

MOLECULAR BIOPHYSICS AND BIOCHEMISTRY

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Members of the Department of Molecular Biophysics and Biochemistry (MB&B) are united by a common view that processes in biology are understood when molecular, chemical, kinetic, and thermodynamic contributions to mechanisms have been elucidated. Correspondingly, our faculty and students are joined by a shared fascination with biochemistry, physical chemistry, structural biology, computation, spectroscopy, macromolecular engineering, imaging and the molecular basis of disease.

Three quarters of our graduates matriculate into PhD, MD, and MD/PhD programs. Other recent graduates have joined companies specializing in finance, management consulting, biotechnology, and pharma. Others have matriculated in law or business school and doctoral programs in the humanities. Still others have performed public service, entered secondary education, or joined the United States armed forces as officers.

INTRODUCTORY COURSES

The basic introductory science courses suggested for all majors include a two-term lecture sequence in general chemistry with its associated laboratories (CHEM 1610, 1650, or CHEM 1630, 1670, and CHEM 1340L and 1360L); a one-term course in organic chemistry with its associated laboratory (CHEM 2200 or 1740 with CHEM 2220L); two terms of calculus (MATH 1120 and 1150 or MATH 1160); two half-term units of biochemistry, biophysics and cell biology (BIOL 1010, 1020). Some concentrations, described below, require additional introductory biology satisfied by (BIOL 1030, 1040).

REQUIREMENTS OF THE MAJOR

The core elements of the major are biophysics, biochemistry, and science and society. The requirements beyond these core elements teach advanced concepts, and teach the technology and practical skills that enable scholarship in the discipline.

B.A. Degree Program The B.A. degree program requires a total of 9.5 course credits to include: 3 biophysics credits; 3 biochemistry credits, a half-credit for science and society; 1 credit to fulfill the practical skills requirement; 1 elective; and the senior requirement.

The *core Biophysics requirements* are two semesters of physics (PHYS 1700 and 1710 or higher) and one semester of biophysical chemistry (MB&B 2750 or CHEM 3320).

The *core Biochemistry requirements* include MB&B 3000 and 3010 (substitutions are not permitted), and CHEM 1750 or any 2000+ level Chemistry course.

The *Science and Society core requirement* is 0.5 credit (MB&B 2680 is recommended) and addresses the intersection of Molecular Biophysics & Biochemistry with human identity and society. Alternatives to MB&B 2680 are MB&B 1070, AFAM 1370, HSHM 2060,

241, 4060, 4240, 4750, 4810, HIST 1779, SOCY 1600, 1601, 3760, MCDB 3750, WGSS 2270, 4457. Students may petition for course substitutions.

The *Practical skills* requirement is fulfilled with one full-credit or two half-credit courses spread across two or three of the categories listed below. At least one half-credit must come from MB&B.

- Physics lab options include MB&B 1210L, 1220L, 1230L, 1240L, 4700 and 4710*, PHYS 1650L, 1660L, CHEM 3550L, other 2000+ level lab courses with DUS approval.
- Biochemistry Lab options include MB&B 2510L, 4700 and 4710*, CHEM 3550L, other 2000+ level lab courses with DUS approval.
- Critical Tools options include MB&B 4350, 4700 and 4710*, S&DS 2380, CPSC 1001 and others with DUS approval.

*MB&B 4700 and 4710 are research for credit courses. Above categorization is dependent on the research project. Up to two credits may be taken for a letter grade.

The *Elective course* should be a lecture or seminar MB&B course at the 2000+ level.

B.S. Degree Program The B.S. degree program requires a total of 12.5 course credits including the senior requirement. This program follows the requirements and policies of the B.A. degree program with the following additions.

For the *core Biophysics requirement*: one additional 3000+ course in physical sciences, mathematics, statistics or computer science

For the *Practical Skills requirement*: one additional credit for a total of two credits

For the *elective courses*: one additional 2000+ level seminar or lecture course in STEM

Combined B.S./M.S. Degree Program The B.S./M.S. degree program requires a total of 18.5 course credits including the senior requirement. See Academic Regulations, section L, Special Academic Arrangements, "Simultaneous Award of the Bachelor's and Master's Degrees." Interested students should consult their academic adviser prior to the fifth term of enrollment for details and application requirements (due December 1 of the fifth semester). The B.S./M.S. program follows the requirements of the B.S. Degree program with the following additions.

