Quantitative Biosciences and Engineering

Degrees Offered

- Master of Science in Quantitative Biosciences and Engineering (Non-Thesis)
- Master of Science in Quantitative Biosciences and Engineering (Thesis)
- Doctor of Philosophy in 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 quantitative biosciences and engineering. 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, at the graduate level, 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 35 faculty members across the Mines campus participate in this program, which will in the future also involve faculty of nearby collaborating institutions and scientists from the biotech/healthcare industry.

Quantitative Biosciences and Engineering (QBE) Program Requirements

For admission, students may enter with biology or health-related undergraduate degrees or with a technical degree, e.g. in engineering, mathematics, or computer science.

Current Mines undergraduate students have the option to apply to the Office of Graduate Studies for the Combined program while pursuing their undergraduate degree (see information below).

Each of the three degrees (non-thesis Master of Science, thesis-based Master of Science, and Doctor of Philosophy) require the successful completion of four core courses for a total of 13 credits, as detailed below.

QBE Core Courses

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOL500</td>
<td>CELL BIOLOGY AND BIOCHEMISTRY</td>
<td>4.0</td>
</tr>
<tr>
<td>BIOL501</td>
<td>ADVANCED BIOCHEMISTRY</td>
<td>3.0</td>
</tr>
<tr>
<td>BIOL510</td>
<td>BIOINFORMATICS</td>
<td>3.0</td>
</tr>
<tr>
<td>BIOL520</td>
<td>SYSTEMS BIOLOGY</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Total Semester Hrs 13.0

QBE Graduate Seminar

Full-time graduate students in the QBE program are expected to maintain continuous enrollment in BIOL 590, QBE Graduate Seminar, a 1 credit course. A maximum of 2 credits will be granted toward the MS degree requirements while a maximum of 4 credits will be granted toward PhD requirements, as shown below. Students who are concurrently enrolled in a different degree program that also requires seminar attendance may have this requirement waived at the discretion of the QBE Program Director.

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

The Master of Science Non-Thesis (MS-NT) degree requires a minimum of 30 credits of acceptable coursework.
**Master of Science in Quantitative Biosciences and Engineering (Thesis Option)**

The thesis-based Master of Science (MS-T) requires a minimum of 30 semester hours of acceptable coursework and thesis research credits. Students conduct an in-depth research project with one of the participating faculty members who are currently accepting masters degree students. The student must also submit a thesis and pass the Thesis Defense examination before the Thesis Committee.

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>QBE Core Courses</td>
<td>13.0</td>
</tr>
<tr>
<td>QBE Elective</td>
<td>3.0</td>
</tr>
<tr>
<td>BIOL590: QUANTITATIVE BIOSCIENCES &amp; ENGINEERING GRADUATE SEMINAR</td>
<td>2.0</td>
</tr>
<tr>
<td>BIOL707: GRADUATE THESIS / DISSERTATION RESEARCH CREDIT</td>
<td>12.0</td>
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</tbody>
</table>

**Total Semester Hrs: 30.0**

*While full-time MS-T students are expected to maintain continuous enrollment in BIOL 590, the QBE Graduate Seminar; a maximum of 2 credits will be granted toward the MS-T degree requirements.

**Doctor of Philosophy in Quantitative Biosciences and Engineering**

The Doctor of Philosophy (PhD) degree requires a minimum of 72 hours of course and research credit including at least 24 credits in coursework and at least 24 credits in research. Doctoral students must also pass a qualifying examination and thesis proposal defense, complete a satisfactory thesis, and successfully defend their thesis.

<table>
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<tr>
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<tr>
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<td>2.0</td>
</tr>
<tr>
<td>BIOL707: GRADUATE THESIS / DISSERTATION RESEARCH CREDIT</td>
<td>12.0</td>
</tr>
</tbody>
</table>

**Total Semester Hrs: 30.0**

*While full-time PhD students are expected to maintain continuous enrollment in BIOL 590, the QBE Graduate Seminar; a maximum of 4 credits will be granted toward the PhD degree requirements.

**QBE Elective Courses:**

The current list of available electives is shown below. Because course options are continually expanding, additional complementary courses (beyond those listed here) may be approved on an ad hoc basis by the advisor in consultation with the program director.

