

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 161, 165, 134L and 136L); a one-term course in organic chemistry with its associated laboratory (CHEM 220 or 174 with CHEM 222L); two terms of calculus (MATH 112 and MATH 115 or 116); two half-term units of biochemistry, biophysics and cell biology (BIOL 101, 102). Some concentrations, described below, require additional introductory biology satisfied by (BIOL 103, 104).

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.

The major requirements for the Class of 2024 and Class of 2025 With approval from the DUS, the following changes to the major may be fulfilled by students who declared their major under previous requirements.

The following changes to the major requirements for the Class of 2026 and subsequent classes apply to the B.S. degree, the B.A. degree, and the B.S./M.S. degree.

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 170 and 171 or higher) and one semester of biophysical chemistry (MB&B 275 or CHEM 332).

The *core Biochemistry requirements* include MB&B 300 and 301 (substitutions are not permitted), and CHEM 175 or any 200+ level Chemistry course.

The *Science and Society core requirement* is 0.5 credit (MB&B 268 is recommended) and addresses the intersection of Molecular Biophysics & Biochemistry with human identity and society. Alternatives to MB&B 268 are MB&B 107, AFAM 170, HSHM 206, HSHM 241, HSHM 406, HSHM 409, HSHM 424, HSHM 436, HSHM 475, HSHM 481, HIST 479, SOCY 126, SOCY 127, SOCY 351, MCDB 375, WGSS 270, WGSS 457, WGSS 741. Petitions for course substitutions (see below) are encouraged.

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 121L, MB&B 124L, MB&B 470 and MB&B 471*, PHYS 165L, PHYS 166L, CHEM 355L, other 200+ level lab courses with DUS approval.
- Biochemistry Lab options include MB&B 251L, MB&B 470 and MB&B 471*, CHEM 355L, other 200+ level lab courses with DUS approval.
- Critical Tools options include MB&B 435, MB&B 470 and MB&B 471*, S&DS 105, 238, CPSC 112 and others with DUS approval.

*MB&B 470 and MB&B 471 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 200+ 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 300+ 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 200+ 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 advisor 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 300+ course in thermodynamics, statistical mech, quantum and/or spectroscopy (CHEM 332 is recommended). PHYS 180 and 181 in place of PHYS 170 and 171.

The *Practical Skills* requirement is replaced by one semester of MB&B 470 or 471 which must be completed by the end of the fifth semester.

For the *Elective course*, the single MB&B 200+ seminar or lecture elective is replaced by two MB&B electives at 500+ and four 500+ 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 One course taken Credit/D/Fail may be counted toward the requirements of the major. This does not affect students' ability to graduate with distinction, but does count against Yale's limit of 6 total Credit/D/Fail courses. Qualifying courses must be 400+ in MB&B, and 300+ in any other STEM subject. For B.S./M.S. students, all required coursework must be taken for a letter grade.

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 490 and prepare a written report and make an oral presentation of a literature project or students may enroll in MB&B 491 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 490.

The senior requirement for B.S./M.S. is completion of MB&B 570 and 571 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 advisors 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 the DUS 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 students' assigned MB&B academic advisor. The academic advisor 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 advisor 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 DUSes 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 six-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 advisor 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 161, 165, 134L and 136L), introductory calculus (e.g. MATH 112) and introductory Biochemistry, Biophysics and Cell Biology (BIOL 101, 102) 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 101 and 102; 2 terms general chem with associated labs; 1 term organic chem with associated lab; 2 terms of calculus; BIOL 103 and 104 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 275 or CHEM 332 and PHYS 170 and PHYS 171 or higher; 3 biochemistry credits to incl MB&B 300, 301, and CHEM 175 or 200+ Chem course; MB&B 268, 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 200+ level or higher; B.S.–same reqs as for B.A.degree plus 1 addtl Practical Skills credit; 1 addtl 300+ biophysics credit; and one addtl 200+ credit in STEM

Senior requirement MB&B 490 or MB&B 491

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 103 and 104

Molecular, Cellular, or Organismal Biology: MCDB 205, 202, or as approved by the DUS

Research in Biochemistry: MB&B 470 or 471 or course-based undergraduate research

Advanced Chemical Biology lecture or seminar (1 credit for B.A. degree and 2 credits for B.S. degree): 300+ courses such as MB&B 365, 330, 445, 449, or 443

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 120, 225, S&DS 100+, or CPSC 112

Computer Science, Math, Statistics (for B.S. degree): one from MATH 120, 225, S&DS 238, or CPSC 112

