BIOMEDICAL ENGINEERING

GRADUATE STUDENT HANDBOOK

RUTGERS
School of Graduate Studies

RUTGERS
School of Engineering

https://bme.rutgers.edu/graduate-program

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Biomedical Engineering History and Overview

Biomedical Engineering 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. Finally, the Masters of Engineering (M.Eng) degree was approved in BME in June 2012. On July 1, 2013, UMDNJ became a part of Rutgers. The former UMDNJ Graduate School in Biomedical Sciences (UMDNJ- GSBS) became the Rutgers Biomedical and Health Sciences (RBHS). Our program was considered "joint" with the Rutgers Graduate School of New Brunswick (RU-GSNB) and RBHS-GSBS. In July 2017, GSNB and GSBS merged to form one graduate school named the School of Graduate Studies (SGS).

The graduate program in Biomedical Engineering includes over 70 faculty from Rutgers science and engineering departments, Robert Wood Johnson basic biomedical and engineering clinical science departments, other academic institutions in the area, and researchers from local industry.

As of February 2025, the department census is as follows:

- 26 core departmental faculty
- 83 graduate program faculty
- 3 educational and administrative staff members
- more than 361 undergraduate students
- 20 M.S., 8 M.Eng, and 4 Doctoral Track Masters students
- 47 Ph.D. students

The BME building (shown on the cover) was dedicated on April 18, 2007 and has about 80,000 square feet of high quality educational and research space and houses state-of-the art micro fabrication, tissue culture, and microscopy laboratories, including small animal facilities. The BME department is located on the Busch Campus in Piscataway.

The Department hosts and co-hosts a number of nationally recognized research and training programs including:

- NIH Biotechnology and Bioengineering Ph.D. Training Program
- NIH Postdoctoral Training Program in Tissue Engineering and Implant Science

Faculty within the Department of Biomedical Engineering hold prominent positions in the following university-wide "Centers-of-Excellence":

- Rutgers Engineering Research Center on Structured Organic Compounds
- Rutgers Center for Advanced Biotechnology and Medicine
- Rutgers Center for Computational Bioengineering, Imaging and Modeling
- Rutgers Center for Pharmaceutical Science and Engineering
- Princeton-Rutgers Center for Biomolecular Imaging
- Rutgers Center for Packaging Science and Engineering
- Rutgers Laboratory of Vision Research
- Rutgers Center for Advanced Information Processing
- Institute for Quantitative Biology
- Stem Cell Institute of New Jersey
- Cancer Institute of New Jersey

Graduate Program Description

The mission of the graduate program is to provide outstanding graduate level training in critical areas of biomedical engineering and technology. Thesis/dissertation/projects may straddle multiple areas given that these areas are broadly defined and overlapping.

- Molecular, Cellular, and Nanosystems Bioengineering
- Biomaterials, Tissue Engineering, and Regenerative Medicine
- Nano-Microsystems Engineering
- Biomechanics and Rehabilitation Engineering
- Physiologic Systems and Bioinstrumentation
- Computational Modeling
- Biomedical Imaging

All graduate students (M.S., M.Eng and Ph.D.) must take: three of five BME core courses; one advanced engineering mathematics course; one advanced course in molecular biology of cells; bioengineering electives; Clinical Practicum; Engineering Ethics; Engineering Writing; and BME Seminar course each fall/spring after taking 601/602. Students must have a background in Physiology at the undergraduate level or graduate physiology courses must be taken. PhD students are required to take Life Science/Medical electives and can elect to receive the M.Eng degree after successfully completing their oral PhD Proposal Defense. Students are expected to attend the Biomedical Engineering Seminar Series throughout their graduate careers. The M.S., M.Eng and Ph.D. curriculum can be found starting on page 10. Students are encouraged to take a Biostatistics course during their first year to aid in data analysis. The M.S. degree requires 6 research credits. M.Eng requires 3 non-thesis study credits. The Ph.D. requires at least 34 research credits and 3 "rotation" credits.

The department wants each student to excel in their studies and to facilitate that, grades of "C+" or below in any core/required BME course will be handled as follows: One C+ = notification of probation. Two C+'s = warning that upon the third C+ grade, the student must leave the Program. Three or more C+'s = Immediate de-registration and failure to register in future semesters.

During the first academic year, students are required to select their dissertation research advisor. Selection must take place no later than the end of the first summer (beginning of next summer for students entering in January). During the first summer of the M.S. and Ph.D. programs,

each student has the option to complete a one-month research rotation with three different principal investigators if they are unable to determine an advisor by that time. All Ph.D. students must undergo an Annual Research Meeting and have a form signed by the committee and advisor and submitted for the Graduate Program Director. Information for this procedure starts on page 18.

At the end of the first academic year (June), students admitted to the PhD program must a qualifying exam. This Procedure is comprised of a written literature review and research proposal (along the lines of a NIH proposal) presented to and evaluated by a panel of faculty examiners, during the month of June after the first year of graduate studies. See additional information on Pages 13 and 32 for details. This research proposal is distinct from a thesis proposal and should not be confused with the PhD thesis proposal presentation described below. **The outcomes of this procedure in combination with core course-based performance will be used to determine qualification for PhD Candidacy.**

In collaboration with the research advisor, the Ph.D. student will formally defend a proposed dissertation topic, preferably by the end of the second academic year and in any case no later than at the end of the fall semester of the third academic year. Ph.D. students should plan to defend their thesis dissertation by the end of their fifth year. **It is a Graduate School regulation that students must complete all of their Ph.D. work no later than 7 years after entering the program.** Rutgers BME students are expected to maintain the highest academic standards. Beyond the requirements of the School of Graduate Studies, the BME Graduate Program permits no more than 2 grades below a B: students whose grades fall below this standard will be required to leave the program. The department is committed to being flexible to meet our students' needs in reaching these goals, however, we seek at the same time to advance our students toward robust and successful scientific and engineering careers, and for this reason we believe in setting goals and monitoring student progress to achieve these goals.

MD/PhD Combined Program

Students who are interested in this Dual Degree program will take their medical training at Robert Wood Johnson Medical School and PhD training at one of three collaborating institutions: RWJMS, Rutgers, or Princeton. The program provides 3 years of graduate training and 4 years of Medical training. Year 3 starts the graduate training years. Applications are made through the American Medical College Application Service (AMCAS) primary application (www.aamc.org). You must select "Rutgers Robert Wood Johnson Medical School" as the school name and "Combined Medical Degree /Ph.D." as the program type. More information can be found at

https://grad.rutgers.edu/academics/graduate-programs/mdphd-program. This program is highly competitive, only about 6 students are accepted each year into the MD/PhD program. Students who are admitted into this program may substitute some of their MD courses as BME Program Requirements subject to written approval of the Graduate Program Director. A passing score on the USMLE step 1 is accepted in lieu of the Physiology course requirement and its associated portion on the Qualifying Exam. Typically, M.D. students will also have taken graduate-level Molecular Biology and Biochemistry courses that may be substituted for the BME requirement on this topic with the BME Graduate Director's approval. Finally, M.D. students may have taken courses that can be used as Life Science or other electives as appropriate. M.D. /PhD students should meet with the BME Graduate Director as soon as they are admitted into the joint program to clarify what requirements may be waived in their case.

MASTER'S DEGREE REQUIREMENTS, MS and M.Eng

Students have two Master's Degree options. All Thesis-based students should seek to complete M.S.; students who have not completed this option by the end of their third year will be required to leave the graduate program with an M.Eng. The options consist of the following course requirements:

M.S. (thesis option): 27 Course Credits + 6 Research Credits:

3 BME Core Courses (9); Advanced Math (3); Advanced Cell Biology (3); Professional Development Credits (3); 3 Electives (9); Research Credits (6); BME Seminars (0). 33 credits total.

M.ENG (non-thesis option): 30 Course Credits + 3 Non-Thesis Study Credits:

3 BME Core Courses (9); Advanced Math (3); Advanced Cell Biology (3); Professional Development Credits (3); 4 Electives (12); Non-Thesis Study (3); BME Seminars (0). The M.Eng. is considered a terminal degree that does not lead to a Ph.D. 33 credits total.

In both degree programs there is a final comprehensive examination (thesis defense or paper/literature review/project), normally taken during the term that will complete the student's course of study, which will emphasize the student's area of concentration.

Final Comprehensive Examination: A final comprehensive examination will be taken by all students enrolled in the M.S. and M.Eng program. The examination will be conducted by the student's committee. This committee will be composed of at least three members of the BME graduate faculty. For M.S, the student must defend his or her written M.S. dissertation by oral examination. For M.Eng, the student must defend his or her independent study or research based final paper/project. The final paper can be a critical analysis of a current research topic, a laboratory research-based report, an NIH style research proposal, or another project directed by the advisor.

"Bill of Rights"
For
Graduate Students in Biomedical Engineering
Rutgers University

Guidelines for the education and mentoring of PhD students were adopted by the faculty of Rutgers Biomedical Engineering on February 17, 2006. It is not possible or desirable to specify rigid criteria for mentorship that will fit all situations; nevertheless, these guidelines were endorsed as goals that all faculty and students should strive for. As a matter of policy, the Rutgers BME faculty believes that mentors have a responsibility to educate, guide, and support their students in a scholarly and respectful manner. Students for their parts are expected to uphold the highest standards of scholarship and academic integrity. Specifically,

1. PhD students should meet with their advisors on their research projects frequently enough so that guidance toward meaningful scientific and education progress is made. Typically, students should meet with their advisors weekly or once every two weeks, depending on the stage of their research.

