

BBS COURSE GUIDE

Yale University

**A comprehensive listing of graduate level courses affiliated with the
Yale Combined Program in the Biological & Biomedical Sciences**

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YALE
BBS Combined Program in the
Biological & Biomedical Sciences

This guide contains all courses offered by the 12 Ph.D. programs affiliated with the Yale BBS Program. Courses with an “a” in the course number are offered in the fall semester. Courses with a “b” in the course number are offered in the spring semester. Some courses are offered only every other year and are noted as such. Some courses are limited to students in special programs and are noted as such

Visit the Online Course Information system at <http://students.yale.edu/oci/search.jsp> to find course times, dates, and locations.

CELL BIOLOGY

<http://cellbiology.yale.edu/graduate/courses.aspx#page4>

CBIO 502a/b, Molecules to Systems

This full-year course is designed to provide medical students with a current and comprehensive review of biologic structure and function at the cellular, tissue, and organ system levels. Areas covered in the first term include replication and transcription of the genome; regulation of the cell cycle and mitosis; protein biosynthesis and membrane targeting; cell motility and the cytoskeleton; signal transduction; nerve and muscle function. The second term covers cell and tissue organization of organ systems including respiratory, renal, gastrointestinal, endocrine, and reproductive systems. Clinical correlation sessions, which illustrate the contributions of cell biology to specific medical problems, are interspersed in the lecture schedule. Histophysiology laboratories provide practical experience with an understanding of exploring cell and tissue structure. The course is offered only to M.D. and M.D./Ph.D. students. It runs from September to mid-May and is equivalent to three graduate credits.

CBIO 601a/b, Molecular and Cellular Basis of Human Disease

The course emphasizes the connections between diseases and basic science using a lecture and seminar format. It is designed for students who are committed to a career in medical research, those who are considering such a career, or students who wish to explore scientific topics in depth. The first half of the course is organized in four- to five-week blocks that typically parallel CBIO 502a/b. Examples of blocks from past years include “Diseases of protein folding” and “Diseases of ion channels.” Each topic is introduced with a lecture given by the faculty. The lecture is followed by sessions in which students review relevant manuscripts under the supervision of a faculty mentor. The second half of the course focuses on the relationship of basic science to disease processes while emphasizing translational and clinical research. In addition, sessions are devoted to academic careers and cover subjects such as obtaining an academic position, promotions, and grant writing. The course is open to M.D. and M.D./Ph.D. students who are taking or have taken CBIO 502a/b. Student evaluations are based on attendance, participation in group discussions, formal presentations, and a written review of an NIH proposal. The course runs from September to mid-May and is equivalent to three graduate credits.

CBIO 602a/MB&B 602a/MCDB 602a, Molecular Cell Biology

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.

CBIO 603a/MCDB 603a, Seminar in Molecular Cell Biology

A graduate-level seminar course 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 602a lecture schedule. Thus, concurrent enrollment in CBIO 602a is required.

CBIO 604b, Systems Cell Biology

Introduction to the organization and function of cells within complex multicellular systems as encountered in the human body. Covers major tissues and organs as well as the cardiovascular, immune, and nervous systems, with special emphasis on the molecular and cellular bases of developmental processes and human diseases. Lectures supplemented by electronic-based tutorials on the histology of tissues and organs.

CBIO 606b, Advanced Topics in Cell Biology

This seminar course, which meets once weekly, covers advanced topics in cell biology. Each topic is spread over two or three sessions, which start with an introductory overview and are followed by a discussion of key papers led by an expert in the field. Special emphasis is given to application of state-of-the-art imaging techniques to topical areas covering a wide range of contemporary cell biology.

CBIO 611b, Vascular Cell Biology

This course introduces the structure and organ-level physiology of the vascular system, then covers in greater depth the development, regulation, mechanics, and pathology of blood vessels. The major focus is on cellular and molecular mechanisms. The course includes both lectures and reading and discussion of recent literature.

CBIO 655a/GENE 655a, Stem Cells: Biology and Application

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.

CBIO 701b, Illuminating Cellular Function

Introduction to the principles and practical methods of live cell imaging. Covers principles of fluorescent microscopy (including genetically encoded probes and physiological indicators), image formation, image detection, and image analysis. Includes hands-on demonstrations of state-of-the-art instrumentation, such as video-rate confocal and multi-photon microscopes.

CBIO 900a/GENE 900a/MCDB 900a, First-Year Introduction to Research and Rotations

Scientific writing and laboratory rotation talks for Molecular Cell Biology, Genetics, and Development track students.

CBIO 901b/GENE 901b/MCDB 901b, First-Year Introduction to Research—Ethics: Scientific Integrity in Biomedical Research

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

CBIO 903a or b, Reading Course in Cell Biology

Independent study of specific topics in cell biology through directed reading of the literature under faculty supervision. Student may choose any topic and any Yale faculty subject to approval by the Cell Biology DGS. Open to Cell Biology students, and to students in other departments with approval from their respective DGS. Term paper required.

CBIO 911a/GENE 911a/MCDB 911a, First Laboratory Rotation

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

CBIO 912b/GENE 912b/MCDB 912b, Second Laboratory Rotation

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

CBIO 913b/GENE 913b/MCDB 913b, Third Laboratory Rotation

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

CELLULAR AND MOLECULAR PHYSIOLOGY

<http://physiology.yale.edu/education/courses.aspx>

C&MP 550a/ENAS 550a/MCDB 550a/PHAR 550a, Physiological Systems

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.

C&MP 560b/ENAS 570b/MCDB 560b/PHAR 560b, Cellular and Molecular Physiology: Molecular Machines in Human Disease

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.

C&MP 570b/NBIO 570b, Sensory Physiology

The course provides an overview of the mammalian special sensory systems, including molecular and cellular bases of vision, audition, taste, olfaction, and somatosensation. Faculty with focus in those areas lead presentations and discussions on peripheral and central mechanisms. Psychophysical aspects of sensation are introduced.

C&MP 600, Medical Physiology Case Conferences (open only to MD/PhD & MRSP students)

Two-term course taught in groups of ten to twelve students by the same group leader(s) throughout the year. Workshop format permits students to apply basic concepts of physiology to clinical syndromes and disease processes. Students are expected to participate actively in a weekly discussion of a clinical case that illustrates principles of human physiology and pathophysiology at the whole-body, system, organ, cellular, or molecular level. Prerequisites: C&MP 550a and permission of the instructor. Credit for full year only.

C&MP 610, Medical Research Scholars Program: Mentored Clinical Experience (open only to MRSP students)

The goals of the course are to introduce MRSP students to aspects of clinically important human diseases. Students explore each disease over three one-and-one-half-hour sessions led by a clinician-scientist who is an expert in the relevant organ system. Students explore two disease processes per term. The first of the three sessions is devoted to a discussion of the clinical presentation, natural history, pathology, epidemiology, treatment, and prognosis of the disease process. During this session students have the opportunity to view gross or microscopic specimens of diseased tissue in association with members of the Pathology faculty. Students are assigned readings in pathology, pathophysiology, and clinical texts to prepare for the first class session. The second session focuses on translational aspects of the disease process. Students read and present papers relevant to the molecular basis of the disease and cutting-edge approaches to its therapy. In the third session students meet with patients who have experienced the disease and/or visit and explore facilities associated with diagnosis and treatment of the disease process. Prior to the third session students receive guidance as to what they will observe and how to approach the experience; and at the end of the session, the group discusses its thoughts and impressions. Students are expected to prepare for

sessions, to participate actively, and to be scrupulously respectful of patients and patient facilities.

C&MP 620b/NBIO 610b, Fundamentals in Neurophysiology

The course is designed for students who wish to gain a theoretical and practical knowledge of modern neurophysiology. Graduate students specializing in neurophysiology and non-neurophysiology are encouraged to attend, as the course begins at a very basic level and progresses to more complicated topics. Topics include properties of ion channels, firing properties of neurons, synaptic transmission, and neurophysiology methodology.

