Department of

Biochemistry

Courses of Study:
Major (BA/BS)
Combined BS/MS
Master of Science
Doctor of Philosophy

Objectives

Undergraduate Major
The biochemistry major is designed to equip students with a broad understanding of the chemical and molecular events involved in biological processes. The biochemistry major provides a foundation for careers in medicine, biotechnology, or research in all branches of the biological sciences.

The general aim of the major is to ensure that the students first learn the necessary chemical and physical chemical background and then the basic principles and observations of biochemistry and molecular biology. The department also offers a variety of introductory and advanced courses in more specialized subjects such as neurobiology, X-ray crystallography, and physical biochemistry. These courses sample the range of subjects that can be studied by biochemical methods and from a biochemical point of view.

Graduate Program in Biochemistry
The Graduate Program in Biochemistry leading to the degree of Doctor of Philosophy is designed to provide students with a deep understanding of the chemical principles governing the workings of biological macromolecules. The bioorganic chemistry specialization of this program gives students the option of training in organic chemistry in addition to biochemistry. The emphasis in the graduate program is placed upon experimental research work to train students to carry out independent original research. Students are required, however, to complete formal course work in advanced biochemistry and physical biochemistry. Students in the bioorganic chemistry specialization supplement this core curriculum with courses in organic synthesis and other topics in organic chemistry. Additional courses and seminars are available in a wide range of subjects, including enzyme regulation and mechanism, neurobiology, immunology, structural biochemistry, membrane biology, and molecular genetics. Students are encouraged to choose advanced courses and seminars according to their particular interests. Doctoral research topics are chosen in areas under investigation by the faculty; these include problems in macromolecular structure and function, enzyme function and regulation, RNA processing, gene regulation, membrane transport and receptor function, molecular pharmacology, mechanisms of cell motility, microbial metabolism, and the biochemistry of cellular electrical excitability. A theme running through this research is the relationship of biochemical functions to underlying molecular structures and mechanisms.

The Graduate Program in Biochemistry leading to the degree of Master of Science is designed to give students a substantial understanding of the chemical and molecular events in biological processes and experience in research. The program is divided among formal course work, biochemical techniques, and a research project. Additional courses and seminars are available in a wide range of subjects, as described above.

How to Become a Major

Students who are interested in majoring in biochemistry should speak with the department advising head.

How to Be Admitted to the Graduate Program

The general requirements for admission to the Graduate School, given in an earlier section of the *Bulletin*, apply here. Applicants for admission to the biochemistry PhD program are also required to take the Graduate Record Examination. It is strongly suggested that the applicant take one of the advanced sections of this examination. The applicant's undergraduate curriculum should include fundamental courses in biology and chemistry.

Faculty

Jeff Gelles, Chair
Mechanisms of mechanoenzymes. Stochastic processes in single enzyme molecules. Light microscopy as a tool to study enzyme mechanisms.

Nikolaus Grigorieff
High-resolution electron cryo-microscopy of membrane proteins and channels.

Lizbeth Hedstrom
Enzyme structure-function studies. Protein engineering. Design of enzyme inhibitors.

Dorothee Kern (Chair, Biophysics and Structural Biology)
Dynamics of enzymes. Magnetic resonance methods.

John Lowenstein
Role of phospholipids in hormone action. Regulation of lipogenesis. Regulation and function of the purine nucleotide cycle. Regulation and function of adenosine production in the heart. Techniques of cloning and high-level expression of proteins.

Christopher Miller, Graduate Program Chair
Structure and function of ion channel proteins. Membrane transport and mechanisms of electrical excitation.

Daniel Oprian
Structure-function studies of visual pigments and other cell surface receptors.

Gregory Petsko
X-ray crystallographic analysis of protein structure and enzyme mechanisms.

Dagmar Ringe (Rosenstiel Center)
Structures of enzymes and enzyme-substrate complexes. X-ray crystallography.

Douglas Theobald
Structural bioinformatics analysis of telomeric complexes, integrating X-ray crystallographic structure determination, molecular evolution, and structure-function studies.