2. Faculty should evaluate their graduate students' progress in a timely and constructive way. There will be exceptions, but it is reasonable for students to expect to receive feedback every week or two.

3. All PhD students should expect to attend and present at national meetings and publish in peer-reviewed papers in leading journals. At a minimum, the expectation of our graduate program is that all PhD students will give at least one presentation at a national meeting and publish at least one first author paper in a peer-reviewed journal before they graduate.

4. Students can expect exposure to and some experience in grant and progress report writing, paper reviewing, and other responsibilities involved in an active, modern lab.

5. It is the responsibility of the PhD advisor to financially support their PhD students who are in good standing. Funding can never be guaranteed; nevertheless, faculty members make a commitment to the students when they enter the program that they will receive tuition and competitive stipends, and insofar as it is at all possible, members of the faculty must uphold this commitment. It is the responsibility of students to maintain the highest achievable productivity and academic standing.

In most situations, if these guidelines are not met, the problem can be resolved by open discussion between the student and advisor. If a resolution cannot be achieved after these discussions, the Graduate Program Director – or failing that, the Department Ombudsman – will make every effort to help either resolve the problem or direct the student to an alternative advisor.

Addendum:

Students must stay in touch with the BME Graduate Program Director and Program Administrator to request and receive the proper forms and documentations required by the program and graduate school, to keep them informed and updated on your progress, and to verify that you are on track by taking the right courses and making progress in your area of research.

It is important that enough time is given to your advisor and/or committee to review your papers, publications, thesis, and other work. Our program has a guideline that students should give 2 weeks' notice to their advisor/committee before any deadline and the program expects the advisor/committee to return your work back to you within 2 weeks, pending any complications.

BME M.S./M.Eng Program Curriculum (1/6/20)

FALL Year 1

16:125:xxx	BME Core Course (3cr)
16:125:xxx	BME Core Course (3cr)*
16:125:xxx	Bioengineering Elective (3cr)
16:125:501	Mathematical Modeling for BME (3cr)
16:125:601	Engineering Ethics/Seminar(1cr)

Advisor Selection Forms (December through June)

SPRING Year 1

16:125:xxx	BME Core Course (3cr)
16:125:xxx	BME Core Course (3cr)*
16:125:xxx	Bioengineering Elective (3cr)
16:125:586	Structure and Dynamics in Adult and Stem Cell Biology (3cr)
16:125:602	Engineering Writing/Seminar (1cr)

FALL & SPRING Year 2/Year 3

16:125:xxx	Bioengineering Elective (3cr)
16:125:xxx	Bioengineering Elective (3cr) (As Needed)
16:125:628	Clinical Practicum (1cr)
16:125:701/702	Research (3cr/3cr)
16:125:699	Non-Thesis Study (3cr) (M.Eng Only)
16:125:605	BME Seminar (zero credit, no tuition charge)

BME Core Courses **Must take 3 out of 5:**

1)	16:125:561	BioImaging Methods (3cr)
2)	16:125:571	Biosignal Processing and Biomedical Imaging (3cr)
3)	16:125:572	Biocontrol, Modeling and Computation (3cr)
4)	16:125:573	Kinetics, Thermodynamics and Transport in Biomedicine (3cr)
5)	16:125:574	Biomechanics and Biomaterials (3cr)

Physiology

Students **must** have taken an UG level Physiology course previously or the following course must be taken.

1)	16:125:581	Mammalian Physiology (online course-3cr)
OR		Other Rutgers or RWJMS Physiology Courses – Contact the Graduate Program for information

Advanced Engineering Mathematics^

1)	16:125:501	Mathematical Modeling for BME (3cr)

^Students may be asked to complete an alternate graduate-level math course based on need or availability. Students wishing to take an alternate math class should petition the graduate program director.

Advanced Cell Biology

1)	16:125:586	Structure and Dynamics in Adult and Stem Cell Biology (3cr)

Professional Developmental Courses **Must take 1, 2 and 5…3&4 are optional**

1)	16:125:601	Engineering Ethics and Seminar (1cr)
2)	16:125:602	Engineering Writing and Seminar (1cr)
3)	16:125:607	Preparing Future Faculty I (1cr)
4)	16:125:608	Preparing Future Faculty II (1cr)
5)	16:125:628	Clinical Practicum (1cr)

BME Seminar (Required each semester after taking 601/602)

1)	16:125:605	BME Seminar (0cr)

Summary of Minimum M.S./M.Eng Requirements

3 out of 5 BME Core Courses	**9 credits**
Advanced Engineering Math Course	**3 credits**
Advanced Cell Biology Course	**3 credits**
3 Bioengineering Electives (4 if M.Eng)	**9 credits (12 credits if M.Eng)**
3 out of 5 Professional Developmental Courses	**3 credits**
Research (M.S. ONLY)	**6 credits**
Non-Thesis Study (M.Eng ONLY)	**3 credits (MUST take an additional 3 credit elective)**
BME Seminars each fall/spring semester after Y1	**0 credits *(REQUIRED COURSE 605)***
Total	**33 credits**

* If schedule allows, take up to two core classes per semester. Minimum of three core classes required.

BME Ph.D. Program Curriculum (1/6/20)

Fall Year 1

16:125:xxx	BME Core Course (3cr) (*Register for one, possibly two core courses*)
16:125:xxx	BME Core Course (3cr)
16:155:501	Mathematical Modeling for BME (3cr)
16:125:699	Non-Thesis Rotation (3cr)
16:125:601	Engineering Ethics/Seminar (1cr)

Advisor Selection Forms (Due in June)

SPRING Year 1

16:125:xxx	BME Core Course (3cr) (*Register for one or two core courses*)
16:125:xxx	Bioengineering Elective (3cr)
16:125:586	Structure and Dynamics in Adult and Stem Cell Biology (3cr)
16:125:602	Engineering Writing/Seminar (1cr)
16:125:702	Research (3+cr)

SUMMER Year 1

Research Based Qualifying Exam for Doctoral Studies tied in with "Engineering Writing 602" (May/June)

FALL Year 2

16:125:605	BME Seminar (Attendance required)
16:125:xxx	BME Core Course (3cr) (*Register for one remaining core course, if any* – see note*)
16:125:xxx	Bioengineering Elective (3cr) (*Register for one or two core courses)*
16:125:607	Preparing Future Faculty I (1cr)
16:125:701	Research (3+cr)

SPRING Year 2

16:125:605	BME Seminar (Attendance required)
16:125:578	Interdisciplinary BioStatistics Research Training (3cr)
16:125:xxx	Bioengineering Elective (3cr)
16:125:xxx	Life/Medical Sciences Elective (3cr)
16:125:608	Preparing Future Faculty II (1cr)
16:125:628	Clinical Practicum (1cr)
16:125:702	Research (3+cr)

SUMMER Year 2

Annual Research Verification Meeting
IDP Meeting
Prepare Thesis/Dissertation Proposal

FALL Year 3

16:125:605	BME Seminar (Attendance required)
16:125:701	Research (3+cr)
Electives	(As required)

Deadline for Defense of Thesis/Dissertation Proposal

SPRING Year 3

16:125:605	BME Seminar (Attendance required)
16:125:702	Research (3+cr)
Electives	(As required)

Years 4-6

16:125:605	BME Seminar (Attendance required)
16:125:701/2	Research (3+cr)
Electives	(Optional)

Annual Research Verification Meetings (Summers of years 4-6)
IDP Meetings (Summers of years 4-6)
Final Thesis/Dissertation and Defense (Year 5 or 6)

***Students are required to complete a total of 3 core BME courses, in addition to Math, Cell Biology and BioStatistics within the first four academic semesters.**

Curriculum Summary

BME Core Courses **Must take 3 out of 5:**

1) 16:125:561 BioImaging Methods (3cr)
2) 16:125:571 Biosignal Processing and Biomedical Imaging (3cr)
3) 16:125:572 Biocontrol, Modeling and Computation (3cr)
4) 16:125:573 Kinetics, Thermodynamics and Transport in Biomedicine (3cr)
5) 16:125:574 Biomechanics and Biomaterials (3cr)

Physiology

Students **must** have taken an UG level Physiology course previously or the following course must be taken.

1) 16:125:581 Mammalian Physiology (online course-3cr)
OR Other Rutgers or RWJMS Physiology Courses – Contact the Graduate Program for information

Advanced Engineering Mathematics^

1) 16:125:501 Mathematical Modeling for BME (3cr)

^Students may be asked to complete an alternate graduate-level math course based on need or availability. Students wishing to take an alternate math class should petition the graduate program director.

