University of Vermont
Biomedical Engineering Ph.D. Program
Student Handbook

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CURRICULUM

DOCTOR OF PHILOSOPHY IN BIOMEDICAL ENGINEERING

Revised: 8-31-2022

This document is intended as a guide for BME Ph.D. students but does not include all of the University of Vermont Graduate College requirements. Consult the Graduate College for further information.

Requirements for Admission

Prospective students must apply to the Biomedical Engineering Ph.D. program through the UVM Graduate College. Three letters of reference are required. Letters from research advisors or supervisors are highly desirable and should attest to the applicant's ability to work independently in an academic setting. A complete application for Fall admission will be reviewed on a rolling basis, but applications received before January 15 will be given priority.

Students entering the Biomedical Engineering Ph.D. program should have a Bachelor's or Master's degree in an appropriate field of study and should have demonstrated good academic performance as measured by grades. Graduate Record Examination (GRE) scores are not required, but applicants may submit them for consideration with the application if desired. We evaluate non-native English speakers' testing scores according to UVM Graduate College guidelines (https://www.uvm.edu/graduate/international_students). Prior coursework in engineering, computational science, and/or the life sciences is highly desirable. The ideal applicant will have a broad technical background encompassing engineering, mathematics (including differential equations and linear algebra), and science (including physics and chemistry). Specific remedial coursework may be required of those who lack a sufficiently strong background in certain areas.

Retention in the Program

For complete requirements, students must read the UVM Graduate College resources (https://www.uvm.edu/graduate/resources) and the Requirements for the Doctor of Philosophy Degree (https://catalogue.uvm.edu/graduate/degreerequirements/requirementsforthedoctorofphilosophydegree/). For retention, students must maintain good academic standing (GPA 3.00) and continue to progress towards their Ph.D. degree requirements. In addition, students must participate in seminars and reading clubs, as appropriate. Students will be required to pass a comprehensive exam, as described below, in order to move on to the final dissertation stage of their Ph.D. requirements.

Program of Study

Students will have a primary research advisor from the list of affiliated Biomedical Engineering faculty, and they must form a graduate studies committee by the end of the first year of enrollment. The student's graduate studies committee will be comprised of four regular members of the graduate faculty from both the *College of Engineering and Mathematical Sciences* and the *Larner College of Medicine* and should bridge both experimental and computational expertise. The chair of the graduate studies committee serves as the student's academic advisor and also as the dissertation advisor or supervisor. The committee should be approved by the BME Graduate Coordinator and the Dean of the Graduate College. It is the responsibility of the graduate studies committee to supervise the graduate student's program and to review progress at regular intervals. Students must take at least 75 credits in courses and dissertation research including 14 credits of Core Courses, at least 16 credits of Technical Electives, and a minimum of 20 credits of dissertation research.

Students are required to develop an **Individual Development Plan** (uvm.edu/graduate/resources), annually and discuss it with their primary advisor and graduate studies committee.

Biomedical Engineering Core Courses 14 credits

The core courses required of all Biomedical Engineering Ph.D. students are:

- Domain-Specific Course (e.g., Adv. Bioeng. Systems, Complex Sys, or Biomaterials) (6 credits)
- MPBP 301 (or equivalent) Human Physiology & Pharmacology (4 credits)
- Math or Stats Course (3 credits)
- Research Ethics Course (e.g. NSCI 327 Responsible Conduct in Biomedical Research, PBIO Ethics in Graduate Research, NFS 362 Intro to Research Methods) (1 credit) or equivalent

Note that students may pursue alternatives to any of the above core courses as befits the goals of their graduate training, but this requires approval from the BME Graduate Coordinator. A student wishing to make a substitution should submit a justification in writing to the BME Graduate Coordinator who will then seek approval from the BME Curriculum Committee and transmit this back to the student. The student should provide the following documentation when submitting their request: current copies of the syllabi of the course they are proposing to replace and its proposed replacement as well as a statement about why the proposed course would be more suitable for their research area. Ethics and rigor in research are paramount and cannot be overstated; advice on equivalent options if listed courses are not available should be sought from the BME Graduate Coordinator.

