentration:

- Biomaterials and Tissue Engineering

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

The 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 Bioscience and Biotechnology, Chemistry, Physics, Mathematics, Computer Science, Chemical Engineering, Mechanical Engineering, Materials Engineering, Electrical and Computer Engineering, and the College of Information Science and Technology.

For more information, visit the The School of Biomedical Engineering, Science, and Health Systems' web site.

Biomaterials and Tissue Engineering

Bachelor of Science Degree in Biomedical Engineering: 200.0 credits

About the concentration

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

Biomaterials research has recently expanded to include fibrous materials and various prosthetic devices requiring the use of both synthetic and natural fibers. The emphasis is on improved materials and design of biological replacement tissues through cellular tissue engineering.

Upon graduation, students will be able to:

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

For more information about this concentration, see Drexel's School of Biomedical Engineering, Science, and Health Systems web site.

Biomedical Engineering

Biomaterials and Tissue Engineering Concentration
Bachelor of Science Degree: 202.5 credits
Degree requirements (incoming students, 2008/2009)

General education requirements		29.0 Credits
HIST 285	**Technology in Historical Perspective**	3.0
ENGL 101	**Expository Writing and Reading**	3.0
ENGL 102	**Persuasive Writing and Reading**	3.0
ENGL 103	**Analytical Writing and Reading**	3.0
UNIV 101	**The Drexel Experience**	2.0
	Liberal and General studies electives (5)	15.0

Engineering core courses		67.0 Credits
MATH 121	**Calculus I**	4.0
MATH 122	**Calculus II**	4.0
MATH 200	**Multivariate Calculus**	4.0
PHYS 101	**Fundamentals of Physics I**	4.0
PHYS 102	**Fundamentals of Physics II**	4.0
PHYS 201	**Fundamentals of Physics III**	4.0
CHEM 101	**General Chemistry I**	3.5
CHEM 102	**General Chemistry II**	4.5
BIO 122	**Cells and Genetics**	3.0
CS 121	**Computational Laboratory I**	1.0
CS 122	**Computational Laboratory II**	1.0
CS 123	**Computational Laboratory III**	1.0
ENGR 100	**Beginning CAD for Design**	1.0
ENGR 101	**Engineering Design Laboratory I**	2.0
ENGR 102	**Engineering Design Laboratory II**	2.0
ENGR 103	**Engineering Design Laboratory III**	2.0
ENGR 201	**Evaluation/Presentation of Experimental Data I**	3.0
ENGR 202	**Evaluation/Presentation of Experimental Data II**	3.0
ENGR 210	**Introduction to Thermodynamics**	3.0
ENGR 220	**Fundamentals of Materials**	4.0
ENGR 231	**Linear Engineering Systems**	3.0
ENGR 232	**Dynamic Engineering Systems**	3.0
MEM 202	**Engineering Mechanics: Statics**	3.0

Required Biomedical Engineering courses	49.0 Credits

BIO 201	**Human Physiology I**	4.0
BIO 203	**Human Physiology II**	4.0
BMES 125	**Foundations of Biomedical Engineering**	2.0
BMES 212	**The Body Synthetic**	3.0
BMES 302	**Lab II: Biomeasurements**	2.0
BMES 303	**Lab III: Biomedical Electronics**	2.0
BMES 310	**Biomedical Statistics**	4.0
BMES 325	**Engineering Principles of Living Systems I**	3.0
BMES 326	**Engineering Principles of Living Systems II**	3.0
BMES 338	**Biomedical Ethics and Law**	4.0
BMES 372	**Biosimulation**	3.0
BMES 381	**Junior Design Seminar I**	2.0
BMES 382	**Junior Design Seminar II**	2.0
BMES 491	**Senior Design I**	3.0
BMES 492	**Senior Design II**	3.0
BMES 493	**Senior Design III**	3.0
ECE 201	**Foundations of Electric Circuits**	3.0

Biomaterials and Tissue Engineering concentration courses		**53.5 Credits**
BIO 218	**Principles of Molecular Biology**	3.0
BIO 219	**Techniques of Molecular Biology**	2.5
BMES 301	**Lab I: Experimental Biomechanics**	2.0
BMES 375	**Computational Bioengineering**	4.0
BMES 451	**Transport Phenomena in Living Systems I**	4.0
BMES 460	**Biomaterials I**	4.0
BMES 461	**Biomaterials II**	4.0
BMES 471	**Foundations of Tissue Engineering I**	4.0
BMES 472	**Foundations of Tissue Engineering II**	4.0
BMES 475	**Biomaterials and Tissue Engineering III**	4.0
CHEM 241	**Organic Chemistry I**	4.0
CHEM 242	**Organic Chemistry II**	4.0
CHEM 244	**Organic Chemistry Laboratory I**	3.0
CHEM 245	**Organic Chemistry Laboratory II**	3.0
MEM 230	**Mechanics of Materials I**	4.0

*General studies electivesinclude all liberal arts electives plus additional subjects, such as business, which do not fall under the subject area of science, math or engineering. See the Biomedical Engineering General and Liberal Studies List for approved courses. A certain number of General Studies credits are required for graduation with this major.

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 indicates that this course can fulfill a writing-intensive requirement. Departments will designate specific sections of such courses as writing-intensive. Sections of writing-intensive courses are not indicated

in this catalog. Students should check the section comments in Banner when registering. Students scheduling their courses in Banner can also conduct a search for courses with the attribute "WI" to bring up a list of all writing-intensive courses available that term. For more information on writing-intensive courses, see the Drexel University Writing Program's Writing-Intensive Course page.

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Recommended Plan Of Study

BS Biomedical Engineering

5 YR UG Co-op Concentration /Biomaterials & Tissue Engineer

Term 1		Credits
BMES 125	Foundations of Biomedical Engineering 2.	0
CHEM 101	General Chemistry I	3.5
CS 121	Computation Lab I	1.0
ENGL 101	Expository Writing and Reading	3.0
ENGR 100	Beginning CAD for Design	1.0
ENGR 101	Engineering Design Laboratory I	2.0
MATH 121	Calculus I	4.0
UNIV 101	The Drexel Experience	1.0
	Term Credits	*17.5*

Term 2		Credits
CHEM 102	General Chemistry II	4.5
CS 122	Computation Lab II	1.0
ENGL 102	Persuasive Writing and Reading 3.	0
ENGR 102	Engineering Design Laboratory II	2.0
MATH 122	Calculus II	4.0
PHYS 101	Fundamentals of Physics I	4.0
UNIV 101	The Drexel Experience	1.0
	Term Credits	*19.5*

Term 3		Credits
BIO 122	Cells and Genetics	4.5
CS 123	Computation Lab III	1.0
ENGL 103	Analytical Writing and Reading	3.0
ENGR 103	Engineering Design Laboratory III	2.0
MATH 200	Multivariate Calculus	4.0
PHYS 102	Fundamentals of Physics II	4.0
UNIV 101	The Drexel Experience	0.5
	Term Credits	*19.0*

