Quantitative Biosciences and Engineering

Program Description

The graduate program in quantitative biosciences and engineering brings together faculty across the Mines campus working on diverse areas of biology to educate students, with at least a Bachelor of Science degree in engineering or science, in the diverse field of biology. Biology deals broadly with life on this planet, the human organism and its health, and harnessing biological processes to produce fuels, chemicals, and consumer products. Thus, biology in general and human health and well-being in particular are important application areas for virtually all other areas of science, technology and engineering. This is reflected in the fact that any academic discipline exists today with a bio- prefix, such as biophysics, biochemistry, bioengineering, mathematical biology, computational biology, systems biology, structural biology, biomedicine, biomaterials, biomechanics, bioinformatics, biological chemistry, geobiology, environmental biology, microbiology to name just a few. Similarly, health is included in many labels, e.g. digital healthcare, health economics, health informatics. Educating students at the interfaces of biology, health and engineering with other disciplines is a primary goal of this program.

Many departments at Mines jointly administer this cross-departmental program in interdisciplinary biosciences. The program co-exists alongside strong disciplinary programs, in chemistry and geochemistry, chemical and biochemical engineering, physics, computer science, mathematics and statistics, mechanical engineering and metallurgical and materials engineering, civil and environmental engineering, economics, geology and geological engineering and geophysics, and thus draws from the strengths of these programs through close links and joint courses. For administrative purposes, the student will reside in the advisor’s home academic department. The student’s graduate committee will have final approval of the course of study.

Fields of Research

Research at Mines in this rapidly growing field currently includes but is not limited to the following general areas:

· Laser Design and Imaging
· Biofuels and Metabolic Engineering
· Omics and Systems Biology
· Environmental Toxicology and Microbiology
· Biosensors and Devices
· Biotechnology
· Biomechanics
· Biofluid mechanics
· Bioinformatics and Computational Biology
· Tissue Engineering & Biomaterials
· Physical Biochemistry
· Biophysics and Analytical Methodology Development
· Digital Healthcare
· Mathematical Biology

More than 45 faculty members across the CSM campus participate in this program, which will in the future also involve faculty of nearby collaborating institutions and scientists from the biotech/healthcare industry.

Program Requirements

For admission, students may enter with biology or health related undergraduate degrees of with a technical degree, e.g. in engineering, mathematics, or computer science. Ideally, students with a technical major will either have one of the biology related minors form Mines, or demonstrate the equivalent background, e.g., through a biology or health related minor at another institution. Current Mines undergraduate students have the option to apply to the Office of Graduate Studies for the 4+1 combined program while pursuing their undergraduate degree.

Each of the three degree programs (non-thesis MS, thesis-based MS, and PhD) require the successful completion of three mandatory core courses for a total of 10 credit hours.

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOL5XX</td>
<td>CELL BIOLOGY AND BIOCHEMISTRY</td>
<td>4.0</td>
</tr>
<tr>
<td>BIOL5XX</td>
<td>APPLIED BIOINFORMATICS</td>
<td>3.0</td>
</tr>
<tr>
<td>BIOL5XX</td>
<td>SYSTEMS BIOLOGY</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Total Semester Hrs 10.0

List of Electives:

Students must also take different numbers of electives, as per the degree chosen (see below). The current list of available electives is shown here but is dynamic. We expect the number of graduate level electives to increase over the time as this and other bio-related programs on campus evolve and expand. This list will therefore be updated annually subject to approval by the program’s curriculum committee.

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBEN432</td>
<td>TRANSPORT PHENOMENA IN BIOLOGICAL SYSTEMS</td>
<td>3.0</td>
</tr>
<tr>
<td>CBEN531</td>
<td>IMMUNOLOGY FOR SCIENTISTS AND ENGINEERS</td>
<td>3.0</td>
</tr>
<tr>
<td>CBEN570</td>
<td>INTRODUCTION TO MICROFLUIDICS</td>
<td>3.0</td>
</tr>
<tr>
<td>CEEN501</td>
<td>LIFE CYCLE ASSESSMENT</td>
<td>3.0</td>
</tr>
<tr>
<td>CEEN560</td>
<td>MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT</td>
<td>3.0</td>
</tr>
<tr>
<td>CEEN562</td>
<td>ENVIRONMENTAL GEOMICROBIOLOGY</td>
<td>3.0</td>
</tr>
<tr>
<td>CEEN566</td>
<td>MICROBIAL PROCESSES, ANALYSIS AND MODELING</td>
<td>3.0</td>
</tr>
<tr>
<td>CEEN570</td>
<td>WATER AND WASTEWATER TREATMENT</td>
<td>3.0</td>
</tr>
<tr>
<td>CHGN429</td>
<td>BIOCHEMISTRY II</td>
<td>3.0</td>
</tr>
<tr>
<td>CSCI562</td>
<td>APPLIED ALGORITHMS AND DATA STRUCTURES</td>
<td>3.0</td>
</tr>
<tr>
<td>CSCI575</td>
<td>MACHINE LEARNING</td>
<td>3.0</td>
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</tbody>
</table>
Master of Science in Quantitative Biosciences and Engineering (Thesis Option)

Here, the student conducts an in-depth research project with one of the participating faculty members who are currently accepting masters degree students. The Master of Science degree requires a minimum of 30 semester hours of acceptable course work and thesis research credits. The student must also submit a thesis and pass the Thesis Defense examination before the Thesis Committee.