Advanced Cell Biology

1) 16:125:586 Structure and Dynamics in Adult and Stem Cell Biology (3cr)

Rigor and Reproducibility

1) 16:125:578 Interdisciplinary BioStatistics Research Training (3cr)

Medical/Life Science Elective

1) Life Science elective from the list in the Graduate Handbook or recommendation from Program Director

Developmental Courses

1) 16:125:601 Engineering Ethics (1cr) **(Required during 1st year)**
2) 16:125:602 Engineering Writing (1cr) **(Required during 1st year)**
3) 16:125:607 Preparing Future Faculty I (1cr) **(Required)**
4) 16:125:608 Preparing Future Faculty II (1cr) **(Required)**
5) 16:125:628 Clinical Practicum (1cr) **(Required)**

BME Seminar (Required each semester after taking 601/602)

1) 16:125:605 BME Seminar (0cr)

Summary of Minimum Ph.D. Requirements

3 out of 5 BME Core Courses	**9 credits**
Advanced Engineering Math Course	**3 credits**
Advanced Cell Biology Course	**3 credits**
BioStatistics Course	**3 credits**
Life Science/Medical Elective	**3 credits**
3 Bioengineering Electives	**9 credits**
5 Developmental Courses	**5 credits**
Non-Thesis Study (1st year Rotation)	**3 credits**
Research (minimum)	**34 credits**
BME Seminars each fall/spring semester after Y1	**0 credits** *(REQUIRED COURSE 605)*
Total	**72 credits (35 course credits)**

Note:

- Prerequisite work may not count as an elective. Please check with the program first.

Ph.D. Qualifying Exam

Please note: Non-PhD students may NOT take the qualifier unless he/she has approval from the Graduate Program Director.

The first part of the Ph.D. qualifying procedure is based on a combination of written and oral examination that is administered during the first week of June, during the first year of studies, and core course grades accumulated during the first three semesters. The examination is comprised of a written literature review and research proposal (along the lines of a NIH proposal) presented to and evaluated by a panel of faculty examiners. The outcomes of the research examination in combination with core course-based performance (students receiving less than 2 C+ grades in core courses are considered qualified and eligible) will be used to determine the first step of qualification for PhD Candidacy.

The second part of Ph.D. qualifying exam involves a satisfactory defense of a thesis proposal as early as 6 months after passing the qualifying exam and no later than the end of the fall semester of year 3.

To successfully give you post-qualifying status, both the written qualifier and oral proposal, have to be completed in a satisfactory manner.

For PhD students, a guide to progress is as follows:

1. Work on a research topic assigned by the Graduate Qualifying Coordinator and complete the written/oral research qualifier in June at the end of your first year.
2. Schedule and defend your Ph.D. proposal as early as 6 months after passing the written qualifier and no later than the fall semester of your third year.
3. Conduct "Annual Verification", which is an annual review of your research progress by your research advisory/thesis committee, to be completed by August 15 of each year.
4. Schedule and successfully defend the Ph.D. thesis within 2 years after the Ph.D. proposal.
5. Corrections on the Ph.D. thesis should not take longer than 1 semester.
6. The graduate school mandates that a student finish the Ph.D. within 7 years after the student's enter date. However, our program expects you to finish within 5 - 6 years, which students should be able to accomplish.

SUMMARY:

All applicants to the PhD degree program will be evaluated based on a revised PhD Qualifying Procedure. This Procedure is comprised of a written literature review and research proposal (along the lines of a NIH proposal) presented to and evaluated by a panel of faculty examiners, during the month of June after the first year of graduate studies. See Proposal format on page 30.

The outcomes of this procedure in combination with core course-based performance (students receiving less than 2 C+s in core courses are considered qualified and eligible) will be used to determine qualification for PhD Candidacy.

DETAILS:

1. One part of the qualification for PhD candidacy is based on exceeding minimum grade requirements for core BME courses. The BME program will permit fewer than 2 C+-grades (1 C+ grade or less) in the core courses. The program will continue to permit up to 2 C+-grades overall. Any student who gets more than 1 C+grade in a core course will be de-enrolled from the PhD program, reclassified in the Master's program, and given a maximum of 1 year to complete her/his work.

2. The major part of the qualification for PhD Candidacy is comprised of examination based on an original research proposal, which is described further below. *Note that this proposal is distinct from the PhD thesis proposal and should not be confused with the thesis review or evaluation.*
   Each PhD candidate will be assigned a research topic by the Graduate Qualifier Coordinator prior to Spring Break of the semester immediately preceding the qualifiers. By the third Wednesday following the end of exam week of the first year, the candidates will be required to provide a written proposal not to exceed 12 pages including references (NIH font & margin guidelines) to a panel of examiners. Within 2 weeks following this date, the student must give an oral presentation to a faculty panel who will then conduct an oral examination on the proposal. The panel will consist of 3 BME graduate program faculty, who will be previously selected by the Qualifier Coordinator. The students actively confer with the panel faculty to clarify the topic, obtain guidance on content, etc., and students will be encouraged to use existing research documents (e.g. from their research mentor) as guidelines for their qualifier proposals. Text from existing proposals may not be included in the qualifier proposal (except for revised proposals as described below).

Initially, the topics assigned will be come from a list provided by the Qualifier Coordinator, who in turn will solicit these from BME faculty. In future years, other formats for assigning topics may be considered, for example, topics provided by the panel or identified by the students themselves after prior approval from the panel.

Each faculty panel will evaluate up to three PhD candidates. Depending on the number of PhD candidates being evaluated, 2-4 such panels may be needed to oversee the entire qualifying process in a given year.

Possible Outcomes: The examiners may:

a) pass the student; OR b) not pass the student; OR c) conditionally pass the student depending on well-defined criteria - e.g. the student must take certain courses within a year and get a B grade or better, or the student must revise the proposal in specified ways, to be approved by the panel within a prescribed time limit (typically 1 year).

A student who does not pass, either outright or by unsatisfactorily completing the conditional outcomes, will be disenrolled from the PhD program and enrolled in the Master's program with the requirement of completing his or her work within 1 year of the qualifier date. As always, for students with extenuating circumstances (illness etc.), these criteria may be relaxed with written approval from the Graduate Program Director.

Contingency: If an examiner cannot be present, the presentation may be sent electronically and the examiner may participate in the oral examination by teleconference and approve or disapprove the proposal by email. In exceptional circumstances and with the written approval of the Graduate Program Director, the qualifier clock for a particular student can be delayed by up to one year.

Life Science/Medical Electives

The BME program requires one Life Science/Medical Elective as part of the PhD program. The purpose of the Life Science/Medical Elective is to formally provide the opportunity for students to gain the depth in a biological or medical field that augments their dissertation research. As such, students should take their Life Science/Medical elective after they have selected a laboratory and a dissertation subject.

The following courses may count as a Life Science/Medical Elective. Note that these courses may be offered only every alternate year.*

16:125:582	NANO-AND MICRO-ENGINEERED BIOINTERFACES
16:125:583	BIOINTERFACIAL CHARACTERIZATION
16:125:584	INTEGRATIVE MOLECULAR AND CELL BIOENGINEERING
16:115:511	MOLECULAR BIOLOGY & BIOCHEMISTRY
16:148:514	MOLECULAR BIOLOGY OF CELLS
16:148:519	CELLULAR AND GENETIC MECHANISMS
16:148:550	ADVANCED DEVELOPMENTAL BIOLOGY
16:148:556	SYSTEMS HISTOLOGY
16:148:565	GROSS AND DEVELOPMENTAL ANATOMY
16:155:532	ADVANCES IN LIFE SCIENCES, BIOENGINEERING, & BIOMANUFACTURING ENABLED BY GLYCOSCIENCES
16:160:537	BIOPHYSICAL CHEMISTRY I
16:340:510	NEUROENDOCRINOLOGY
16:681:502	MOLECULAR GENETICS
16:681:530	MOLECULAR MEDICINE
16:681:534	CURRENT CONCEPTS OF IMMUNOLOGY
16:681:555	MOLECULAR VIROLOGY
16:681:585	CANCER MOLECULAR BIOLOGY
16:710:555	NEUROBIOLOGY
16:761:515	MEDICAL PHYSIOLOGY

*Other courses not listed ***may*** be acceptable with PRIOR approval from the Graduate Director.

Master's Thesis Guidelines

Procedures for Filing for a Master's degree:
An application for Admission to Candidacy must be completed by all Master's students, listing courses that will be applied toward the Master's degree. The application can be picked up from the program assistant in BME-111. For M.S., the student is required to list at least 27 course credits and 6 research credits, for M.Eng, 30 course credits and 3 non-thesis study credits. The Graduate Program Director must approve any course not in the curriculum that will be used to satisfy the degree requirements. This includes any courses that can be transferred from a previous institution. Prior to the Master's thesis defense, the student should confirm with the BME Graduate Program Administrator that all requirements are satisfied. Application for Diploma must also be filled out during the semester of intended graduation. That form can be picked up from BME-111 or filled out online at: https://www.ugadmissions.rutgers.edu/Diploma.

Selection of M.S. Thesis and M.Eng Non-Thesis Advisor and Committee:
The M.S. and M.Eng committee consists of at least three members: the thesis/non-thesis advisor and two members of the BME graduate faculty. No outside member is required for the Master's committee. Additional members are permitted. The student should choose committee members who can help the student either in the research topic or in his or her future career. For example, a student interested in clinical research could benefit from a member of the Medical School; likewise, a student interested in industry may want to include committee members with industrial contacts. Students should confirm the committee composition with the Graduate Program before the defense or final presentation.

Master's Comprehensive Examination:
For either M.S. or M.Eng Master's degrees, the student must pass a comprehensive examination. This examination consists of a presentation of a thesis (M.S.) or a report (M.Eng) and an oral examination on the research by the three committee members. 2 weeks prior to the oral exam (thesis defense), the student MUST submit to the program administrator: Title, location, committee members and abstract. The student is expected to send their thesis and/or presentation slides to their committees at least 2 weeks in advance of the defense date.

