RUTGERS

School of Engineering

BioMedical Engineering UnderGraduate ProGram HandBook

Rutgers, The State University of New Jersey
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UnderGraduate Program Administration

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Track	Track Designation	Advisors	Advising
1	Biomedical Computing, Imaging, and Instrumentation (BCII)	M. Pierce mark.pierce@rutgers.edu	Email for Appointment
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3	Tissue Engineering and Molecular Bioengineering (TEMB)	Li Cai lcai@soe.rutgers.edu T. Shinbrot shinbrot@soe.rutgers.edu	Email for Appointment

Special Permission Number/Pre-req Override

Please email **Undergraduate Administrator or Director** with your:

~FULL NAME, RUID#, Class of 20XX and COURSE NAME (not Index #) ~

Please inform me of any messages during registration such as *course is closed, don't have pre-reqs, etc.*
Please wait patiently for a response.

Introduction to Biomedical Engineering

The Biomedical Engineering program at Rutgers University was initially established in 1965 as a track within Electrical Engineering, offering M.S. degrees with a Biomedical Engineering emphasis. In 1986, the State of New Jersey formally chartered the Rutgers Department of Biomedical Engineering as an independent entity within the School of Engineering with exclusive responsibility for granting M.S. and Ph.D. degrees in biomedical engineering. The Department developed its graduate programs in collaboration with the University of Medicine and Dentistry of New Jersey (UMDNJ) to provide a strong foundation in the basic biomedical and clinical sciences along with rigorous training in engineering fundamentals. The undergraduate program in Biomedical Engineering was inaugurated in 1991 under the "Applied Sciences' option within the School of Engineering; a formal undergraduate B.S. degree in BME was approved by the University in 1997 and by the State in 1999.

The achievements of biomedical engineering constantly touch our daily lives. Past and current breakthroughs that were pioneered at Rutgers include: techniques for online analysis and operating room lesioning of brain tissue for Parkinson's disease; an artificial hand with finger dexterity; the use of virtual reality in the rehabilitation of limbs; revolutionary techniques for making large numbers of new biopolymers for implants; and rapid NMR analysis of protein structure, balloon catheters, and pacemakers.

The BME program currently offers three main curriculum options, called "tracks": 1) biomedical computing, imaging, and instrumentation, 2) biomechanics and rehabilitation engineering, and 3) tissue engineering and molecular bioengineering. The biomedical computing, imaging, and instrumentation track provides training in computational approaches, various imaging modalities, bioelectronic device design, and in theoretical modeling related to microscopic and macroscopic biomedical phenomena.

A focus in biomechanics and rehabilitation engineering offers instruction on development of devices for improved human performance. In the tissue engineering and molecular bioengineering track, students apply principles of materials science, biochemistry, cell and molecular biology and engineering to design engineered tissues, biomaterials, and molecular medicine, through the pursuit of problems on the cellular, molecular and nano-scale. The broad education provided by these tracks allows students to choose from a wide variety of careers. Many graduates work in large corporations and smaller companies as practicing biomedical engineers. Increasing numbers of graduates are finding rewarding jobs in state and federal institutions, including the Patent and Trademark Office and many of the National Laboratories of Advanced Research. The degree program also prepares qualified students for graduate study leading to the M.S. or Ph.D. degrees in biomedical engineering. In addition, students are prepared to meet the graduate entrance requirements for medical and law schools, business administration, and other professional disciplines.

There are several exciting opportunities for conducting research at the Undergraduate level. The Department has recently established a Research Scholars Academy in Biomedical Engineering. Additionally, the department participates in the School of Engineering's James J. Slade Scholars Research Program. Both selective programs can serve as springboards for highly qualified students to commence work toward the M.S. or Ph.D. degree in the senior year of the undergraduate curriculum.

Biomedical Engineering Mission, Goals, Educational Objectives and Educational Outcomes

Biomedical Engineering Mission Statement

The mission of the BME undergraduate program is to provide students with a broad and flexible education in engineering and biological science as well as medically related subjects. The students are prepared to analyze, synthesize, and link knowledge in the multi-disciplinary fields, with the emphasis on quantitative approaches and methods. The students will be integral part of the society to improve the understanding and control of biological processes towards improving human health. Our curriculum guides our students toward skill in creating new knowledge and technologies as well as applying current knowledge.

Rutgers Mission & Vision Statements are published at http://studentaffairs.rutgers.edu/about-us/mission-statement

Mission of the School of Engineering:

The School of Engineering Mission Statement was revised and ratified by the faculty on October 7, 2011. The mission statement is as follows.

- To educate and train the future engineers of a complex, diverse, and global workplace
- Provide high quality, relevant education programs to undergraduate and graduate students using the latest technology and education techniques
- To conduct state-of-the-art research that embraces technology to address societal challenges of a multifaceted United States and a globally connected world
- Create an environment to encourage and assist faculty to become leaders in their fields, and to further gain national and international recognition
- Conduct cutting-edge research in strategically important engineering areas
- To serve as a resource to local, New Jersey, and regional stakeholders in advancing the public's interest
- Promote economic development through technology, entrepreneurship, and innovation

The mission statement is published at: http://www.soe.rutgers.edu/administration

Program Educational Objectives (PEOs)

The BME program educational objectives (PEO) are consistent with the mission of Rutgers University and with the overall mission of the School of Engineering stated above. These objectives were modified and ratified by the faculty on April 12, 2012.The University mission and aims of the School are printed in the Undergraduate Catalog for the School of Engineering, read by prospective students and entering freshmen. The educational objectives of the Biomedical Engineering Program are to educate students to attain the following:

1. To establish themselves as practicing professionals in biomedical or biotechnology industries or engage themselves in advance study in biomedical engineering or a related field.
2. To make positive contributions in biomedical industries and/or other sectors.
3. To demonstrate their ability to work successfully as a member of a professional team and function effectively as responsible professionals.

The BME mission statement and PEOs are available to the public at the departmental Web page, http://www.bme.rutgers.edu/content/educationABET.php Also, note that one change has been made to the educational objectives since the last ABET visit. The change was a rewording of the objectives to make them consistent with the most recent ABET definition of Program Educational Objectives, although the sense of the objectives is unchanged.

C. Student Outcomes (Sos)

The student outcomes were adapted in the previous first ABET cycle. These outcomes reviewed and ratified by the faculty on April 12, 2012.Therefore, each Biomedical Engineering student will demonstrate the following attributes by the time they graduate:

a. an ability to apply knowledge of mathematics (including multivariable calculus, differential equations linear algebra and statistics), science (including chemistry, calculus-based physics and the life sciences), and engineering.
b. an ability to design and conduct experiments, as well as to analyze and interpret data.
c. an ability to design and realize a biomedical device, component, or process to meet desired needs.
d. an ability to function on multi-disciplinary teams.
e. an ability to identify, formulate, and solve engineering problems.
f. an understanding of professional and ethical responsibility.
g. an ability to communicate effectively.
h. the broad education necessary to understand the impact of engineering solutions in a global and societal context.
i. a recognition of the need for, and an ability to engage in life-long learning.
j. a knowledge of contemporary issues.
k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The student outcomes were established with the goal that they must be compatible with the program educational objectives and the mission of the School and University. Furthermore, the outcomes should be measurable, in the sense that our success in achieving them can be quantified. The BME student outcomes are available to the public at the departmental Web page, http://www.bme.rutgers.edu/content/educationABET.php

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Basic Curriculum
Department of Biomedical Engineering
Class of 2019

Freshman Year

160:159	Gen Chem for Engrs	3
160:171	Intro to Experiment.	1
355:101	Expository Writing I	3
640:151	Calculus I: Math/Phys	4
750:123	Analytical Physics Ia	2
440:100	Eng'g Orient Lecture	1
___:___	Hum/Soc Elective	3
	Total	17

160:160	Gen Chem for Engrs	3
440:127	Intro Comp for Engrs	3
640:152	Calculus II: Math/Phys	4
750:124	Analytical Physics Ib	2
440:221	Eng'g Mech: Statics	3
___:___	Hum/Soc Elective	3
	Total	18

Sophomore Year

← Summer/Fall/ Spring Courses→

*** Major Begins***

125:201	Intro to Biomed Eng	3
640:251	Multivariable Calculus	4
750:227	Analytical Physics IIa	3
750:229	Analytical Phys IIa Lab	1
119:115	Biology I	4
___:___	Hum/Soc Elective	3
	Total	18

125:255	Systems Physiology	3
640:244	Diff Eqs Eng'g & Phys	4
750:228	Analytical Physics IIb	3
750:230	Analytical Phys IIb Lab	1
119:117	Biology Lab	2
220:102	MicroEconomics	3
	Total	16

Junior Year

Courses offered Both semesters Except *

125:303	Biomed Trans Phenom	3
125:305	Num Model in Bio Sys	3
125:308	Biomechanics	3
125:309*	BME Devices/Systems	3
125:310*	BME Dev/Sys Lab	1
___:___	Technical Elective	3

125:304	Biomaterials	3
125:306	Bio Kinetics & Thermo	3
125:315*	BME Meas/Analy Lab	2
___:___	Technical Elective	3
___:___	Life Science Elective	3
	Total	14

Senior Year

125:401*	Senior Design I Lecture	1
125:421*	Senior Design I Project	2
___:___	Departmental Elective	3
___:___	Departmental Elective	3
___:___	Technical Elective	3
___:___	Hum/Soc Elective	3
	Total	15

125:402*	Senior Design II Lecture	1
125:422*	Senior Design II Project	2
___:___	Departmental Elective	3
___:___	Departmental Elective	3
___:___	Technical Elective	3
___:___	General Elective	3
	Total	15

Total Credits: 129

∞ Organic Chemistry is required for the **Pre-medical School** option and is also strongly recommended for the Tissue Engineering and Molecular Bioengineering Track in BME. (Organic Chemistry I + Organic Chemistry II + Lab will count for 3 technical electives each totaling 9 credits) Take 2 of 3= 6 credits, Take 1 of 3= 3 credits.