C&MP 630a/PATH 680a/PHAR 502a, Seminar in Molecular Medicine, Pharmacology, and Physiology

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).

C&MP 650/PATH 660/PHAR 580, Ethics

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.

C&MP 710b/MB&B 710b4, Electron Cryo-Microscopy for Protein Structure Determination

Understanding cellular function requires structural and biochemical studies at an ever-increasing level of complexity. The course is an introduction to the concepts and applications of high-resolution electron cryo-microscopy. This rapidly emerging new technique is the only method that allows biological macromolecules to be studied at all levels of resolution from cellular organization to near atomic detail. Counts as 0.5 credit.

COMPUTATIONAL BIOLOGY AND BIOINFORMATICS

<http://cbb.yale.edu/courses.html>

CB&B 523a/MB&B 523a/PHYS 523a/ENAS 541a, Biological Physics

The course has two aims: 1) to introduce students to the physics of biological systems and 2) to introduce students to the basics of scientific computing. The course will focus on studies of a broad-range of biophysical phenomena including diffusion, polymer statistics, protein folding, macromolecular crowding, cell motion, and tissue development using computational tools and methods. We will provide intensive tutorials for Matlab including basic syntax, arrays, for-loops, conditional statements, functions, plotting, and importing and exporting data.

CB&B 555a/CPSC 453a/GENE 555a/CPSC 553a, Computational Methods for Analysis and Modeling of Biological Data.

This course introduces biology as a systems and data science to computer science and biomedical science students through open computational problems in biology, the types of high-throughput data that are being produced by modern biological technologies, and computational approaches that may be used to tackle such problems. We will cover applications of machine learning methods in the analysis of high-throughput biological data, especially focusing on genomic and proteomic data. This will include methods for denoising data, non-linear dimensionality reduction for visualization and progression analysis, unsupervised clustering, and information theoretic analysis of gene regulatory and signaling networks. Students' grades will be based on programming assignments, a mid-term, paper presentation and a final project.

CB&B 562a/AMTH 562a/MB&B 562a/MCDB 562a/PHYS 562a Dynamical Systems in Biology

Advanced topics in computational biology. Processes by which cells compute, count, tell time, oscillate, and generate spatial patterns. Time-dependent dynamics in regulatory, signal-transduction, and neuronal networks; fluctuations, growth, and form. The dynamical properties of biological systems examined using MATLAB to create models. Prerequisite: MCDB 561b or equivalent, or a 200-level biology course, or permission of the instructor.

CB&B 601b/IBIO 601b, Fundamentals of Research: Responsible Conduct of Research

A weekly seminar presented by faculty trainers on topics relating to proper conduct of research. Required for first-year CB&B students, first-year Immunobiology students, and training grant-funded postdocs. Pass/Fail.

CB&B 645b/BIS 692b/STAT 645b, Statistical Methods in Genetics and Bioinformatics

Introduction to problems, algorithms, and data analysis approaches in computational biology and bioinformatics; stochastic modeling and statistical methods applied to problems such as mapping disease-associated genes, analyzing gene expression microarray data, sequence alignment, and SNP analysis. Statistical methods include maximum likelihood, EM, Bayesian inference, Markov chain Monte Carlo, and some methods of classification and clustering; models include hidden Markov models, Bayesian networks, and the coalescent. The limitations of current models, and the future opportunities for model building, are critically addressed. Prerequisite: STAT 538a, 542b, or 661a. Prior knowledge of biology is not required, but some interest in the subject and a willingness to carry out calculations using R is assumed.

CB&B 647b/GENE 645b/BIS 645b, Statistical Methods in Human Genetics

Probability modeling and statistical methodology for the analysis of human genetics data are presented. Topics include population genetics, single locus and polygenic inheritance, parametric and nonparametric linkage analysis, population-based association studies, family-based association studies, next-generation sequencing data analysis, genome-wide association studies, genetic risk prediction models, and DNA fingerprinting. Prerequisites: genetics; BIS 505a and b, or equivalent; and permission of the instructor. (offered every other year)

CB&B 711a, 712b, 713b, Lab Rotations

Three 2.5–3-month research rotations in faculty laboratories are required during the first year of graduate study. These rotations are arranged by each student with individual faculty members.

CB&B 740a, Clinical and Translational Informatics

The course provides an introduction to clinical and translational informatics. Topics include (1) overview of biomedical informatics, (2) design, function, and evaluation of clinical information systems, (3) clinical decision making and practice guidelines, (4) clinical decision support systems, (5) informatics support of clinical research, (6) privacy and confidentiality of clinical data, (7) standards, and (8) topics in translational bioinformatics. Permission of the instructor required.

CB&B 745b/AMTH 745b/CPSC 745b, Advanced Topics in Machine Learning and Data Mining

An overview of advances in the past decade in machine learning and automatic datamining approaches for dealing with the broad scope of modern data-analysis challenges, including deep learning, kernel methods, dictionary learning, and bag of words/features.

This year, the focus is on a broad scope of biomedical data-analysis tasks, such as singlecell RNA sequencing, single-cell signaling and proteomic analysis, health care assessment, and medical diagnosis and treatment recommendations. The seminar is based on student presentations and discussions of recent prominent publications from leading journals and conferences in the field. Prerequisite: basic concepts in data analysis (e.g., CPSC 545 or 563) or permission of the instructor.

CB&B 750, Core Topics in Biomedical Informatics

The course focuses on providing an introduction to common unifying themes that serve as the foundation for different areas of biomedical informatics, including clinical, neuro-, and genome informatics. The course is designed for students with significant computer experience and coursework who plan to build databases and computational tools for use in biomedical research. Emphasis is on understanding basic principles underlying informatics approaches to interoperation among biomedical databases and software tools, standardized biomedical vocabularies and ontologies, biomedical natural language processing, modeling of biological systems, high performance computation in biomedicine, and other related topics.

CB&B 752b/MB&B 752b, Biological Data Science: Mining & Modeling

Bioinformatics 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 of 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 for data integration. Prerequisites: biochemistry and calculus, or permission of the instructor.

EXPERIMENTAL PATHOLOGY

<http://medicine.yale.edu/pathology/education/graduatecourses.aspx>

Note: Pathology 600, 616, 617, and 618b are primarily geared toward medical students, but may be taken by graduate students with the permission of the Director of Medical Studies.

PATH 600, Pathological Basis of Human Disease

Fundamental principles underlying the pathological alterations in function and structure that constitute the reaction of the organism to injury. Pathology of diseases involving neoplasia and special organs and systems. Correlation of the clinical and anatomical manifestations is emphasized. For Public Health graduate students and MSTP students who are required to take PATH 100 for graduate credit.

PATH 616, Autopsy Pathology

The course will provide participation in the autopsy service with house staff in pathology. The course will cover proper performance of the autopsy including dissection, documentation and reporting, presentation of autopsy findings and communication of medical opinions formed from the autopsy. The work will include involvement in dissection of cases, review of gross pathology, submission of sections for histology, review of microscopic slides, preparation of reports of findings and involvement in investigative procedures related to necropsy material. Opportunities exist for correlation studies with previous biopsies, and clinical investigative and cell biologic techniques in relation to necropsy material and attendance. Content and enrollment to be determined in conjunction with the Director of Autopsy Services.

PATH 620a and b, Laboratory Rotations in Experimental Pathology

Laboratory rotations for first-year graduate students.

PATH 630b/ENAS 535b, Biomaterial-Tissue Interactions

The course addresses the interactions between tissues and biomaterials, with an emphasis on the importance of molecular- and cellular-level events in dictating the performance and longevity of clinically relevant devices. In addition, specific areas such as biomaterials for tissue engineering and the importance of stem/progenitor cells, and biomaterial-mediated gene and drug delivery are addressed.

PATH 640a/BBS 640a, Developing and Writing a Scientific Research Proposal

The course will cover the intricacies of scientific writing and guide students in the development of a scientific research proposal on the topic of their research. All elements of an NIH fellowship application will be covered and eligible students will submit their applications for funding.

