Molecular, Cellular, and Developmental Biology (MCDB)

* MCDB 040b, The Science and Politics of Cancer  Robert Bazell
Fundamentals of cell biology, Darwinian evolution, immunology, and genetics that underlie cancer; the history of cancer science and treatment; historical and current policy issues. Enrollment limited to first-year students. Preregistration required; see under First-Year Seminar Program. SC

* MCDB 050a, Immunity and Microbes  Paula Kavathas
Introduction to the immune system and its interaction with specific microbes. Microbes that cause illness such as influenza, coronaviruses, HIV, and HPV are discussed as well as how we live in harmony with microbes that compose our microbiome. Readings include novels and historical works on diseases such as polio and AIDS. Enrollment limited to first-year students. Preregistration required; see under First-Year Seminar Program. SC

* MCDB 065a, The Science and Politics of HIV/AIDS  Robert Bazell
Study of the basic virology and immunology of HIV/AIDS, along with its extraordinary historical and social effects. Issues include the threat of new epidemics emerging from a changing global environment; the potential harm of conspiracy theories based on false science; and how stigmas associated with poverty, gender inequality, sexual preference, and race facilitate an ongoing epidemic. For all first-year students regardless of whether they are considering a science major. Prerequisite: AP Biology or equivalent. Enrollment limited to first-year students. Preregistration required; see under First-Year Seminar Program. SC

* MCDB 099b / MR&B 099b / MENG 099b / PHYS 099b / SCIE 099b, Introduction to Research Methods in Physics and Biology: Preparing for a First Research Experience  Staff
Spanning both the classroom and laboratory, this seminar course provides an immersive introduction to scientific research. Students build practical laboratory skills, computational competency, and begin to build fluency in the structures and modes of communication that define modern research. The course also facilitates identification of a laboratory mentor and devising a research proposal (with mentorship) for competitive summer research fellowship applications. This class is open to first-year students, interested in any STEM major, who have no prior research experience. This course does not count toward major requirements. Enrollment limited to first-year students. Preregistration required; see under First-Year Seminar Program.

* MCDB 103b, Cancer  Alexia Belperron
The main purpose of this course is the development of an understanding of the biology of cancer, with emphasis on understanding the core biological principles and how an understanding of these principles is essential to understanding how cancer develops, how it can be treated, and how we can try to prevent its development. Topics include genetics, biochemistry, immunity, infection agents, and challenges for prevention and treatment. Intended for non-science majors and preference is given to first years and sophomores. Prerequisite: High school biology is required. SC

* MCDB 105a or b / MB&B 105a or b, Biology, the World, and Us  Staff
This course is for non-science majors who wish to gain an understanding of modern biology by examining the scientific basis of current issues. We'll consider issues related to: i) pandemics and global infectious disease; ii) the climate crisis; iii) the future of genetics and the new green revolution. Many of the topics have an increasingly large impact on our daily lives. The issues are both social and biological, and it’s crucial that social debate be based on a clear understanding of the underlying science. The instructors will explain the scientific foundation beneath each issue. We’ll emphasize the nature of science as a process of inquiry rather than a fixed body of terminology and facts. The course is not intended to be a comprehensive survey of biology. SC o Course cr

* MCDB 106a / E&E 106a / HLTH 155a, Biology of Malaria, Lyme, and Other Vector-Borne Diseases  Alexia Belperron
Introduction to the biology of pathogen transmission from one organism to another by insects; special focus on malaria, dengue, and Lyme disease. Biology of the pathogens including modes of transmission, establishment of infection, and immune responses; the challenges associated with vector control, prevention, development of vaccines, and treatments. Intended for non-science majors; preference to freshmen and sophomores. Prerequisite: high school biology. SC

* MCDB 109b, Immunity and Contagion  Staff
This interdisciplinary course is for students who want to learn about infectious diseases, pandemics, and the immune system. The immune system evolved to fight pathogens while maintaining homeostasis with our microbiome. The first part of the course is on how the immune system works; this is followed by discussion of different microbes and associated pandemics. This includes flu (1918 pandemic), HIV (AIDS), human papillomavirus (link to cancer), and coronaviruses (COVID-19). Other topics include the human microbiome, cancer immunotherapy and vaccines. Artwork and relevant history are included with a class at the Yale Art Gallery and a class at the medical school. SC o Course cr