<table>
<thead>
<tr>
<th>Core Courses</th>
<th>10.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electives</td>
<td>8.0</td>
</tr>
<tr>
<td>BIOL707 Research</td>
<td>12.0</td>
</tr>
<tr>
<td>Total Semester Hrs</td>
<td>30.0</td>
</tr>
</tbody>
</table>

Master of Science in Quantitative Biosciences and Engineering (Non-Thesis Option)

Here, the student can opt to conduct a case study instead of a full-fledged research project. The case studies can be chosen from projects provided by program faculty, local industry or academic partners. Students can also opt to enroll in further electives instead of conducting an independent study where this is more in line with their career goals. The Master of Science degree requires a minimum of 30 semester hours of acceptable course work and project credits.

<table>
<thead>
<tr>
<th>Core Courses</th>
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</thead>
<tbody>
<tr>
<td>Electives</td>
<td>14.0</td>
</tr>
<tr>
<td>BIOL599 Independent Study</td>
<td>6.0</td>
</tr>
<tr>
<td>Total Semester Hrs</td>
<td>30.0</td>
</tr>
</tbody>
</table>

Doctor of Philosophy in Quantitative Biosciences and Engineering

The Doctor of Philosophy degree requires a minimum of 72.0 hours of course and research credit including at least 24 credits in coursework and at least 24 credits in research:

<table>
<thead>
<tr>
<th>Core Courses</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Electives</td>
<td>14.0</td>
</tr>
<tr>
<td>BIOL707 Research</td>
<td>24.0</td>
</tr>
<tr>
<td>Electives or BIOL707 Research</td>
<td>24.0</td>
</tr>
<tr>
<td>Total Semester Hrs</td>
<td>72.0</td>
</tr>
</tbody>
</table>

Checklist

The program is interdisciplinary and it is therefore expected that there will be diverse backgrounds in the students admitted to this program. To ensure that all fundamental knowledge is adequately present, candidates may need to complete courses, which depend on the candidates’ backgrounds. For example, a student with an experimental biology background needs to take programming courses. The courses are thus individualized for each candidate based on their previous experience and research activities to be pursued where applicable. Some candidates may already possess this background information. In such circumstances, the candidate’s Thesis Committee may award credit for previous experience. These courses can be at the undergraduate level but do not count towards the 30 credits in the case of the Masters and 72 credits in case of the PhD degrees. Students with sufficient background can start taking graduate level classes counting towards the graduate degree in their junior year, but the majority will do so in their senior year. The program will be flexible given the expected diverse backgrounds of the students, and will offer bookcamp style activities at the beginning of each core class in order to account for the differences in backgrounds, where students from one background will help teach students with other backgrounds to acquire complementary skills.

PhD Qualifying Process

Core Curriculum – The three required core classes must be completed in the first two full academic years for all doctoral candidates, except where remedial classes or prerequisites need to be taken prior. Students must obtain a grade of B- or better in each class and have a cumulative GPA of 3.0 or higher to be eligible to take the qualifying examination at the end of the succeeding spring semester. If not allowed to complete the qualifying examination at the end of the spring semester, students will be discouraged from the PhD program and encouraged, rather, to finish with a Masters degree.

PhD Qualifying Examination – All first-year Quantitative Biosciences and Engineering PhD students are expected to successfully complete the qualifying examination at the end of the first year to remain in good standing in the program. The examination covers material from the core curriculum plus the theoretical background of their chosen area of research. If a student performs below the expectations of the faculty administering the oral exam, a student may need to finish with a Masters degree.

PhD Thesis Proposal – A student’s PhD thesis committee administers the PhD Thesis Proposal defense. The PhD proposal defense should occur no later than the student’s fourth semester. While the proposal itself should focus on the central topic of the student’s research, during the proposal defense, candidates may expect to receive a wide range of questions from the Committee. This would include all manner of questions directly related to the proposal. Candidates, however, should also expect questions related to the major concept areas of Biology within the context of a candidate’s research focus. The Committee formally reports the results of the PhD proposal defense to the Quantitative Biosciences and Engineering Program Director using the Committee Reporting form developed by the Office of Graduate Studies.

Upon completion of these steps and upon completion of all required coursework, candidates are admitted to candidacy. Following successful completion of coursework and the PhD qualifying process, candidates must also submit a thesis and successfully complete the PhD Defense of Thesis examination before the PhD Thesis Committee.

Combined Undergraduate/Graduate BS/MS Degree ("4+1")
The interdisciplinary biology degree programs will offer Mines undergraduate students the opportunity to begin work on the Graduate Degree while completing the requirements of their Bachelors Degree. The purpose is to give students a head start on graduate education and enable them to finish their Masters degree in one year after their Bachelors. Admission into a Combined Undergraduate/Graduate degree program is available only to current Mines undergraduate students. Students need to plan with their advisor what classes they would like to take and which prerequisites might be required in order to be able to fit the classes into their undergraduate curriculum.

**Advising Faculty**

Joel Bach  
Cecilia Diniz Behn  
Steven Boyes  
Nanette Boyle  
John Bradford  
Kevin Cash  
Dylan Domaille  
Christopher Higgins  
Judith Klein-Seetharaman  
Melissa Krebs  
Amy Landis  
Karin Leiderman-Gregg  
Terry Lowe  
David Marr  
Keith Neeves  
Steve Pankavich  
Tony Petrella  
Andrew Petruska  
Matt Posewitz  
James Ranville  
Susanta Sarkar  
Josh Sharp  
Anne Silverman  
Dendy Sloan  
John Spear  
Jeff Squier  
Amadeu Sum  
Brian Trewyn

Shubham Vyas  
Hua Wang  
Kim Williams  
Xioli Zhang

**Teaching Faculty**

Linda Battalora  
Kristine Csavina  
Cynthia Norrgran  
Josh Ramey  
Jeffrey Schowalter