

Center for Computational Molecular Biology

The prime intellectual mission of Brown University's Center for Computational Molecular Biology (CCMB) (<https://www.brown.edu/academics/computational-molecular-biology/>) is to promote the development, implementation and application of analytical and computational methods to foundational questions in the biological and medical sciences. The research programs of the Core Faculty in CCMB lie fundamentally at the intersection of computer science, evolutionary biology, mathematics, and molecular and cellular biology.

Biological questions that currently unite the CCMB Core and Associate Faculty are: How do genotypes and genes interact to produce phenotypes, and how does this happen from womb to tomb? What drives the formation, maintenance and evolutionary transformations of communities of organisms over time? Quantitative questions that currently unite the CCMB faculty are: how can we design powerful algorithms to make sense of the sea of data produced in the genomic era? What principles are required for a theoretical framework to completely model cellular systems?

The research challenges at the heart of CCMB are a rich source of mathematical problems motivated by the complex nature of genomes, disease processes and evolutionary relationships. These challenges are both multi-scale (with units of interest ranging from molecules to communities of organisms) and large-scale (data-intensive, due to advances in sequencing technologies). Thus, CCMB rounds out the broader landscape of research in methodological development at Brown University by partnering with and complementing the Data Science Initiative (<https://www.brown.edu/initiatives/data-science/>) and the Brown Center for Biomedical Informatics. (<https://www.brown.edu/academics/medical/about-us/research/centers-institutes-and-programs/biomedical-informatics/>)

In addition to these research interests, CCMB Faculty members are actively involved in the operation of Brown's NIH-funded COBRE Center for the Computational Biology of Human Disease (<https://www.brown.edu/research/projects/computational-biology-of-human-disease/>), and administer both an undergraduate concentration (<https://www.brown.edu/academics/computational-molecular-biology/courses-study/>) and an interdisciplinary doctoral program (<https://www.brown.edu/academics/computational-molecular-biology/courses-study/>) in Computational Biology. This is a short video about our Ph.D. program in Computational Biology (<https://www.youtube.com/watch?v=p3zBdW-ENTU>).

Computational Biology Concentration Requirements

Computational biology involves the analysis and discovery of biological phenomena using computational tools, and the algorithmic design and analysis of such tools. The field is widely defined and includes foundations in computer science, applied mathematics, statistics, biochemistry, molecular biology, genetics, ecology, evolution, anatomy, neuroscience, and visualization.

Students may pursue a Bachelor of Arts or a Bachelor of Science. Students pursuing the ScB have the option of electing a concentration in Computational Biology with one of three focus areas: Computer Sciences, Biological Sciences, or Applied Mathematics & Statistics. Both programs require a senior capstone experience that pairs students and faculty in creative research collaborations.

Standard program for the A.B. degree

Please see the bottom of the page for more information regarding the University Writing Requirement, the Capstone Experience, and the Computational Biology Honors Program.

| | |
|--|---|
| Prerequisites: | 2 |
| MATH 0100 | Single Variable Calculus, Part II |
| or MATH 0170 | Single Variable Calculus, Part II (Accelerated) |
| BIOL 0200 | The Foundation of Living Systems |
| General Core Requirements: Biology | 2 |
| BIOL 0470 | Genetics |
| BIOL 0280 | Biochemistry |
| or BIOL 0500 | Cell and Molecular Biology |
| General Core Requirements: Chemistry | 1 |
| CHEM 0330 | Equilibrium, Rate, and Structure |
| or CHEM 0350 | Organic Chemistry I |
| General Core Requirements: Computer Science | 2-3 |
| Choose one of the following groupings of introductory courses: | |
| Group A | |
| CSCI 0111 & CSCI 0112 & CSCI 0200 | Computing Foundations: Data and Computing Foundations: Program Organization and Program Design with Data Structures and Algorithms ¹ |
| Group B | |
| CSCI 0150 & CSCI 0200 | Introduction to Object-Oriented Programming and Computer Science and Program Design with Data Structures and Algorithms |
| Group C | |
| CSCI 0170 & CSCI 0200 | Computer Science: An Integrated Introduction and Program Design with Data Structures and Algorithms |
| Group D | |
| CSCI 0190 | Accelerated Introduction to Computer Science (and any full-credit computer science course above CSCI 0190) |
| General Core Requirements: Probability & Statistics | 1 |
| APMA 1650 | Statistical Inference I |
| OR | |
| CSCI 1450 | Advanced Introduction to Probability for Computing and Data Science |
| OR | |
| MATH 1210 | Probability |
| Comp Bio Core Course Requirements | 4 |
| CSCI 1810 | Computational Molecular Biology |
| APMA 1080 | Inference in Genomics and Molecular Biology |
| AND two of the following: | |
| APMA 1660 | Statistical Inference II |
| APMA 1690 | Computational Probability and Statistics |
| BIOL 1430 | Foundations of Population Genetics |
| BIOL 1435 | Computational Methods for Studying Demographic History with Molecular Data |
| BIOL 1465 | Human Population Genomics |
| BIOL 1555 | Methods in Informatics and Data Science for Health |
| CSCI 1420 | Machine Learning |
| CSCI 1470 | Deep Learning |
| CSCI 1820 | Algorithmic Foundations of Computational Biology |
| Additional course with Director approval | |
| Capstone Experience | |