The candidate's thesis advisor and committee must agree unanimously. Students submitting a thesis must follow the required format defined in the Graduate School's Thesis and Dissertation Style Guide and must meet all deadlines prescribed by the Graduate School.

Final approval for the Master's degree must come from the Graduate Director, verifying that the candidate has satisfied all program requirements for the degree, including coursework, research, and the completed and signed M.S. comprehensive examination. The student must upload his/her thesis (final with any revisions as a result of the Defense) to the BME Canvas Text Submission site at least one week prior to any deadline. Elaine Connors would give you access to the Canvas site if you do not have it. The information about this process is on the Canvas site. Once the thesis is checked and the report generated, the Graduate Director will review the report for plagiarism and if ok, will sign the candidacy form and the student will then submit the form and the thesis abstract to the School of Graduate Studies at 25 Bishop Place on College Avenue Campus. The thesis is submitted electronically here: https://etd.libraries.rutgers.edu/submit-your-etd. Checklist for degree completion is on the BME Graduate Canvas website as well as on the SGS Website here: https://gsnb.rutgers.edu/academics/how-apply- degrees

Doctoral Dissertation Guidelines

General Dissertation Information

The doctoral dissertation topic may be chosen in virtually any research area at the interface of physical science/engineering and the biomedical sciences. Students are encouraged to begin research activities early in their graduate career (generally in the second semester of their first year); research work towards the thesis may be done on campus, at teaching hospitals or at other research sites (for example, in one of our associated industrial or clinical research laboratories). The Program encourages students to explore areas that are relevant to clinical medicine, but this is not an absolute requirement. The candidate pursues the thesis under the direction of a research supervisor and is guided by a thesis committee.

Laboratory Rotations

To facilitate the advisor selection process, new graduate students have the option of rotating through available laboratories. These rotations typically last for one month and can start as soon as a student is accepted into the program. Laboratory rotations must be arranged by the student in consultation with the laboratory director. The Graduate Program Director or knowledgeable faculty can direct the student to laboratories accepting rotations.

The Dissertation Committee: Composition and Function

Dissertation Committee: Doctoral dissertation work is performed under the guidance of a dissertation committee consisting of at least four faculty members (including a chair/supervisor) who will help guide the research and act as readers of the thesis. At least three of the committee members should represent the disciplines of engineering and science that are relevant to the student's proposed research. These three members must be affiliated with the BME Graduate Faculty. The list of acceptable faculty members can be found on page 34. A final committee member from outside of the department, the fourth member, is included to broaden the student's perspective. This outside member must be approved by the BME Graduate Director and the Graduate School for the final dissertation defense. The dissertation committee should be formed early in the course of the research and in no case later than six weeks prior to the dissertation proposal date. **The BME Graduate Director must approve the composition of the dissertation committee.** This should be done before the thesis proposal. The student should choose committee members who can help the student either in the research topic or in his or her future career. For example, a student interested in clinical research could benefit from a member of the Medical School; likewise, a student interested in industry may want to include committee members with industrial contacts.

Dissertation Chair: A chair, who must be a full member of the graduate faculty, heads each dissertation committee. The role of the chair is to ensure that all policies and procedures of the thesis committee are followed correctly, and particularly that dissertation committee meetings are scheduled each year.

Dissertation Research Supervisor: The research supervisor from the BME graduate faculty is ordinarily a faculty member of Rutgers or the Medical School. A senior research staff member may act as the dissertation supervisor with special permission by the BME Graduate Program Director (examples of thesis committee composition are found later in this booklet). The research supervisor may also be, but need not be, the chair of the committee.

Dissertation Proposal and Proposal Defense

The proposal: Each candidate writes a dissertation proposal that must be approved by his/her committee before the end of the fall semester of the third year. The proposal should reflect the guidance of the dissertation committee. The proposal should contain sufficient detail to clearly define the research problem, describe the proposed research plan, and defend the significance of the work. Preliminary results are expected. The suggested length including figures, tables, and references is 15-30 pages, but the format is ultimately decided by the advisor/committee of the student.

Format of the proposal:

- The proposal with properly formatted title page signed by the student.
- An abstract of the proposal (suggested length 300 words) that serves as a concise description of the proposed work and can be read independently of the full proposal. The BME Dissertation Tracking Committee will use the abstract when reviewing the proposal for final approval. The abstract should be comprehensible to a general scientific audience, yet should contain sufficient information for evaluation of the project. The components of the abstract are 1) a brief description of the project background and significance, explaining why the work is important; 2) the specific aims of the proposal; and 3) a summary of the methods to be used to accomplish the specific aims. Headings within the abstract (Background, Specific Aims, and Methods) are optional.

Proposal Defense: The student obtains the candidacy form from the BME graduate program office and fills out the requested information. The student must formally defend the written dissertation proposal before the full dissertation committee. The proposal title, date, abstract and committee members MUST be submitted to the Program Administrator, Elaine Connors, in the BME office suite *two weeks* before the proposal defense. After the defense, the student corrects deficiencies in the proposal identified by the committee, and the committee then reviews the amended proposal. When the committee deems the proposal acceptable, the final proposal is uploaded to the BME Canvas Text Submission where it will be checked for plagiarism. The student will have access to the Canvas site and the site will explain the process more in-depth. After the report is generated, the GPD checks the document and if ok, signs off on Part I of the candidacy form. The student is responsible for obtaining the required signatures from the dissertation committee at the time of the defense or shortly thereafter. After the committee and GPD have signed Part I of the candidacy form, it must then be submitted by hand to the School of Graduate Studies, 25 Bishop Place, College Avenue Campus.

Dissertation Committee Meetings and Reports

While the student should freely seek the advice and counsel of thesis committee members on an individual basis, periodic thesis committee meetings must be held to review progress and guide the ongoing research. These meetings must occur at least once per year; typically, students will receive weekly or bi-weekly feedback from committee members engaged in the ongoing research. An Annual Research Verification form must be submitted to the graduate program office by August 15th of each year. New incoming PhD students have until August 15th of the SECOND year to submit this form. More information is on the following page.

Dissertation Defense: When the written dissertation is substantially complete and acceptable to the dissertation committee, a public dissertation defense will be scheduled at which the student presents his/her work to the dissertation committee and other members of the Rutgers community.
The student must submit his/her information to the Graduate Administrator about their defense information 2-3 weeks prior to the defense date. Through the defense, the dissertation committee judges the adequacy of the dissertation research. Formally, the candidate meets with the dissertation committee privately following a public question period. During this private meeting, the committee may perform an oral examination or may request additional materials. The committee will then adjourn for a discussion of the candidate's performance, after which it will agree that the candidate has (a) successfully defended the work, (b) needs to perform specified additional work by a defined date, or (c) has not adequately defended the work. Only one dissention vote will be allowed and Graduate School regulations apply in all of these cases.

Once the dissertation is satisfactorily defended, the final written dissertation document (signed by the dissertation supervisor) is uploaded to the BME Canvas Text Submission site just as was done for the written Proposal. After the dissertation is checked, the GPD will then sign Part II of the candidacy form. The title page of the dissertation must be signed by the entire dissertation committee. After the Graduate Director signs the candidacy form, the student submits the form and 3 copies of the thesis abstract to the School of Graduate Studies at 25 Bishop Place on College Avenue Campus. The thesis is submitted electronically here: https://etd.libraries.rutgers.edu/submit-your-etd

Procedures:

In summary, procedures for a dissertation defense are as follows:

- The dissertation committee, working with the student and reviewing dissertation drafts, concludes at some point before the end of the 6th or 7th year of study that the doctoral work is complete.
- The student requests that an "Outside Committee Member" letter be prepared by the Graduate Program Assistant with approval from the Graduate Director. This is for the 4th committee member.
- A complete final draft of the dissertation document is due to the dissertation committee no less than two weeks prior to the dissertation defense to allow the committee time to review.
- A dissertation defense is held to which the public is invited. The Graduate Program Administrator will assist the student by making a flyer and announcing the date of the dissertation via e-mail.
- Immediately following the public dissertation presentation, the student and committee members have a follow-up discussion in which additional questions can be explored at the discretion of the faculty.
- The dissertation committee meets in executive session to decide whether the thesis defense was satisfactory. Additions or editorial changes to the thesis document may be suggested to the student by the committee at this point.
- The student makes final corrections on the written dissertation and follows the guidelines set by the BME Graduate program to upload to Canvas site for checking and the Graduate School regarding the timely submission of all forms, the collection of signatures on the candidacy form and title page and the submission of all dissertation materials, as outlined in the Dissertation Style Guide.

Annual Research Progress

Timely progression to completion of the Ph.D. is a goal of all students and faculty within Biomedical Engineering. A reasonable goal is for the Ph.D. to be completed within five years; however, the rules of the Graduate School of New Brunswick allow a maximum of seven years. In order to promote timely progression, effective January 3, 2008, the Biomedical Engineering Graduate Program requires that the progress of all Ph.D. candidates be reviewed annually, so that students and their research mentors will have adequate feedback to assist them in making progress towards degree completion. This will be done through a required annual meeting with the student and her/his committee. The meeting involves having an Annual Research Verification form signed and returned to the Graduate Program Office in BME*. This completed and signed form will be due for submission to the office on or about August 15th of each year following the first year. If the form is not submitted to the office by this date, the student's registration in subsequent semesters will be put on hold. The form is on the following page.