Term 4		Credits
BIO 201	Human Physiology I	4.0
ENGR 201	Evaluation & Presentation of Experimental Data I	3.0
ENGR 220	Fundamentals of Materials	4.0
ENGR 231	Linear Engineering Systems	3.0
PHYS 201	Fundamentals of Physics III	4.0
	Term Credits	*18.0*

Term 5		Credits
BIO 203	Human Physiology II	4.0
BMES 212	The Body Synthetic 3.0	
ENGR 202	Evaluation & Presentation of Experimental Data II	3.0
ENGR 210	Introduction to Thermodynamics 3.0	
ENGR 232	Dynamic Engineering Systems 3	.0
MEM 202	Engineering Mechanics-Statics	3.0
	Term Credits	*19.0*

Term 6		Credits
BMES 301	Biomedical Engineering Lab I: Experimental Biomechanics	2.0
BMES 302	Lab II: Biomeasurements	2.0
BMES 325	Principles of Biomedical Engineering I	3.0
BMES 372	Biosimulation 3	.0
ECE 201	Electric Circuits	3.0
HIST 285	Technology in Historical Perspective	3.0

	Term Credits	*16.0*

Term 7		Credits
BMES 303	Lab III: Biomed Electronics	2.0
BMES 310	Biomedical Statistics	4.0
BMES 326	Principles of Biomedical Engineering II	3.0
MEM 230	Mechanics of Materials I	4.0
	Liberal studies elective	3.0
	Term Credits	*16.0*

Term 8		Credits
BIO 218	Principles of Molecular Biology 3.	0
BIO 219	Techniques in Molecular Biology 2.	5
BMES 338	Biomedical Ethics and Law	3.0
BMES 381	Junior Design Seminar I	2.0
CHEM 241	Organic Chemistry I	4.0
	Term Credits	*14.5*

Term 9		Credits
BMES 375	Computational Bioengineering	4.0
BMES 382	Junior Design Seminar II	2.0
BMES 451	Transport Phenomena in Living Systems I	4.0
CHEM 242	Organic Chemistry II	4.0
CHEM 244	Organic Chemistry Laboratory I	3.0
	Term Credits	*17.0*

Term 10		Credits
BMES 460	Biomaterials I	4.0
BMES 471	Tissue Engineering I	4.0
BMES 491	Senior Design Project I	2.0
CHEM 245	Organic Chemistry Laboratory II	3.0
	Liberal studies elective	3.0
	Term Credits	*16.0*

Term 11		Credits
BMES 461	Biomaterials II	4.0
BMES 472	Tissue Engineering II	4.0
BMES 492	Senior Design Project II	2.0
	General studies elective	3.0
	Term Credits	*13.0*

Term 12		Credits
BMES 475	Biomaterials and Tissue Engineering III	4.0
BMES 493	Senior Design Project III	4.0
	General studies elective	3.0
	Liberal studies electives	3.0
	Term Credits	*14.0*

	Total Credits (minimum) 1	99.5

Biomechanics and Human Performance Engineering

Bachelor of Science Degree in Biomedical Engineering: 201.5 credits

About the concentration

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

Upon graduation, students will be able to:

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

For more information about this concentration, see Drexel's School of Biomedical Engineering, Science, and Health Systems web site.

Biomedical Engineering

Biomechanics and Human Performance Engineering Concentration
Bachelor of Science Degree: 201.5 credits
Degree requirements (incoming students, 2008/2009)

General education requirements		**29.0 Credits**
HIST 285	**Technology in Historical Perspective**	3.0
ENGL 101	**Expository Writing and Reading**	3.0
ENGL 102	**Persuasive Writing and Reading**	3.0
ENGL 103	**Analytical Writing and Reading**	3.0
UNIV 101	**The Drexel Experience**	2.0
	Liberal and General studies electives (5)	15.0
	Free elective	2.0

Engineering core courses		
MATH 121	**Calculus I**	4.0
MATH 122	**Calculus II**	4.0
MATH 200	**Multivariate Calculus**	4.0
PHYS 101	**Fundamentals of Physics I**	4.0
PHYS 102	**Fundamentals of Physics II**	4.0
PHYS 201	**Fundamentals of Physics III**	4.0
CHEM 101	**General Chemistry I**	3.5
CHEM 102	**General Chemistry II**	4.5
BIO 122	**Cells and Genetics**	3.0
CS 121	**Computational Laboratory I**	1.0
CS 122	**Computational Laboratory II**	1.0
CS 123	**Computational Laboratory III**	1.0
ENGR 100	**Beginning CAD for Design**	1.0
ENGR 101	**Engineering Design Laboratory I**	2.0
ENGR 102	**Engineering Design Laboratory II**	2.0
ENGR 103	**Engineering Design Laboratory III**	2.0
ENGR 201	**Evaluation/Presentation of Experimental Data I**	3.0
ENGR 202	**Evaluation/Presentation of Experimental Data II**	3.0
ENGR 210	**Introduction to Thermodynamics**	3.0
ENGR 220	**Fundamentals of Materials**	4.0
ENGR 231	**Linear Engineering Systems**	3.0
ENGR 232	**Dynamic Engineering Systems**	3.0
MEM 202	**Engineering Mechanics: Statics**	3.0

Required Biomedical Engineering courses	**49.0 Credits**

BIO 201	**Human Physiology I**	4.0
BIO 203	**Human Physiology II**	4.0
BMES 125	**Foundations of Biomedical Engineering**	2.0
BMES 212	**The Body Synthetic**	3.0
BMES 302	**Lab II: Biomeasurements**	2.0
BMES 303	**Lab III: Biomedical Electronics**	2.0
BMES 310	**Biomedical Statistics**	4.0
BMES 325	**Engineering Principles of Living Systems I**	3.0
BMES 326	**Engineering Principles of Living Systems II**	3.0
BMES 338	**Biomedical Ethics and Law**	4.0
BMES 372	**Biosimulation**	3.0
BMES 381	**Junior Design Seminar I**	2.0
BMES 382	**Junior Design Seminar II**	2.0
BMES 491	**Senior Design I**	2.0
BMES 492	**Senior Design II**	2.0
BMES 493	**Senior Design III**	4.0
ECE 201	**Foundations of Electric Circuits**	3.0

Biomechanics and Human Performance Engineering concentration courses		**59.0 Credits**
BMES 301	**Lab I: Experimental Biomechanics**	2.0
BMES 305	**Lab V: Musculoskeletal Anatomy for Biomedical Engineering**	2.0
BMES 375	**Computational Bioengineering**	4.0
or		
BMES 401	**Biosensors I**	4.0
BMES 411	**Chronoengineering I**	3.0
BMES 412	**Chronoengineering II**	3.0
BMES 430	**Neural Aspects of Posture and Locomotion**	3.0
BMES 440	**Biodynamics**	3.0
BMES 441	**Biomechanics I**	4.0
BMES 442	**Biomechanics II**	4.0
BMES 444	**Biofluid Mechanics**	3.0
BMES 451	**Transport Phenomena in Living Systems I**	4.0
MEM 201	**Foundations of CAD**	4.0
MEM 230	**Mechanics of Materials I**	4.0
MEM 238	**Engineering Mechanics: Dynamics**	4.0
PSY 101	**General Psychology**	3.0
	Biomechanics and Human Performance electives (3)	9.0

Suggested Biomechanics and Human Performance concentration electives		
PSY 213	**Sensation and Perception**	3.0
PSY 332	**Human Factors and Cognitive Engineering**	3.0
PSY 410	**Neuropsychology**	3.0

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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.

