



# **BIOMEDICAL ENGINEERING GRADUATE PROGRAM**

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## **GRADUATION PROGRAM IN BIOMEDICAL ENGINEERING**

The Graduate Program in Biomedical Engineering offers advanced training appropriate for careers in academia or industry in the field of Biomedical Engineering. Admission is open to both master's-level and Ph.D.-level students.

### **I. Governance**

To fulfill Ph.D. requirements, students must complete a prescribed course of study, pass a Qualifying Examination, complete and publicly defend a doctoral dissertation, and participate in the undergraduate and graduate teaching programs in Biomedical Engineering, which include course offerings in both the School of Engineering and the Division of Biology and Medicine. Attainment of the Ph.D. degree normally requires four to six years for Ph.D. candidates and three to four years of graduate work for M.D./Ph.D. candidates. A Master's Degree will require one to two full years depending upon the student's undergraduate preparation.

The Graduate Program in Biomedical Engineering is administered by the Program Director and a series of standing and ad hoc committees, as a component of the Division of Biology and Medicine and the School of Engineering. Standing committees are the Steering Committee and the Graduate Program Committee, described below. Ad hoc committees include a Qualifying Examination Committee, Thesis Advisory Committee, and Thesis Committee for each graduate student. These committees, chosen at appropriate stages in the student's career, are described below.

The Steering Committee is composed of one senior faculty member of the School of Engineering, one senior faculty member of the Division of Biology and Medicine, and the Director(s) of the Center for Biomedical Engineering. The Steering Committee is responsible for establishing policy, allocating resources and designating faculty as trainers or members within the Graduate Program, as outlined below. The term for faculty members of the Steering Committee is five years, renewable. Senior faculty member, in this context, means tenured faculty member.

The Program Director is a senior faculty member jointly appointed by the Dean of Medicine and Biological Sciences and the Dean of Engineering upon recommendation by the Steering Committee for a term of three years, renewable. The same individual may serve as both Director of the Center for Biomedical Engineering and as Graduate Program Director, or different individuals may hold each post.

The Graduate Program Committee is composed of the Program Director and at least two other faculty members. The faculty members are appointed by the Program Director in consultation with the Steering Committee. The term for faculty members of the Graduate Program Committee is three years, renewable. The responsibilities of the Graduate Program Committee include admissions recommendations to the Graduate School and curriculum recommendations to the Steering Committee.

The faculty of the Graduate Program will be divided, with respect to graduate training, into two categories, members and trainers.

Members will have an active research interest in the area of Biomedical Engineering. They will participate in one or more of the following activities associated with the Program: Serve as an instructor in an upper level course; Attend program seminars or journal clubs; or Serve on ad hoc committees focused on maintaining the excellence of the Program. They may serve as thesis advisors for Master's of Science students.

Trainers are those faculty who may serve as thesis advisors for Ph.D. students. Trainers must conduct an active research program and must be prepared to commit the time and effort required to supervise the student's research. They are also expected to have the financial resources to support research projects by graduate students. When accepting a graduate student into the lab, trainers must make a commitment to provide funding for stipend, tuition, health insurance, and fees until the student's thesis is completed. Ph.D. training is most appropriate in an environment where the student can interact with other active investigators and graduate students.

Potential members and trainers are proposed to the Steering Committee by one of its members, who will provide the committee with documentation of the candidate's credentials. Designation of faculty status, as a member or trainer, is made on the basis of the credentials, subject to review every three years. New trainers must provide a summary of the academic and research guidance they provided to their student following the first year annual review for assessment of the training environment by the Steering Committee.

## **II. Admission**

Entering students are expected to have an undergraduate bachelor's degree in either engineering or science. The Graduate Program will make recommendations to the full faculty for interviews and acceptance after the applications have been made available for review by the faculty. Students participating in the Ph.D.-level Program in Biomedical Engineering are admitted by the Graduate School and must primarily affiliate with the MPPB or Neuroscience departments in the Division of Biology and Medicine, the School of Engineering, or other department as deemed appropriate by the Program Director.

## **III. Counseling**

Until the Thesis Advisory Committee is selected, counseling on academic matters and review of student progress will be carried out by the Graduate Program Committee. This committee will put students in touch with other faculty members with related interests who may also provide useful advice. In subsequent years, counseling will be provided by the adviser and the student's qualification exam/thesis committees.

## **IV. Ph.D. Course of Study**

The University requires three years of full time study (i.e., 24 tuition units) for graduation at the Ph.D. level. Students must receive a grade of B or better on courses used in fulfillment of the Ph.D.

requirement and these courses must be taken for a grade rather than on a credit/no credit basis. A maximum of 8 tuition units can be transferred from post baccalaureate work. Additionally, students in the M.D./Ph.D. program can receive 8 credits for satisfactory completion of the first two years of the Program in Medicine, fulfilling the BIOL-related course requirements.

