

**Biomedical Engineering  
Graduate Program Handbook  
(Revised October 2014)**

**Overview**

Through the Biomedical Engineering (BME) program at UD, graduate students can obtain a PhD (and soon will be able to obtain a Master's degree). The PhD program is built on a first year core curriculum with advanced curricula that are based on the research the student will perform for the thesis. Due to the interdisciplinary nature of Biomedical Engineering, faculty that are affiliated with this program come from multiple colleges and departments at UD. PhD students will identify a Faculty Advisor from among these faculty who will be responsible for defining the student's research responsibilities and for evaluating the student's performance. The PhD degree will be administered by the BME Program and will be awarded by the College of Engineering.

This multi-disciplinary graduate program will build upon the established biomedical research strength at the University of Delaware, largely within the College of Engineering. It will offer academic rigor, as well as flexibility, to meet the needs and interests of students from different backgrounds and of their faculty advisors from different research areas.

**PhD Program**

The PhD program in Biomedical Engineering consists of 39 credits of graduate level course work including at least 9 credits of Doctoral Dissertation. The program allows for considerable flexibility in course selection. The PhD program also requires completion of a Teaching Aid requirement, the Qualifying Exam, the Candidacy Defense and the Doctoral Dissertation.

The table below lists the credit requirements for a PhD degree in BME.

| <b>PhD requirements in Biomedical Engineering: 39 credits total</b> |                   |
|---|-------------------|
| 5 Core courses  |                   |
| Principles of Biomedical Engineering<br>(2 courses)                 | 6 credits         |
| Advanced Math   | 3 credits         |
| Statistics  | 3 credits         |
| Communication and Ethics  | 3 credits         |
| 4 Technical electives (minimum)                                     | 12 credits        |
| Research  | 3 credits minimum |
| Dissertation  | 9 credits minimum |
| Seminar series (3 semesters)  | 0 credits         |

## Course Requirements

### Core courses

| <b>Core Courses (15 credits)</b>                 |  |
|--|--|
| Principles of Biomedical Engineering (6 credits) | BMEG 605 Principles of Biomedical Engineering I: Molecular and cellular systems (allow BISC 605 Advanced Mammalian Physiology as a substitute)<br><br>BMEG 606 Principles of Biomedical Engineering II: Tissue and organ systems (allow BISC 606 Advanced Mammalian Physiology II as a substitute) |
| Advanced Math (3 credits)<br>Choose 1            | MATH 607 Survey of Scientific Computing<br>MATH 616 Introductions to Applied Mathematics I<br>MEEG 690 Intermediate Engineering Mathematics<br>ELEG 671 Mathematical Physiology  |
| Statistics (3 credits)<br>Choose 1               | BISC 643 Biological data analysis<br>STAT 608 Statistical research methods   |
| Communication and Ethics (3 credits)             | BMEG 801 Communication and Ethics in Biomedical Engineering  |

### Technical Electives

Technical Electives can be chosen from courses offered across engineering departments.

| <b>Technical Elective Courses (12 credits minimum, choose 4 minimum)</b> |                                    |
|--|------------------------------------|
| BISC 602   | Molecular Biology of Animal Cells  |
| BISC 605   | Advanced Mammalian Physiology      |
| BISC 612   | Advanced Cell Biology              |
| BISC 625   | Cancer Biology                     |
| BISC 626   | Advanced Neuroanatomy              |
| BISC 627   | Advanced Neurophysiology           |
| BISC 639   | Developmental Neurobiology         |
| BISC 660   | Environmental Physiology           |
| BISC 671   | Cellular and Molecular Immunology  |
| BISC 675   | Cardiovascular Physiology          |
| BISC 806   | Advances in Cell and Organ Systems |
| <br>   |                                    |
| CHEG 620   | Biochemical Engineering            |
| CHEG 621   | Metabolic Engineering              |
| CHEG/CHEM 649  | Molecular Biophysics               |
| CHEG 650   | Biomedical Engineering             |
| CHEG 801   | Process Control and Dynamics       |

