BIOCHEMISTRY - BACHELOR OF ARTS (BA)

The biochemistry major provides interdisciplinary training, education and experience in the chemical and biological sciences. Biochemistry focuses on understanding the chemical processes of living organisms, the reaction pathways that sustain life, the principles of how structure defines function and the physical basis of biomolecular interactions. Students who major in biochemistry are prepared for diverse careers in medicine, scientific research, biotechnology, pharmacy, biomedical consulting, teaching and education, among other professions.

The undergraduate degree in biochemistry emphasizes knowledge and understanding of:

- Foundational principles of biology and chemistry.
- The building blocks of life (DNA, RNA and proteins), how they evolved, how they interact and how organisms make and degrade these building blocks.
- How living organisms maintain homeostasis and regulate metabolism.
- The molecular mechanisms of how living systems respond to changes, such as environmental perturbations, disease and chemical therapeutics.
- How chemical reactions impact human health.

The undergraduate degree in biochemistry also emphasizes and cultivates development of the following skills:

- Quantitative problem solving.
- Critical thinking and analytical reasoning.
- Communication of scientific concepts and ideas.

Because biochemistry connects to scientific disciplines ranging from genetics, human physiology, microbiology, neuroscience, cell biology, chemistry and geology, biochemistry majors are given the freedom to explore advanced electives in many of these subjects. Additional information about the biochemistry BA can be found on the Biochemistry Department website (https://www.colorado.edu/biochemistry/).

Biochemistry major students are prepared for many different careers after graduation. Career Services (http://www.colorado.edu/careerservices/) offers a number of programs and services designed to help students plan their career, including workshops, internships and placement services after graduation. For an appointment with a career counselor or for more information, call 303-492-6541 or stop by Center for Community, N352.

Undergraduate Research

Undergraduates are encouraged to participate in research to prepare themselves for graduate school, professional school or industry. There are multiple opportunities for undergraduates to be involved in research within the Department of Biochemistry. For more information, visit our Departmental Undergraduate research page (https://www.colorado.edu/biochemistry/current-students/undergraduate/undergraduate-research/).

Study Abroad

The experience of studying abroad can prove invaluable. For information about study abroad programs, visit the Education Abroad (https://abroad.colorado.edu/) website.

Teaching Certification

Biochemistry majors can also earn certification as teachers through the School of Education. The program for a secondary school science-teaching certificate is challenging requiring a broad, strong background in science, as well as coursework in education and practice teaching. It usually requires at least five years of study. Students interested in teacher certification are encouraged to contact the School of Education (http://www.colorado.edu/education/).

Requirements

Program Requirements

The biochemistry major provides interdisciplinary training in the biological and chemical sciences, including courses in general chemistry, organic chemistry, physical chemistry and biochemistry, as well as in biology, calculus and physics.

Students must complete the general requirements of the College of Arts and Sciences and the required courses listed below. No more than 45 credits of CHEM and BCHM courses can be applied to the 120-credit minimum to graduate. All courses counted towards the major must be completed with a grade of C- or better and none of the courses may be taken for a pass/fail grade. The cumulative GPA in courses that can count toward the major must be at least 2.0.

Transfer students who plan to complete a BA degree in biochemistry must complete at the Boulder campus a minimum of 12 credits of upper-division courses in biochemistry covering at least two of the sub-disciplines in their major: organic, physical and biochemistry.

Students may want to consult each semester’s Registration Handbook and Schedule of Courses (http://www.colorado.edu/registrar/), as well as the Professor Performance Guide (http://www.colorado.edu/pba/fcq/) for further information about course offerings and faculty.

Required Courses and Credits

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 1400 &amp; CHEM 1401</td>
<td>Foundations of Chemistry and Foundations of Chemistry Lab (Recommended)</td>
<td>5</td>
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<tr>
<td>or CHEM 1113 &amp; CHEM 1114</td>
<td>General Chemistry 1 and Laboratory in General Chemistry 1</td>
<td>1</td>
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<tr>
<td>&amp; CHEM 1133 &amp; CHEM 1134</td>
<td>General Chemistry 2 and Laboratory in General Chemistry 2</td>
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<tr>
<td>CHEM 3451</td>
<td>Organic Chemistry 1 for Chemistry and Biochemistry Majors (Recommended)</td>
<td>4</td>
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<tr>
<td>or CHEM 3311</td>
<td>Organic Chemistry 1</td>
<td>1</td>
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<tr>
<td>CHEM 3321</td>
<td>Laboratory in Organic Chemistry 1</td>
<td>1</td>
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<tr>
<td>BCHM 3491</td>
<td>Organic Chemistry 2 for Biochemistry Majors (Recommended)</td>
<td>4</td>
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<tr>
<td>or CHEM 3471 &amp; CHEM 3331</td>
<td>Organic Chemistry 2 for Chemistry Majors</td>
<td>2</td>
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</tbody>
</table>
### Biochemistry - Bachelor of Arts (BA)