Students must complete an approved sequence of six structured upper level courses, at least two of which must be in engineering, two of which must be in biology, and two of which must be 2000-level courses. The Program Director has discretion to approve courses outside of biology and engineering in cases where they appropriately supplement or support a student's thesis research.

In addition to the structured course requirements, all students must fulfill training in Responsible Conduct of Research (RCR) and statistics. Students with demonstrated experience in statistical design and analysis may be excused from the latter training requirement at the discretion of the Program Director.

## **V. Program Seminars**

Graduate students must attend and participate in regularly scheduled biomedical engineering seminars. Each student will give at least one departmental seminar each year in the BME/Biotechnology Seminar course. This presentation may be based on the student's original research or may consist of a critical analysis of the literature. Students are encouraged to also attend seminar series of individual interest hosted by other programs/departments.

## **VI. Teaching**

Graduate students are encouraged to gain experience in teaching. Students may serve as a teaching assistant, preferably in a course in which graduate students conduct a discussion or laboratory section or present a small number of lectures. Participation in seminars and certificate programs offered through the Sheridan Center is another way to enhance teaching skills.

## **VII. Research**

The choice of a thesis advisor and research area will be made no later than by the end of the first semester unless an exception has been made by the Program Director. Entering students who have not identified a thesis advisor before coming to Brown are encouraged to attend seminars, talk with faculty, and participate in available opportunities for rotation through different research areas. Progress of entering students will be reviewed by the Graduate Program Committee at the end of the first year. These students will compile a one page report describing their academic and research progress and have it reviewed by their adviser, who will send it to the Graduate Program Committee along with a full evaluation of the student's performance in the first year.

## VIII. Ph.D. Qualifying Examination

Before the start of 5<sup>th</sup> semester, each student is required to take a Qualifying Examination. The examining committee, designated the Qualifying Examination Committee, shall consist of the thesis advisor, three other members of the Brown Faculty (one whose primary appointment is as faculty in the School of Engineering and one whose primary appointment is as faculty in the Division of Biology and Medicine), and, where possible, an authority in the area of the thesis research from another institution. At least one member of the committee must also be a member of the Graduate Program Committee (who will give continuity from exam to exam). The student and thesis advisor will jointly select members of the committee, extending requests to serve in a timely manner. The student or thesis advisor will send a memo to the Graduate Program Director and Coordinator listing the membership of the committee for inclusion in the student's file. The thesis advisor will also schedule the meeting time of this committee but should not chair the committee. The Program Director will designate the chair of the committee, which typically will be the Graduate Program Committee representative. Requests for delays in achieving the stated deadline will be reviewed by the Steering Committee of the Graduate Program before approval of the request by that committee.

The Qualifying Examination will consist of written and oral parts. The student will submit a detailed, written document describing both his/her research progress and a proposal for thesis research. The thesis proposal document will be written in the style of an NIH R01 research grant proposal with the following sections; specific aims (1 page), background/motivation and significance, innovation, preliminary results, research strategy, and literature cited. The research strategy should include relevant subsections such as validation/evaluation and potential problems/alternative strategies, as well as a realistic timeline. A final draft of the thesis proposal must be provided to all Qualifying Examination Committee members at least two weeks prior to the date of the oral examination. This document will be the primary focus of the oral examination. The exam will consist of an oral presentation of the proposal, including research progress, by the student, followed by a question and answer session with the committee. The Qualifying Examination Committee will assess the student's written and oral communications skills, progress in research, ability to devise a research plan, and his/her depth and breadth of knowledge of the chosen topic and the discipline of Biomedical Engineering. Based on the student's overall performance, the committee will make one of three recommendations; "pass, pass with stipulations or fail." If a recommendation of "pass with stipulations" is made, the committee will devise a plan and a time line for the student to correct all deficiencies and a means to assess that the deficiencies have been corrected. If a recommendation of "fail" is made, the student will be immediately placed on warning/probation and allowed to retake the Qualifying Examination once, but it must occur before the end of the 5th semester. If a student fails for a second time, the committee chairperson will recommend to the Program Director and Graduate Program Committee that the student be dismissed. The chairperson will communicate the final decision and summarize the Qualification Exam Committee's response to the candidate. Written notification of the outcome of the examination and a copy of the student's written proposal will be sent by the chairperson to the Program Director for inclusion in the student's record. Qualifying Examination results will be reported to the Registrar. Each student who passes and satisfies the requirements of the Qualifying Examination will become a candidate for a Ph.D. in Biomedical Engineering.