|               |   |
|---------------|---|
| CHEG 825      | Chemical Engineering Thermodynamics               |
| CHEG 827      | Chemical Engineering Problems                     |
| CHEG 828      | Statistical Thermodynamics                        |
| CHEG 842      | Selected Topics in Biochemical Engineering        |
| CHEG 845      | Advanced Transport Phenomena                      |
|               |   |
| CHEM 641      | Biochemistry                                      |
| CHEM 642      | Biochemistry                                      |
| CHEM 643      | Intermediary Metabolism                           |
| CHEM 645      | Protein Structure and Function                    |
| CHEM 646      | DNA-Protein Interactions                          |
| CHEM 647      | Biochemical Evolution                             |
| CHEM 648      | Membrane Biochemistry                             |
|               |   |
| CISC 642      | Intro to Computer Vision                          |
| CISC 681      | Artificial Intelligence                           |
| CISC/BINF 689 | Topics: Artificial Intelligence                   |
| CISC/BINF 849 | Advanced Topics in Computer Applications          |
| CISC 852      | Computer Network Performance                      |
| CISC 887      | Internet Information Gathering                    |
|               |   |
| ELEG 630      | Information theory                                |
| ELEG 631      | Digital signal processing                         |
| ELEG 636      | Statistical signal processing                     |
| ELEG 671      | Mathematical Physiology                           |
| ELEG 675      | Image processing with biomedical applications     |
| ELEG 679      | Intro to medical imaging systems                  |
| ELEG 680      | Immunology for engineers                          |
| ELEG 801      | Advanced topics in biomedical engineering         |
| MATH 529      | Fundamentals of Optimization                      |
| MATH 611      | Introduction to Numerical Discretization          |
| MATH 617      | Introductions to Applied Mathematics II           |
| MATH 630      | Probability Theory and Applications               |
| MATH 660      | Intro to Systems Biology                          |
|               |   |
| MEEG 612      | Biomechanics of human movement                    |
| MEEG 624      | Control of dynamic systems                        |
| MEEG 682      | Clinical biomechanics                             |
| MEEG 683      | Orthopedic biomechanics                           |
| MEEG 684      | Biomaterials and tissue engineering               |
| MEEG 685      | Control of human movement                         |
| MEEG 686      | Cell and tissue transport                         |
| MEEG 862      | Advanced Engineering Analysis                     |
|               |   |
| MSEG/CHEG 601 | Structure and Properties of Polymer Materials     |
| MSEG 625      | Entrepreneurship and risk: meeting the challenges |

|                   |   |
|-------------------|---|
| MSEG 630/CHEG 600 | Introduction to Polymer Science and Engineering   |
| MSEG 633/833      | Polymer Synthesis and Characterization Laboratory |
| MSEG 635/835      | Principles of Polymer Physics                     |
| MSEG 660          | Biomaterials and Tissue engineering               |
| MSEG 803          | Equilibria in Materials Systems                   |
| MSEG 804          | Kinetics in Materials Systems                     |
| MSEG 817          | Composite Materials                               |
| MSEG/CHEG 823     | TEM in Materials Science                          |
| MSEG 832          | Principles of Polymerization                      |
| STAT 609          | Regression and Experimental Design                |

Courses not on the above Technical Elective list can be substituted with permission of the Faculty Advisor and the Graduate Director. Check for updated lists periodically. For descriptions of technical electives, please refer to the UD Course Catalog (at <http://academiccatalog.udel.edu/>).

BME may waive the requirement for up to 18 credit hours of course work for students entering with a Master's Degree or credits for graduate course work performed at another recognized graduate school. Waivers will only be granted for courses that cover subjects eligible for credit toward a PhD in Biomedical Engineering from the University of Delaware. Requests for a course waiver must be initiated by the student before the beginning of their third semester at UD. Waivers must be approved by the Faculty Advisor and the BME Graduate Director and will be contingent on the student's demonstration of satisfactory performance in course work taken at UD.

### **Other Course Requirements**

PhD students must complete 27 credit hours of course work (described above), plus at least 3 credit hours of research (BMEG 868) and 9 credit hours of dissertation research (BMEG 969). They must also attend 3 semesters of a seminar series (BMEG 890).

### **Seminar Series**

Biomedical engineering is an emerging and rapidly expanding field where engineering and biological disciplines converge. To keep up to date with the wide variety of research encompassed by this field, students are required to take 3 semesters of the seminar series BMEG 890.

