GENETICS

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http://medicine.yale.edu/genetics
M.S., M.Phil., Ph.D.

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Associate Professors Kaya Bilguvar, Sidi Chen, Daniel Greif (Internal Medicine/Cardiology), Marc Hammarlund, Smita Krishnaswamy, Peining Li, Janghoo Lim, Jun Lu, Stefania Nicoli (Internal Medicine/Cardiology), Sabrina Nunez, In-Hyun Park, Curt Scharfe, Zhaoxia Sun, Andrew Xiao, Hui Zhang

Assistant Professors Grace Chen (Immunobiology) Nada Derar, Nadya Dimitrova (Molecular, Cellular, and Developmental Biology), Rama Kastury, Monkol Lek, Bluma Lesch, Duyendo Massilani, Mandar Muzumdar, Steven Reilly, Jason Sheltzer (Surgery/Oncology) Zachary Smith, Trevor Sorrells, Berna Sozen, Michele Spencer-Manzon, Kaelyn Sumigray, Siyuan Wang, Frederick Wilson (Internal Medicine/Oncology)

FIELDS OF STUDY

Molecular Genetics: chromosome structure and function, genetic recombination, viral genetics, DNA damage repair, ribosome biogenesis, protein folding, neurodegenerative diseases, non-coding RNA function, and the regulation of gene expression. Genomics: genome mapping, genome modification, high-throughput technology, evolutionary genetics, and functional genomics. Cellular and Developmental Genetics: limb development, kidney development, cilia function, stem cell development, genetic control of the cytoskeleton, cell death, aging, cell fate determination, cell cycle progression, cell migration, cell signaling, and growth control. Cancer Genetics: oncogenesis and tumor suppression, tumor progression and metastasis. Model Organism Genetics: forward genetic screens in Drosophila, C. elegans, yeast, zebrafish,
frogs, and mouse, transposon and insertional mutagenesis, gene and protein trapping, mosaic genetics. Medical Genetics: genetic basis of human disease, chromosome rearrangements, population and quantitative genetics.

To enter the Ph.D. program, students apply to the Molecular Cell Biology, Genetics, and Development (MCGD) track within the interdepartmental graduate program in Biological and Biomedical Sciences (BBS), https://medicine.yale.edu/bbs.

SPECIAL REQUIREMENTS FOR THE PH.D. DEGREE

The Ph.D. program in Genetics is designed to provide the student with a broad background in general genetics and the opportunity to conduct original research in a specific area of genetics. The student is expected to acquire a broad understanding of genetics, spanning knowledge of at least three basic areas of genetics, which include molecular, cellular, organismal, and population genetics. Normally this requirement is accomplished through the satisfactory completion of formal courses, many of which cover more than one of these areas. Students are required to pass at least five graduate-level courses that are taken for a grade. Advanced graduate study becomes increasingly focused on the successful completion of original research and the preparation of a written dissertation under the direct supervision of a faculty adviser along with the guidance of a thesis committee.

A qualifying examination is given during the second year of study. This examination consists of a period of directed reading with the faculty followed by the submission of two written proposals and an oral examination. Following the completion of course work and the qualifying examination, the student submits a dissertation prospectus and is admitted to candidacy for the Ph.D.!degree. There is no language requirement. An important aspect of graduate training in genetics is the acquisition of communication and teaching skills. Students participate in presentation seminars and two terms (or the equivalent) of teaching. Teaching activities are drawn from a diverse menu of lecture, laboratory, and seminar courses given at the undergraduate, graduate, and medical school levels. Students are not expected to teach during their first year. In addition to all other requirements, students must successfully complete GENE 900 and GENE 901, Research Skills and Ethics I and II, prior to the end of their first year of study. In their fourth year of study, all students must successfully complete B&BS 503, RCR Refresher for Senior BBS Students. Students will typically take two to three courses each term and three research rotations (GENE 911, GENE 912, GENE 913) during the first year.

HONORS REQUIREMENT

Students must meet the Graduate School’s Honors requirement by the end of the fourth term of full-time study.

