

**Biomedical Engineering MS and PhD  
Program Guidelines and Regulations**

- I. Introduction.** To complete the requirements for the Doctorate (PhD) degree, graduate students in the Biomedical Engineering Program must successfully complete required and elective courses, attend Biomedical Engineering (BME) departmental seminars, pass a qualifying examination, perform research and write and defend a dissertation. The program requires the completion of at least 135 hours of course and research credits, of which at least 54 hours must be in PhD Dissertation Research (begun after advancement to candidacy). Students are expected to enroll in 12 credit-hours per term (including summer term).

Students can enter the BME graduate program directly or through Program in Molecular and Cellular Biosciences (PMCB). The first year of graduate studies in PMCB involves laboratory research rotations and completion of PMCB core courses that can contribute to fulfilling BME course requirements.

To complete the requirements for the Masters (MS) degree, graduate students in the Biomedical Engineering Program must successfully complete required and elective courses, attend BME departmental seminars, perform research and write and defend a thesis. The program requires the completion of at least 45 hours of course and research credits, of which at least 24 hours must be in MS Thesis Research.

- II. Required courses.** The following courses must be successfully completed with a grade of “C” or better except for courses graded on a pass/not-passed (P/NP) basis for which a grade of “P” must be received.

Requirements	Course Number	Title	Term Offered	Credit Hours
At least 3 terms (every term expected)	BME 507/607	Biomedical Engineering Seminars	All terms except Summer	0
Required	CONJ 650	Principles of Scientific Conduct and Practice	Fall	1
Required	CONJ 620	Introduction to Biostatistics for the Basic Sciences	Winter	3
	BME 601	Pre-qualifying PhD Research	All terms	
At least 54 credits	BME 603	PhD Dissertation Research	All terms	
At least 24 credits	BME 503	MS Thesis Research	All terms	
4 electives			Any term	>8

**A. Course Waiver due to previous course work.** If a student feels that they have completed an equivalent, graduate-level course to any of the required or elective courses, they may petition to have the course requirement waived. Waived courses will not count toward credit hour requirements. To petition, the student and advisor should write a memo requesting that the course requirement be waived and explain why the student feels that the previous course is equivalent to the required course. A course description or syllabus that indicates the subjects covered by the previous course should be included with the memo. Upon approval by the advisor, course director and BME graduate program director, the waiver will be submitted to the School of Medicine Graduate Studies Office for approval by the Associate Dean of the School of Medicine (SoM).

**B. BME Departmental Seminar.** All students are required to enroll in and attend BME 507/607, Biomedical Engineering Seminars, for at least 3 terms throughout their graduate tenure. Enrollment and attendance every term, except Summer, is expected.

**C. Elective Courses.** BME requires that students successfully complete at least four elective graduate courses offered by BME or other SoM departments or equivalent prior to taking their qualifying exam. See Appendix A – Course Descriptions for a list of some of the BME electives.

**III. Academic Progress.** The School of Medicine requires that graduate students maintain an overall 3.0 grade point average in coursework (A=4; B=3; C=2; D=1). Courses graded on a P/NP basis do not contribute to a calculation of the grade point average. Students are recommended to review the Graduate Studies By-Laws for more information regarding GPA and academic probation.

**IV. Student Stipends.** Students are expected to register for a normal, full-time course load each term, but may register for course loads that are less than full time with approval from the Program Director. However, students should be advised that reduced course loads may affect eligibility for scholarships, tuition waivers and financial aid. Please refer to the School of Medicine stipend policy for more information.

**V. Qualifying Examination for PhD students (end of year 2).**

**A. Eligibility.** To be eligible to take the BME Qualifying Examination (QE), students must have successfully completed all coursework required in the first two years of the BME curriculum. Students may not take the qualifying examination if they are on academic probation or if an incomplete grade remains on their transcript.