### **Choosing a Faculty Advisor**

Students will be matched to a Faculty Advisor from a list of Biomedical Engineering-affiliated faculty members participating in the degree program. For the first 2 months following fall matriculation, the student will be advised by the Graduate Director (unless a direct match to an advisor is made during the admission process). The student will be responsible for identifying potential faculty advisors by meeting with faculty in early September, attending faculty presentations in BMEG 801, and attending research group meetings. By Dec 1<sup>st</sup> students must submit a ranked list that contains at least 3 potential advisors. Advisors also submit a ranked list

of students (blind to student ranking). The Graduate Director will match the student to a Faculty Advisor by December 15.

The Faculty Advisor will be the primary contact of the student for questions and advice on his/her thesis research throughout the remainder of the program. The student will develop a plan of study for the program with the Faculty Advisor by the end of the second semester of their first year. Any changes to a student's program of study must be approved by the Faculty Advisor and the BME Graduate Director.

### **Candidacy Requirements**

To qualify to be a PhD candidate, students must complete the following:

- a. Complete a one semester Teaching Aid Requirement.**
- b. Pass the Qualifying Exam.**
- c. Establish a Dissertation Committee.**
- d. Complete all coursework.**

### **Teaching Aid Requirement**

The ability to communicate ideas, concepts, and factual information is an essential skill for all PhD graduates, even those who have no interest in an academic position. In recognition of this, all PhD students are required to fulfill a Teaching Aid Requirement for 1 semester that consists of serving as a Teaching Aid. Note that this is different from the Teaching Assistantships offered as financial aid (described in **Financial Aid** section). While fulfilling this Teaching Aid Requirement, students are expected to continue being actively involved in their research.

The responsibilities of the Teaching Aid Requirement will be defined by the course instructor and should not exceed approximately 10 hours per week. In general, the PhD student should not merely be assigned grading responsibilities. He/she should have an opportunity to plan and deliver lectures, lead discussion sections and lead laboratory exercises. Direct interaction with course students is highly encouraged.

The University requires that all first time Teaching Aids take a 2-day TA teaching conference offered by the Center for Teaching and Learning. International students must also enroll in the winter session of the ELIITA (English Language Institute International Teaching Assistant) program before performing their teaching requirement.

Although the exact timing of these appointments is flexible, it is highly desirable to complete all teaching responsibilities by the end of the 2nd year, although they can be extended to the 3rd year. The BME Graduate Committee assigns these positions in November (for the upcoming spring semester) and in May (for the following fall). Students are encouraged to submit their preferences for specific positions early to facilitate the process. Although every effort will be made to satisfy these requests, students should recognize that this is not always possible.

### **Qualifying Exam**

The Qualifying Exam must be taken in the summer after the first year (and after completion of at least 5 approved courses with a cumulative GPA of 3.00 or better). For students with non-fall matriculation or part-time study, the timing of this exam will be set based on course completion and approval by the Graduate Director.

The purpose of the Qualifying Exam is to evaluate whether the student can independently develop a well-formulated research question with clearly defined testable hypotheses and aims, is able to develop a research plan to address those questions, and has acquired a level of background knowledge and a competency in written and oral scientific communication expected of a student completing their first year in a Biomedical Engineering PhD program. These criteria will be evaluated through both a written exam and an oral exam.

### *Written Exam*

The written exam requires the student to prepare an NIH R21-style grant proposal, including a 1 page Specific Aims section and a 4-6 page Research Plan section, with a separate Works Cited section (no page limit). Examples may be found online here:

<http://www.niaid.nih.gov/researchfunding/grant/pages/appsamples.aspx>

Faculty members may also supply the student with example proposals. The proposal should be 12-point, single-spaced with at least 1-inch margins. Correct citation style, conforming to the NIH SF424 guide requirements and the standards of the student's field, should be used throughout. The research proposal should be adequately researched, with at least 20 appropriately chosen citations to support the proposal.

This proposal is NOT the student's thesis proposal. The general topic of the grant proposal shall be assigned by the student's research advisor, and should be in the areas of the student's research interest. The topic should be distinct from existing research in the group, and sufficiently broad to allow the student to independently develop 1) a well-formulated research question with 2) clearly defined testable hypotheses and aims and 3) a study design that addresses these aims. Once the advisor has assigned the topic, the student will have one month (July) in which to prepare the written proposal. The student will still be expected to participate in research activities during this month. The advisor or other graduate students or other mentors may NOT assist the student in writing or proofreading the proposal. The proposal should be the student's own independent work. At the end of the month, the student will submit the proposal in PDF form by e-mail to the Graduate Director.