Technical Electives (at least 16 credits)

Examples of possible elective courses are listed below. Students may take courses in areas germane to their research that are *not* included on this list with prior approval from their graduate studies committee.

Engineering

- BME/EE 227 Biomedical Instrumentation
- BME/EE 229 Biosignal Decoding
- BME 240 Wearable Sensing
- BME 241 Biomedical Signal Processing
- BME 250 Nanobiomaterials
- BME 396 Special Topics
- ME/BME 201 Biomaterials Engineering
- ME/BME 204 Biothermodynamics
- ME/BME 206 Biomechanics of Human Motion
- ME/BME 208 Biomechanics: Tissue Engineering
- ME 249 Computational Fluids Engineering
- ME 252 Mechanical Behaviors of Materials
- ME 255 Advanced Engineering Materials
- ME 257 Composite Materials
- ME 271 Micro and Nano Systems
- ME 312 Advanced Bioengineering Systems
- ME 338 Advanced Dynamics
- ME 336 Continuum Mechanics
- EE/ME 210 Control Systems
- EE 221 Real Time Control Systems
- EE 228 Sensors
- EE 275 Digital Signal Processing
- CE 201 Sustainable Eng Materials
- CE/ME 218 Numerical Methods for Engineers

- CE 256 Biol Proc Water/Wastewater Treatment

Computational Science and Mathematics

- CS 228 Human-Computer Interaction
- CS 253 QR: Reinforcement Learning
- CS 254 QR: Machine Learning
- CS/CSYS 302 Modeling Complex Systems
- CS/CSYS 352 Evolutionary Computation
- CSYS/CE 395 Applied Artificial Neural Networks
- CSYS/Stat/CE 369 Applied Geostatistics
- MATH 237 Numerical Methods
- MATH 337 Numerical Diff Equations
- ME 304 Adv Engineering Analysis I
- ME 305 Adv Engineering Analysis II
- MATH 266 Chaos, Fractals & Dynamical Systems
- MATH 268 Mathematical Biology & Ecology
- MATH 303 Complex Networks

Statistics

- STAT 200 Med Biostatistics & Epidemiology
- STAT 201 Statistical Computing & Data Analysis
- STAT 211 Statistical Methods I
- STAT 231 Experimental Design
- STAT 235 Categorical Data Analysis
- STAT 241 Statistical Inference
- STAT 251 Probability Theory
- STAT 253 Applied Time Series & Forecasting
- STAT/CS/CSYS 287 Data Science I

Biosciences and other

- MPBP 310 Molecular Control of the Cell
- MPBP 330 Biomedical Grantsmanship (2 credits)
- BIOC 205 Biochemistry I
- BIOC 206 Biochemistry II
- BIOC 275 Adv Biochemistry of Human Disease
- BIOC 301 General Biochemistry I
- BIOC 302 General Biochemistry II
- BIOC 372 Cancer Biology
- MMG 211 Prokaryotic Molecular Genetics
- MMG 222 Advanced Medical Microbiology
- MMG 223 Immunology
- MMG 231 Bioinformatics & Data Analysis
- MMG 232 Advanced Bioinformatics
- MMG 320 Cellular Microbiology
- BIOL 261 Neurobiology
- BIOL 270 Speciation and Phylogeny
- BIOL 271 Evolution
- CLBI 295 Adult Stem Cells & Regenerative Med

- CLBI 301 Cell Biology
- CLBI 401 Critical Reading and Analysis (coreq CLBI 301)
- CLBI 402 Biomedical Data Analysis
- PHYS 301 Mathematical Physics
- PHYS 333 Biological Physics
- HLTH 241 Exploring Healthcare Systems

Comprehensive Exam

The comprehensive exam for the Biomedical Engineering Ph.D. will normally be taken at the end of a candidate's third or fourth semester of study (before the end of Year 2) and will consist of a written exam and an oral exam. Should the candidate fail the examination, only one reexamination is permitted.