∞ ONLY **Pre-med students** are required to take all three of the following courses: 119:115 (Biology I) and 119:116 (Biology II) and 119:117 (Biology Lab).

∞ **Rule I**: without **both** intro courses (Intro to BME + Sys. Phys.) **NO** 300-level courses – You MUST see UGD Androulakis for Approval.

∞ **Rule II:** for anyone to register in Senior Design they need to have passed 6 out the 8 core BME courses (**Passed courses must include 309, 310, and 315**)

∞ Total of **12 credits of** Technical Electives is Required.

∞ 14:650:388 Computer-Aided Design in Mechanical Engineering (3 cr TE) is strongly recommended for the Biomechanics and Rehab Track.

∞ 125;309/310 Devices Lec/Lab and 125:401/421 Senior Design I Lec/Proj are only offered in the Fall.

∞ 125:315 Measurements Lab and 125:402/422 Senior Design II Lec/Proj are only offered in the Spring.

∞ Allowed to use an additional Technical Elective 3 cr. (TE) to replace Life Science Elective 3 cr. (LSE). See page 21.

Basic Curriculum
Department of Biomedical Engineering
Class of 2020 <

Freshman

160:159	Gen Chem for Engrs	3
160:160	Gen Chem for Engrs	3
160:171	Intro to Experiment.	1
355:101	Expository Writing I	3
440:100	Eng'g Orient Lecture	1
440:127	Intro Comp for Engrs	3
440:221	Eng'g Mech: Statics	3
640:151	Calculus I: Math/Phys	4
640:152	Calculus II: Math/Phys	4
750:123	Analytical Physics Ia	2
750:124	Analytical Physics Ib	2
___:___	Hum/Soc Elective	3
___:___	Hum/Soc Elective	3

Total 35

Sophomore

119:115	Biology I	4
119:117	Biology Lab	2
125:201	Intro to Biomed Eng	3
125:255	Systems Physiology	3
220:102	MicroEconomics	3
640:244	Diff Eqs Eng'g & Phys	4
640:251	Multivariable Calculus	4
750:227	Analytical Physics IIa	3
750:228	Analytical Physics IIb	3
750:229	Analytical Phys IIa Lab	1
750:230	Analytical Phys IIb Lab	1
___:___	Hum/Soc Elective 300+	3

Total 34

Junior

125:303	Biomed Trans Phenom	3
125:304	Biomaterials	3
125:305	Num Model in Bio Sys	3
125:306	Bio Kinetics & Thermo	3
125:308	Biomechanics	3
125:309*	BME Devices/Systems	3
125:310*	BME Dev/Sys Lab	1
125:315*	BME Meas/Analy Lab	2
___:___	Life Science Elective	3
___:___	Technical Elective	3
___:___	Technical Elective	3

Total 30

Senior

125:401*	Senior Design I Lecture	1
125:402*	Senior Design II Lecture	1
125:421*	Senior Design I Project	2
125:422*	Senior Design II Project	2
___:___	Departmental Elective	3
___:___	Departmental Elective	3
___:___	Departmental Elective	3
___:___	Departmental Elective	3
___:___	General Elective	3
___:___	Technical Elective	3
___:___	Technical Elective	3
___:___	Hum/Soc Elective 300+	3

Total 30

Grand Total of Credits **129**

∞ Organic Chemistry is required for the **Pre-medical School** option and is also strongly recommended for the Tissue Engineering and Molecular Bioengineering Track in BME. (Organic Chemistry I + Organic Chemistry II + Lab will count for 3 technical electives each totaling 9 credits) Take 2 of 3= 6 credits, Take 1 of 3= 3 credits.

∞ ONLY **Pre-med students** are required to take all three of the following courses: 119:115 (Biology I) and 119:116 (Biology II) and 119:117 (Biology Lab).

∞ **Rule I**: without **both** intro courses (Intro to BME + Sys. Phys.) **NO** 300-level courses – You MUST see UGD Androulakis for Approval.

∞ **Rule II:** for anyone to register in Senior Design they need to have passed 6 out the 8 core BME courses (**Passed courses must include 309, 310, and 315**)

∞ Total of **12 credits of** Technical Electives is Required.

∞ 14:650:388 Computer-Aided Design in Mechanical Engineering (3 cr TE) is strongly recommended for the Biomechanics and Rehab Track.

∞ *125:309/310 Devices Lec/Lab and *125:401/421 Senior Design I Lec/Proj are only offered in the Fall.

∞ *125:315 Measurements Lab and *125:402/422 Senior Design II Lec/Proj are only offered in the Spring.

∞ Allowed to use an additional Technical Elective 3 cr. (TE) to replace Life Science Elective 3 cr. (LSE). See page 21.

Departmental Guidelines

∞ **Organic Chemistry is required for the Pre-Medical School option** and is also strongly recommended for the Tissue Engineering and Molecular Bioengineering Track in BME. Organic Chemistry I + Organic Chemistry II + Lab will count for 1 technical elective each.
Take 3 of 3 = 9 credits, or Take 2 of 3= 6 credits, or Take 1 of 3 = 3 credits.

∞ Total of **12 credits** of Technical Electives is **Required!**

∞ **ONLY Pre-med students are required** to take all three of the following courses: 119:115 (Biology I) and 119:116 (Biology II) and 119:117 (Lab).

∞ **Class of 2017+**, the number of required credits for BS Degree will decrease to **129**.

∞ 14:650:388 Computer-Aided Design in Mechanical Engineering (3 cr TE) is strongly recommended for the Biomechanics and Rehab Track.

CLASS OF 2019 + (see below):

∞ **Rule I:** Without **both** 200-level courses (Intro to BME [125:201] **+** Sys. Phys. [125:255])
NO 300-level courses – You MUST see UGD Androulakis for Approval.

∞ **Rule II:** For anyone registering for Senior Design they need to have passed 6 out the 8 core BME courses (**Must complete 309, 310, and 315** PLUS at least THREE out of 303, 304, 305, 306, and 308). So basically, we will allow you to take Senior Design if you fail AT MOST TWO COURSES (without counting for the labs).

∞ **Rule III:** The rule for CO-OP is (assuming you are on track)
--> You MUST to have completed 309/310.
--> You will be allowed to take 304/306/315 as co-reqs in the senior year.
--> You must have successfully completed everything else.

So, basically CO-OP students are allowed one extra course (315) in the senior year.

This is a fair resolution. It requires that you move to Senior Design after having completed successfully a significant fraction of the course-work (6/8) and still we give you the benefit to recover from mishaps without penalizing you with an extra year. If you are 3 or more courses behind, including the labs, YOU should not be in Senior Design.

TRANSFER STUDENTS:

∞ Your curriculum will be determined by the number of credits that are transferred to Rutgers and the remaining courses needed to complete program. The rules above may or may not apply to you. You will find out after your evaluation by the Office of Academic Affairs (OAA).

The OAA handles Transfer Orientation Sessions, please contact that office for more information (848-445-2212).

Department Core Course Requirements

The following is a description of the **Required** core courses that are currently offered by the Biomedical Engineering Department to the School of Engineering undergraduates. Please check with Schedule of Courses online to see which courses will be offered. Although they may appear on list, doesn't mean they are offered.

14:125:201 Introduction to Biomedical Engineering (3)

Prerequisites: 01:640:152 and 01:750:124

Overview of applications of engineering in medicine and healthcare. Introduction to biological and biomedical problems using fundamental concepts and tools from electrical, mechanical, and chemical engineering.

14:125:255 (old 355) **Biomedical Engineering System Physiology (3)**

Prerequisites: (640:152 or 640:192) and (750:124 or 750:203)

Introduction to quantitative modeling of physiological systems geared towards the Biomedical Engineering student. It will cover fundamental topics in physiology ranging from cell membrane models and chemical messengers to neuronal signaling and control of body movement. In addition, specific physiological systems are discussed in detail, including the cardiovascular, pulmonary, and visual systems. Furthermore, pharmacokinetic models provide quantitative assessment of the dynamics of drug distribution and compartmental interactions.

14:125:303 Biomedical Transport Phenomena (3)

Prerequisites: 01:640:244 and 14:125:201 and (14:125:255 or 14:125:355)

Biomedical mass transport processes involving diffusion, diffusion-convection and diffusion-reaction schemes; Introduction to biofluid dynamics; Transport processes in the cardiovascular system, hemorheology, extracorporeal mass transport devices and tissue engineering.

