

The BME PhD Handbook

The PhD Program in Biomedical Engineering

in

The McCormick School of Engineering and Applied Science

at

Northwestern University



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THE PhD PROGRAM

The purpose of Northwestern University's doctoral degree program in Biomedical Engineering (BME) is to produce graduates who are qualified to fill research positions at the highest levels in private industry and in government laboratories, to teach in this field at universities, and to perform and direct original research on the staffs of universities, hospitals or companies. Students entering the program with a degree in a field other than BME, e.g., traditional areas of biology, civil engineering, etc., are expected to concentrate their elective course work to gain expertise in the areas of BME that are new to them.

Students in the BME doctoral program study approximately equal portions of engineering, life sciences, and mathematics. Biomedical Engineering is a diverse field, and thus breadth is required. At the same time, students are expected to develop depth and understanding in one particular area of engineering and one of the life sciences. The areas of mathematical and computational development are also somewhat flexible, with some breadth expected, but should be appropriate for the student's area of study. The relative effort devoted to engineering, life sciences, and mathematics will depend on the student's previous background.

Students in the PhD program enter into one of six "tracks" representing the broad research areas in our department. The purpose of these tracks is to guide students in their course selection, providing depth in areas relevant to their selected research area. The current tracks offered are:

- Biomaterials
- Imaging and Biophotonics
- Mechanics and Transport
- Neural Engineering
- Rehabilitation
- Regenerative Medicine and Engineering

Specific requirements for each track are contained in the [Track Requirements section of the BME website](#). Graduate students are admitted to The Graduate School (TGS), not the Engineering School. At Northwestern University, almost all advanced degrees are conferred via TGS. Thus, students must meet degree requirements as stipulated on [The Graduate School website](#). All courses taken for graduate credit must be listed as graduate-level on CAESAR (e.g., BME 395 does not qualify for graduate credit).

REQUIREMENTS FOR OBTAINING THE PhD IN BIOMEDICAL ENGINEERING

Students entering with a BS degree must complete a minimum of 12 courses at Northwestern University. These are to include the required courses listed below, as well as sufficient additional coursework to meet the described competencies for the selected **course track**. All additional courses must be in Engineering, Science, or Mathematics. Students are to work with their primary BME advisor to ensure that the plan of study is sufficient for meeting all specified competencies. All courses used to meet these minimum requirements must be for a letter grade (i.e., P/N courses are not accepted) and none can be a 499 (research credit).

The following course is required for all students in the PhD program:

- BMD_ENG 407: Experimental Design and Measurement

All first-year students are required to complete BMD_ENG 512 in the fall, winter, and spring quarters. Upon petition to the Graduate Program Chair, a student may delay completion of BMD_ENG 512 until a subsequent time if the student is enrolled in a class that meets in conflict with BMD_ENG 512.

The following professional skills are recommended for all students, but not required:

- Public speaking: TGS offers public speaking workshops throughout the year. Students are strongly encouraged to participate prior to taking the oral Qualifying Exam.
- Grant writing: TGS offers grant writing workshops throughout the year. Students are strongly encouraged to participate prior to taking the oral Qualifying Exam. Workshops relevant to NIH funding are most relevant to this particular exam.

Students are required to complete a Plan of Study by the end of January during the first year. This plan must be approved by the primary research advisor and the Director of Graduate Studies (DGS). Note that this is just an initial plan and is likely to change depending on course offerings and the student's developing research interests. Appropriate changes can be made with approval of the primary advisor and the DGS.

The requirements for students entering with an MS or students in the MSTP or PhD/DPT programs are identical to those for students entering with a BS, with the following exceptions. Note that these students must also demonstrate competency in all areas of the selected **course track**.

- *Students entering with an MS or in the PhD/DPT programs:* A minimum of nine 300 or 400-level graduate courses must be taken for a letter grade (i.e., P/N courses are not accepted). One of these may be a 499 (research credit). All of these courses must be science, engineering, or mathematics courses, and include BMD_ENG 407.
- *Students in the MSTP:* A total of at least six 300 or 400-level graduate courses for a letter grade (i.e., P/N courses are not accepted). None of these may be a 499 (research credit). All of these courses must be science, engineering or mathematics courses.