The Written Exam

The written part of the examination will be a report written in the form of a research grant proposal (7-12 pages) and delivered to the student's graduate studies committee at least 2 weeks before the oral exam. The proposal will be based on a research idea in the candidate's dissertation work area and will comprise three Specific Aims. The first two aims will be focused on the area of the candidate's Ph.D. research and will be expected to include some preliminary data and a research plan that is grounded in techniques that the candidate understands well. The third aim will be a "stretch aim" that extends beyond the scope of the candidate's research. In this third aim, the candidate will be expected to exhibit evidence of an ability to generate imaginative and thoughtful hypotheses and to think laterally about how their Ph.D. research area could be developed in a new direction. The candidate should gain the approval of their graduate studies committee regarding the general area of the proposal before beginning work on it.

The report will follow the format of the research plan for an R01 grant submission to the NIH, although it is not expected that as much preliminary data will be included as would be expected for a typical R01.

Detailed instructions about R01 proposals can be found at:

https://grants.nih.gov/grants/how-to-apply-application-guide/forms-g/general-forms-g.pdf

However, for the purposes of the comprehensive exam, the R01 components that must be included in the report are:

A. Specific Aims (1 page): This gives an overview of the proposal and will typically provide an overarching hypothesis and/or goal, together with a maximum of 3 specific aims that are to be accomplished over a projected 5-year period of research.

B. Research Strategy (6-12 pages): This section provides a detailed description of the research that will be undertaken, including any figures and tables, and is divided into 3 sections.

   a) **Significance**. Describe how the proposed research is significant to the field of investigation as well as to bioengineering in general. Give appropriate background as needed to make the case.

   b) **Innovation**. Explain how the proposed research is novel. The Significance and Innovation sections are typically not more than 1 page together.

   c) **Approach**. This is the main body of the proposal and provides the preliminary data and experimental design necessary to support each specific aim. The Approach should address the hypothesis(es) and/or goal(s) put forward in the Specific Aims page. Appropriate statistical methods should be described, including calculations to justify sample sizes (i.e., power analysis) for experiments involving replicates.

C. References (no page limit)

These components must be prepared on 8.5 x 11-inch pages with 0.5-inch margins. The text should be in 11-point Arial font and line spacing set at 12 points.

The proposal must deal substantively with both the engineering and the biological aspects of the proposed research. The engineering component will include a description of the project's design, analysis, and/or modeling aspects and must include appropriate attention to mathematical and statistical details. The biological component of the proposal should be hypothesis-driven and will explain the historical context of the project, the biomedical background that is appropriate, and the potential significance of the work. The proposal will also include:

a) alternative engineering methods that could be used on their biological question of interest (i.e., methods other than those to be used in the dissertation), and

b) alternative biological systems (other than those in the dissertation project) that could be studied using the engineering methods of the dissertation project.

These latter two aspects of the report will allow the student to demonstrate an ability to generalize both in terms of the application of engineering methods and approaches to biological problem-solving.

The Oral Exam

The oral part of the comprehensive examination will be a formal seminar by the student in front of their graduate studies committee, to take place after the committee members have had a chance to review the written proposal, which should be submitted at least 2 weeks before the oral presentation. The student will be asked to defend the proposal and to answer any additional questions the committee members feel appropriate after the seminar. It is expected that there will be specific questions directly associated with broad engineering and biomedical sciences.

After the oral part of the exam, the committee will meet to discuss both written and verbal components. The committee will then decide if the student can proceed to complete the Ph.D.; if the exam needs to be retaken, or (in the case of repeat failure), the student may be allowed to complete work for a master's degree. If successful, the Proof of Successful Completion of Comprehensive Exam form must be submitted to the BME Graduate Coordinator and Graduate College.

Dissertation Proposal

Students will present a proposal around the end of the 6th semester (i.e., third year) of study. The proposal will take place in front of the candidate's dissertation committee, and it will be open to UVM students and faculty. Committee membership must meet the Requirements for the Doctor of Philosophy degree stipulations (https://catalogue.uvm.edu/graduate/degreerequirements/). The proposal meeting will begin with a statement of the ground rules for the meeting given by the committee chair and a brief introduction from the candidate's supervisor. The candidate will then give a presentation (typically 45 minutes) in which their research progress to date is outlined and plans for the completion of the dissertation are described.

