

# Computational Biology

Under the auspices of the Center for Computational Biology, the Computational Biology Graduate Group offers the PhD in Computational Biology as well as the Designated Emphasis in Computational and Genomic Biology, a specialization for doctoral students in affiliated programs. The PhD is concerned with advancing knowledge at the interface of the computational and biological sciences and is therefore intended for students who are passionate about being high functioning in both fields. The designated emphasis augments disciplinary training with a solid foundation in the different facets of genomic research and provides students with the skills needed to collaborate across disciplinary boundaries to solve a wide range of computational biology and genomic problems.

## Admission to the University

### Minimum Requirements for Admission

The following minimum requirements apply to all graduate programs and will be verified by the Graduate Division:

1. A bachelor's degree or recognized equivalent from an accredited institution;
2. A grade point average of B or better (3.0);
3. If the applicant comes from a country or political entity (e.g., Quebec) where English is not the official language, adequate proficiency in English to do graduate work, as evidenced by a TOEFL score of at least 90 on the iBT test, 570 on the paper-and-pencil test, or an IELTS Band score of at least 7 on a 9-point scale (note that individual programs may set higher levels for any of these); and
4. Sufficient undergraduate training to do graduate work in the given field.

### Applicants Who Already Hold a Graduate Degree

The Graduate Council views academic degrees not as vocational training certificates, but as evidence of broad training in research methods, independent study, and articulation of learning. Therefore, applicants who already have academic graduate degrees should be able to pursue new subject matter at an advanced level without need to enroll in a related or similar graduate program.

Programs may consider students for an additional academic master's or professional master's degree only if the additional degree is in a distinctly different field.

Applicants admitted to a doctoral program that requires a master's degree to be earned at Berkeley as a prerequisite (even though the applicant already has a master's degree from another institution in the same or a closely allied field of study) will be permitted to undertake the second master's degree, despite the overlap in field.

The Graduate Division will admit students for a second doctoral degree only if they meet the following guidelines:

1. Applicants with doctoral degrees may be admitted for an additional doctoral degree only if that degree program is in a general area of knowledge distinctly different from the field in which they earned their original degree. For example, a physics PhD could be admitted to a doctoral degree program in music or history; however, a student with a doctoral degree in mathematics would not be permitted to add a PhD in statistics.

2. Applicants who hold the PhD degree may be admitted to a professional doctorate or professional master's degree program if there is no duplication of training involved.

Applicants may apply only to one single degree program or one concurrent degree program per admission cycle.

## Required Documents for Applications

1. **Transcripts:** Applicants may upload *unofficial* transcripts with your application for the departmental initial review. *If the applicant is admitted*, then *official* transcripts of all college-level work will be required. Official transcripts must be in sealed envelopes as issued by the school(s) attended. If you have attended Berkeley, upload your unofficial transcript with your application for the departmental initial review. *If you are admitted*, an official transcript with evidence of degree conferral *will not* be required.
2. **Letters of recommendation:** Applicants may request online letters of recommendation through the online application system. Hard copies of recommendation letters must be sent directly to the program, not the Graduate Division.
3. **Evidence of English language proficiency:** All applicants from countries or political entities in which the official language is not English are required to submit official evidence of English language proficiency. This applies to applicants from Bangladesh, Burma, Nepal, India, Pakistan, Latin America, the Middle East, the People's Republic of China, Taiwan, Japan, Korea, Southeast Asia, most European countries, and Quebec (Canada). However, applicants who, at the time of application, have already completed at least one year of full-time academic course work with grades of B or better at a US university may submit an official transcript from the US university to fulfill this requirement. The following courses will not fulfill this requirement:
  - courses in English as a Second Language,
  - courses conducted in a language other than English,
  - courses that will be completed after the application is submitted, and
  - courses of a non-academic nature.

If applicants have previously been denied admission to Berkeley on the basis of their English language proficiency, they must submit new test scores that meet the current minimum from one of the standardized tests. Official TOEFL score reports must be sent directly from Educational Test Services (ETS). The institution code for Berkeley is 4833. Official IELTS score reports must be mailed directly to our office from British Council. TOEFL and IELTS score reports are only valid for two years.