For the *core Biophysics requirement*: one additional 3000+ course in thermodynamics, statistical mech, quantum and/or spectroscopy (CHEM 3320 is recommended). PHYS 1800 and 1810 in place of PHYS 1700 and 1710.

The *Practical Skills* requirement is replaced by one semester of MB&B 4700 or MB&B 4710 which must be completed by the end of the fifth semester.

For the *Elective course*, the single MB&B 2000+ seminar or lecture elective is replaced by two MB&B electives at 5000+ and four 5000+ electives in STEM.

CONCENTRATIONS

Concentrations in MB&B are sets of electives, curated by faculty, designed to focus attention on specific subfields of Molecular Biophysics and Biochemistry. Concentrations appear on a student's official Yale transcript and are

currently available in Biochemistry; Biophysics and Structural Biology; Chemical Biology; Computational Biology and Bioinformatics; Environment and Climate Change; and Medicine. Students must fulfill all major degree requirements, earning a concentration is optional. For specific concentration requirements see the Concentrations section.

Electives taken for the major that meet the same criteria as requirements for a concentration may be used to fulfill both requirements. Placement exams and acceleration credits do not count towards completion of concentration-specific requirements. Instead, majors enroll in higher-level courses in the same concentration-specific category. Depending on the particular concentration and the choice of electives, concentrations add between zero and three additional credits to major requirements.

Some concentrations include research-for-credit courses or course-based undergraduate research experiences (CUREs) as a mechanism to fulfill a requirement. These courses must directly relate to the chosen concentration (broadly interpreted) and require DUS approval.

Credit/D/Fail No more than one course taken Credit/D/Fail may be applied toward the requirements of the major. This does count against Yale's limit of 6 total Credit/D/Fail courses. Qualifying courses must be 4000+ in MB&B, and 3000+ in any other STEM subject. For B.S./M.S. students, all required coursework must be taken for a letter grade.

Outside credit Courses taken at another institution or during an approved summer or term-time study abroad program may count toward the major requirements with DUS approval.

SENIOR REQUIREMENT

The senior requirement for both the B.S. and the B.A. is fulfilled by successful completion of a one credit senior essay. Students may enroll in MB&B 4900 and prepare a written report and make an oral presentation of a literature project or students may enroll in MB&B 4910 and write an essay that draws on laboratory research performed at Yale College. Students meet with faculty members in charge of the courses during the first two weeks of the term in which they are writing their essay, to agree on a topic and an approach. It is appropriate for students who took research for credit earlier in their training to write on their research topic. The literature project for the senior requirement should be original work approved by the faculty member overseeing MB&B 4900.

The senior requirement for B.S./M.S. is completion of MB&B 5700 and 5701 taken during senior year.

ADVISING

Students are encouraged to declare their major long before completion of the introductory courses. This greatly improves academic advising. Changing majors at Yale does not require approval and is non-binding.

Students are assigned a member of MB&B faculty for academic advising as soon as they declare their major. Requests to change advisers should be sent to the registrar via email (elizabeth.vellali@yale.edu). Justification is not required nor is DUS approval.

Course Substitutions Students may petition their MB&B academic adviser for course substitutions by assembling the relevant syllabi and writing a short justification (less than 300 words). Thoughtful requests in line with MB&Bs teaching goals are always welcome.

DUS approvals: DUS approvals for waivers, course substitutions, endorsement of petitions to the Committee on Honors and Academic Standing, applications to the B.S./M.S. program etc., are initiated by an email of support from student's assigned MB&B academic adviser. The academic adviser functions as the student's advocate on requests to the DUS with the MB&B registrar giving oversight and interfacing with the University registrar. One-on-one meetings by majors with their MB&B academic adviser during every registration period are logged. Failure to schedule meetings and missed meetings are factored into the DUS approval process.

Graduate work Graduate courses in molecular biophysics and biochemistry, biology, and the biomedical sciences that may be of interest to undergraduates are listed in the Graduate School online bulletin, and many are posted on the Biological and Biomedical Sciences website. Additional information is available from the DUSs and the director of graduate studies. Undergraduates with an appropriate background may enroll with the permission of the director of graduate studies and the instructor.

