

COMPUTATIONAL BIOLOGY AND BIOMEDICAL INFORMATICS

100 College St., cbb-registrar@yale.edu

<http://cbb.yale.edu>

M.S., Ph.D.

Directors of Graduate Studies

Mark Gerstein (Bass 432A, 203.432.6105, cbb-dgs@yale.edu)

Steven Kleinstein (300 George St., Suite 505, 203.785.6685, cbb-dgs@yale.edu)

Professors Frederick Altice (*Internal Medicine; Infections Diseases; Epidemiology of Microbial Diseases*), Marcus Bosenberg (*Dermatology; Pathology*), Cynthia Brandt (*Emergency Medicine; Anesthesiology*), Joseph Chang (*Statistics and Data Science*), Kei-Hoi Cheung (*Emergency Medicine; Anesthesiology*), Ronald Coifman (*Mathematics; Computer Science*), Stephen Dellaporta (*Molecular, Cellular, and Developmental Biology*), Rong Fan (*Biomedical Engineering; Pathology*), Richard Flavell (*Immunobiology*), Joel Gelernter (*Psychiatry; Genetics*), Mark Gerstein (*Biomedical Informatics; Molecular Biophysics and Biochemistry; Computer Science; Statistics and Data Science*), Antonio Giraldez (*Genetics*), Jeffrey Gruen (*Genetics; Investigative Medicine; Pediatric*), Murat Gunel (*Neurosurgery; Genetics*), Ira Hall (*Genetics*), Amy Justice (*Internal Medicine; Public Health*), Naftali Kaminski (*Internal Medicine*), Steven Kleinstein (*Pathology; Immunobiology*), Yuval Kluger (*Pathology*), Harlan Krumholz (*Internal Medicine; Investigative Medicine; Public Health*), Haifan Lin (*Cell Biology; Genetics*), Shuangge (Steven) Ma (*Biostatistics*), Zongming Ma (*Statistics and Data Science*), Andrew Miranker (*Molecular Biophysics and Biochemistry; Chemical and Environmental Engineering*), James Noonan (*Genetics; Neuroscience*), Corey O'Hern (*Mechanical Engineering and Materials Science; Applied Physics; Physics*), Xenophon Papademetris (*Biomedical Informatics and Data Science; Radiology and Biomedical Imaging*), Lajos Pusztai (*Internal Medicine*), Anna Pyle (*Molecular, Cellular, and Developmental Biology; Chemistry*), David Stern (*Pathology*), Hemant Tagare (*Radiology and Biomedical Imaging; Biomedical Engineering*), Jeffrey Townsend (*Public Health; Ecology and Evolutionary Biology*), John Tsang (*Immunobiology*), Hua Xu (*Biomedical Informatics and Data Science*), Heping Zhang (*Biostatistics; Statistics and Data Science*), Hongyu Zhao (*Biostatistics; Statistics and Data Science*), Steven Zucker (*Computer Science; Electrical Engineering; Biomedical Engineering*)

Associate Professors Julien Berro (*Molecular Biophysics and Biochemistry*), Sidi Chen (*Genetics; Neurosurgery*), Forrest Crawford (*Biostatistics; Ecology and Evolutionary Biology*), Samah Jarad (*Emergency Medicine; Biostatistics*), Smita Krishnaswamy (*Genetics; Computer Science*), Bluma Lesch (*Genetics*), Jun Lu (*Genetics*), Ted Melnick (*Biostatistics; Emergency Medicine*), Kathryn Miller-Jensen (*Engineering and Applied Science*), John Murray (*Psychiatry; Neuroscience; Physics*), Renato Polimanti (*Psychiatry*), Edward Stites (*Laboratory Medicine*), Andrew Taylor (*Emergency Medicine*), Zuoheng (Anita) Wang (*Biostatistics*), Yize Zhao (*Biostatistics*)

Assistant Professors Arnaud Augert (*Pathology*), David Braun (*Medical Oncology*), Purushottam Dixit (*Biomedical Engineering*), Salil Garg (*Laboratory*)

Medicine; Pathology), Leying Guan (*Biostatistics*), Mary-Anne Hartley (*Biomedical Informatics and Data Science*), Albert Higgins-Chen (*Psychiatry; Pathology*), Jeffrey Ishizuka (*Internal Medicine; Medical Oncology; Pathology*), Rohan Khera (*Internal Medicine, Cardiovascular Medicine; EPH Biostatistics*), Monkol Lek (*Genetics*), Benjamin Machta (*Physics*), Robert McDougal (*Biostatistics*), Jacob Musser (*Molecular, Cellular, and Developmental Biology*), C. Brandon Ogbunu (*Ecology and Evolutionary Biology*), Carlos Oliveira (*Pediatrics; Infectious Diseases*), Steven Reilly (*Genetics*), Wade Schulz (*Laboratory Medicine*), Serena Tucci (*Anthropology*), David van Dijk (*Internal Medicine, Cardiology; Computer Science*), Rex Ying (*Computer Science*), Jack Zhang (*Molecular Biophysics and Biochemistry*)

FIELDS OF STUDY

Computational biology and biomedical informatics (CB&B) is a rapidly developing multidisciplinary field. The past two decades have witnessed a revolution in the biological and biomedical sciences driven by the development of technologies such as high-dimensional phenotypic profiling, next-generation sequencing, macromolecular structure determination and high-resolution imaging, wearable sensor devices, and large-scale electronic health records. These data-generation technologies demand new computational analysis approaches, which, in turn, have given rise to the field of computational biology and biomedical informatics (CB&B).

