# BIOENGINEERING, PHD

**Banner Code: EC-PHD-BIOE**

**Academic Advisor: Parag Chitnis, PhD**

Phone: 703-993-5039
Email: pchitnis@gmu.edu
Website: https://bioengineering.gmu.edu/academics/phd-bioengineering

Rapid technologically driven advances in understanding and treating human disease have opened up vast opportunities to advance human health through research that integrates engineering, basic sciences, medical sciences, and knowledge of industry practices. The doctoral program will prepare leaders in bioengineering in this broader, integrative sense of the discipline. A major distinguishing feature of the curriculum is its emphasis on understanding how biomedical technology is translated from bench to bedside. Graduates from this program will eventually work in universities, industry or government in a variety of roles, including scientific research, technology development, and regulatory affairs.

## Admissions & Policies

# Admissions

### Application Requirements

In addition to fulfilling Mason's admission requirements for graduate study, applicants should:

- Have a baccalaureate degree in engineering or the sciences from an accredited program with a reputation for high academic standards and an earned GPA of 3.3 or better in their highest-level engineering-related credits.
- Provide three letters of recommendation, preferably from academic references or references in industry or government who are familiar with the applicant's aptitude for research.
- Provide a resume and detailed statement of career goals and professional aspirations, including why they want to study at Mason, and two faculty with whom they want to work.
- Demonstrate interest in combining engineering and the natural sciences with discovery and application in the life science; i.e., via a degree which reflects the desired combination (such as bioengineering, biomedical engineering, biophysics); a degree in engineering or the natural sciences which includes coursework in life sciences; a degree in biology which includes coursework in mathematics, physics, or engineering; a project or research experience with combined complementary expertise.
- If their native language is not English, students must take the English Proficiency exam. Test score minimum requirements are available at https://www2.gmu.edu/admissions-aid/how-apply/graduate/standardized-test-information (https://www2.gmu.edu/admissions-aid/how-apply/graduate/standardized-test-information/).

# Policies

### Reduction of Credit

Students must complete a minimum of 72 graduate credits, which may be reduced by a maximum of 30 credits from a related master's degree. Reduction of credit requires the approval of the program director or designee and the dean or designee of the school. They determine how many credits are eligible for the reduction of credit.

### Program Requirements

The Bioengineering PhD program requires successful completion of coursework detailed in a plan of study, qualifying examination, dissertation proposal, and final dissertation defense. Additional training requirements include seminar attendance, ethics training, and mentoring and teaching experience. All the general requirements for doctoral degrees at Mason apply to this program as well.

For students to remain eligible for the PhD program, they must maintain a "B" average. Grades of "C" or lower in courses cannot be counted towards degree completion. Refer to the University policy AP 6.6.2 (https://catalog.gmu.edu/policies/academic/graduate-policies/) and the Mason Engineering Graduate Student Resources (https://mymasonportal.gmu.edu/webapps/blackboard/content/listContent.jsp?course_id=_336120_1&content_id=_7643583_1) regarding academic termination policies.

## Requirements

# Degree Requirements

Total credits: 72

### Complementary Background

| Code | Title | Credits |
|---|---|---|
| **Students choose 6 credits of complementary courses** [1] | | **6** |
| Students with a background in engineering or related field select: | | |
| BINF 531 | Molecular Cell Biology for Bioinformatics | |
| NEUR 600 | Chemistry and the Brain | |
| Students with a background in a non-engineering or related field select: | | |
| MATH 446 | Numerical Analysis I | |
| or OR 481 | Numerical Methods in Engineering | |
| SYST 500 | Quantitative Foundations for Systems Engineering | |
| Total Credits | | 6 |

[1] Students who have taken courses equivalent to the complimentary courses may replace them with 6 credits of technical electives.

