Bioengineering PhD Program

Student Handbook

DRAFT 08/21/202017

PROGRAM PERSONNEL

Graduate Coordinator:	Jason H.T. Bates, PhD, DSc Professor of Medicine HSRF 228, Phone: (802) 656-8912 Email: jason.h.bates@med.uvm.edu
Curriculum Committee:	Christopher Berger, PhD Associate Professor of Molecular Physiology & Biophysics christopher.berger@uvm.edu
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CURRICULUM

DOCTOR OF PHILOSOPHY IN BIOENGINEERING

Revised: 06-26-2015

Requirements for Admission

Prospective students must apply to the Bioengineering PhD 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 must be received by **January 15**.

Students entering the Bioengineering PhD program should have a degree in an appropriate field of study and should have demonstrated academic performance as measured by grades. The Graduate Record Examination (GRE) is not required, but applicants are free to submit them if they want. Non-native English speakers need a TOEFL score above 7 (new system) or 90 (old system) for entry into the program. 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 retention, students must maintain good academic standing and must continue to progress towards their PhD 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 thesis stage of their PhD requirements.

Programs of Study

Students will have a primary advisor from the list of affiliated bioengineering faculty, and must form a program committee containing faculty from both the *College of Engineering and Mathematical Sciences* and the *College of Medicine*. The committee must include faculty with both experimental and computational expertise.

Bioengineering Core Courses 17 credits

The core courses required of all bioengineering PhD students will be:

- ME312 Advanced Bioengineering Systems (3 credits)
- MPBP 301 & 302 (or equivalent) Human Physiology (8 credits)
- CS 302/CSYS 302 (or equivalent) Complex Systems Modeling (3 credits)
- Advanced Math or Stats Course (3 credits)

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 BioE PhD Graduate Coordinator. A student wishing to make a substitution should submit a justification in writing to the Graduate Coordinator who will then seek approval from the BioE Curriculum Committee and transmit this back to the student. The student should provide the following documentation when submitting their request: Current copies, obtained from the instructors, of the syllabuses of the course they are proposing to replace and its proposed replacement,

a statement about why the proposed course would be more suitable to their research area, and a description of how the technical content of the original course would be replaced in an equivalent fashion (for example, a biology course may not be replaced with a mathematics course).

Technical Electives (at least 13 credits)

Examples of possible elective courses are listed below.

Engineering

- ME 207 Biomechanics I
- ME 208 Biomechanics II
- ME 209 Biofluids
- EE 227 Biomedical Measurements, Instrumentation and Systems
- ME 249 Computational Fluids Engineering
- ME 252 Mechanical Behaviors of Materials
- ME 257 Composite Materials
- ME 338 Advanced Dynamics
- ME 336 Continuum Mechanics
- EE 210 Introduction to Control Systems
- EE 275 Digital Signal Processing
- EE 276 Image Processing
- EE 270 Stochastic Processes
- CE 220 Finite Element Analysis
- CE 256 Biol Proc Water/Wastewater Treatment

Computational Science

- CS 231 Bioinformatics
- CS 251 Artificial Intelligence
- CS 256 Neural Computing
- CS 260 Parallel Computing
- CS 352 Evolutionary Computation
- CS 355 Statistical Pattern Recognition
- CS 331 Data Mining
- CSYS/CE 359 Applied Artificial Neural Networks
- CSYS/Stat/CE 369 Applied Geostatistics
- MATH 221 Operations Research
- MATH 237, 274 Numerical Methods

- MATH 337 Numerical Diff Equations

Mathematics

- ME 304 Adv Engineering Analysis I
- ME 305 Adv Engineering Analysis II
- MATH 266 Chaos, Fractals & Dynamical Systems
- MATH 268 Mathematical Biology & Ecology
- MATH 295 Complex Networks

Statistics

- STAT 231 Experimental Design (Same as Biostatistics 231.)
- STAT 233 Survey Sampling (Same as Biostatistics 233.)
- STAT 235 Categorical Data Analysis (Same as Biostatistics 235.)
- STAT 237 Nonparametric Statistical Methods (Same as Biostatistics 237.)
- STAT 241 Statistical Inference (Same as Biostatistics 241.)
- STAT 251 Probability Theory
- STAT 252 Applied Discrete Stochastic Processing Models
- STAT 253 Applied Time Series & Forecasting (Same as Biostatistics 253.)
- STAT 254 Applied Continuous Stochastic Processing Models

Biosciences and other

- MPBP 295 Medical Physiology
- MPBP 310 Molecular Basis of Biological Motility
- MPBP 323 Biophysical Techniques
- BIOC 205 Biochemistry I
- BIOC 206 Biochemistry II
- BIOC 301 General Biochemistry I
- BIOC 302 General Biochemistry II
- BIOC 370 Physical Biochemistry
- MMG 203 Mammalian Cell Culture: Molecular Biology
- MMG 211 Prokaryotic Molecular Genetics
- MMG 240 Macromolecular Structure of Proteins & Nucleic Acids
- MMG 352 Protein:Nucleic Acid Interactions
- BIOL 261 Neurobiology
- BIOL 270 Speciation and Phylogeny
- BIOL 271 Evolution

- BOT 252 Molecular Genetics II
- CLBI 295 Adult Stem Cells & Regenerative Med
- CLBI 301 Cell Biology
- CLBI 302 Specialized Cells & Cell Processes
- PHYS 301 Mathematical Physics

Research Ethics

At some point during their studies, students must attend a course in research ethics such as ANNB/Path 327: Responsible Conduct in Research, or BIOL 381: Integrity in Science.

