MOLECULAR, CELLULAR, AND DEVELOPMENTAL BIOLOGY

Yale Science Building, 203.432.3538
http://mcdb.yale.edu
M.S., Ph.D.

Chair
Vivian Irish

Director of Graduate Studies
Farren Isaacs

Professors Ronald Breaker, John Carlson, Lynn Cooley,* Craig Crews, Stephen Dellaporta, Thierry Emonet, Paul Forscher, Mark Hochstrasser,* Scott Holley, Valerie Horsley, Vivian Irish, Akiko Iwasaki,* Douglas Kankel, Paula Kavathas,* Haig Keshishian, Mark Mooseker, Anna Pyle, Hugh Taylor*

Associate Professors Damon Clark, Joshua Gendron, Megan King,* Farren Isaacs, Kathryn Miller-Jensen,* Weimin Zhong

Assistant Professors Shirin Bahmanyar, David Breslow, Nadya Dimitrova, Stavroura Hatzios, Yannick Jacob, Sigrid Nachtergaele, Michael O'Donnell, Josien van Wolfswinkel, Jing Yan

Lecturers Megan Bathgate,* Alexia Belperron, * Francine Carland, Surjit Chandhoke,* Iain Dawson, Seth Guller,* Amaleah Hartman, Ronit Kaufman, Rebecca LaCroix, Thomas Loreng, Maria Moreno, Kenneth Nelson, Aruna Pawashe,* Joseph Wolenski

* A secondary appointment with primary affiliation in another department or school.

FIELDS OF STUDY

Research in the Department of Molecular, Cellular, and Developmental Biology spans biology from the organismal to the molecular levels. Topics in genetics and molecular biology include studies of non-coding RNAs, genome engineering, genome organization and regulation, gene dosage, bacterial chemotaxis, oncogenes, and systems and synthetic biology. Research topics in cellular and developmental biology include structure and dynamics of the cell cytoskeleton, molecular motors, chemical biology, the nuclear envelope, lncRNAs, regeneration, developmental biomechanics, vertebral column development, stem cell biology, and systems developmental biology. Research in neurobiology focuses on growth cone motility, neural differentiation, synaptogenesis, visual perception, olfaction, and the formation of topographic maps. Research in the plant sciences provides training in the molecular genetics of flowering, meristematic activity, epigenetics, the physiology of hormone action, sex determination, and the circadian clock. Because of the breadth of the department, students are provided with unique training and research opportunities for interdisciplinary studies.

To enter the Ph.D. program, students apply to the Molecular Cell Biology, Genetics, and Development (MCGD) track; the Biochemistry, Quantitative Biology, Biophysics, and Structural Biology (BQBS) track; or the Plant Molecular Biology (PMB) 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 the MCGD or BQBS track 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**

Each student is expected to take at least three courses, in addition to MCDB 900/MCDB 901, Research Skills and Ethics I and II. With the help of a faculty committee, each student will plan a specific program that includes appropriate courses, seminars, laboratory rotations, and independent reading fitted to individual needs and career goals. There is no foreign language requirement. At the beginning of the third term of study, the student meets with a faculty committee to decide on a preliminary topic for dissertation work and to define the research areas in which the student is expected to demonstrate competence. By the end of the fall term of the second year, each student prepares a dissertation prospectus outlining the research proposed for the Ph.D. The student is admitted to candidacy for the Ph.D. when (1) the prospectus is accepted by a dissertation committee of faculty members, (2) the committee is satisfied that the student has demonstrated competence in the areas necessary to conduct the proposed work, and (3) the other requirements indicated above are fulfilled. The student should complete the requirements for admission to candidacy by the end of the fall term of the second year and no later than the end of the second year of study. Following admission to candidacy, students are required to meet with their thesis advisory committee at least once a year. The remaining requirements include completion of the dissertation research, presentation and defense of the dissertation, and submission of acceptable copies of the dissertation to the Graduate School and to the Marx Science and Social Science Library. All students are required to teach in two one-term courses during their Ph.D. study, but not during the first year of graduate study. Students who require additional support from the Graduate School must teach additional terms, if needed, after they have fulfilled the academic teaching requirement. Requirements for M.D./Ph.D. students are the same as for Ph.D. students, except that a single term of teaching is required. During their first year of study, students must successfully complete MCDB 900/MCDB 901, Research Skills and Ethics I and II, to fulfill the responsible conduct and ethics in research requirement. This requirement must be met prior to registering for a second year of study. Further, in the fourth year of study, all students must successfully complete B&BS 503, RCR Refresher for Senior BBS Students.