### Core Bioengineering

| Code | Title | Credits |
|---|---|---|
| BENG 801 | Bioengineering Colloquium II [1] | 3 |
| Select 12 credits from the following bioengineering courses: [2] | | 12 |
| BENG 501 | Bioengineering Research Methods | |
| BENG 514 | Pathophysiology and the Role of New Technologies in Human Diseases | |
| BENG 575 | Intellectual Property, Regulatory Concepts and Product Development | |

| | | |
|---|---|---|
| BENG 601 | Collaborative Bioengineering Basic Science Research | |
| BENG 602 | Collaborative Bioengineering Clinical Science Research | |
| STAT 554 | Applied Statistics I [3] | 3 |
| or STAT 535 | Analysis of Experimental Data | |
| or STAT 560 | Biostatistical Methods | |
| Total Credits | | 18 |

1

Students must first register for the 0-credit BENG 800 Bioengineering Colloquium and attend at least 5 seminars per semester for 3 semesters before being able to take BENG 801. Note, students must continue to register for BENG 800 until they have attended the required number of seminars, then they can register for BENG 801 to receive credit.

2

One of BENG 501, BENG 514, BENG 575, BENG 601, and BENG 602 can be replaced with a technical elective.

3

Recommended option.

## Concentrations

Select one concentration and complete the requirements therein.

- Biomedical Imaging and Devices (BMID)
- Computational Biomedical Engineering (CBME)
- Biomaterials and Nanomedicine (BNM)
- Neurotechnology and Computational Neuroscience (NTCN)

### Biomedical Imaging and Devices (BMID)

| Code | Title | Credits |
|---|---|---|
| BENG 538 | Medical Imaging | 3 |
| BENG 537 | Medical Image Processing | 3 |
| or BENG 570 | Bioinstrumentation and Devices II | |
| BENG 704 | Laboratory Rotations in Biomedical Imaging and Devices | 3 |
| BENG 738 | Advanced Medical Image Processing | 3 |
| Total Credits | | 12 |

### Computational Biomedical Engineering (CBME)

| Code | Title | Credits |
|---|---|---|
| BENG 520 | Biomedical Data Analytics | 3 |
| BENG 530 | Continuum Biomechanics and Biotransport II | 3 |
| BENG 535 | Multi-Scale Modeling and Simulation in Biomedicine | 3 |
| BENG 705 | Laboratory Rotations in Computational Biomedical Engineering | 3 |
| Total Credits | | 12 |

### Biomaterials and Nanomedicine (BNM)

| Code | Title | Credits |
|---|---|---|
| BENG 521 | Cell and Tissue Engineering | 3 |
| BENG 540 | Advanced Biomaterials and Biomimetic Devices for Nanomedicine | 3 |
| BENG 641 | Advanced Nanotechnology in Health | 3 |
| BENG 703 | Laboratory Rotations in Biomaterials and Nanomedicine | 3 |
| Total Credits | | 12 |

### Neurotechnology and Computational Neuroscience (NTCN)

| Code | Title | Credits |
|---|---|---|
| BENG 526 | Neural Engineering | 3 |
| NEUR 634 | Neural Modeling | 3 |
| NEUR 689 | Topics in Neuroscience | 3 |
| BENG 706 | Laboratory Rotations in Neurotechnology and Computational Neuroscience | 3 |
| Total Credits | | 12 |

## Technical Electives

These graduate courses develop additional technical expertise in a student's PhD concentration. Students must choose 12 credits from the following list and/or from the concentration courses that are not already being taken for the concentration requirement.

| Code | Title | Credits |
|---|---|---|
| **Technical Specialization** | | **12** |
| Bioengineering | | |
| BENG 615 | Biomanufacturing | |
| BENG 699 | Advanced Topics in Bioengineering | |
| BENG 725 | Computational Motor Control | |
| BENG 797 | Graduate Practicum | |
| BENG 798 | Independent Reading and Research in Bioengineering | |
| Electrical, Computer & Mechanical Engineering | | |
| ECE 511 | Computer Architecture | |
| ECE 528 | Introduction to Random Processes in Electrical and Computer Engineering | |
| ECE 530 | Sensor Engineering | |
| ECE 550 | System Engineering Design | |
| ECE 635 | Adaptive Signal Processing | |
| ME 621 | Foundations of Fluid Mechanics | |
| Bioinformatics | | |
| BINF 641 | Biomolecular Modeling | |
| BINF 690 | Numerical Methods for Bioinformatics | |
| BINF 701 | Systems Biology | |
| BINF 731 | Protein Structure Analysis | |
| BINF 740 | Introduction to Biophysics | |
| BINF 741 | Introduction to Computer Simulations of Biomolecules | |
| BINF 751 | Biochemical and Cellular Systems Modeling | |
| BINF 760 | Machine Learning for Bioinformatics | |
| Biology and Chemistry | | |
| BIOL 562 | Personalized Medicine | |
| BIOL 563 | Virology | |
| BIOL 566 | Cancer Genomics | |
| BIOL 572 | Human Genetics | |
| BIOL 583 | General Biochemistry | |
| BIOL 682 | Advanced Eukaryotic Cell Biology | |
| CHEM 563 | General Biochemistry I | |