PATH 650b, Cellular and Molecular Biology of Cancer

A comprehensive survey of cancer research from the cellular to the clinical level. The relation of cancer to intracellular and intercellular regulation of cell proliferation is emphasized, as are animal models for cancer research. Background in molecular genetics and cell biology is assumed. Open to advanced undergraduates with permission of the organizers.

PATH 660/C&MP 650/PHAR 580, Ethics

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.

PATH 670b, Biological Mechanisms of Reaction to Injury

An introduction to human biology and disease as a manifestation of reaction to injury. Topics include organ structure and function, cell injury, circulatory and inflammatory responses, disordered physiology, and neoplasia.

PATH 680a/C&MP 630a/PHAR 502a, Seminar in Molecular Medicine, Pharmacology, and Physiology

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).

PATH 681a/BBS 681a, Advanced Topics in Cancer Biology

This advanced graduate level course focuses on readings and discussion on 3-4 major topics in cancer biology, such as targeted therapy, tumor immunology, tumor metabolism, and genomic evolution of cancer. For each topic, the class starts with an interactive lecture, followed by critical analysis of primary research literature. Recent research articles are assigned on these topics, and a student leads discussions with input from faculty who are experts in the topic area. Pre-requisites: PATH 650b or at the discretion of the instructor.

PATH 690a, Molecular Mechanisms of Disease

This course covers aspects of the fundamental molecular and cellular mechanisms underlying various human diseases. Many of the disorders discussed represent major forms of infectious, degenerative, vascular, neoplastic, and inflammatory disease. Additionally, certain rarer diseases that illustrate good models for investigation and/or application of basic biologic principles are covered in the course. The objective is to highlight advances in experimental and molecular medicine as they relate to understanding the pathogenesis of disease and the formulation of therapies.

GENETICS

GENE 555a/CB&B 555a/CPSC 453a/553a, Computational Methods for Analysis and Modeling of Biological Data.

This course introduces biology as a systems and data science to computer science and biomedical science students through open computational problems in biology, the types of high-throughput data that are being produced by modern biological technologies, and computational approaches that may be used to tackle such problems. We will cover applications of machine learning methods in the analysis of high-throughput biological data, especially focusing on genomic and proteomic data. This will include methods for denoising data, non-linear dimensionality reduction for visualization and progression analysis, unsupervised clustering, and information theoretic analysis of gene regulatory and signaling networks. Students' grades will be based on programming assignments, a mid-term, paper presentation and a final project. Prerequisite: GENE 760 or permission of the instructor

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

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/CBIO 655a, Stem Cells: Biology and Application

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 b, Graduate Student Seminar: Critical Analysis and Presentation of Scientific Literature

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 for all second-year students in Genetics. Graded Satisfactory/Unsatisfactory.

GENE 703b, The Mouse in Biomedical Research

This course describes aspects of comparative genomics, construction of genetically altered mice, mouse phenotyping, and study design relevant to the use of mice in the study of human disease. Prerequisites: undergraduate-level genetics and mammalian anatomy and physiology. (offered every other year)

GENE 734a Molecular Biology of Animal Viruses

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

Selected topics in transcriptional control, regulation of chromatin structure, mRNA processing, mRNA stability, RNA interference, translation, protein degradation, DNA replication, DNA repair, site-specific DNA recombination, somatic hypermutation. Prerequisite: biochemistry or permission of the instructor.

GENE 749a/MB&B 749a, Medical Impact of Basic Science

Consideration of examples of recent discoveries in basic science that have elucidated the molecular origins of disease or that have suggested new therapies for disease. Emphasis is placed on the fundamental principles on which these advances rely. Reading is from the primary scientific and medical literature, with emphasis on developing the ability to read this literature critically. Aimed primarily at undergraduates. Prerequisite: biochemistry or permission of the instructor.

GENE 760b, Genomic Methods for Genetic Analysis

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 genomic approaches but who have had little prior experience in genomics or bioinformatics. Enrollment limited to twenty. Prerequisite: permission of the instructor.

GENE 777b/MCDB 677b, Mechanisms of Development

An advanced course on mechanisms of animal and plant development focusing on the genetic specification of cell organization and identity during embryogenesis and somatic differentiation. The use of evolutionarily conserved signaling pathways to carry out developmental decisions in a range of animals is highlighted. Course work includes student participation in critical analysis of primary literature and a research proposal term paper.

GENE 840a and b, Medical Genetics

Clinical rotation offering medical and graduate students the opportunity to participate in the Genetic Consultation Clinic, genetic rounds, consultation rounds, and genetic analysis of clinical diagnostic problems.

GENE 900a/CBIO 900a/MCDB 900a, First-Year Introduction to Research and Rotations

Scientific writing and laboratory rotation talks for Molecular Cell Biology, Genetics, and Development track students.

GENE 901b/CBIO 901b/MCDB 901b, First-Year Introduction to Research—Ethics: Scientific Integrity in Biomedical Research

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

GENE 911a/CBIO 911a/MCDB 911a, First Laboratory Rotation

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

GENE 912b/CBIO 912b/MCDB 912b, Second Laboratory Rotation

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

GENE 913b/CBIO 913b/MCDB 913b, Third Laboratory Rotation

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

GENE 921a and b, Reading Course in Genetics and Molecular Biology

Directed reading with faculty. Term paper required. Prerequisite: permission of Genetics DGS.

IMMUNOBIOLOGY

<http://medicine.yale.edu/immuno/programs/courses.aspx>

IBIO 503b, Responsible Conduct in Research, Refresher Course

NIH requirement, 4th year students to receive training in the responsible conduct of research every 4 years, and Immunobiology 503b meets this requirement. The course has two components:

1. One large-group session will be held for all 4th year students through the BBS. The main topics will be Scientific Misconduct and Authorship.
2. Two Immunobiology faculty facilitate discussions based on RCR topics which are gathered in advance from the students. These anonymous-hypothetical stories are selected by the faculty and discussed. A workshop environment where students are then asked to analyze each case and suggest courses of actions.

IBIO 530a/MBIO 530a/MCDB 430a, Biology of the Immune System

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. Required for all First Year Immunology/BBS students

IBIO 531b, Advanced Immunology

The historical development and central paradigms of key areas in immunology. The course attempts to develop a clear understanding of how these paradigms were established experimentally. Landmark studies are discussed to determine how the conclusions were obtained and why they were important at the time they were done. Lecture and discussion format; readings of primary research papers and review articles. Prerequisite: IBIO 530a or equivalent. Enrollment limited to fifteen. Required for all first year BBS/Immunology Students.

IBIO 532b, Inflammation

This course covers fundamentals of inflammation from a broad biological perspective. Both physiological and pathological aspects of inflammation are the focus.

IBIO 536a, Advanced Immunology Seminar: Mucosal Immunity and Microbiome

This seminar course covers key concepts in immune responses against pathogens in mucosal tissues. We cover seminal studies that probe how microbiota and virobiota regulate the immune system and vice versa in health and disease states, and how dysbiosis impacts human health.

IBIO 539b, Advanced Immunology Seminar: Cancer Immunology.

Major concepts in cancer immunology will be covered in this interactive and original research-based seminar course. Topics include features of the tumor immune microenvironment, cancer vaccines, immune checkpoint blockade, adoptive T-cell therapies, immunogenomics, inflammation and cancer, . Prerequisites: IBIO 530a and IBIO531b or equivalent.

IBIO 600a, Introduction to Research: Faculty Research Presentations

Introduction to the research interests of the faculty. Required for all first-year Immunology/BBS students. Pass/Fail.

IBIO 601b/CB&B 601b, Fundamentals of Research: Responsible Conduct of Research

A weekly seminar presented by faculty trainers on topics relating to proper conduct of research. Required for first-year Immunobiology students, first-year CB&B students, and training grant-funded postdocs. Pass/Fail.