14:125:304 (old 404) **Biomaterials (3)**

Prerequisites: 14:125:201 and (14:125:255 or 14:125:355) OR 14:635:203 and 14:635:204

This course is designed to introduce the subjects of material properties, testing, biomaterial requirements and device design. It is the intention of the instructor to convey the basic knowledge of this large volume of information and to give an elementary understanding of the terminology used in the academic and commercial settings. This will provide the student with rudimentary skills that will allow them to succeed in grasping the ideas and theories of biomaterial science for future work.

14:125:305 Numerical Modeling in Biomedical Systems (3)

Prerequisites: 01:640:244 and 14:125:201 and 14:125:255 and 14:440:127

Introduction to modeling and simulation techniques in the analysis of biomedical systems. Application of numerical methods for the solution of complex biomedical process problems. Development and use of PC computer software for the analysis and solution of engineering problems.

14:125:306 Kinetics and Thermodynamics of Biological Systems (3)

Prerequisites: 01:119:115 and 01:640:244 and 14:125:201 and 14:125:255

Fundamentals of thermodynamics and kinetic analysis as applied to biomedical systems and technologies. Essential principles in thermodynamics will be introduced, including First Law, Second Law, and interrelationships among thermodynamic variables. Fundamental tools in kinetic analysis are also covered, including interpretation of rate data, enzyme kinetics, and pharmacokinetics. Application to biological systems and biomedical technologies are provided.

14:125:308 (old 208) **Biomechanics (3)**

Prerequisites: 01:640:251and 14:125:201 and 14:125:255 and 14:440:221

This course emphasizes the relationship between applied and resultant forces and stresses acting on the musculoskeletal system. Students are exposed to the basic concepts of vectors, internal and external forces, functional anatomy, trusses and equilibria of spatial force systems, moments and work and energy concepts. In addition, students learn about stress and strain tensors, principal forces, viscoelasticity, and failure analysis from classical mechanics.

14:125:309 Biomedical Devices and Systems (3)

Prerequisites: 01:640:251 and 01:750:227 and 14:125:201 and 14:125:255

Co-requisite: 14:125:310

Time and frequency domain analysis of electrical networks; hydrodynamic, mechanical, and thermal analogs; basic medical electronics, and energy conversion systems. Design of biological sensors.

14:125:310 Biomedical Devices & Systems Lab (1)

Prerequisites: 01:640:251 and 01:750:227 and 14:125:201 and 14:125:255

Co-requisite: 14:125:309

Experiments and demonstrations dealing with basic medical electronics and signal analysis. Provides an overview of current biomedical technology and its uses.

14:125:315 BME Measurement and Analysis Lab (2)

Prerequisites: 14:125:201 and 14:125:255 and 14:125:309 and 14:125:310

Experiments and demonstrations dealing with the measurement and analysis of various physiological quantities of cardiovascular and respiratory systems, and the measurement of cellular viability, metabolism, morphogenesis, and protein and nucleic acid composition.

14:125:401/402 and 421/422 Biomedical Senior Design I/II and Projects I/II (1, 2)

Prerequisites: Senior Standing (Passed 6 out of 8 junior level courses)

The purpose of this course is to give the student a comprehensive design experience in the biomedical engineering field. The student will complete a design project under the supervision of a faculty member. The project will typically involve the experimental or computational study of a design-oriented problem in biomedical engineering.

ELECTIVES

Departmental Electives

Please check with Schedule of Courses online to see which courses will be offered. Although they may appear on list, doesn't mean they are offered.

14:125:403 Cardiovascular Engineering (3)

Prerequisites: 14:125:303 and 14:125:306 and (14:125:208 or 14:125:308) and 14:125:315

Introduction to modeling and measurement methods for the cardiovascular system, analysis of blood flow dynamics, the function of the heart, and noninvasive approaches. Applications to cardiovascular instrumentation, basic cardiovascular system research, assist devices, and disease processes.

14:125:409 Introduction to Prosthetic and Orthotic Devices (3)

Prerequisites: 14:125:303 and (14:125:208 or 14:125:308) and 14:125:315

Cross listed with 16:125:540

The course introduces the application of mechanical engineering principles to the design of artificial limbs and braces. Teaching includes basic anatomy and physiology of limb defects, biomechanics, motion analysis, and current device designs. Design and visualization tools will include MatLab, and other application software.

14:125:411 Bioelectric Systems (3)

Prerequisites: 14:125:309 and 14:125: 310

Introduction to the understanding of bioelectric phenomena that occur in physiological systems. This includes the origin of biopotentials, the use of biopotential electrodes in their measurements and subsequent amplification, signal processing and analysis of their physiological relevance. Applications of physical principles and basic electric engineering techniques are emphasized.

14:125:417 Introduction to Musculoskeletal Mechanics (3)

Prerequisite: 14:125:208 or 14:125:308

Introduction to motion-actuation, force-generation, and load- support mechanisms in musculoskeletal system, as explained from basic engineering principles. Experimental and analytical approaches to solve realistic orthopaedic and recreational activities problems.

14:125:424 Biomedical Instrumentation Laboratory (3)

Prerequisite: 14:125:315 **or** 14:332:221 **or** 14:332:373

Practical hands-on designs of biomedical instrumentation including biopotential and physiological signal processing amplifiers, electrodes, biosensor and transducers, electro-optical, acoustic, and ultrasonic devices.

14:125:431 Introduction to Optical Imaging (3)

Prerequisite: 14:125:303 and 14:125:309

Introductory overview of optical phenomena and the optical properties of biological tissue. The course is specifically focused on optical imaging applications in biology and medicine. Topics will include reflection, refraction, interference, diffraction, polarization, light scattering, fluorescence and Raman techniques, and their application in biomedical imaging and microscopy.

14:125:432 Cytomechanics (3)

Prerequisites: 14:125:303 and (14:125:208 or 14:125:308)

This course will cover the structural and mechanical components of cells, with emphasis on the regulatory roles of physical forces in cell function. Cytomechanics emphasizes the processes that drive tissue growth, degeneration, and regeneration. Several subtopics will be addressed ranging from the study of cellular signaling and metabolism, gene expression, to the study of the biomechanical properties of cells and their components.

14:125:433 Fundamentals and Tools of Tissue Engineering (3)

Prerequisite: 14:125:303

Fundamentals of polymer scaffolds and their use in artificial tissues. Regulation of cell responses in the rational design and development of engineered replacement tissue. Understanding the biological, chemical and mechanical components of intra and intercellular communication. Preliminary discussions on real-life clinical experiences.

14:125:434 Tissue Eng II, Biomed and Biotechnological Applications (3)

Prerequisites: 14:125:433

This course will cover the applications of tissue engineering and builds upon the prior course fundamentals and tools. Emphasis is placed on applying the fundamental principles and concepts to problems in clinical medicine and large scale industrial manufacturing. Topics include: skin replacement, cartilage tissue repair, bone tissue engineering, nerve regeneration, corneal and retinal transplants, ligaments and tendons, blood substitutes, artificial pancreas, artificial liver, tissue integration with prosthetics, vascular grafts, cell encapsulation and angiogensis.

14:125:437 Computational Systems Biology (3)

Prerequisites: 14:125:303 and 14:125:305 and 14:125:306

The course will provide an introductory overview of some of the key issues in computational systems biology. The course is designed in a way that will define the systems component and the biology component independently to give the students the opportunity to appreciate the special features of both elements. A novelty of the course is the introduction of medical informatics concepts.

14:125:445 Principles of Drug Delivery (3)

Prerequisites: 14:125:303

Fundamental concepts in drug delivery from an engineering perspective. Biological organisms are viewed as highly interconnected networks where the surfaces/interfaces can be activated or altered 'chemically' and 'physically/mechanically'. The importance of intermolecular and interfacial interactions on drug delivery carriers is the focal point of this course. Topics include: drug delivery mechanisms (passive, targeted); therapeutic modalities and mechanisms of action; engineering principles of controlled release and quantitative understanding of drug transport (diffusion, convection); effects of electrostatics, macromolecular conformation, and molecular dynamics on interfacial interactions; thermodynamic principles of self-assembly; chemical and physical characteristics of delivery molecules and assemblies (polymer based, lipid based); significance of biodistributions and pharmacokinetic models; toxicity issues and immune responses.

14:125:455 BME Global Health (3)

Prerequisites: 14:125:401

This course provides an overview of how biomedical technologies are developed and translated into clinical practice. The course identifies the major diseases facing industrialized and developing countries alongside the technological advances which can be used to tackle these problems. Throughout the course, particular attention will be paid to the economic, ethical, social, and regulatory constraints which often determine the true impact of new technologies.