Students enrolled in the computational biology concentration will complete a research project in their senior year under faculty supervision (i.e: BIOL 1950/1960, CSCI 1970, APMA 1970). The themes of such projects evolve with the field and the technology, but should represent a synthesis of the various specialties of the program. The requirements are either one semester of reading and research with a CCMB Faculty member or approved advisor, or a 2000-level Computational Biology course.

Students enrolled in the computational biology concentration will complete a research project in their senior year under faculty supervision (i.e: BIOL 1950/1960, CSCI 1970, APMA 1970). The themes of such projects evolve with the field and the technology, but should represent a synthesis of the various specialties of the program. The requirements are either one semester of reading and research with a CCMB Faculty member or approved advisor, or a 2000-level Computational Biology course.

Total Credits 12-13

Six Courses in one of the following 3 tracks 6

Standard program for the Sc.B. degree

Computer Science Track:

Please see the bottom of the page for more information regarding the University Writing Requirement, the Capstone Experience, and the Computational Biology Honors Program.

Prerequisites 2

Three of the following:

- MATH 0100 Single Variable Calculus, Part II (or equivalent)
- or MATH 0170 Single Variable Calculus, Part II (Accelerated)
- BIOL 0200 The Foundation of Living Systems (or equivalent)

- CSCI 1230 Introduction to Computer Graphics
 - CSCI 1270 Database Management Systems
 - CSCI 1410 Artificial Intelligence
 - CSCI 1420 Machine Learning
 - CSCI 1470 Deep Learning
 - CSCI 1550 Probabilistic Methods in Computer Science
 - CSCI 1570 Design and Analysis of Algorithms
- or other Computer Science courses approved by the concentration advisor.

General Core Course Requirements: Biology 2

AND three of the following:

- BIOL 0470 Genetics (prerequisite BIOL 0200 or equivalent)
- BIOL 0280 Biochemistry
- or BIOL 0500 Cell and Molecular Biology

- APMA 1660 Statistical Inference II
- APMA 1690 Computational Probability and Statistics
- BIOL 1430 Foundations of Population Genetics
- BIOL 1435 Computational Methods for Studying Demographic History with Molecular Data
- BIOL 1465 Human Population Genomics
- CSCI 0320 Introduction to Software Engineering & CSCI 0330 and Introduction to Computer Systems
- CSCI 1820 Algorithmic Foundations of Computational Biology
- PHP 2620 Statistical Methods in Bioinformatics, I

General Core Requirements: Chemistry 1

- CHEM 0330 Equilibrium, Rate, and Structure
- or CHEM 0350 Organic Chemistry I

General Core Requirements: Computer Science 3-4

- CSCI 0220 Introduction to Discrete Structures and Probability

AND complete one of the following groupings of introductory courses:

Biological Sciences track

At least four courses comprising a coherent theme in one of the following areas: Biochemistry, Ecology, Evolution, or Neurobiology.

AND two courses from the following:

- Group A
 - CSCI 0111 Computing Foundations: Data & CSCI 0112 and Computing Foundations: Program Organization and Program Design with Data Structures and Algorithms¹
- Group B
 - CSCI 0150 Introduction to Object-Oriented Programming and Computer Science & CSCI 0200 and Program Design with Data Structures and Algorithms
- Group C
 - CSCI 0170 Computer Science: An Integrated Introduction & CSCI 0200 and Program Design with Data Structures and Algorithms
- Group D
 - CSCI 0190 Accelerated Introduction to Computer Science (and any full-credit computer science course above CSCI 0190.)