Requirements for the Major

Degree of Bachelor of Arts
One year of general chemistry with laboratory; one year of organic chemistry with laboratory; one year of physics taught using calculus (PHYS 15a,b) with laboratory; BIOL 22a (formerly BIBC 22a) with laboratory (Genetics and Molecular Biology); BIOL 22b with laboratory (Cell Structure and Function) (the above courses must be taken prior to the senior year); BCHM 100a (Introductory Biochemistry); one year of physical chemistry, CHEM 141a (Physical Chemistry, Lectures I), and either BCHM 104b (Chemical Thermodynamics) or CHEM 143b (Kinetics); and one elective consisting of a biochemistry-related 100-level course (excluding research courses) from any science department. The course used to fulfill the elective requirement must be approved in advance by the biochemistry undergraduate advising head.

Degree of Bachelor of Science
In addition to the degree requirements listed above for the Bachelor of Arts degree, the Bachelor of Science degree requires one year of BCHM 101a and 103b (Advanced Biochemistry).

Required of all students: No course offered for major requirements may be taken pass/fail. Grades below C- in upper-level courses (CHEM 141a and b, and any course numbered 100 or above) cannot be used to fulfill the requirements for the major. Furthermore, no more than one D will be allowed in any other course required for the major.

Senior Honors Program
In addition to the degree requirements listed above, departmental honors require completion of two semesters of BCHM 99 (Research for Undergraduates), submission of an acceptable research thesis, and a final GPA 3.00 or better in the sciences and mathematics. Honors candidates are also expected to give a short oral presentation of their thesis research to members of the department at the end of their senior year. BCHM 99 may not exceed three semester credits. Petition to the department for participation in this program is made at the beginning of the senior year.

Combined BS/MS Program

In addition to all courses required for the BS degree, the BS/MS degree requires completion of one additional elective (excluding research courses) approved in advance by the biochemistry undergraduate advising head, three semesters of research (one or two semesters of BCHM 99 plus one or two semesters of BCHM 150), a full-time (i.e., no concurrent course work) summer research residency lasting at least ten weeks, submission of an acceptable thesis, a GPA of 3.00 or better in the sciences and mathematics, and grades of B- or better in all 100-level biochemistry and biology courses. This program requires completion of thirty-eight courses; no more than four semesters of research (BCHM 99 or 150) can count toward this total. Application to this program is made to the department and Graduate School no later than May 1 preceding the senior year, and all work, including the thesis, must be completed by the time the BS is awarded. To qualify for the BS/MS degree, the thesis must constitute a significant research contribution; if a thesis is found unacceptable under the BS/MS program, it will automatically be considered under the honors program.

In order to complete the honors program or the combined BS/MS program, it is advisable to gain exemption where possible from introductory courses in science and mathematics. This is especially important for the premedical students who must also fulfill the requirements imposed by medical schools.

Requirements for the Degree of Master of Science

Program of Study
Students must successfully complete an approved program of at least six courses. These courses are:

BCHM 101a	Advanced Biochemistry: Enzyme Mechanisms
BCHM 102a	Quantitative Approaches to Biochemical Systems
BIOP 200b	Readings in Macromolecular Structure-Function Analysis

One advanced (100-200 level) course from the School of Science, approved in advance by the graduate program chair.

BCHM 300a,b	Biochemical Techniques (Lab rotations)

Residence Requirement
The minimum residence requirement is one year.

Language Requirement
There is no language requirement.

Thesis
The student must complete an acceptable MS thesis describing original research.

Requirements for the Degree of Doctor of Philosophy in Biochemistry

Students must successfully complete the curriculum defined below.

A. The core curriculum consisting of:

BCHM 101a	Advanced Biochemistry: Enzyme Mechanisms
BCHM 102a	Quantitative Approaches to Biochemical Systems
BCHM 300a,b	Biochemical Techniques (laboratory rotations course)
BIOP 200b	Readings in Macromolecular Structure-Function Analysis
CONT 300b	Ethical Practices in Health-Related Sciences

B. Elective courses: Four advanced (100- and 200-level) courses from the School of Science. Each course used to satisfy this requirement must be approved in advance by the graduate program chair. Ordinarily, at least one of these courses will be an advanced graduate seminar (200-level) offered by the biochemistry department.

C. Students in their second and higher years of study must register for BCHM 401d Biochemical Research (dissertation research course) during every semester in which they are enrolled.

D. Students in their third and higher years of study will have yearly progress meetings with a faculty committee of three for the purpose of maintaining a satisfactory trajectory toward completion of the thesis defense.