Combined B.S./M.S. degree program A very small number of students will be eligible to complete a four-year course of study within 8 terms of enrollment leading to the simultaneous award of the B.S. and M.S. degrees. See Academic Regulations, section L, Special Academic Arrangements, "Simultaneous Award of the Bachelor's and Master's Degrees." Interested students should consult their academic adviser prior to the fifth term of enrollment.

Sample schedules Diverse pathways exist for navigating the B.A. and B.S. degrees. In general, students are strongly encouraged to complete General Chemistry (e.g. CHEM 1610, 1650, 1340L and 1360L), introductory calculus (e.g. MATH 1120) and introductory Biochemistry, Biophysics and Cell Biology (BIOL 1010, 1020) by the end of their first year. See the MB&B website for 4-year sample degree programs covering all six concentrations and for students who do not elect to pursue a concentration.

SUMMARY OF MAJOR REQUIREMENTS

Introductory courses BIOL 1010 and 1020; 2 terms general chem with associated labs; 1 term organic chem with associated lab; 2 terms of calculus; BIOL 1030 and 1040 for some concentrations

Number of courses B.A. –9.5 course credits (incl senior project); B.S. –12.5 course credits (incl senior project)

Distribution of courses B.A. –3 biophysics credits to incl MB&B 2750 or CHEM 3320 and PHYS 1700 and 1710 or higher; 3 biochemistry credits to incl MB&B 3000, 3010, and CHEM 1750 or 2000+ Chem course; MB&B 2680, a half-credit for science and society or other course as approved by DUS; 1 credit practical skills course(s); and 1 MB&B elective 2000+ level or higher; B.S. –same reqs as for B.A.degree plus 1 addtl Practical Skills credit; 1 addtl 3000+ biophysics credit; and one addtl 2000+ credit in STEM

Senior requirement MB&B 4900 or MB&B 4910

CONCENTRATIONS

BIOCHEMISTRY CONCENTRATION

The concentration in Biochemistry is geared towards students seeking robust training in structure and function of nucleic acids and proteins in the context of life processes. Molecular length scale biochemistry is foundational to the mechanisms by which dynamic networks of molecular machines enable everything from cellular function to whole organism physiology. Failures in these networks are responsible for pathology in plants and animals, agriculture and medicine. MB&B majors interested in working in these fields directly after graduation, or who hope to pursue graduate studies including PhD and MD/PhD, are particularly encouraged to fulfill this concentration.

In addition to, or as part of, the degree requirements, the following courses are required:

Genetics and Development and Ecology and Evolution: BIOL 1030 and 1040

Molecular, Cellular, or Organismal Biology: MCDB 2050, MCDB 2020, or as approved by the DUS

Research in Biochemistry: MB&B 4700 or MB&B 4710 or course-based undergraduate research

Advanced Chemical Biology lecture or seminar (1 credit for B.A. degree and 2 credits for B.S. degree): 3000+ courses such as MB&B 3650, MB&B 3310, MB&B 4450, MB&B 4490, or MB&B 4430

BIOPHYSICS AND STRUCTURAL BIOLOGY CONCENTRATION

This concentration is designed for students with strong interests in life processes on the molecular length scale. Majors aspiring to graduate studies in biophysics, molecular medicine, and biotechnology are particularly encouraged to fulfill this concentration.

Biophysics and Structural Biology are made possible by fundamental quantitative and physical tools such as linear algebra, Fourier analysis, x-ray diffraction, imaging, and optical spectroscopy to measure biomolecular dynamics and atomic resolution structure. Seminar courses applicable to this area focus on the basic biology enabled by exquisitely specific macromolecular interactions, the molecular basis of disease and drug-design.