**HONORS REQUIREMENT**

Students must meet the Graduate School’s Honors requirement by the end of the fourth term of full-time study. (See Degree Requirements under Policies and Regulations.)
MASTER’S DEGREE

M.S. (en route to the Ph.D.) The minimum requirements for award of the Master of Science degree are (1) two academic years registered and in residence full-time in the graduate program; (2) satisfactory completion of the first two years of study and research leading to the Ph.D.; this requirement may be met either (a) by completing a minimum of five courses with an average grade of High Pass and at least one Honors grade, in addition to satisfactory performance in MCDB 900/MCDB 901, or (b) by (i) successfully completing at least three courses with an average grade of High Pass and at least one Honors grade, (ii) satisfactory performance in MCDB 900/MCDB 901, and (iii) passing the prospectus examination; (3) recommendation by the department for award of the degree, subject to final review and approval by the degree committee. No courses that were taken prior to matriculation in the graduate program, or in Yale College, or in summer programs may be applied toward these requirements.

Prospective applicants are encouraged to visit the BBS website (https://medicine.yale.edu/bbs), MCGD, BQBS, and PMB tracks.

COURSES

MCDB 500a or b / MB&B 500a or b, Biochemistry Ronald Breaker and Staff
An introduction to the biochemistry of animals, plants, and microorganisms, emphasizing the relations of chemical principles and structure to the evolution and regulation of living systems.

MCDB 517b / ENAS 517b / MB&B 517b / PHYS 517b, Methods and Logic in Interdisciplinary Research Corey O’Hern
This half-term PEB class is intended to introduce students to integrated approaches to research. Each week, the first of two sessions is student-led, while the second session is led by faculty with complementary expertise and discusses papers that use different approaches to the same topic (for example, physical and biological or experiment and theory). Counts as 0.5 credit toward graduate course requirements. ½ Course cr

MCDB 530a / IBIO 530a / MBIO 530a, Biology of the Immune System Eric Meffre, Carla Rothlin, David Schatz, Peter Cresswell, Jordan Poher, Joao Pereira, Craig Roy, Nikhil Joshi, Noah Palm, Kevan Herold, Carrie Lucas, and Ruslan Medzhitov
The development of the immune system. Cellular and molecular mechanisms of immune recognition. Effector responses against pathogens. Immunologic memory and vaccines. Human diseases including allergy, autoimmunity, cancer, immunodeficiency, HIV/AIDS.

MCDB 550a / C&MP 550a / ENAS 550a / PHAR 550a / PTB 550a, Physiological Systems W. Mark Saltzman and Stuart Campbell
The course develops a foundation in human physiology by examining the homeostasis of vital parameters within the body, and the biophysical properties of cells, tissues, and organs. Basic concepts in cell and membrane physiology are synthesized through exploring the function of skeletal, smooth, and cardiac muscle. The physical basis of blood flow, mechanisms of vascular exchange, cardiac performance, and regulation of overall circulatory function are discussed. Respiratory physiology explores the mechanics of ventilation, gas diffusion, and acid-base balance. Renal physiology examines the formation and composition of urine and the regulation of electrolyte, fluid, and acid-base balance. Organs of the digestive system are discussed from the
perspective of substrate metabolism and energy balance. Hormonal regulation is applied to metabolic control and to calcium, water, and electrolyte balance. The biology of nerve cells is addressed with emphasis on synaptic transmission and simple neuronal circuits within the central nervous system. The special senses are considered in the framework of sensory transduction. Weekly discussion sections provide a forum for in-depth exploration of topics. Graduate students evaluate research findings through literature review and weekly meetings with the instructor.

**MCDB 591a / ENAS 991a / MB&B 591a / PHYS 991a, Integrated Workshop**  Corey O’Hern

This required course for students in the PEB graduate program involves a series of modules, co-taught by faculty, in which students from different academic backgrounds and research skills collaborate on projects at the interface of physics, engineering, and biology. The modules cover a broad range of PEB research areas and skills. The course starts with an introduction to MATLAB, which is used throughout the course for analysis, simulations, and modeling.

**MCDB 595a, Intensive Research in MCDB for B.S./M.S. Candidates**  Valerie Horsley

A four-credit, yearlong course (two credits each term) that is similar to MCDB 495/496 and is taken during the senior year. During this course, students give an oral presentation describing their work. At the end of the course, students are expected to present their work to the department in the form of a poster presentation. In addition, students are expected to give an oral thesis defense, followed by a comprehensive examination of the thesis conducted by the thesis committee. Upon successful completion of this examination, as well as other requirements, the student is awarded the combined B.S./M.S. degree. Required of students in the joint B.S./M.S. program with Yale College.

**MCDB 602a / CBIO 602a / MB&B 602a, Molecular Cell Biology**  Thomas Melia and Patrick Lusk

A comprehensive introduction to the molecular and mechanistic aspects of cell biology for graduate students in all programs. Emphasizes fundamental issues of cellular organization, regulation, biogenesis, and function at the molecular level. Prerequisites: none, but some knowledge of basic cell biology and biochemistry is assumed. Students who have not taken courses in these areas can prepare by reading relevant sections in basic molecular cell biology texts. We recommend Pollard et al., *Cell Biology* (3rd ed., 2016), Alberts et al., *Molecular Biology of the Cell* (6th ed., 2014), or Lodish et al., *Molecular Cell Biology* (8th edition, 2016).