## **IX. Ph.D. Thesis Advisory Committee**

Each Ph.D. candidate will have a Thesis Advisory Committee, consisting of the thesis advisor, three other members of the Brown Faculty (one whose primary faculty appointment is in the School of Engineering and one whose primary faculty appointment is in the Division of Biology and Medicine), and an authority in the area of the thesis research from another institution. The student and thesis advisor will jointly select members of the committee, extending requests to serve in a timely manner. Members of the Qualifying Examination Committee are encouraged to serve as members of the Thesis Advisory Committee. The student or thesis advisor will send a memo to the Graduate Program Director and Coordinator listing the membership of the Thesis Advisory Committee for inclusion in the student's file. The thesis advisor will also schedule the meeting times of this committee and will chair the committee. The student and thesis advisor should arrange a meeting of the Brown affiliated members of the Thesis Advisory Committee at least once a year after completion of the Qualifying Examination. The purpose of this committee is to follow the progress of the student, to help the student with difficulties encountered in the dissertation research, and to aid with the evolution of the project. These meetings could be scheduled for the intersession between semesters in the academic year, a time when both faculty and students are likely to be available and free of teaching responsibilities. The student will prepare a written report of progress and proposed work to be distributed to committee members prior to each annual meeting. Examples of an acceptable annual report include a manuscript published, submitted, or in preparation along with a detailed description of planned experiments. A copy of the student's annual progress report must be sent to the Program Director for inclusion in the student's file. Accompanying this file should be an assessment by the adviser and/or thesis committee on the acceptability of the student's progress and any concerns that might exist.

The Thesis Advisory Committee must approve that the research is sufficiently near completion between 1-3 months prior to the defense date. A written memo will be sent by the Committee to the Program Director confirming the status of the research, in order to schedule the thesis defense (see below).

## **X. Ph.D. Thesis**

The Thesis Committee consists of the thesis advisor, three other members of the Brown faculty (one from the School of Engineering and one from the Division of Biology and Medicine), and a reader external to Brown. The Program Director will designate the chair of the committee, typically the ranking BME faculty member other than the thesis advisor. The chair will preside over the thesis examination proceedings. The doctoral thesis will represent a comprehensive summation of the student's total research effort. It must contribute significantly to the field of study and be of sufficient quality to merit publication in a refereed journal. The thesis can be presented in either of two formats. The first format, which may be used by any degree candidate, will contain the following elements:

- a) Abstract – less than 350 words summarizing the thesis problem, methods used to solve the problem, results, and conclusions.
- b) Introduction – a comprehensive review of the field and reasons for performing the research.
- c) Methods and Results – a description of the research performed.

- d) Discussion – an evaluation of the contribution of the thesis research to the field of study and consideration of future directions.

The second format may only be used by candidates whose thesis work forms the basis for two or more papers accepted for publication in refereed journals. In this case the published papers (or relevant portions of the manuscripts) may be substituted for the Methods and Results section of the thesis. Otherwise the format will be the same as that given above; i.e., it should contain a complete Abstract, Introduction, and Discussion. *All candidates must publish or show proof of acceptance of at least one first-author, original research paper by the date of thesis defense.*

If portions of the student's work have been done in collaboration with other investigators, the candidate will explicitly state his/her contribution to the work. Detailed instructions on preparation and format of the Ph.D. dissertation should be obtained from the Graduate School.

Students must submit a copy of their thesis to the Thesis Committee at least two weeks prior to the date of the thesis defense. This defense copy of the thesis must be approved by the thesis advisor prior to submission to the Thesis Committee. After submission of the thesis, the student will present his/her work in a seminar, following which there will be an oral examination attended by members of the Thesis Committee and other faculty members who choose to participate. The student, in consultation with his/her thesis advisor, will schedule the thesis defense and notify the Program Director and all program faculty at least one week before the defense. This is typically done through the Biomedical Engineering program coordinator. Program faculty members are welcome to attend the thesis seminar and participate in the examination.

The oral examination must follow the Graduate School's rules, provided to the thesis advisor prior to the defense:

- 1) A brief preliminary consultation is appropriate among the members of the committee on their reactions to the dissertation, as well as agreement on the general plan of the examination, the order in which questioners will be called upon, etc.
- 2) Then comes admission of the candidate to the examination room and introduction of the candidate and any faculty or others attending who do not know each other. Formal proceedings are opened by the thesis advisor, who gives a brief resume of the candidate's career to date.
- 3) At the conclusion of the examination, the candidate is asked to withdraw to a nearby area to await the committee's decision. Under the presiding officer's direction, the committee members discuss the candidate's performance. When this discussion is concluded, the committee votes, and the votes are recorded on the "Report of Final Examination". Member of the department of professorial rank (Assistant Professor and above) are ordinarily asked to vote.
- 4) If the examination is satisfactory, the candidate is called back into the room to receive congratulations. If the examination is not satisfactory, the presiding officer should communicate that conclusion to the candidate privately. In case of serious disagreement among committee members,

the question might be held in abeyance for a day or two to allow time for reflection and further discussion, in which event the candidate should be informed that he or she will be notified shortly.