RESEARCH ADVISOR AND THESIS COMMITTEE

Vocabulary Notes:

- Core and Courtesy BME faculty members are identified on the BME website.
- Your research advisor is often, but not always, the Chair of your thesis committee.
- Please see separate video for instructions to determine who is a member of TGS Faculty.

1. By Thanksgiving, all first-year students are required to pick a research advisor who agrees to support them as a research assistant. Students who choose to work with a research advisor who is not core faculty in BME must also select a BME co-advisor by this time.

2. Details on co-advisors:

2A) Students who choose to work with a research advisor who is not a core BME faculty member must select a BME co-advisor by Thanksgiving of the first year. The BME co-advisor must be core BME faculty. The role of the co-advisor is to serve on the thesis committee and to provide access to a faculty member who is well-versed in the requirements of the BME department. The co-advisor's role in your PhD research is no different than any other thesis committee member.

2B) Occasionally, students who choose to work with a research advisor who is a core BME faculty member might also select a co-advisor, if they anticipate that their thesis project will be joint between two laboratories. The decision to add a co-advisor should be carefully discussed with the research advisor. The co-advisor can be added at any time during the student's PhD.

3. Students are required to form a thesis committee by the end of the summer quarter of their first year.

3A) The Chair of the committee:

- Must be a core member of the BME department.
- Is typically, but not always, your advisor.
- If your advisor is not a core member of the BME department, the co-advisor can be Chair.
- Must be a member of the Graduate School Faculty. See separate video for instructions to determine who is a member of the Graduate School Faculty.

3B) A thesis committee must consist of at least four faculty members. The Chair counts as one of these faculty members.

- At least three members must be full-time members of Northwestern University faculty.
- At least two members must be members of the Graduate School Faculty. See separate video for instructions to determine who is a member of the Graduate School Faculty.
- At least two members must be core or courtesy members of the BME department.
- One member should be your advisor (who may or may not also be the Chair).

4. The thesis committee must meet at least once per academic year, beginning in the second year, to review student progress. The first committee meeting should occur soon after the initial research project (see Research Component of the PhD Qualifying Exam) is completed. The occurrence of this initial meeting can be no later than March 31st of the second year. At least two committee meetings must be held before the final doctoral defense can be scheduled

PhD QUALIFYING EXAMS

PhD Qualifying Exams must be completed by the end of the second year of study. Prior to taking these exams, students must complete at least 9 courses, including the required physiology and mathematics courses, and the two required courses for the selected research track. MSTP students must take all six required courses before Qualifying Exams.

There are three components to the PhD Qualifying Exam: a course-based component, a research component, and an oral exam. The requirements for each component are directly related to the student's area of research.

- i. **The course-based component** of the exam ensures that the candidate has understood the basics of the chosen biomedical research area. Two core courses are specified for each research track. Students must receive a grade of A- or better in these core courses. Failure to do so will require the student to pass a written Qualifying Exam for core courses in which a grade less than A- was received.
- ii. **The research component** of the Qualifying Exam is to be completed under the supervision of the student's primary research advisor. The scope of the project should be equivalent to six months of full-time research effort. Project details and specific goals are to be agreed upon by the student and the advisor prior to the start of work. The project must be started no later than June 15th of the first year and completed no later than March 1st of the second year. Earlier start and completion dates are encouraged. At the end of the project, the student must present a summary of the research to the thesis committee at the first committee meeting (no later than March 31st of the second year). The student's thesis committee will grade the progress on a Pass/Fail basis.

For students entering with a BS, this initial research project should form the basis of the MS thesis. The committee will assess the student's expected timeline to submit a document to meet the MS writing requirements as listed in the next section. For those entering with an MS, or in a program that does not require an MS to be completed (e.g., MSTP, PhD/DPT), this initial research project can be incorporated into the PhD dissertation. The committee will assess the student's expected timeline to submit a first-author manuscript to a peer-reviewed journal.