## Where to Apply

Visit the Berkeley Graduate Division application page (<http://grad.berkeley.edu/admissions/apply>).

## Admission to the Program

Applicants for the Computational Biology PhD are expected to have a strong foundation in the basic sciences (e.g., biology, mathematics, chemistry), in addition to training in computing/informatics/probability, significant programming experience, and substantial research experience. Typical students admitted to the program have demonstrated outstanding potential as a research scientist and have clear academic aptitude in multiple disciplines, as well as excellent communication skills. This is assessed based on research experience, grades, standardized

exams, course selection, essays, personal background, and letters of recommendation. Three letters of recommendation are required, as is the general GRE. A GRE subject examination in an appropriate area is recommended, but not required. The program does not accept applicants interested in a Master of Science in Computational Biology.

## Normative Time Requirements

### Normative Time to Advancement: Two years

#### Year 1

Students perform three laboratory rotations with the chief aim of identifying a research area and thesis laboratory. They also take courses to advance their knowledge in their area of expertise or fill in gaps in foundational knowledge. With guidance from the program, students are expected to complete six total graded courses by the end of the first or second year (not including the Doc Sem or Ethics course).

#### Year 2

Students attend seminars, prepare a dissertation prospectus, complete course requirements, and prepare for their PhD oral qualifying examination. With the successful passing of the orals, students select their thesis committee and advance to candidacy for the PhD degree.

### Normative Time in Candidacy: Three years

#### Years 3 to 5

Students undertake research for the PhD dissertation under a four-person committee in charge of their research and dissertation. Students conduct original laboratory research, and then write the dissertation based on the results of this research. On completion of the research and approval of the dissertation by the committee, the students are awarded the doctorate.

## Total Normative Time: 5-5.5 years

### Time to Advancement

#### Curriculum

##### Courses Required

CMPBIO 293	Doctoral Seminar in Computational Biology	2
CMPBIO 294A	Introduction to Research in Computational Biology (rotation units, Fall semester)	2-12
CMPBIO 294B	Introduction to Research in Computational Biology (rotation units, Spring semester)	2-12
STAT 200A	Introduction to Probability and Statistics at an Advanced Level	4
STAT 200B	Introduction to Probability and Statistics at an Advanced Level	4
COMPSCI 61A	The Structure and Interpretation of Computer Programs (or demonstrate they have completed the equivalent in another course; a syllabus is required for approval. Note: Students will need to complete CS61B and CS70 or the equivalent in order to enroll in upper division CS courses.)	4

CS 61A is a minimum requirement and students who demonstrate they have completed the equivalent in another course (via syllabus), can take an advanced CS course of their choosing.

Three additional courses, drawn from existing campus offerings. These courses are intended to resolve deficiencies in training and ensure competency in the fundamental knowledge of each discipline. Students are expected to develop a course plan for remaining program requirements (such as biology coursework) and any additional electives, and to consult with the Head Graduate Advisor before the Spring semester of their first year for formal approval (signature required). The course plan will take into account the student's undergraduate training areas and goals for PhD research areas. 12

#### MCELLBI 293C Responsible Conduct in Research 1

Complete an experimental training component in one of three ways: 1) complete a laboratory course at Berkeley (or equivalent) with a minimum grade of B, 2) complete a rotation in an experimental lab (w/ an experimental project), with a positive evaluation from the PI, 3) demonstrate proof of previous experience, such as: a biological sciences undergraduate major with at least two upper division laboratory-based courses, a semester or equivalent of supervised undergraduate experimental laboratory-based research at a university, or previous paid or volunteer/internship work in an industry-based experimental laboratory. Students will provide a brief summary of this experience to the Head Graduate Advisor for approval before taking the QE.

### Lab Rotations

Students conduct three 9-week laboratory rotations in the first year. The thesis lab, where dissertation research will take place, is chosen at the end of the third rotation in late April/early May.