14:125:465 BME Microfluidics (3)

Prerequisites: 14:125:303 or 14:650:312

Microfluidics is the study of flow phenomena at small length scales with characteristic channel dimensions typically less than the diameter of a human hair. Small length scale effects become important as surface forces such as viscous drag and surface tension govern flow behavior rather than body forces (inertia) as seen in macroscale fluid mechanics. Miniaturization of fluid handling systems also allows the development of cell handling and manipulation devices, or micro Total Analysis Systems (TAS) also called "lab on a chip", which combines biological sample preparation, separation and analysis in a single device. Topics explored in this class include: fundamental understanding and derivation of constitutive balances in fluid mechanics (i.e. Navier Stokes equation), exploration of electrokinetic flow phenomena for electrophoresis, fabrication techniques for microfluidics, overview of (TAS) systems especially capillary electrophoresis and miniaturized polymerase chain reaction for biochips, and exploration of integrated microfluidics for personalized medicine and drug delivery.

14:125:470 - Advanced Biomedical Devices Lab- 3 credits

Prerequisites: 14:125:309, 310, and 315

The course applies the background obtained from the Biomedical Systems and Devices Laboratory and Lecture courses (125:309 and 310) that are restricted to linear systems and devices. This proposed course introduces advanced nonlinear electronics and devices. The Advanced Biomedical Devices lab will also cover: device standards and precision laboratory test methods; introduction to medical device interface systems; biomedical device power sources; wireless data transmission, basic radio systems; the blue tooth standard. Lastly, students will learn how to apply nonlinear data reduction methods to process long duration wireless data records that they will obtain during lab exercises.

14:125:475 - Design and Advanced Fabrication of Biomedical Devices- 3 credits

Prerequisites: 14:125:304

The purpose of this course is to provide an overview of fabrication techniques and bioconjugate chemistry, as applied in the biomedical field. The course will cover topics covering to macro- to molecular-scale considerations for medical devices and implants. Students that complete the course will gain an understanding of the factors that go into the design and fabrication of medical devices as well as the tradeoffs between biomaterials theory and device implementation. They will also have hands-on exposure to digital design tools used in fabrication and observe traditional and cutting-edge fabrication instruments in use.

14:125:489/490 BME Research Scholars Academy (0, 3)

Prerequisite: Biomedical Engineering Research Scholars Academy **Junior** Students Only*

These courses provide advanced research immersion activity and the supporting educational tools for members of the BME Research Scholars Academy that participate within a formalized two-year research experience.
Students work independently with faculty members on a research project of relevance to biomedical engineering. In addition, students meet monthly for roundtable discussions of a wide range of scientific ethical and professional issues.

14:125:493/494 BME Research Scholars Academy (3, 3)

Prerequisite: Biomedical Engineering Research Scholars Academy **Senior** Students Only*

These courses provide advanced research immersion activity and the supporting educational tools for members of the BME Research Scholars Academy that participate within a formalized two-year research experience.
Students work independently with faculty members on a research project of relevance to biomedical engineering. In addition, students meet monthly for roundtable discussions of a wide range of scientific ethical and professional issues.

14:440:404 INNOVATION AND ENTREPRENEURSHIP (3)

The course arms the student with the knowledge and perspective needed to evaluate their research for commercial application, to legally protect their innovation, to seek financial resources for venture monetization, to market and present their ideas to interested parties, and to document their venture details within a business plan. With innovation case studies focused upon engineering in the life and physical sciences, and team-based projects to develop feasibility and business plans, the student can easily bridge the current graduate curriculum, focused upon engineering and science, to its natural and successful application in the businessworld.

16:125:5XX All BME Graduate courses will count as a Department Elective for Undergraduates.
Except 587/588.

Acceptable Technical Electives

Some of the courses listed below have multiple prerequisites. Please check with the Rutgers Schedule of Classes or contact the Department offering these courses regarding updated information about the prerequisites.

Biomedical Engineering

14:125:4XX	**Any of the BME departmental elective courses can be counted toward technical electives.**
14:125:490	BME Research Scholars Academy (Prereq: Research Scholars Academy Juniors Only) (Contact RSA Advisor[s] for permission)
14:125:491/2	Independent Study in Biomedical Engineering in Research (Up to 6 credits count towards technical electives) (Only by approval of the Faculty research advisor)
14:125:493/4	BME Research Scholars Academy (Prereq: Research Scholars Academy Seniors Only) (Contact RSA Advisor[s] for permission)
14:125:495	BME Internship
14:125:496/7	BME Co-op Internship (By Permission of Undergraduate Director Only) [Form at end of handbook]
16:125:5XX	**Any of the BME Graduate 3 credit course can be counted toward technical electives.**

General Engineering

14:440:221.	Engineering Mech
14:440:222.	Engineering Mech
14:440:291	Honors Eng Mech-Stat
14:440:292	Honors Eng Mech-Dyna
14:440:301.	Intro Packaging Eng
14:440:302	Cad For Packaging Engineering
14:440:371	Packaging Eval Mtds
14:440:373	Packaging Manufacturing
14:440:378	Sustainable Packaging
14:440:404	Innovation & Entrepreneurship for Science and tech
14:440:419	Innovation & Design

Anthropology

01:070:349	Advanced Physical Anthropology
01:070:354	Functional and Dev Anatomy of the Primate Skeleton
01:070:358	Introduction to Human Osteology (corequisite: 01:070:359)

Biochemistry (Cook College)

11:115:301	Intro Biochemistry
11:115:403	General Biochemistry I
11:115:404	General Biochemistry II

Biology

01:119:116.	Biology II

Business

33:799:460	Six Sigma & Lean Manufacturing

Cell Biology and Neuroscience

01:146:245	Fundamentals of Neurobiology
01:146:270	Fundamentals of Cell and Developmental Biology
01:146:295	Essentials of Cell Biology & Neuroscience
01:146:302	Computers in Biology
01:146:445	Advanced Neurobiology I
01:146:446	Advanced Neurobiology lab
01:146:450	Endocrinology
01:146:470	Advanced Cell Biology I
01:146:471	Advanced Cell Biology Laboratory
01:146:474	Immunology
01:146:478	Molecular Biology

Ceramics/Material Science Engineering

14:635:203	Intro to Material Science
14:635:204	Processing I
14:635:205	Crystal Chemistry and Structure of Materials
14:635:206	Thermodynamics

14:635:323 Bio Applications of Nanomaterials
14:635:330 Introduction of Nanomaterials
14:635:340 Electrochemical Materials and Devices
14:635:407. Mechanical Properties of Materials
14:635:410. Biological Applications of NanoMaterials and NanoStructures

Chemical and Biochemical Engineering

14:155:201 Material and Energy Balances
14:155:208 Chemical Thermodynamics
14:155:216 Computer-Aided Design and Drafting
14:155:243 Mechanics of Solids
14:155:411 Introduction t Biochemical Engineering
14:155:551 Polymer Science and Engineering I (*by permission from the Graduate Director in CBE)*
14:155:552 Polymer Science and Engineering II (*by permission from the Graduate Director in CBE)*

Chemistry

01:160:307.* Organic Chemistry I
01:160:308* Organic Chemistry II
01:160:311* Organic Chemistry Lab
01:160:323 Physical Chemistry *(Credit not given for this and 341-342)*
01:160:327 Physical Chemistry
01:160:341 Physical Chemistry: Biochemical Systems
01:160:344 Introduction to Molecular Biophysics Research
01:160:409 Organic Chemistry of High Polymers
01:160:437 Physical Chemistry of Biological Systems

Computer Science

01:198:112 Data Structures
01:198:205 Intro Discrete Structures
01:198:206 Intro to Discrete Structures II
01:198:211 Computer Architecture
01:198:314 Principles of Programming Languages
01:198:416 Operating Systems Design
01:198:417 Distributed Systems: Concepts and Design
01:198:424 Modeling and Simulation of Continuous Systems
01:198:433 Integration of Brain + Computer Sciences
01:198:440 Intro to Artificial Intelligence
01:198:476 Advanced Web Applications: Design and Implementation

Electrical and Computer Engineering

14:332:221 Principles of Electrical Eng I
14:332:222 Principles of Elecrical Eng II
14:332:231 Digital Logic Design
14:332:252 Programming Methodology
14:332:346 Digital Signal Processing
14:332:361 Electronic Devices
14:332:373. Elements of Electrical Engineering
14:332:376 Virtual Reality (corequisite: 14:332:378, Cross-listed 16:332:571)
14:332:417 Concepts in Control System Design
14:332:437 Concepts in Digital System Design
14:332:447 Concepts in Digital Signal Processing Design
14:332:448 Digital Signal Processing Design
14:332:452 Introduction to Software Engineering
14:332:461 Pulse Circuits (*Corequisite: 14:332:463)*
14:332:465 Physical Electronics
14:332:466 Opto-Electronic Devices
14:332:468 Microelectronic Processing – Design
14:332:471 Concepts in Robotics and Computer Vision
14:332:481 Electromagnetic Waves

English Department

01:355:302. Scientific and Technical Writing

Genetics

01:447:245 Intro to Cancer
01:447:380 Genetics
01:447:390 General Microbiology

01:447:489 Advanced Independent Study in Genetics
01:447:495 Cancer

Industrial Engineering

14:540:201 Work Design and ergonomics
14:540:210 Engineering Probability
14:540:343. Engineering Economics *(Prereq: Juniors and Seniors only)*

