PHARMACOLOGY

Sterling Hall of Medicine B316, 203.785.7469
http://medicine.yale.edu/pharm
M.S., M.Phil., Ph.D.

Chair
Joseph Schlessinger

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Professors

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Titus Boggon, David Calderwood, Kathryn Ferguson, Ya Ha, Benjamin Turk

Assistant Professors
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FIELDS OF STUDY
Major emphases in the department are in the areas of molecular pharmacology, mechanisms of drug action, signal transduction, structural biology, neuropharmacology, and chemotherapy.

To enter the Ph.D. program, students should apply to an interest-based track within the interdepartmental graduate program in Biological and Biomedical Sciences (BBS), https://medicine.yale.edu/bbs. Most students interested in a Ph.D. in Pharmacology apply through the Molecular Medicine, Pharmacology, and Physiology (MMPP) track or the Biochemistry, Quantitative Biology, Biophysics, and Structural Biology (BQBS) track.

SPECIAL REQUIREMENTS FOR THE PH.D. DEGREE
Because the field of pharmacology encompasses many disciplines, the department’s flexible program of study toward the Ph.D. degree permits students to concentrate in areas of their particular interest. Students must take both terms of the graduate seminar course (PHAR 501 and PHAR 502) or equivalents from another department. The other courses will be selected based on each student's interest but must include at least one of the following courses: PHAR 504, PHAR 528, and PHAR 529. Students are required to do three laboratory rotations. The Graduate School requires a grade of Honors for a minimum of two courses. Honors for rotations cannot be used toward this requirement. Students must meet the Honors requirement prior to being admitted to candidacy. Students must pass a total of five courses and maintain an overall High Pass average. A grade of Honors or High Pass is required for the core Pharmacology courses. Student progress toward these goals is reviewed at the end of the second term.

Prior to registering for a second year of study, students must successfully complete PHAR 580, The Responsible Conduct of Research, or the equivalent from another department. In addition, B&BS 503, RCR Refresher for Senior BBS Students, must be completed by the end of the fourth year.

Students are also required to pass the qualifying examination by the end of their fourth term. Before the end of the third year, a thesis prospectus must be submitted and accepted for admission to candidacy. A doctoral dissertation based upon original research includes an oral presentation given only to the pharmacology faculty (pre-defense). Within six months of passing the pre-defense, the student must submit a preliminary written thesis to the thesis committee and an outside reader. A public Ph.D. dissertation seminar will be scheduled, followed by a closed examination by the thesis committee and the outside examiner. Once the draft of the written thesis is approved by the thesis committee, it is submitted to the Graduate School. One first-author manuscript is required from the thesis research. The Pharmacology faculty recognizes that some thesis-related work takes a longer time and may not yield anticipated results. As long as the student has made significant progress in parallel experiments, the faculty can exempt a student from the one first-author paper requirement.

An important aspect of graduate training in pharmacology is the acquisition of teaching skills through the participation in courses related to the student’s scientific interests. These opportunities can be drawn from a diverse menu of lecture, laboratory, and seminar courses given at the undergraduate, graduate, and medical school levels. Ph.D. students are required to participate in two terms (or the equivalent) of teaching. Students are not expected to teach during their first year.

M.D./PH.D. STUDENTS
M.D./Ph.D. students must satisfy all of the above requirements for the Ph.D. with the following modifications: (1) only two of three laboratory rotations are required; (2) some medical school courses (except Pharmacology) can qualify as Graduate School courses as long
as the M.D./Ph.D. student registers for them in OCS (Online Course Selection); and (3) only one term of teaching is required. Current Graduate School courses cannot be used to fulfill any medical school course requirements.

**MASTER’S DEGREES**

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

M.S. (en route to the Ph.D.) Students are eligible for the M.S. degree upon successful completion of the first three terms of the Ph.D. program. This includes one year of lab rotations and course requirements.

Program materials are available upon request to the Director of Graduate Studies, Department of Pharmacology, Yale University, PO Box 208066, New Haven CT 06520-8066.

**COURSES**

**PHAR 501a and PHAR 502b / C&MP 629a and C&MP 630b / PATH 679a and PATH 680b, Seminar in Molecular Medicine, Pharmacology, and Physiology** Susumu Tomita, Titus Boggon, and Don Nguyen
Readings and discussion on a diverse range of current topics in molecular medicine, pharmacology, and physiology. The class emphasizes analysis of primary research literature and development of presentation and writing skills. Contemporary articles are assigned on a related topic every week, and a student leads discussions with input from faculty who are experts in the topic area. The overall goal is to cover a specific topic of medical relevance (e.g., cancer, neurodegeneration) from the perspective of three primary disciplines (i.e., physiology: normal function; pathology: abnormal function; and pharmacology: intervention). Required of and open only to Ph.D. and M.D./Ph.D. students in the Molecular Medicine, Pharmacology, and Physiology track.