The proposal will be evaluated by a committee of 3 BME faculty members chosen by the BME graduate committee (none of which may be the student's advisor, though the advisor may be consulted as to which faculty would be most appropriate). The student's advisor will also receive a copy of the proposal and its written reviews, and may participate in the oral evaluation as an observer. These committee members will evaluate the written proposal to determine (1) whether the student demonstrates an acceptable knowledge of the scientific background relevant to their topic, (2) whether the proposal presents a well-formulated research question, clearly defined testable hypotheses, and an appropriate study design, and (3) whether the student demonstrates written scientific communication skills expected of a student completing the first year of a Biomedical Engineering Ph.D. program.

The committee will also provide the student with a written NIH-style summary statement providing a one paragraph evaluation of Overall Impact, and bullet lists of Strengths and Weaknesses in the areas of Significance, Innovation, and Approach (Investigator and Environment should not be considered). This written feedback should be communicated to the student at least one week prior to the oral exam date.

### *Oral Exam*

After the written exam has been evaluated, a 75-minute oral exam will be scheduled with the same committee that evaluated the written proposal. The student should prepare a 15-minute oral presentation based on their written proposal. Following the presentation, there will be one hour for questions, which will be divided between Q&A relating to the proposal and questions on general biomedical engineering knowledge based on the student's completed core and elective courses.

### *Possible Outcomes*

The committee will submit a recommendation to the graduate committee that the student either Pass, Conditionally Pass, or Fail the Qualifying Exam, with recommendations of appropriate conditions in the case of a Conditional Pass. These recommendations will be reviewed by the Graduate Committee, who will make final recommendations to the BME Faculty. The Graduate Director will communicate the decision to the student.

With a Conditional Pass, the student must address the specific concerns within a period designated by the committee that cannot be more than 1 year (e.g., take certain courses, revise the proposal in a specific manner). If the Conditional Pass terms are not met within the specified time period or if the student Fails, he/she will be dis-enrolled from the PhD program.

### **Dissertation Committee**

As soon as possible, but no more than 1 year after passing the Qualifying Exam, the student must establish a Dissertation Committee. The Dissertation Committee is selected by the Faculty Advisor and the student, and must have a minimum of 4 members including the advisor and at least 3 additional faculty. 3 members must have an appointment in BME (Primary, Joint, or Affiliated), at least one member must hold a Primary or Voting Joint appointment in BME, and 1 must be from outside the primary research area of the thesis topic. 3 members must be from the University of Delaware. The student must submit a 1-2 page research plan approved by the committee to the graduate director. The research plan should contain a brief description of the student's proposed research area including major questions to be addressed, a brief summary of research accomplishments so far, one paragraph justifying the committee composition, and a preliminary timeline for the completion of the degree. The Graduate Director must approve the committee, chair, and research plan, and any subsequent changes in committee members.

### **Sustaining Status**

Once a student has completed all coursework required for the BME PhD degree, completed the Teaching Aid requirement, passed the Qualifying Exam, and established a Dissertation Committee, they will be considered a PhD Candidate eligible for sustaining status by the BME

department. Once all these requirements are met, the student must submit a Candidacy Form to the Office of Graduate and Professional Education (<http://www.udel.edu/gradoffice/forms/candidacyform.pdf>).

### **Dissertation Proposal**

The Dissertation Proposal requires a written proposal outlining the plan of research for the PhD and an oral presentation and defense of this proposal to the Dissertation Committee. The written proposal will follow a NIH R01 format, with a page limit of 15 pages. A curriculum vita, Progress Report Form (<http://bme.udel.edu/files/2014/06/ProgressReport-1mx50u7.pdf>), and a graduate-level transcript should also be included. All materials should be distributed to the Dissertation Committee at least 2 weeks before the oral proposal. The defense will include a 30 min presentation by the student, followed by a 60 min Q&A discussion. The student must complete the Dissertation Proposal within 2 years of the Qualifying Exam or must petition the Graduate Director for an extension.