In addition to, and/or as part of, the degree requirements, the following courses are required:

Computer Science, Math, Statistics (for B.A. degree): one from MATH 1200, MATH 2250, S&DS 1000+, or CPSC 1001

Computer Science, Math, Statistics (for B.S. degree): one from MATH 1200, MATH 2250, S&DS 2380, or CPSC 1001

Biophysical Chemistry (for B.S. degree): one from CHEM 3320 or any 3000+ elective in thermodynamics, statistical mech, quantum mechanics or spectroscopy

Research in Biophysics and Structural Biology (for both degrees): one from MB&B 4700, MB&B 4710, CHEM 3550L, or course-based undergraduate research

Tools and Quantitative Analysis (for B.S. degree): one 2000+ course with emphasis on measurement and/or modeling of energy, kinetics, or structure relevant to the molecular length scale, such as MB&B 3300, MB&B 4200, MB&B 4350, CHEM 3330, CHEM 4060, CHEM 4920, or as approved by the DUS

Advanced Biophysics and Structural Biology lecture or seminar (both degrees): one from MB&B 4200, MB&B 5200, or as approved by the DUS

CHEMICAL BIOLOGY CONCENTRATION

Chemical Biology leverages the tools and concepts of chemistry to understand and/or manipulate biological processes. Students interested in the MB&B concentration in Chemical Biology select electives from organic and inorganic chemistry as well as advanced courses in cell biology. Majors interested in additional studies in chemical biology, drug development, and/or biotechnology after graduation are particularly encouraged to fulfill this concentration.

In addition to, or as part of, the degree requirements, the following courses are required:

Organic Chemistry (both degrees): second semester of Organic Chemistry and accompanying half-credit lab

Cell Biology and Chemistry (for B.S. degree only): two 2000+ electives *and* one 3000+ elective in Chemistry or Cell Biology (at least one credit must cover cell biology or chemistry)

Cell Biology (for B.A. degree only): one 2000+ elective in cell-based biology

Research in Chemical Biology (both degrees): one from MB&B 4700, MB&B 4710, or MB&B 3640, or course-based undergraduate research

Advanced Chemical Biology lecture or seminar (both degrees): MB&B 4430 or CHEM 4190 or as approved by the DUS

COMPUTATIONAL BIOLOGY AND BIOINFORMATICS CONCENTRATION

This concentration is designed for students with strong interests in computer science, data science, statistics, and biology. Majors aspiring to graduate studies in computational biology, bioinformatics, medical informatics or biotechnology are particularly encouraged to fulfill this concentration.

In addition to, and/or as part of, the degree requirements, the following courses are required:

Genetics and Evolutionary Biology (B.A. degree): BIOL 1030 and 1040

Genetics and Evolutionary Biology (B.S. degree): one 2000+ elective in genetics, MCDB 2000, MCDB 2020, MCDB 3100, MB&B 3310

Computer Science, Math, Statistics (B.A. degree): CPSC 2010 *and* one S&DS 1000+ course

Computer Science, Math, Statistics (B.S. degree): CPSC 2230, CPSC 2010, and S&DS 2380 (CPSC 2230 may also be used to fulfill the 3000+ core biophysics elective requirement). Other courses may be substituted with permission of the DUS.

Advanced Computational Biology & Bioinformatics (both degrees): MB&B 3520 or CPSC 4530 or as approved by the DUS.

ENVIRONMENT AND CLIMATE CHANGE CONCENTRATION

This concentration is geared towards students seeking robust training in life processes as they affect, and are affected by the environment, human activity, and climate change. MB&B majors interested in working in these fields directly after graduation, or who hope to pursue graduate studies are particularly encouraged to fulfill this concentration.

In addition to, or as part of, the degree requirements, the following courses are required:

Physical environmental science (for B.S. degree): one credit 3000+ course from EVST 3620, EPS 3100, EPS 3230, EPS 3350, CHEM 3320, or CHEM 3330

Environmental chemistry (both degrees): one credit 2000+ course from EVST 3307, EPS 3100, CHEM 2520, or ENVE 4380. May be used to fulfill 2000+ elective requirement in chemistry.

Math, statistics and/or computer science (both degrees): one credit course from MATH 1200, MATH 1210, MATH 2220 or higher, S&DS 1000 or higher, or CPSC 1001 or higher. May be used to fulfill the practical skills requirement.

Ecology and evolution (both degrees): one credit 1000+ course from BIOL 1040, EEB 2225, or ANTH 2667. May be used to fulfill the 2000+ STEM requirement for the B.S. degree.

Environmental Sciences (both degrees): one credit 1000+ course from CENG 1200, EVST 2200, EVST 2550, EPS 1010, EPS 1250, EPS 1400, EPS 2320, or EPS 2610. May be used to fulfill 2000+ STEM requirement for B.S. degree.