**PHAR 504a, Molecular Mechanisms of Drug Actions** Elias Lolis
This course covers the molecular mechanisms of therapeutics, which are presented in a conceptual framework to increase understanding but decrease memorization. Topics include (but are not limited to) receptor affinity, efficacy, multiple equilibria, pharmacokinetics, and toxicity; enzyme kinetics and inhibition, drug discovery and design; molecular basis of antimicrobial therapy, cardiology drugs, anticancer and antiviral therapies; and therapeutics for inflammatory disorders, asthma, and allergy.

**PHAR 528b, Principles of Signal Transduction** Anton Bennett
The regulation of intracellular signaling is of fundamental importance to the understanding of cell function and regulation. This course introduces the broad principles of intracellular signal transduction. More detailed lectures on specific intracellular signaling pathways are given in which students learn both the basic and most recent and cutting-edge concepts of intracellular signaling. Topics include regulation of signaling by protein phosphorylation, small G proteins, G-protein-coupled receptors, hormones, phospholipids, adhesion, and gases.

**PHAR 529b / MB&B 529b, Structural Biology and Drug Discovery** Titus Boggon and Ya Ha
A comprehensive introduction to the concepts and practical uses of structural biology and structural biology-related techniques in drug discovery. The first half of the course focuses on techniques used to discover and optimize small and macromolecule drugs. Students are introduced to topics such as small molecule lead discovery, X-ray crystallography, cryo-electron microscopy, and biophysical techniques. The first half of the course also includes a practical component where students conduct hands-on structural biology experiments and learn about biophysical techniques in a laboratory setting. The second half of the course focuses on drug discovery, particularly for protein kinases. It includes a field trip to the Yale Center for Drug Discovery, where the students are introduced to the in-house Yale screening facilities for small molecule drug discovery. Two half-credit courses—PHAR 530 and PHAR 531—are also offered for the two halves of PHAR 529.

**PHAR 530b, Targeted Use of Structural Biology in Drug Discovery** Titus Boggon and Ya Ha
This 0.5-credit course, the second half of PHAR 529, begins in February. The goal of the course is to show students how concepts of structural biology are applied to areas of great importance in pharmacology such as protein kinases, proteases, cell surface receptors, integrins and other membrane-bound enzymes, and transporters and channels, and how these concepts facilitate drug development. ½ Course cr

**PHAR 531b, Concepts of Structural Pharmacology** Titus Boggon and Ya Ha
This 0.5-credit course, the first half of PHAR 529, introduces students to the concepts of structural biology and provides the background for how these concepts are applied to areas of great importance in pharmacology and how they facilitate drug development. ½ Course cr

**PHAR 537b, Systems Pharmacology and Integrated Therapeutics** Kathryn Ferguson
The goal of this course is to provide an in-depth, “hands-on” experience in drug design, drug discovery, high-throughput screening, state-of-the-art proteomics, and target validation.

**PHAR 550a / C&MP 550a / ENAS 550a / MCDB 550a, Physiological Systems** Stuart Campbell and W. Mark Saltzman
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
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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.

PHAR 560b / C&MP 560b / ENAS 570b / MCDB 560b, Cellular and Molecular Physiology: Molecular Machines in Human Disease
Emile Boulpaep
The course focuses on understanding the processes that transfer molecules across membranes at the cellular, molecular, biophysical, and physiological levels. Students learn about the different classes of molecular machines that mediate membrane transport, generate electrical currents, or perform mechanical displacement. Emphasis is placed on the relationship between the molecular structures of membrane proteins and their individual functions. The interactions among transport proteins in determining the physiological behaviors of cells and tissues are also stressed. Molecular motors are introduced and their mechanical relationship to cell function is explored. Students read papers from the scientific literature that establish the connections between mutations in genes encoding membrane proteins and a wide variety of human genetic diseases.

PHAR 580b / C&MP 650b / PATH 660b, The Responsible Conduct of Research
Barbara Ehrlich
Organized to foster discussion, the course is taught by faculty in the Pharmacology, Pathology, and Physiology departments and two or three senior graduate students. Each session is based on case studies from primary literature, reviews, and two texts: Francis Macrina's Scientific Integrity and Kathy Barker's At the Bench. Each week, students are required to submit a reaction paper discussing the reading assignment. Students take turns leading the class discussion; a final short paper on a hot topic in bioethics is required.