

# 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

Code	Title	Credit Hours
<b>General Chemistry</b>		
CHEM 1400 & CHEM 1401	Foundations of Chemistry and Foundations of Chemistry Lab (Recommended)	5
or CHEM 1113 & CHEM 1114 & CHEM 1133 & CHEM 1134	General Chemistry 1 and Laboratory in General Chemistry 1 and General Chemistry 2 and Laboratory in General Chemistry 2	
<b>Organic Chemistry</b>		
CHEM 3451	Organic Chemistry 1 for Chemistry and Biochemistry Majors (Recommended)	4
or CHEM 3311	Organic Chemistry 1	
CHEM 3321	Laboratory in Organic Chemistry 1	1
BCHM 3491	Organic Chemistry 2 for Biochemistry Majors (Recommended)	4
or CHEM 3471	Organic Chemistry 2 for Chemistry Majors	
or CHEM 3331	Organic Chemistry 2	

CHEM 3341 or CHEM 3381	Laboratory in Organic Chemistry 2 Laboratory in Advanced Organic Chemistry	1-2	MCDB 4300	Immunology (cannot also count IPHY 4600 as a required Advanced Major Elective)
<b>Biochemistry</b>			MCDB 4310	Microbial Genetics and Physiology
BCHM 2700	Foundations of Biochemistry	4	MCDB 4350	Microbial Diversity and the Biosphere
BCHM 4720	Metabolic Pathways and Human Disease	4	MCDB 4410	Human Molecular Genetics
BCHM 4740	Biochemistry of Gene Transmission, Expression and Regulation <sup>1</sup>	4	MCDB 4426	Cell Signaling and Developmental Regulation
BCHM 4761	Biochemistry Laboratory	3	MCDB 4444	Cellular Basis of Disease
<b>Physical Chemistry</b>			MCDB 4471	Mechanisms of Gene Regulation in Eukaryotes
BCHM 4400	Core Concepts in Physical Chemistry for Biochemists <sup>2</sup>	4	MCDB 4520	Bioinformatics and Genomics
<b>Advanced Major Electives</b>			MCDB 4615	Biology of Stem Cells
Select three of the following elective courses:		9-12	MCDB 4750	Animal Virology
BCHM 3100 & BCHM 3110	Engineering RNA Aptamers and Literature-based Co-seminar for BCHM 3100 CURE Laboratory Course		MCDB 4790	Oocytes, Stem Cells, Organisms: Experiments to Discoveries
BCHM 3400	Mechanisms of Cancer		EBIO 2070	Genetics: Molecules to Populations (cannot also count MCDB 2150 as a required ancillary course or an advanced elective)
BCHM 3450	Principles of Pharmacology and Toxicology		EBIO 3040	Conservation Biology
BCHM 4491	Modern Biophysical Methods		EBIO 3080	Evolutionary Biology
BCHM 4631	Computational Genomics Lab		EBIO 3180	Global Ecology
BCHM 4751	Current Topics in Biochemical Research		EBIO 3190	Tropical Marine Ecology
BCHM 4850	Therapeutic and Diagnostic Nucleic Acids		EBIO 3240	Animal Behavior
BCHM 5341	Chemical Biology and Drug Design		EBIO 3400	Microbiology
APPM 3310	Matrix Methods and Applications		EBIO 3523	The Art and Strategy of Science Communication: Branding Climate Change
APPM 3570	Applied Probability		EBIO 3590	Plants and Society
APPM 4360	Methods in Applied Mathematics: Complex Variables and Applications		EBIO 3630	Parasitology
ATOC 4200	Biogeochemical Oceanography		EBIO 3850	Animal Diversity: Invertebrates
CHEM 4011	Modern Inorganic Chemistry		EBIO 4030	Limnology
CHEM 4171	Instrumental Analysis - Lecture and Laboratory 1		EBIO 4060	Landscape Ecology
CHEM 4181	Instrumental Analysis - Lecture and Laboratory 2		EBIO 4080	Freshwater Phycology
CHEN 3010	Applied Data Analysis		EBIO 4140	Plant Ecology
CHEN 3200	Chemical Engineering Fluid Mechanics		EBIO 4155	Ecosystem Ecology
CHEN 3210	Chemical Engineering Heat and Mass Transfer		EBIO 4290	Phylogenetics and Comparative Biology
MCDB 2150	Principles of Genetics (cannot also count EBIO 2070 as a required ancillary course or an advanced elective)		EBIO 4410	Biological Statistics
MCDB 3000	Synthetic Biology: Engineering Biomolecular Systems in the Laboratory		EBIO 4420	Computational Biology
MCDB 3145	Cell Biology		EBIO 4440	Animal Developmental Diversity
MCDB 3150	Biology of the Cancer Cell		EBIO 4500	Plant Biodiversity and Evolution
MCDB 3160	Infectious Disease		EBIO 4510	Plant Anatomy and Development
MCDB 3350	Fertility, Sterility, and Early Mammalian Development		EBIO 4800	Critical Thinking in Biology
MCDB 3450	Biological Data Science		IPHY 3410	Human Anatomy
MCDB 3501	Structural Methods for Biological Macromolecules		IPHY 3430	Human Physiology
MCDB 3650	The Brain - From Molecules to Behavior		IPHY 3490	Introduction to Epidemiology
MCDB 3990	Introduction to Systems Biology for Biologists		IPHY 4440	Endocrinology
			IPHY 4470	Biology of Human Reproduction
			IPHY 4600	Immunology (cannot also count MCDB 4300 as a required Advanced Major Elective)
			IPHY 4720	Neurophysiology
			MATH 4520	Introduction to Mathematical Statistics