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Recommended Plan Of Study

BS Biomedical Engineering

5 YR UG Co-op Concentration /Biomechanics & Human Perf Eng

Term 1		Credits
BMES 125	Foundations of Biomedical Engineering 2.	0
CHEM 101	General Chemistry I	3.5
CS 121	Computation Lab I	1.0
ENGL 101	Expository Writing and Reading	3.0
ENGR 100	Beginning CAD for Design	1.0
ENGR 101	Engineering Design Laboratory I	2.0
MATH 121	Calculus I	4.0
UNIV 101	The Drexel Experience	1.0
	Term Credits	*17.5*

Term 2		Credits
CHEM 102	General Chemistry II	4.5
CS 122	Computation Lab II	1.0
ENGL 102	Persuasive Writing and Reading 3.	0
ENGR 102	Engineering Design Laboratory II	2.0
MATH 122	Calculus II	4.0
PHYS 101	Fundamentals of Physics I	4.0
UNIV 101	The Drexel Experience	1.0
	Term Credits	*19.5*

Term 3		Credits
BIO 122	Cells and Genetics	4.5
CS 123	Computation Lab III	1.0
ENGL 103	Analytical Writing and Reading	3.0
ENGR 103	Engineering Design Laboratory III	2.0
MATH 200	Multivariate Calculus	4.0
PHYS 102	Fundamentals of Physics II	4.0
UNIV 101	The Drexel Experience	0.5
	Term Credits	*19.0*

Term 4		Credits
BIO 201	Human Physiology I	4.0
ENGR 201	Evaluation & Presentation of Experimental Data I	3.0
ENGR 220	Fundamentals of Materials	4.0
ENGR 231	Linear Engineering Systems	3.0
PHYS 201	Fundamentals of Physics III	4.0
	Term Credits	*18.0*

Term 5		Credits
BIO 203	Human Physiology II	4.0
BMES 212	The Body Synthetic 3.0	
ENGR 202	Evaluation & Presentation of Experimental Data II	3.0
ENGR 210	Introduction to Thermodynamics 3.0	
ENGR 232	Dynamic Engineering Systems 3	.0
MEM 202	Engineering Mechanics-Statics	3.0
	Term Credits	*19.0*

Term 6		Credits
BMES 301	Biomedical Engineering Lab I: Experimental Biomechanics	2.0
BMES 302	Biomedical Engineering Lab II: Biomeasurements	2.0
BMES 325	Principles of Biomedical Engineering I	3.0
BMES 372	Biosimulation 3	.0
ECE 201	Electric Circuits	3.0
MEM 201	Foundations of Computer Aided Design	3.0

	Term Credits	*16.0*

Term 7		Credits
BMES 303	Biomedical Engineering Lab III: Biomedical Electronics	2.0
BMES 310	Biomedical Statistics	4.0
BMES 326	Principles of Biomedical Engineering II	3.0
MEM 230	Mechanics of Materials I	4.0
PSY 101	General Psychology I	3.0
	Term Credits	*16.0*

Term 8		Credits
BMES 305	Lab V: Musculoskeletal Anatomy for BME	2.0
BMES 338	Biomedical Ethics and Law	3.0
BMES 381	Junior Design Seminar I	2.0
BMES 411	Chronoengineering I: Biorhythms	3.0
BMES 430	Neural Aspects of Posture and Locomotion	3.0
	Biomechanics & Human Performance Concentration elective (See degree requirements)	3.0
	Term Credits	*16.0*

Term 9		Credits
BMES 382	Junior Design Seminar II	2.0
BMES 412	Chronoengineering II: Sleep Functions	3.0
MEM 238	Dynamics 4	.0
BMES 401	Biosensors I	4.0
or		
BMES 375	Computational Bioengineering	4.0
	Liberal studies elective	3.0
	Term Credits	*16.0*

Term 10		Credits
BMES 440	Introduction to Biodynamics	3.0
BMES 441	Biomechanics I:	4.0
BMES 451	Transport Phenomena in Living Systems I	4.0
BMES 491	Senior Design Project I	2.0
	Liberal studies elective	3.0
	Term Credits	*16.0*

Term 11		Credits
HIST 285	Technology in Historical Perspective	3.0
BMES 442	Biomechanics II	4.0
BMES 492	Senior Design Project II	2.0
	Biomechanics & Human Performance Concentration elective (See degree requirements)	3.0
	General studies elective	3.0
	Term Credits	*15.0*

Term 12		Credits
BMES 444	Biofluid Mechanics	3.0
BMES 493	Senior Design Project III	4.0
	Biomechanics & Human Performance Concentration elective (See degree requirements)	3.0
	General studies elective	3.0
	Term Credits	*13.0*

	Total Credits (minimum)	201.0

Biomedical Informatics

Bachelor of Science Degree in Biomedical Engineering: 200.0 credits

About the concentration

Bioinformatics is an emerging field of science that is concerned with the management, analysis and visualization of the flood of data being generated in molecular and cellular biology, genomics and other areas of biology and biomedicine. The field of bioinformatics enables information at the gene, protein, cell, tissue, organ, and system level to be integrated and interpreted for early detection, accurate diagnosis, and effective treatment of complex diseases such as cancer.

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

Upon graduation, students will be able to:

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

For more information about this concentration, see Drexel's School of Biomedical Engineering, Science, and Health Systems web site.

Biomedical Engineering

Biomedical Informatics Concentration

Bachelor of Science Degree: 200.0 credits

Degree requirements (incoming students, 2008/2009)

General education requirements		**29.0 Credits**
HIST 285	**Technology in Historical Perspective**	3.0
ENGL 101	**Expository Writing and Reading**	3.0
ENGL 102	**Persuasive Writing and Reading**	3.0
ENGL 103	**Analytical Writing and Reading**	3.0
UNIV 101	**The Drexel Experience**	2.0
	Liberal and General studies electives (5)	15.0

Engineering core courses		
MATH 121	**Calculus I**	4.0
MATH 122	**Calculus II**	4.0
MATH 200	**Multivariate Calculus**	4.0
PHYS 101	**Fundamentals of Physics I**	4.0
PHYS 102	**Fundamentals of Physics II**	4.0
PHYS 201	**Fundamentals of Physics III**	4.0
CHEM 101	**General Chemistry I**	3.5
CHEM 102	**General Chemistry II**	4.5
BIO 122	**Cells and Genetics**	3.0
CS 121	**Computational Laboratory I**	1.0
CS 122	**Computational Laboratory II**	1.0
CS 123	**Computational Laboratory III**	1.0
ENGR 100	**Beginning CAD for Design**	1.0
ENGR 101	**Engineering Design Laboratory I**	2.0
ENGR 102	**Engineering Design Laboratory II**	2.0
ENGR 103	**Engineering Design Laboratory III**	2.0
ENGR 201	**Evaluation/Presentation of Experimental Data I**	3.0
ENGR 202	**Evaluation/Presentation of Experimental Data II**	3.0
ENGR 210	**Introduction to Thermodynamics**	3.0
ENGR 220	**Fundamentals of Materials**	4.0
ENGR 231	**Linear Engineering Systems**	3.0
ENGR 232	**Dynamic Engineering Systems**	3.0
MEM 202	**Engineering Mechanics: Statics**	3.0