Students ordinarily complete the core curriculum plus one elective in the first year and complete the remaining requirements in their subsequent years in the program.

Requirements for the Degree of Doctor of Philosophy in Biochemistry with Specialization in Bioorganic Chemistry
In order to receive a PhD in biochemistry with a specialization in bioorganic chemistry, students must complete the requirements defined above for the biochemistry PhD degree, with the following restrictions:

A. As one of their four elective courses, students must complete one course in synthetic organic chemistry, chosen from the following:

CHEM 134b Advanced Organic Chemistry: Synthesis

CHEM 135a Advanced Organic Chemistry: Synthesis II

B. As one of their four elective courses, students must complete one other advanced chemistry course approved in advance by the graduate program chair.

Students wishing to obtain the specialization must first gain approval of the graduate program chair. This should be done as early as possible, ideally during the first year of graduate studies.

Requirements for the Degree of Doctor of Philosophy in Biochemistry with Specialization in Quantitative Biology
In order to receive a PhD in biochemistry with a specialization in quantitative biology, students must complete the requirements defined above for the biochemistry PhD degree and in addition must satisfy the course requirements for the quantitative biology specialization that are described in the quantitative biology section of this *Bulletin.* Any alteration to the quantitative biology course requirements must be approved by the quantitative biology program faculty advisory committee. With the approval of the biochemistry graduate program chair, courses taken to satisfy the quantitative biology specialization requirements can be used to satisfy course requirements of the biochemistry PhD degree.

Students wishing to obtain the specialization must first gain approval of the graduate program chair or quantitative biology liaison. This should be done as early as possible, ideally during the first year of graduate studies.

Teaching Requirement
As a part of their PhD training, students are required to assist with the teaching of two one-semester courses.

Residence Requirement
The minimum residence requirement is three years.

Language Requirements
There is no foreign language requirement.

Financial Support
Students may receive financial support (tuition and stipend) throughout their participation in the PhD program. This support is provided by a combination of university funds, training grants, and individual research grants.

Qualifying Examinations
A qualifying examination must be taken following the first year of course work. In this examination, the student will be asked to present and defend an original proposition put forth by the student. In addition, the student must successfully pass a comprehensive examination administered following the second year of course work.

Dissertation and Defense
A dissertation will be required that summarizes the results of an original investigation of an approved subject and demonstrates the competence of the candidate in independent research. This dissertation will be presented in a departmental lecture and defended in a final oral examination.

Special Note Relating to Graduate Students

In addition to the formal courses listed below, all graduate students are expected to participate in the department's research clubs and colloquia. Colloquia are general meetings of the department in which department and guest speakers present their current investigations. Research clubs are organized by various research groups of the department.

Courses of Instruction

(1–99) Primarily for Undergraduate Students

BCSC 1a Designer Genes
[sn]
Does NOT satisfy the requirement for the major in biochemistry.
We are living during a far-reaching biological revolution. This course investigates: identifying undesirable mutations; creating desirable mutations; cloning of cells, organs, and animals in agriculture and medicine. Usually offered every second year.
Mr. Lowenstein

BCSC 7b Drug Discovery and Development
[sn]
Prerequisite: High school-level chemistry. Does NOT meet the requirements for the major in biochemistry.
A study of how pharmaceuticals work, how they are discovered, and how they are produced. Topics include: cells and their constituents, infectious and non-infectious diseases, antibiotics, development of drug resistance, psychoactive drugs, cancer-causing mutations, anti-cancer drugs, heart disease, anti-inflammatory and anti-cholesterol drugs, economics of drug discovery and development, FDA approval and drug production, patent protection, and generic drugs. Usually offered every second year.
Mr. Lowenstein

BCHM 98a Readings in Biochemistry
Prerequisites: BIOL 22a (formerly BIBC 22a), BCHM 100a, and one year of organic chemistry with laboratory. Does NOT satisfy the requirement for the major in biochemistry.
Directed scholarship on selected topics in biochemistry for outstanding juniors or seniors. Regularly scheduled discussion and written assignments leading to a substantive term paper. The tutorial is arranged only by mutual agreement between a faculty mentor and student. Usually offered every year.
Staff