MCDB 200b, Molecular Biology  Anna Marie Pyle and Farren Isaacs
The way we think about our health, our material world, and even our national economy, is undergoing radical change because of the revolution in biology. In this course, students learn the basic concepts that drive this revolution to become active and informed participants. Specifically, this course provides a comprehensive overview of modern molecular biology and its applications. Topics include the structure, function, and chemical behavior of biological macromolecules (DNA, RNA, and protein), chromosome and
genome organization, replication and maintenance of the genome, genome editing, transcriptional and translational regulation, structure and function of regulatory noncoding RNAs, RNA splicing, editing and modification and first principles of synthetic biology. Upon completion of the course, students understand the molecular basis for regulated gene expression and the many implications for medicine, biotechnology, and biological engineering. Prerequisites: CHEM 161 or 163, and BIOL 101 (or placement out of BIOL 101 via BIOL 101 placement exam, or via AP5 or IB5-HL with permission of core course instructor). sc 0 Course cr

MCDB 201Lb, Molecular Biology Laboratory  Maria Moreno
Basic molecular biology training in a project-based laboratory setting. Experiments analyze gene function through techniques of PCR, plasmid and cDNA cloning, DNA sequence analysis, and protein expression and purification. Instruction in experimental design, data analysis, and interpretation. Concurrently with or after MCDB 200, or with permission from instructor. For freshmen and sophomores interested in research integrated laboratory experience. Special registration procedures apply. Interested students must contact the instructor and attend an organizational meeting during the first week of classes. WR, SC ½ Course cr

MCDB 202a, Genetics  Stephen Dellaporta and Josh Gendron
An introduction to classical, molecular, and population genetics of both prokaryotes and eukaryotes and their central importance in biological sciences. Emphasis on analytical approaches and techniques of genetics used to investigate mechanisms of heredity and variation. Topics include transmission genetics, cytotgenetics, DNA structure and function, recombination, gene mutation, selection, and recombinant DNA technology. Prerequisite: BIOL 103 or equivalent performance on the corresponding biological sciences placement examination. sc 0 Course cr

* MCDB 203La, Laboratory for Genetics  Amaleah Hartman
Introduction to laboratory techniques used in genetic analysis. Genetic model organisms—bacteria, yeast, *Drosophila*, and *Arabidopsis*—are used to provide practical experience with various classical and molecular genetic techniques including cytotgenetics; complementation, epistasis, and genetic suppressors; mutagenesis and mutant analysis, recombination and gene mapping, isolation and manipulation of DNA, and transformation of model organisms. Concurrently with or after MCDB 202. sc 0 Course cr

MCDB 205b, Cell Biology  David Breslow and Megan King
A comprehensive introductory course in cell biology. Emphasis on the general principles that explain the molecular mechanisms of cellular function. Prerequisites: BIOL 101 and 102, or equivalent performance on the corresponding biological sciences placement examinations, or a score of 5 on the Advanced Placement test in Biology, or a score of 710 or above on the SAT Biology M test, or MCDB 200. sc 0 Course cr

MCDB 210b, Developmental Biology  Scott Holley and Douglas Kankel
A survey of the molecular and genetic control of embryonic development, cell-cell communication, and cell differentiation. Emphasis on mechanistic investigation in model organisms that reveal fundamental concepts explaining human birth defects and disease. Topics include gastrulation; neural and mesoderm induction; limb development; heart and vascular development; craniofacial development; adult and embryonic stem cells; regeneration; evolution and development. Prerequisites: BIOL 101, 102, and 103, or equivalent performance on the corresponding biological sciences placement examinations. SC