M.D./PH.D. STUDENTS

M.D./Ph.D. students affiliate with the Department of Genetics graduate program via a different route than other incoming graduate students in the department, resulting in some modification of the academic requirements for the Ph.D. portion of the M.D./Ph.D. degree. Typically, one or more research rotations are done during the first two years of medical school (in many cases, the first rotation is done during the summer between years one and two). No set number of research rotations is required. M.D./Ph.D. students officially affiliate with the Department of Genetics after selecting a
thesis adviser and consulting with the director of graduate studies (DGS). M.D./Ph.D. students interested in Genetics are required to consult with the DGS prior to formal affiliation to determine an appropriate set of courses tailored to the student’s background and interests.

The courses, rotations, and teaching requirements for M.D./Ph.D. students entering the Genetics graduate program (see below) are modified from the normal requirements for Ph.D. students. Besides the modifications in these three requirements, M.D./Ph.D. students in the Department of Genetics are subject to all of the same requirements as the other graduate students in the department.

**Courses** Four graduate-level courses taken for a grade are required. (Two Yale graduate-level courses taken for a grade during medical school may be counted toward this requirement at the discretion of the DGS.) Course work is aimed at providing a firm basis in genetics and in cellular molecular mechanisms, with graduate-level proficiency in genetics, cell biology, and biochemistry.

*Required courses:* In addition to the four graduate-level courses, all M.D./Ph.D. students must take: Graduate Student Seminar: Critical Analysis and Presentation of Scientific Literature (2 terms; GENE 675 and GENE 676, graded Satisfactory/Unsatisfactory); Responsible Conduct of Research (B&BS 501, graded Satisfactory/Unsatisfactory); and, in their fifth year of study, RCR Refresher for Senior BBS Students (B&BS 503).

*Recommended courses:* Advanced Eukaryotic Molecular Biology (GENE 743); Biochemical and Biophysical Approaches in Molecular and Cellular Biology (MCDB 630); Molecules to Systems (CBIO 502); Science at the Frontiers of Medicine (CBIO 601).

*Electives:* Other courses may be taken in a wide variety of fields relevant to the biological and biomedical sciences.

**Laboratory rotations** One or more rotations are necessary to identify a thesis adviser. No set number of research rotations is required.

**Teaching** One term of teaching is required. Previous teaching while enrolled at the Yale School of Medicine may count toward this requirement at the discretion of the DGS.

**Qualifying exam** M.D./Ph.D. students take their qualifying exam in the term following the completion of their course work. The structure of the qualifying exam is identical to that for other Ph.D. students in Genetics. Students read with three faculty members for five weeks, one of whom supervises the reading on the thesis research topic, but who is not the thesis adviser. The following two weeks are devoted to writing two research proposals, one on the student’s thesis research. An oral exam follows in the eighth week.

**Prospectus** M.D./Ph.D. students submit their prospectus once their qualifying exam has been completed, but no later than the 30th of June following their exam.

**Candidacy** M.D./Ph.D. students will be admitted to candidacy once they have completed their course work, obtained two Honors grades, passed their qualifying exam, and submitted their dissertation prospectus.
Thesis committee M.D./Ph.D. students are required to have one thesis committee meeting per year, beginning the term after passing their qualifying exam. However, students are strongly encouraged to consider having additional meetings if they feel their project could benefit from the assistance of members of the thesis committee.

MASTER’S DEGREES

M.Phil. See Degree Requirements under Policies and Regulations.

M.S. Students are not admitted for this degree. They may receive this recognition if they leave Yale without completing the qualifying exam but have satisfied the course requirements as described above, as well as the Graduate School’s Honors requirement. Students who are eligible for or who have already received the M.Phil. will not be awarded the M.S.

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

COURSES

GENE 555a / AMTH 553a / CB&B 555a / CPSC 553a, Unsupervised Learning for Big Data Staff
This course focuses on machine-learning methods well-suited to tackling problems associated with analyzing high-dimensional, high-throughput noisy data including: manifold learning, graph signal processing, nonlinear dimensionality reduction, clustering, and information theory. Though the class goes over some biomedical applications, such methods can be applied in any field. Prerequisites: knowledge of linear algebra and Python programming.