IBIO 611a, Research Rotation 1

Intensive experience in the design and execution of experiments in immunology or other areas of biology. Students design a focused research project in consultation with a faculty mentor and execute the designed experiments in the mentor's laboratory. Students are expected to read relevant background papers from the literature, design and perform experiments, interpret the resulting data, and propose follow-up experiments. Students are also expected to attend the mentor's weekly lab meeting(s) as well as weekly Immunobiology departmental seminars and

Research in Progress seminars. The course concludes with the student giving a brief presentation of the work performed at Rotation Talks, attended by other first-year immunology-track graduate students. Evaluation is by the mentor; students also evaluate the rotation experience. Students must turn in a prioritized list of four possible mentors to Barbara Cotton in the office of the director of graduate studies at least one week prior to the beginning of the course. Mentors are assigned by the DGS. Graded Pass/Fail. Course dates are Sept. 7–Nov 13. (1 course credit; minimum of 20 hours/week). Required for all first-year Immunology/BBS students.

IBIO 612b, Research Rotation 2

See description under IBIO 611a.

IBIO 613b, Research Rotation 3

See description under IBIO 611a.

MICROBIOLOGY

MBIO530a/MCDB 530a/IBIO 530a, Biology of the Immune System

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.

MBIO 547b/EMD 547b, Vaccines: Concepts in Biology

Vaccines are one of the major public health preventive approaches for disease control. However, the underlying biological mechanisms are still being explored, with the purpose of designing better and more efficacious vaccines. Vaccine-preventable diseases now include many infectious diseases as well as cancer. This course briefly reviews the immunological basis of immunity to infection and disease. Topics then include the basic science underlying vaccine development, current vaccine-preventable diseases, as well as vaccines under development. Prerequisites: immunology and microbiology.

MBIO 670, 671, 672, Laboratory Rotations

Rotation in three laboratories. Required for all first-year graduate students.

MBIO 680a/EMD 680a, Molecular and Cellular Processes of Parasitic Eukaryotes

An introductory topic-based course in modern parasitology. For each topic there is an introductory lecture followed by a journal club-like discussion session of relevant papers selected from the literature. The course provides an introduction to basic biological concepts of parasitic eukaryotes causing diseases in humans. Topics include strategies used by parasitic eukaryotes to establish infections in the host and approaches to disease control, through either chemotherapy, vaccines, or genomics. In addition, emphasis is placed on evaluating the quality and limitation of scientific publications and developing skills in scientific communication. Prerequisite: permission of the instructor.

MBIO 685b, Molecular Mechanisms of Microbial Pathogenesis

This interdisciplinary course focuses on current topics related to host-pathogen interactions. Each week a lecture is given on the topic, followed by student presentations of seminal papers in the field. All participants are required to present a paper.

MBIO 686a, Bacterial Determinants of Pathogenesis

The course provides an introduction to basic principles in bacterial pathogenesis. Topics focus on the bacterial determinants mediating infection and pathogenesis, as well as strategies to prevent and treat diseases. Each week a lecture is given on the topic, followed by student presentations of seminal papers in the field. All participants are required to present a paper.

MBIO 701ab, Research in Progress

All students, beginning in their third year, are required to present their research once a year at the Graduate Student Research in Progress. These presentations are intended to give each student practice in presenting his or her own work before a sympathetic but critical audience and to familiarize the faculty with the research.

MBIO 702ab, Microbiology Seminar Series

All students are required to attend all Microbiology seminars scheduled throughout the academic year. Microbiologists from around the world are invited to describe their research.

MBIO 703b, Evasion of Host Defense by Viruses, Bacteria and Eukaryotic Parasites

The course, in student seminar format, is required for all first and second year Microbiology Graduate Program students. Subjects to be discussed include strategies employed by viruses, bacteria or eukaryotic parasites to evade either cell intrinsic defenses, such as programmed cell death or innate immune sensing, or responses operating at the level of the organism, such as the adaptive immune response.

MBIO 734b/GENE 734b/MB&B 734b, Molecular Biology of Animal Viruses

Lecture course with emphasis on mechanisms of viral replication, oncogenic transformation, and virus-host cell interactions.

MOLECULAR BIOPHYSICS AND BIOCHEMISTRY

MB&B 500b/MCDB 500b, Biochemistry

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.

MB&B 517b3/ENAS 517b/MCDB 517b3/PHYS 517b3, Methods and Logic in Interdisciplinary Research

This half-term IGPPEB class is intended to introduce students to integrated approaches to research. Each 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 MB&B graduate course requirements. Required for students in IGPPEB.

MB&B 520a1, Boot Camp Biology

An intensive introduction to biological nomenclature, systems, processes, and techniques for graduate students with previous backgrounds in non-biological fields including physics, engineering, and computer science who wish to perform graduate research in the biological sciences. Counts as 0.5 credit toward MB&B graduate course requirements. Required for students in IGPPEB.

MB&B 523a/CB&B 523a/ENAS 541a/PHYS 523a, Biological Physics

An introduction to the physics of several important biological phenomena, including molecular motors, protein folding, bacterial locomotion, and allostery. The material and approach are positioned at the interface of the physical and biological sciences.

MB&B 561a/PHYS561a/MCDB561a, Introduction to Dynamical in Biology

Biological systems make sophisticated decisions at many levels. This course explores the molecular and computational underpinnings of how these decisions are made, with a focus on modeling static and dynamic processes in example biological systems. We emphasize analytical and numerical models to explore the relationship between molecular mechanisms and behavior. Topics include molecular switches, regulatory networks, feedback, and signal transduction. The course contains significant instruction in MATLAB, while students also read papers from the primary literature. The course aims to turn ball-and-arrow diagrams into quantitative models with testable predictions. Prerequisite: PHYS 170 or equivalent, or permission of the instructor.

MB&B 562a/CB&B 562a/MCDB 361/562/PHYS 562a, Dynamical Systems in Biology

This course covers advanced topics in computational biology. How do cells compute, how do they count and tell time, how do they oscillate and generate spatial patterns? Topics include time-dependent dynamics in regulatory, signal-transduction, and neuronal networks; fluctuations, growth, and form; mechanics of cell shape and motion; spatially heterogeneous processes; diffusion.

MB&B 600a, Principles of Biochemistry I

Discussion of the physical, structural, and functional properties of proteins, lipids, and carbohydrates, three major classes of molecules in living organisms. Energy metabolism, hormone signaling, and muscle contraction as examples of complex biological processes whose underlying mechanisms can be understood by identifying and analyzing the molecules responsible for these phenomena.

MB&B 601b, Principles of Biochemistry II

A continuation of MB&B 600a that considers the chemistry and metabolism of nucleic acids, the mechanism and regulation of protein and nucleic acid synthesis, and selected topics in macromolecular biochemistry.

MB&B 602a/CBIO 602a/MCDB 602a, Molecular Cell Biology

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.

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

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.

MB&B 630b/MCDB 630b, Biochemical and Biophysical Approaches in Molecular and Cellular Biology

This graduate course introduces the theory and application of biochemical and bio-physical 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 BBSB graduate students.

MB&B 635a/ENAS 518a, Quantitative Approaches in Biophysics and Biochemistry

The course offers an introduction to quantitative methods relevant to analysis and interpretation of biophysical and biochemical data. Topics covered include statistical testing, data presentation, and error analysis; introduction to dynamical systems; analysis of large datasets; and Fourier analysis in signal/image processing and macromolecular structural studies. The course also includes an introduction to basic programming skills and data analysis using MATLAB. Real data from research groups in MB&B are used for practice. Prerequisites: MATH 120 and MB&B 600a or equivalents, or permission of the instructors.

MB&B 650, Lab Rotation for First-Year Students

Required for all first-year BBSB graduate students. Credit for full year only.

MB&B 675a, Seminar for First-Year Students

Required for all first-year BBSB graduate students.