BCHM 99a Research for Undergraduates
Prerequisites: BIOL 22a (formerly BIBC 22a), BCHM 100a, and one year of organic chemistry with laboratory. Requirement of BCHM 100a may be waived.
Undergraduate research. A maximum of three course credits may be taken as BCHM 99a and/or 99b. At the discretion of the department, one semester may be taken for double credit (99e). Offered every year.
Staff

BCHM 99b Research for Undergraduates
See BCHM 99a for special notes and course description.
Staff

BCHM 99e Research for Undergraduates
See BCHM 99a for special notes and course description.
Staff

(100–199) For Both Undergraduate and Graduate Students

BCHM 100a Introductory Biochemistry
[qr sn]
Prerequisite: One year of organic chemistry with laboratory.
Topics include chemistry, reaction, and metabolism of biologically important compounds; formation and utilization of "energy-rich" compounds; introduction to enzyme mechanisms; interrelation and comparison of basic biochemical and chemical processes; and metabolic regulation. Usually offered every year in multiple sections.
Mr. Oprian (fall) and Ms. Hedstrom (spring)

BCHM 101a Advanced Biochemistry: Enzyme Mechanisms
[sn]
Prerequisites: One year of organic chemistry with laboratory and BCHM 100a or their equivalent.
Describes the principles of biological catalysts and the chemical logic of metabolic pathways. Discusses representative enzymes from each reaction class, with an emphasis on understanding how mechanisms are derived from experimental evidence. Topics include serine proteases, phosphatases, isomerases, carboxylases, and dehydrogenases. Usually offered every year.
Ms. Kern

BCHM 102a Quantitative Approaches to Biochemical Systems
[sn]
Prerequisite: BCHM 100a or equivalent.
Introduces quantitative approaches to analyzing macromolecular structure and function. Emphasizes the use of basic thermodynamics and single-molecule and ensemble kinetics to elucidate biochemical reaction mechanisms. Also discusses the physical bases of spectroscopic and diffraction methods commonly used in the study of proteins and nucleic acids. Usually offered every year.
Mr. Miller

BCHM 103b Advanced Biochemistry: Information Transfer Mechanisms
[sn]
This course may not be repeated for credit by students who have taken BCHM 101b in previous years. Prerequisites: One year of organic chemistry with laboratory and BCHM 100a or their equivalent.
Addresses fundamental issues of gene expression and signal transduction at a molecular level. Discusses parallels between nucleic acid and protein biosynthesis, modification, transport, and degradation with an emphasis on understanding the mechanisms of specificity and regulation of these complex macromolecular processes. Usually offered every year.
Staff

BCHM 104b Physical Chemistry of Macromolecules
[sn]
Prerequisites: CHEM 141a or equivalent and BCHM 100a or equivalent.
Illustrates the basic principles on which biological macromolecules are constructed and by which they function. Describes overall structures of proteins, nucleic acids, and membranes in terms of the underlying molecular forces: electrostatics, hydrophobic interactions, and H-bonding. The energetics of macromolecular folding and of the linkage between ligand binding and conformational changes will also be discussed. Usually offered every year.
Mr. Miller

BCHM 150a Research for the BS/MS Candidates
[sn]
Prerequisites: BIOL 22a (formerly BIBC 22a) and BCHM 100a, one year of organic chemistry and laboratory, and BCHM 99.
The final semester(s) of laboratory research under the BS/MS program, to be pursued under the supervision of a faculty advisor. Usually offered every year.
Staff

BCHM 150b Research for the BS/MS Candidates
[sn]
See BCHM 150a for special notes and course description. Usually offered every year.
Staff

BCHM 150e Research for the BS/MS Candidates
See BCHM 150a for special notes and course description.
Staff

BCHM 153b Methods in High-Resolution Electron Cyro-Microscopy
[sn]
Transmission electron microscopy is introduced as a method in structural biology. Instrumentation, data collection, image processing, and interpretation of biological structures visualized by this method are discussed. Usually offered every second year.
Mr. Grigorieff

BCHM 170b Bioinformatics
[sn]
Prerequisites: Familiarity with computing is necessary and a basic biochemistry course is recommended. A joint offering between Brandeis University and Wellesley College.
Familiarizes students with the basic tools of bioinformatics and provides a practical guide to biological sequence analysis. Topics covered include an introduction to probability and statistics; sequence alignments; database searches; alignments and phylogenetic trees; sequence pattern discovery; structure determination by secondary structure prediction; and three-dimensional structure prediction by homology modeling. In all cases the strengths and limitations of the methods will be discussed. Usually offered every third year.
Ms. Ringe