- iii. **The oral component** of the Qualifying Exam will take, as its starting point, a written research proposal that the student submits to a standing committee of BME faculty, different from the student's thesis committee. The written proposal will either be in the form of an NIH NRSA application, following the current guidelines posted on the NIH website (1 page Specific Aims, 6 page proposal), or students may choose to reduce the total length of the proposal by one page (1 page Specific Aims, 5 page proposal). Ideally, the research proposal would be an extension of the initial research project described above, and/or a component of the planned dissertation, though this is not absolutely necessary. The scope of the proposal should be equivalent to the work required for a single publication, equivalent to approximately 1 year of full-time research. The student will defend the proposal during a 1-hour oral exam before the standing committee. This exam emphasizes general questions related to the area of research. The goal of this exam is to evaluate the student's preparedness for independent graduate research.

The oral component of the Qualifying Exam must be taken in June of the second academic year. Upon failure, students may petition to the Graduate Program Committee for permission to retake the oral component of the exam. Permission will be granted in only rare circumstances. If granted, the exam must be taken prior to the start of the third year of study. Students who remain in good standing but fail the oral exam will be given the option to leave the program with an MS degree, upon completion of all additional requirements for the MS program.

MS DEGREE REQUIREMENT FOR STUDENTS IN THE PhD PROGRAM

Students entering with a BS degree and not enrolled in the MSTP or PhD/DPT programs are required to complete an MS degree no later than the end of their third year of study. Ideally, the MS degree will be completed within two years. Completion of the MS degree is required for admission to PhD candidacy. Students not completing the MS by the end of the third year will be placed on probation by TGS.

The requirements for the MS degree are as follows:

- i. Completion of all courses required for the PhD Qualifying Exams.
- ii. A committee meeting in which the thesis committee agrees that the completed research is sufficient for the MS degree. An estimate of the timeline for completing research sufficient for the MS degree should be obtained at the first committee meeting in the spring of the second year.
- iii. Completion of the MS writing requirement. This requirement can be met by submitting the MS research to a peer-reviewed journal approved by the thesis committee. The student must be the first or co-first author on this publication. Conference proceedings cannot be used to meet this requirement. If the MS research is not suitable for publication in a peer-reviewed journal, this requirement can be met by submitting an MS thesis before the end of the three-year deadline. Only the primary research advisor needs to approve the MS thesis.

GRADES

Credit for the MS or PhD degree will be given only for courses in which a grade above a C- has been received. No P/N registration will be accepted. A GPA greater than a 3.0 is required for graduation with an MS or PhD. 499 courses do not count toward the GPA, except with approval by the Chair of the Graduate Program Committee. A student whose overall GPA is below 3.0 is not meeting academic standards and will be placed on probation. Failure to improve the GPA may lead to exclusion by TGS. Further grading details can be found on the [TGS website](#).

PUBLICATION REQUIREMENT

All students are required to be the first or co-first author on a peer-reviewed journal article accepted for publication prior to defending their PhD research. For students entering with a BS degree, this publication can be the same used to meet the MS degree requirements. The thesis committee must approve the selected journal. Conference proceedings cannot be used to meet this requirement.

THESIS/DISSERTATION REQUIREMENTS

Upon written recommendation from the thesis committee and following a thesis committee meeting, a final thesis defense can be scheduled. Notification of this defense must be circulated to all faculty members of the department a minimum of three weeks before the defense and cannot be circulated prior to written approval by the thesis committee. All thesis committee members must receive a copy of the thesis at least two weeks prior to the defense. The thesis defense is open to all members of the Northwestern University community and their guests.

An acceptable dissertation resulting from original research must conform to [guidelines](#) set forth by TGS. Each student must submit a PDF of the completed thesis to the department office. An electronic copy also must be submitted to TGS, as described on their [website](#).

TEACHING REQUIREMENT FOR PhD STUDENTS

Whether working in academia, industry, or a research laboratory, recipients of a PhD degree are often in the position of mentoring and educating others. Teaching is not limited to academic lectures; presentations at international meetings and in corporate boardrooms are forums that require teaching skills, and patents must teach the reader the utility and novelty of the disclosed design or process. Thus, the BME department requires that all PhD students serve as teaching assistants (TA) within the first 3 years of their tenure at Northwestern University. Extensions beyond this time require prior approval of the Graduate Program Committee.

