

# Undergraduate Computational Biology Program

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<http://cbd.cmu.edu>

## Bachelor of Science in Computational Biology

**Program Director:** Dr. Phillip Compeau  
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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 2018)

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.

### Mathematics/Statistics 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
36-218	Probability Theory for Computer Scientists (Students taking 15-359 should take 36-326 instead.)	9
or 36-226	Introduction to Statistical Inference	
or 36-326	Mathematical Statistics (Honors)	
21-241	Matrices and Linear Transformations	10
or 21-242	Matrix Theory	
Total Units		49

### 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
03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis (or 03-220 if not offered)	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	Honors Biochemistry	
03-320	Cell Biology	9
Total Units		36

### Computer Science Core

07-128	Freshman Immigration Course (This course may be replaced by 03-201 or 03-202 if and only if 07-128 is not offered)	1
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		47

### Computational Biology Core

02-251	Great Ideas in Computational Biology	12
02-261	Quantitative Cell and Molecular Biology Laboratory	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		48-51

### 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 <sup>09-217 also counts as a biology elective</sup>	9-12
15-xxx	Computer Science or 10-xxx Machine Learning Electives	18-24
Total Units		45-60

### Humanities & Arts

All candidates for the bachelor's degree in Computer Science must complete a minimum of 63 units offered by the College of Humanities & Social Sciences and/or the College of Fine Arts. These courses offer students breadth in their education and perspectives and provide students with a better appreciation of social, artistic, cultural, political and economic issues that can influence their effectiveness as computer scientists upon graduation.

Requirements for this component of the degree are listed under the SCS main page under General Education Requirements (<http://coursecatalog.web.cmu.edu/schoolofcomputerscience/#genedtext>).

## Computing @ Carnegie Mellon (1 course)

The following course is required of all students to familiarize them with the campus computing environment:

99-101	Computing @ Carnegie Mellon	3
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## 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.

## Summary of Degree Requirements

Area	
Math/Stats Core	49
General Science Core	22
Biological Core	36
Computer Science Core	50
Computational Biology Core	48-51
Major Electives	45-60
General Education (Humanities & Arts)	63
Remaining Units	29-47
<b>Total Units</b>	<b>360</b>

## Sample Course Sequence

The sample given below assumes a student has credit for an introductory programming course, but no credit for calculus. The course sequence below 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
07-128 Freshman Immigration Course	02-251 Great Ideas in Computational Biology	02-261 Quantitative Cell and Molecular Biology Laboratory	03-232 Biochemistry I
15-122 Principles of Imperative Computation	03-121 Modern Biology	03-221 Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	15-251 Great Ideas in Theoretical Computer Science
15-131 Great Practical Ideas for Computer Scientists	09-105 Introduction to Modern Chemistry I	15-351 Algorithms and Advanced Data Structures	21-241 Matrices and Linear Transformations
15-151 Mathematical Foundations for Computer Science	21-122 Integration and Approximation	33-121 Physics I for Science Students	02-xxx Computational Biology Elective
21-120 Differential and Integral Calculus	xx-xxx Humanities and Arts Elective	xx-xxx Humanities and Arts Elective	
76-101 Interpretation and Argument			
99-101 Computing @ Carnegie Mellon			

Junior		Senior	
Fall	Spring	Fall	Spring
02-512 Computational Methods for Biological Modeling and Simulation	02-402 Computational Biology Seminar	02-xxx Computational Biology Elective	xx-xxx Humanities and Arts Elective
03-320 Cell Biology	02-510 Computational Genomics	15-xxx/10-xxx Computer Science/Machine Learning Elective	xx-xxx Free Elective
36-218 Probability Theory for Computer Scientists	10-401 Introduction to Machine Learning (Undergrad)	xx-xxx Humanities and Arts Elective	xx-xxx Free Elective
15-xxx/10-xxx CS/ML Elective	03-xxx Biology Elective	xx-xxx Free Elective	xx-xxx Free Elective
xx-xxx Humanities and Arts Elective	xx-xxx Humanities and Arts Elective		

## Additional Major in Computational Biology

The Additional Major in Computational Biology is designed for undergraduate students wishing to study computational biology as a second field of study at Carnegie Mellon University in addition to their primary major.

The additional major is open to all students who complete the prerequisite coursework listed below, with the requirement that a student from outside SCS must have a 3.0 overall QPA when applying.

To prevent double-counting, students must complete at least seven courses of at least 9 units each as part of the additional major in computational biology (not including pre-requisites) that are unique to the additional major.

Students interested in the Additional Major in Computational Biology should contact the Computational Biology Undergrad Program Director.

## Prerequisite Courses

02-250	Introduction to Computational Biology	12
or 02-251	Great Ideas in Computational Biology	
03-121	Modern Biology	9
or 03-151	Honors Modern Biology	
15-122	Principles of Imperative Computation	10
15-151	Mathematical Foundations for Computer Science	10
or 21-127	Concepts of Mathematics	
or 21-128	Mathematical Concepts and Proofs	
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
<b>Total Units</b>		<b>61</b>

## Mathematics/Statistics Core

36-218	Probability Theory for Computer Scientists	9
or 36-226	Introduction to Statistical Inference	
or 36-326	Mathematical Statistics (Honors)	
21-241	Matrices and Linear Transformations	10
or 21-242	Matrix Theory	
<b>Total Units</b>		<b>19</b>

## 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	
<b>Total Units</b>		<b>22</b>

## Biological Core

03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	9
or 03-220	Genetics	
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	Honors Biochemistry	
03-320	Cell Biology	9
<b>Total Units</b>		<b>27</b>

## Computer Science Core

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		36

## Computational Biology Core

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		33-39

## Major Electives

02-3xx	Computational Biology Electives at 300 level or above (Includes 03-500 if research is computational)	18-24
03-3xx	Biology Electives at 300 level or above <sup>09-217 also counts as a biology elective</sup>	9-12
15-xxx	Computer Science or 10-xxx Machine Learning Electives	18-24
Total Units		45-60

## General Education (Humanities & Arts)

For specific courses that may be used to satisfy each elective, please consult the General Education Requirements for your primary major.

## Computational Biology Minor

**Director:** Ziv Bar-Joseph, PhD

**Advisor:** Phillip Compeau, PhD

**Program Manager:** Samantha Mudrinich

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 45 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
or 02-251	Great Ideas in Computational Biology	
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)	9-12
Students must take one of the following courses:		
02-510	Computational Genomics	9-12
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:		
03-220	Genetics	9
03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	9
03-231	Honors Biochemistry	9
03-232	Biochemistry I	9
03-320	Cell Biology	9
03-327	Phylogenetics	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	Image-Based Computational Modeling and Analysis	12