

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	Var.
02-512	Computational Methods for Biological Modeling and Simulation	9-12
or 02-530	Cell and Systems Modeling	
Total Units		33-40

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