**B. Timeline and description.** Specific dates for the exam may vary slightly from year to year, but the following are general guidelines for stages of the QE. Students are expected to take the qualifying exam by the end of their 8<sup>th</sup> term of graduate study. Extension of this deadline for any reason will only be considered by written request to the BME Graduate Program director. If the

student fails to complete the QE by the end of the 12<sup>th</sup> term of graduate study, they will be recommended for dismissal for failure to progress academically. Students may request permission to take the QE earlier than the schedule below. The request must be made in writing to the BME Graduate Program Director at least two months prior to the proposed exam date. The request must be pre-approved by the student's advisor.

**C. Qualifying Examination Committee involved in the administration of BME Qualifying Examinations (QEC - 5 members).** This committee is responsible for administering a specific qualifying examination. For each student, the BME Graduate Program director will appoint an examination panel of five faculty members and assign one panel member to serve as chair. Three of the panel members may have primary appointments in BME, while the others may have primary appointments outside of the department. SoM graduate faculty members with joint or adjunct appointments with BME may serve as outside members of the panel. Each of the five members of the QEC will participate in the examination process and vote on the outcome. In addition, a non-voting member representing BME may attend all deliberations and meetings of each QEC. The student's advisor/mentor may NOT be appointed to the panel. The QEC will be responsible for evaluating the written and oral components of the examination, for determining the outcome, and for identifying any requirements that a student must complete in the case of a conditional pass. Each student will have their own QEC, though BME and SoM faculty may serve on multiple panels.

**D. Role of Advisor/Mentor.** To facilitate an objective examination, the student's advisor/mentor is not permitted to edit the written proposal. Neither is the advisor/mentor permitted to coach the student in a rehearsal of their oral presentation or serve on the QEC.

**E. Format.** The QE consists of a written and oral component. The candidate must pass both the written and oral portions of the examination in order to pass. The written component will resemble a National Institutes of Health (NIH)-style National Research Service Award (NRSA) grant proposal on any topic chosen by the student, including the student's proposed dissertation research. The oral component will consist of a closed 30-minute presentation by the student on the topic of the written proposal. Members of the student's Qualifying Exam Committee (QEC) will ask the student a series of questions on the proposal and related science.

**F. Format of Written Proposal.** The proposal shall be written following current general guidelines of a NRSA-style application. It is the student's responsibility to check on the current guidelines, which are available on the NIH website. The proposal shall be no shorter than 6 pages, and no longer than 12 pages (single-spaced), excluding figures and references. Students are encouraged to discuss topics and proposed experiments with all sources (fellow students, post-doctoral fellows, faculty, and visiting scientists). Students may also seek general assistance in scientific writing and proofreading. However, it must be remembered that the written proposal is an examination, and must represent the student's ideas and development of the research topic.

Students are expected to adhere to established guidelines for professional ethical conduct in the preparation of their QE proposal topics.

**G. Format of Oral Qualifier Examination.** The oral examination will probe the sufficiency of the student's preparedness to conduct the proposed research and also the depth of the student's understanding of his/her research proposal. Students are expected to begin the oral examination by giving a short (30-minute) formal presentation summarizing the written proposal. Audio-visual aids may be used during the summary of the proposal. During the oral examination, by the panel, the use of prepared visual aids, textbooks, or other reference material is not permitted. Slides and figures from the oral summary may be referred to if they are the subject of a question from the exam panel. Questions from the QEC should focus primarily on issues pertaining to the proposal; however, the student is responsible for all areas that have been covered during the first two years of graduate course work. Therefore, students also should expect questions on general knowledge in addition to questions relating to the scientific background pertinent to their areas of specialization, as well as more general issues related to the proposed experiments. Students may be asked about the choice of methodologies, their relative advantages and disadvantages, and potential alternative strategies (when appropriate). Students will be expected to understand and be ready to explain the scientific basis of technical methods they intend to employ. The student should be prepared to discuss the rationale for the proposed study, the strengths and limitations of the proposed experimental strategies, and potential pitfalls and alternatives.

**H. Preparation for the Oral Qualifier Examination.** Students should be thoroughly familiar with key historical and background publications that provide the foundation for their proposal, as well as any current literature that directly pertains to their specific aims. In addition, students are encouraged to review the more general scientific areas that provide the conceptual framework for their proposal. Once a student has submitted their final written proposal to their QEC, they may contact panel members for guidance in preparing their oral exam presentation.

