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

**Courses**

* 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.

* 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.

[ MB&B 110, Current Issues in Biological Science ]

* MB&B 200a / MCDB 300a, 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.
MB&B 230, Rain Forest Expedition and Laboratory

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.

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