MB&B 676b, Responsible Conduct of Research

Designed for students who are beginning to do scientific research. The course seeks to describe some of the basic features of life in contemporary research and some of the personal and professional issues that researchers encounter in their work. Approximately six sessions, run in a seminar/discussion format. Required for all first-year BBSB graduate students.

MB&B 710b4/C&MP 710b, Electron Cryo-Microscopy for Protein Structure Determination

Understanding cellular function requires structural and biochemical studies at an ever-increasing level of complexity. The course is an introduction to the concepts and applications of high-resolution electron cryo-microscopy. This rapidly emerging new technique is the only method that allows biological macromolecules to be studied at all levels of resolution from cellular organization to near atomic detail. Counts as 0.5 credit toward MB&B graduate course requirements.

MB&B 715b/ENAS 705b/PHYS 705b, Numerical Simulations of Liquids

An in-depth introduction to numerical simulations including molecular dynamics, discrete element modeling, Monte Carlo methods, and Markov chains. These techniques are applied to simulate liquids, granular media, polymers, and proteins. Experience with C++, Fortran, or Matlab is required. Not offered in Calendar year 2015-16.

MB&B 720a, Macromolecular Structure and Biophysical Analysis

An in-depth analysis of macromolecular structure and its elucidation using modern methods of structural biology and biochemistry. Topics include architectural arrangements of proteins, RNA, and DNA; practical methods in structural analysis; and an introduction to diffraction and NMR. Prerequisites: physical chemistry (may be taken concurrently) and biochemistry.

MB&B 723b4, Macromolecular Interactions: Atoms to Networks

The course examines the nature of the intricate networks of macromolecular interactions that underlie the functioning of every cell and the modern biophysical methods available for their study across multiple length, time,

and energy scales. Counts as 0.5 credit toward MB&B graduate course requirements.

MB&B 730a, Methods and Logic in Molecular Biology

The course examines fundamental concepts in molecular biology through intense critical analysis of the primary literature. The objective is to develop primary literature reading and critical thinking skills. Required of and open only to first-year graduate students in BBSB.

MB&B 743b/GENE 743b/MCDB 743b, Advanced Eukaryotic Molecular Biology

Selected topics in transcriptional control, regulation of chromatin structure, mRNA processing, mRNA stability, RNA interference, translation, protein degradation, DNA replication, DNA repair, site-specific DNA recombination, somatic hypermutation. Prerequisite: biochemistry or permission of the instructor.

MB&B 749a/GENE 749a, Medical Impact of Basic Science

Consideration of examples of recent discoveries in basic science that have elucidated the molecular origins of disease or that have suggested new therapies for disease. Emphasis is placed on the fundamental principles on which these advances rely. Reading is from the primary scientific and medical literature, with emphasis on developing the ability to read this literature critically. Aimed primarily at undergraduates. Prerequisite: biochemistry or permission of the instructor. May not be taken by MB&B B.S./MS. students for graduate course credit.

MB&B 750a2, Biological Membranes

Biological membranes and their resident proteins are essential for cellular function; yet comparatively little is known about their structure and dynamics. This class provides an introduction to the biochemistry and biophysics of lipids, lipid bilayers, and lipid-derived second messengers. In addition, structural as well as functional aspects of the different classes of membrane proteins are discussed along with an outline of experimental approaches used to achieve an understanding of membrane protein structure and function at a molecular level. Counts as 0.5 credit toward MB&B graduate course requirements. Prerequisite: biochemistry

MB&B 752b/CB&B 752b, Biological Data Science: Mining & Modeling

Bioinformatics 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 of 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 for data integration. Prerequisites: biochemistry and calculus, or permission of the instructor.

MB&B 753b3/MCDB452/MB&B752/MB&B754/MCDB752/CPSC752, Biomedical Data Science: Mining

Bioinformatics 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. This module focuses on the first of these techniques, data mining. Specific topics to be covered include sequence alignment, comparative genomics and phylogenetics, biological databases, microarray normalization, and machine-learning approaches to data integration.

MB&B 754b4/MCDB452/MB&B752/MB&B753/ MCDB752/CPSC752, Biomedical Data Science: Modeling

Bioinformatics 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. This module focuses on the second of these techniques, simulation. Specific topics to be covered include geometric analysis of protein structure, molecular-dynamics simulation, and biological networks. Counts as 0.5 credit toward MB&B graduate course requirements. Prerequisites: biochemistry and calculus, or permission of the instructor.

MB&B 760b3, Principles of Macromolecular Crystallography

Rigorous introduction to the principles of macromolecular crystallography, aimed at students who are planning to

carry out structural studies involving X-ray crystallography or who want to obtain in-depth knowledge for critical analysis of published crystal structures. Counts as 0.5 credit toward MB&B graduate course requirements.

Prerequisites: physical chemistry and biochemistry.

MB&B 761b4, X-ray Crystallography Workshop

This laboratory course provides hands-on training in the practical aspects of macromolecular structure determination by X-ray crystallography. Topics include data collection, data reduction, phasing by multi-wavelength anomalous diffraction and molecular replacement, solvent flattening, noncrystallographic symmetry averaging, electron density interpretation, model building, structure refinement, and structure validation. The course includes training in the use of computer programs used to perform these calculations. Counts as 0.5 credit toward MB&B graduate course requirements. Prerequisites: MB&B 760b3 and a working exposure to the Unix operating system. Not offered in Calendar year 2015-16.

MB&B 800a, Advanced Topics in Molecular Medicine

The seminar, which covers topics in the molecular mechanisms of disease, illustrates timely issues in areas such as protein chemistry and enzymology, intermediary metabolism, nucleic acid biochemistry, gene expression, and virology. M.D. and M.D./Ph.D. students only. Prerequisite: biochemistry (may be taken concurrently).

MB&B 900a or 901b, Reading Course in Biophysics

Directed reading course in biophysics. Term paper required. By arrangement with faculty. Open only to graduate students in MB&B. Please see syllabus for additional requirements.

MB&B 902a or 903b, Reading Course in Molecular Genetics

Directed reading course in molecular genetics. Term paper required. By arrangement with faculty. Open only to graduate students in MB&B. Please see syllabus for additional requirements.

MB&B 904a or 905b, Reading Course in Biochemistry

Directed reading course in biochemistry. Term paper required. By arrangement with faculty. Open only to graduate students in MB&B. Please see syllabus for additional requirements.

MOLECULAR, CELLULAR, AND DEVELOPMENTAL BIOLOGY

<http://mcdb.yale.edu/courses/graduate>

MCDB 500b/MB&B 500b, Biochemistry

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 517b3/ENAS 517b/MB&B 517b3/PHYS 517b3, Methods and Logic in Interdisciplinary Research

This half-term IGPPEB class is intended to introduce students to integrated approaches to research. Each 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. Required for students in IGPPEB.

MCDB 530a/IBIO 530a/MBIO 530a, Biology of the Immune System

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, Physiological Systems

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 560b/C&MP 560b/ENAS 570b/PHAR 560b, Cellular and Molecular Physiology: Molecular Machines in Human Disease

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.

MCDB 561b/AMTH 665b/CB&B 561b/PHYS 561b, Introduction to Computation Biology

An introduction to the techniques of integrating knowledge from mathematics, physics, and engineering into the analysis of complex living systems. Use of these techniques to address key questions about the design principles of biological systems. Discussion of experiments and corresponding mathematical models. Reading of research papers from the literature. Students build their own models using MATLAB

MCDB 562a/CB&B 562a/AMTH 562a/MB&B 562a Computational Biology

Advanced topics in computational biology. Processes by which cells compute, count, tell time, oscillate, and generate spatial patterns. Time-dependent dynamics in regulatory, signal-transduction, and neuronal networks; fluctuations, growth, and form. The dynamical properties of biological systems examined using MATLAB to create models.

MCDB 570b, Biotechnology

The principles and applications of cellular, molecular, and chemical techniques that advance biotechnology. Topics include the most recent tools and strategies used by government agencies, industrial labs, and academic research to adapt biological and chemical compounds as medical treatments, as industrial agents, or for the further study of biological systems.