Mathematics

01:640:250. Introductory Linear Algebra
01:640:300. Introduction to Mathematical Reasoning
01:640:321 Applied Mathematics
01:640:325 Foundation of Quantum Mechanics
01:640:350 Linear Algebra
01:640:351 Intro to Abstract Algebra I
01:640:352 Intro to Abstract Algebra II
01:640:354 Linear Optimization
01:640:357 Topics in Applied Algebra
01:640:373. Numerical Analysis I
01:640:374 Numerical Analysis II
01:640:421. Advanced Calculus for Engineering *(Credit not given for both this course and 01:640:423)*
01:640:423. Elementary Partial Differential Equations *(Credit not given for both this and 01:640:421)*
01:640:424 Stochastic Models in Operation Research *(Credit not given for both this and 01:640:250,477)*
01:640:428 Graph Theory
01:640:454 Combinatorics
01:640:495. Selected Topics and Mathematics

Mechanical and Aerospace Engineering

14:650:210 Intro to Aerospace Engineering
14:650:231 Computational Analysis and Design
14:650:291 Mechanics of Materials
14:650:342 Design of Mechanical Components
14:650:388. Computer-Aided Design in Mechanical Engineering
14:650:401 Mechanical Control Systems
14:650:449 Introduction to Mechanics of Composite Materials
14:650:455 Design of Mechanisms
14:650:472 Biofluid Mechanics

Molecular Biology and Biochemistry

01:694:301 Introductory Biochemistry & Molecular Biology
01:694:407/8 Molecular Biology & Biochemistry
01:694:411 Molecular Pathways & Signal Transduction

Pharmacology and Toxicology

30:718:304 Pathophysiology

Pharmaceutics

30:721:301 Introduction to Pharmaceutics
30:721:320 Drug Delivery I and Laboratory
30:721:430. Introduction to Biopharmaceutics and Pharmacokinetics

Physics

01:750:305 Modern Optics
01:750:313 Modern Physics
01:750:406 Introductory Solid State Physics
01:750:417 Intermediate Quantum Mechanics
01:750:464 Mathematical Physics

Statistics

01:960:379. Basic Probability and Statistics
01:960:384 Intermediate Statistical Analysis
01:960:401. Basic Statistics for Research
01:960:463 Regression Methods
01:960:467 Applied Multivariable Analysis
01:960:484 Basic Applied Statistics

*** Organic Chemistry is required for the Pre-Medical School option. It is also strongly recommendedfor the Tissue Engineering and Molecular Bioengineering Tracks in BME.**

Acceptable Life Science Electives "or ANY course from the BME TE list"

Biochemistry (Cook College)

11:115:301	Intro to Biochemistry
11:115:403	General Biochemistry I
11:115:404	General Biochemistry II

Cellular Biology and Neuroscience

01:146:245	Fundamentals of Neurobiology
01:146:270	Fundamentals of Cell and Developmental Biology
01:146:295	Essentials of Cell Biology & Neuroscience
01:146:302	Computers in Biology
01:146:445	Advanced Neurobiology I
01:146:446	Advanced Neurobiology Lab
01:146:450	Endocrinology
01:146:470	Advanced Cell Biology I
01:146:471	Advanced Cell Biology Laboratory
01:146:474	Immunology
01:146:478	Molecular Biology

Genetics

01:447:245	Intro to Cancer
01:447:390	General Microbiology
01:447:495	Cancer
01:680:390	General Microbiology

Molecular Biology and Biochemistry

01:694:301	Intro to Biochem & Mol.Biology
01:694:407	Molecular Biology & Biochemistry I
01:694:408	Molecular Biology & Biochemistry II
01:694:411	Molecular Pathways & Signal Transduction

Pharmacology and Toxicology

30:718:304	Pathophysiology

Psychology

01:830:313	Physiological Psychology

Please refer to:

http://www.soe.rutgers.edu/oas/electives

for list of Humanities/Social Science & General Electives

Office of Academic Affairs (B100) maintains & approves this list.

**** BME supports and approves these listings ****

Tracks in BME

Modern applications of Biomedical Engineering encompass a wide range of technical areas. The goal of the Rutgers Biomedical Engineering Department is to educate its students with a broad base in core biomedical engineering and provide depth in the frontier areas of biomedical engineering profession through exposure to key areas of specialization. The entire spectrum of these application areas is organized into three distinct "tracks". Every student is urged to carefully select one of the three tracks. Based on the choice of the track, the student can then design the appropriate technical elective, life-science elective, and departmental elective supportive of the track at junior and senior levels. In the event there are specific questions related to each track, track faculty advisors should be contacted. More information on the scope and composition of each of the three tracks appears in the order of the tabulated tracks on the following pages. The track compositions will be continually revised to reflect the emerging advances and opportunities in Biomedical Engineering.

*** Please check with the Track Advisors for updates to required and/or recommended track electives.**

{Please see page 3 for Track Advisor(s)}

*** Beyond four (4) BME departmental elective courses can be counted toward technical electives.**

❖ **Your degree will say: "Biomedical Engineering"**
(<u>it will not specify a track</u>)

Track 1. Biomedical Computing, Imaging & Instrumentation (BCII)

Target Audience:

This track is designed to train students who are interested in academic or industrial careers that involve the measuring and modeling of physiological systems, medical imaging, medical image processing and analysis and the graphics and visualization industries. Emphasis is placed both on understanding the physiological system as well as the engineering and development of new sensors and measurement devices. Specialists in Medical Imaging and Medical Image Analysis find careers in small and large industries as well as research centers and universities. This track will also prepare students with a solid background for graduate study.

BME Department Electives for BCII Track

14:125:403	Cardiovascular Engineering
14:125:411	Bioelectric Systems
14:125:424	Biomedical Instrumentation Lab
14:125:431	Introduction to Optical Imaging
14:125:437	Computational Systems Biology
14:125:455	BME Global Health
14:125:465	BME Microfluidics

Recommended Life Science Electives for BCII Track *(see complete list of Life Sciences in Handbook)*

01:146:245	Fundamentals of Neurobiology
01:146:270	Fundamentals of Cell and Developmental Biology
01:146:295	Essentials of Cell Biology & Neuroscience

Recommended Technical Science Electives for BCII Track *(see complete list of TE in Handbook)*

01:198:424	Modeling and Simulation of Continuous Systems
14:332:346	Digital Signal Processing
14:332:361	Electronic Devices
14:332:376	Virtual Reality
14:332:417	Control Systems Design
14:332:448	Image Processing-Design
14:332:466	Opto-Electronic Devices
14:332:471	Robotics and Computer Vision
01:640:350	Linear Algebra
01:640:421	Advanced Calculus for Engineering
01:750:305	Modern Optics

Track 2. Biomechanics and Rehabilitation Engineering (BRE)

Target Audience:

The biomechanics "option" has added emphasis on tissue and fluid mechanics, whereas the rehabilitation engineering option has an emphasis on prosthetics and assisted devices. Track-specific electives have been identified as more appropriate for an emphasis on rehabilitation engineering (R) and/or biomechanics (B). Students undertaking this curriculum will be well prepared for employment in the medical device industry (orthopedic, imaging, cardiovascular), and positions involving direct contact with health care, rehabilitation, and human performance. The track is also an excellent background for students seeking advanced degrees in engineering, medicine, and physical/occupational therapy.

BME Department Electives for BRE

14:125:409	Introduction to Prosthetics (R)
14:125:417	Musculoskeletal Mechanics
14:125:432	Cytomechanics (B)
14:125:433	Tissue Engineering I: Fundamentals and Tools (B)
14:125:434	Tissue Engineering II: Biomedical and Biotechnological Applications (B)
14:125:455	BME Global Health
14:125:460	Motor Control & Motion Analysis
14:125:465	BME Microfluidics

Recommended Life Science Electives for BRE Track *(see complete list of Life Sciences in Handbook)*

01:146:270	Fundamentals of Cell and Developmental Biology (B)

Recommended Technical Science Electives for BRE Track *(see complete list of TE in Handbook)*

14:155:551	Polymer Science and Engineering I
14:155:552	Polymer Science and Engineering II
14:332:376	Virtual Reality
14:332:471	Robotics and Computer Vision
14:440:222	Dynamics
14:540:461	Engineering Law
14:635:320	Introduction to Nanomaterials
14:635:407	Mechanical Properties of Materials
01:640:421	Advanced Calculus for Engineering
14:650:342	Design of Mechanical Components
14:650:388	Computer-Aided Design
14:650:401	Control Systems
14:650:455	Design of Mechanisms
14:650:472	Biofluid Mechanics (B)
01:960:384	Intermediate Statistical Analysis

Track 3. Tissue Engineering and Molecular Bioengineering (TEMB)

Target Audience:

This track is designed for students who desire to apply engineering principles to the development of biomedical technologies underlying tissue engineering, biomaterials design and applications, and molecular medicine. An emphasis is placed on biochemistry and on molecular and cell biology in the life sciences arena and on thermodynamics, kinetics, and transport and materials sciences within the engineering sciences. Students undertaking this curriculum will be well prepared for employment in the tissue engineering, pharmaceutical and biotechnology industries, for medical school, or for graduate study in Biomedical Engineering.