Biophysical Chemistry (for B.S. degree): one from CHEM 332 or MB&B 431 or any 300+ elective in thermodynamics, statistical mech, quantum mechanics or spectroscopy

Research in Biophysics and Structural Biology (for both degrees): one from MB&B 470, MB&B 471, CHEM 355, or course-based undergraduate research

Tools and Quantitative Analysis (for B.S. degree): one 200+ course with emphasis on measurement and/or modeling of energy, kinetics, or structure relevant to the molecular length scale, such as MB&B 330, 420, 431, 435, CHEM 333, 406, 492, or as approved by the DUS

Advanced Biophysics and Structural Biology lecture or seminar (both degrees): one from MB&B 420, 431, 520, 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 200+ electives and one 300+ elective in Chemistry or Cell Biology (at least one credit must cover cell biology or chemistry)

Cell Biology (for B.A. degree only): one 200+ elective in cell-based biology

Research in Chemical Biology (both degrees): one from MB&B 470, 471, or MB&B 364, or course-based undergraduate research

Advanced Chemical Biology lecture or seminar (both degrees): MB&B 443 or CHEM 419 or as approved by the DUS

COMPUTATIONAL BIOLOGY & 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 103 and 104

Genetics and Evolutionary Biology (B.S. degree): one 200+ elective in genetics, MCDB 200, 202, 310, MB&B 330

Computer Science, Math, Statistics (B.A. degree): CPSC 201 and one S&DS 100+ course

Computer Science, Math, Statistics (B.S. degree): CPSC 223, CPSC 201, and S&DS 238 (CPSC 223 may also be used to fulfill the 300+ core biophysics elective requirement). Other courses may be substituted with permission of the DUS.

Advanced Computational Biology & Bioinformatics (both degrees): MB&B 452 or CPSC 453 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 300+ course from EVST 362, EPS 310, EPS 323, EPS 335, CHEM 332, or CHEM 333

Environmental chemistry (both degrees): one credit 200+ course from EVST 307, EPS 310, CHEM 252, or ENVE 438. May be used to fulfill 200+ elective requirement in chemistry.

Math, statistics and/or computer science (both degrees): one credit course from MATH 120, MATH 121, MATH 222 or higher, S&DS 100 or higher, or CPSC 100 or higher. May be used to fulfill the practical skills requirement.

Ecology and evolution (both degrees): one credit 100+ course from BIOL 104, E&EB 225, or ANTH 267. May be used to fulfill the 200+ STEM requirement for the B.S. degree.

Environmental Sciences (both degrees): one credit 100+ course from CENG 120, EVST 223, EVST 265, EPS 101, EPS 125, EPS 140, EPS 232, or EPS 261. May be used to fulfill 200+ 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 365, ENVE 464, EVST 415, EPS 355, ENVE 441, EPS 323, ENVE 360, ENVE 438. MB&B 365 be used to fulfill 200+ 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 103 and 104

Organic Chemistry: second term of organic chemistry (CHEM 175 or 221)

Statistics: Any introductory S&DS 100+ course, S&DS 150, S&DS 230 recommended

Psychology: PSYC 110 or higher or PSYC 312

Physics labs (1 credit): MB&B 121L, MB&B 124L, PHYS 165L, 166L, MB&B 364, or others as approved by the DUS (see below) are encouraged.

Biomedical research (total for 1 credit): MB&B 470 or MB&B 471, or course based undergraduate research including MB&B 251L, MCDB 291L, or others

Advanced Seminar: one

from MB&B 445, MB&B 452, MB&B 449, MCDB 315, MCDB 450, or others as approved by the DUS

The Department of Molecular Biophysics and Biochemistry (MB&B) is for students interested not just in what life is, but also in how it works. MB&B invites interested students to join the department and share in its fascination with biochemistry, biophysical chemistry, structural biology, computation, spectroscopy, macromolecular engineering, imaging and the molecular basis of disease. For example biochemistry was used to determine the building blocks of DNA and that DNA carries genetic information; biophysics was used to determine the atomic structures and chemical mechanisms by which two meters of this information, encoding six billion letters, is compressed one-million fold, stored and read inside every cell of the body.

The major offers B.A., B.S., and B.S./M.S. degrees to directly engage students' specific interests.

To maximize elective opportunities both within the major and for other aspects of a liberal arts education, first years interested in the MB&B major should start by taking the most advanced chemistry courses for which they are eligible. Most MB&B students take General Chemistry, CHEM 161 and CHEM 165, with the associated labs in their first year. Others, who place into Organic Chemistry, take CHEM 174 and the associated lab in their first year.