### **Completing the PhD**

To complete the PhD, students must pass a Dissertation Exam. This exam involves approval of the written dissertation and an oral defense of the dissertation. The written dissertation must be submitted to his/her Dissertation Committee at least 2 weeks before the defense. The oral presentation will be open to the public and will last ~45 min. After questions from the public not to exceed 15 minutes, a closed Q&A session with the Dissertation Committee of 30-60 minutes will follow. The student will be responsible for making corrections to the dissertation document and for meeting all Graduate School deadlines for submission. Student must complete the Dissertation Exam within 5 years of the Qualifying Exam (6 years after matriculation) or must petition the Graduate Director for an extension.

### **Satisfactory progress**

#### **Academic Load**

Full-time students are expected to complete the PhD program in 4-6 years. The program may be completed over a longer time frame for part-time students. Students must be enrolled in at least 9 credit hours or in sustaining credit to be considered full-time students. Those enrolled for fewer than 9 credit hours are considered part-time students, although students holding assistantships are considered full-time with six credits. Students are expected to take 9 credit hours of course work for the first semester in order to be funded. All graduate students are expected to register for research credits during the summer term but not the winter term. Generally, a maximum load is 12 graduate credit hours in spring and fall; however, additional credit hours may be taken with the approval of the student's adviser and the Office of Graduate and Professional Education.

#### **Transferability**

If the student has a Master's degree, he/she can petition to substitute research credits (BMEG 868) or elective course credits for a maximum of 3 of the 5 required core courses. Both the Faculty Advisor and the BME Graduate Director must approve petitions for course substitution.

#### **Annual Progress Report**

The student's progress toward his/her PhD will be monitored annually by the BME Graduate Committee. Before July 1<sup>st</sup> each year, the student must submit a Progress Report Form to the

Graduate Director that is signed by the Faculty Advisor. This form (see **Forms** section) includes a checklist of course requirements, research accomplishments, self-assessment, advisor feedback, and verifications that annual Dissertation Committee meetings are occurring.

### **Grade Requirements**

Only graduate courses completed with a grade of B- or higher will count towards the requirements of the BME program. Students must maintain at least a 3.0 cumulative grade point average in the courses in the curriculum to receive the degree. If student does not achieve a B- or higher in a core course, he/she must retake the course (or any of the optional core courses in that category), and if the retake is below a B-, the student will be recommended for dismissal. If student achieves lower than a B- on an elective course, he/she can retake the course or replace it with another elective course. University of Delaware has a No Replacement policy so both grades of a repeated course are included in the cumulative GPA and the University requires that this GPA must be over 3.0. However, the cumulative GPA for the courses that lead to the PhD degree only use the higher grade of the repeated course.

### **Consequences of Unsatisfactory Progress**

The BME Graduate Committee will meet at least once each year to evaluate each student's progress. To monitor this progress, the student must annually submit a Progress Report Form (see **Forms** section) to the BME Graduate Director before July 1. If the student does not complete a Progress Report, fall registration is cancelled and funding is stopped until it has been completed. If the student is failing to make satisfactory progress towards a degree, the committee will recommend suitable action to the BME Graduate Director. Possible actions include (but are not limited to): (i) requirement for additional courses, (ii) suspension of financial support, and (iii) recommendation for dismissal.

### **Standards of Student Conduct**

All graduate students are subject to University of Delaware regulations regarding academic honesty. Violations of the UD regulations regarding academic honesty or other forms of gross misconduct may result in immediate dismissal from the Program.

### **Dismissal**

The procedures for dismissal as detailed in the University Catalog will be followed. Briefly, the BME Graduate Committee will report its recommendation and reason for dismissal to the BME Graduate Director. He/she will make a recommendation to the Office of Graduate Studies, who will decide whether to dismiss the student. The student may appeal this decision to the Office of Graduate Studies, following the procedure given in the University Catalog.

### **Graduate Student Grievance Procedure**

Students who feel that they have been graded inappropriately or have received what they perceive as an unfair evaluation by a faculty member may file grievances in accordance with University of Delaware policies. Students are encouraged to contact the BME Graduate Director and/or the Director of the BME Program prior to filing a formal grievance in an effort to resolve the situation informally.