BCHM 171b Protein X-ray Crystallography
[sn]
This course may not be repeated for credit by students who have taken BCHM 217b in previous years.
A practical guide to the determination of three-dimensional structures of proteins and nucleic acids by X-ray diffraction. Students learn the theory behind diffraction from macromolecular crystals and carry out all the calculations necessary to solve a protein structure at high resolution. Usually offered every second year.
Ms. Ringe

(200 and above) Primarily for Graduate Students

BIOP 200b Reading in Macromolecular Structure-Function Analysis
Required for first-year biochemistry and biophysics and structural biology graduate students.
Introduces students to chemical and physical approaches to biological problems through critical evaluation of the original literature. Students analyze scientific papers on a wide range of topics in the fields of biochemistry and biophysics. Discussion focuses on understanding of the scientific motivation for and experimental design of the studies. Particular emphasis is placed on making an independent determination of whether the author's conclusions are well justified by the experimental results. Usually offered every year.
Mr. Gelles

BCHM 219b Enzyme Mechanisms
Ms. Hedstrom

BCHM 220a Proteases
Ms. Hedstrom

BCHM 223a Enzymology of Biofuels, Bioplastics, and Bioremediation
Mr. Oprian

BCHM 224a Single-Molecule Biochemistry and Biophysics
Mr. Gelles

BCHM 225b Protein Dynamics
Prerequisite: BCHM 101a.
Introduces the fundamental concept of atomic fluctuations in proteins and their relation to protein function. Protein dynamics on different timescales is discussed with emphasis on different experimental and computational approaches to this problem. Usually offered every third year.
Ms. Kern

BCHM 251b Structure and Function of Membrane Proteins
This course may not be repeated for credit by students who took BCHM 151b in previous years.
Considers the molecular properties of membrane transport proteins, including ion channels, aquaporins, solute pumps, and secondary active transporters. Readings focus on primary literature aimed at interpreting the mechanisms of transmembrane solute movements in terms of the structures of these integral membrane proteins. Specific subjects chosen vary depending upon the trajectory of recent advances in this fast-moving research area. Usually offered every third year.
Mr. Miller

BCHM 300a Biochemistry Techniques
Prerequisite: BCHM 101. May be taken concurrently.
Usually offered every year.
Staff

BCHM 300b Biochemistry Techniques
Prerequisite: BCHM 101. May be taken concurrently.
Usually offered every year.
Staff

BCHM 401d Biochemical Research Problems
All graduate students beyond the first year must register for this course.
Independent research for the MS and PhD degrees. Specific sections for individual faculty members as requested.
Staff

Required First-Year Graduate Health-Related Science Programs Cours

CONT 300b Ethical Practice in Health-Related Sciences
Required of all first-year graduate students in health-related science programs. Not for credit.
Ethics is an essential aspect of scientific research. This course, taught by university faculty from several graduate disciplines, covers major ethical issues germane to the broader scientific enterprise, including areas or applications from a number of fields of study. Lectures and relevant case studies are complemented by public lectures during the course. Usually offered every year.
Mr. Morris

Cross-Listed Courses

CHEM 123b
Bioinorganic Chemistry

CHEM 129b
Special Topics in Inorganic Chemistry: Introduction to X-ray Structure Determination

CHEM 130a
Advanced Organic Chemistry: Structure

CHEM 131a
Advanced Organic Chemistry: Topics in Structure and Reactivity

CHEM 132b
Advanced Organic Chemistry: Spectroscopy

CHEM 134b
Advanced Organic Chemistry: Synthesis

CHEM 137b
The Chemistry of Organic Natural Products

CHEM 143b
Kinetics, Dynamics, and Transport

CHEM 144a
Computational Chemistry

CHEM 146a
Single Molecule Spectroscopy

CHEM 147b
Mass Spectrometry

CHEM 246b
Advanced NMR Spectroscopy

COSI 230a
Topics in Computational Biology

PHYS 105a
Biological Physics

QBIO 110a
Numerical Modeling of Biological Systems

QBIO 120b
Quantitative Biology Instrumentation Laboratory