<table>
<thead>
<tr>
<th>Course</th>
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</thead>
<tbody>
<tr>
<td>BIOL599: INDEPENDENT STUDY</td>
<td>0.5-6</td>
</tr>
<tr>
<td>CBEN412: INTRODUCTION TO PHARMACOKINETICS</td>
<td>3.0</td>
</tr>
<tr>
<td>CBEN432/532: TRANSPORT PHENOMENA IN BIOLOGICAL SYSTEMS</td>
<td>3.0</td>
</tr>
<tr>
<td>CBEN505: NUMERICAL METHODS IN CHEMICAL ENGINEERING</td>
<td>3.0</td>
</tr>
<tr>
<td>CBEN511: NEUROSCIENCE, MEMORY, AND LEARNING</td>
<td>3.0</td>
</tr>
<tr>
<td>CBEN531: IMMUNOLOGY FOR SCIENTISTS AND ENGINEERS</td>
<td>3.0</td>
</tr>
<tr>
<td>CBEN570: INTRODUCTION TO MICROFLUIDICS</td>
<td>3.0</td>
</tr>
<tr>
<td>CBEN624: APPLIED STATISTICAL MECHANICS</td>
<td>3.0</td>
</tr>
<tr>
<td>CBEN625: MOLECULAR SIMULATION</td>
<td>3.0</td>
</tr>
<tr>
<td>CEEN501: LIFE CYCLE ASSESSMENT</td>
<td>3.0</td>
</tr>
<tr>
<td>CEEN551: ENVIRONMENTAL ORGANIC CHEMISTRY</td>
<td>3.0</td>
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<tr>
<td>CEEN560: MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT</td>
<td>3.0</td>
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<tr>
<td>CEEN562: ENVIRONMENTAL GEOMICROBIOLOGY</td>
<td>3.0</td>
</tr>
<tr>
<td>CEEN566: MICROBIAL PROCESSES, ANALYSIS AND MODELING</td>
<td>3.0</td>
</tr>
<tr>
<td>CEEN570: WATER AND WASTEWATER TREATMENT</td>
<td>3.0</td>
</tr>
<tr>
<td>CHGN409/509: BIOLOGICAL INORGANIC CHEMISTRY</td>
<td>3.0</td>
</tr>
<tr>
<td>CHGN441: THE CHEMISTRY AND BIOCHEMISTRY OF PHARMACEUTICALS</td>
<td>3.0</td>
</tr>
<tr>
<td>CHGN507: ADVANCED ANALYTICAL CHEMISTRY</td>
<td>3.0</td>
</tr>
<tr>
<td>CSCI562: APPLIED ALGORITHMS AND DATA STRUCTURES</td>
<td>3.0</td>
</tr>
<tr>
<td>CSCI575: ADVANCED MACHINE LEARNING</td>
<td>3.0</td>
</tr>
<tr>
<td>EBN525: BUSINESS ANALYTICS</td>
<td>3.0</td>
</tr>
<tr>
<td>EBN553: PROJECT MANAGEMENT</td>
<td>3.0</td>
</tr>
<tr>
<td>MATH431: MATHEMATICAL BIOLOGY</td>
<td>3.0</td>
</tr>
<tr>
<td>MATH530: INTRODUCTION TO STATISTICAL METHODS</td>
<td>3.0</td>
</tr>
<tr>
<td>MATH572: MATHEMATICAL AND COMPUTATIONAL NEUROSCIENCE</td>
<td>3.0</td>
</tr>
<tr>
<td>MEGN531: PROSTHETIC AND IMPLANT ENGINEERING</td>
<td>3.0</td>
</tr>
<tr>
<td>MEGN532: EXPERIMENTAL METHODS IN BIOMECHANICS</td>
<td>3.0</td>
</tr>
<tr>
<td>MEGN535: MODELING AND SIMULATION OF HUMAN MOVEMENT</td>
<td>3.0</td>
</tr>
<tr>
<td>MEGN536: COMPUTATIONAL BIOMECHANICS</td>
<td>3.0</td>
</tr>
<tr>
<td>MEGN537: PROBABILISTIC BIOMECHANICS</td>
<td>3.0</td>
</tr>
<tr>
<td>MTGN570: BIOMATERIALS</td>
<td>3.0</td>
</tr>
<tr>
<td>MTGN572: BIOPHYSICS</td>
<td>3.0</td>
</tr>
</tbody>
</table>

**Combined Undergraduate / Graduate Degree Program**

Students enrolled in Mines’ combined undergraduate/graduate program may double count up to six credits of graduate coursework to fulfill requirements of both their undergraduate and graduate degree programs. These courses must have been passed with "B-" or better, not be substitutes for required coursework, and meet all other University, Department, and Program requirements for graduate credit.

Students are advised to consult with their undergraduate and graduate advisors for appropriate courses to double count upon admission to the combined program.
BIOL500. CELL BIOLOGY AND BIOCHEMISTRY. 4.0 Semester Hrs.
This course will provide students with deep biological insight as well as
hands-on experience of studying a biological question at the level of the
cell, including gene expression and localization of proteins in eukaryotic
cells, to the level of the protein, from molecular biology of the gene to
characterization of posttranslational modifications, and protein purification
and biochemical and biophysical characterization of protein structure
and dynamics. These fundamental properties will be linked to protein
activity and function. The emphasis of this course is on quantitative
biology. Wherever appropriate, advanced concepts of protein chemistry
and physics will be integrated into the delivery of the basic concepts. The
course includes a 3 credit hour lecture section and a 1 credit hour lab
section.

BIOL501. ADVANCED BIOCHEMISTRY. 3.0 Semester Hrs.
Advanced study of the major molecules of biochemistry: amino acids,
proteins, enzymes, nucleic acids, lipids, and saccharides- their structure,
chemistry, biological function, biosynthesis, and interaction. Stresses
bienergetics and the cell as a biological unit of organization. Advanced
discussion of the intertwining of molecular genetics, biomolecule
synthesis, and metabolic cycles. Prerequisites: CHGN428 or BIOL500.