### **Attendance at Conferences and Professional Meetings**

The BME program encourages students to attend conferences and professional meetings. They

provide opportunities to meet future employers and colleagues, and can offer specialized training beyond course work.

## **Financial Aid**

### **Financial Awards**

Financial assistance is awarded on a competitive basis to the pool of admitted applicants. The University of Delaware's policies apply to all forms of financial aid. Please refer to the University Policies for Graduate Student Assistantships and Fellowships.

The majority of students in the BME program will be supported on research contracts and grants obtained by their Faculty Advisors. Students on projects without external funding will be provided support (assuming that their progress is satisfactory) through the use of either other program funds or by appointment as a Teaching Assistant. No student will be supported by departmental funds for more than 2 semesters; funds beyond such a commitment must be provided by the Faculty Advisor or by appointment as a Teaching Assistant. In general, funding is not guaranteed beyond five years.

Students in the Biomedical Engineering program may be provided Graduate Assistantships:

- **Research Assistants (RAs)** are generally funded by research grants and contracts provided by external funding agencies. Students should be supported as an RA through their Faculty Advisor's research funds once they are matched (usually following the first full semester of the student's matriculating year). RAships provide full tuition and a stipend.
- **Teaching Assistants (TAs)** are offered for graduate students to perform teaching and other instructional activities. Note that this is different from the Teaching Aid Requirement described in the **Candidacy Requirements** section. The amount of service may vary from week to week but the average is usually expected to be 20 hours per week. A TA-ship provides full tuition and a stipend. In accordance with University of Delaware regulations, TAs must fulfill the requirements detailed for the Teaching Aid Requirement in the **Candidacy Requirements** section above in order to qualify for this type of assistantships.

### **Continuation of Financial Aid**

Students who are awarded financial aid must maintain satisfactory academic progress with satisfactory performance of assistantship duties (see below). Satisfactory academic progress includes maintaining full-time status and maintaining the grade requirements detailed in the **Satisfactory Progress** section.

The Faculty Advisor will establish the Research Assistant (RA) responsibilities and performance standards. In the event of an unsatisfactory performance by an RA, the Faculty Advisor will notify the BME Graduate Director and the student of the problem in writing. The Advisor will give the student a performance appraisal that lists the specific areas that need improvement and a timeline by which to rectify the situation (typically 1 to 3 months) before the assistantship is terminated.

The director of the course in which the student teaches will establish the Teaching Assistant (TA) responsibilities and performance standards. In the event of an unsatisfactory performance by a TA, the course director will notify the student and the BME Graduate Director in writing detailing the specific areas that need improvement. If the student does not rectify the situation (typically within 2-4 weeks), the BME Graduate Director may recommend termination of the assistantship.

During the student's time in the graduate program, the student must fill out a Graduate Student Contractual Agreement to show how he/she is being funded. This may be done once a year (if funding source is constant) or separately for spring, summer, and fall (if funding source varies). Changes in status from TA to RA or from full time to sustaining require updating with a new form. Once this has been approved, a Student Funding Allocation Form (SFAF) must be completed in order to put the student into the payroll system.

## **BME people**

### **BME Graduate Committee**

This committee consists of at least 5 BME-affiliated faculty. It is responsible for 1) reviewing applications, 2) recommending student visits and admissions, 3) matching students to an advisor, 4) developing and approving the curriculum, 5) reviewing annual Progress Reports, 6) assigning Qualifying Exam committee, 7) reviewing and approving Dissertation Committee members and chair, 8) dealing with petitions for course substitutions, and 9) dealing with petitions for the extension of Candidacy and Dissertation Defenses.

### **BME Graduate Director**

The Associate Director for Graduate Studies in BME chairs the BME Graduate Committee and is called the BME Graduate Director. He/she will be responsible for the overall implementation, quality and progress of the degree program, advised by the BME Graduate Committee. He/she will also act as advisor to the student during the first semester until the student has a Faculty Advisor. At the end of the PhD program, he/she will approve the application for the degree upon verifying that the student has successfully completed the requirements.

## **Forms**

All forms can be accessed at: <http://bme.udel.edu/graduate-program-forms/>

Choose Advisor Form

Progress Report Form

Candidacy Form

Graduate Student Contractual Agreement

Student Funding Allocation Form