MCDB 591b/ENAS 991b/MB&B 591b/PHYS 991b, Integrated Workshop

This required course for students in IGPPEB involves hands-on laboratory modules with students working in pairs. A biology student is paired with a physics or engineering student; a computation/theory student is paired with an experimental student. The modules are devised so that a range of skills are acquired, and students learn from each other.

MCDB 602a/CBIO 602a/MB&B 602a, Molecular Cell Biology

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.

MCDB 603a/CBIO 603a, Seminar in Molecular Cell Biology

A graduate-level seminar course 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 MCDB 602a lecture schedule. Thus, concurrent enrollment in MCDB 602a is required.

MCDB 625a/GENE 625a/MB&B 625a^U, Basic Concepts of Genetic Analysis

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

This graduate 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.

MCDB 660a/F&ES 654a, Structure, Function, and Development of Trees and Other Vascular Plants

Morphogenesis and adaptation of vascular plants considered from seed formation and germination to maturity. Physiological and developmental processes associated with structural changes in response to environment discussed from both a phylogenetic and an adaptive point of view.

MCDB 670a, Advanced Seminar in Biochemistry and Genetics

New aspects of the molecular biology of RNA, ribonucleoproteins, and prions. Topics include the localization and function of RNA and ribonucleoproteins; siRNAs and microRNAs; the role of RNA in dosage compensation, chromosome silencing, and gene regulation; novel ribozymes and RNA technology; prions. Discussion; involvement and attendance are required.

MCDB 677b/GENE 777b, Mechanisms of Development

An advanced course on mechanisms of animal development focusing on the genetic specification of cell organization and identity during embryogenesis and somatic differentiation. The use of evolutionarily conserved signaling pathways to carry out developmental decisions in a range of animals is highlighted. Course work includes student participation in critical analysis of primary literature and a research proposal term paper.

MCDB 720a/NBIO 720a/INP 720a, Neurobiology

Examination of the excitability of the nerve cell membrane as a starting point for the study of molecular, cellular,

and intercellular mechanisms underlying the generation and control of behavior.

MCDB 721La, Laboratory for Neurobiology

Optional laboratory. Introduction to the neurosciences. Projects include the study of neuronal excitability, sensory transduction, CNS function, synaptic physiology, and neuroanatomy.

MCDB 735b/NBIO 504b/INP 504b, Seminar in Brain Development and Plasticity

Weekly seminars and discussion sessions to explore recent advances in our understanding of brain development and plasticity, including neuronal determination, axon guidance, synaptogenesis, and developmental plasticity.

MCDB 743b/GENE 743b/MB&B 743b, Advanced Eukaryotic Molecular Biology

Selected topics in transcriptional control, regulation of chromatin structure, mRNA processing, mRNA stability, RNA interference, translation, protein degradation, DNA replication, DNA repair, site-specific DNA recombination, somatic hypermutation. Prerequisite: biochemistry or permission of the instructor.

MCDB 752a/ /CPSC 752a, Bioinformatics: Practical Application of Simulation and Data Mining

Bioinformatics 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 for data integration. Prerequisites: biochemistry and calculus, or permission of the instructor.

MCDB 861b/F&ES 770b, The Human Population Explosion

Global population growth in its human, environmental, and economic dimensions. Social and sociobiological bases of reproductive behavior. Population history and the causes of demographic change. Interactions of population growth with economic development and environmental alteration. Overconsumption of the rich and overpopulation of the poor. "Hot-button" issues surrounding fertility: contraception, abortion, infanticide, and the status of women.

MCDB 900a/CBIO 900a/GENE 900a, First-Year Introduction to Research and Rotations

Scientific writing and laboratory rotation talks for Molecular Cell Biology, Genetics, and Development track students.

MCDB 901b/CBIO 901b/GENE 901b, First-Year Introduction to Research—Ethics: Scientific Integrity in Biomedical Research

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

MCDB 902a and 903b, Advanced Graduate Seminar

The course allows students to hone their presentation skills through yearly presentation of their dissertation work. Two students each give thirty-minute presentations in each class session. Students are required to present every year beginning in their third year in the MCDB program. Each MCDB graduate student is expected to attend at least 80 percent of the class sessions. Two faculty members co-direct the course, attend the seminars, and provide feedback to the students.

MCDB 911a/CBIO 911a/GENE 911a, First Laboratory Rotation

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

MCDB 912b/CBIO 912b/GENE 912b, Second Laboratory Rotation

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

MCDB 913b/CBIO 913b/GENE 913b, Third Laboratory Rotation

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

MCDB 950a and 951b, Second-Year Research

By arrangement with faculty.

NEUROBIOLOGY

NBIO 500b/INP 510b, Structural and Functional Organization of the Human Nervous System

An integrative overview of the structure and function of the human brain as it pertains to major neurological and psychiatric disorders. Neuroanatomy, neurophysiology, and clinical correlations are interrelated to provide essential background in the neurosciences. Lectures in neurocytology and neuroanatomy survey neuronal organization in the human brain, with emphasis on long fiber tracts related to clinical neurology. Weekly three-hour laboratory sessions in close collaboration with faculty members. Lectures in neurophysiology cover various aspects of neural function at the cellular level, with a strong emphasis on the mammalian nervous system. Clinical correlations consist of five sessions given by one or two faculty members representing both basic and clinical sciences. These sessions relate neurological symptoms to cellular processes in various diseases of the brain. Variable class schedule; contact course instructors. This course is offered to graduate and M.D./Ph.D. students only and cannot be audited.

NBIO 501a/INP 501a, Principles of Neuroscience

General neuroscience seminar: lectures, readings, and discussion of selected topics in neuroscience. Emphasis is on how approaches at the molecular, cellular, physiological, and organismal levels can lead to understanding of neuronal and brain function.

NBIO 504b/MCDB 735b/INP 504b, Seminar in Brain Development and Plasticity

Weekly seminars and discussion sessions to explore recent advances in our understanding of brain development and plasticity, including neuronal determination, axon guidance, synaptogenesis, and developmental plasticity.

NBIO 507b/INP 507b, Cellular and Molecular Mechanisms of Neurological Disease

The course focuses on those diseases (Alzheimer's, Parkinson's, ALS, and other neurodegenerative diseases, triplet repeat induced diseases, multiple sclerosis, epilepsy, etc.) in which modern neuroscience has advanced mechanistic explanations for clinical conditions. It highlights recent molecular, electrophysiological, and imaging experiments in parsing disease mechanisms. The application of pathophysiologic understanding to therapeutics is considered.

NBIO 510a, Introduction to Methods in Cellular and Molecular Neurobiology

Independent study providing firsthand insight into various techniques and approaches used in neuroscience. Light microscopic techniques include various metallic impregnation methods, autoradiography, anterograde and retrograde axonal transport methods, hybridoma and recombinant DNA technology, deoxyglucose metabolic method, fluorescent and immunocytochemical methods. Electron microscopy encompasses transmission, electronmicroscopic auto-radiography, and immuno-peroxidase methodology. Choice of techniques and hours to be arranged with individual faculty or staff members of the Department of Neurobiology.

NBIO 511, Introduction to Techniques Used in Electrophysiological Analysis at the Cellular Level

Independent study providing practical training in in vivo and in vitro nervous system preparations, extracellular and intracellular recordings, sensory stimulation, dye injections, and selected neuropharmacological procedures. Choice of techniques and hours to be arranged with individual faculty of the Department of Neurobiology.

NBIO 512a/b/INP 512a/b, Lab Rotation for First-Year Students

Required for all first-year Neuroscience graduate students. Rotation period is one term. Both terms required. Grading is Satisfactory/Unsatisfactory.

NBIO 513a/b, Second-Year Thesis Research

Required for all second-year Neuroscience graduate students. Both terms required. Grading is Satisfactory/Unsatisfactory.