Required Biomedical Engineering courses		**49.0 Credits**
BIO 201	**Human Physiology I**	4.0

BIO 203	**Human Physiology II**	4.0
BMES 125	**Foundations of Biomedical Engineering**	2.0
BMES 212	**The Body Synthetic**	3.0
BMES 302	**Lab II: Biomeasurements**	2.0
BMES 303	**Lab III: Biomedical Electronics**	2.0
BMES 310	**Biomedical Statistics**	4.0
BMES 325	**Engineering Principles of Living Systems I**	3.0
BMES 326	**Engineering Principles of Living Systems II**	3.0
BMES 338	**Biomedical Ethics and Law**	4.0
BMES 372	**Biosimulation**	3.0
BMES 381	**Junior Design Seminar I**	2.0
BMES 382	**Junior Design Seminar II**	2.0
BMES 491	**Senior Design I**	2.0
BMES 492	**Senior Design II**	2.0
BMES 493	**Senior Design III**	4.0
ECE 201	**Foundations of Electric Circuits**	3.0

Biomedical Informatics concentration courses		**51.5 Credits**
BIO 218	**Principles of Molecular Biology**	3.0
BIO 219	**Techniques of Molecular Biology**	2.5
BMES 315	**Experimental Drugs**	2.0
BMES 375	**Computational Bioengineering**	4.0
BMES 401	**Biosensors I**	4.0
BMES 483	**Quantitative Systems Biology**	4.5
BMES 484	**Genome Information Engineering**	4.5
CS 171	**Computer Programming I**	3.0
CS 172	**Computer Programming II**	3.0
CS 260	**Data Structures**	3.0
CS 265	**Advanced Programming Tools and Techniques**	3.0
INFO 110	**Human-Computer Interaction I**	3.0
INFO 200	**Systems Analysis I**	3.0
INFO 210	**Database Management Systems**	3.0
	Bioinformatics concentration electives (2)	6.0

Suggested Bioinformatics electives		
BMES 335	**Biomedical Informatics I**	3.0
BMES 336	**Biomedical Informatics II**	3.0

*General studies electives include all liberal arts electives plus additional subjects, such as business, which do not fall under the subject area of are science, math or engineering. See the Biomedical Engineering General and Liberal Studies List for approved courses. A certain number of General Studies credits are required for graduation with this major.

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.

Recommended Plan Of Study

BS Biomedical Engineering
5 YR UG Co-op Concentration /Biomedical Informatics

Term 1		Credits
BMES 125	Foundations of Biomedical Engineering 2.	0
CHEM 101	General Chemistry I	3.5
CS 121	Computation Lab I	1.0
ENGL 101	Expository Writing and Reading	3.0
ENGR 100	Beginning CAD for Design	1.0
ENGR 101	Engineering Design Laboratory I	2.0
MATH 121	Calculus I	4.0
UNIV 101	The Drexel Experience	1.0
	Term Credits	*17.5*

Term 2		Credits
CHEM 102	General Chemistry II	4.5
CS 122	Computation Lab II	1.0
ENGL 102	Persuasive Writing and Reading 3.	0
ENGR 102	Engineering Design Laboratory II	2.0
MATH 122	Calculus II	4.0
PHYS 101	Fundamentals of Physics I	4.0
UNIV 101	The Drexel Experience	1.0
	Term Credits	*19.5*

Term 3		Credits
BIO 122	Cells and Genetics	4.5
CS 123	Computation Lab III	1.0
ENGL 103	Analytical Writing and Reading	3.0
ENGR 103	Engineering Design Laboratory III	2.0
MATH 200	Multivariate Calculus	4.0
PHYS 102	Fundamentals of Physics II	4.0
UNIV 101	The Drexel Experience	0.5
	Term Credits	*19.0*

Term 4		Credits
BIO 201	Human Physiology I	4.0
ENGR 201	Evaluation & Presentation of Experimental Data I	3.0
ENGR 220	Fundamentals of Materials	4.0
ENGR 231	Linear Engineering Systems	3.0
PHYS 201	Fundamentals of Physics III	4.0
	Term Credits	*18.0*

Term 5		Credits
BIO 203	Human Physiology II	4.0
BMES 212	The Body Synthetic 3.0	
ENGR 202	Evaluation & Presentation of Experimental Data II	3.0
ENGR 210	Introduction to Thermodynamics 3.0	
ENGR 232	Dynamic Engineering Systems 3	.0
MEM 202	Engineering Mechanics-Statics	3.0
	Term Credits	*19.0*

Term 6		Credits
BIO 218	Principles of Molecular Biology	3.0
BIO 219	Techniques in Molecular Biology	2.5
BMES 325	Principles of Biomedical Engineering I	3.0
BMES 372	Biosimulation 3	.0
CS 171	Computer Programming I	3.0
ECE 201	Electric Circuits	3.0

	Term Credits	*17.5*

Term 7		Credits
BMES 303	Lab III: Biomed Electronics	2.0
BMES 310	Biomedical Statistics	4.0
BMES 326	Principles of Biomedical Engineering II	3.0
CS 172	Computer Programming II	3.0
INFO 110	Human-Computer Interaction I	3.0
	Term Credits	*15.0*

Term 8		Credits
BMES 302	Lab II: Biomeasurements	2.0
BMES 315	Experimental Design in Biomed Research	4.0
BMES 338	Biomedical Ethics and Law	3.0
BMES 381	Junior Design Seminar I	2.0
CS 265	Advanced Programming Tools and Techniques	3.0
INFO 200	Systems Analysis I	3.0
	Term Credits	*17.0*

Term 9		Credits
BMES 375	Computational Bioengineering	4.0
BMES 382	Junior Design Seminar II	2.0
CS 260	Data Structures	3.0
INFO 210	Database Management Systems 3	.0
	General studies elective	3.0
	Term Credits	*15.0*

Term 10		Credits
BMES 401	Biosensors I	4.0
BMES 491	Senior Design Project I	2.0
HIST 285	Technology in Historical Perspective	3.0
	Biomedical Informatics concentration elective (See degree requirements)	3.0
	General studies elective	3.0
	Term Credits	*15.0*

Term 11		Credits
BMES 483	Quantitative Systems Biology	4.5
BMES 492	Senior Design Project II	2.0
	Biomedical Informatics concentration elective (See degree requirements)	3.0
	General studies elective	3.0
	Term Credits	*12.5*

Term 12		Credits
BMES 484	Genome Information Engineering	4.5
BMES 493	Senior Design Project III	4.0
	General studies electives	6.0
	Term Credits	*14.5*

	Total Credits (minimum)	199.5

Biomedical Devices and Imaging

Bachelor of Science Degree in Biomedical Engineering: 200.5 credits

About the concentration

Biomedical imaging focuses on the theoretical and practical issues related to machine vision, image processing and analysis, and signal processing associated with such medical applications as ultrasound, optics, magnetic resonance, and autoradiographic imaging.