**CHEM 3341**  
Laboratory in Organic Chemistry 2  
1-2  
*or CHEM 3381*  
Laboratory in Advanced Organic Chemistry  

**Biochemistry**  

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>BCHM 2700</td>
<td>Foundations of Biochemistry</td>
<td>4</td>
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<td>BCHM 4720</td>
<td>Metabolic Pathways and Human Disease</td>
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<tr>
<td>BCHM 4740</td>
<td>Biochemistry of Gene Transmission, Expression and Regulation 1</td>
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<td>BCHM 4761</td>
<td>Biochemistry Laboratory</td>
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**Physical Chemistry**  

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<tr>
<td>BCHM 4400</td>
<td>Core Concepts in Physical Chemistry for Biochemists 2</td>
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**Advanced Major Electives**  

Select three of the following elective courses:  
9-12

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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<tbody>
<tr>
<td>BCHM 3100 &amp; 3110</td>
<td>Engineering RNA Aptamers and Literature-based Co-seminar for BCHM 3100 CURE Laboratory Course</td>
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<tr>
<td>BCHM 3400</td>
<td>Mechanisms of Cancer</td>
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<tr>
<td>BCHM 3450</td>
<td>Principles of Pharmacology and Toxicology</td>
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<tr>
<td>BCHM 4491</td>
<td>Modern Biophysical Methods</td>
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<tr>
<td>BCHM 4631</td>
<td>Computational Genomics Lab</td>
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<tr>
<td>BCHM 4751</td>
<td>Current Topics in Biochemical Research</td>
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<tr>
<td>BCHM 4850</td>
<td>Therapeutic and Diagnostic Nucleic Acids</td>
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<tr>
<td>BCHM 5341</td>
<td>Chemical Biology and Drug Design</td>
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<tr>
<td>APPM 3310</td>
<td>Matrix Methods and Applications</td>
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<tr>
<td>APPM 3570</td>
<td>Applied Probability</td>
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<tr>
<td>APPM 4360</td>
<td>Methods in Applied Mathematics: Complex Variables and Applications</td>
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<td>ATOC 4200</td>
<td>Biogeochemical Oceanography</td>
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<td>CHEM 4011</td>
<td>Modern Inorganic Chemistry</td>
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<td>CHEM 4171</td>
<td>Instrumental Analysis - Lecture and Laboratory 1</td>
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<tr>
<td>CHEM 4181</td>
<td>Instrumental Analysis - Lecture and Laboratory 2</td>
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<tr>
<td>CHEN 3010</td>
<td>Applied Data Analysis</td>
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<tr>
<td>CHEN 3200</td>
<td>Chemical Engineering Fluid Mechanics</td>
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<tr>
<td>CHEN 3210</td>
<td>Chemical Engineering Heat and Mass Transfer</td>
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<tr>
<td>MCDB 2150</td>
<td>Principles of Genetics (cannot also count EBIO 2070 as a required ancillary course or an advanced elective)</td>
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<tr>
<td>MCDB 3000</td>
<td>Synthetic Biology: Engineering Biomolecular Systems in the Laboratory</td>
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<tr>
<td>MCDB 3145</td>
<td>Cell Biology</td>
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<tr>
<td>MCDB 3150</td>
<td>Biology of the Cancer Cell</td>
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<tr>
<td>MCDB 3160</td>
<td>Infectious Disease</td>
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</tr>
<tr>
<td>MCDB 3350</td>
<td>Fertility, Sterility, and Early Mammalian Development</td>
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<tr>
<td>MCDB 3450</td>
<td>Biological Data Science</td>
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<tr>
<td>MCDB 3501</td>
<td>Structural Methods for Biological Macromolecules</td>
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<tr>
<td>MCDB 3650</td>
<td>The Brain - From Molecules to Behavior</td>
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<tr>
<td>MCDB 3990</td>
<td>Introduction to Systems Biology for Biologists</td>
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<tr>
<td>MCDB 4300</td>