**I. Outcomes.** The outcome will be decided by majority vote of the QEC and be recorded on the BME Qualifying Examination form. The form shall be signed by all voting members of the QEC and returned promptly to the BME Graduate Program Director, who will inform students of the outcome immediately after the results are received. Possible outcomes include:

**Pass** – The student passes both the written and oral examination. In certain circumstances, the QEC may identify specific areas of weakness that the student needs to address during subsequent thesis/dissertation work. This information will be communicated in writing to the student, advisor, and BME program director by the chair of the examination panel.

**Conditional Pass** – A conditional pass may be given for either the written or oral components of the examination if significant deficits are identified. In this case, the student will

be provided with specific requirements that must be met within a prescribed time frame. A variety of requirements may be assigned at the discretion of the QEC to correct a perceived deficit, including (but not limited to) additional coursework; revision of some or the entire written proposal; assignment of additional directed reading; preparation of a written review of a particular topic; or presentations in journal club formats. In the case of assigned additional coursework, the student must complete the assigned course(s) with a grade of “B” or better. Within one week of the oral examination, the chair of the QEC will prepare a written statement to the student describing the conditions required to remove the conditional pass.

The chair of the student’s QEC will be responsible for notifying the student, the student’s advisor, and the BME Graduate Program Director when the student has successfully completed the requirements of the conditional pass. Failure on the part of the student to complete the requirements within the prescribed time frame will be considered unsatisfactory progress, and the student may be subject to dismissal from the BME Program.

**Fail** – If the student fails either portion of the examination, the student fails the QE. Within one week of the examination, the chair of the QEC will provide a written statement to the student, the advisor and the BME Graduate Program Director, describing the deficiencies that led to failing the qualifying examination. The student may petition the QEC to take the qualifying examination (written and oral) again within the subsequent three months, or alternatively may resign from the graduate program. The QEC may also elect to offer the student the option to complete a Master’s Degree, rather than re-taking the Qualifying Examination. In such a case, students will be obligated to complete all the requirements for a Master’s Degree in BME. The QEC will counsel the student with respect to the most prudent course of action. If the student decides to re-take the Qualifying Examination, then he/she must submit a revised or new proposal to the QEC as summarized above; and will have five weeks to complete the full proposal.

**J. Timeline for re-examination.** The re-examination procedure should be completed within three months of the original examination, and no later than the end of following academic term.

**K. Outcome for re-examination.** Students will be assigned a “pass,” “conditional pass,” or “fail” by the same criteria as summarized above. Failure to pass the QE after two attempts will result in recommendation to the School of Medicine for dismissal from the graduate program. (SOM By-laws Article X).

**L. Advancement to Candidacy.** Upon successful completion of the QE, students will become eligible for recommendation for advancement to candidacy. Please refer to the Graduate Studies By-Laws (Article IX) for the SOM Guidelines for Advancement to Candidacy. The BME Graduate

Program Director will sign the Qualifying Examination form indicating successful completion of all BME requirements for advancement to PhD candidacy.

**VI. Thesis/Dissertation Advisory Committee.** Please refer to the School of Medicine Graduate Studies Dissertation Advisory Committee and Thesis Advisory Committee policies for the requirements for Thesis/Dissertation Advisory Committee.

A thesis/dissertation advisory committee shall be appointed by the Program Director to guide and advise the student in the thesis/dissertation research and preparation of the thesis/dissertation document. The committee shall be appointed within one term after advancement to PhD candidacy or upon commencement of thesis research for MS students. The Associate Dean for Graduate Studies must approve the appointment of each Advisory Committee based upon the recommendation of the Program Director. Students must meet with their Thesis/Dissertation Advisory Committee within 6 months of passing the Qualifying Examination (QE) or upon commencement of thesis research. During the initial meeting, one member of the committee, excluding the mentor, should be selected to serve as chair of the advisory committee. The advisory committee shall meet at least twice annually to evaluate progress toward completion of the thesis or dissertation. Thesis/ Dissertation Advisory Committee meetings will usually involve oral presentation by the student of their research goals and progress. Following each committee meeting, the committee chair should complete a summary evaluating the student's progress which should be sent to the BME Graduate Program Director.

