

Undergraduate Computational Biology Program

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<http://cbd.cmu.edu>

Bachelor of Science in Computational Biology

Program Director: Dr. Phillip Compeau
Program Manager: Nicole Stenger

Success in computational biology requires significant technical knowledge of fundamental computer science as well as a broad biological intuition and general understanding of experimental biology. However, most importantly, it requires students who can integrate their knowledge by making connections between the two fields.

There is significant industry demand for excellent computational biology students, in biotech firms, biomedical research, as well as in pharmaceutical research. Both established companies and startups struggle to find employees with the correct skillset, and our students will be able to take advantage of the fact that an undergraduate computational biology major has the rigorous training required to handle the challenges of modern research that is not provided by any of our peer institutions.

Students completing the undergraduate program in computational biology will also be ideally prepared for Ph.D. programs in any of a range of biomedical areas, including Computational Biology, Systems Biology, or Quantitative Biology. Students who complete pre-medical requirements will be very well-prepared to attend medical school; after all, the next generation of physicians will need to better understand the computational approaches needed for automated medical testing, automated medical imaging, and the coming personalized medicine revolution.

Degree Requirements (students entering Fall 2017)

Students completing the Bachelor of Science in Computational Biology follow certain policies that apply to all SCS students; please consult the SCS policies page (<http://coursecatalog.web.cmu.edu/schoolofcomputerscience/#policiestext>) for a complete listing of these expectations.

Students must complete a **minimum of 360 units** for the degree in computational biology.

For Mellon College of Sciences students interested in computational biology who matriculated at Carnegie Mellon before fall 2017, please go to Previous Catalogs (<http://coursecatalog.web.cmu.edu/previous>) for degree requirements.

Math/Stats Core

| | | |
|-------------|---|-------|
| 21-120 | Differential and Integral Calculus | 10 |
| 21-122 | Integration and Approximation | 10 |
| 15-151 | Mathematical Foundations for Computer Science (or 21-127 if not offered) | 10 |
| 36-217 | Probability Theory and Random Processes (does not require 21-259 as a prerequisite) | 9-12 |
| or 15-359 | Probability and Computing | |
| or 36-225 | Introduction to Probability Theory | |
| or 21-325 | Probability | |
| 36-226 | Introduction to Statistical Inference (Students taking 15-359 should take 36-326 instead.) | 9 |
| or 36-326 | Mathematical Statistics (Honors) | |
| Total Units | | 48-51 |

General Science Core

| | | |
|-------------|---|----|
| 09-105 | Introduction to Modern Chemistry I | 10 |
| or 09-107 | Honors Chemistry: Fundamentals, Concepts and Applications | |
| 33-121 | Physics I for Science Students | 12 |
| or 33-141 | Physics I for Engineering Students | |
| Total Units | | 22 |

Biological Core

| | | |
|-------------|---|----|
| 03-121 | Modern Biology | 9 |
| 03-220 | Genetics | 9 |
| 03-232 | Biochemistry I (Students taking 03-231, including pre-med students, will take organic chemistry as a prerequisite, which will satisfy a biology elective requirement.) | 9 |
| or 03-231 | Biochemistry I | |
| 03-320 | Cell Biology | 9 |
| Total Units | | 36 |

Computer Science Core

| | | |
|-------------|---|----|
| 15-128 | Freshman Immigration Course (This course may be replaced by 03-201 or 03-202 if and only if 15-128 is not offered) | 1 |
| 99-101 | Computing @ Carnegie Mellon | 3 |
| or 99-102 | Computing @ Carnegie Mellon | |
| 15-122 | Principles of Imperative Computation | 10 |
| 15-251 | Great Ideas in Theoretical Computer Science | 12 |
| 15-351 | Algorithms and Advanced Data Structures (Students taking 15-150 and 15-210 as prerequisites for 15-451 may apply these courses as CS electives.) | 12 |
| or 15-451 | Algorithm Design and Analysis | |
| 10-401 | Introduction to Machine Learning (Undergrad) | 12 |
| Total Units | | 50 |