<td>Immunology (cannot also count IPHY 4600 as a required Advanced Major Elective)</td>
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<tr>
<td>MCDB 4310</td>
<td>Microbial Genetics and Physiology</td>
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<tr>
<td>MCDB 4350</td>
<td>Microbial Diversity and the Biosphere</td>
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<tr>
<td>MCDB 4410</td>
<td>Human Molecular Genetics</td>
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<tr>
<td>MCDB 4426</td>
<td>Cell Signaling and Developmental Regulation</td>
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<tr>
<td>MCDB 4444</td>
<td>Cellular Basis of Disease</td>
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<tr>
<td>MCDB 4471</td>
<td>Mechanisms of Gene Regulation in Eukaryotes</td>
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<tr>
<td>MCDB 4520</td>
<td>Bioinformatics and Genomics</td>
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<tr>
<td>MCDB 4615</td>
<td>Biology of Stem Cells</td>
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<tr>
<td>MCDB 4750</td>
<td>Animal Virology</td>
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<tr>
<td>MCDB 4790</td>
<td>Oocytes, Stem Cells, Organisms: Experiments to Discoveries</td>
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<tr>
<td>EBIO 2070</td>
<td>Genetics: Molecules to Populations (cannot also count MCDB 2150 as a required ancillary course or an advanced elective)</td>
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<tr>
<td>EBIO 3040</td>
<td>Conservation Biology</td>
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<tr>
<td>EBIO 3080</td>
<td>Evolutionary Biology</td>
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<tr>
<td>EBIO 3180</td>
<td>Global Ecology</td>
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<tr>
<td>EBIO 3190</td>
<td>Tropical Marine Ecology</td>
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<td>EBIO 3240</td>
<td>Animal Behavior</td>
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<tr>
<td>EBIO 3400</td>
<td>Microbiology</td>
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<tr>
<td>EBIO 3523</td>
<td>The Art and Strategy of Science Communication: Branding Climate Change</td>
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<tr>
<td>EBIO 3590</td>
<td>Plants and Society</td>
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<tr>
<td>EBIO 3630</td>
<td>Parasitology</td>
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<tr>
<td>EBIO 3850</td>
<td>Animal Diversity: Invertebrates</td>
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<tr>
<td>EBIO 4030</td>
<td>Limnology</td>
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<tr>
<td>EBIO 4060</td>
<td>Landscape Ecology</td>
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<tr>
<td>EBIO 4080</td>
<td>Freshwater Phyiology</td>
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<tr>
<td>EBIO 4140</td>
<td>Plant Ecology</td>
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<tr>
<td>EBIO 4155</td>
<td>Ecosystem Ecology</td>
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<tr>
<td>EBIO 4290</td>
<td>Phylogenetics and Comparative Biology</td>
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<tr>
<td>EBIO 4410</td>
<td>Biological Statistics</td>
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<tr>
<td>EBIO 4420</td>
<td>Computational Biology</td>
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<tr>
<td>EBIO 4440</td>
<td>Animal Developmental Diversity</td>
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<tr>
<td>EBIO 4500</td>
<td>Plant Biodiversity and Evolution</td>
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<tr>
<td>EBIO 4510</td>
<td>Plant Anatomy and Development</td>
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<tr>
<td>EBIO 4800</td>
<td>Critical Thinking in Biology</td>
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<tr>
<td>IPHY 3410</td>
<td>Human Anatomy</td>
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<tr>
<td>IPHY 3430</td>
<td>Human Physiology</td>
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<tr>
<td>IPHY 3490</td>
<td>Introduction to Epidemiology</td>
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<tr>
<td>IPHY 4440</td>
<td>Endocrinology</td>
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<td>IPHY 4470</td>
<td>Biology of Human Reproduction</td>
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<td>IPHY 4600</td>
<td>Immunology (cannot also count MCDB 4300 as a required Advanced Major Elective)</td>
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<tr>
<td>IPHY 4720</td>
<td>Neurophysiology</td>
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<tr>