MCDB 4202	The Python Project
MCDB 4650	Developmental Biology
MCDB 4777	Molecular Neurobiology
NRSC 2100	Introduction to Neuroscience
NRSC 4032	Neurobiology of Learning and Memory
NRSC 4082	Neural Circuits of Learning and Decision Making
NRSC 4092	Behavioral Neuroendocrinology
NRSC 4132	Neuropharmacology
NRSC 4545	Neurobiology of Addiction
PSYC 3102	Behavioral Genetics
GEOL 3320	Introduction to Geochemistry
GEOL 4160	Introduction to Biogeochemistry
GEOL 4270	Marine Chemistry and Geochemistry
GEOL 4330	Cosmochemistry
GEOL 4670	Isotope Geology
GEOL 4675	Stable Isotopes in Paleoclimate and Paleocology
PHIL 3140	Environmental Ethics (cannot also count PHIL 3160 as a required Advanced Major Elective)
PHIL 3160	Bioethics (cannot also count PHIL 3140 as a required Advanced Major Elective)

**Total Credit Hours** **43-47**

#### Required Ancillary Coursework from Outside Biochemistry

Code	Title	Credit Hours
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##### Physics

PHYS 1110	General Physics 1	4
PHYS 1120	General Physics 2	4
PHYS 1140	Experimental Physics 1	1

##### Calculus

MATH 1300	Calculus 1	4-5
or MATH 1310	Calculus for Life Sciences	
or APPM 1350	Calculus 1 for Engineers	
MATH 2300	Calculus 2	4-5
or APPM 1360	Calculus 2 for Engineers	

##### Biology Sequence with Labs

Lectures (One of the following sequences) 6

MCDB 1150 & MCDB 2150	Introduction to Cellular and Molecular Biology and Principles of Genetics
MCDB 1111 & MCDB 2222	Core Concepts in Biology I: Evolutionary, Molecular and Cell Biology and Core Concepts in Biology II: Genes, Genetics and Phenotypes
EBIO 1210 & EBIO 1220	General Biology 1 and General Biology 2

Labs (One of the following sequences) 2

MCDB 1161	From Dirt to DNA: Phage Genomics Laboratory I
or MCDB 1171	Antibiotics Discovery Through Hands-on Screens I
or MCDB 2171	Chemotherapeutic Discovery Through Hands-On Screens 2