Computational Biology Core

| | | |
|-------------|--|-------|
| 02-250 | Introduction to Computational Biology | 12 |
| 02-261 | Quantitative Cell and Molecular Biology Laboratory | 9-12 |
| or 03-343 | Experimental Techniques in Molecular Biology | |
| 02-402 | Computational Biology Seminar | 3 |
| 02-510 | Computational Genomics | 12 |
| 02-512 | Computational Methods for Biological Modeling and Simulation | 9-12 |
| or 02-530 | Cell and Systems Modeling | |
| Total Units | | 45-51 |

Major Electives

| | | |
|-------------|--|-------|
| 02-3xx | Computational Biology Electives at 300 level or above (Includes a few courses outside of 02-xxx, such as 03-500 if research is computational; list of acceptable courses updated annually) | 18-24 |
| 03-3xx | Biology Electives at 300 level or above | 9-12 |
| 15-xxx | Computer Science or 10-xxx Machine Learning Electives | 18-24 |
| Total Units | | 45-60 |

General Education (Humanities & Arts)

Expectations for Humanities & Arts courses are shared between the Computer Science and Computational Biology undergraduate programs. For specific courses that may be used to satisfy each elective, please see the SCS General Education Requirements (<http://coursecatalog.web.cmu.edu/schoolofcomputerscience/#genedtext>) page.

| | | |
|---|-----------------------------|----|
| 76-101 | Interpretation and Argument | 9 |
| Elective Cognition, Choice and Behavior | | 9 |
| Elective Economics, Political and Social Institutions | | 9 |
| Elective Cultural Analysis | | 9 |
| Non-technical Electives (x 3) | | 27 |
| Total Units | | 63 |

Free Electives

A free elective is any Carnegie Mellon course. However, a maximum of nine (9) units of Physical Education and/or Military Science (ROTC) and/or Student-Led (StuCo) courses may be used toward fulfilling graduation requirements.

| | |
|----------------|-------|
| Free Electives | 27-54 |
| Total Units | 27-54 |

Sample Course Sequence

Please note that the below course sequence is simply a suggested guide to which courses may be appropriate for students completing the undergraduate program in computational biology in each term. Individual students will have individual paths based on their backgrounds and needs.

| Freshman | | Sophomore | |
|--|--|---|--|
| Fall | Spring | Fall | Spring |
| 21-120 Differential and Integral Calculus | 02-250 Introduction to Computational Biology | 02-261 Quantitative Cell and Molecular Biology Laboratory | 15-251 Great Ideas in Theoretical Computer Science |
| 15-122 Principles of Imperative Computation | 21-122 Integration and Approximation | 03-220 Genetics | 03-232 Biochemistry I |
| 15-128 Freshman Immigration Course | 03-121 Modern Biology | 33-121 Physics I for Science Students | xx-xxx Humanities and Arts Elective |
| 15-131 Great Practical Ideas for Computer Scientists | 09-105 Introduction to Modern Chemistry I | 15-351 Algorithms and Advanced Data Structures | xx-xxx Free Elective |
| 15-151 Mathematical Foundations for Computer Science | xx-xxx Humanities and Arts Elective | xx-xxx Humanities and Arts Elective | |
| 99-101 Computing @ Carnegie Mellon (or 99-102) | | | |
| 76-101 Interpretation and Argument | | | |

| Junior | | Senior | |
|---|---|--|--|
| Fall | Spring | Fall | Spring |
| 02-512 Computational Methods for Biological Modeling and Simulation | 02-510 Computational Genomics | 02-402 Computational Biology Seminar | 02-xxx Computational Biology Elective |
| 36-217 Probability Theory and Random Processes | 36-226 Introduction to Statistical Inference | 02-xxx Computational Biology Elective | 15-xxx/10-xxx Computer Science/Machine Learning Elective |
| 03-320 Cell Biology | 10-401 Introduction to Machine Learning (Undergrad) | 03-xxx Biology Elective | xx-xxx Humanities and Arts Elective |
| xx-xxx Humanities and Arts Elective | xx-xxx Humanities and Arts Elective | 15-xxx/10-xxx Computer Science/Machine Learning Elective | xx-xxx Free Elective |
| xx-xxx Free Elective | xx-xxx Free Elective | xx-xxx Free Elective | |

