**BIOMEDICAL ENGINEERING, DOCTOR OF PHILOSOPHY (PH.D.)**

**Program mission**
The mission of the Doctor of Philosophy in Biomedical Engineering is to educate biomedical engineering students to be significant contributors in health care and in research and development in biomedicine and bioengineering. The curriculum closely links technical fundamentals in science, engineering and the life sciences, together with the ability to function on multidisciplinary teams, to communicate effectively and to achieve the knowledge tools necessary for lifelong learning.

**Program goals**
1. Provide students with a graduate education that prepares them for current and future challenges in biomedical engineering
2. Produce graduates who possess the necessary advanced analytical and technical skills in engineering and sciences — responds directly to the higher goals of fulfilling the needs of industry for effective, productive engineers and of providing economic development for the region, state and nation
3. Produce graduates who possess a facility with both written and oral communications — emanates from the requirement that engineers must be able to interact and share ideas with others in the work environment, and at a higher level, be capable of creative self-expression and leadership
4. Produce graduates who demonstrate creativity and innovation in solving technological problems — stems from the realization that new knowledge and new solutions to existing problems are necessary to meet the needs of our changing society and to advance the quality of human life

Graduates possess the ability to formulate, analyze and solve problems, analytically and/or experimentally, in the biomedical engineering industry, in the clinical setting or in biomedical research. Graduates can work effectively in teams to solve biomedical and/or clinical problems including the interconnection of engineering and clinical personnel toward the solution of problems of compelling clinical and biomedical interest and need, with particular reference to the biomedical engineering industry, in the clinical setting or in biomedical research. The career paths of BME graduates in these arenas would be enhanced as a result of these skills.

**Student learning outcomes**
1. Graduates will demonstrate an ability to apply advanced knowledge of mathematics, biomedical sciences and engineering.
2. Graduates will demonstrate an ability to communicate effectively.
3. Graduates will demonstrate an ability to identify, formulate and solve biomedical engineering problems.
4. Graduates will demonstrate an ability to conduct independent research.

**VCU Graduate Bulletin, VCU Graduate School and general academic policies and regulations for all graduate students in all graduate programs**
The VCU Graduate Bulletin website documents the official admission and academic rules and regulations that govern graduate education for all graduate programs at the university. These policies are established by the graduate faculty of the university through their elected representatives to the University Graduate Council.

It is the responsibility of all graduate students, both on- and off-campus, to be familiar with the VCU Graduate Bulletin as well as the Graduate School website (http://www.graduate.vcu.edu/) and academic regulations in individual school and department publications and on program websites. However, in all cases, the official policies and procedures of the University Graduate Council, as published on the VCU Graduate Bulletin and Graduate School websites, take precedence over individual program policies and guidelines.

Visit the academic regulations section for additional information on academic regulations for graduate students. (http://bulletin.vcu.edu/academic-reg/)

**Degree candidacy requirements**
A graduate student admitted to a program or concentration requiring a final research project, work of art, thesis or dissertation, must qualify for continuing master’s or doctoral status according to the degree candidacy requirements of the student’s graduate program. Admission to degree candidacy, if applicable, is a formal statement by the graduate student’s faculty regarding the student’s academic achievements and the student’s readiness to proceed to the final research phase of the degree program.

Graduate students and program directors should refer to the following degree candidacy policy as published in the VCU Graduate Bulletin for complete information and instructions.

Visit the academic regulations section for additional information on degree candidacy requirements. (http://bulletin.vcu.edu/academic-reg/grad/candidacy/)

**Graduation requirements**
As graduate students approach the end of their academic programs and the final semester of matriculation, they must make formal application to graduate. No degrees will be conferred until the application to graduate has been finalized.

Graduate students and program directors should refer to the following graduation requirements as published in the Graduate Bulletin for a complete list of instructions and a graduation checklist.

Visit the academic regulations section for additional information on graduation requirements. (http://bulletin.vcu.edu/academic-reg/grad/graduation-info/)

**Other information**
Student handbook (http://www.egr.vcu.edu/current-students/graduate-student-services/resources-forms/) is available on the College of Engineering website.
Apply online at graduate.admissions.vcu.edu (http://graduate.admissions.vcu.edu).

**Admission requirements**

<table>
<thead>
<tr>
<th>Degree:</th>
<th>Semester(s) of entry:</th>
<th>Deadline dates:</th>
<th>Test requirements:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ph.D.</td>
<td>Fall (preferred)</td>
<td>Jan 15</td>
<td>GRE-General; international students require TOEFL</td>
</tr>
<tr>
<td></td>
<td>Spring</td>
<td>Oct 1</td>
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</tbody>
</table>

**Special requirements**

- Acceptance of an applicant is based upon the recommendation of the admissions committee.