With the approval of the Program Director, the committee may place a student on academic probation if it is determined that progress has not been adequate. The Program Director shall notify the student and the Associate Dean for Graduate Studies in writing of the probationary status and specify in what way(s) the student is failing to meet standards and specify time limits for correcting the deficiencies. If the student fails to correct the deficiencies within the specified time limits, the Program Director may recommend dismissal of the student.

**VII. Student Seminar – Third Year.** PhD students should present a departmental research seminar during the third year of graduate studies. It is the sole responsibility of the student to schedule their seminar with the BME seminar chair during their 3<sup>rd</sup> year.

**VIII. Oral Examination Committee.** Please refer to the School of Medicine Graduate Studies By-Laws (Article IX) for requirements for the oral examination committee.

Candidates for the MS/PhD degree must present a written description of the research carried out during their course of study in the form of a thesis/dissertation. The thesis/dissertation must demonstrate ability on the part of the student to plan and execute original research, and the results must represent a definite contribution to scientific knowledge. Although there is flexibility in the amount of work required for the thesis/dissertation, in general the thesis/dissertation should

represent the equivalent of at least two first-author publications in significant, peer-reviewed journals, and should be submitted for publication prior to the defense. BME requires that the Advisory Committee meet to review and approve the proposed thesis/dissertation research before a thesis/dissertation defense can be scheduled. The chair of the Advisory Committee should send a memo to the BME Graduate Program Director recording approval of the thesis/dissertation project and approval for scheduling the oral defense. The composition of the Oral Exam Committee (OEC) should be suggested by the student and mentor, and must be approved by the BME Graduate Program Director. The oral examination committee shall be appointed by the Associate Dean for Graduate Studies upon the recommendation of the BME Graduate Program Director.

After these approvals are obtained, the BME Academic Coordinator will submit the form to the SoM Graduate Studies Office for final approval of the composition of the Oral Exam Committee (OEC) by the Associate Dean for Graduate Studies. This form must be submitted no later than 4 weeks prior to the scheduled defense.

**IX. Time limit for completing degree requirements.** It is the SoM Graduate Council policy that students must complete all requirements for the PhD within 7 years of matriculation. Students that do not complete degree requirements within this deadline may be dismissed from the graduate program. Students, mentors and the thesis/dissertation Advisory Committee should consider this deadline when evaluating thesis research goals and progress. It is a SoM requirement that the student be *continuously enrolled* until the thesis is bound.

**X. General timetable for most graduate students.** Twelve credit-hours should be taken each term, including Summer Terms.

**A. Year 1 – BME Core Courses**

The main goal for the first year is to work with your mentor (advisor) to identify those courses of most relevance to your area of research, and to take as many core courses and electives as practical during the first 9 months in preparation for your proposal development and oral exam. Some electives are offered once every two years and it may be desirable to take some electives during the first year in order to prepare for the qualifying exam at the end of the second year. Students should also participate in a journal club and/or work with their mentor to critically review the scientific literature in their area.

**B. Year 2 – Complete BME course requirements and prepare for qualifying exam**

Students should enroll in any remaining required and/or elective courses and BME seminars to fulfill requirements for taking the qualifying exam. The majority of the student's time and effort should be in research. A major goal for the second year is to begin to acquire the laboratory skills and conceptual framework necessary for thesis work. The student should also be spending free moments reading the scientific literature. BME students are required to take the qualifying exam

during the summer of their second year. Immediately following passing the qualifying exam, students in consultation with their mentor should nominate a thesis/dissertation Advisory Committee which must be approved by the BME Graduate Program Committee. Students must meet with their thesis/dissertation Advisory Committee within 6 months of passing the Qualifying Examination.