MCDB 221La, Laboratory for Foundations of Biology  Maria Moreno
This lab complements the BIOL 101-103 series. An introduction to research and common methodologies in the biological sciences, with emphasis on the utility of model organisms. Techniques and methods commonly used in biochemistry, cell biology, genetics, and molecular and developmental biology; experimental design; data analysis and display; scientific writing. With permission of instructor or concurrently with or after BIOL 101, 102 or 103. WR, SC 0 Course cr

MCDB 231La, RNAseq Analysis/Intro to Bioinformatics  Josien van Wolfswinkel
This course is about learning to analyze High-throughput sequencing data. This requires insight in what the data represents, as well as the ability to perform basic computational analysis. We approach this by using various scripting languages, to organize and modify the data for further analysis, and use the High Performance Computing Cluster and R to obtain new insights. No prior experience with coding is required, but access to a laptop and an internet connection is essential. Prerequisites: BIOL 101-104, and one 200 level course, or instructor permission. sc

MCDB 250b, Biology of Reproduction  Hugh Taylor and Seth Guller
Introduction to reproductive biology, with emphasis on human reproduction. Development and hormonal regulation of reproductive systems; sexuality, fertilization, and pregnancy; modern diagnosis and treatment of reproductive and developmental disorders; social and ethical issues. BIOL 101, 102, and 103, or equivalent performance on the corresponding biological sciences placement examinations, or a score of 5 on the Advanced Placement test in Biology, or a score of 710 or above on the SAT Biology M test. SC

MCDB 251Lb, Laboratory for Biology of Reproduction and Development  Seth Guller, Shannon Whirledge, and Hugh Taylor
Laboratory focus on aspects of human reproductive biology and connections with normal reproductive outcomes. Clinically relevant consideration of human tissue and cell models to study ovarian, uterine, and placental structure and function. Testing of the role of tissue specific cellular differentiation; human trophoblast function; and the roles of steroid hormones in the regulation of uterine, placental, and ovarian function. Mouse tissue models will be employed. Enrollment limited. Concurrently with or after MCDB 210 or 250. Not open to first-year students. Special registration procedures apply; students must consult the instructor prior to the first week of classes. SC ½ Course cr
MCDB 290b, Microbiology  Stavroura Hatzios and Jing Yan
Cell structure of bacteria, bacterial genetics, microbial evolution and diversity, bacterial development, microbial interaction, chemotaxis and motility, gene regulation, microbial genomics and proteomics, CRISPR, metabolism, infectious diseases, mechanisms of pathogenesis, host defense systems, viruses, gut microbiota in health and disease. Prerequisites: BIOL 101, 102, and 103, or equivalent performance on the corresponding biological sciences placement examinations; or one term of biochemistry, or cell biology, or genetics; or with permission of instructor. sc

* MCDB 291Lb, Laboratory for Microbiology  Amaleah Hartman
Practical approaches used when working with microbes, primarily bacteria. Topics include microscopy, culture techniques, biochemical/metabolic assays, and basic environmental and medical microbiology. Concurrently with or after MCDB 290. Electronic permission key required; students should contact the instructor prior to the first class meeting. sc ½ Course cr

* MCDB 300a or b / MB&B 200a or b, Biochemistry  Ronald Breaker
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. Prerequisites: BIOL 101 or equivalent performance on the corresponding biological sciences placement examination; one term of organic chemistry; or with permission of instructor. sc 0 Course cr

* MCDB 301Lb or b / MB&B 251Lb or b, Laboratory for Biochemistry  Aruna Pawashe and Staff
An introduction to current experimental methods in molecular biology, biophysics, and biochemistry. Limited enrollment. Prerequisite: BIOL 101. sc ½ Course cr

* MCDB 303Lb, Advanced Molecular Biology Laboratory  Maria Moreno and F Kenneth Nelson
A laboratory course that provides advanced biology research skills. Weekly workshops focus on laboratory practice, experimental design, data analysis, reading of primary literature, scientific presentations, and scientific writing skills. Application of these skills in project-based laboratory training sponsored by a faculty member. Enrollment limited. Special registration procedures apply; interested students must contact the instructor and attend an organizational meeting. This class is recommended to students in the sciences who are in their junior year and will be completing a senior research project requirement for graduation. sc RP