GENE 625a / MB&B 625a / MCDB 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.

GENE 655a or b / CBIO 655a or b, Stem Cells: Biology and Application In-Hyun Park
This course is designed for first-year or second-year students to learn the fundamentals of stem cell biology and to gain familiarity with current research in the field. The course is presented in a lecture and discussion format based on primary literature. Topics include stem cell concepts, methodologies for stem cell research, embryonic stem cells, adult stem cells, cloning and stem cell reprogramming, and clinical applications of stem cell research. Prerequisites: undergraduate-level cell biology, molecular biology, and genetics.

GENE 675a and GENE 676b, Graduate Student Seminar: Critical Analysis and Presentation of Scientific Literature Mandar Muzumdar and Siyuan Wang
Students gain experience in preparing and delivering seminars and in discussing presentations by other students. A variety of topics in molecular, cellular, developmental, and population genetics are covered. Required of all second-year students in Genetics. Graded Satisfactory/Unsatisfactory.
GENE 734b / MB&B 734b / MBIO 734b, Molecular Biology of Animal Viruses  
Brett Lindenbach
Lecture course with emphasis on mechanisms of viral replication, oncogenic transformation, and virus-host cell interactions.

GENE 743b / MB&B 743b / MCDB 743b, Advanced Eukaryotic Molecular Biology  
Mark Hochstrasser, Wendy Gilbert, Matthew Simon, and Franziska Bleichert
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.

GENE 760b, Genomic Methods for Genetic Analysis  
Steven Reilly and Bluma Lesch
Introduction to the analysis and interpretation of genomic datasets. The focus is on next-generation sequencing (NGS) applications including RNA-seq, ChIP-seq, and exome and whole genome sequencing. By the end of the course, each student will be able to process and analyze large-scale NGS datasets and interpret the results. This course is intended only for graduate students who are interested in applying genomic approaches in their thesis research. At a minimum, students must have basic familiarity with working in a UNIX/Linux computing environment. Prior experience with shell scripting or a scripting language such as Perl, Python, or Ruby is strongly recommended. Interested students must contact the instructor early in the fall term to discuss their prior experience and expectations for the course. Enrollment limited to twenty. Prerequisite: permission of the instructor.

GENE 777b / MCDB 677b, Mechanisms of Development  
Kaelyn Sumigray and Zachary Smith
An advanced graduate seminar on animal development focusing on conserved mechanisms that govern germline development, embryogenesis, and somatic differentiation in molecular detail. The course runs in parallel to the Spring session of the Department of Genetics Seminar Series and is divided into two components: six Yale faculty-led lectures on core concepts in development and six combined journal club/student-led discussions with outside developmental biology speakers on their cutting-edge research. Over the course of the term, small student groups are responsible for presenting one journal club-formatted discussion on two papers selected from the outside speaker’s lab, as well as emceeing a dedicated question and answer session between the class and the speaker. This course provides a rare opportunity for students to actively engage with world leaders on their work in developmental genetics, epigenetics, and cell biology, as well as learn essential skills in experimental thinking and scientific communication. The course grade is based on forty percent take-home problems, forty percent class participation and twenty percent student-led journal club / distinguished speaker question and answer session. 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.
GENE 901b / CBIO 901b / MCDB 901b, Research Skills and Ethics II  Chenxiang Lin
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 third laboratory rotation.

GENE 911a / CBIO 911a / MCDB 911a, First Laboratory Rotation  Chenxiang Lin
First laboratory rotation for Molecular Cell Biology, Genetics, and Development (MCGD) and Plant Molecular Biology (PMB) track students.

GENE 912a / CBIO 912a / MCDB 912a, Second Laboratory Rotation  Staff
Second laboratory rotation for Molecular Cell Biology, Genetics, and Development (MCGD) and Plant Molecular Biology (PMB) track students.

GENE 913b / CBIO 913b / MCDB 913b, Third Laboratory Rotation  Shirin Bahmanyar
Third laboratory rotation for Molecular Cell Biology, Genetics, and Development (MCGD) and Plant Molecular Biology (PMB) track students.