Comprehensive Exam

The comprehensive exam for the Bioengineering PhD will normally be taken at the end of a candidate's forth semester of study (typically around May of Year 2) and will consist of a written part and an oral part.

The Written Part

The written part of the examination will be a report written in the form of a research grant proposal. The proposal will be based around a research idea in the area of the candidate's thesis work, and will comprise three Specific Aims. The first two aims will be focused in the area of the candidate's PhD research, and will be expected to include some preliminary data and a research plan that is grounded in techniques that are well understood by the candidate. 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 PhD research area could be developed in a new direction. The candidate should gain the approval of their thesis committee regarding the general area of the proposal prior to beginning work on it.

The report will follow the format of the research plan for a 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:

http://grants.nih.gov/grants/funding/424/SF424_RR_Guide_General_Adobe_VerB.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 as follows.

   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 much 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, as appropriate, including calculations to justify sample sizes (i.e. power analysis) for experiments involving replicates.

C. References (no page limit)

These components are to be prepared on 8.5 x 11 inch pages with 0.5 inch margins all around. The text should be in 11 point Arial font.

The proposal must deal in a substantive way with both the engineering and the biological aspects of the proposed research. The engineering component will include a description of design, analysis and/or modeling aspects of the project, 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, any biological background that is appropriate, and will state those hypotheses to be tested as well as the potential significance of the work. The proposal will also include:

(a) a discussion of the way in which the theory or philosophy of complex systems bears on the project,

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

c) 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 application of engineering methods and approaches to biological problem solving.

The Oral Part

The oral part of the comprehensive examination will be a formal seminar by the student in front of their advisory committee, to take place after the committee members have had a chance to review the written proposal, which should be in the hands of the committee members at least 2 weeks prior to 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 biological sciences, as well as complex systems analyses and approaches.

After the oral part of the exam, the committee will meet to discuss both written and oral components. The committee will then decide if the student can proceed to complete the PhD, 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.

Thesis Proposal

Students will present a thesis 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 thesis committee, and is open to UVM students and faculty. 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 thesis are described.

The candidate must prepare a tentative table of contents for the thesis 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 thesis committee in closed session. The committee will then deliberate in private after which its

recommendations will be passed to the candidate. The entire thesis proposal meeting will take roughly 90 minutes.

The purpose of the thesis proposal is to satisfy the thesis committee members that the candidate is on track toward completion of their thesis and that the research contained within it will meet the standards of scholarship and originality required for the PhD degree. Note that the purpose of the thesis 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.

Thesis Defense

The defense of a PhD thesis will take place at the discretion of the candidate and their supervisor at a point when the thesis is complete and has been distributed (at least 2 weeks prior) to the members of the committee and to the thesis examiner. It is open to the public.

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 closed session. The committee will then deliberate in private after which its recommendations will be passed to the candidate. The entire thesis defense will take 2-3 hours.

Student Check Sheet

Bioengineering PhD Degree

Revised: 03-06-12

Student: _____

Studies Committee:

Name	Department	Signature	Date
_____ Chair	_____	_____	_____
_____ Advisor	_____	_____	_____
_____ Co-Advisor	_____	_____	_____
_____ External member	_____	_____	_____

Degree program outline sent to Graduate College ☐ _____

(Must be done prior to the 3rd semester of study) Studies Committee Chair signature Date

Core Courses (17 credits)

The following courses, or their equivalents, are required.

1. CS302/CSYS302 Complex Systems (3 credits) ☐ _____
   Studies Committee Chair signature Date
2. ME312/CSYS312 Advanced Bioengineering Systems (3 credits) ☐ _____
   Studies Committee Chair signature Date
3. MPBP 301 & 302 Human Physiology & Pharm (8 credits) ☐ _____
   Studies Committee Chair signature Date
4. Advanced Math or Statistics Course (3 credits) ☐ _____
   Studies Committee Chair signature Date

Technical Electives (≥13 credits)

A minimum of 13 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.

5. Course: _____ ☐ _____
Studies Committee Chair signature Date

6. Course: _____ ☐ _____
Studies Committee Chair signature Date

7. Course: _____ ☐ _____
Studies Committee Chair signature Date

8. Course: _____ ☐ _____
Studies Committee Chair signature Date

9. Course: _____ ☐ _____
Studies Committee Chair signature Date

Teaching requirements:

Either ☐ giving three research seminars, or

☐ serving as a GTA for one semester

_____
Completion date Advisor signature

Comprehensive Examination

(Aim for completion by the end of the 4th semester of study)

☐ _____
Studies Committee Chair signature Date

Thesis (≥45 credits)

Proposal

(Aim for completion by the end of the 6th semester of study)

☐ _____
Studies Committee Chair signature Date

Defense

☐ _____
Studies Committee Chair signature Date