In addition to the general admission requirements of the VCU Graduate School (http://bulletin.vcu.edu/graduate/study/admission-graduate-study/admission-requirements/), biomedical engineering has the following admission criteria for all entering graduate students:

1. Minimum GPA of 3.0 during the previous 60 credit hours (for applicants with a B.S.)
2. Minimum GRE score of 300 (combined verbal reasoning and quantitative reasoning) including a minimum 150 on the quantitative reasoning
3. Minimum TOEFL score of 101 Internet-based for students whose first or native language is not English

Biomedical engineering will accept a maximum of six credit hours for transfer into the Ph.D. program if the original grades for such courses are B or higher (or equivalent).

**Degree requirements**

In addition to the VCU Graduate School graduation requirements (http://bulletin.vcu.edu/academic-regs/grad/graduation-info/), the Ph.D. will require a minimum of 72 credit hours beyond the B.S. or a minimum of 60 credit hours beyond the M.S. Students may enter the Ph.D. program with either a B.S. or an M.S.

**Comprehensive examinations**

In order to advance to doctoral candidacy, the student must pass both written and oral comprehensive examinations. The written examination focuses on the subject matter deemed critical as a foundation in the program. The examination is largely based on material covered in required course work and its application to theoretical and practical problems. The oral examination, which follows successful completion of the written examination(s), is administered by a committee of three biomedical engineering faculty members and assesses the ability of the student to integrate information and display an appropriate mastery of problem-solving capabilities. For further details, see the graduate program director or the program chair.

**Research adviser and graduate dissertation committee**

Students will be expected to select a research adviser and dissertation committee within the first year of enrollment in the Ph.D. program. The dissertation committee will consist of five faculty members, including the primary research adviser, two faculty members from the biomedical engineering graduate program and two faculty members from outside of the biomedical engineering graduate program. This committee reviews and votes to approve or disapprove the student's dissertation research proposal and the final Ph.D. dissertation and oral defense. This committee also makes the final recommendation to award the Ph.D. degree.

**Proposal presentation exam**

Within one year of passing the qualifying examination the student will submit one copy of an original dissertation research proposal based upon their proposed research project to each member of his or her dissertation committee. The proposal consists of the research topic and proposed research plan. The proposal should include a thorough literature review of the topic and contain information sufficient to judge the feasibility, scope and potential impact of the research. The dissertation committee will then administer an exam based on the material submitted in the dissertation research proposal. The format of the exam is an oral presentation by the candidate with questions by the dissertation committee members. A favorable decision by the dissertation committee with no more than one negative vote (all members are required to vote) shall be required to pass the exam. If a student fails the exam, one re-examination may be given with the consent of the dissertation committee. Failure to pass the second exam will result in dismissal from the program.

**Publication requirement**

A Ph.D. student appearing for the final defense in the Department of Biomedical Engineering must provide evidence of a minimum of two manuscripts accepted for publication in peer-reviewed archival journals recognized by the ISI Web of Science at the time of defense. These publications should be based on the student's dissertation research and must also be acceptable to the student's dissertation committee. The student is expected to have served as the first author in one or more of the papers. Specific publication requirements are available on the department's website as well as in the School of Engineering graduate handbook.

**Dissertation defense**

No earlier than six months after passing the oral candidacy examination, the student will defend the dissertation in an open forum administered by the dissertation committee. At least two weeks prior to the defense, the candidate will submit a written copy of the dissertation to each committee member and schedule a date for the defense. The defense will be advertised and faculty and student colleagues will be invited to attend. During the defense, the student will present a detailed summary of their research project, which should be the original problem presented and approved during the proposal presentation exam. If a solution of the original problem proves elusive for reasons beyond the student's control, the student may be allowed to redirect the research with permission from the dissertation committee and find an alternate pathway to the solution of a redefined problem. The format of the dissertation defense will be a presentation by the student followed by questions from the dissertation committee and other attendees. After the first round of questions are completed, the non-committee members in attendance will be asked to leave and the dissertation committee members will hold a second round of questions in closed session. After the second round of questions is completed the student will be asked to leave and the committee members will deliberate privately. The problem presented and solved must be of sufficient importance and interest to warrant publication in a peer-reviewed journal in the student's area of specialization. A favorable decision by the dissertation committee with no more than one negative vote (all members are required to vote) shall be required to pass the
dissertation defense. If a student fails the dissertation defense, one re-examination may be given. Failure to pass the second dissertation defense will result in dismissal from the program.