<td>MATH 4520</td>
<td>Introduction to Mathematical Statistics</td>
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<tr>
<td>MCDB 4202</td>
<td>The Python Project</td>
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<tr>
<td>MCDB 4650</td>
<td>Developmental Biology</td>
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<tr>
<td>MCDB 4777</td>
<td>Molecular Neurobiology</td>
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<tr>
<td>NRSC 2100</td>
<td>Introduction to Neuroscience</td>
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<td>NRSC 4032</td>
<td>Neurobiology of Learning and Memory</td>
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<td>NRSC 4082</td>
<td>Neural Circuits of Learning and Decision Making</td>
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<td>NRSC 4092</td>
<td>Behavioral Neuroendocrinology</td>
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<td>NRSC 4132</td>
<td>Neuropharmacology</td>
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<tr>
<td>NRSC 4545</td>
<td>Neurobiology of Addiction</td>
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<tr>
<td>PSYC 3102</td>
<td>Behavioral Genetics</td>
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<tr>
<td>GEOL 3320</td>
<td>Introduction to Geochemistry</td>
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<td>GEOL 4160</td>
<td>Introduction to Biogeochemistry</td>
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<tr>
<td>GEOL 4270</td>
<td>Marine Chemistry and Geochemistry</td>
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<td>GEOL 4330</td>
<td>Cosmochemistry</td>
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<tr>
<td>GEOL 4670</td>
<td>Isotope Geology</td>
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<tr>
<td>GEOL 4675</td>
<td>Stable isotopes in Paleoclimate and Paleoeoclogy</td>
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<tr>
<td>PHIL 3140</td>
<td>Environmental Ethics (cannot also count PHIL 3160 as a required Advanced Major Elective)</td>
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<tr>
<td>PHIL 3160</td>
<td>Bioethics (cannot also count PHIL 3140 as a required Advanced Major Elective)</td>
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<table>
<thead>
<tr>
<th>Required Ancillary Coursework from Outside Biochemistry</th>
<th>Credit Hours</th>
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<tbody>
<tr>
<td><strong>Physics</strong></td>
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</tr>
<tr>
<td>PHYS 1110 General Physics 1</td>
<td>4</td>
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<tr>
<td>PHYS 1120 General Physics 2</td>
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<tr>
<td>PHYS 1140 Experimental Physics 1</td>
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<tr>
<td><strong>Calculus</strong></td>
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<tr>
<td>MATH 1300 Calculus 1</td>
<td>4-5</td>
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<tr>
<td>or MATH 1310 Calculus for Life Sciences</td>
<td></td>
</tr>
<tr>
<td>or APPM 1350 Calculus 1 for Engineers</td>
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</tr>
<tr>
<td>MATH 2300 Calculus 2</td>
<td>4-5</td>
</tr>
<tr>
<td>or APPM 1360 Calculus 2 for Engineers</td>
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<tr>
<td><strong>Biology Sequence with Labs</strong></td>
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<tr>
<td>Lectures (One of the following sequences)</td>
<td>6</td>
</tr>
<tr>
<td>MCDB 1150 &amp; MCDB 2150 Introduction to Cellular and Molecular Biology and Principles of Genetics</td>
<td></td>
</tr>
<tr>
<td>MCDB 1111 &amp; MCDB 2222 Core Concepts in Biology I: Evolutionary, Molecular and Cell Biology and Core Concepts in Biology II: Genes, Genetics and Phenotypes</td>
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</tr>
<tr>
<td>EBIOS 1210 &amp; EBIOS 1220 General Biology 1 and General Biology 2</td>
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<tr>
<td>Labs (One of the following sequences)</td>
<td>2</td>
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<tr>
<td>MCDB 1161 From Dirt to DNA: Phage Genomics Laboratory I</td>
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<tr>
<td>or MCDB 1171 Antibiotics Discovery Through Hands-on Screens I</td>
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</tr>
<tr>
<td>or MCDB 2171 Chemotherapeutic Discovery Through Hands-On Screens 2</td>
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| EBIOS 1230 General Biology Laboratory 1 and EBIOS 1240 General Biology Laboratory 2 |              |
|**Total Credit Hours**|**25-27**|