**MCDB 603a / CBIO 603a, Seminar in Molecular Cell Biology**  Megan King

A graduate-level seminar in modern cell biology. The class is devoted to the reading and critical evaluation of classical and current papers. The topics are coordinated with the CBIO 602 lecture schedule. Thus, concurrent enrollment in CBIO 602 is required.

**MCDB 625a / GENE 625a / MB&B 625a, Basic Concepts of Genetic Analysis**  Jun Lu

The universal principles of genetic analysis in eukaryotes are discussed in lectures. Students also read a small selection of primary papers illustrating the very best of genetic analysis and dissect them in detail in the discussion sections. While other Yale graduate molecular genetics courses emphasize molecular biology, this course focuses on the concepts and logic underlying modern genetic analysis.
MCDB 630b / MB&B 630b, Biochemical and Biophysical Approaches in Molecular and Cellular Biology  Karin Reinisch, Julien Berro, and J Patrick Loria
This course introduces the theory and application of biochemical and biophysical methods to study the structure and function of biological macromolecules. The course considers the basic physical chemistry required in cellular and molecular biology but does not require a previous course in physical chemistry. One class per week is a lecture introducing a topic. The second class is a discussion of one or two research papers utilizing those methods. Does not count for graduate course credit for BQBS graduate students.

MCDB 677b / GENE 777b, Mechanisms of Development  Zhaoxia Sun
An advanced seminar on animal development focusing on conserved mechanisms during germline development, embryogenesis, and somatic differentiation in molecular details. The relationship between development and disease is also emphasized. The course format is one class comprised of a lecture and a paper discussion per week. Course work includes student participation in critical analysis of primary literature and biweekly take-home problems. Extensive class participation, especially in the discussion, is required. The course grade is based on 60 percent take-home problems and 40 percent class participation. There are no official prerequisites. However, some familiarity with concepts and techniques of modern biology is necessary to get the most out of the course.

MCDB 680a, Advances in Plant Molecular Biology  Yannick Jacob, Josh Gendron, and Vivian Irish
The study of basic processes in plant growth and development to provide a foundation for addressing critical agricultural needs in response to a changing climate. Topics include the latest breakthroughs in plant sciences with emphasis on molecular, cellular, and developmental biology; biotic and abiotic plant interactions; development, genomics, proteomics, epigenetics, and chemical biology in the context of plant biology; and the current societal debates about agrobiotechnology.

MCDB 720a / INP 720a, Neurobiology  Haig Keshishian and Paul Forscher
Examination of the excitability of the nerve cell membrane as a starting point for the study of molecular, cellular, and intracellular mechanisms underlying the generation and control of behavior.

MCDB 743b / GENE 743b / MB&B 743b, Advanced Eukaryotic Molecular Biology  Mark Hochstrasser, Wendy Gilbert, and Matthew Simon
Selected topics in transcriptional control, regulation of chromatin structure, mRNA processing including spliceosomal splicing, mRNA turnover, RNA interference, translational regulation, protein modification, and protein degradation. Emphasis is placed on how these processes are regulated and the experiments that led to their discovery and understanding. Prerequisite: biochemistry or permission of the instructor.

MCDB 752b / CB&B 752b / CPSC 752b / MB&B 752b and MB&B 753b and MB&B 754b / MB&B 753b and MB&B 754b / MB&B 754b, Biomedical Data Science: Mining and Modeling  Mark Gerstein
Biomedical data science encompasses the analysis of gene sequences, macromolecular structures, and functional genomics data on a large scale. It represents a major practical application for modern techniques in data mining and simulation. Specific topics
to be covered include sequence alignment, large-scale processing, next-generation sequencing data, comparative genomics, phylogenetics, biological database design, geometric analysis of protein structure, molecular-dynamics simulation, biological networks, normalization of microarray data, mining of functional genomics data sets, and machine-learning approaches to data integration. Prerequisites: biochemistry and calculus, or permission of the instructor.

**MCDB 900a / CBIO 900a / GENE 900a, Research Skills and Ethics I**  
Shirin Bahmanyar

This course consists of a weekly seminar that covers ethics, writing, and research methods in cellular and molecular biology as well as student presentations (“rotation talks”) of work completed in the first and second laboratory rotations.

**MCDB 911a / CBIO 911a / GENE 911a, First Laboratory Rotation**  
Shirin Bahmanyar

First laboratory rotation for Molecular Cell Biology, Genetics, and Development track students.

**MCDB 912a / CBIO 912a / GENE 912a, Second Laboratory Rotation**  
Shirin Bahmanyar

Second laboratory rotation for Molecular Cell Biology, Genetics, and Development track students.

**MCDB 950a, Second-Year Research**  
Staff

By arrangement with faculty.