Students are required to form their research advisory committees by the end of the spring semester of the 2nd year. The Qualifier (and committee) satisfies the annual meeting for the first year. The advisory committee can be equivalent to or slightly different from the PhD thesis committee. The advisory committee should consist of the thesis advisor; two other faculty of the BME graduate program; and an "outside" member (not a faculty of BME graduate program. The outside member can be from an outside institution or organization.

The intended format of the meeting is for the student to present:

- An overview of her/his thesis project.
- Progress since the last Research Advisory Committee meeting.
- Proposed work for the next one-year period.
- An evaluation of the student's progress and prospects is to be written on the Annual Research Verification form by the Chair of the Committee immediately following the meeting and distributed to the student, committee members, the director of the student's Graduate Program with all required signatures.

*A thesis proposal form can be substituted for the verification form if the student has successfully defended his/her thesis proposal no more than six months prior to the August deadline, or if the student has scheduled her/his thesis proposal defense within four months after the August deadline.

RUTGERS School of Engineering

RUTGERS School of Graduate Studies

Graduate Program in Biomedical Engineering

ANNUAL RESEARCH VERIFICATION FORM

(To be completed by student's advisor and committee. Must be submitted to BME Graduate Program Office by Aug 15 of each year)

Student's Name:_____Date Entered BME Program: _____

Proposal/Dissertation Title: _____

Date of Research Committee Meeting:_____Publications so far (if any): _____

Progress of Dissertation Research:
___Satisfactory

___Unsatisfactory (Please give detailed description of inadequacies below and notify GPD ASAP)

Comments and Recommendations for the Student for the following year from date of meeting:
Please consider the student's progress and goals in research, writing, and presenting their research in your comments and recommendations. THIS SECTION MUST BE FILLED IN

_____

_____

_____

_____

_____

_____

_____

_____

Committee:

Name (please print)	Signature	Concur	Dissent
_____ Advisor	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

_____
Student Signature

_____
Anticipated Proposal *OR* Defense Date

_____
Graduate Program Director Signature

MAKEUP OF THESIS COMMITTEES

EXAMPLE #1

Committee Member	Discipline	Institution
1. Chair	BME Graduate Faculty: BME Professor	Rutgers
2. Research Supervisor	BME Graduate Faculty: Hospital-based MD	Rutgers
3. Reader #1	BME Graduate Faculty: Engineering Professor	Rutgers
4. Reader #2	Approved Outside Member*	As Desired

EXAMPLE #2

Committee Member	Discipline	Institution
1. Chair/Research Supervisor	BME Graduate Faculty: BME Professor	Rutgers
2. Reader #1	BME Graduate Faculty: Engineering Professor	Rutgers
3. Reader #2	BME Graduate Faculty: MD faculty member	Rutgers
4. Reader #3	Approved Outside Member*	As Desired

EXAMPLE #3

Committee Member	Discipline	Institution
1. Chair	BME Graduate Faculty: BME Professor	Rutgers
2. Research Supervisor	BME Graduate Faculty: Cell Biology Professor	Rutgers
3. Reader #1	BME Graduate Faculty: Engineering Professor	Rutgers
4. Reader #2	Approved Outside Member*	As Desired

* The Graduate School requires an "Outside Member Letter", obtained from the Graduate Program Administrator.

Appendix

Core Course Descriptions

16:125:561 BioImaging Methods

The course will present the general physical principles underlying resolution and contrast in two-dimensional and three-dimensional bioimaging techniques. The course will focus on current key areas of imaging and their applications in biology and medicine. These include optical imaging, MRI, Ultrasound, CT and ultra-high-resolution microscopic methods. The course presentation will be comprised of lecture material, representative problems, and paper discussions. The students will be evaluated though team projects/presentations, and quizzes.

16:125:571 Biosignal Processing

Application of basic signal analysis to biological signals and the analysis of medical image. Extensive use of the MATLAB language in example and problems.

16:125:572 Biocontrol, Modeling, and Computation

Application of control theory to the analysis of biological systems. As foundation for other biomedical engineering courses, topics include (biocontrol) control systems principles, Nyguist and root locus stability analysis; (modeling) Nernst membrane model, action potential, cardiovascular mechanics, circulatory dynamics, pulmonary mechanics, accommodation, vergence eye movements, and saccades; and (computation) numerical solutions to differential equations, computer methods using Matlab and Simulink.

16:125:573 Kinetics, Thermodynamics, and Transport in Biomedicine

Intended for those seeking familiarity with the effects of, and tools to deal with, fluid, multiphase, chemical, and thermal transport and kinetics problems in biological systems.

16:125:574 Biomechanics and Biomaterials

The objective of the course is to understand the principles that underlay complex, graduate level problems in continuum mechanics, with an emphasis on material that can be applied to graduate level problems in biomechanics.

16:125:501 BME Math Modeling

Prerequisites: Multivariate calculus and ordinary differential equations; basic programming in Matlab or consent of instructor.

Mathematical tools and computational skills necessary to model and solve problems in the core BME graduate curriculum.

16:125:578 Interdisciplinary BioStatistics

This course will provide both life science and engineering students with a strong foundation in statistical approaches to data analysis and will be specifically tailored to the molecular, cellular, and tissue biotechnology and bioengineering data relevant to their thesis projects. Two particularly important components of the course involve the training of students on how to: 1) critically assess and interpret published scientific data, and 2) enhance and optimize experimental rigor and reproducibility.

16:125:581 Mammalian Physiology (Online and as needed)

Prerequisites: undergraduate physiology and general biology

This advanced physiology course is organized around integrative issues, i.e., focus is on the physiological parameter to be controlled and to show how the different systems (nervous, endocrine, respiratory, cardiovascular, renal, gastrointestinal) contribute to homeostatis of a particular parameter.

16:125:586 Structure and Dynamics in Adult Stem Cell Biology

This course is designed to present basic information as well as the most recent developments in key areas of cell biology. The course consists of lectures based primarily on textbook readings and discussions that delve more deeply into lecture material and discuss primary literature. Both formats will expose students to current experimental approaches in cell biology with an emphasis on quantitative methods and analysis. Students will be expected to demonstrate their knowledge of course material by participation in discussions, in presentations, and by examination.

Developmental Courses and Descriptions

16:125:601 Engineering Ethics and Seminar (1)
Each Fall semester all students are expected to attend the Seminar Series. First year students are required to take this course which coincides with the Seminar Series in BME. Every other week, students will have a discussion about ethics in engineering and medicine. On the alternating weeks, students will hear speakers from within and outside the Rutgers/RWJ community present their research results.

16:125:602 Engineering Writing and Seminar (1)
Each Spring semester all students are expected to attend the Seminar Series. Every other week, students will learn how to successfully write a "white paper" on subjects in BME. On the alternating weeks, students will hear speakers from within and outside the Rutgers/RWJ community present their research results.

16:125:607,608 Preparing Future Faculty I,II (1,1)
During the second year of studies, all Ph.D. candidates will take two one-credit courses over the span of the year. These course cover basic concepts in teaching and learning. Students will be exposed to different styles of learning and teaching methods and their application to Biomedical Engineering. Students will be expected to apply the principles to laboratories and lectures in the undergraduate program.

16:125:628 Clinical Practicum (1)
Students are introduced to clinical aspects of biomedical engineering by attending regular grand rounds given by clinical specialists from medical schools and hospitals. Selected demonstrations of clinical procedures with applications of modern technology are also arranged.

16:115:556 Ethical Scientific Conduct (1)
Introduction to ethical issues of scientific investigation, including intellectual property, plagiarism, conflict of interest, human and animal subjects, record keeping, etc. Intended for Ph.D. candidates in the biomedical sciences.

Elective Courses and Descriptions*

**List is subject to change as some courses are no longer offered or offered infrequently*

16:125:506 ARTIFICIAL IMPLANTS

This course presents basic concepts concerning structure and properties of materials used to replace biological tissues. Emphasis will be placed on understanding the physical properties of the tissue to be replaced through development of structure-property relationships. Discussed properties include phase transitions, mechanical and hydrodynamic properties.

16:125:509 MEDICAL DEVICE DEVELOPMENT

This course details the development of medical devices that employ primarily polymeric materials in their construction. Course work will include concepts involving materials selection, feasibility studies, prototype fabrication, functionality testing, prototype final selection, biocompatibility considerations, efficacy testing, sterilization validation, FDA regulatory approaches, writing of IDE, 510(k) and PMAs, device production and record keeping. Several former graduates in BME from Rutgers will give lectures on industrial aspects of medical device development.

16:125:513 VISION AND NEUROTECHNOLOGY

This course investigates oculomotor control and the complex interactions that control focus. The course will discuss the design and use of instrumentation used to measure the control of eye movement. Moreover, the course will provide an overview of state-of-the-art technologies such as retinal prosthesis, and novel brain function techniques to treat Alzheimer's and drug addiction, as well as brain-computer interfaces for control of computer screens and prostheses.

16:125:575 TOPICS IN BME: APPLICATIONS IN MEDICAL DEVICE DEVELOPMENT

This course will provide students insight into the practical aspects of medical device applications and introduce business concepts as they relate to medical devices from a realistic industrial perspective.