The concentration in Biomedical Devices and Imaging is for those individuals interested in careers in medical imaging, medical device development, and clinical engineering. The concentration covers the fundamentals of modern imaging methodologies, covering aspects of light imaging, ultrasound imaging, and volumetric and functional imaging systems, and the principles of Magnetic Resonance Imaging (MRI).

Upon graduation, students will be able to:

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

For more information about this concentration, see Drexel's School of Biomedical Engineering, Science, and Health Systems web site.

Biomedical Engineering

Biomedical Devices and Imaging Concentration
Bachelor of Science Degree: 200.5 credits
Degree requirements (incoming students, 2008/2009)

General education requirements		**29.0 Credits**
HIST 285	**Technology in Historical Perspective**	3.0
ENGL 101	**Expository Writing and Reading**	3.0
ENGL 102	**Persuasive Writing and Reading**	3.0
ENGL 103	**Analytical Writing and Reading**	3.0
UNIV 101	**The Drexel Experience**	2.0
	Liberal and General studies electives (5)	15.0

Engineering core courses		
MATH 121	**Calculus I**	4.0
MATH 122	**Calculus II**	4.0
MATH 200	**Multivariate Calculus**	4.0
PHYS 101	**Fundamentals of Physics I**	4.0
PHYS 102	**Fundamentals of Physics II**	4.0
PHYS 201	**Fundamentals of Physics III**	4.0
CHEM 101	**General Chemistry I**	3.5
CHEM 102	**General Chemistry II**	4.5
BIO 122	**Cells and Genetics**	3.0
CS 121	**Computational Laboratory I**	1.0
CS 122	**Computational Laboratory II**	1.0
CS 123	**Computational Laboratory III**	1.0
ENGR 100	**Beginning CAD for Design**	1.0
ENGR 101	**Engineering Design Laboratory I**	2.0
ENGR 102	**Engineering Design Laboratory II**	2.0
ENGR 103	**Engineering Design Laboratory III**	2.0
ENGR 201	**Evaluation/Presentation of Experimental Data I**	3.0
ENGR 202	**Evaluation/Presentation of Experimental Data II**	3.0
ENGR 210	**Introduction to Thermodynamics**	3.0
ENGR 220	**Fundamentals of Materials**	4.0
ENGR 231	**Linear Engineering Systems**	3.0
ENGR 232	**Dynamic Engineering Systems**	3.0
MEM 202	**Engineering Mechanics: Statics**	3.0

Required Biomedical Engineering courses		**49.0 Credits**
BIO 201	**Human Physiology I**	4.0

BIO 203	**Human Physiology II**	4.0
BMES 125	**Foundations of Biomedical Engineering**	2.0
BMES 212	**The Body Synthetic**	3.0
BMES 302	**Lab II: Biomeasurements**	2.0
BMES 303	**Lab III: Biomedical Electronics**	2.0
BMES 310	**Biomedical Statistics**	4.0
BMES 325	**Engineering Principles of Living Systems I**	3.0
BMES 326	**Engineering Principles of Living Systems II**	3.0
BMES 338	**Biomedical Ethics and Law**	4.0
BMES 372	**Biosimulation**	3.0
BMES 381	**Junior Design Seminar I**	2.0
BMES 382	**Junior Design Seminar II**	2.0
BMES 491	**Senior Design I**	2.0
BMES 492	**Senior Design II**	2.0
BMES 493	**Senior Design III**	4.0
ECE 201	**Foundations of Electric Circuits**	3.0

Biomedical Systems and Imaging concentration courses		**57.0 Credits**
BIO 202	**Human Physiology Laboratory**	2.0
BMES 301	**Lab I: Experimental Biomechanics**	2.0
BMES 304	**Lab IV:Ultrasound Images**	2.0
BMES 315	**Experimental Design**	3.0
BMES 391	**Biomedical Instrumentation I**	3.0
BMES 392	**Biomedical Instrumentation II**	3.0
BMES 375	**Computational Bioengineering**	4.0
BMES 401	**Biosensors I**	4.0
BMES 421	**Biomedical Imaging I**	4.0
BMES 422	**Biomedical Imaging II**	4.0
BMES 423	**Biomedical Imaging III**	4.0
BMES 432	**Biomedical Systems and Signals**	3.0
ECES 302	**Transform Methods and Filtering**	4.0
ECES 304	**Dynamic Systems and Stability**	4.0
ECES 352	**Digital Signals**	4.0
	Biomedical Systems and Imaging elective	3.0

Suggested Biomedical Systems and Imaging electives		
BMES 488	**Medical Device Development**	3.0
BMES 494	**Clinical Practicum I**	3.0
BMES 495	**Clinical Practicum II**	3.0
BMES 496	**Clinical Practicum III**	3.0

*General studies electives include all liberal arts electives plus additional subjects, such as business, which do not fall under the subject area of science, math or engineering. See the Biomedical Engineering General and Liberal Studies List for approved courses. A certain number of General Studies credits are required for graduation with this major.

Writing-Intensive Course Requirements
In order to graduate, all 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.

Recommended Plan Of Study

BS Biomedical Engineering

5 YR UG Co-op Concentration /Biomedical Devices & Imaging

Term 1		Credits
BMES 125	Foundations of Biomedical Engineering 2.	0
CHEM 101	General Chemistry I	3.5
CS 121	Computation Lab I	1.0
ENGL 101	Expository Writing and Reading	3.0
ENGR 100	Beginning CAD for Design	1.0
ENGR 101	Engineering Design Laboratory I	2.0
MATH 121	Calculus I	4.0
UNIV 101	The Drexel Experience	1.0
	Term Credits	*17.5*

Term 2		Credits
CHEM 102	General Chemistry II	4.5
CS 122	Computation Lab II	1.0
ENGL 102	Persuasive Writing and Reading 3.	0
ENGR 102	Engineering Design Laboratory II	2.0
MATH 122	Calculus II	4.0
PHYS 101	Fundamentals of Physics I	4.0
UNIV 101	The Drexel Experience	1.0
	Term Credits	*19.5*

Term 3		Credits
BIO 122	Cells and Genetics	4.5
CS 123	Computation Lab III	1.0
ENGL 103	Analytical Writing and Reading	3.0
ENGR 103	Engineering Design Laboratory III	2.0
MATH 200	Multivariate Calculus	4.0
PHYS 102	Fundamentals of Physics II	4.0
UNIV 101	The Drexel Experience	0.5
	Term Credits	*19.0*

Term 4		Credits
BIO 201	Human Physiology I	4.0
ENGR 201	Evaluation & Presentation of Experimental Data I	3.0
ENGR 220	Fundamentals of Materials	4.0
ENGR 231	Linear Engineering Systems	3.0
PHYS 201	Fundamentals of Physics III	4.0
	Term Credits	*18.0*