### Qualifying Examination

The qualifying examination will evaluate a student's depth of knowledge in his or her research area, breadth of knowledge in fundamentals of computational biology, ability to formulate a research plan, and critical thinking. The QE prospectus will include a description of the specific research problem, but will serve as a framework for the QE committee members to probe the student's foundational knowledge in the field and area of research. Proposals will be written in the manner of a NIH-style grant proposal. The prospectus must be completed and submitted to the chair no fewer than four weeks prior to the oral qualifying examination. Students are expected to pass the qualifying examination by the end of the fourth semester in the program.

## Time in Candidacy

### Advancement

After passing the qualifying exam by the end of the second year, students have until the fifth semester to select a thesis committee and submit the Advancement to Candidacy paperwork to the Graduate Division.

### Dissertation

Primary dissertation research is conducted in years 3-5/5.5. Requirements for the dissertation are decided in consultation with the thesis adviser and thesis committee members. To this end, students are required to have yearly thesis committee meetings with the committee after advancing to candidacy.

## Dissertation Presentation/Finishing Talk

There is no formal defense of the completed dissertation; however, students are expected to publicly present a talk about their dissertation research in their final year.

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## Required Professional Development

### Presentations

All computational biology students are expected to attend the annual retreat, and will regularly present research talks there. They are also encouraged to attend national and international conferences to present research.

### Teaching

Computational biology students are required to teach two semesters, and may teach more. The requirement can be modified if the student has funding that does not allow teaching.

### Curriculum/Coursework

The DE curriculum consists of three courses, one each from the three broad areas listed below, which may be independent from or an integral part of a student's Associated Program, plus a year-long doctoral seminar in computational biology. Two of the three courses should be from departments other than the student's home program. *These requirements must be fulfilled with coursework taken with a grade of B or better while the student is enrolled as a graduate student at UC Berkeley. S/U graded courses do not count.* See below for recommended coursework.

Students must take the Comp Bio doctoral seminar leading up to the QE exam, but need not have completed all of the other course requirements prior to the application. The DE will be rescinded if coursework has not been completed upon graduation (students should report their progress each year to the DE advisor).

1. Computer Science and Engineering: A single course at the level of CS61A or higher will fulfill this requirement. Students with a more advanced background are recommended to take a higher level CS course to fulfill the requirement.
2. Biostatistics, Mathematics and Statistics: A single course at the level of Stat 133, 134, or 135 or higher will fulfill this requirement. Students with a more advanced background are recommended to take one of either Stat 200A & 200B or a higher level course to fulfill the requirement. Statistics or probability courses from other departments may be able to fulfill this requirement with prior approval of the program.
3. Biology: please select an appropriate biology course from the list on the website or petition program for alternative course.
4. Computational Biology: CMPBIO 293, Doctoral Seminar, Fall & Spring.

More information can be found on the CCB website (<http://ccb.berkeley.edu/academics/designated-emphasis>).

### Qualifying Examination and Dissertation

The qualifying examination and dissertation committees must include at least one, but preferably two, Core faculty members from the Computational Biology Graduate Group. The faculty member(s) may either represent the home department or serve as an outside member (Academic Senate Representative). The Qualifying Examination must include examination of knowledge within the area of Computational and

Genomic Biology. The Comp Bio Doctoral Seminar must be completed before the QE, as it will be important preparation for the exam.

### Seminars & Retreat

Students must attend the annual Computational Biology Retreat (generally held in November) as well as regular seminar series, or equivalent, as designated by the Curriculum Committee. Students are also strongly encouraged to attend or volunteer with program events during Orientation, Recruitment, Symposia, etc. Available travel funds will be dependent upon participation.

