Quantitative Biosciences and Engineering

Degrees Offered

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

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.

BIOL5XX	CELL BIOLOGY AND BIOCHEMISTRY Course not yet created. See advisor for course numbers.	4.0
BIOL5XX	APPLIED BIOINFORMATICS Course not yet created. See advisor for course numbers.	3.0
BIOL5XX	SYSTEMS BIOLOGY Course not yet created. See advisor for course numbers.	3.0
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.

CBEN432	TRANSPORT PHENOMENA IN BIOLOGICAL SYSTEMS	3.0
CBEN531	IMMUNOLOGY FOR SCIENTISTS AND ENGINEERS	3.0
CBEN570	INTRODUCTION TO MICROFLUIDICS	3.0
CEEN501	LIFE CYCLE ASSESSMENT	3.0
CEEN560	MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT	3.0
CEEN562	ENVIRONMENTAL GEOMICROBIOLOGY	3.0

CEEN566	MICROBIAL PROCESSES, ANALYSIS AND MODELING	3.0
CEEN570	WATER AND WASTEWATER TREATMENT	3.0
CHGN429	BIOCHEMISTRY II	3.0
CSCI562	APPLIED ALGORITHMS AND DATA STRUCTURES	3.0
CSCI575	ADVANCED MACHINE LEARNING	3.0
MATH572	MATHEMATICAL AND COMPUTATIONAL NEUROSCIENCE	3.0
MEGN531	PROSTHETIC AND IMPLANT ENGINEERING	3.0
MEGN532	EXPERIMENTAL METHODS IN BIOMECHANICS	3.0
MEGN535	MODELING AND SIMULATION OF HUMAN MOVEMENT	3.0
MEGN536	COMPUTATIONAL BIOMECHANICS	3.0
MEGN537	PROBABILISTIC BIOMECHANICS	3.0
MTGN570	BIOCOMPATIBILITY OF MATERIALS	3.0
MTGN572	BIOMATERIALS	3.0
PHGN433	BIOPHYSICS	3.0

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.

Core Courses	10.0
Electives	8.0
BIOL707 Research	12.0
Total Semester Hrs	**30.0**

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.

Core Courses	10.0
Electives	14.0
BIOL599 Independent Study	6.0
Total Semester Hrs	**30.0**

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:

Core Courses	10.0
Electives	14.0
BIOL707 Research	24.0
Electives or BIOL707 Research	24.0
Total Semester Hrs	**72.0**

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 bootcamp 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.

Mines' Combined Undergraduate / Graduate Degree Program

Students enrolled in Mines' combined undergraduate/graduate program may double count up to six hours of credits which were used in fulfilling the requirements of their undergraduate degree at Mines, towards their Quantitative Biosciences and Engineering (QBE) Graduate Program.. Any 400+ level courses that count towards the undergraduate degree requirements as "Elective Coursework" or any 500+ level course, may be used for the purposes of double counting at the discretion of the graduate advisor (MS Non-Thesis) or thesis committee (MS Thesis of PhD). These courses must have been passed with a "B-" or better and meet all other University, Department, Division, and Program requirements for graduate credit.

BIOL500. CELL BIOLOGY AND BIOCHEMISTRY. 3.0 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.

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: CSCI102.

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 IN BIOLOGY. 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. Prerequisite: none. 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, Professor of Mechanical Engineering

Cecilia Diniz Behn, Assistant Professor of Applied Mathematics & Statistics

Steven Boyes, Associate Professor of Chemistry

Nanette Boyle, Assistant Professor of Chemical and Biological Engineering

John Bradford, Professor of Geophysics

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, Associate Professor of Civil and Environmental Engineering

Judith Klein-Seetharaman, Associate Professor of Biosciences and Engineering

Melissa Krebs, Associate Professor of Chemical and Biological Engineering

Lokender Kumar, Research Assistant Professor of Physics

Amy Landis, Professor of Civil and Environmental Engineering

Karin Leiderman-Gregg, Assistant 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

Steve Pankavich, Associate Professor of Applied Mathematics & Statistics

Tony Petrella, Associate Professor of Mechanical Engineering

Andrew Petruska, Assistant Professor of Mechanical Engineering

Matt Posewitz, Professor of Chemistry

James Ranville, Professor of Chemistry

James Rosenblum, Research Assistant Professor of Civil and Environmental Engineering

Susanta Sarkar, Assistant Professor of Physics

Josh Sharp, Associate Professor of Civil and Environmental Engineering

Anne Silverman, Associate Professor of Mechanical Engineering

Dendy Sloan, Emeritus Professor of Chemical and Biological Engineering

John Spear, Director of Biosciences and Bioengineering

Jeff Squier, Professor of Physics

Blake Stamps, Research Assistant Professor of Civil and Environmental Engineering

Amadeu Sum, Professor of Chemical and Biological Engineering

Brian Trewyn, Associate Professor of Chemistry

Shubham Vyas, Assistant Professor of Chemistry

Hua Wang, Associate Professor of Computer Science

Kim Williams, Professor of Chemistry

Xioli Zhang, Assistant Professor of Mechanical Engineering

Teaching Faculty

Linda Battalora, Teaching Professor of Petroleum Engineering

Kristine Csavina, Teaching Professor of Mechanical Engineering

Laura Legault, Teaching Assistant Professor of Computer Science

Cynthia Norrgran, eaching Associate Professor of Chemical and Biological Engineering

Josh Ramey, Teaching Associate Professor of Chemical and Biological Engineering

Jeffrey Schowalter, Teaching Professor of Electrical Engineering