Advanced Environment Lecture or Seminar (one credit for B.A. degree/two credits for B.S. degree): one or two credit courses from MB&B 3650, ENVE 4640, EVST 4005, EPS 3550, ENVE 4100, EPS 3230, ENVE 3600, ENVE 4380. MB&B 3650 may be used to fulfill 2000+ MB&B requirement for all degrees.

MEDICINE CONCENTRATION

This concentration is designed for students with strong interests in the molecular basis of physiology and disease. Majors aspiring to graduate studies in biomedical sciences, work in biotechnology, or medical school are particularly encouraged to fulfill this concentration.

In addition to, or as part of, the degree requirements, the following courses are required:

Genetics and Development: BIOL 1030 and 1040

Organic Chemistry: second term of organic chemistry (CHEM 1750 or 2210)

Statistics: Any introductory S&DS 1000+ or a 2000+ MATH course in linear algebra, probability, statistics or stochastic processes

Psychology: PSYC 1100 or higher

Physics labs (1 credit): MB&B 1210L, MB&B 1240L, PHYS 1650L, 1660L, MB&B 3640, or others as approved by the DUS (see below).

Biomedical research (total for 1 credit): MB&B 4700 or MB&B 4710, or course based undergraduate research including MB&B 2510L, MCDB 2910L, or others

Advanced Seminar: one

from MB&B 4450, MB&B 3520, MB&B 4490, MCDB 3150, MCDB 4500, or others as approved by the DUS.

FACULTY OF THE DEPARTMENT OF MOLECULAR BIOPHYSICS AND BIOCHEMISTRY

Professors †Karen Anderson, Susan Baserga, †Ronald Breaker, †Gary Brudvig, †Sandy Chang, Enrique De La Cruz, †Daniel DiMaio, Donald Engelman, Mark Gerstein, Wendy Gilbert, Nigel Grindley (*Emeritus*), Mark Hochstrasser, Jonathon Howard, Michael Koelle, Anthony Koleske, William Konigsberg (*Emeritus*), †Mark Lemmon, †Patrick Loria, †I. George Miller, Andrew Miranker, †Peter Moore (*Emeritus*), Karla Neugebauer, Lynne Regan (*Emeritus*), †Karen Reinisch, †David Schatz, Christian Schlieker, Robert Schulman (*Emeritus*), †Frederick Sigworth, Dieter Söll (*Emeritus*), Mark Solomon, Joan Steitz, Scott Strobel, Steven Tang, Yong Xiong

Associate Professors Julien Berro, †Titus Boggon, †Erdem Karatekin, Nikhil Malvankar, Matthew Simon, †Sarah Slavoff, †Shervin Takyar, †Yongli Zhang

Assistant Professors Franziska Bleichert, Allison Didychuk, †Luisa Escobar-Hoyos, Lilian Kabeche, †Wei Mi, Candice Paulsen, Kai Zhang

Adjunct Professors Kenneth Williams, Carl Zimmer

Lecturer Ghazia Abbas

†A joint appointment with primary affiliation in another department.

Courses

* MB&B 0500b, Topics in Cancer Biology Sandy Chang

Introduction to cancer as a genetic disease, with a focus on major discoveries in cancer biology that offer mechanistic insights into the disease process. A brief history of cancer; influence of the genomic revolution on cancer diagnostics; molecular defects underlying specific cancers; current and future cancer therapeutics. Patient case studies highlight specific molecular pathways and treatment strategies. Enrollment limited to first-year students with a strong background in biology and/or chemistry, typically demonstrated by a score of 5 on Advanced Placement examinations. WR, SC

MB&B 1050a or b / MCDB 1050a 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

*** MB&B 1070b / EDST 107 / EDST 3107b / PHYS 1070b, Being Human in STEM**
Staff

A collaboratively designed, project-oriented course that seeks to examine, understand, and disseminate how diversity of gender, race, religion, sexuality, economic circumstances, etc. shape the STEM experience at Yale and nationally, and that seeks to formulate and implement solutions to issues that are identified. Study of relevant peer-reviewed literature and popular-press articles. OpEd writing project and design and implementation of an intervention project focusing on improving belonging in Yale STEM communities. SO