5) Satisfactory outcomes can still require minor, textual changes to the physical thesis document. Non-satisfactory outcomes are caused by significant problems with the thesis, such as a clear lack of understanding of the work or revisions that would require any laboratory research. In the case of a non-satisfactory outcome, the candidate will leave the program with a terminal master's degree. The thesis defense can only be taken once.

5) The forms which must be filled out are sent to the administrative assistant of the department, who sees that the presiding officer has them at the appropriate time. After the examination, these documents should be returned to the Graduate School.

## **XI. Financial Support**

Graduate students pursuing the Ph.D. degree are generally accepted into the Program of Biomedical Engineering with a commitment of financial support while their research and academic studies progress satisfactorily and they are otherwise in good standing.

Any doctoral student in good standing and in compliance with all program requirements may request limited, annual travel funds from the Graduate Program Director, who administers the Graduate Program budget. These funds are available to students presenting an abstract at a scientific meeting and can only be requested once per fiscal year (July-June).

Ph.D. students accepted through the standard admissions process will be guaranteed five years of support by Brown University. This covers tuition, stipend, and health insurance and fees and is contingent on the student remaining in good standing. Financial support for degrees other than the Ph.D. are not provided by the University.

## **XII. Sc.M. Degree**

Students can be admitted to the Graduate Program in Biomedical Engineering as candidates for a terminal Sc.M. degree. Students may enter the 5th year Baccalaureate/Master's (Integrated Program) or the Master's only degree program (Master's Program) which may require 1-2 years of study depending on the student's background. Students in these programs are normally not eligible for financial aid.

For the Integrated Program, a student must apply in their final year of undergraduate study at Brown no later than May 31 for Fall semester matriculation or November 15 for Spring semester matriculation. Admission for students in good standing to the Integrated Program for the fifth year will ordinarily be a matter of course; however, such admission must be applied for at the proper time and decided on in the regular way.

To satisfy the requirements of the Integrated Program, students must complete an approved program of study consisting of a minimum of eight semester-courses (eight tuition units), not more than

three of which are for thesis research. Students must complete the core requirements in basic science, engineering, and biology for an undergraduate concentration in Biomedical Engineering at Brown and also complete at least five, structured, advanced-level biology and engineering courses, at least two of which must be in biology and two in engineering. Students must attain a grade designation of B or better on these five courses, which may not be taken on an S/NC basis. As many as two graduate-level courses taken at Brown as part of the student's undergraduate concentration may be applied towards the requirements of the graduate degree as long as they are not used towards fulfillment of the student's undergraduate concentration. Students must submit and defend an acceptable thesis, as determined by the thesis committee.

For the Master's Program, a student must apply by completing the standard Graduate School application and indicate their interest in the Sc.M. degree program. To satisfy the requirements of the Master's Program, students must complete an approved program of study consisting of a minimum of eight semester-courses (eight tuition units), not more than three of which are for thesis research. Students must complete at least five, structured, advanced-level biology and engineering courses, at least two of which must be in biology and two in engineering. Students must attain a grade designation of B or better on these five courses, which may not be taken on an S/NC basis. Transfer of credit towards the Master's Program is not accepted. Students must submit and defend an acceptable thesis.

### **XIII. M.D./Ph.D. Degree**

Applicants to the Brown University Program in Medicine may also apply to the M.D./Ph.D. Program. M.D./Ph.D. students must complete all of the BME Program requirements specified for the Ph.D. degree. Prior to leaving for continued medical training, the student must successfully pass the thesis defense, have the final written thesis signed by committee members, and submit this document to the Graduate School. If these requirements are not completed by the time the M.D./Ph.D. student leaves, then the student will be removed from the Ph.D. graduate program and awarded a terminal master's degree, commensurate with the completed requirements.

### **XIV. Dismissal**

Failure to fulfill any requirements in a timely fashion will result in a student being placed on warning/probation. A student on probation may be dismissed from the Graduate Program. A student may be dismissed from the Graduate Program for academic or non-academic reasons. The Graduate Program Committee will review each case. Two thirds of the Graduate Program Committee will constitute a quorum, and final decisions will require a majority vote. Appeal of such decision is to the Dean of the Graduate School.