The teaching requirement is to be fulfilled by serving for at least one quarter as a full-time TA (approximate time commitment: 20 hr/week) for a BME course. Serving as a TA in a department other than BME will not fulfill the TA requirement unless prior approval by the DGS has been granted. The responsibilities of a TA include but are not limited to: tutoring students, conducting problem solving sessions, preparing and supervising laboratory sessions, and grading. It is expected that some students will want more than this minimal teaching experience; where possible, these students will be accommodated. The teaching requirement is usually completed during a student's second or third year in the program.

TYPICAL PhD TIMELINE

Figure 1 summarizes the major milestones during the PhD qualifying process and the approximate expected effort during this time. Darker bars correspond to increased effort. Failure to meet the required milestones will result in the student being placed on probation by TGS and may result in exclusion from the PhD program. Unless specified, the listed milestones are deadlines, not suggested completion dates. Students are encouraged to complete milestones, especially those in the first year, as soon as possible.

The target duration for completing the PhD in BME is 5-6 years, though the exact duration will depend upon the details of the selected research project and the ability of the student and advisor to work together to complete research and publications. After the Qualifying Exams of the second year, it is expected that most students will dedicate 100% of effort towards research, fulfilling their teaching requirement, and completing any remaining coursework.

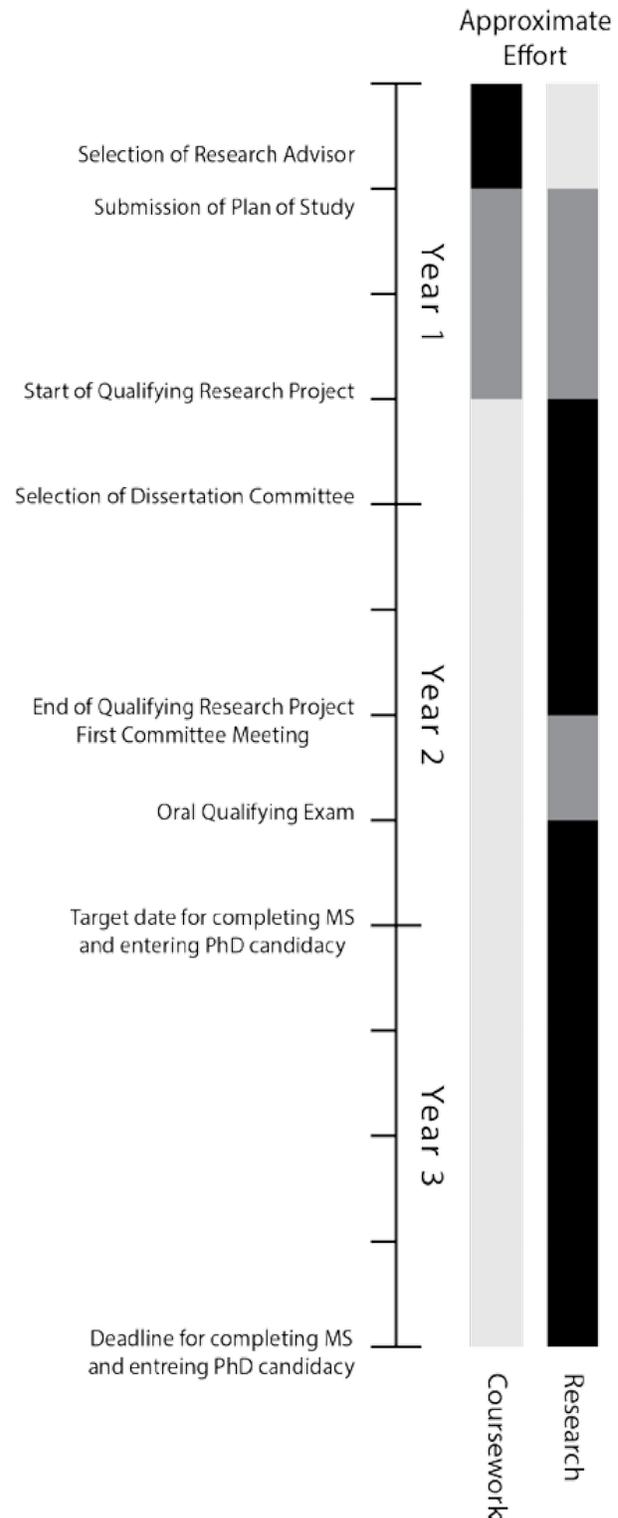


Figure 1. PhD Major Milestones

REGISTRATION

All students using departmental facilities in any quarter must be registered. Registration details and recommended patterns of registration can be found on the [TGS website](#). A full-time registration of 4 units of courses and/or research (BMD_ENG 590 or TGS 500) is typical. Generally, in the first two years of PhD study, students complete courses and some units of BMD_ENG 590. Once students complete the first eight quarters of full-time enrollment in the PhD program, they should enroll in TGS 500 (Advanced Doctoral Study).

The maximum time allowed for completing all PhD requirements is 9 years. Beyond this time period, students will not be eligible to receive federal loans or to qualify for the university health insurance subsidy, nor will they be eligible for fellowships, traineeships, teaching or research assistantships, or scholarships. This status is considered less than half-time and therefore does not provide students with the ability to defer loans or extend visas. Petitions based on hardship will be reviewed on a case-by-case basis by the Dean of TGS. Other alterations in the residency timeline can be managed through Leave of Absence requests from TGS.

Per the [Continuous Registration Policy](#), all doctoral students must be registered at Northwestern University in each of the fall, winter, and spring terms until all degree requirements have been completed. Five types of post-residency registration are available. They are:

1. TGS_588: Resident Master's Study (applies to most post-residency MS students)