*** MB&B 1210La / PHYS 1210La, Introduction to Physics in Living Systems I: Observation and Analysis** Staff

A hands-on introduction to the physics that enables life and human measurement of living things. This lab builds student knowledge of scientific experimental design and practice. Topics include detection of light, basic circuit building, sterile technique in biology and physics, data collection with student-built instrumentation, and quantitative assessment. For students choosing to major in MB&B, this course may be used to fulfill the MB&B requirement for *Practical Skills* in physics. There are no prerequisites to this ½ credit class and it is helpful to take it in the same semester as MB&B 122L. Priority is given to first-year students looking to fulfill medical school application requirements and students seeking to join research labs at Yale. SC

o Course cr

*** MB&B 1220La / PHYS 1220La, Introduction to Physics in Living Systems: Observation and Analysis II** Staff

A hands-on introduction to the physics that enables life and human measurement of living things. This lab builds student knowledge of scientific experimental design and practice, focusing on building models from experimental data. Topics included electrical circuits, magnetism, data collection with student-built instrumentation, and quantitative assessment. For students choosing to major in MB&B, this course may be used to fulfill the MB&B requirement for *Practical Skills* in physics. Previously MB&B 122L. Taking MB&B/PHYS 1210L before this class is required, as the material builds on itself. Priority is given to first-year students looking to fulfill medical school application. SC

o Course cr

*** MB&B 1230Lb / PHYS 1230Lb and PHYS 123Lb / PHYS 123Lb, Introduction to Physics in Living Systems III: Mechanics** Andrew Miranker

A hands-on introduction to the physics that enables life and human measurement of living things. The course focuses on the principles of mechanics at work in the biological sciences. This lab builds student knowledge, centering diffusion as an emergent phenomenon from elastic collisions, from which statistical mechanics is introduced. For students choosing to major in MB&B, this course may be used to fulfill the MB&B requirement for *Practical Skills* in physics. Priority for this 1/2 credit course is

given to first-year students looking to fulfill medical school application requirements. It is helpful to take this course in the same semester as MB&B 124L. ½ Course cr

*** MB&B 124oLb / PHYS 124oLb, Introduction to Physics in Living Systems**

Laboratory IV: Electricity, Magnetism, and Radiation Andrew Miranker

Introduction to the physics that enables life and human measurement of living things. This lab introduces principles of electricity, magnetism, light and optics at work in the biological sciences. The syllabus emphasizes electric dipoles as a model for biomolecules, electric fields such as those across cell membranes, electric current, and magnetic fields. Light is developed in terms of electromagnetic radiation, ray optics and photons. The interaction of light with biomolecules to understand basic biological research and medical diagnostics are also covered. For students choosing to major in MB&B, this course may be used to fulfill the MB&B requirement for *Practical Skills* in physics. There are no prerequisites to this ½ credit class and it is helpful to take it in the same semester as MB&B 123L. May not be taken after PHYS 166L. Priority is given to first-year students looking to fulfill medical school application requirements and students seeking to join research labs at Yale. SC o Course cr

*** MB&B 2000a or b / MCDB 3000a or b, Biochemistry** Staff

An introduction to the biochemistry of animals, plants, and microorganisms, emphasizing the relations of chemical principles and structure to the evolution and regulation of living systems. Introductory biology coursework (BIOL 101, BIOL 102, BIOL 103) or equivalent performance on the corresponding biological sciences placement examination; one term of organic chemistry (CHEM 174 or CHEM 220); or with permission of instructor. Note for MB&B majors: this course does not substitute for MB&B 300 and MB&B 301. SC o Course cr

*** MB&B 251oLa or b / MCDB 301oLa or b, Laboratory for Biochemistry** Ghazia Abbas

An introduction to current experimental methods in molecular biology, biophysics, and biochemistry. Limited enrollment. Prerequisite: BIOL 101. SC ½ Course cr

MB&B 2750a, Biology at the Molecular Level Enrique De La Cruz and Allison Didychuk

An introductory course for students to learn the key concepts from physics and physical chemistry that govern the structure and function of biomolecules in biology and medicine. Emphasis is placed on atomic-scale biomolecular motions, energy, reaction rates and mechanisms; core elements that underpin the exquisite specificity and regulated control of life processes. This course prepares students for upper level course content where these concepts are revisited. Connections to medicine and research are made through the use of practical examples, laboratory-based activities and training in biologically relevant areas of math, statistics and computer programming. This course is open to all Yale students. For MB&B majors, this course is accepted as fulfillment of one semester of MB&B's two-semester requirement in physical chemistry. Prerequisites: BIOL 101-102, MATH 112 (or equivalent), college level General Chemistry, and high school Physics. SC