Term 5		Credits
BIO 203	Human Physiology II	4.0
BMES 212	The Body Synthetic 3.0	
ENGR 202	Evaluation & Presentation of Experimental Data II	3.0
ENGR 210	Introduction to Thermodynamics 3.0	
ENGR 232	Dynamic Engineering Systems 3	.0
MEM 202	Engineering Mechanics-Statics	3.0
	Term Credits	*19.0*

Term 6		Credits
BMES 301	Biomedical Engineering Lab I: Experimental Biomechanics	2.0
BMES 302	Lab II: Biomeasurements	2.0
BMES 325	Principles of Biomedical Engineering I	3.0
BMES 372	Biosimulation 3	.0
ECE 201	Electric Circuits	3.0
HIST 285	Technology in Historical Perspective	3.0

	Term Credits	*16.0*

Term 7		Credits
BMES 303	Lab III: Biomed Electronics	2.0
BMES 310	Biomedical Statistics	4.0
BMES 326	Principles of Biomedical Engineering II	3.0
ECES 302	Transform Methods & Filtering	4.0
	Liberal studies elective	3.0
	Term Credits	*16.0*

Term 8		Credits
BIO 202	Human Physiology Laboratory 2.	0
BMES 304	Lab IV: Ultrasound Images 2	.0
BMES 315	Experimental Design in Biomed Research	4.0
BMES 338	Biomedical Ethics and Law	3.0
BMES 381	Junior Design Seminar I	2.0
BMES 401	Biosensors I	4.0
	Term Credits	*17.0*

Term 9		Credits
BMES 375	Computational Bioengineering	4.0
BMES 382	Junior Design Seminar II	2.0
ECES 304	Dynamic Systems and Stability	4.0
ECES 352	Introduction to Digital Signal Processing 4.	0
	Term Credits	*14.0*

Term 10		Credits
BMES 391	Biomedical Instrumentation I	3.0
BMES 421	Biomedical Imaging Systems I	4.0
BMES 432	Biomed Systems and Signals	3.0
BMES 491	Senior Design Project I	2.0
	Liberal studies elective	3.0
	Term Credits	*15.0*

Term 11		Credits
BMES 392	Biomedical Instrumentation II	3.0
BMES 422	Biomedical Imaging Systems II	4.0
BMES 492	Senior Design Project II	2.0
	General studies electives	6.0
	Term Credits	*15.0*

Term 12		Credits
BMES 423	Biomedical Imaging Systems III	4.0
BMES 493	Senior Design Project III	4.0
	Biomedical Devices and Imaging concentration elective (See degree requirements)	3.0
	Liberal studies elective	3.0
	Term Credits	*14.0*
	Total Credits (minimum)	200.0

Neuroengineering

Bachelor of Science Degree in Biomedical Engineering: 197.5 credits

About the concentration

This concentration focuses on the theory of neural signaling, as well as addressing issues that have a neuroscientific basis, such as locomotion and pattern generation, central control of movement, and the processing of sensory information. Students pursing this concentration will learn the fundamental theory of cellular potentials and chemical signaling, the Hodgkin Huxeley description of action potential generation, circuit representations of neurons and be able to derive and integrate equations describing the circuit as well as design computer models.

Upon graduation, students will be able to:

- model specific aspects of neural systems;
- understand control system theory as applied to neural systems;
- understand how neuroengineering can be applied in clinical situations.

For more information about this concentration, see Drexel's School of Biomedical Engineering, Science, and Health Systems web page.

Biomedical Engineering

Bachelor of Science Degree: 197.5 credits

Neuroengineering Concentration

Required courses (incoming students, 2008/2009)

General education requirements		**29.0 Credits**
HIST 285	**Technology in Historical Perspective**	3.0
ENGL 101	**Expository Writing and Reading**	3.0
ENGL 102	**Persuasive Writing and Reading**	3.0
ENGL 103	**Analytical Writing and Reading**	3.0
UNIV 101	**The Drexel Experience**	2.0
	Liberal and General studies electives (5)	15.0

Engineering core courses		
MATH 121	**Calculus I**	4.0
MATH 122	**Calculus II**	4.0
MATH 200	**Multivariate Calculus**	4.0
PHYS 101	**Fundamentals of Physics I**	4.0
PHYS 102	**Fundamentals of Physics II**	4.0
PHYS 201	**Fundamentals of Physics III**	4.0
CHEM 101	**General Chemistry I**	3.5
CHEM 102	**General Chemistry II**	4.5
BIO 122	**Cells and Genetics**	3.0
CS 121	**Computational Laboratory I**	1.0
CS 122	**Computational Laboratory II**	1.0
CS 123	**Computational Laboratory III**	1.0
ENGR 100	**Beginning CAD for Design**	1.0
ENGR 101	**Engineering Design Laboratory I**	2.0
ENGR 102	**Engineering Design Laboratory II**	2.0
ENGR 103	**Engineering Design Laboratory III**	2.0
ENGR 201	**Evaluation/Presentation of Experimental Data I**	3.0
ENGR 202	**Evaluation/Presentation of Experimental Data II**	3.0
ENGR 210	**Introduction to Thermodynamics**	3.0
ENGR 220	**Fundamentals of Materials**	4.0
ENGR 231	**Linear Engineering Systems**	3.0
ENGR 232	**Dynamic Engineering Systems**	3.0
MEM 202	**Engineering Mechanics: Statics**	3.0

Required Biomedical Engineering courses		**49.0 Credits**
BIO 201	**Human Physiology I**	4.0

BIO 203	**Human Physiology II**	4.0
BMES 125	**Foundations of Biomedical Engineering**	2.0
BMES 212	**The Body Synthetic**	3.0
BMES 302	**Lab II: Biomeasurements**	2.0
BMES 303	**Lab III: Biomedical Electronics**	2.0
BMES 310	**Biomedical Statistics**	4.0
BMES 325	**Engineering Principles of Living Systems I**	3.0
BMES 326	**Engineering Principles of Living Systems II**	3.0
BMES 338	**Biomedical Ethics and Law**	4.0
BMES 372	**Biosimulation**	3.0
BMES 381	**Junior Design Seminar I**	2.0
BMES 382	**Junior Design Seminar II**	2.0
BMES 491	**Senior Design I**	2.0
BMES 492	**Senior Design II**	2.0
BMES 493	**Senior Design III**	4.0
ECE 201	**Foundations of Electric Circuits**	3.0

Neuroengineering concentration courses		**55.0 Credits**
BIO 462	**Biology of Neuron Function**	3.0
BMES 301	**Lab I: Experimental Biomechanics**	2.0
BMES 304	**Lab IV: Ultrasound Images**	2.0
BMES 305	**Lab V: Musculoskeletal Anatomy for Biomedical Engineering**	2.0
BMES 375	**Computational Bioengineering**	4.0
BMES 401	**Biosensors I**	4.0
BMES 405	**Psysiological Control Systems**	4.0
BMES 411	**Chronoengineering I**	3.0
BMES 430	**Neural Aspects of Posture and Locomotion**	3.0
BMES 451	**Transport Phenomena in Living Systems I**	4.0
BMES 477	**Neuroengineering I**	3.0
BMES 478	**Neuroengineering II**	3.0
ECES 302	**Transform Methods and Filtering**	4.0
ECES 304	**Dynamic Systems and Stability**	4.0
ECES 356	**Theory of Control**	4.0
PSY 101	**General Psychology**	3.0
PSY 213	**Sensation and Perception**	3.0

*General studies electives include all liberal arts electives plus additional subjects, such as business, which do not fall under the subject area of science, math or engineering. See the Biomedical Engineering General and Liberal Studies List for approved courses. A certain number of General Studies credits are required for graduation with this major.