MCDB 315b, Pathobiology  Jon Morrow, Samuel Katz, Karin Finberg, Gilbert Moeckel, Harold Sanchez, and Declan McGuone
Mechanisms of human disease from a pathologic perspective. Topics include general cell injury and the biology of cellular senescence, cancer genetics, renal disease, neurologic disease, Gastrointestinal and lung disease, along with the systemic manifestations of disease with clinical correlations. Opportunities to observe under the tutelage of an attending pathologist the manifestations of disease in autopsies at Yale-New Haven Hospital and the role of molecular-based diagnostics in medical decision making will be available. Enrollment limited; preference to junior and senior majors in MCDB or MB&B. Prerequisites: MCDB 205, 300, or 310. sc RP

MCDB 320a / NSCI 320a, Neurobiology  Haig Keshishian and Paul Forscher
The excitability of the nerve cell membrane as a starting point for the study of molecular, cellular, and systems-level mechanisms underlying the generation and control of behavior. At least 1 semester of college chemistry is strongly recommended. sc 0 Course cr

MCDB 321La / NSCI 321La, Laboratory for Neurobiology  Haig Keshishian and Paul Forscher
Introduction to the neurosciences. Projects include the study of neuronal excitability, sensory transduction, CNS function, synaptic physiology, and neuroanatomy. Concurrently with or after MCDB 320. sc ½ Course cr

MCDB 325a, Molecular Hallmarks of Cancer  Staff
This course provides a comprehensive introduction to the fundamentals of cancer biology and cancer treatment. Topics covered include: cancer genetics, genomics and epigenetics; familial cancer syndromes; signal transduction, cell cycle control, and apoptosis; cancer metabolism; stem cells and cancer; metastasis; cancer immunology and immunotherapy; conventional and molecularly-targeted therapies; and early detection and prevention. Prerequisites: Introductory courses (BIOL101-104) and two MCDB200-level courses (selected from MCDB200, MCDB202, MCDB205, and MCDB210) or instructor permission. 0 Course cr

MCDB 329a / NSCI 329a, Sensory Neuroscience Through Illusions  Damon Clark and Michael O’Donnell
Animals use sensory systems to obtain and process information about the environment around them. Sensory illusions occur when our sensory systems provide us with surprising or unexpected percepts of the world. The goal of this course is to introduce students to sensory neuroscience at the levels of sensor physiology and of the neural circuits that process information from sensors. The course is centered around sensory illusions, which are special cases of sensory processing that can be especially illustrative, as well as delightful. These special cases are used to learn about the general principles that organize sensation across modalities and species. Prerequisites: BIOL 101-104; NSCI 160 or NSCI 320 or permission of instructor. sc

MCDB 330a / BENG 230a / MB&B 330a / NSCI 324a, Modeling Biological Systems I  Thierry Emonet and Jing Yan
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. This course is aimed at biology students and teaches the analytic and computational methods needed to model genetic networks and protein signaling.
pathways. Students present and discuss original papers in class. They learn to model using MatLab in a series of in-class hackathons that illustrate the biological examples discussed in the lectures. Biological systems and processes that are modeled include: (i) gene expression, including the kinetics of RNA and protein synthesis and degradation; (ii) activators and repressors; (iii) the lysozyme/lysis switch of lambda phage; (iv) network motifs and how they shape response dynamics; (v) cell signaling, MAP kinase networks and cell fate decisions; and (vi) noise in gene expression. Prerequisites: MATH 115 or 116. BIOL 101-104, or with permission of instructors. This course also benefits students who have taken more advanced biology courses (e.g. MCDB 200, MCDB 310, MB&B 300/301). QR, SC 0 Course cr

* MCDB 342La, Laboratory in Nucleic Acids I  
F Kenneth Nelson

A project from a research laboratory within the MCDB department, using technologies from molecular and cell biology. Laboratories meet twice a week for the first half of the term. Concurrently with or after MCBD 202, 205, or 300. Enrollment limited. Special registration procedures apply; students should contact the instructor during January of the year you intend to take the course. SC 0 Course cr