1. BCHM 4740 can be waived upon completion of the MCDB major.
2. Or CHEM 4511 and CHEM 4531

All students, and especially those intending to go onto graduate school in biochemistry, will benefit from additional advanced courses. Recommended electives include graduate courses in various fields of chemistry, or advanced courses in biology or mathematics.

**Graduating in Four Years**

Consult the Four-Year Guarantee Requirements for information on eligibility. The concept of "adequate progress" as it is used here only refers to maintaining eligibility for the four-year guarantee; it is not a requirement for the major. To maintain progress in biochemistry, students should declare the biochemistry major in the first semester.

Students must consult with a major advisor to determine adequate progress toward completion of the major.

**Recommended Four-Year Plan of Study**

Through the required coursework for the major, students will fulfill all 12 credits of the Natural Sciences area of the Gen Ed Distribution Requirement, including the required laboratory or field experience, and the QRMS component of the Gen Ed Skills Requirement.

**Year One**

<table>
<thead>
<tr>
<th>Fall Semester</th>
<th>Credit Hours</th>
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<tbody>
<tr>
<td>CHEM 1400 Foundations of Chemistry</td>
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<tr>
<td>CHEM 1401 Foundations of Chemistry Lab</td>
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<tr>
<td>MATH 1300 Calculus 1</td>
<td>4-5</td>
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<tr>
<td>or MATH 1310 Calculus for Life Sciences</td>
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</tr>
<tr>
<td>or APPM 1350 Calculus 1 for Engineers</td>
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<tr>
<td>Gen. Ed. Distribution course (example: Social Sciences)</td>
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<tr>
<td>Gen. Ed. Skills course (example: Lower-division Written Communication)</td>
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</tr>
<tr>
<td><strong>Credit Hours</strong></td>
<td><strong>15-16</strong></td>
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<thead>
<tr>
<th>Spring Semester</th>
<th>Credit Hours</th>
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<tbody>
<tr>
<td>CHEM 3451 Organic Chemistry 1 for Chemistry and Biochemistry Majors</td>
<td>4</td>
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<tr>
<td>CHEM 3321 Laboratory in Organic Chemistry 1</td>
<td>1</td>
</tr>
<tr>
<td>MATH 2300 Calculus 2</td>
<td>4-5</td>
</tr>
<tr>
<td>or APPM 1360 Calculus 2 for Engineers</td>
<td></td>
</tr>
<tr>
<td>Gen. Ed. Distribution/Diversity course (example: Arts &amp; Humanities/US Perspective)</td>
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</tr>
<tr>
<td>Gen. Ed. Distribution/Diversity course (example: Social Sciences/Global Perspective)</td>
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<tr>
<td><strong>Credit Hours</strong></td>
<td><strong>15-16</strong></td>
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**Year Two**

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>BCHM 3491 Organic Chemistry 2 for Biochemistry Majors</td>
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<tr>
<td>CHEM 3341 Laboratory in Organic Chemistry 2</td>
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<tr>
<td>BCHM 4720</td>
<td>Metabolic Pathways and Human Disease</td>
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<tr>
<td>PHYS 1110</td>
<td>General Physics 1</td>
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<td><strong>Total Credit Hours</strong></td>
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### Spring Semester

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<th>Course Title</th>
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<tbody>
<tr>
<td>BCHM 4740</td>
<td>Biochemistry of Gene Transmission, Expression and Regulation</td>
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<tr>
<td>PHYS 1120</td>
<td>General Physics 2</td>
<td>4</td>
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<td>PHYS 1140</td>
<td>Experimental Physics 1</td>
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### Year Four

#### Fall Semester

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<td>BCHM 4400</td>
<td>Core Concepts in Physical Chemistry for Biochemists</td>
<td>4</td>
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<tr>
<td>Advanced Major Elective</td>
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#### Spring Semester

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<td>BCHM 4761</td>
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<td><strong>Total Credit Hours</strong></td>
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### Learning Outcomes

Upon completing the program, students will be able to:

- Master the foundational concepts of general and organic chemistry, including equilibrium, kinetics, bonding (covalent and non-covalent) and reactivity and apply these concepts to biological systems.
- Explain how biomolecules (DNA, RNA, proteins, lipids, carbohydrates and metabolites) are synthesized and control biological processes.
- Identify the factors that determine the three-dimensional structures of biological macromolecules (DNA, RNA, proteins), and membranes (including organelles) and explain how structure relates to function.
- Describe how cells sense their environment and use this information to regulate cellular functions such as DNA replication, gene expression, signal transduction, cell division and cell death.
- Develop a conceptual, mechanistic and mathematical understanding of biomolecular interactions, including binding and catalysis.
- Explain how energy is stored, transformed and harnessed in biological systems.
- Analyze data, interpret graphs, solve quantitative problems to interpret results of scientific studies. Evaluate the rigor and reproducibility of scientific results.
- Learn and apply the rigorous scientific methods on which (bio)chemical knowledge is built: making observations, formulating hypotheses, executing experiments, evaluating rigor and reproducibility.
- Effectively communicate scientific information in oral, written and visual formats to specialized and general audiences.