NBIO 532a/b, Neurobiology of Cortical Systems

This is a lecture, reading, and discussion-based course focused on the mammalian cerebral cortex. Students learn about the evolution, development, function, and dysfunction of the cortex. Significant emphasis is placed on examining unique aspects of the cortex, including cortical circuit structure, plasticity, cognition, and models of

higher-order cognitive processing. We also examine disease processes in which cortical dysfunction is specifically implicated. Offered every other year.

NBIO 535b/INP 535b, History of Modern Neuroscience

In this course we focus on the original breakthroughs that led to major lines of research being pursued today. Subjects include classic papers in the discoveries of DNA, action potential, synaptic transmission, growth factors, second messengers, neurotransmitters, Hebb synapse, dendrites, hippocampus and memory, cortical columns, REM sleep, neuroendocrine system, instrumental conditioning, reticular activating system, psychoactive drugs, computer modeling, and artificial intelligence.

NBIO 570b/C&MP 570b, Sensory Physiology

The course provides an overview of the mammalian special sensory systems, including molecular and cellular bases of vision, audition, taste, olfaction, and somatosensation. Faculty with focus in those areas lead presentations and discussions on peripheral and central mechanisms. Psychophysical aspects of sensation are introduced.

NBIO 580b/INP 580b, Bioethics in Neuroscience

This course is an introduction to ethics and ethical decision making in the neurosciences. Format for the course is an informal discussion. Each week we are joined by members of the Yale faculty and community who can share their experiences and expertise as it relates to the topic of the week. This course is mandatory for first-year graduate students in the Interdepartmental Neuroscience Program (INP). Grading is Satisfactory/Unsatisfactory and is based on attendance/participation, weekly reaction papers, and a final term paper. The successful (Satisfactory) completion of this course is worth one full graduate course credit.

NBIO 590a, Sensory Neuroethology: Bats and Owls, Electric Fish, and Beyond

In this course we review the neurophysiology of sensory processing with particular attention to animal behavior (ethology) and computation. We begin with the classic neuroethology literature and end with current work on neocortical circuits underlying sensory processing in higher vertebrates. This seminar course meets once per week to read and discuss (mostly) primary research papers selected and presented by the students. Offered every other year

NBIO 595a/INP 595a, Seminar in Visuomotor Neurophysiology

Review and discussion of seminal papers in neurophysiological and computational studies of visual system, covering papers on the receptive field physiology of neurons in the retina and central visual pathway, motor cortex, and computational theories of vision and motor control. The course largely focuses on the literature in primates, but also draws on behavioral and neurophysiological studies in other mammals, such as cats and humans.

NBIO 596a/INP 596a, Seminar in Neurophysiology of Decision Making

NBIO 597b/INP 597b, Neuroeconomics

This course introduces some of the main topics in decision-making research. We discuss how behavioral economics methods are combined with neuroscientific tools, in particular functional MRI and single-neuron recordings, to study the neural mechanisms underlying decision and valuation processes. The course includes both introductory presentations by the instructors and paper presentations by the students. Offered every other year.

NBIO 602a/b, Topics in Cortical Development and Evolution

This advanced tutorial course involves extensive reading, discussion, and pilot experiments on the topic.

NBIO 610b/C&MP 620b, Fundamentals in Neurophysiology

The course is designed for students who wish to gain a theoretical and practical knowledge of modern neurophysiology. Graduate students specializing in neurophysiology and non-neurophysiology are encouraged to attend, as the course begins at a very basic level and progresses to more complicated topics. Topics include properties of ion channels, firing properties of neurons, synaptic transmission, and neurophysiology methodology.

NBIO 720a/MCDB 720a/INP 720a, Neurobiology

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.

NEUROSCIENCE

<http://medicine.yale.edu/INP/index.aspx>

INP 502b/MCDB 730b, Cell Biology of the Neuron

A comprehensive introduction to neuronal cell biology. Basic principles of cell biology reviewed in the context of the developing nervous system. Membrane trafficking, receptor mechanisms, neurotrophin signaling, neuronal cytoskeleton, axon guidance, and synapse formation and maintenance are discussed.

INP 504b/MCDB 735b, Seminar in Brain Development & Plasticity

Weekly seminars (Monday) and discussion sessions (Wednesday) to explore recent advances in our understanding of brain development and plasticity, including neuronal determination, axon guidance, synaptogenesis and developmental plasticity.

INP 507b/Neurology 108, Cellular and Molecular Mechanisms of Neurological Diseases

This course focuses on diseases such as Alzheimer's, Parkinson's, Schizophrenia, Multiple Sclerosis, and Epilepsy, in which modern neuroscience has advanced mechanistic explanations for clinical conditions. The course will highlight recent genetic, molecular, electrophysiological, and imaging experiments in parsing disease mechanisms.

INP 510b/NBIO 500b, Structural and Functional Organization of the Human Nervous System

An integrative overview of the structure and function of the human brain pertaining to major neurological and psychiatric disorders. Neuroanatomy, neurophysiology, and clinical correlations are interrelated to provide essential background in the neurosciences. Lectures in neurocytology and neuroanatomy survey neuronal organization in the human brain, with emphasis on long fiber tracts related to clinical neurology. Weekly three-hour laboratory sections in close collaboration with faculty members. Lectures in neurophysiology cover various aspects of neural function at the cellular level, with a strong emphasis on the mammalian nervous system. Clinical correlations consist of five sessions given by one or two faculty members representing both basic and clinical sciences. These sessions relate neurological symptoms to cellular processes in various diseases of the brain. Variable class schedule; contact course instructor. Registration for this course is by permission of the instructor.

INP 512a/b, Lab Rotation for First-Year Students

Required for all first-year Neuroscience graduate students. Rotation period is one term. Grading is Sat/Unsat based on PI's rotation evaluation.

INP 513a/b, Second Year Thesis Research

Required for all second-year INP graduate students. Both terms required. Grading is Sat/Unsat based on PI's certification.

INP 519a/b, Tutorial

By arrangement with faculty and approval of DGS.

INP 521b, Neuroimaging in Neuropsychiatry II: Clinical Applications

Neuroimaging methodologies including Positron Emission Tomography (PET); Single Photon Emission Computed Tomography (SPECT); Magnetic Resonance Imaging (MRI); functional Magnetic Resonance Imaging (fMRI); Magnetic Resonance Spectroscopy (MRS) are rapidly evolving tools used to study the living human brain. Neuroimaging has unprecedented implications for routine clinical diagnosis, for assessment of drug efficacy; for determination of psychotropic drug occupancy and for the study of pathophysiological mechanisms underlying neurologic and psychiatric disorders. This course is designed to provide an overview the application of state of the art neuroimaging methods to research in neurologic and psychiatric disorders.

INP 523a/ENAS 880a, Imaging Drugs in the Brain

Seminar course to explore the uses of PET, SPECT, and fMRI to study the mechanisms of action, and long term effects of drugs (legal and illegal) on brain function. Basic research will be the main focus, augmented by two class periods allotted to uses of imaging in drug development by Pharma. Syllabus will be comprised of review articles,

book chapters and journal articles. Some class periods will begin with short lecture to cover methodological concepts followed by discussion of reading material.

INP 532a/NBIO 532a, Neurobiology of Cortical Systems

This is a lecture, reading and discussion based course focused on the mammalian cerebral cortex. Students will learn about the evolution, development, function and dysfunction of the cortex. Significant emphasis will be placed on examining unique aspects of the cortex, including cortical circuit structure, plasticity, cognition and models of higher-order cognitive processing. We will also examine disease processes in which cortical dysfunction are specifically implicated.

INP 533a/NBIO 533a, Function and Dysfunction of the Visual System.

A survey course on the visual system, covering the retina, central visual pathways, and visual centers. Topics on the development, structure, function, dysfunction, and repair of the visual system will be introduced by faculty members and discussed among students, postdoctoral fellows and faculty members. The class will meet for one 1.5 hr lecture and one 1.5 hr paper discussion session per week.

