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		
BIOL500	CELL BIOLOGY AND BIOCHEMISTRY	4.0
BIOL501	ADVANCED BIOCHEMISTRY	3.0
BIOL510	BIOINFORMATICS	3.0
BIOL520	SYSTEMS BIOLOGY	3.0
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.

QBE Core Courses		13.0
QBE Electives (see list below)		15.0
BIOL590	QUANTITATIVE BIOSCIENCES & ENGINEERING GRADUATE SEMINAR (*)	2.0
Total Semester Hrs		**30.0**

*While full-time MS-NT 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-NT degree requirements.

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 conducts 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.

QBE Core Courses		13.0
QBE Elective		3.0
BIOL590	QUANTITATIVE BIOSCIENCES & ENGINEERING GRADUATE SEMINAR (*)	2.0
BIOL707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	12.0
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.

QBE Core Courses		13.0
QBE Electives		11.0
BIOL590	QUANTITATIVE BIOSCIENCES & ENGINEERING GRADUATE SEMINAR (*)	4.0
BIOL707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	24.0
QBE Electives or BIOL707 Research		20.0
Total Semester Hrs		**72.0**

*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.

BIOL599	INDEPENDENT STUDY	0.5-6
CBEN412	INTRODUCTION TO PHARMACOKINETICS	3.0
CBEN432/532	TRANSPORT PHENOMENA IN BIOLOGICAL SYSTEMS	3.0
CBEN505	NUMERICAL METHODS IN CHEMICAL ENGINEERING	3.0
CBEN511	NEUROSCIENCE, MEMORY, AND LEARNING	3.0
CBEN531	IMMUNOLOGY FOR SCIENTISTS AND ENGINEERS	3.0
CBEN570	INTRODUCTION TO MICROFLUIDICS	3.0
CBEN624	APPLIED STATISTICAL MECHANICS	3.0
CBEN625	MOLECULAR SIMULATION	3.0
CEEN501	LIFE CYCLE ASSESSMENT	3.0
CEEN551	ENVIRONMENTAL ORGANIC CHEMISTRY	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
CHGN409/509	BIOLOGICAL INORGANIC CHEMISTRY	3.0
CHGN441	THE CHEMISTRY AND BIOCHEMISTRY OF PHARMACEUTICALS	3.0
CHGN507	ADVANCED ANALYTICAL CHEMISTRY	3.0
CSCI562	APPLIED ALGORITHMS AND DATA STRUCTURES	3.0
CSCI575	ADVANCED MACHINE LEARNING	3.0
EBGN525	BUSINESS ANALYTICS	3.0
EBGN553	PROJECT MANAGEMENT	3.0
MATH431	MATHEMATICAL BIOLOGY	3.0
MATH530	INTRODUCTION TO STATISTICAL METHODS	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

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 bioenergetics 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: 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. 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

Karin 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 & Statistics

Anthony Petrella, 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

John Spear, Professor, Civil and Environmental Engineering

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