| | |
|---|---|
| CHEM 568 | Bioorganic Chemistry |
| CHEM 613 | Modern Polymer Chemistry |
| CHEM 660 | Protein Biochemistry |
| Physics | |
| PHYS 510 | Computational Physics I |
| PHYS 612 | Physics of Modern Imaging |
| PHYS 640 | Finite Element Analysis of Solids and Fluids |
| PHYS 694 | Applied Mechanics of Solids |
| PHYS 695 | Applied Fluid Mechanics |
| Mathematics and Statistics | |
| MATH 685 | Numerical Analysis |
| STAT 517 | Experimental Design |
| STAT 522 | Applied Multivariate Statistics |
| STAT 526 | Applied Regression Analysis |
| STAT 662 | Multivariate Analysis and Statistical Learning |
| STAT 672 | Statistical Learning and Data Analytics |
| Neuroscience | |
| NEUR 601 | Developmental Neuroscience |
| NEUR 602 | Cellular Neuroscience |
| NEUR 603 | Mammalian Neuroanatomy |
| NEUR 651 | Molecular Neuropharmacology |
| NEUR 734 | Computational Neurobiology |
| Total Credits | 12 |

## Program of Study

Upon starting the PhD program, the student should review the course requirements in the catalog and, in consultation with their advisor, define a plan of study and declare a concentration. The recommended timeline, milestones, instructions, and forms can all be found on the Bioengineering PhD program's website: https://bioengineering.gmu.edu/academics/phd-bioengineering (https://bioengineering.gmu.edu/academics/phd-bioengineering/).

## Qualifying Examination

Students entering the Bioengineering PhD program having already earned a MS degree in Bioengineering or Biomedical Engineering from a US institution are exempt from the qualifying exam. All other students entering the Bioengineering PhD program are expected to pass a qualifying exam within one to two years of entering the program. Detailed instructions and forms can be found here (https://bioengineering.gmu.edu/academics/phd-bioengineering/). The goal of the qualifying exam is to test the student's preparation to undertake doctoral level research. The exam will test the student's research competency as well as knowledge of core bioengineering concepts and competency in complementary areas.

A committee identified by the student's advisor (dissertation director) will administer the exam. The exam consists of a written and oral component, times and dates of which are determined by the student's dissertation director. The candidate's dissertation director communicates with the committee to determine the four topics of the exam, completes the qualifying exam topics form and transmits the form to the candidate. At least two months prior to the written exam, the student will receive a reading list from each committee member. The committee members provide their written questions to the committee chair who puts them together into the final form of the written exam. The student will take the written exam and their answers will be transmitted to the committee members. The oral exam will take place about one week after the written exam.

### Composition of the Qualifying Exam Committee:

The committees for the qualifying exam consists of four individuals:

- A minimum of two members, including the chair of the committee must be graduate faculty in the Department of Bioengineering.
- One member must be graduate faculty from outside the department.
- The chair of the committee is responsible for ensuring the correct forms are completed and procedures are followed.
- The dissertation director is the main scientist guiding the student's research and cannot be chair of the committee.

### Written Exam:

A set of four topics, relevant to the student's concentration and research topic, will be assigned to the student as representing essential knowledge that the student should master to be successful in their research, at least two months prior to the qualifying exam. In addition, the qualifying exam committee will provide the student a list of readings for each topic that the student is expected to master. The list of readings can include specific articles, books or book chapters, or syllabus items (e.g. from a class at Mason) for each of the topics. Each of the committee members creates written questions for one of the topics which will be provided to the student on the day of the exam.

The written component is a four hour exam with questions from each of the four examiners. There will be one question per examiner and each question is expected to require one hour to answer. The exam is closed book. One question can be replaced by a computational assignment to be completed by the time of the oral. In that case, the total written exam time will be reduced to three hours.