BME Department electives appropriate for TEMB

14:125:433	Tissue Engineering I: Fundamentals and Tools
14:125:434	Tissue Engineering II: Biomedical and Biotechnological Applications[1]
14:125:437	Computational Systems Biology
14:125:445	Principles of Drug Delivery
14:125:455	BME Global Health
14:125:465	BME Microfluidics

Recommended Life Science Electives *(see complete list of Life Sciences in Handbook)*

01:694:301	Intro. to Biochemistry & Molecular Biology
01:694:407	Molecular Biology & Biochemistry I
01:694:408	Molecular Biology & Biochemistry II
01:146:270	Fundamentals of Cell and Developmental Biology

Recommended Technical Science Electives *(see complete list of TE in Handbook)*

01:146:474	Immunology
01:146:470	Advanced Cell Biology I
14:155:411	Introduction to Biochemical Engineering
14:155:551	Polymer Science and Engineering I
14:155:552	Polymer Science and Engineering II
01:160:409	Organic Chemistry of High Polymers
01:447:380	Genetics
14:635:320	Introduction to Nanomaterials
14:635:323	Bio. Applications of Nanomaterials
01:640:250	Introduction to Linear Algebra
01:640:421	Advanced Calculus for Engineering
01:694:411	Molecular Pathways and Signaling
01:960:379	Basic Probability and Statistics
01:960:384	Intermediate Statistical Analysis

Special Programs

Declaring a Minor

There are no official minors in any engineering subject. It is possible for students to pursue 2 engineering BS degrees, simultaneously or sequentially. In this case only 1 set of humanities/social science electives need to be completed.

Declaring a Different Major within Engineering

Careful thought should precede any change of curriculum. Students should consult the executive officers or appropriate faculty advisors in the two majors.

Double Major vs. Dual Degree

A Double Major means that you must fulfill the 'major requirements' as described for that department (refer to the Undergraduate catalog for details). Generally, a second major is in the area of 30 credits. You would remain a School 14 student, but you would have the second major denoted on your transcript.

A Dual Degree means that you apply to the other college and be accepted. After you are accepted, you must fulfill all requirements for the BA for that college (like Rutgers College or Cook College). This is a more involved process and includes additional work on top of the ~30 credits for the major. For example, if you declare a technical major like Mathematics or Physics, Rutgers College requires that you take additional non-western humanity courses as well as completing a minor in a H/SS area. Consult the specific college for more details.

You would receive two separate degrees, one from each school. If you do not complete both degrees concurrently (example, you have a few classes left for you BA, and you decide to graduate with just your BS from Engineering), you may not come back to finish your remaining classes and obtain the second degree.

For either option, refer to the department in which you want to get the major/degree for advice on course selection, and check the RU catalog and departmental websites. Fill out the form and bring it to EN B100 (Academic Affairs).

B.S./M.B.A. Program

Qualified candidates for the Bachelor of Science (BS) degree in the School of Engineering are given the opportunity to obtain the Master of Business Administration (MBA) degree from the Rutgers Graduate School of Management in one year of academic work following the completion of the requirements for the BS degree.

If accepted into the program, during the fourth year, BME students will take graduate courses towards the MBA degree which will be offered at Rutgers Business School: Graduate Program — Newark and New Brunswick's campuses. The fourth year is declared as the senior year of undergraduate school. The student, consequently, receives the benefit of undergraduate tuition rates. At the end of the fourth year, students should have completed successfully all undergraduate requirements for the BS Degree. During the fifth year, the students will complete graduate studies and receive the MBA degree.

A 3.0 grade point average is required. The GMAT should be taken during the junior year. The application to the MBA program should be pursued during the spring semester of the junior year. Please contact the Business School for more information.

B.S./M.S. Program

The goal of the BME B.S./M.S. Program is to allow academically qualified students to receive the B.S. and M.S. degrees for BME in a shortened time frame (5 years). It is strongly recommended students use the James J. Slade Scholars program (below) along with the BS/MS program. This highly intensive academic program gives students more research experience and better prepares them for research and development careers or further graduate study.

B.S./M.D. Program

BME students either are not eligible to do the BS/MD program or that they will be expected to take the full 4 years to complete the program.

James J. Slade Scholars Program

Administered through Office of Academic Affairs

www.soe.rutgers.edu/oaa

Application & Completion forms for James J. Slade Scholar can be found on the above link

Please complete forms in its entirety.

Please read Completion Form as well to know what is required of you. No Allowances will be permitted.

Directed Research in Biomedical Engineering

These courses (291,292) provides opportunity to students (with 3.25 or higher GPA) to participate in research project earlier within biomedical engineering environment. The underclass students are provided with appropriate facilities and other professional development opportunities.

Note: The credits earned are extra and they **do not count towards** the graduation requirements of BME Degree.

Prerequisite: Permission of department.

****Extra Special Problem courses (491-492) credits or other technical courses may be used to replace up to four required technical courses (including those in the major) with the approval of research advisor and executive officer.***

Industrial Interactions

The Rutgers University Biomedical Engineering Industrial Internship Program has successfully assisted students in obtaining internships for over ten years. We are proud of our role in helping students to gain industry experience.

Effective Fall 2014, BME will now take on the role of a liaison between our department and career services.

Recently, Career Services has reorganized and they will be assisting you with career development and employment opportunities. They have a variety of resources (CareerKnight, Online Career Self-Assessment and Planning, On-Campus Interviewing Program), various clinics (Mock Interview Clinic, Drop-in Resume Clinic, Networking Clinic, Internship Clinic) and the staff (Liaisons for Engineering: Joe Scott, Tamara Peters and Mindy O'Mealia) to provide you with the guidance you will need and the career opportunities you are seeking.

Your next step should be to access the CareerKnight system at http://careers.rutgers.edu. All students automatically have a CareerKnight account. This system will allow you to begin your career development plan from scheduling an appointment with a career counselor to applying for internships. You can also contact Career Services at 848-932-7997, if you have any questions.

If you have any questions, please feel free to send me an email to Robin Yarborough at ryarboro@rci.rutgers.edu or stop by her office in the Biomedical Engineering Building, Room 112.

Co-op Program

The Co-op program is a formal mechanism where students earn course credits by working for a local company for six months (one semester plus a summer). This provides the students with a capstone experience to the undergraduate curriculum by integrating prior coursework into a working engineering environment. Previous Co-op students have worked at companies such as Johnson & Johnson Ethicon, Johnson & Johnson McNeil, Howmedica Osteonics, and Boston Scientific. Please see the Undergraduate Director for approval.

Faculty Research Expertise

Ioannis P. Androulakis	Ph.D., Purdue University *Novel computational algorithms, microarray experiment and molecular dynamics simulations, combustion phenomena*
Francois Berthiaume	Ph.D., Pennsylvania State University *Wound Healing, Tissue Engineering & Regenerative Medicine, Metabolic Engineering*
Nada Boustany	Ph.D., Massachusetts Institute of Technology *Biomedical Imaging, Cellular Biophysics, Optical Microscopy*
Helen Buettner	Ph.D., University of Pennsylvania *Nerve growth and regeneration, cellular engineering, modeling of biological processes, computer graphics and simulation, video microscopy*
Li Cai	Ph.D., Dana Farber Cancer Institute *Nerve growth and regeneration, cellular engineering, modeling of biological processes, computer graphics and simulation, video microscopy*
William Craelius	Ph.D., Northwestern University *Ion channels in cell membranes, molecular electronics cardio-neural reflexes*
Gary Drzewiecki	Ph.D., University of Pennsylvania *The cardiovascular system, new methods of blood pressure determination, mathematical models of the normal and diseased heart, study of flow in circulation, application of chaos and fractals*
Joseph Freeman	Ph.D., Rutgers University *Tissue engineering, Biomechanics, Biomaterials, and Musculoskeletal regeneration*
Adam Gormley	Ph.D., University of Utah *Biomaterials, nanomedicine, self-assembly, biosensing and diagnostics*
Ilker Hacihaliloglu	Ph.D., University of British Columbia *Biomedical Imaging, Computer Assisted Surgery, Image Guided Orthopedic Surgery*
Kristen Labazzo	Ph.D., Rutgers University *Biomaterials, mesenchymal stem cells, medical devices, assistive technologies*
Noshir Langrana	Ph.D., Cornell University *Orthopedic biomechanics, biomechanical design, finite element methods and tissue engineering*
John K-J. Li	Ph.D., University of Pennsylvania *Cardiovascular mechanics, biosensors and transducers, cardiac arrhythmias and assist devices, controlled drug delivery systems, ultrasound and electro-optics*