MB&B 3000a, Principles of Biochemistry I Staff

Discussion of the physical, structural, and functional properties of proteins, lipids, and carbohydrates, three major classes of molecules in living organisms. Energy metabolism and hormone signaling as examples of complex biological processes whose underlying

mechanisms can be understood by identifying and analyzing the molecules responsible for these phenomena. Prerequisites: After BIOL 101 and CHEM 174 or CHEM 220. SC o Course cr

MB&B 301ob, Principles of Biochemistry II Christian Schlieker and Franziska Bleichert

Building on the principles of MB&B 300 through study of the chemistry and metabolism of DNA, RNA, and proteins. Critical thinking emphasized by exploration of experimental methods and data interpretation, from classic experiments in biochemistry and molecular biology through current approaches. Prerequisite: MB&B 300 or permission of instructor. SC

MB&B 3300a and MB&B 3310a / BENG 3230a / MCDB 3310a / NSCI 3240a, Modeling Biological Systems I Thierry Emonet and Kathryn Miller-Jensen

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 lysogeny/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 o Course cr per term

MB&B 352ob / MCDB 352ob / S&DS 352ob, Biomedical Data Science, Mining and Modeling Mark Gerstein and Matthew Simon

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 o Course cr

*** MB&B 3640a / MCDB 3640a, Light Microscopy: Techniques and Image Analysis** Joseph Wolenski and Jonathon Howard

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: MCDB 205, PHYS 170/171 or above, either CHEM 161/165 or above; with CHEM 134L, 136L or permission from the instructor. SC

MB&B 3650b / EVST 3650b, Biochemistry and Our Changing Climate Karla Neugebauer

Climate change is impacting how cells and organisms grow and reproduce. Imagine the ocean spiking a fever: cold-blooded organisms of all shapes, sizes and complexities struggle to survive when water temperatures go up 2-4 degrees. Some organisms adapt to extremes, while others cannot. Predicted and observed changes in temperature, pH and salt concentration do and will affect many parameters of the living world, from the kinetics of chemical reactions and cellular signaling pathways to the accumulation of unforeseen chemicals in the environment, the appearance and dispersal of new diseases, and the development of new foods. In this course, we approach climate change from the molecular point of view, identifying how cells and organisms—from microbes to plants and animals—respond to changing environmental conditions. To embrace the concept of “one health” for all life on the planet, this course leverages biochemistry, cell biology, molecular biophysics, and genetics to develop an understanding of the impact of climate change on the living world. We consider the foundational knowledge that biochemistry can bring to the table as we meet the challenge of climate change. Prerequisites: MB&B 300/301 or MB&B 200/MCDB 300 or permission of the instructor. Can be taken concurrently with MB&B 301. WR, SC o Course cr

MB&B 4200a, Macromolecular Structure and Biophysical Analysis Yong Xiong, Jonathon Howard, Steven Tang, and Franziska Bleichert

Analysis of macromolecular architecture 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: MBB 301 and 302. SC

*** MB&B 4250a / MCDB 4250a, 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

MB&B 4350a, Quantitative Methods in Biology Nikhil Malvankar, Julien Berro, and Yong Xiong

An introduction to quantitative methods relevant to analysis and interpretation of **biological** data. Topics include statistical testing, data presentation, and error analysis; introduction to artificial intelligence-based data analysis tools, Alpha Fold Tutorial, introduction to mathematical modeling of biological dynamics; and Fourier analysis in signal/image processing and macromolecular structural studies. Instruction in basic programming skills and data analysis using MATLAB; study of real data from MB&B research groups. Prerequisites: MATH 120 and MB&B 300 or equivalents, or with permission of instructors. QR, SC

MB&B 4430b, Advanced Eukaryotic Molecular Biology Mark Hochstrasser, Wendy Gilbert, Matthew Simon, and Franziska Bleichert

Selected topics in regulation of chromatin structure and remodeling, mRNA processing, mRNA stability, translation, protein degradation, DNA replication, DNA

repair, site-specific DNA recombination, and somatic hypermutation. Prerequisites: MB&B 300 and 301, or permission of instructor. SC