**C. Year 3 until graduation**

The student must meet with their thesis/dissertation Advisory Committee at least once a year to bring them up to date on research progress and to discuss future directions. The student must present a departmental research seminar during the third year. About 6 months prior to anticipated thesis defense, it is useful to meet with the thesis/dissertation Advisory Committee to establish a consensus on items that need to be completed. It is expected that most PhD graduate students will defend their dissertation sometime in their fifth calendar year; most MS graduate students will defend their thesis sometime within their third year. It is a SoM requirement that the student be continuously enrolled until the thesis is bound. Students may not use a leave of absence to make corrections to the thesis.



## APPENDIX A – Course Descriptions

### REQUIREMENTS

#### BME 507/607 Biomedical Engineering Seminar

This seminar course will feature presentations and discussions on topics in biomedical engineering that exemplify the wide range of applications of biomedical engineering to science and medicine. The goals are to provide the students with an overview of the diverse opportunities for research and application, to foster development of critical analysis and thinking, and to stimulate creative problem solving and research planning.

#### CONJ 620 Biostatistics

This course is designed for students enrolled in basic science graduate programs to provide an introduction to biostatistics concepts and analysis methods that are required to conduct research in these fields. The course is a combination of lectures (some of which may be online), statistical computing tutorial sessions and journal clubs. Some homework/projects will require the use of a statistical software package.

#### CONJ 650 The Practice and Ethics of Science

This course is designed to provide students in biomedical research with survival skills and an understanding of ethical conduct. Topics covered include: being a trainee, scientific integrity and misconduct, scientific publication, oral presentations, lab safety, use of laboratory animals, human subjects research, and research funding. Ethical dilemmas and issues are discussed in context of the practice of science.

### ELECTIVES

BME requires that students successfully complete at least four elective graduate courses offered by BME or other SOM departments on campus prior to taking their qualifying exam. Below is a listing of some of the more common electives taken by our students:

#### BME 540/640 Fluid Mechanics and Biotransport

This course introduces basic concepts of fluid mechanics and convective mass transport. It will start with a derivation of mass, momentum and energy conservation equations for fluid flows. The importance of non-dimensional parameters such as Reynolds number and the Womersley parameter will be extensively discussed, and non-dimensional equations will be derived. Other topics to be covered include Bernoulli's equation, low and high Reynolds number flows, oscillatory flows, interactions of fluid flows with tissue and boundary layers. The final part of the course will cover the derivation and use of mass transport equations in fluid flows. Examples from different areas of biomechanics will be discussed throughout the course.

As part of this course, each student will be asked to work on a project. Students will be encouraged to choose project themes from their own research areas or interests. Access to a finite element package will be available for interested students. Through the project, students will be exposed to current analytical and computational methodologies to analyze fluid flow dynamics.

#### BME 565/665 Introduction to Computational Neurophysiology

Mathematical overview of how neurons communicate through electrical signals, how information transmission between neurons occurs, and how connectivity between neurons determines activity patterns and results in specialized behavior. Topics to be covered include Hodgkin-Huxley models of simple and complex morphologies; central pattern generators; models of simple invertebrate circuits; integrate-and-fire and spike-response neuron models for use in network models; models of neural development, ocular dominance and orientation columns; and rate versus spike-timing dependent plasticity. A solid math background is needed; some programming (in MATLAB) will be required.

#### BME 580/680 Signals and Linear Systems

This course introduces the basic tools for continuous- and discrete-time signal analysis and modeling: Laplace and continuous-time Fourier transform, z-transform and discrete time Fourier transform, Fourier series, discrete Fourier transform, continuous time filter design, FIR and IIR filter design, wavelet transform. Applications areas covered are ECG, IEGM, blood pressure measurement, cardiac impedance measurement, and heart rate variability.

#### BME 582/682 Nature and Analysis of Biomedical Signals

This course explores, from an engineering and modeling perspective, the physiological origins and characteristics of signals that are used medically to monitor patient functions and scientifically to study biological systems. The signals will include arterial and venous blood pressures, electrocardiogram, electroencephalogram, electromyogram, peripheral nerve action potentials and pulse oximetry. Topics will include physiological signal generators, instrumentation, signal processing, and modeling of biological systems. The format will include lectures, lab demonstrations and visits to clinical facilities. Prerequisite BME 680.