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 indicates that this course can fulfill a writing-intensive requirement. Departments will designate specific sections of such courses as writing-intensive.

Recommended Plan Of Study

BS Biomedical Engineering
5 YR UG Co-op Concentration /Neuroengineering

Term 1		Credits
BMES 125	Foundations of Biomedical Engineering 2.	0
CHEM 101	General Chemistry I	3.5
CS 121	Computation Lab I	1.0
ENGL 101	Expository Writing and Reading	3.0
ENGR 100	Beginning CAD for Design	1.0
ENGR 101	Engineering Design Laboratory I	2.0
MATH 121	Calculus I	4.0
UNIV 101	The Drexel Experience	1.0
	Term Credits	*17.5*

Term 2		Credits
CHEM 102	General Chemistry II	4.5
CS 122	Computation Lab II	1.0
ENGL 102	Persuasive Writing and Reading 3.	0
ENGR 102	Engineering Design Laboratory II	2.0
MATH 122	Calculus II	4.0
PHYS 101	Fundamentals of Physics I	4.0
UNIV 101	The Drexel Experience	1.0
	Term Credits	*19.5*

Term 3		Credits
BIO 122	Cells and Genetics	4.5
CS 123	Computation Lab III	1.0
ENGL 103	Analytical Writing and Reading	3.0
ENGR 103	Engineering Design Laboratory III	2.0
MATH 200	Multivariate Calculus	4.0
PHYS 102	Fundamentals of Physics II	4.0
UNIV 101	The Drexel Experience	0.5
	Term Credits	*19.0*

Term 4		Credits
BIO 201	Human Physiology I	4.0
ENGR 201	Evaluation & Presentation of Experimental Data I	3.0
ENGR 220	Fundamentals of Materials	4.0
ENGR 231	Linear Engineering Systems	3.0
PHYS 201	Fundamentals of Physics III	4.0
	Term Credits	*18.0*

Term 5		Credits
BIO 203	Human Physiology II	4.0
BMES 212	The Body Synthetic 3.0	
ENGR 202	Evaluation & Presentation of Experimental Data II	3.0
ENGR 210	Introduction to Thermodynamics 3.0	
ENGR 232	Dynamic Engineering Systems 3	.0
MEM 202	Engineering Mechanics-Statics	3.0
	Term Credits	*19.0*

Term 6		Credits
BMES 301	Biomedical Engineering Lab I: Experimental Biomechanics	2.0
BMES 302	Lab II: Biomeasurements	2.0
BMES 325	Principles of Biomedical Engineering I	3.0
BMES 372	Biosimulation 3	.0
ECE 201	Electric Circuits	3.0
HIST 285	Technology in Historical Perspective	3.0

	Term Credits	*16.0*

Term 7		Credits
BMES 303	Lab III: Biomed Electronics	2.0
BMES 310	Biomedical Statistics	4.0
BMES 326	Principles of Biomedical Engineering II	3.0
ECES 302	Transform Methods & Filtering	4.0
	Term Credits	*13.0*

Term 8		Credits
BMES 304	Lab IV: Ultrasound Images 2	.0
BMES 338	Biomedical Ethics and Law	3.0
BMES 381	Junior Design Seminar I	2.0
BMES 411	Chronoengineering I: Biorhythms	3.0
ECES 356	Theory of Control	4.0
PSY 101	General Psychology I	3.0
	Term Credits	*17.0*

Term 9		Credits
BMES 375	Computational Bioengineering	4.0
BMES 382	Junior Design Seminar II	2.0
BMES 405	Physiological Control Systems	3.0
BMES 451	Transport Phenomena in Living Sys	4.0
ECES 304	Dynamic Systems and Stability 4.	0
	Term Credits	*17.0*

Term 10		Credits
BIO 462	Biology of Neuron Function	3.0
BMES 401	Biosensors I	4.0
BMES 430	Neural Aspects of Posture and Locomotion	3.0
BMES 491	Senior Design Project I	2.0
PSY 213	Sensation and Perception	3.0
	Term Credits	*15.0*

Term 11		Credits
BMES 477	Neuroengineering I	3.0
BMES 492	Senior Design Project II	2.0
	General studies electives	9.0
	Term Credits	*14.0*

Term 12		Credits
BMES 305	Lab V: Musculoskeletal Anatomy for BME	2.0
BMES 478	Neuroengineering II	3.0
BMES 493	Senior Design Project III	4.0
	Liberal studies elective	3.0
	Term Credits	*12.0*

	Total Credits (minimum) 1	**97.0**

Biomedical Engineering

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

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

For more information, visit the The School of Biomedical Engineering, Science, and Health Systems' web site.

Master of Science Program in Biomedical Engineering

The core requirements for the master's in biomedical engineering encompass approximately 45 course credits. (Most courses carry three credits each.) A thesis is highly recommended. A non-thesis option is also offered. Students who choose the non-thesis option must take 51 credits of coursework and cannot register for thesis or research credits.

Curriculum

Courses		Credits
BMES 501	**Medical Sciences I: Cellular and Tissue Biology**	3.0
BMES 502	**Medical Sciences II: Organ-Level Physiology**	3.0
BMES 503	**Medical Sciences III: Neural and Endocrine Control Systems**	3.0
BMES 672	**Biosimulation I**	3.0
BMES 673	**Biosimulation II**	3.0
BMES 864	**Seminar**	0.0

Students select three BMES electives from a list that may include the following:		**9.0-10.0**
BMES 508	**Cardiovascular Engineering**	3.0
BMES 551	**Biomedical Signal Processing**	3.0
BMES 561	**Introduction to Systems Analysis in Biology**	3.0
BMES 621	**Medical Imaging Systems I**	3.0
BMES 641	**Biomedical Mechanics I**	3.0
BMES 661	**Biomedical Materials I**	3.0
BMES 711	**Principles of Neuroengineering**	4.0

Electives (selection varies by area of focus)

The sum of electives, core credits, and/or thesis credits must total 45 for thesis students and and 51 for non-thesis students.

BMES 897	**Research**
BMES 898	**Master's Thesis***

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

Biomedical Engineering: Areas of Focus

The graduate program of the School does not offer concentration areas in sub-disciplines. However, 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. The focus areas of the School's faculty from which students can learn and participate in research are:

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.

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 provides the 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.

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.

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.

Doctoral Program in Biomedical Engineering

To be awarded the Ph.D., students must complete 90 credits (credits earned toward a masterís degree may apply toward the 90), fulfill a one-year residency requirement, and successfully pass the qualifying examination, the candidacy examination, and a Ph.D. dissertation and oral defense.

