Chemical and Biochemical Engineering, M.S.

Graduate students in the Department of Chemical and Biochemical Engineering gain an understanding of the principles of engineering science and use those principles in contemporary applications related to energy, the environment, biotechnology, and materials. The department emphasizes research, since most opportunities for graduates are in research and development.

Research and Study Areas

Current research strengths of the Department of Chemical and Biochemical Engineering are in the areas of global and regional atmospheric modeling, biomaterials and medical engineering, cellular engineering, photopolymerization, biocatalysis, and biofuels.

Biochemical Engineering

Biochemical engineering involves the industrial application of enzymes, microorganisms, cells, and tissues for production of chemicals, pharmaceuticals, and other materials of commercial value.

The department is working to solve problems with the use of insect cell culture for recombinant protein and viral insecticide production. Research is being conducted to improve the quality and quantity of recombinant proteins produced in large-scale bioreactors. In addition, a continuous viral insecticide production system is being developed for the large-scale production of these environmentally safe alternatives to chemical insecticides. The insect cell/baculovirus system is being used as a model system to investigate the role of oxidative stress in viral cytopotoxicity.

Carbon dioxide accumulation, which commonly occurs in large-scale bioreactor systems, affects insect cell growth. The department’s researchers are investigating the corresponding effect on insect cell growth and the baculovirus infection process.

The department works to design technologies for the characterization and use of extremophiles, organisms that possess unusual abilities to survive in harsh chemical environments. In these studies, novel bioreactor systems that can withstand extremes of temperature, pressure, pH, and salinity are being developed. Extremophile strategies for survival also are being studied, with the aim of discovering unique enzymes for industrial application as well as evaluating molecular interactions that govern protein stability under extreme conditions.

In addition to the study of natural extremophiles, efforts to engineer stability in biocatalysts for industrial processing are under way. Novel solvent-tolerant enzymes and organisms for environmentally beneficial chemical reactions are being generated using molecular biology tools. Combinations of chemical and biological processing are being used to produce valued chemicals from renewable feedstocks. This work contributes to the interdisciplinary training of engineers and scientists to address the challenges of minimizing and cleaning up environmental pollution, while maximizing the economic benefits of chemical processing.

The department also conducts research in structural enzymology, molecular mechanisms of host-pathogen interactions, and biocatalysis. The laboratory uses biophysical, structural, and molecular biology techniques to understand the details of enzyme action. This information is used to design and engineer biocatalysts for the production of chiral compounds. Work also is under way on cellular recognition and signaling processing during infection and inflammation. Knowledge gained from these studies aids the design of drugs and biological sensors for bacterial presence.

The integration of biotechnology with traditional chemical engineering has led to an interdisciplinary area involving other engineering departments and the Departments of Chemistry and Biology (College of Liberal Arts and Sciences); the Department of Biochemistry, the Free Radical and Radiation Biology Program, and the Department of Microbiology and Immunology (Carver College of Medicine); and the College of Pharmacy. This focus includes involvement in the University’s Center for Biocatalysis and Bioprocessing, whose fermentation capabilities are highlighted by its 1,500-liter fermentor.

Biomedical Research

The department’s research involves a multidisciplinary approach to solving problems in the medical field, particularly in drug delivery and biomaterials.

Researchers are working to develop safe delivery systems that target drugs precisely in the human body and avoid premature metabolization or elimination. To treat respiratory infections, micron-sized particles are being engineered with properties that enhance aerodynamic performance, particle stability, and targeting within the respiratory tract. Polymeric vehicles are being designed to provide sustained protection and prevention against cancers by kick-starting the immune system. Finally, work is under way to overcome barriers to efficient delivery of DNA, with the potential to provide cures for genetic disorders such as cystic fibrosis and X-Linked Severe Combined Immunodeficiency (X-SCID). This work brings together collaborators from the Carver College of Medicine, the Colleges of Dentistry and Pharmacy, and the Departments of Chemistry and Biomedical Engineering.

In the biomaterials realm, new materials are being developed that can interact with the human body to perform certain functions while maintaining compatibility. A project with the Department of Ophthalmology and Visual Sciences involves development of biodegradable stent materials to alleviate a serious eye disease induced by a blood clot in the central retinal vein. Research with the Department of Otolaryngology—Head and Neck Surgery is exploring the development of photo-patterned surfaces for directed growth of cells to improve cochlear implants. Current research in the tissue engineering field applies microfabrication techniques to develop scaffolds that are biodegradable and biocompatible with cell-interactive properties, and that directly incorporate controlled-release functionality within the scaffold.