16:125:577 BIOENGINEERING IN THE BIOTECHNOLOGY AND PHARMACEUTICAL INDUSTRIES: FUNDAMENTAL AND REAL-WORLD PERSPECTIVES

The goal of this course is to offer students insight into the practical aspects of industrial bioprocessing. Industrial practitioners from various fields of expertise provide lectures and facilitate discussions highlighting problems and issues that engineers and scientists encounter. This course provides students with exposure to topics which are beyond the scope of a purely theoretically-structured course. After taking this course, students should have a better understanding of the challenges that engineers and scientists face in industrial bioprocessing.

16:125:578 INTERDISCIPLINARY BIOSTATISTICS RESEARCH TRAINING FOR MOLECULAR AND CELLULAR SCIENCES: ENHANCING RIGOR AND REPRODUCIBILITY

This course will provide both life science and engineering students with a strong foundation in statistical approaches to data analysis and will be specifically tailored to the molecular, cellular, and tissue biotechnology and bioengineering data relevant to their thesis projects. Two particularly important components of the course involve the training of students on how to: 1) critically assess and interpret published scientific data, and 2) enhance and optimize experimental rigor and reproducibility.

16:125:582 NANO-AND MICRO-ENGINEERED BIOINTERFACES

This course introduces students to the methods and mechanisms for engineering interfaces on the nano- and micro-scale. Two approaches to engineering interfaces, generally classified as synthesis and fabrication, specifically include: i) preparing substrates that have nano- and/or micro-scale features; and ii) creating anao and/or micro-scale substrates. The substrate materials discussed will typically consist of ceramics, polymers, and metals whereas biological systems will comprise cells, genes and ligands.

16:125:583 BIOINTERFACIAL CHARACTERIZATION

This course will introduce students to various physical, chemical, and biological methods of characterizing biointerfaces, broadly defined. Biointerfaces will include conventional interfaces of biomolecules (e.g., proteins) on artificial substrates, as well as interfaces of submicroscopic and nanoscale particles with biomolecules and cells.

16:125:584 INTEGRATIVE MOLECULAR AND CELL BIOENGINEERING (3)

This course provides an integration of engineering and mathematical principles with molecular and cell biology entities for the understanding of physiology and solution of medical problems.

16:125:589 BIOMEMS

The objectives of this course are to build basic foundation for understanding of mechanisms on electrical, mechanical, chemical, and optical transducers in the context of biomedical applications. To teach critical thinking considering microengineering design and fabrication, material compatibility with biological systems, and cellular interaction at the interface. Finally current MEMS activities will be reviewed with emphasis on the examination of the viability of nanoscale devices and bioMEMS technology in particular biomedical applications such as capillary electrophoresis and miniaturizedpolymerase chain reaction for biochips, and exploration of integrated microdevices for minimally invasive surgery, personalized medicine and drug delivery

16:125:590 DRUG DELIVERY FUNDAMENTALS AND APPLICATIONS

This course will discuss the engineering of novel pharmaceutical delivery systems with enhanced efficacy and safety profiles, with an emphasis on the design and application of materials that overcome drug delivery barriers or challenges.

16:125:599 CO-OPERATIVE TRAINING IN BIOMEDICAL ENGINEERING

This course is for graduate students who seek academic credit for an external co-operative or internship experience.

16:125:615 ADVANCED TOPICS IN BRAIN RESEARCH

Advanced study of current areas of brain research. Topics include information processing in the brain, pattern recognition in different sensory modalities, advanced techniques of diagnosing different system disorders, and data recording and techniques of analysis. Topics vary depending on student interest and faculty availability.

16:125:618 INNOVATION AND ENTREPRENEURSHIP FOR SCIENCE AND TECHNOLOGY

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 business world.

EXAMPLES OF ELECTIVES FROM OTHER DEPARTMENTS

16:155:501 ADVANCED FLUID MECHANICS IN CHECMICAL ENGINEERING

Momentum transport processes in laminar and turbulent flow systems. Development and application of steady and unsteady boundary layer processes including growth, similitude principles, and separation. Potential flow theory coupled with viscous dissipation at boundaries. Momentum transport in fixed and fluid bed exchangers and reactors.

16:155:502 ADVANCED HEAT AND MASS TRANSPORT

Energy balances derived from first and second law approaches to open systems, with reaction. Conduction in fluids and solids, both steady and unsteady examples. Convection in laminar and turbulent flow systems. Diffusion and its treatment in stagnant and flowing

16:681:502 MOLECULAR GENETICS

Prokaryotic and eukaryotic molecular genetics. Bacteria, bacterio-phage, yeast, Drosophila, and mammals.

16:198:503 COMPUTATIONAL THINK

Intended for students who have not had undergraduate preparation in the subject. May not be taken for credit toward a graduate degree in computer science. Models of computation and complexity. Sorting, stacks, queues, linked lists, trees, search trees, hashing, graphs, and graph algorithms.

16:761:505 COMPUTATIONAL GENOMICS

The main focus of this course is the application of R programming to the analysis of genetic data, particularly “big data” sets with multiple measurements. The course provides the introductory skills needed to conduct basic computational research in the life sciences, including many aspects of computer programming and data analysis.

16:160:509 ORGANIC CHEMISTRY OF HIGH POLYMERS

This course is an introduction to the chemistry and materials properties of high polymers. The underlying rationale of this course is to provide chemists as well as chemical and biomedical engineers a sound understanding of the key principles that differentiate polymers as unique materials.

16:137:510 DRUG DEVELOPMENT FROM CONCEPT TO MARKET

This course provides an overview of the pharmaceutical industry, ranging from early drug discovery to bringing new small molecule and biological pharmaceutical products to the market. In addition to learning about key areas of the pharmaceutical industry from experts in the field, students will work in teams to investigate and present on several topics including: the features of a drug label; project management; the biological basis of novel therapeutics; reviewing therapeutic areas; and examining product portfolios for several pharmaceutical companies.

16:198:510 NUMERICAL ANALYSIS

Derivation, analysis, and application of methods used to solve numerical problems with computers; solution of equations by iteration, approximation of functions, differentiation and quadrature, differential equations, linear equations and matrices, least squares.

16:650:512 ROBOTICS AND MECHATRONICS

Introduction to robotics, including mechanisms and control theories as well as applications; manipulator mechanics; design considerations; control fundamentals; adaptive and sensory controls; algorithm development; robotic assembly techniques.

16:635:513 MECHANICAL BEHAVIOR OF MATERIALS

Mechanical behavior and properties of oxide and nonoxide ceramics, emphasizing fracture, microstructure, and environment. Differences in plastic behavior of ceramics related to creep, wear resistance, and hardness.

16:761:513 CARDIOVASCULAR PHYSIOLOGY

Comprehensive study of the cardiovascular system in mammals. Special consideration given to coronary circulation, myocardial-oxygen consumption, and cardiac arrhythmias.

16:155:514 ADVANCED CHEMICAL KINETICS AND REACTION ENGINEERING

Principles of applied chemical kinetics, reaction mechanisms and rate laws, and engineering design of reactor vessels. Applications to homogeneous and heterogeneous process reaction systems with internal, transphase, and external mass transfer. Noncatalytic gas-solid reaction and gas-liquid absorption with reaction. Micromixing and macromixing in reactor systems.

16:761:515 MEDICAL PHYSIOLOGY

Study of human physiology from the molecular to the systems level. Emphasis is on the integration of the systems within the healthy individual. Teaching modalities include lectures, small discussion groups, and laboratories in pulmonary and cardiovascular physiology.

16:650:518 BIOMECHANICAL SYSTEMS

Selected topics from the study of the human body as a mechanical system, with emphasis on modeling, analysis, and design. Investigation of biomechanical systems frequently encountered in orthopedic surgery and physical rehabilitation.

16:148:519 CELLULAR AND GENETIC MECHANISMS

Beginning with a consideration of basic cellular constituents and cell and tissue types, this course reviews cellular processes in the cytoplasm, cell and organellar membranes and the nucleus. Uses of recombinant DNA technology in investigating gene structure and function and in diagnosing genetic diseases complement examination of inheritance patterns in humans and review of genetic loci that underlie human disease.

16:198:520 INTRODUCTION TO ARTIFICIAL INTELLIGENCE

Overview of artificial intelligence. Basic problems and methods; deductive inference, declarative programming, heuristic search; reasoning and representation in perception, planning, and learning.

16:332:521 DIGITAL SIGNALS ANALYTICS

Sampling and quantization of analog signals; z-transforms; digital filter structures and hardware realizations; digital filter design methods; DFT and FFT methods and their application to fast convolution and spectrum estimation; introduction to discrete-time random signals.

16:198:527 DATABASE SYSTEMS FOR DATA SCIENCE

The purpose of this course is to introduce relational and NoSQL database concepts with emphasis on both theoretical and practical learning. This course helps students learn and apply knowledge.

16:332:527 DIGITAL SPEECH PROCESSING

Acoustics of speech generation; perceptual criteria for digital representation of audio signals; signal processing methods for speech analysis; waveform coders; vocoders; linear prediction; differential coders (DPCM, delta modulation); speech synthesis; automatic speech recognition; voice-interactive information systems.

16:148:530 HUMAN GENETICS

Examination of molecular and chromosomal bases for human inherited diseases. Molecular approaches to gene identification, including position cloning and linkage analysis. Role of mutations, evaluation of repetitive sequences in the human genome.