## Computational Biology

### CMPBIO C256A Human Genome, Environment and Human Health 3 Units

Terms offered: Spring 2017

This introductory course will cover basic principles of human/population genetics and molecular biology relevant to understanding how data from the human genome are being used to study disease and other health outcomes. The latest designs and methods for genome-wide association studies and other approaches to identify genetic variants, environmental risk factors and the combined effects of gene and environment important to disease and health will be presented. The application of biomarkers to define exposures and outcomes will be explored. The course will cover recent developments in genomics, epigenomics and other 'omics', including applications of the latest sequencing technology and characterization of the human microbiome.

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Human Genome, Environment and Human Health: Read More [-]

#### Rules & Requirements

**Prerequisites:** Introductory level biology course. Completion of introductory biostatistics and epidemiology courses strongly recommended and may be taken concurrently

#### Hours & Format

**Fall and/or spring:** 15 weeks - 3 hours of lecture per week

#### Additional Details

**Subject/Course Level:** Computational Biology/Graduate

**Grading:** Letter grade.

**Instructors:** Barcellos, Holland

**Also listed as:** PB HLTH C256A

Human Genome, Environment and Human Health: Read Less [-]

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Human Genome, Environment and Human Health: Read More [-]

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#### Hours & Format

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Human Genome, Environment and Human Health: [Read More \[+\]](#)

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Human Genome, Environment and Human Health: [Read Less \[-\]](#)

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Human Genome, Environment and Human Health: [Read More \[+\]](#)

### Rules & Requirements

**Prerequisites:** Introductory level biology course. Completion of introductory biostatistics and epidemiology courses strongly recommended and may be taken concurrently

### Hours & Format

**Fall and/or spring:** 15 weeks - 3 hours of lecture per week

### Additional Details

**Subject/Course Level:** Computational Biology/Graduate

**Grading:** Letter grade.

**Instructors:** Barcellos, Holland

**Also listed as:** PB HLTH C256A

Human Genome, Environment and Human Health: [Read Less \[-\]](#)

## CMPBIO C256B Genetic Analysis Method 3 Units

Terms offered: Not yet offered

This introductory course will provide hands-on experience with modern wet laboratory techniques and computer analysis tools for studies in molecular and genetic epidemiology and other areas of genomics in human health. Students will also participate in critical review of journal articles. Students are expected to understand basic principles of human/population genetics and molecular biology, latest designs and methods for genome-wide association studies and other approaches to identify genetic variants, environmental risk factors and the combined effects of gene and environment important to human health. Students will learn how to perform DNA extraction, polymerase chain reaction and methods for genotyping, sequencing, and cytogenetics.

Genetic Analysis Method: Read More [+]

### Rules & Requirements

**Prerequisites:** Introductory level biology course. Completion of introductory biostatistics and epidemiology courses strongly recommended and may be taken concurrently with permission. PH256A is a requirement for PH256B; they can be taken concurrently

### Hours & Format

**Fall and/or spring:** 15 weeks - 2-2 hours of lecture and 1-3 hours of laboratory per week

### Additional Details

**Subject/Course Level:** Computational Biology/Graduate

**Grading:** Letter grade.

**Instructors:** Barcellos, Holland

**Also listed as:** PB HLTH C256B

Genetic Analysis Method: Read Less [-]

## CMPBIO 290 Special Topics - Computational Biology 1 - 4 Units

Terms offered: Spring 2016, Spring 2015

A graduate seminar class in which students closely examine recent computational methods in molecular and systems biology, for example for modeling mechanisms related to the regulation of gene expression and/or high-throughput sequencing data. The course will focus on computational methodology but will also cover relevant and interesting biological applications.

Special Topics - Computational Biology: Read More [+]

### Rules & Requirements

**Prerequisites:** Graduate standing in EECS, MCB, Computational Biology or related fields; or consent of the instructor

**Repeat rules:** Course may be repeated for credit when topic changes.

### Hours & Format

**Fall and/or spring:** 15 weeks - 1-3 hours of lecture per week

### Additional Details

**Subject/Course Level:** Computational Biology/Graduate

**Grading:** Letter grade.

**Instructor:** Yosef

Special Topics - Computational Biology: Read Less [-]

## CMPBIO 293 Doctoral Seminar in Computational Biology 2 Units

Terms offered: Fall 2017, Spring 2017, Fall 2016

This one-year interactive seminar builds skills, knowledge and community in computational biology for first year PhD and second year Designated Emphasis students. Topics covered include concepts in human genetics/genomics, laboratory methodologies and data sources for computational biology, workshops/instruction on use of various bioinformatics tools, critical review of current research studies and computational methods, preparation for success in the PhD program and career development. Faculty members of the graduate program in computational biology and scientists from other institutions will participate. Topics will vary each semester.