Students entering with a B.S. degree who are terminated from the Ph.D. program because of a failure to pass the QE, proposal presentation exam or dissertation defense (but not for other reasons such as academic dishonesty) will have the option to continue toward the M.S. in Biomedical Engineering.

**Time limit**

It is anticipated that students entering with a B.S. will complete the program in four years from the time the student passes the qualifying examination. Students must be continuously enrolled in the program (minimum of one credit hour per semester). All requirements for the Ph.D. must be completed within eight years of passing the qualifying examination.

It is anticipated that students entering with an M.S. will complete the program in three years from the time the student passes the qualifying examination. Students must be continuously enrolled in the program (minimum of one credit hour per semester). All requirements for the Ph.D. must be completed within six years of passing the qualifying examination.

Any student may request a one-year extension of the maximum time for extenuating circumstances such as a medical situation. The graduate program committee will review and approve or deny all such requests. The maximum time cannot be extended longer than one year. Students who do not satisfy the degree requirements within the maximum time will be dismissed from the program.

Because of the maximum time limits imposed on students in the Ph.D. program, the program does not accept part-time students.

**Curriculum requirements**

**B.S. to Ph.D. in Biomedical Engineering**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGRB 601</td>
<td>Numerical Methods and Modeling in Biomedical Engineering</td>
<td>4</td>
</tr>
<tr>
<td>EGRB 602</td>
<td>Biomedical Engineering Systems Physiology</td>
<td>4</td>
</tr>
</tbody>
</table>

**Restricted electives**

Choose three courses from:

- EGRB 507 Biomedical Electronics and Instrumentation
- EGRB 511 Fundamentals of Biomechanics
- EGRB 513 Cellular Signal Processing
- EGRB 521 Human Factors Engineering
- EGRB 603 Biomedical Signal Processing
- EGRB 613 Biomaterials

**Required courses in other departments**

- GRAD 614 Introduction to Grant Writing 1
- OVPR 603 Responsible Conduct of Research 1
- Statistics (BIOS or STAT at 500 level or above) 3

**Minimum elective courses**

- e.g. EGRB, EGRM, ENGR, PHYS, MATH, BIOL, PHIS, BIOC at 500 level or above 12

**Research**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGRB 690</td>
<td>Biomedical Engineering Research Seminar</td>
<td>4</td>
</tr>
<tr>
<td>EGRB 697</td>
<td>Directed Research in Biomedical Engineering (required at a level to be determined by each student's graduate advisory committee)</td>
<td>34</td>
</tr>
</tbody>
</table>

**Total Hours** 72

For students entering with a B.S., the minimum total of graduate credit hours required for this degree is 72.

**M.S. to Ph.D. in Biomedical Engineering**

<table>
<thead>
<tr>
<th>Course</th>
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<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGRB 601</td>
<td>Numerical Methods and Modeling in Biomedical Engineering</td>
<td>4</td>
</tr>
<tr>
<td>EGRB 602</td>
<td>Biomedical Engineering Systems Physiology</td>
<td>4</td>
</tr>
</tbody>
</table>

**Restricted electives**

Choose two courses from:

- EGRB 507 Biomedical Electronics and Instrumentation
- EGRB 511 Fundamentals of Biomechanics
- EGRB 513 Cellular Signal Processing
- EGRB 521 Human Factors Engineering
- EGRB 603 Biomedical Signal Processing
- EGRB 613 Biomaterials

**Required courses in other departments**

- GRAD 614 Introduction to Grant Writing 1
- OVPR 603 Responsible Conduct of Research 1
- Statistics (BIOS or STAT at 500 level or above) 3

**Minimum elective courses**

- e.g. EGRB, EGRM, ENGR, PHYS, MATH, BIOL, PHIS, BIOC at 500 level or above 3

**Research**

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<td>Biomedical Engineering Research Seminar</td>
<td>4</td>
</tr>
<tr>
<td>EGRB 697</td>
<td>Directed Research in Biomedical Engineering (required at a level to be determined by each student's graduate advisory committee)</td>
<td>34</td>
</tr>
</tbody>
</table>

**Total Hours** 60

For students entering with an M.S., the minimum total of graduate credit hours required for this degree is 60.

**Graduate program director**

Christopher A. Lemmon, Ph.D.
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Email: clemmon@vcu.edu
(804) 827-0446

**Additional contact**

Henry J. Donahue, Ph.D.
Professor and chair, Department of Biomedical Engineering
Email: hjdonahue@vcu.edu
(804) 828-7956

Program website: biomedical.egr.vcu.edu (http://biomedical.egr.vcu.edu/)