Adrian Mann	D. Phil., Oxford University *Biomaterial fabrication and characterization, Nanomechanics and Nanoprobe Microscopy*
Prabhas Moghe	Ph.D., University of Minnesota *Cell and tissue engineering, Cell-interactive Biomaterials, Micro/Nanobiotechnology*
Ronke Olabisi	Ph.D., University of Wisconsin *Biomechanical, computational, histological and tissue engineering tools*
Thomas Papathomas	Ph.D., Columbia University *Modeling of motion, texture and stereo mechanisms of the human visual system, psychophysical experimentation and image processing, computer vision, and scientific visualization*
Biju Parekkadan	Ph.D., Harvard-MIT Division of Health Sciences and Technology *Cell & Genetic Engineering, Bioreactor engineering, Regenerative Medicine & Immunotherapy*
Mark Pierce	Ph.D., University of Manchester *Biomedical optics, Microscopy, Contrast agents, Cancer imaging*
Charles Roth	Ph.D., University of Delaware *Molecular bioengineering; nucleic acid biotechnology; liver systems engineering; cancer therapeutics*
Troy Shinbrot	Ph.D., University of Maryland *Nerve regeneration; structure from noise; pharmaceutical engineering*
George Shoane	Ph.D., University of California, Berkeley *Biological Control and Feedback; Biomedical Modeling*
David Shreiber	Ph.D., University of Pennsylvania *Tissue engineering, injury biomechanics, and nerve regeneration*
Jay Sy	PhD, Georgia Institute of Technology & Emory University *Drug delivery, Biomaterials, Medical Devices*
Maribel Vazquez	Sc.D., Massachusetts Institute of Technology *Microfluidics-based biosystems, neural cell migration and retinal regeneration*
Martin Yarmush	Ph.D. Rockefeller University M.D. Yale University School of Medicine *Tissue engineering, molecular bioengineering, bioseparations and biothermodynamics, and metabolic engineering*
Jeffrey Zahn	Ph.D., University of California, Berkeley *Microfabrications and microfluidics*

Forms Rules

Internship in Biomedical Engineering: Courses graded as Pass/No Credit can be counted as 3 credit technical electives.

The UAB has agreed to accept up to 6 credits in experiential based learning toward the Engineering degree in addition to the capstone design. Exceptions can be made by the UGDs to accept up to 9 credits max. We had an implicit rule for making such an exception:
- We accept 9 credits max for students who have completed both an Internship (125:495; 3 credits) and a co-op (125:496/497; 6 credits)
- We accept 6 credits max for students who have not completed a co-op, which means two 3-credit Internship courses can be counted.

Some additional notes:
- For any given semester, students can only take up to 6 credits of experiential based learning, so students are not allowed to register co-op and internship together.
- By default, departmental Independent Study courses are also considered as experiential based learning, so they are part of the mix as well. UGDs can override this default if an independent study is offered in a classroom setting.

Application for Directed Research 14:125:291/292

DEPARTMENT OF BIOMEDICAL ENGINEERING

**** FRESHMAN AND SOPHOMORE STUDENTS ****

Instructions:

1) **MUST be a BME Student with GPA of 3.25 or higher.**
2) **Complete this form and obtain all required signatures.**
3) **Submit it to the Undergraduate Program Administrator in BME-110 for the Special Permission Number in order to register during registration period.**
4) **Use the Special Permission number given to register for 3 credits ! to be a full-time student only**
5) **CREDITS Do Not count toward BS DEGREE. No Exceptions !**
6) **Advisor(s) must submit grade via email to Undergraduate Director promptly during grading period. (Grades of A, B, and C correspond to Pass)**

Student's Name (Print)_____**,**_____**#**_____
(Last) (First) (RUID)

E-Mail: _____ **Avg. GPA:** _____

Semester: _____ **Class of:** _____

Are you on academic probation? Yes _____ **No** _____

***Print advisor(s) name(s):** _____

Project Title:

_____

_____

_____

Approval Signature(s) of Supervising Advisors(s):

_____

Department Chair or Undergraduate Director's Signature:

_____**Date:** _____

Signature of Student:_____**Date:** _____

Index Number: _____ **Special Permission Number:**_____

Appl. for Independent Study in BME 14:125:491/492 (3 cr.)

DEPARTMENT OF BIOMEDICAL ENGINEERING

**** JUNIOR AND SENIOR STUDENTS ****

Instructions:

1) **Complete this form and have it signed by the research advisor you will be working under.**
2) **Submit it to the Undergraduate Program Administrator in BME-110 for the Special Permission Number in order to register during registration period.**
3) **Use the Special Permission number given to register for 3 credits !**
4) **TECHNICAL ELECTIVE credit only. No Exceptions !**
5) **You must have completed Devices Lecture and Lab to be eligible.**
6) **Advisor(s) must submit grade via email to Undergraduate Director promptly during grading period.**

Student's Name (Print)_____,_____#_____
(Last) (First) (RUID)

E-Mail: _____ **Avg. GPA: _____**

Semester: _____ **Class of: _____**

Are you on academic probation? Yes _____ No _____
If yes, you cannot receive credit for Independent Study in Biomedical Engineering.

(Maximum number of credits students can earn for Independent Study in Biomedical Engineering is six, but no more than three in any semester.)

***Print advisor(s) name(s): _____**

Project Title:

_____

_____

If you are not a BME student,
Please give your department name: _____

Approval Signature(s) of Supervising Advisors(s) and Email Address(es):

_____Email: _____

Signature of Student:_____Date: _____

Index Number: _____ **Special Permission Number:_____**

BME Research Scholars Academy

****MUST BE ENTERING JUNIOR YEAR IN ORDER TO APPLY****

For Online Application- http://rci.rutgers.edu/~rmo45/ha/

The BME Research Scholars Academy is designed for a highly selective group of biomedical engineering undergraduates, who, based on their demonstrated academic record and/or research potential, are given the opportunity to immerse themselves in an accelerated research program at Rutgers. It is anticipated that most Research Scholars Academy members will go on to further graduate and/or professional training after graduation.

- Applications are submitted online by Aug. 31st (junior year). We adhere to a minimum 3.5 GPA. Student must have made arrangements with the prospective mentors prior to filling out the application.
- Selected candidates are provisionally admitted to the RSA and are assigned to mentors by the end of September (junior year).
- Students are evaluated by their mentors during the remaining of the fall semester and a final decision for accepting a student into the RSA is made by the mentor by the end of the semester and is communicated to the faculty responsible for the RSA program. We will establish general guidelines regarding what constitutes an evaluation. The process needs to be clear and transparent and students need to be aware of what is required of them. Students who fail during the probation period cannot re-apply and /or be assigned to a different faculty member. The final decision is not negotiable. The fall semester of the junior year is a trial period for which students do not receive credit for.
- Students admitted to the RSA register for the upcoming 3 consecutive semesters (490 spring junior, 493 fall senior, 494 spring senior) and receive 9 credits and policies are the same. No co-op is allowed unless it is the result of prior coordination between the mentor and the industrial partner and it involves work related to a student's HA project.
- Grading Policy:
  a. active participation of research in mentor's lab
  b. presentation on RSA student's research project (RSA project and Senior Design project should be different, if they are the same, significant amount of efforts should be put into the project)
  c. a short project report (includes: Abstract, Intro, Methods, Results, and Discussions) to both the mentor and the RSA coordinator.
  d. participation of RSA activities (e.g., seminars on poster preparation, preparation for Graduate/ Medical school applications, Graduate/Medical student lives, etc.)
- The Academy members are nominated for the Rutgers University Research Fellowship (RURF) and other appropriate fellowship opportunities.
- In appropriate cases, the Academy members will be supported by faculty research grants through Research Experiences for Undergraduate Supplements or other federal and industrial grants.

REGISTRATION FOR CREDITS: The Research Scholars Academy members can count up to six credits of Advanced BME Research (125:493 or 494) toward their BME technical electives or BME departmental electives. (**In addition**, Academy members can count a maximum of three credits of Independent Study in Biomedical Engineering (125:491, 492) electives toward their technical electives.

Note: Students that do not belong to the Research Scholars Academy and perform individual research with a BME faculty can count up to six credits of Independent Study in Biomedical Engineering in Research (125:491, 492) toward their technical electives, but they will not be allowed to register for 125:493 or 125:494, nor count any of their research toward departmental elective requirements.

For further information on the Research Scholars Academy, including application procedure, **please contact Dr. Ronke Olabisi,** See Faculty Locator page for info.

Application for Internship 14:125:495 (3 cr.)

DEPARTMENT OF BIOMEDICAL ENGINEERING

*This form **MUST** be completed **before** registering for Internship. It must be approved by the Undergraduate Director. Then given to Undergraduate Administrator, who will assign a special permission number.*

I. PERSONAL INFORMATION

Student's Name (Print)_____,_____
(Last) **(First)**

Phone: _____ Class of: _____

Email: _____ **RUID#**_____

II. EMPLOYER INFORMATION

Employing Institution: _____

Supervisor/Contact Name(s):

1. _____ 2._____

Phone/Fax: _____ Phone/Fax: _____

Email: _____ Email: _____

Job Description: _____

_____

_____

_____

III. Regulations:

1. Internship credits counts as a **Technical Electives ONLY. No Exceptions!**
2. Graded on a **Pass/No Credit** scale
3. Final report (1-2 pages) **MUST** be submitted to ***UG Director*** at end of Internship summarizing work
4. Supervisor(s) **MUST** submit evaluation to ***UG Director*** at the end of the Internship
5. Register during open registration period.
6. **Limit is TWO** Internship 3cr. Courses will count towards degree.