16:198:530 PRINCIPLES OF ARTIFICIAL INTELLIGENCE

We will cover basic foundations of modern AI: intelligent agents, actions, and planning under uncertainty. You will learn about modeling, algorithmic implementations, and applications of AI techniques to areas such as data mining, computer vision, and computational biology.

16:681:530 MOLECULAR MEDICINE

Application of molecular and cell biology to a wide variety of human diseases; recent advances in understanding basic mechanisms.

16:155:531 BIOCHEMICAL ENGINEERING

Integration of the principles of chemical engineering, biochemistry, and microbiology. Development and application of biochemical engineering principles. Analysis of biochemical and microbial reactions.

16:682:531 BASIC BIOCHEMISTRY

This course is a one semester survey of biochemistry, including (1) enzyme structure, function, and kinetics, (2) carbohydrate, lipid, amino acid, and nucleotide metabolic pathways, and (3) replication, transcription, translation, and gene regulation.

16:150:532 KINETICS OF MATERIALS SYSTEMS

Diffusion in solids. Solutions to Fick's first and second laws under important boundary conditions. Ionic diffusion. Diffusion applied to sintering. Solid-state reaction kinetics. Nucleation, crystal growth, and precipitation.

16:155:532 ENGINEERING OF SUGARS: GLYCOSCIENCES IN HEALTH, ENERGY, AND MATERIALS/ENGINEERING SUGARS

This course will provide an introductory survey of the fundamental principles of glycosciences (i.e., science and technology of carbohydrates or the 'glycome'), followed by discussions of some the cutting-edge applications of the principles of glycosciences to several interdisciplinary problems relevant to the disciplines of biochemical engineering.

16:198:535 PATTERN RECOGNITION THEORY AND APPLICATIONS

Pattern recognition as an inductive process, statistical classification, parametric and nonparametric methods, adaptive methods, error estimation, applications in image processing, character, speech recognition, and diagnostic decision making.

16:198:536 MACHINE LEARNING

An in-depth study of **supervised methods** for machine learning, to impart an understanding of the major topics in this area, the capabilities and limitations of existing methods, and research topics in this field.

16:160:537 BIOPHYSICAL CHEMISTRY I

Introduction to the physical chemistry of proteins, nucleic acids, and their complexes. Forces that determine biopolymer structure. Principles of protein and nucleic acid structure. Transitions and
interactions of biopolymers.

16:155:541 PHARMACEUTICAL MATERIALS ENGINEERING

Introduction to pharmaceutical materials and its application to designing and manufacturing drug products. Focus is on materials encountered in the pharmaceutical industry and how the materials affect processes they are used in. The course focuses on the choice of materials, troubleshooting and optimization.

16:681:543 CURRENT CONCEPTS OF IMMUNOLOGY

Cellular basis of immunology; analysis, activation, and function of lymphoid cells; regulatory mechanisms, relevance to tumor and transplantation immunity.

16:155:544 PHARMACEUTICAL ORGANIC NANOTECHNOLOGY

This course will discuss the engineering of novel pharmaceutical delivery systems with enhanced efficacy and safety profiles, particularly those that involve the use of nanostructured materials. Topics will include drug delivery fundamentals and membrane transport, nanoparticles for drug delivery, applications and case studies.

16:148:550 ADVANCED DEVELOPMENTAL BIOLOGY

Molecular mechanisms of cell type differentiation and body part specification. Cell-cell interaction, signal transduction during development, morphogenetic gradients, pattern formation, focusing on three experimental organisms: the nematode C. elegans, Drosophila, and the mouse. Genetic experimental approaches will be emphasized.

16:155:551 POLYMER SCIENCE AND ENGINEERING I

Physical and chemical structure of polymers; morphology of polymer crystals; microscopic texture. Mechanical properties; influence of orientation; effects of temperature and environment; engineering applications.

16:137:552 PYTHON METHODOLOGIES

This course is an introduction to computer programming with the Python programming language. The course covers imperative programming as well as selected areas of computer science, object oriented programming and data structures.

16:155:552 POLYMER SCIENCE AND ENGINEERING II

Emphasis on a modern treatment of polymers, including statistical mechanics scaling concepts and polymer properties and characterization.

16:681:555 MOLECULAR VIROLOGY

Detailed consideration of fundamental physical-chemical properties, schemes of classification, genetics, and modes of replication of selected animal viruses.

16:710:555 NEUROBIOLOGY

This course will serve as the basis for an advanced understanding of how the fundamental processes in neurons mediate communication and go awry in disease states.

16:148:556 SYSTEMS HISTOLOGY

Analysis of the microscopic structure of the cells making up the tissues and organs of the body provides a foundational knowledge for future studies in the area of histopathology. In addition to normal histological structure, the course exposes students to relevant histopathologies, which illustrate changes in normal architecture produced by diseases.

16:332:561 MACHINE VISION

The goal the course is to provide an overview on different aspects of recovering the geometry from single or multiple cameras. You are assumed to know the basic concepts of linear algebra and random processes. The textbook will be more difficult to follow without some background. Previous exposure to computer vision is also recommended.

16:148:565 GROSS AND DEVELOPMENTAL ANATOMY

Study of macroscopic structure of the human body by dissection and other methods with reference to functional mechanisms and changes during development and clinical correlations.

16:642:573, 574 NUMERICAL ANALYSIS

Ideas and techniques of numerical analysis illustrated by problems in the approximation of functions, numerical solution of linear and nonlinear systems of equations, approximation of matrix eigen-values and eigenvectors, numerical quadrature, and numerical solution of ordinary differential equations.

16:332:579 ADVANCED TOPICS IN COMPUTER ENGINEERING

The course will introduce students to a step-wise design process of biotechnology development and students will design and develop the specific biotechnology during the course related to global health application. Biomedical technologies will utilize the principles of microfluidics, BioMEMS, multi biosensing modalities, surface functionalization, mathematical modeling and on-chip sample processing.

16:198:580 TOPICS IN COMPUTERS IN BIOMEDICINE

A survey of computational methods in biology or medicine; topics vary from instructor to instructor and may include

computational molecular biology, medical reasoning, and imaging.

16:332:583 SEMICONDUCTOR DEVICES I

Charge transport, diffusion and drift current, injection, lifetime, recombination, and generation processes, p-n junction devices, transient behavior, FET's, I-V, and frequency characteristics, MOS devices C-V, C-f, and I-V characteristics, operation of bipolar transistors.

16:332:584 SEMICONDUCTOR DEVICES II

Review of microwave devices, O- and M-type devices, microwave diodes, Gunn, IMPATT, TRAPATT, etc., scattering parameters and microwave amplifiers, heterostructures and III-V compound-based BJTs and FETs.

16:960:584 BIOSTATISTICS I

Statistical techniques for biomedical data. Analysis of observational studies emphasized. Topics include measures of disease frequency and association; inferences for dichotomous and grouped case-control data; logistic regression for identification of risk factors; Poisson models for grouped data; Cox model for continuous data; life table analysis; and SAS used in analysis of data.

16:960:585 BIOSTATISTICS II

Statistical techniques used in design and analysis of controlled clinical experiments. Topics include introduction to four phases of clinical trials; randomization, blocking, stratification, balancing, power, and sample-size calculation; data monitoring and interim analyses; baseline covariate adjustment; crossover trials; brief introduction to categorical and event-time data; and SAS used in analysis of data.

16:681:585 CANCER MOLECULAR BIOLOGY

Emphasis on the molecular, cellular, and genetic basis for cancer. Oncogenes and tumor suppressor genes. Signal transduction and cell cycle control in cancer cells. Metastasis. Diagnosis and therapy. Recent understanding of the molecular basis of selected human cancers. Lectures and critical discussion of the current literature.

16:765:585 BIOINFORMATICS

This course is designed to introduce experimental biologists to bioinformatics concepts, principles, and techniques within the framework of basic shell scripting and web-based databases/tools.

16:830:585 PSYCHONEUROIMMUNOLOGY

The course will focus on the immune system and inflammation, as it relates to brain function (i.e. the impact of neuroinflammation), with relevance to all manner of cognitive and emotional behaviors, as well as neuropsychiatric conditions.

16:155:588 SPECIAL TOPICS IN CHEMICAL AND BIOCHEMICAL ENGINEERING

Covers the theoretical and multiscale simulation methods which bridge macroscopic thermodynamics and continuum transport theories with atomistic quantum mechanics and molecular dynamics.

16:960:590 DESIGN OF EXPERIMENTS

Fundamental principles of experimental design; completely randomized variance component designs; randomized blocks; Latin squares; incomplete blocks; partially hierarchic mixed-model experiments; factorial experiments; fractional factorials; and response surface exploration.

16:332:591 OPTOELECTRONICS I

Principles of laser action, efficiency, CW and pulse operation, mode locking, output coupling, equivalent circuits, gaseous and molecular lasers, solid-state lasers, single and double heterojunction lasers, different geometrics, fabrication, degradation, and application to holography, communication, medicine, and fusion.

16:215:599 SPECIAL TOPICS

This course focuses on the foundations of modern genomics: from experimental design to data acquisition, analysis, and interpretation.

16:650:606 ADVANCED MMECHANICAL ENGINEERING TOPICS

Understand the major categories, tools, components and applications of microfluidic and nanofluidic systems. Microfabrication, physicochemical description of hydrodynamics, low Reynolds number flows and other phenomena will be discussed

*Other electives may be used for graduate credit upon approval from the BME Graduate Program Director. For a course not listed above, the student should send the course description and/or syllabus to the GPD and the BME Program Administrator for review PRIOIR to registering for the course.