The qualifying examination is intended to test students' general knowledge of biomedical engineering and science. It is a written examination that covers the basic knowledge expected of students wishing to proceed toward a Ph.D. Biomedical engineering students are also expected to demonstrate physical science aptitude and preparation.

Prospective Ph.D. students are welcome to contact the school to discuss their research interests For more information, visit the School's Academics web page.

Biomedical Science

General Information
Biomedical science is a broad field concerned with the application of fundamental biological research and quantitative analysis to human health.

The overall objective of the School of Biomedical Engineering, Science and Health Systems is to provide multidisciplinary programs offering an instructional core curriculum and research in selected areas.

The graduate program in biomedical science educates students whose undergraduate education is in basic life sciences (e.g., biology or biochemistry) or paramedical disciplines (e.g., nursing, physical therapy, or medical technology) in quantitative analysis, mathematical modeling, fundamental computing skills, and informatics.

For students entering with degrees in physics, mathematics, and/or computer science, the School, in close collaboration with the Department of Biology, provides the coursework needed to acquire proficiency in the life sciences. Students in biomedical science achieve depth in the modeling of living systems and biomedical information processing and display.

Students may choose to specialize in **Biomaterials and Tissue Engineering** or **Bioinformatics**. Students who graduate with a master's degree from the biomedical science program often continue clinical training in medicine, dentistry, or veterinary medicine; pursue further graduate study toward the Ph.D. degree; or work in industry in such fields as health care, pharmaceuticals, biotechnology, medical devices, etc.

For more information, visit the The School of Biomedical Engineering, Science, and Health Systems' web site.

Master of Science Program in Biomedical Science

The core requirements for the master's in Biomedical science encompass approximately 45 course credits (most courses carry three credits each). A thesis is highly recommended. A Non-Thesis option is also offered. The School of Biomedical Engineering, Science and Health Systems has recently decided to eliminate the comprehensive exam as a part of the requirements for the Non-Thesis master's degree. This change is effective immediately for those students that commenced their studies in the Fall term of the 2006-2007 Academic Year. Students who began their studies prior to that date are subject to the original requirements. However, students will be allowed to appeal to the Graduate Advising Committee for a waiver of the exam. Appeal requests will be considered on an individual basis by a committee and will be based on academic performance.

A unique aspect of the School's Biomedical sciences program is its ability to integrate aspects of physiology and molecular biology with quantitative analysis, mathematical modeling, and computer processing to create a systems approach to biomedical research and applications. Elective courses such as Biological Controls Systems; Applied Evolution; and Human Chronobiology and Sleep reflect the School's emphasis on multidisciplinary approaches to the most current research in biology and medicine.

Curriculum

Courses		Credits
BMES 505	**Mathematics for Biomedical Science I**	3.0
BMES 506	**Mathematics for Biomedical Science II**	3.0
BMES 507	**Mathematics for Biomedical Science III**	3.0
BMES 510	**Biomedical Statistics**	4.0
BMES 511	**Principles of Systems Analysis Applied to Biomedicine I**	3.0
BMES 512	**Principles of Systems Analysis Applied to Biomedicine II**	3.0
BMES 514	**Computer Applications for Biomedical Research**	3.0
BMES 515	**Experimental Design in Biomedical Research**	4.0
BMES 538	**Biomedical Ethics and Law**	3.0

Electives		18.0
BMES 897	**Research**	variable
BMES 898	**Master's Thesis**	variable

Areas of Specialization
Two concentrations are currently offered within the Biomedical Science graduate program:

- **Biomaterials and Tissue Engineering**
- **Bioinformatics**

Additional Courses in Biomaterials and Tissue Engineering

BMES 623	**Tissue Engineering I**	4.0
BMES 624	**Tissue Engineering II**	4.0
BMES 625	**Tissue Engineering III**	4.0
BMES 660	**Biomaterials I**	4.0
BMES 661	**Biomaterials II**	4.0
BMES 662	**Biomaterials III**	4.0

Additional Courses in Bioinformatics

BMES 543	**Quantitative Systems Biology**	4.5
BMES 544	**Genome Information Engineering**	4.5
BMES 545	**Biocomputational Languages**	4.5
BMES 546	**Biosystems Modeling**	4.5
BMES 551	**Biomedical Signal Processing**	3.0
BMES 604	**Pharmacology**	3.0

Biomedical Science Areas of Specialization

Two concentrations are currently offered within the Biomedical Science graduate program:

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 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.

Doctoral Program in Biomedical Science

Superior students with training in engineering, natural science, or physical science as well as individuals with academic or professional degrees in the medical science disciplines will be considered for admission to the doctoral program.

To be awarded the Ph.D., students must complete 90 credits (credits earned toward a master's degree may apply toward the 90), fulfill a one-year residency requirement, and successfully pass the qualifying examination, the candidacy examination, and a Ph.D. dissertation and oral defense. Prospective Ph.D. students are welcome to contact the school to discuss their research interests For more information, visit the School’s web site and click on Graduate Programs.

Articulation with Interdepartmental Medical Science Program at the Drexel College of Medicine

The School of Biomedical Engineering, Science and Health Systems collaborates with the Drexel College of Medicine, specifically with the Interdepartmental Medical Science Program (IMSP), to offer a unique pathway to a Masters in Biomedical Science. Students complete 1 year in the IMS program (described below) and then complete their second year at the School. This involves completing the core sequence and a thesis or taking a non-thesis option with additional coursework. Student may elect to pursue **Certificates of Advanced Study** in either **Biomaterials and Tissue Engineering** or **Bioinformatics**.

IMSP Curriculum
The IMS curriculum involves a full-time commitment to rigorous coursework with strong academic requirements. Six major medical school courses are taken simultaneously with the College of Medicine first-year class. These include Medical Biochemistry, Cell Biology & Microanatomy, Medical Physiology, Medical Nutrition, Medical Immunology, and Medical Neuroscience.

The medical school lectures are simulcast to the Health Sciences Campus (located in Center City, Philadelphia) from the Drexel University College of Medicine campus (located in East Falls, Philadelphia). The lectures are also videotaped and available in the Health Sciences library as well as being accessible via streaming video on the web. The students take the exact same courses and exams as the medical students and are evaluated based on their performance in comparison to our medical school students. Performance on tests, quizzes, and assignments equal to the mean grade of the medical school class signifies a letter grade of “B” for the IMS students. Thus, IMS students receiving A's and B's are performing at the top 50% of the medical school class and can then present themselves with strong academic credentials before the admissions committee. This permits medical school admissions committees to directly evaluate the student's competence compared with their own first year medical school class. This allows students an opportunity to test their preparation, motivation, and commitment to medicine.

In addition to the medical school courses, students take a medical ethics course each semester. The campuses are approximately five miles apart and a University shuttle provides free transportation between the two.

Additionally, course conferences and laboratory components for IMS students are conducted at the Health Sciences Campus where the program is based. The IMS curriculum allows exposure to both medical school lectures and individual attention from medical school professors in small group conferences.

For more information, visit Drexel's College of Medicine Interdepartmental Medical Science Program web page.