Computational Biology Minor

Director: Ziv Bar-Joseph, PhD

Advisor: Phillip Compeau, PhD

Program Manager: Nicole Stenger

The computational biology minor is open to students in any major of any college at Carnegie Mellon. The curriculum and course requirements are designed to maximize the participation of students from diverse academic disciplines. The program seeks to produce students with both basic computational skills and knowledge in biological sciences that are central to computational biology.

Students are encouraged to declare the minor as early as possible in their undergraduate careers and in all cases before their final semester so that the minor advisor can provide advice on their curriculum.

Why Minor in Computational Biology?

Computational Biology is concerned with solving biological and biomedical problems using mathematical and computational methods. It is recognized as an essential element in modern biological and biomedical research. There have been fundamental changes in biology and medicine over the past two decades due to spectacular advances in high throughput data collection for genomics, proteomics and biomedical imaging. The resulting availability of unprecedented amounts of biological data demands the application of advanced computational tools to build integrated models of biological systems, and to use them to devise methods of prevent or treat disease. Computational Biologists inhabit and expand the interface of computation and biology, making them integral to the future of biology and medicine.

Computational Biology is a growing field not only in academia, but also in industry. Major players in computation and medicine have invested heavily in computational biology, including Google, Microsoft, Roche and Merck.

Policy on Double Counting

No more than two courses may be double counted with your major's core requirements. Courses in the minor may not be counted towards another SCS minor. Consult the minor advisor for more information.

Curriculum Overview

The minor in computational biology requires a total of five courses: 3 core courses, 1 biology elective, and 1 computational biology elective, for a **total of at least 48 units**.

Prerequisites

| Students must take both of the following courses as prerequisites: | | Units |
|--|--------------------------------------|-------|
| 03-121 | Modern Biology | 9-10 |
| or 03-151 | Honors Modern Biology | |
| 15-122 | Principles of Imperative Computation | 10 |

Core Classes

Students must take both of the following courses:

| | | |
|--------|--|----|
| 02-250 | Introduction to Computational Biology | 12 |
| 02-261 | Quantitative Cell and Molecular Biology Laboratory (03-343 Experimental Techniques in Molecular Biology may be substituted for 02-261 with permission of the minor advisor; 03-115 and 03-116 may be used to replace 02-261 if and only if the latter is not offered) | 9 |

Students must take one of the following courses:

| | | |
|--------|--|------|
| 02-510 | Computational Genomics | Var. |
| 02-512 | Computational Methods for Biological Modeling and Simulation | 9 |
| 02-530 | Cell and Systems Modeling | 12 |

Biology Elective

Please select one of the following courses:

| | | |
|--------|--|---|
| 03-231 | Biochemistry I | 9 |
| 03-232 | Biochemistry I | 9 |
| 03-320 | Cell Biology | 9 |
| 03-327 | Phylogenetics | 9 |
| 03-330 | Genetics | 9 |
| 03-362 | Cellular Neuroscience | 9 |
| 03-363 | Systems Neuroscience | 9 |
| 03-364 | Developmental Neuroscience | 9 |
| 03-439 | Introduction to Biophysics | 9 |
| 03-442 | Molecular Biology | 9 |
| 03-534 | Biological Imaging and Fluorescence Spectroscopy | 9 |
| 42-202 | Physiology | 9 |

Computational Biology Elective

Please select one of the following courses:

| | | |
|---------------|--|------|
| 02-xxx | Any 02-xxx listed course 02-300 or above | 9-12 |
| 09-560 | Computational Chemistry | 12 |
| 15-386 | Neural Computation | 9 |
| 15-883 | Computational Models of Neural Systems | 12 |
| 16-725 | Medical Image Analysis | 12 |
| 42-640/24-658 | Computational Bio-Modeling and Visualization | 12 |