EBIO 1230 & EBIO 1240	General Biology Laboratory 1 and General Biology Laboratory 2
<b>Total Credit Hours</b>	<b>25-27</b>

- <sup>1</sup> BCHM 4740 can be waived upon completion of the MCDB major.
- <sup>2</sup> 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

Fall Semester		Credit Hours
CHEM 1400	Foundations of Chemistry	4
CHEM 1401	Foundations of Chemistry Lab	1
MATH 1300	Calculus 1	4-5
or MATH 1310	or Calculus for Life Sciences	
or APPM 1350	or Calculus 1 for Engineers	
Gen. Ed. Distribution course (example: Social Sciences)		3
Gen. Ed. Skills course (example: Lower-division Written Communication)		3
<b>Credit Hours</b>		<b>15-16</b>

### Spring Semester

CHEM 3451	Organic Chemistry 1 for Chemistry and Biochemistry Majors	4
CHEM 3321	Laboratory in Organic Chemistry 1	1
MATH 2300	Calculus 2	4-5
or APPM 1360	or Calculus 2 for Engineers	
Gen. Ed. Distribution/Diversity course (example: Arts & Humanities/US Perspective)		3
Gen. Ed. Distribution/Diversity course (example: Social Sciences/Global Perspective)		3
<b>Credit Hours</b>		<b>15-16</b>

### Year Two

Fall Semester		Credit Hours
BCHM 3491	Organic Chemistry 2 for Biochemistry Majors	4
CHEM 3341	Laboratory in Organic Chemistry 2	1

MCDB 1150 or MCDB 1111 or EBIO 1210	Introduction to Cellular and Molecular Biology or Core Concepts in Biology I: Evolutionary, Molecular and Cell Biology or General Biology 1	3
MCDB 1161 or MCDB 1171 or EBIO 1230	From Dirt to DNA: Phage Genomics Laboratory I or Antibiotics Discovery Through Hands-on Screens I or General Biology Laboratory 1	2
Gen. Ed. Distribution course (example: Social Sciences)		3
Gen. Ed. Distribution course (example: Arts & Humanities)		3

**Credit Hours 16**

#### Spring Semester

BCHM 2700	Foundations of Biochemistry	4
MCDB 2150 or MCDB 2222 or EBIO 1220	Principles of Genetics or Core Concepts in Biology II: Genes, Genetics and Phenotypes or General Biology 2	3
MCDB 1171 or MCDB 2171 or EBIO 1240	Antibiotics Discovery Through Hands-on Screens I or Chemotherapeutic Discovery Through Hands-On Screens 2 or General Biology Laboratory 2	2
Gen. Ed. Distribution course (example: Social Sciences)		3
Elective		3

**Credit Hours 15**

#### Year Three

##### Fall Semester

BCHM 4720	Metabolic Pathways and Human Disease	4
PHYS 1110	General Physics 1	4
Gen. Ed. Distribution course (example: Social Sciences)		3
Elective		3

**Credit Hours 14**

##### Spring Semester

BCHM 4740	Biochemistry of Gene Transmission, Expression and Regulation	4
PHYS 1120	General Physics 2	4
PHYS 1140	Experimental Physics 1	1
Gen. Ed. Skills course (example: Upper-division Written Communication)		3
Elective		3

**Credit Hours 15**

#### Year Four

##### Fall Semester

BCHM 4400	Core Concepts in Physical Chemistry for Biochemists	4
Advanced Major Elective		3
Advanced Major Elective		3
Gen. Ed. Distribution (example: Arts & Humanities)		3
Elective		3

**Credit Hours 16**

##### Spring Semester

BCHM 4761	Biochemistry Laboratory	3
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Advanced Major Elective	3
Gen. Ed. Distribution course (example: Arts & Humanities)	3
Elective	3
Elective	3
<b>Credit Hours</b>	<b>15</b>
<b>Total Credit Hours</b>	<b>121-123</b>

## 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.