### Oral Exam:

At least one week after the written exam, the student will take the oral exam. The oral consists of answering questions by the qualifying committee related to the topics of the written exam.

### Grading:

The committee determines whether the candidate has passed or failed the exam based on the written report and oral exam and reports the results in the qualifying exam results form. The committee optionally provides a list of recommendations, e.g. additional material the student needs to master. If the student fails the exam, the student can re-take the exam once. The committee may specify a time frame for the second exam. A student who fails to pass on their second try will be terminated from the program.

## Dissertation Proposal

Each student must prepare and defend a written dissertation proposal to their dissertation committee. The student's dissertation director names the committee and chooses the date and time of the oral presentation. Detailed instructions, grading rubrics, and required forms are all found here (https://bioengineering.gmu.edu/academics/phd-bioengineering/). While preparing this proposal, the student enrolls in BENG 998 Doctoral Dissertation Proposal. The proposal must be made available to the committee at least two weeks in advance of the presentation. The proposal must be presented to and approved by the dissertation committee. All committee members assess the written proposal and oral presentation using the grading rubrics. The committee determines whether the proposal has merit and can lead to significant

contributions to the area and whether the student has the knowledge and skills to complete the proposed work successfully and in a timely manner. Students may present their dissertation proposal only after passing the qualifying exam, and the presentation may not be on the same day as the qualifying exam. If the student fails to defend the proposal, the student may present a dissertation proposal a second time at a later date. Failure in the second attempt results in termination from the program.

### Written Proposal:

The proposal should at a minimum clearly state the research question and the specific aims of the research, provide a critical review of the literature, present the hypotheses, the rationale and the significance of the research in addressing a gap in scientific knowledge, describe the research methods and study design in sufficient detail and present preliminary results demonstrating the feasibility of the research. Additional guidelines are provided in the written proposal rubric.

### Oral Presentation and Exam:

The candidate must present the proposal to committee in a venue open to the public. The presentation should be 30 - 45 minutes long. Following the research presentation, the dissertation committee will ask the students a number of questions to evaluate the students understanding of the relevant literature and methods that are broadly related to the chosen area of research, and whether the student has the knowledge and skills to complete the proposed work successfully and in a timely manner. Additional guidelines are provided in the oral presentation rubric.

### Grading:

The written proposal and oral presentation are graded according to rubrics and the results reported in the proposal results form. If the dissertation committee feels that the student is not adequately prepared, they may recommend remedial measures, including additional coursework to address any gaps in knowledge, or modification of the aims of the proposal. The proposal may be repeated once.

## Advancement to Candidacy

The student is advanced to candidacy for the PhD degree once they have successfully presented and defended a written dissertation proposal, completed all 48 course credits, and completed a minimum of 6 credits of BENG 998 Doctoral Dissertation Proposal. The student should also submit the Advancement to Candidacy form. The instructions for advancement to candidacy and the required form can be found here (https://bioengineering.gmu.edu/academics/phd-bioengineering/).

## Dissertation Research

Students are expected to complete 24 credits of BENG 998 Doctoral Dissertation Proposal and BENG 999 Doctoral Dissertation towards their degree. Students cannot enroll in BENG 998 Doctoral Dissertation Proposal before they have passed the qualifying exam. Students cannot enroll in BENG 999 Doctoral Dissertation before they have advanced to candidacy. Students who advanced to candidacy after the add period for a given semester must wait until the following semester to register for BENG 999 Doctoral Dissertation. Students cannot advance to candidacy and defend their dissertation during the same semester. Once enrolled in BENG 999 Doctoral Dissertation, students must maintain continuous registration in BENG 999 Doctoral Dissertation each semester until graduation, excluding summers. Students who defend in the summer must be registered for at least 1 credit of BENG 999 Doctoral Dissertation during that summer term.

| Code | Title | Credits |
|---|---|---|
| Select 24 credits from the following: | | 24 |
| BENG 998 | Doctoral Dissertation Proposal (6 credit minimum, 12 credit maximum) | |
| BENG 999 | Doctoral Dissertation (12 credit minimum) | |
| Total Credits | | 24 |

## Dissertation Committee Selection

Each student must form a dissertation committee, comprising four or five individuals:

- A minimum of two members, including the chair of the committee must be graduate faculty in the Department of Bioengineering.
- One member must be graduate faculty from outside the department.
- The chair of the committee is responsible for ensuring the correct forms are completed and procedures are followed.
- The dissertation director is the main scientist guiding the student's research and cannot be the chair of the committee.
- It is strongly recommended that one of the committee members be external to the university.