Doctoral Seminar in Computational Biology: Read More [+]

### Hours & Format

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

### Additional Details

**Subject/Course Level:** Computational Biology/Graduate

**Grading:** Letter grade.

Doctoral Seminar in Computational Biology: Read Less [-]

## CMPBIO 294A Introduction to Research in Computational Biology 2 - 12 Units

Terms offered: Fall 2017, Fall 2016, Fall 2015

Closely supervised experimental or computational work under the direction of an individual faculty member; an introduction to methods and research approaches in particular areas of computational biology. Introduction to Research in Computational Biology: Read More [+]

### Rules & Requirements

**Prerequisites:** Standing as a Computational Biology graduate student

**Repeat rules:** Course may be repeated for credit.

### Hours & Format

**Fall and/or spring:** 15 weeks - 2-20 hours of laboratory per week

### Additional Details

**Subject/Course Level:** Computational Biology/Graduate

**Grading:** Letter grade.

Introduction to Research in Computational Biology: Read Less [-]

## CMPBIO 294B Introduction to Research in Computational Biology 2 - 12 Units

Terms offered: Spring 2017, Spring 2016, Spring 2015

Closely supervised experimental or computational work under the direction of an individual faculty member; an introduction to methods and research approaches in particular areas of computational biology. Introduction to Research in Computational Biology: Read More [+]

### Rules & Requirements

**Prerequisites:** Standing as a Computational Biology graduate student

**Repeat rules:** Course may be repeated for credit.

### Hours & Format

**Fall and/or spring:** 15 weeks - 2-20 hours of laboratory per week

### Additional Details

**Subject/Course Level:** Computational Biology/Graduate

**Grading:** Letter grade.

Introduction to Research in Computational Biology: Read Less [-]

## CMPBIO 295 Individual Research for Doctoral Students 1 - 12 Units

Terms offered: Summer 2017 10 Week Session, Spring 2017, Fall 2016  
Laboratory research, conferences. Individual research under the supervision of a faculty member.

Individual Research for Doctoral Students: Read More [+]

### Rules & Requirements

**Prerequisites:** Acceptance in the Computational Biology PhD program; consent of instructor

**Repeat rules:** Course may be repeated for credit.

### Hours & Format

**Fall and/or spring:** 15 weeks - 1-20 hours of laboratory per week

**Summer:** 10 weeks - 1.5-30 hours of laboratory per week

### Additional Details

**Subject/Course Level:** Computational Biology/Graduate

**Grading:** Letter grade.

Individual Research for Doctoral Students: Read Less [-]

## CMPBIO 477 Introduction to Programming for Bioinformatics Bootcamp 1.5 Unit

Terms offered: Prior to 2007

The goals of this course are to introduce students to Python, a simple and powerful programming language that is used for many applications, and to expose them to the practical bioinformatic utility of Python and programming in general. The course will allow students to apply programming to the problems that they face in the lab and to leave this course with a sufficiently generalized knowledge of programming (and the confidence to read the manuals) that they will be able to apply their skills to whatever projects they happen to be working on.

Introduction to Programming for Bioinformatics Bootcamp: Read More [+]

### Rules & Requirements

**Prerequisites:** This is a graduate course and upper level undergraduate students can only enroll with the consent of the instructor

### Hours & Format

**Summer:** 3 weeks - 40-40 hours of workshop per week

### Additional Details

**Subject/Course Level:** Computational Biology/Other professional

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Introduction to Programming for Bioinformatics Bootcamp: Read Less [-]