IV. Signatures:

I have read the above regulations *and* understand the rules for my Internship assignment

Student's Signature:_____Date: _____

UG Director Signature:_____Date: _____

Index Number: _____ **Special Permission Number:** _____

Application for CO-OP 14:125:496/497 (6 cr.)

DEPARTMENT OF BIOMEDICAL ENGINEERING

*This form **MUST** be completed **before** registering for Co-op. It must be approved by the Undergraduate Director. Then given to Undergraduate Administrator, who will assign a special permission number.*

I. **PERSONAL INFORMATION**

Student's Name (Print)_____,_____#_____
(Last) (First) (RUID)

Phone: _____ Class of: _____

Email: _____ Course: 125:496____or 125:497_____

II. **EMPLOYER INFORMATION**

Employing Institution: _____

Supervisor/Contact Name(s):

1. _____ 2._____

Phone/Fax: _____ Phone/Fax: _____

Email: _____ Email: _____

Job Description: _____

III. **Regulations:**

a. Co-op credits counts as a **Technical Electives ONLY. No Exceptions!**
b. Graded on a **Pass/No Credit** scale
c. Final report (1-2 pages) **MUST** be submitted to ***UG Director*** at end of Co-op summarizing work
d. Supervisor(s) **MUST** submit evaluation to ***UG Director*** at the end of the Co-op
e. **Only TWO** courses may be taken while on Co-op. Only **ONE** course during the day
f. **MUST** work ****continuously**** for 6 months **(Semester + Summer [not negotiable])**
g. ***Full-time*** job assignment required
h. Register during open registration period.
i. Non-compliant with all above – NOT ELIGIBLE FOR CO-OP…see Independent Study in Biomedical Engineering.
j. **Only ONE** Co-Op will count towards degree.

IV. **Signatures:**

I have read the above regulations *and* understand the rules for my co-op assignment

Student's Signature:_____Date: _____

UG Director Signature:_____Date: _____

Index Number: _____ **Special Permission Number:** _____

*Revised November 20, 2018

5-Year Combined Bachelor's/Master's Program

Department of Biomedical Engineering

Objectives

The goal of the BME B.S./M.S. or B.S./M.Eng 5-Year Program is to allow academically qualified students to receive the B.S and M.S. /M.Eng degrees in a shortened time frame (up to 5+ years total for the BS/MS/ME). This highly intensive academic program gives students more research experience and better prepares them for research and development careers or further graduate study. Completing the B.S./M.S. or B.S./M.Eng Program is possible if the candidate also enrolls in the J.J. Slade Scholars Program and take graduate-level courses in the senior year **in addition to** completing all of the undergraduate degree requirements. (Courses cannot double-count for both UG requirements and graduate credit)

Eligibility

In order to be considered for the B.S./M.S. or B.S./M.Eng Program, candidates must:

1. Have a GPA of 3.0 or higher and maintain at least a 3.2 GPA throughout Senior Year;
2. Apply after the end of Spring exams but before July 1 going into the Senior Year;
3. Also apply to the J.J. Slade Scholar Program by July 1: https://soe.rutgers.edu/slade
4. Have completed most, if not all, the School of Engineering Undergraduate requirements for General, Humanities and Social Science Electives by the start of Senior Year;
5. Have three letters of recommendation and a personal statement. At least one of the letters must be from the candidate's research and/or intended J.J. Slade Scholar faculty advisor.

*There is no GRE requirement although the GRE's will be required to apply for a PhD program or any type of future funding or fellowships.

*** Remember, candidates must apply to BOTH BME's 5-Year Program and SoE's J.J. Slade Program.**

Curriculum

The B.S./M.S. or B.S./M.Eng Program requires the student to take up to 24 Undergraduate credits during the Senior Year and 33 Graduate level credits during Senior and Graduate Years (5th Year). The timeline for the Program is as follows:

After Spring Finals of the Junior Year: Candidates should identify an advisor for their Slade Scholar Research and apply for the James J. Slade Scholars Program (2 separate programs). Apply to BOTH programs by July 1.
Summer following the Junior Year: Begin/identify the Slade Project and faculty advisor.
Senior Year: Take Slade Scholar Research courses. The 587/588 credits will count only as elective course credits towards the M.S. or. M.Eng degree. This Slade research may become the thesis topic for the M.S. degree, but students are not tied to continue the Slade project for the master's.
Fifth Year (1st graduate year): Remainder of master's courses and work on the master's thesis or project. Candidates can take fewer courses, but this would lengthen the duration of the master's degree.
Summer and Fall following the Fifth Year: If necessary, students will complete the M.S. thesis and defend it or present the M.Eng project.

Please Note:

1) Students can change advisors at the end of the B.S. Senior year, as the Slade Scholar topic does not necessarily have to be the M.S. thesis or M.Eng topic.
2) You need to graduate with a B.S. at the end of the spring semester of your 4th year to continue (officially) in the master's program, as a full-fledged graduate student, starting in the 5th year.
3) Continuation in the BS/MS or BS/M.Eng program is contingent on receiving **no more than one C grade** in the graduate courses in the 4th year.

*Revised November 20, 2018

Sample BME 5-Year Bachelor's/Master's Curriculum

Summer: Rising 4th year undergraduate/1st year "graduate" (technically an undergraduate still)

Slade Scholar Thesis Research Begins

Fall: 4th year undergraduate/1st year "graduate" (technically an undergraduate still)

14:125:401/421	Senior Design I	3
xx:125:xxx	Departmental Elective	3
xx:125:xxx	Departmental Elective	3
xx:xxx:xxx	Technical Elective	3
16:125:587	Slade Scholar Thesis Research I	3
16:125:xxx	Graduate Core Course **or**	3 (1 of 2 courses)
16:125:xxx	Graduate Elective Course	

12 UG credits, 6 graduate credits

Spring: 4th year undergraduate/1st year "graduate"

14:125:402/422	Senior Design II	3
xx:125:xxx	Departmental Elective	3
xx:125:xxx	Departmental Elective	3
xx:xxx:xxx	Technical Elective	3
14:125:588	Slade Scholar Thesis Research II	3
16:125:xxx	Graduate Core Course **or**	3 (1 of 2 courses)
16:125:xxx	Graduate Elective Course	

12 UG credits, 6 graduate credits

Fall: 2nd year graduate (Official Graduate Student in Graduate School)

16:125:xxx	Graduate Core Course **or**	3 (1 of 2 courses)
16:125:xxx	Graduate Elective Course	
16:125:501	BME Math Modeling Course	3
16:125:701	Research (MS Only)	3
16:125:699	Non-Thesis Study (M.Eng Only)	3
16:125:601	Engineering Ethics and Seminar	1

Spring: 2nd year graduate

16:125:xxx	Graduate Core Course **or**	3 (1 to 3 courses as needed)
16:125:xxx	Graduate Elective Course **or**	
16:125:586	BME Cell Biology Course	3
16:125:628	Clinical Practicum	1
16:125:702	Research (MS Only)	3
16:125:699	Non-Thesis Study (M.Eng Only)(as needed)	3
16:125:602	Engineering Writing and Seminar	1

Summer: 2nd year graduate

Finish up Thesis or M.Eng project

Summary:

Sample Undergraduate Curriculum for Year 5: 24 credits

Senior Design I & II
4 Departmental Electives
2 Technical Electives

Master's Curriculum: 33 credits minimum

3 Core Courses (out of 5)	9 credits
1 BME Math Methods Course	3 credits
1 BME Adult and Stem Cell Biology Course	3 credits
3 One-Credit Developmental Courses	3 credits
2 Slade Scholar 587/588 Courses as Electives	6 credits
1 Elective Course (2 electives if pursuing M.Eng)	3 or 6 credits
If pursuing MS: 6 Research Credits/ M.Eng: 3 Non-Thesis Study Credits	3 or 6 credits

33 Total Graduate Credits

*Revised November 20, 2018

Application for 5-Year Bachelor's/Master's Program

RUTGERS UNIVERSITY

DEPARTMENT OF BIOMEDICAL ENGINEERING

Instructions:

1) Fill out this application and attach your personal statement and transcript.

2) Have three letters of reference sent to Lawrence Stromberg in BME-111. (YOU SHOULD NOT SEE YOUR OWN LETTERS) Email: les42@soe.rutgers.edu

3) Send/Email the completed application package to Lawrence Stromberg in BME-111 after the spring semester final exams end but before July 1.

Please Type or Print Legibly

Name: _____ RUID: _____

Home mailing address: _____

_____

Campus mailing address: _____

RU and Non-RU Email Addresses: _____

Overall GPA: _____ Major GPA (If known): _____

Year started at Rutgers: _____ Credits completed so far: _____

Expected graduation date (BS degree): _____

Faculty advisor who will supervise the Slade Scholar Research (Slade advisor must submit a reference letter):

_____

Title of Slade project (if known already):

_____

1) Name of first reference (Slade Advisor): _____

2) Name of second reference: _____

3) Name of third reference: _____

"I have read and understand the requirements for the BME 5-Year BS/MS or BS/M.Eng degrees":

Student Signature: _____ Date: _____

For BME Use Only: Admit Conditional Admit Deny Date: _____

Comments/Reasons: _____

_____

Undergraduate Program Director Approval: _____

Graduate Program Director Approval: _____