* MCDB 343La, Laboratory in Nucleic Acids II  
F Kenneth Nelson

Continuation of MCBD 342L to more advanced projects in molecular and cell biology, such as microarray screening and analysis, next-generation DNA sequencing, or CRISPR/Cas editing of genes. Laboratories meet twice a week for the second half of the term. 0.5 Yale College course credit(s) Enrollment limited. Special registration procedures apply; students should contact the instructor during January of the year you intend to take the course. Prerequisite: MCBD 342L or permission of instructor. SC 0 Course cr

* MCDB 344Lb, Experimental Techniques in Cellular Biology  
Joseph Wolenski

An inquiry-based approach to research in cell and molecular biology, with emphasis on experimental techniques commonly used in modern biomedical laboratories. Research is module-based and covers pertinent and timely topics. Methods include SDS-PAGE, immunoblotting, immunoprecipitation of proteins, column chromatography, mammalian cell culture, cell fractionation, cell transfection, DNA purification, PCR, and phase contrast and confocal microscopy. Meets during January and February. Prerequisite: MCBD 205. Special registration procedures apply; interested students must contact the instructor at least eighteen months in advance. SC ½ Course cr

* MCDB 345Lb, Experimental Strategies in Cellular Biology  
Joseph Wolenski

Continuation of MCBD 344L, with increased emphasis on experimental design, independent research, presentation of data and research seminars. Students develop semi-independent research projects in modern biomedical research. Emphasis on key components of being a successful principal investigator, including benchmark, seminar presentations, lab meetings, and critical analysis of data. Prepares for MCBD 475, 485, or 495. Meets during March and April. Prerequisite: MCBD 344L. Special registration procedures apply; interested students should contact the instructor. SC ½ Course cr

* MCDB 353a, The Cytoskeleton, Associated Proteins, and Disease  
Surjit Chadha

In-depth discussion of the cytoskeleton, proteins associated with the cytoskeleton, and diseases that implicate members of these protein families. Preference given to seniors in the MCBD major. Prerequisites: BIOL 101-104 and at least one MCBD 200-level course. SC 0 Course cr

MCBD 361b / BENG 465b / MB&MB 361b / NSCI 325b, Modeling Biological Systems II  
Jonathan Howard, Thierry Emonet, and Damon Clark

Advanced topics related to dynamical processes in biological systems. 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. Comparisons between models and experimental data. Dynamical models applied to neurons, neural systems, and cellular biophysical processes. Use of MATLAB to create models. Prerequisite: MCBD 330 or equivalent, or a 200-level biology course, or with permission of instructor. QR

* MCDB 364a / MB&MB 364a, Light Microscopy: Techniques and Image Analysis  
Joseph Wolenski

A rigorous study of principles and pertinent modalities involved in modern light microscopy. The overall course learning objective is to develop competencies involving advanced light microscopy applications common to multidisciplinary research. Laboratory modules coupled with critical analysis of pertinent research papers cover all major light microscope methods – from the basics (principles of optics, image contrast, detector types, fluorescence, 1P and 2P excitation, widefield, confocal principle, TIRF), to more recent advances, including: superresolution, lightsheet, FLIM/FRET, motion analysis and force measurements. This course is capped at 8 students to promote interactions and ensure a favorable hands-on experience. Priority for enrollment is given to students who are planning on using these techniques in their independent research. Prerequisites: MCBD 205, PHYS 170/171 or above, either CHEM 161/165 or above; with CHEM 134L, 136L or permission from the instructor. SC

* MCDB 370b, Biotechnology  
Staff

The principles and applications of cellular, molecular, and chemical techniques that advance biotechnology. The most recent tools and strategies used by industrial labs, academic research, and government agencies to adapt biological and chemical compounds as medical treatments, as industrial agents, or for the further study of biological systems. Prerequisite: MCBD 200, 202, or 300. SC 0 Course cr

* MCDB 375b, Human Biology: Research Methods, Questions, and Societal impact  
Valerie Horsley and Haig Keshishian