Available to MS degree students who are receiving financial aid. Provides full-time status but allows no accumulation of credit or residency toward the MS degree. This registration requires TGS permission.
2. TGS_500: Advanced Doctoral Study (applies to most post-residency PhD students)
Available to doctoral students who have completed the residency requirement of 8 quarters of full-tuition registration within their program and are receiving aid from the University. Provides full-time status. Students may register for TGS_500 via CAESAR.
3. TGS_512: Continuous Registration
For students who are continuing in their degree programs and are not registered in program coursework or any other TGS courses (500, 588). TGS_512 is \$100/quarter and provides full-time status. Students may register for TGS_512 via CAESAR. See the [Continuous Registration Policy](#) for more information.
4. TGS_513: Advanced Continuous Registration
Graduate students who are beyond their degree deadline (doctoral students after 9 years from first term of enrollment and MS students after 5 years from first term of enrollment) are subject to academic probation. Those on probation for exceeding the degree deadline will be enrolled in TGS_513: Advanced Continuous Registration in each fall, winter, and spring quarter of probationary status.
Students in this Advanced Continuous Registration status are not eligible to receive federal loans or to qualify for the university health insurance subsidy, nor will they be eligible for fellowships, traineeships, teaching or research assistantships, or scholarships. This status is considered less than half-time and therefore does not provide students with the ability to defer loans or extend visas.
Tuition for TGS_513 is currently \$1000/quarter. In cases of extreme hardship, special dispensation might be granted through filing a petition.
5. TGS_514: Continuous Registration Exception
This is a no-tuition registration that keeps your TGS record active. It is applicable only to students in the PhD/DPT program during quarters in which they are working towards their clinical degree. The TGS student advisor must be contacted to approve this registration.

FINANCIAL AID

Incoming PhD students are provided with a minimum of 5 academic years and 4 summers of guaranteed funding. This funding typically comes from a combination of research assistantships in the selected laboratory, and fellowships or scholarships administered by TGS. All graduate students are also strongly encouraged to seek external funding for their research. External grants perform two vital functions: first, they supplement or extend doctoral students' funding to finance research; additionally, such awards – particularly if they are highly competitive and prestigious – can enhance a student's resume.

Students who need additional funds to pay for their education may wish to apply for loans. Only U.S. citizens and permanent residents who are enrolled at least half-time are eligible for federal loans. There are alternative loan options for part-time students and for international students. To be eligible for all forms of financial aid, continuing graduate students must remain in good academic standing and demonstrate satisfactory academic progress toward their respective degrees. Further details and links to additional information can be found on [the TGS website](#).