Industrial Interactions

Rutgers is located in central New Jersey, which is the worldwide epicenter of pharmaceutical and biotechnology research, and has been termed "the Medicine Chest of the World". In 2005 more than half of the new drugs approved by the FDA were produced in New Jersey. The proximity of Rutgers to a rich variety of pharmaceutical, medical device, biotechnology and affiliated industries uniquely positions the Department of Biomedical Engineering to train students who are expertly prepared for dynamic careers in numerous areas at the forefront of modern Science and Engineering.

To facilitate the transition from the university to the workplace, the Department has dedicated several custom-designed programs to strengthen existing ties to local industry while at the same time forging new relationships, both of which will translate into invaluable opportunities for BME students.

Industrial Seminar Series

Leading members of the industrial community are invited to speak to students about real-life experiences in industry during the fall and spring seminar series. Students are encouraged to meet with the speakers for more informal and in-depth discussions.

Annual Senior Design Conference

Each year, the undergraduate BME Seniors present their final research projects at the Annual Senior Design Conference. At this conference, there are student mentors who are often from industry that had time involved with preparing undergraduate students with career and scientific exposure.

Biomedical Engineering Society Annual Meeting

Each fall, the annual BMES Meeting is held in various locations in the nation. Graduate students, undergraduate students, and faculty are urged to present their research at the annual meeting. The annual meetings have a central theme each year and the goal is to foster interactions between universities with BME programs, and industry. Students are encouraged to network, and those engaged in research projects present posters at the event. Please contact the BME Graduate Program for more information on BMES or visit their website here: http://bmes.org/annualmeeting

BioEngineering Student Society (BESS) Annual Research Symposium

Each year, Rutgers' Graduate BME Society, BioEngineering Student Society (BESS) holds an annual research meeting to give our students the opportunity to present their work in a friendly environment among their peers. The meetings have an invited speaker along with oral and poster presentations. Graduate students will have the opportunity to discuss their work and learn about the breadth of research taking place at Rutgers. Attendees are encouraged to network and engage with other students and faculty.

Ph.D. Qualifier Proposal Format

The proposal shall be no more than 10 pages (Specific Aims, Research Strategy), plus 2 pages for references, and must obey NIH guidelines for font size (11 Arial or Helvetica or Georgia), margins (0.5 inch minimum on all sides), line spacing (single) and type density (15 characters per inch maximum) and page layout (8.5" by 11"). Suggested sections for the proposal will be:

SPECIFIC AIMS (1 page maximum)

State concisely the goals of the proposed research and summarize the expected outcome(s), including the impact that the results of the proposed research will exert on the research field(s) involved. List succinctly the specific objectives of the research proposed, e.g., to test a stated hypothesis, create a novel design, solve a specific problem, challenge an existing paradigm or clinical practice, address a critical barrier to progress in the field, or develop new technology.

RESEARCH STRATEGY (9 pages maximum)

Organize the Research Strategy in the specified order and using the instructions provided below. Start each section with the appropriate section heading – (a) *Background and Significance (2 pages suggested), (b) Innovation (1 page suggested), (c) Approach (6 pages suggested).* Cite published experimental details in the Research Strategy section and provide at the end a *Bibliography and References Cited* section (2 additional pages permitted).

(a) Background and Significance

• Explain the importance of the problem or critical barrier to progress in the field that the proposed project addresses.

• Summarize the scientific background of the field relevant to the proposed problem.

• Explain how the proposed project will improve scientific knowledge, technical capability, and/or clinical practice in one or more broad fields.

• Describe how the concepts, methods, technologies, treatments, services, or preventative interventions that drive this field will be changed if the proposed aims are achieved.

(b) Innovation

• Explain how the application challenges and seeks to shift current research or clinical practice paradigms.

• Describe any novel theoretical concepts, approaches or methodologies, instrumentation or interventions to be developed or used, and any advantage over existing methodologies, instrumentation, or interventions.

• Explain any refinements, improvements, or new applications of theoretical concepts, approaches or methodologies, instrumentation, or interventions.

(c) *Approach* (Can be broken down into different sub-sections for each Specific Aim, for example, C1, C2, etc)

• Describe the overall strategy, methodology, and analyses to be used to accomplish the specific aims of the project.

• Discuss potential problems, alternative strategies, and benchmarks for success anticipated to achieve the aims.

The panel will evaluate the proposal and presentation based on the following guidelines. Each guideline will be assigned 1-5 points, a score of 5 being best. A total score of 18 out of 25 is passing, and lower scores may be deemed conditional by the committee. The committee will take into account mitigating factors particular to each student's case in deciding whether to grant a conditional pass – for example a student whose qualifier lacks statistical metrics may be required to take a course on statistics and obtain a grade of B or better within a year, or a student who exhibits another shortcoming

may be given a different remedial course or assignment. The committee is traditionally sensitive to extenuating circumstances (e.g. illness, need for additional training, etc.) and will assign conditions for passing in consultation with the Qualifier director or Graduate Program Director.

Creativity, thoughtfulness of proposal
Hypothesis Based Scientific Design of Experiments
Feasibility and logic of approach
Thoroughness of literature
Clarity of presentation

Sample BME Graduate Faculty

BME Department Faculty

Y. Androulakis
F. Berthiaume
N. Boustany
H. Buettner
L. Cai
G. Drzewiecki
J. Freeman
A. Gormley
A. Krishnan
K. Kyker-Snowman
K. Labazzo
N. Langrana
J. Li
A. Mann
P. Moghe
S. Niu
B. Parekkadan
M. Pierce
C. Roth
T. Shinbrot
G. Shoane
D. Shreiber
V. Tutwiler
M. Vazquez
M. Yarmush
J. Zahn

SGS Faculty

J. Baum
H. Berman
D. Denhardt
R. Ebright
B. Firestein
M. Grumet
S. Khare
C. Kulikowski
K. Lee
S.H. Lee
D. Margolis
B. Michniak-Kohn
S. Murthy
W. Olson
K. Paradiso
M. Plummer
P. Sinko
J. Tischfield
M. Tischfield
E. Torres
W. Young

Engineering Faculty

G. Amatucci
S. Chundawat
M. Dutt
Z. Guo
U. Hassan
M. Javanmard
S. Khare
D. Knight
K. Li
A. Neimark
A. Pelegri
R. Riman
B. Schuster
M. Tomassone

RBHS Faculty

V. Abraira
G. Atlas
S. Danish
M. Dunn
D. Foran
S. Ganesan
C. Gatt
M. Gartenberg
P. Georgopoulos
J. Glod
J. Guarrera
M. Lewis
J. Ma
V. Nanda
J. Neubauer
D. Sant'Angelo
F. Silver
H. Weiss
J. Yang

Industry

K. Alam
H. Alexander
C. Caicedo
R. Cohen
L. Marks
K. Ricci
C. Glass

BME Graduate Faculty Information

Please see our website for the most up-to-date list of faculty and their research interests:

https://bme.rutgers.edu/graduate-faculty

Graduate Admissions Application Fee Waivers

The Office of Graduate Admissions grants application fee waivers to the following groups only: active U.S. military and military veterans who plan to apply for educational benefits under the GI Bill, current Rutgers students and alumni, and participants in various scholar programs. Students are automatically reviewed for fee waiver eligibility based on the information they provide on their Rutgers graduate school application.

- Please ensure your websites do not reflect different information about fee waivers, as this has been creating confusion for applicants. Feel free to copy the language above or, better yet, simply link to our new NB Graduate Admissions website here for more information on how to apply: newbrunswickgrad.rutgers.edu.
- If applicants have questions about the waiver policy, they can contact Graduate Admissions here: go.rutgers.edu/contactgrad (We ask that you have all students submit their inquiries to this contact form and not to an individual admissions staff member. The volume is just too high, so students will hear back from us much quicker using this contact form).

Graduate Degree Material Deadlines

All forms must be signed by the committee and Graduate Program Director and electronically submitted to the School of Graduate Studies by the appropriate deadline to graduate on time.

- October 1st for an October-dated degree
- January 2 for a January-dated degree
- April 1 for a May-dated degree
- August 15 for an August-dated degree

Checklists for M.S., M.Eng., and Ph.D. programs can be found here: https://grad.rutgers.edu/academics/graduation

Forms can be found at the Biomedical Engineering Graduate Canvas site or here: https://grad.rutgers.edu/academics/forms

Credit Transfer Policy

The School of Graduate Studies rules for the transfer of graduate credits and a link to the form is listed here:
https://grad.rutgers.edu/current-students/policies-procedures-students#collapse-accordion-9215-6
The form can also be found on the Biomedical Engineering Graduate Canvas site.

Rules for transfers include:

- Transfer requests are evaluated only upon completion of 9 credits of graduate level course work with grades of B or better as a matriculated student.
- Credit is not normally transferred for courses taken more than six years prior to the application for transfer of credit. Appeals for waiver of this time limit may be made by the graduate director.
- Up to 24 of credits required for a doctoral degree, and up to 40% of the required credits for the master's degree, may be transferred from another institution.
- Credits must not have been used toward meeting the requirements of the undergraduate degree.
- Official transcripts must be provided.
- The courses must be relevant to the student's program of study.
- Transferred courses must meet standards of graduate courses, (c) grades were less than B.