This course is intended for upper level MCDB majors and addresses human biology and human subjects research methods and its impact on our understanding of identity. The first third of the course evaluates human subjects research methods and the impact of genetics research on the concept of identity. In the second section of the course, we examine the biology and research that influences identity
stereotypes. The last third of the term we examine the biology and research methods to study past and current issues in society related to human health and biology. Prerequisites: BIOL 101-104, and two MCDB 200-level courses or with permission of instructor. SC

* MCDB 415b, Cellular and Molecular Physiology  Emile Boulpaep
Study of the processes that transfer molecules across membranes. Classes of molecular machines that mediate membrane transport. Emphasis on interactions among transport proteins in determining the physiologic behaviors of cells and tissues. Intended for seniors majoring in the biological sciences. Recommended preparation: MCDB 205, 310, 320, or permission of instructor. SC

* MCDB 425a / MB&B 425a, Basic Concepts of Genetic Analysis  Jun Lu
The universal principles of genetic analysis in eukaryotes. Reading and analysis of primary papers that illustrate the best of genetic analysis in the study of various biological issues. Focus on the concepts and logic underlying modern genetic analysis. Prerequisite: MCDB 202 or pre-approval of instructor. SC

* MCDB 430a, Biology of the Immune System  Staff
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, immunodeficiency, and HIV/AIDS. After MCDB 300. SC 0 Course cr

* MCDB 450b, The Human Genome  Stephen Dellaporta
A focus on the primary scientific literature covering the principles of genomics and its application to the investigation of complex human traits and diseases. Topics include the technology of genome sequencing and resequencing, the characterization of sequence and structural variation in human populations, haplotype and linkage disequilibrium analysis, genome-wide association studies, the comparative genomics of humans and our closest relatives, and personalized genomics and medicine. Enrollment limited to 15. Students should contact the instructor prior to the first week of classes. Prerequisite: MCDB 202; a course in statistics is strongly recommended. SC

MCDB 452b / MB&B 452b / S&DS 352b, Biomedical Data Science, Mining and Modeling  Mark Gerstein
Techniques in data mining and simulation applied to bioinformatics, the computational analysis of gene sequences, macromolecular structures, and functional genomics data on a large scale. Sequence alignment, comparative genomics and phylogenetics, biological databases, geometric analysis of protein structure, molecular-dynamics simulation, biological networks, microarray normalization, and machine-learning approaches to data integration. Prerequisites: MB&B 301 and MATH 115, or permission of instructor. SC

* MCDB 469a / HSHM 469a, Biology of Humans through History, Science, and Society  Valerie Horsley and Carolyn Roberts
This course is a collaborative course between HSHM and MCDB that brings together humanists and scientists to explore questions of biology, history, and identity. The seminar is intended for STEM and humanities majors interested in understanding the history of science and how it impacts identity, particularly race and gender, in the United States. The course explores how scientific methods and research questions have impacted views of race, sex, gender identity, heterosexism, and obesity. Students learn and evaluate scientific principles and concepts related to biological theories of human difference. There are no prerequisites, this class is open to all. WR, HU, SC

* MCDB 470a or b, Tutorial in Molecular, Cellular, and Developmental Biology  Valerie Horsley
Individual or small-group study for qualified students who wish to investigate a broad area of experimental biology not presently covered by regular courses. A student must be sponsored by a Yale faculty member, who sets the requirements. The course must include one or more written examinations and/or a term paper. Intended to be a supplementary course and, therefore, to have weekly or biweekly discussion meetings between the student and the sponsoring faculty member. To register, the student must prepare a form, which is available at http://mcdb.yale.edu/forms as well as on the course site on Classes*v2, and a written plan of study with bibliography, approved by the faculty research adviser. The form and proposal must be uploaded to Classes*v2 by the end of the second week of classes. The final paper is due in the hands of the sponsoring faculty member, with a copy to the course instructor, by the last day of classes. In special cases, with approval of the director of undergraduate studies, this course may be elected for more than one term, but only one term may count as an elective toward the major. Fulfills the senior requirement for the B.A. degree if taken in the senior year. SC