*** MB&B 4450b, Methods and Logic in Molecular Biology** Candie Paulsen and Julien Berro

An examination of fundamental concepts in molecular biology through analysis of landmark papers. Development of skills in reading the primary scientific literature and in critical thinking. Prerequisites: MB&B 300 and 301. SC

MB&B 4490a, Medical Impact of Basic Science Joan Steitz, Abhijit Patel, George Miller, Andrew Miranker, David Schatz, Sandy Chang, Allison Didychuk, and Daniel DiMaio

Examples of recent discoveries in basic science that have elucidated the molecular origins of disease or that have suggested new therapies for disease. Readings from the primary scientific and medical literature, with emphasis on developing the ability to read this literature critically. Prerequisites: MB&B 300 and 301 or equivalents, or permission of instructor. SC

*** MB&B 4590a / ENGL 4459a / EVST 4469a, Writing about Science, Medicine, and the Environment** Carl Zimmer

Advanced non-fiction workshop in which students write about science, medicine, and the environment for a broad public audience. Students read exemplary work, ranging from newspaper articles to book excerpts, to learn how to translate complex subjects into compelling prose. Admission by permission of the instructor only. Applicants should email the instructor at carl@carlzimmer.com with the following information:

1. One or two samples of nonacademic, nonfiction writing. (No fiction or scientific papers, please.) Indicate the course or publication, if any, for which you wrote each sample.
2. A note in which you briefly describe your background (including writing experience and courses) and explain why you'd like to take the course. Formerly ENGL 459. WR

*** MB&B 4700a or b, Research in Biochemistry and Biophysics for the Major I** Staff

Individual laboratory projects under the supervision of a faculty member. Students must submit an enrollment form that specifies the research supervisor by the date that course schedules are due. Students are expected to commit at least ten hours per week to working in a laboratory. Written assignments include a research proposal, due near the beginning of the term, and a research report that summarizes experimental results, due before the beginning of the final examination period. Students receive a letter grade. Up to 2 credits of MB&B 470/471 may be counted toward the MB&B major requirements. Enrollment limited to MB&B majors. Prerequisite: MB&B 251L or permission of the instructor.

*** MB&B 4900a or b, The Senior Literature Essay** Christian Schlieker

This course fulfills the MB&B senior requirement for BA/BS majors and may be taken in either the fall or spring term of senior year. Students complete an independent project by reading primary literature and writing a critical review on a topic chosen by the student in any area of molecular biophysics and biochemistry. The chosen topic cannot draw directly on the student's research experiences while enrolled at Yale. For topics drawing directly from a student's research experience, students should enroll in MB&B 491: Senior Research Essay. The course structure first assists the student to identify a topic and then identifies a member of the MB&B faculty with appropriate expertise.

The member of faculty meets regularly with the student as the topic is researched, drafted, and submitted at a quality appropriate for publication. A departmental poster session at the end of the semester gives the student the opportunity to disseminate their work to the broader MB&B and Yale community.

MB&B 4910a or b, The Senior Research Essay Christian Schlieker and Nikhil Malvankar

In this class, students complete an independent project by reading primary literature and writing a critical review on a topic chosen by the student in any area of molecular biophysics and biochemistry. The chosen topic must be related to the student's research experiences while enrolled at Yale. For topics that do not draw from a student's research experience, students should enroll in MB&B 490: Senior Literature Essay. The course structure first assists the student to identify a topic and then identifies a member of the MB&B faculty with appropriate expertise. The faculty member, if a member of MB&B, can be the student's research supervisor. The member of faculty meets regularly with the student as the topic is researched, drafted, and submitted at a quality appropriate for publication. A departmental poster session at the end of the semester gives the student the opportunity to disseminate their work to the broader MB&B and Yale community.

MB&B TBD-3a, Seminar in Molecular Cell Biology Min Wu

A graduate-level seminar in modern cell biology. The class is devoted to the reading and critical evaluation of classical and current papers. The topics are coordinated with the CBIO 602 lecture schedule. Thus, concurrent enrollment in CBIO 602 is required. Prerequisites: Any undergraduates wishing to enroll must have already taken MCDB 205. In addition, undergraduates are strongly encouraged to reach out to the course directors prior to enrollment.