The Yale Computational Biology and Biomedical Informatics program combines research training opportunities in a range of different fields within the biological and biomedical sciences, in addition to the computational sciences, applied mathematics, statistics, and data science. The scope and balance of a student's program are highly individualized. Each student in the CB&B program develops, with the assistance of faculty advisers, a specific program of coursework, independent reading, and research that gives a depth of coverage and fits their background, interests, and career goals.

To enter the Ph.D. program, students apply to the CB&B Track within the interdepartmental graduate program in Biological and Biomedical Sciences (BBS), <https://medicine.yale.edu/bbs>.

INTEGRATED GRADUATE PROGRAM IN PHYSICAL AND ENGINEERING BIOLOGY (PEB)

Students applying to one of the tracks of the Biological and Biomedical Sciences program may simultaneously apply to be part of the PEB program. See the description under Non-Degree-Granting Programs, Councils, and Research Institutes for course requirements, and <http://peb.yale.edu> for more information about the benefits of this program and application instructions.

SPECIAL REQUIREMENTS FOR THE PH.D. DEGREE

With the help of a faculty advisory committee, each student plans a program that includes courses, seminars, laboratory rotations, and independent reading. Students are expected to gain competence in three core areas: (1) computational biology and biomedical informatics, (2) biological sciences, and (3) informatics (including computer science, applied mathematics, statistics, and data science). While the courses taken to satisfy the core areas of competency may vary considerably, all students are required to take the following courses: CB&B 740 and CB&B 752. CB&B requires

a minimum of ten course credits. Completion of the core curriculum will typically take three to four terms, depending in part on the prior training of the student. With approval of the CB&B director of graduate studies (DGS), students may take one or two undergraduate courses to satisfy areas of minimum expected competency. Students will typically take two to three courses each term and three research rotations (CB&B 711, CB&B 712, CB&B 713) during the first year. In addition to all other requirements, students must successfully complete CB&B 601, Fundamentals of Research: Responsible Conduct of Research, (or another course that covers the material) prior to the end of their first year of study. After the first year, students will start working in the laboratory of their Ph.D. thesis supervisor. Students must pass a qualifying examination normally given no later than the end of the third year. There is no foreign language requirement. Students will serve as teaching assistants in two terms. In their fourth year of study, all students must successfully complete B&BS 503, RCR Refresher for Senior BBS Students.

M.D.-PH.D. STUDENTS

Students pursuing the joint M.D.-Ph.D. degrees must satisfy the course requirements listed above for Ph.D. students. With approval of the DGS, some courses taken toward the M.D. degree can be counted toward the ten required course credits. Such courses must have a graduate course number, and the student must register for them as graduate courses (in which grades are received). Laboratory rotations are available but not required. One teaching assistantship is required.

MASTER'S DEGREE

Terminal Master's Degree Program Students can be admitted for a terminal M.S. degree in Computational Biology and Biomedical Informatics with the goal of gaining competency in three core areas: (1) computational biology and biomedical informatics, (2) biomedical sciences, (3) informatics (including computer science, applied mathematics, statistics, and data science). This is a two-year program. Students must complete nine courses at Yale, including at least three graduate CB&B courses (including CB&B 740 and CB&B 752), two graduate courses in the biological sciences, two graduate courses in areas of informatics, and two additional courses in any of the three core areas. In addition, M.S. students must take a one-term graduate seminar on research ethics and attend a CB&B seminar series. Finally, students must meet all of the Graduate School's requirements for the two-year terminal M.S. degree.

Terminal M.S. degree students are also expected to complete an M.S. project, write a research paper describing it, and defend the project in a seminar where they present the project and answer questions about the project as well as demonstrate breadth knowledge of their coursework and track of study. The paper is evaluated by the student's research supervisor and a second reader from the CB&B faculty. Students are expected to identify a faculty member to supervise the M.S. project by the end of the first year or early in the second year. Completion of the research paper is facilitated by enrolling in CB&B 650.

M.S. (en route to the Ph.D.) Students enrolled in the Ph.D. program may be awarded an M.S. degree en route as they satisfy the requirements for the Ph.D. degree. To qualify for the awarding of the en route M.S. degree a student must (1) complete two years (four terms) of study in the Ph.D. program; (2) complete the required

course work for the Ph.D. program, with ten required course credits taken at Yale including three successful research rotations; and (3) meet the Graduate School's grade requirements.