- APMA 1660 Statistical Inference II
- APMA 1690 Computational Probability and Statistics
- BIOL 1430 Foundations of Population Genetics
- BIOL 1435 Computational Methods for Studying Demographic History with Molecular Data
- BIOL 1465 Human Population Genomics
- CSCI 1420 Machine Learning
- CSCI 1470 Deep Learning
- CSCI 1820 Algorithmic Foundations of Computational Biology
- PHP 2620 Statistical Methods in Bioinformatics, I

General Core Requirements: Probability & Statistics 1

Applied Mathematics & Statistics Track:

At least three courses from the following:

- APMA 1650 Statistical Inference I
- or CSCI 1450 Advanced Introduction to Probability for Computing and Data Science
- or MATH 1210 Probability

- APMA 1660 Statistical Inference II
- APMA 1690 Computational Probability and Statistics
- CSCI 1410 Artificial Intelligence
- APMA 0330 Methods of Applied Mathematics I & APMA 0340 and Methods of Applied Mathematics II
- APMA 0350 Applied Ordinary Differential Equations & APMA 0360 and Applied Partial Differential Equations I

General Core Requirements: Computational Biology

CSCI 1810 Computational Molecular Biology 1

APMA 1080 Inference in Genomics and Molecular Biology 1

Capstone Experience 1

At least three of the following:

- APMA 1070 Quantitative Models of Biological Systems
- BIOL 1430 Foundations of Population Genetics

| | |
|-----------|--|
| BIOL 1435 | Computational Methods for Studying Demographic History with Molecular Data |
| BIOL 1465 | Human Population Genomics |
| CSCI 1420 | Machine Learning |
| CSCI 1470 | Deep Learning |
| CSCI 1820 | Algorithmic Foundations of Computational Biology |
| PHP 2620 | Statistical Methods in Bioinformatics, I |

Total Credits **18-19**

University Writing Requirement:

As part of Brown's writing requirement, all students must demonstrate that they have worked on their writing both in their general studies and their concentration. There are a number of ways for Computational Biology concentrators to fulfill these requirements:

- Enrolling in an independent study: CSCI 1970, BIOL 1950, APMA 1970
- Writing an Honors Thesis
- Taking a "WRIT" course in the final two years

Capstone Experience:

Students enrolled in the computational biology concentration will complete a research project in their senior year under faculty supervision. The themes of such projects evolve with the field and the technology, but should represent a synthesis of the various specialties of the program. The requirements are either one semester of reading and research with a CCMB Faculty member or approved advisor, or a 2000-level Computational Biology course.

Honors:

In order to be considered a candidate for honors, students will be expected to maintain an outstanding record, with no "C's" in concentration courses and with a minimum of an "A-" average in concentration courses. In addition, students should take at least one semester, and are strongly encouraged to take 2 semesters, of reading and research with a CCMB faculty member or approved advisor. Students must submit to a public defense of their theses to be open to the CCMB community.

- Students seeking honors are advised to choose a Thesis Advisor prior to the end of their Junior year
- Students must complete the Registration form for Comp Bio and submit it to CCMB@BROWN.EDU

Any deviation from these rules must be approved by the director of undergraduate studies, in consultation with the student's advisor.

Computational Biology Graduate Program

The Center for Computational Molecular Biology (CCMB) offers Ph.D. degrees in Computational Biology to train the next generation of scientists to perform cutting edge research in the multidisciplinary field of Computational Biology. During the course of their Ph.D. studies students will develop and apply novel computational, mathematical, and statistical techniques to problems in the life sciences. Students in this program must achieve mastery in three areas - computational science, molecular biology, and probability and statistical inference - through a common core of studies that spans and integrates these areas.

The Ph.D. program in Computational Biology draws on course offerings from the disciplines of the Center's Core faculty members. These areas are Applied Mathematics (APMA), Computer Science (CS), the Division of Biology and Medicine (BioMed), Brown Center for Biomedical Informatics (BCBI), and the School of Public Health/Biostatistics (SPH). Our faculty and Director of Graduate Studies (DGS) work with each student to develop the best plan of coursework and research rotations to meet the student's goals in their research focus and satisfy the University's requirements for graduation.

Applicants should state a preference for at least one of these areas in their personal statement or elsewhere in their application. In addition, students interested in the intersection of Applied Mathematics and Computational

Biology are encouraged to apply directly to the Applied Mathematics Ph.D. program (<http://www.brown.edu/academics/applied-mathematics/graduate/>), and also to contact relevant CCMB faculty members (<https://www.brown.edu/academics/computational-molecular-biology/about/people/faculty-and-staff/>).

Our PhD program assumes the following prerequisites: mathematics through intermediate calculus, linear algebra and discrete mathematics, demonstrated programming skill, and at least one undergraduate course in chemistry and in molecular biology. Exceptional strengths in one area may compensate for limited background in other areas, but some proficiency across the disciplines must be evident for admission.

- Ph.D. Program Overview & Handbook (https://www.brown.edu/academics/computational-molecular-biology/sites/brown.edu.academics.computational-molecular-biology/files/uploads/Comp%20Bio%20Ph.D.%20Program%20requirements%20%26%20handbook_1.pdf) (pdf file)
- FAQ (<http://brown.edu/academics/computational-molecular-biology/frequently-asked-questions/>)

The application process to the CCMB graduate program is run through the Graduate School (<http://www.brown.edu/academics/gradschool/>)