First-year students are encouraged to visit the MB&B web page for undergraduates, and to contact the director of undergraduate studies (MBBUndergrad@yale.edu) if they have any questions.

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*), † Sharon Hammes-Schiffer, Mark Hochstrasser, Jonathon Howard, Michael Koelle, Anthony Koleske, William Konigsberg, †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, Mark Solomon, Joan Steitz, Scott Strobel, Yong Xiong

Associate Professors Julien Berro, †Titus Boggon, Matthew Simon, †Shervin Takyar, †Yongli Zhang

Assistant Professors Franziska Bleichert, Allison Didychuk, †Luisa Escobar-Hoyos, Lilian Kabeche, †Erdem Karatekin, Nikhil Malvankar, †Wei Mi, Candice Paulsen, †Sarah Slavoff, Kai Zhang

Adjunct Professors Kenneth Williams, Carl Zimmer

Lecturer Kate Schilling

†A joint appointment with primary affiliation in another department.

See visual roadmap of the requirements.

View Courses

Courses

* **MB&B 050b, 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. Preregistration required; see under First-Year Seminar Program. WR, SC

* **MB&B 099b / MCDB 099b / MENG 099b / PHYS 099b / SCIE 099b, Introduction to Research Methods in Physics and Biology: Preparing for a First Research Experience** Simon Mochrie

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.

MB&B 105a or b / MCDB 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

* **MB&B 107b / EDST 107b / PHYS 107b, Being Human in STEM** Rona Ramos

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. Implementation of a questionnaire and interviews of STEM participants at Yale. Creation of role-play scenarios for provoking discussions and raising awareness. Design and implementation of group interventions.

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[MB&B 110, Current Issues in Biological Science]*** MB&B 121La or b / PHYS 121La or b, 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 124L. Priority is given to first-year students looking to fulfill medical school application requirements and students seeking to join research labs at Yale. SC ½ Course cr

*** MB&B 124La or b / PHYS 124La or b, Introduction to Physics in Living Systems Laboratory IV: Electricity, Magnetism, and Radiation** Staff

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 121L. 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 200a / MCDB 300a, Biochemistry** Ronald Breaker and Sigrid Nachtergaele
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 230, Rain Forest Expedition and Laboratory]*** MB&B 251La or b / MCDB 301La or b, Laboratory for Biochemistry** Staff

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

MB&B 275a, 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 300a, 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 301b, 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 330a / BENG 230a / MCDB 330a / NSCI 324a, Modeling Biological Systems I Thierry Emonet

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

MB&B 361b / BENG 465b / MCDB 361b / NSCI 325b, Modeling Biological Systems II Joe Howard

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: MCDB 330 or equivalent, or a 200-level biology course, or with permission of instructor. QR

*** MB&B 364a / MCDB 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: 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 365b / EVST 372b, 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. SC

MB&B 420a, Macromolecular Structure and Biophysical Analysis

Yong Xiong and Joe Howard

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 425a / MCDB 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

MB&B 435a, Quantitative Approaches in Biophysics and Biochemistry Julien Berro and Yong Xiong

An introduction to quantitative methods relevant to analysis and interpretation of biophysical and biochemical data. Topics include statistical testing, data presentation, and error analysis; introduction to mathematical modeling of biological dynamics; analysis of large datasets; 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 443b, 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 RP

*** MB&B 445b, Methods and Logic in Molecular Biology** Wendy Gilbert 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 RP

MB&B 449a, Medical Impact of Basic Science Joan Steitz, Karla Neugebauer, Seyedtaghi Takyar, George Miller, David Schatz, Daniel DiMaio, and Franziska Bleichert

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 470a and MB&B 471b, Research in Biochemistry and Biophysics for the Major** Katherine Schilling

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 472a and MB&B 473b, Research in Biochemistry and Biophysics** Katherine Schilling

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 are graded pass/fail. Taken after students have completed two credits of MB&B 470 and 471. These courses do not count toward the major requirements. Prerequisites: MB&B 470, 471 and 251L or permission of the instructor.

*** MB&B 478a and MB&B 479b, Intensive Research in Biochemistry and Biophysics for the Major** Katherine Schilling

Individual laboratory projects under the supervision of a faculty member. Students must submit an enrollment form that specifies the research supervisor by the day that course schedules are due. Students are expected to commit at least twenty 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. No more than two course credits count as electives toward the B.S. degree. Enrollment limited to senior MB&B majors. Prerequisite: MB&B 251L or 360L. 2 Course cr per term

*** MB&B 490a or b, The Senior Literature Essay** Katherine Schilling

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 491a or b, The Senior Research Essay Katherine Schilling

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.