* MCDB 471a, Senior Seminar in Biology  Valerie Horsley
This course instructs students in developing effective writing and speaking skills required for preparation of scientific manuscripts and presentations, and communicating in the scientific world. Students will be required to prepare and present oral presentations and to submit a literature review and written grant proposal by the end of the semester. SC 0 Course cr

* MCDB 474a or b, Independent Research  Joseph Wolenski
Research project under faculty supervision taken Pass/Fail. This is the only independent research course available to undergraduates. Students are expected to spend approximately ten hours per week in the laboratory. To register, the student must submit a form, which is available at http://mcdb.yale.edu/forms as well as on the course site on Canvas@Yale, and a written plan of study with bibliography, approved by the faculty research adviser. The form and proposal must be uploaded to Canvas@Yale by the end of the second week of classes. A final research report is required at the end of the term. Students who take this course more than once must reapply each term. Guidelines for the course should be obtained from the office of the director of undergraduate studies or downloaded from the Canvas@Yale server.

* MCDB 475a or b, Senior Independent Research  Joseph Wolenski
Research project under faculty supervision, ordinarily taken to fulfill the senior requirement. This course is only available to MCDB seniors and they are awarded a letter grade. Students are expected to spend approximately ten hours per week in the laboratory. To
register, the student must prepare a form, which is available at http://mcdb.yale.edu/forms as well as on the course site on Canvas@Yale, and a written plan of study with bibliography, approved by the faculty research adviser. The form and proposal must be uploaded to Canvas@Yale by the end of the second week of classes. The final research paper is due in the hands of the sponsoring faculty member, with a copy uploaded to Canvas@Yale, by the last day of classes. Students who take this course more than once must reapply each term; students planning to conduct two terms of research should consider enrolling in MCDB 485, 486. Students should line up a research laboratory during the term preceding the research. Fulfills the senior requirement for the B.A. degree if taken in the senior year. Two consecutive terms of this course fulfill the senior requirement for the B.S. degree if at least one term is taken in the senior year.

* MCDB 482a, Advanced Seminar in Cell Biology: Intracellular Signal Transduction  Craig Crews
Discussion of intracellular signal transduction pathways. Detailed critique of experimental approaches, controls, results, and conclusions of selected current and classic papers in this field.  

* MCDB 485a or b and MCDB 486a or b, Senior Research  Joseph Wolenski
Individual two-term laboratory research projects under the supervision of a faculty member. For MCDB seniors only. Students are expected to spend ten to twelve hours per week in the laboratory, and to make presentations to students and advisers. Written assignments include a short research proposal summary due at the beginning of the first term, a grant proposal due at the end of the first term, and a research report summarizing experimental results due at the end of the second term. Students are also required to present their research in either the fall or the spring term. A poster session is held at the end of the spring term. Students should line up a research laboratory during the term preceding the research. Guidelines for the course may be obtained at http://mcdb.yale.edu/forms and on the course site on Canvas@Yale. Written proposals are due by the end of the second week of classes. Fulfills the senior requirement for the B.S. degree if taken in the senior year.

* MCDB 495a or b and MCDB 496a or b, Senior Research Intensive  Joseph Wolenski
Individual two-term directed research projects in the field of biology under the supervision of a faculty member. For MCDB seniors only. Before registering, the student must be accepted by a Yale faculty member with a research program in experimental biology and obtain the approval of the instructor in charge of the course. Students spend approximately twenty hours per week in the laboratory, and make written and oral presentations of their research to students and advisers. Written assignments include a short research proposal summary due at the beginning of the first term, a grant proposal due at the end of the first term, and a research report summarizing experimental results due at the end of the second term. Students are also required to present their research during both the fall and spring terms. A poster session is held at the end of the spring term. Guidelines for the course may be obtained at http://mcdb.yale.edu/forms and on the course site on Canvas@Yale. Written proposals are due by the end of the second week of classes. Fulfills the senior requirement for the B.S. degree with an intensive major.  
2 Course cr per term