The department also conducts research that is focused on self-assembling systems, rational design of novel drug and gene delivery systems, and development of sophisticated scaffolds for tissue-specific regeneration. In tissue engineering, microfabrication techniques are applied to novel biomaterials to provide spatial control over tissue formation and to integrate minimally invasive scaffold delivery strategies. In drug and gene delivery, researchers are exploring the synergistic application of degradable particle technology, CpG oligonucleotides, and heat-shock protein
therapy for generating sustained, stronger immune responses against carcinomas.

Students involved in animal research have access to the University’s Office of Animal Resources, which is adjacent to University of Iowa Hospitals and Clinics.

**Energy and Environment**

Chemical engineers are well-suited to make major contributions toward meeting challenges for the environment, energy, and sustainable development. The Department of Chemical and Biochemical Engineering has an active research program in the environmental areas of air pollution, biofuels, atmospheric chemistry, atmospheric CO2 fluxes, environmental change, bioremediation, and the design of new environmentally compatible technologies. Particular emphasis is placed on the chemistry and physics of local, regional, and global air-pollution problems. Research in support of this activity includes high-speed computing and detailed sensitivity analysis.

This work involves three centers and institutes on campus. The Center for Global and Regional Environmental Research brings together University scientists and scholars from more than 20 disciplines, including chemistry, civil and environmental engineering, geography, geology, law, and medicine. The center’s chief area of concern is environmental change. Chemical and biochemical engineering researchers interact with scientists at IIHR—Hydroscience & Engineering, a research institute focusing on applied fluid mechanics; their collaborations involve environmental fluid mechanics and air pollution field studies. The Nanoscience and Nanotechnology Institute provides an interdisciplinary home for chemical and biochemical researchers working on the development, application, and environmental and health effects of nanomaterials.

**Photopolymerization**

Photopolymerizations are chain reactions in which a liquid monomer is converted to a solid, durable polymer in a process triggered by light of the appropriate wavelength. The use of light, rather than heat, to drive a polymerization reaction offers advantages in developing new processes or products. Photopolymerizations provide both spatial control and temporal control of reactions, since light can be directed to locations of interest in the system and is easily shuttered on or off. Photopolymerizations also provide solvent-free formulations, which reduce the emissions of volatile organic pollutants, and they exhibit extremely rapid reaction rates. These advantages have led to tremendous growth in the application of photopolymerizations in the private sector, but much of this growth has occurred without a fundamental understanding of the underlying chemical processes.

The department’s research in this area focuses on comprehensive characterization of the kinetics, mechanisms, structure, and properties of photopolymerizations. Work includes the following types of studies: characterization of the photochemical processes by which polymerizations may be initiated; kinetic characterization of cationic photopolymerization; development of methods for photopolymerization of thick polymers and composites; development of photopolymerization systems based upon agricultural feedstocks; new methods for monitoring high-speed photopolymerization reactions; nanostructured materials through photopolymerization; biomedical devices formed by photopolymerization; and influence of order on photopolymerization reactions.

Chemical and biochemical engineering researchers are members of the Photopolymerization Center, an industry/university cooperative center on fundamentals and applications of photopolymerization. The center brings together experts from the University of Iowa, the University of Colorado, and member companies such as 3M, DSM, and Boeing. In addition, interdisciplinary collaborations are fostered on campus through the Optical Science and Technology Center, which oversees a seminar series, an annual symposium, training at the Microfabrication Facility, and equipment use in shared facilities.

**Requirements**

The Master of Science program in chemical and biochemical engineering requires a minimum of 30 s.h. of graduate credit, with or without thesis. Students must earn at least 24 s.h. in approved graduate-level course work; courses numbered below 3000 do not count toward this requirement. Thesis students earn 6 s.h. in CBE:5999 M.S. Thesis Research: Chemical and Biochemical Engineering. Nonthesis students earn 6 s.h. in additional approved course work. Students must maintain a cumulative g.p.a. of at least 3.00.

Students who receive assistantships, fellowships, or other awarded financial support are expected to pursue an advanced degree with thesis; they may not elect the nonthesis option.

All students select one course in each of the four core chemical engineering branches below; they must earn a cumulative g.p.a. higher than 3.25 in those four courses.