The candidate must prepare a tentative table of contents for the dissertation with a brief paragraph describing what they anticipate will be the subject of each major chapter (including the focus of their literature review) and forward this to the committee at least 1 week prior to the meeting.

The candidate's presentation will be followed by questions from the audience and then questions from the dissertation committee in closed session. The committee will then deliberate in private after which its recommendations will be passed to the candidate. The entire dissertation proposal meeting will take roughly 90 minutes.

The purpose of the dissertation proposal is to satisfy the dissertation committee members that the candidate is on track toward the completion of their dissertation and that the research contained within it will meet the standards of scholarship and originality required for the Ph.D. degree. Note that the purpose of the dissertation proposal is not to conduct an in-depth examination of the candidate's research nor to make significant adjustments to the direction or nature of their research. The BME Graduate Coordinator should be informed of the successful completion of the dissertation proposal.

Dissertation Defense

The Graduate College resources must be carefully utilized during this process; specifically, the Defense Committee Membership form, Intent to Graduate form, and Defense Notice form must be submitted in addition to conducting a format/record check. The Thesis/Dissertation Guidelines and Timetable, which are available on the Graduate College website, must be closely followed.

The dissertation defense examination committee consists of a minimum of 4 members of the graduate faculty. If a student has co-advisors, they count as one defense committee member. At least two graduate faculty members must be from inside the department or program. The chair must be both a member of the graduate faculty and from outside the candidate's and advisor's department and program. The dissertation defense examination committee must be approved by the Graduate College prior to the defense. The dissertation defense examination committee and the graduate studies committee do not have to be the same.

The defense of a Ph.D. dissertation will take place at the discretion of the candidate and their supervisor at a point when the dissertation is complete and has been distributed (at least 2 weeks prior) to the members of the committee. A Public Notice of the defense is required at least 3 weeks prior to the scheduled defense date in order for the student to defend.

The defense will begin with a statement of the ground rules for the meeting given by the committee chair and a brief introduction from the candidate's supervisor. The candidate will then present their research in about 1 hour. This will be followed by questions from the audience and then questions from the examining committee in a closed session. The committee will then deliberate in private after which its recommendations will be passed to the candidate. The entire dissertation defense will take 2-3 hours. If a student's defense examination performance is not satisfactory, then one reexamination, and one only, is permitted.

Biomedical Engineering Ph.D. Degree Check Sheet

Revised: 08-31-22

Student Name: _____

Committee Membership:

Name	Department	Signature	Date
_____ Chair	_____	_____	_____
_____ Member	_____	_____	_____
_____ Member	_____	_____	_____
_____ External member	_____	_____	_____

Core Courses (14 credits)

The following courses are required. Write the course number, name, and semester taken.

1. Domain-Specific Courses (6 credits): _____
   _____
2. Physiology & Pharmacology (4 credits): _____
3. Math or Statistics Course (3 credits): _____
4. Ethics Course (1 credit) or equivalent: _____

☐ _____
Committee Chair Signature Date

Technical Electives (≥17 credits)

A minimum of 17 credits of approved course work in engineering, math, physics together with anatomy, physiology, biology, biochemistry, biophysics or other approved courses at or above the 200 level as necessary to round out the student's pursuit of graduate level competence in both quantitative methods and biomedical systems. These courses will be decided by the student in consultation with the Studies Committee, and the Committee Chair will sign off when each course is successfully completed.

1. Course: _____
2. Course: _____
3. Course: _____
4. Course: _____
5. Course: _____

☐ _____
Committee Chair Signature Date

Teaching requirement

Complete one of the following:

1. Giving three research seminars at UVM,
2. Giving one oral presentation at a scientific conference, or
3. Serving as a GTA for one semester

☐ _____
Advisor Signature Date

Comprehensive Examination ☐ _____

(Complete by the end of the 4th semester of study) Committee Chair Signature Date

Dissertation (≥45 credits)

Proposal ☐ _____

(Complete by the end of the 6th semester of study) Committee Chair Signature Date

Defense ☐ _____

Committee Chair Signature Date

Turn in the completed form to the BME Graduate Coordinator