BIOL510. BIOINFORMATICS. 3.0 Semester Hrs.
Bioinformatics is a blend of multiple areas of study including biology,
data science, mathematics and computer science. The field focuses on
extracting new information from massive quantities of biological data
and requires that scientists know the tools and methods for capturing,
processing and analyzing large data sets. Bioinformatics scientists are
tasked with performing high-throughput, next-generation sequencing.
They analyze DNA sequence alignment to find mutations and anomalies
and understand the impact on cellular processes. The bioinformatician
uses software to analyze protein structure and its impact on cell function.
Learning how to design experiments and perform advanced statistical
analysis is essential for anyone interested in this field, which is main goal
of this course. Prerequisite: CSC1102.

BIOL520. SYSTEMS BIOLOGY. 3.0 Semester Hrs.
This course provides students an introduction to the emerging field of
systems biology. It will consist of lectures, group discussion sessions,
and problem-solving sessions and/or computational labs. Students
will learn strategies and tools to interrogate biological systems using
mathematical modeling. Topics of the course will come from typical
aspects of biomathematical modeling including, but not limited to: the
choice of a modeling framework from various approaches; the design of
interaction diagrams; the identification of variables and processes; the
design of systems models; standard methods of parameter estimation;
the analysis of steady states, stability, sensitivity; numerical evaluations
of transients; phase-plane analysis; simulation of representative biological
scenarios. All theoretical concepts are exemplified with applications.

BIOL598. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special
interests of instructor(s) and student(s). Usually the course is offered
only once, but no more than twice for the same course content.. Variable
credit: 0 to 6 credit hours. Repeatable for credit under different titles.

BIOL599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a
faculty member, also, when a student and instructor agree on a subject
matter, content, and credit hours. Prerequisite: “Independent Study” form
must be completed and submitted to the Registrar. Variable credit: 0.5
to 6 credit hours. Repeatable for credit under different topics/experience
and maximums vary by department. Contact the Department for credit
limits toward the degree.

BIOL707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT.
1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level
thesis or Doctoral dissertation. Research must be carried out under the
direct supervision of the student’s faculty advisor. Variable class and
semester hours. Repeatable for credit.

Advising Faculty
Joel Bach, Associate Professor of Mechanical Engineering
Cecilia Diniz Behn, Associate Professor of Applied Mathematics &
Statistics
Nanette Boyle, Associate Professor of Chemical and Biological
Engineering
Kevin Cash, Assistant Professor of Chemical and Biological Engineering
Anuj Chauhan, Professor of Chemical and Biological Engineering
Dylan Domaille, Assistant Professor of Chemistry
Christopher Higgins, Professor of Civil and Environmental Engineering
Melissa Krebs, Co-Director, QBE Graduate Program and Associate
Professor of Chemical and Biological Engineering
Ramya Kumar, Assistant Professor of Chemical and Biological
Engineering
Karim Leiderman, Co-Director, QBE Graduate Program and Associate
Professor of Applied Mathematics & Statistics
Terry Lowe, Research Professor of Materials and Metallurgical
Engineering
David Marr, Professor of Chemical and Biological Engineering
Christine Morrison, Assistant Professor of Chemistry
Alexander Pak, Assistant Professor, Chemical and Biological Engineering
Steve Pankavich, Associate Professor of Applied Mathematics &
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Anthony Petrrella, Associate Professor of Mechanical Engineering
Andrew Petruska, Assistant Professor of Mechanical Engineering
Matthew Posewitz, Professor of Chemistry
James Ranville, Professor of Chemistry
Susanta Sarkar, Assistant Professor of Physics
Jonathan Sharp, Associate Professor of Civil and Environmental
Engineering
Anne Silverman, Associate Professor of Mechanical Engineering
E. Dendy Sloan, Emeritus Professor of Chemical and Biological
Engineering
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Jeff Squier, Professor of Physics
Amadeu Sum, Professor of Chemical and Biological Engineering
Brian Trewyn, Associate Professor of Chemistry
Shubham Vyas, Associate Professor of Chemistry
Hua Wang, Associate Professor of Computer Science
Kim Williams, Professor of Chemistry
Xiaoli Zhang, Associate Professor of Mechanical Engineering

Teaching Faculty
Linda Battalora, Teaching Professor of Petroleum Engineering
Suzannah Beeler, Assistant Teaching Professor of Chemical and Biological Engineering
Kristine Csavina, Teaching Professor of Mechanical Engineering
Alina Handorean, Teaching Professor of Engineering, Design & Society
Cynthia Norrgran, Teaching Associate Professor of Chemical and Biological Engineering
Josh Ramey, Director of the QBE Undergraduate Program and Teaching Associate Professor of Chemical and Biological Engineering
Justin Shaffer, Teaching Associate Professor of Chemical and Biological Engineering