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<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Hours</th>
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<tr>
<td>CBE:5115</td>
<td>Transport Phenomena I</td>
<td>3</td>
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<tr>
<td>BME:5430</td>
<td>Biotransport</td>
<td>3</td>
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<tr>
<td>ME:5143</td>
<td>Computational Fluid and Thermal Engineering</td>
<td>3</td>
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<tr>
<td>PHAR:7702</td>
<td>Transport Phenomena</td>
<td>3</td>
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<tr>
<td></td>
<td>Another course with consent of advisor</td>
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<tr>
<td>CBE:5110</td>
<td>Intermediate Thermodynamics</td>
<td>3</td>
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<td>Alternate courses approved on a case-by-case basis, and may include:</td>
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<td>A 5000-level thermal physics course</td>
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**Chemical Thermodynamics**

One of these plus corresponding undergraduate chemical reaction engineering:

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<tr>
<td>CBE:5205</td>
<td>Introduction to Biochemical Engineering</td>
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<tr>
<td>CBE:5315</td>
<td>Polymer Chemistry</td>
<td>3</td>
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<tr>
<td>CBE:5425</td>
<td>Atmospheric Chemistry and Physics</td>
<td>3</td>
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**Technical Communication**

One of these:

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<tr>
<td>CBE:5104</td>
<td>Introduction to Literature Review and Technical Writing</td>
<td>3</td>
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All M.S. thesis students are required to take ENGR:7270 Engineering Ethics (1 s.h.) during their first semester. Thesis students also must pass a final M.S. examination.

Students in the nonthesis program may petition for entry into the thesis program or the Ph.D. program by requesting a change of status through the Graduate College. The request is reviewed by the graduate admissions committee. If approved by the committee, it is forwarded to the chemical and biochemical engineering faculty for final approval. Students then are assigned to research advisors as though they were newly admitted graduate students. For a detailed description of program requirements, see Graduate Program on the Department of Chemical and Biochemical Engineering website.

**Admission**

Applicants must meet the admission requirements of the Graduate College; see the Manual of Rules and Regulations of the Graduate College.

Applicants must provide the following:

- Completed application form.
- Unofficial transcript(s). If admitted, official transcripts will be required before enrollment. For international students, all academic records should bear the original stamp or seal of the institution and the signature of a school official. Documents not in English must be accompanied by a complete, literal, English translation, certified by the issuing institution.
- Official Graduate Record Examination (GRE) General Test scores (verbal and quantitative) from Educational Testing Services. The University's institutional code is 6681.
- Statement of purpose.
- Three letters of recommendation.
- Test of English as a Foreign Language (TOEFL) scores for applicants whose native language is not English.

Applicants should have a B.S. degree in chemical engineering or a related discipline with satisfactory grades from a recognized college or university in the United States and a cumulative g.p.a. of at least 3.00 on a 4.00 scale. Graduates of non-U.S. universities may be accepted, depending on evaluation of their records. Applicants who do not meet these requirements may be granted conditional admission by the Graduate Admissions Committee.

Graduate courses in chemical and biochemical engineering are designed for students who have an undergraduate background in chemical engineering. Exceptional students from other areas also may apply for admission to the M.S. program in chemical and biochemical engineering. If admitted, they may be required to take specific undergraduate courses to prepare them for graduate course work.

**Financial Support**

A number of fellowships, assistantships, and scholarships are awarded on a competitive basis to graduate students who qualify.

Graduate students have the opportunity to receive interdisciplinary research training in several fellowship programs administered through the Center for Biocatalysis and Bioprocessing (CBB). The program provides research training in areas that combine basic and applied research. Through these programs, students interact with other students and faculty members from biochemistry, biology, chemistry, civil and environmental engineering, medicinal and natural products chemistry, and microbiology and immunology.

**Career Advancement**

Chemical and biochemical engineers work in a wide range of industries, including petroleum and specialty chemical production, polymer and plastic production, food processing, energy, microelectronics production, pharmaceutical production, biochemical processing, and environmental compliance. Potential jobs include production, process development, plant design and construction, and fundamental research. The engineering profession also is a foundation for a variety of careers in medicine, law, government, and consulting. Many experienced chemical and biochemical engineers move through management ranks to high-level administrative positions. On average, 93-98 percent of graduates are employed in their field of study or pursuing advanced education within seven months of graduation.

Engineering Professional Development (EPD) develops and promotes experiential education and professional opportunities for students in the College of Engineering. Professional staff coordinate the college's co-op and internship program, engage in employer outreach, and provide opportunities for students to network with employers, including an engineering career fair each semester and other programming related to career development.

EPD also offers individual advising and class presentations on résumé and cover letter preparation, job and internship search strategies, interviewing skills, and job offer evaluation.