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 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); and two half-term units of molecular biology, development, ecology and evolution (BIOL 103, 104). The latter may be waived with permission of the director of undergraduate studies (DUS) based on requirements within the concentrations described below. These introductory courses may be satisfied by scores on placement examinations sufficient to earn acceleration credits in the certain subjects, even if the student does not choose to accelerate.

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 2025 and previous classes

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, HSHM 206, 241, 406, 424, 436, 475, 481, SOCY 127, 351 or WGSS 457. 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 101L (available spring 2023), MB&B 470 and 471*, PHYS 165L, 166L, CHEM 355L, other 200+ level lab courses with DUS approval.
- Biochemistry Lab options include MB&B 251L, 470 and 471*, CHEM 355L, other 200+ level lab courses with DUS approval.
- Critical Tools options include MB&B 435, 470 and 471*, S&DS 105, 238, CPSC 112 and others with DUS approval.

*MB&B 470 and 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 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./MS 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 Medicine; Computational Biology and Bioinformatics; Chemical Biology; Biochemistry; and Biophysics and Structural Biology.

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. As incentive to take more challenging coursework, students fulfilling a concentration may take up to one course of upper-level requirements as Credit/D/Fail.

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.

Medicine
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, and/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:* S&DS 105, 230, or higher

*Psychology:* PSYC 110 or higher or PSYC 312

*Physics labs* (1 credit): MB&B 101L (available spring 2023), 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 471, or course based undergraduate research including MB&B 251L, MCDB 291L, or others

*Advanced Seminar:* one from MB&B 445, 452, 449, MCDB 315, 450, or others as approved by the DUS
**Computational Biology & Bioinformatics**

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, or as approved by the DUS (BIOL 103 and 104 may be required for upper level courses)*

*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+ 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.*

**Chemical Biology**

Chemical Biology leverages the tools and concepts of chemistry to understand, leverage, 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, and/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*

**Biochemistry**

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, and/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 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, MB&B 339, 445, 449, or 443

**Biophysics and Structural Biology**

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
Credit/D/Fail  Courses taken Credit/D/Fail may not be counted toward the requirements of the major; however, students fulfilling a concentration may take up to one credit of upper level requirements as Cr/D/F. Qualifying courses include 400-level MB&B courses and 300-level courses in any other STEM subject.

Roadmap  See visual roadmap of the requirements. [roadmap to come]

SENIOR REQUIREMENT
The senior requirement for both the B.S. and the B.A. is fulfilled by successful completion of the senior project, MB&B 490. Students enrolled in this course prepare a written report and make an oral presentation of a literature project. Students meet with faculty members in charge of the colloquium during the first two weeks of the spring term 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 the senior colloquium.

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&B 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 BS/MS 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 five concentrations and for students who do not elect to pursue a concentration.

REQUIREMENTS OF THE MAJOR

Introductory courses BIOL 101 and 102; 2 terms general Chemistry with associated labs; 1 term Organic Chemistry 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)

Specific courses required MB&B 275 or CHEM 332; MB&B 300; MB&B 301; PHYS 170 and 171 (or higher)

Distribution of courses B.A. – 3 biophysics credits to include MB&B 275 or CHEM 332 and PHYS 170 and PHYS 171 or higher; 3 biochemistry credits to include MB&B 300 and 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 req; and 1 elective; 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

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, 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, †Thomas Pollard, Lynne Regan (Emeritus), †Karen Reinisch, †David Schatz, Robert Schulman (Emeritus), †Frederick Sigworth, Dieter Söll, Mark Solomon, Joan Steitz, Scott Strobel, Yong Xiong

Associate Professors Julien Berro, †Titus Boggon, Wendy Gilbert, Christian Schlieker, 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 Aruna Pawashe

†A joint appointment with primary affiliation in another department.

View Courses