Refer to https://catalog.gmu.edu/policies/academic/graduate-policies/#text for who is allowed to be on these committees (see section AP.6.10.5 Dissertation Committee). The dissertation proposal committee has the same requirements as the dissertation committee. It is recommended for continuity that the same faculty should be on the committee for the qualifying exam, dissertation proposal, and dissertation defense; however, committee membership can be changed if circumstances warrant.

## Dissertation Preparation and Defense

The candidate must write and publicly defend their dissertation. The student's dissertation director names the committee and chooses the date and time of the oral defense. The committee must sign and submit a pre-defense form four weeks prior to the defense. Detailed instructions, grading rubrics, and required forms are all found here (https://bioengineering.gmu.edu/academics/phd-bioengineering/). While preparing the dissertation, the candidate enrolls in BENG 999 Doctoral Dissertation. The candidate can proceed to a public defense of the dissertation once their dissertation has been approved by the dissertation committee. The dissertation must make significant contributions to its area as evidenced by refereed journal and/or conference publications.

The candidate should begin early in the term to meet the deadlines (https://registrar.gmu.edu/students/graduation/timelines/). The candidate schedules a Format Review with University Dissertation & Thesis Services (UDTS) at least 2 - 3 weeks prior to the defense (https://library.gmu.edu/udts/process (https://library.gmu.edu/udts/process/)). The candidate provides the written dissertation to the committee at least 4 weeks before the defense. The defense must be announced at least two weeks in advance. The entire dissertation committee must be present at the defense, unless an exception is approved by the director of the PhD in Bioengineering Program in advance of the defense. If the candidate fails to defend the dissertation, the candidate may request a second defense, following the same procedures as for the initial defense. There is no time limit for this request other than general time limits for the doctoral degree. A candidate who fails a second attempt to defend the dissertation is terminated from the program.

### Dissertation:
The dissertation should report on research performed by the candidate during their studies at Mason. Ideally, the main chapters of the dissertation are comprised of published manuscripts, submitted manuscripts, and the student's final manuscript in preparation. The dissertation should include an introductory chapter, which gives a broad overview of all the research, and a concluding chapter, which summarizes the main findings of the body of work, and outlines future directions suggested by the research. Additional guidelines are provided in the written dissertation rubric. Format of the dissertation is determined by University Dissertation & Thesis Services.

### Oral Presentation and Exam:
The candidate must present the dissertation to committee in a venue open to the public. The oral presentation should last 30 - 45 minutes and include a general introduction and background to enable understanding by a broad audience. Explanation of the candidate's research should focus on the most significant results with easy to understand graphics. Additional guidelines for preparing the presentation are provided in the oral presentation rubric.

Following the research presentation, the dissertation committee will ask the candidate a number of questions to evaluate the student's understanding of research. The questioning generally begins with the external examiner and ends with the research director. Multiple rounds of questioning can occur. Once the committee's questions are complete, other attendees have an opportunity to ask questions of the candidate.

### Grading:
Following the presentation and questions, the candidate and other attendees leave the room to allow the committee to deliberate. The deliberations are presided by the chair of the committee who begins by asking the external examiner to evaluate the candidate. Other committee members then provide their evaluations ending with the research supervisor's evaluation. All committee members assess the written dissertation and the oral presentation using the grading rubrics and the results are reported on the dissertation results form. If the dissertation committee feels the dissertation does not make a sufficient contribution, or that the oral presentation was inadequate, the committee may request further research or require a repeat of the oral presentation.

## Additional Training Requirements
### Bioengineering Seminar
All PhD students are required to attend a minimum of 5 departmental seminars per semester. Students will sign an attendance sheet available at the end of each seminar.

### Ethics Training
Prior to beginning research studies in a Bioengineering laboratory, all PhD students must complete the on-line Collaborative Institutional Training Initiative (CITI) Responsible Conduct of Research course. CITI training modules provide students with an understanding of conflicts of interest, research misconduct, peer review, and authorship.