INP 540b/NBIO 540b, How to Give a Talk

This course is a practical introduction to the art and science of giving a data-based neuroscience seminar. The ability to give a clear, convincing, and engaging talk about your work is one of the key career skills of successful scientists. Content, visual presentation, body language, and delivery all combine to determine your impact on your audience. The focus in class will be on student presentation skills and detailed feedback, interspersed with short example talks by invited guests. Students will give at least two talks over the course of the semester and participate in weekly Q&A and feedback. Grading will be based on class participation. Max 10 students.

INP 562/MCDB 361/562, Dynamical Systems in Biology

This course covers advanced topics in computational biology and dynamical systems. How do cells compute, how do they count and tell time, how do they oscillate and generate spatial patterns? Topics include time dependent dynamics in regulatory, signal transduction and neuronal networks, fluctuations, growth and form: mechanics of cell shape and motion, spatially heterogeneous processes, diffusion. This year, the course will spend roughly half its time on mechanical systems at the cellular and tissue level, and half on models of neurons and neural systems in computational neuroscience.

INP 580b Bioethics in Neuroscience

This course is an introduction to ethics and ethical decision-making in the Neurosciences. Format for the course is an informal discussion. Each week, we will be joined by members of the Yale faculty and community who can share their experiences and expertise as it relates to the topic of the week. This course is mandatory for first year graduate students in the Interdepartmental Neuroscience Program (INP). Grading is Sat/Unsat and is determined based on attendance/participation, weekly questions submitted based on assigned readings and a final term paper and presentation.

INP 585b/BME 585b Fundamentals of Neuroimaging

The neuroenergetic and neurochemical basis of several dominant neuroimaging methods, including fMRI. Topics range from technical aspects of different methods to interpretation of the neuroimaging results. Controversies and/or challenges for application of fMRI and related methods in medicine are identified.

INP 588a Computational Modeling & Analysis in Neuroscience

Quantitative methods for exploring and understanding data are becoming increasingly common in neuroscience. The aim of this course is to introduce students to state-of-the-art methods that are used for data analysis and computational modeling of behavior and neural activity. Classes will combine discussions of primary research papers with coding tutorials to facilitate focused, hands-on exploration of quantitative methods of interest. Topics will include modeling decision-making, model selection, time-frequency analysis of neural activity, and neural population models. Students will need their own computers and access to MATLAB. Minimal programming experience is helpful but not required.

INP 595a, Seminar in Visuomotor Neurophysiology

Review and discussion of seminal papers in neurophysiological and computational studies of visual system. It will cover papers on the receptive field physiology of neurons in the retina and central visual pathway, motor cortex, and computational theories of vision and motor control. The course will largely focus on the literature in primates, but will also draw on behavioral and neurophysiological studies in other mammals, such as cats and humans.

INP 596a/NBIO 596a, Seminar in Neurophysiology of Decision Making

This course involves the critical reading and discussion of both historical and contemporary papers on neurobiology of decision making. Although it covers some key papers in behavioral economics, reinforcement learning, and neuroeconomics, the major emphasis will be on the studies directed at understanding the mechanisms of decision making using neurobiological methods, including single-neuron recording and functional neuroimaging.

INP 597b/NBIO 597b, Neuroeconomics

This course will introduce some of the main topics in human decision-making research. We will discuss how behavioral economics methods are combined with neuroscientific tools, in particular functional MRI, to study the neural mechanisms underlying decision and valuation processes. The course will include both introductory presentations by the instructors and paper presentations by the students.

INP 600a, Experimental Methods in Neuroscience

This course will examine the experimental techniques currently available to neuroscientists. It will explore the kinds of information obtainable in studying phenomena ranging from electrophysiological recordings of individual neurons, to metabolic processes, ensembles of neurons, to behavioral output. Techniques to be covered include microscopic methods (light, electron), electrophysiology (extracellular/ intracellular single cell recordings, multiple cell recording methods, brain slices), macroscopic methods (ERP, MEG, TMR), metabolic measures (microdialysis, biosensors, MR spectroscopy), imaging approaches (optical tomography, PET, SPECT, functional MRI), and interventional techniques (lesions, cortical stimulation, knockout genetics, surgery, drugs). The knowledge gained from each of these approaches, the limitations of the methods, and future developments will be considered. This is a lecture course and students will be evaluated through oral class presentations in a journal club format. No prior familiarity with these methods is needed in order to participate.

INP 610b/C&MP 620b, Neurophysiology

This course will give students instruction in both the theoretical and practical aspects of modern experimental neurophysiology. The course will begin with mathematical calculations of excitable membrane electrical properties. Other lectures will cover different neurophysiology approaches including: patch clamp, extracellular unit recording, optical methods, electrochemical approaches and optogenetics. The course will be team taught and will give students an in depth survey of modern neurophysiology. Course format: Lectures combined with student interactions (Student presentations).

INP 611b/PSYC 611b/411b, Introduction to Systems Neuroscience

This course provides an overview of the fundamental principles governing the central nervous system. Topics include the anatomy of the central nervous system, the neural mechanisms underlying cortical and subcortical control of behavior, various neuroscience techniques, as well as implications for nervous system disorders. The lectures will combine basic knowledge of the nervous system with the key experimental findings that led to new discoveries in brain function.

INP 614b/PSYC 750b/C&MP 750b, Research Topics in Neurobiology of Learning and Memory

This seminar integrates hypotheses and research methods used to elucidate the neurobiological mechanisms underlying learning and memory. Levels of analysis range from molecular and cellular to systems and behavioral, with a primary focus on cellular and systems neurophysiology. Discussion includes the philosophy and rationale underlying some of the more successful and interesting methods. A goal is to evaluate critically how one might connect synaptic phenomena such as long-term potentiation and depression to behavioral changes such as acquisition and extinction. Focus is on combining in vitro and in vivo methods that offer the possibility for yielding quantitative theoretical or computational models.

INP 645a/PSYC 535a/C&M Phys 535a, Foundations of Behavioral Neuroscience

Introduction to the mammalian brain from the perspective of its synaptic organization. The course summarizes principles of biophysics and cellular and systems neurophysiology that provide the foundation for understanding information processing and storage in various brain regions.

INP 648b, Cellular Analysis of Learning and Memory: Vertebrate Model Systems.

We focus on the brain circuitries and cellular/molecular mechanisms involved in learning and memory, with particular emphasis on vertebrate model systems. Review of work on habituation, sensitization, Pavlovian and instrumental conditioning, and declarative memory formation. *Also Psych 648b*

INP 701a, Principles of Neuroscience

General neuroscience seminar: Lectures, readings and discussion of selected topics in neuroscience. Emphasis will be on how approaches at the molecular, cellular, physiological and organismal levels can lead to understanding of neuronal and brain function.

INP 720a/MCDB 720a, Neurobiology

Examination of the excitability of the nerve cell membrane provides a starting point for the study of molecular, cellular and intracellular mechanisms underlying the generation and control of behavior.

PHARMACOLOGY

<http://medicine.yale.edu/pharm/graduate/courses.aspx>

PHAR 502a/C&MP 630a/PATH 680a, Seminar in Molecular Medicine, Pharmacology, and Physiology

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).

PHAR 504a, Principles of Pharmacology

Lectures covering antibiotics, immunotherapy, and chemotherapy.

PHAR 506a and b, Methods in Pharmacological Research (Rotations)

Students work in laboratories of faculty of their choice. The period spent in each laboratory is one term.

PHAR 528a, Principles of Signal Transduction

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 gasses.

PHAR 529b, Structural Pharmacology

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.

PHAR 550a/C&MP 550a/ENAS 550a/MCDB 550a, Physiological Systems

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.

PHAR 560b/C&MP 560b/ENAS 570b/MCDB 560b, Cellular and Molecular Physiology: Molecular Machines in Human Disease

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 580/C&MP 650/PATH 660, Responsible Conduct of Research (RCR)

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.