MOLECULAR BIOPHYSICS AND BIOCHEMISTRY

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FACULTY OF THE DEPARTMENT OF MOLECULAR BIOPHYSICS AND BIOCHEMISTRY

Professors  †Karen Anderson, Susan Baserga, †Ronald Breaker, †Gary Brudvig, Enrique De La Cruz, †Daniel DiMaio, Donald Engelman, Alan Garen, Mark Gerstein, Mark Hochstrasser, Jonathon Howard, Anthony Koleske, William Konigsberg, †Patrick Loria, †I. George Miller, Andrew Miranker, †Peter Moore (Emeritus), Karla Neugebauer, †Thomas Pollard, Lynne Regan, †David Schatz, Robert Schulman (Emeritus), Dieter Soll, Mark Solomon, Joan Steitz, Thomas Steitz, Scott Strobel, †William Summers, Patrick Sung, Kenneth Williams (Adjunct), †Sandra Wolin

Associate Professors Michael Koelle, A. Elizabeth Rhoades, Yong Xiong

Assistant Professors †Richard Baxter, Julien Berro, Christian Schlicker, Matthew Simon, Chuck Sindelar, †Corey Wilson

Lecturers †Sandy Chang, Aruna Pawashe

†A joint appointment with primary affiliation in another department.

The programs offered by the Department of Molecular Biophysics and Biochemistry are planned for students interested in the molecular and chemical basis of biological processes and are well suited to students hoping to attend medical school or pursue graduate studies in biochemistry, molecular biology, genetics, or biophysics. The B.S. major, designed for those with a strong commitment to research, provides an intensive introduction to laboratory techniques in biochemistry and biophysics. Students in this program usually carry out research projects in faculty laboratories during their junior and senior years. The B.A. major provides the intellectual discipline of biochemistry and biophysics for students who also wish to have sufficient time to pursue in-depth studies outside the major or who are interested in molecular biology as a liberal education; they, too, may engage in research during their junior and senior years.

Basic science prerequisites The basic science courses required of all majors include four half-term units of introductory biology (Biol 101, 102, 103, 104); a general chemistry course with laboratory, (Chem 161, 165, or Chem 163, 167, or Chem 112, 113, or Chem 114, 115, or Chem 118; and Chem 134L, 136L, or Chem 116L, 117L, or Chem 119L); a year course in organic chemistry with laboratory, (Chem 174, 175, or Chem 124, 125, or Chem 220 with 221 or 230; and Chem 222L, 223L); one term of physical chemistry (Chem 328); two terms of calculus (Math 112 and 115); and one year of physics (Phys 170, 171, or Phys 180, 181, or Phys 200, 201). The B.A. major also requires one term of biology laboratory (MCDB 221L or E&EB 223L, or MCDB 121L or E&EB 123L). Some of the prerequisites in biology, chemistry, mathematics, and physics may be satisfied by scores on Advanced Placement tests or placement examinations sufficient to earn acceleration credits in the particular subjects, even if the student does not choose to accelerate.

B.S. degree Nine courses are required beyond the prerequisites: MB&B 300, 301, 302, 360L, and 490; two additional upper-level MB&B electives, one of which must be a non-laboratory course; one quantitative reasoning elective (e.g., Math 120 or above, Stat 105 or 230 or above, CPSC 201 or above, or ENAS 130 or above); and one elective in the natural sciences at a level higher than required in the prerequisites. Students choose the elective courses in consultation with a faculty adviser (see below). Only two course credits of MB&B 470, 471, and 478, 479 may count toward these electives. Students may substitute Chem 335 for MB&B 302. The quantitative reasoning requirement may not be fulfilled by Advanced Placement test scores.

B.A. degree Seven courses are required beyond the prerequisites: MB&B 251L, 300, 301, 302, and 490; one additional upper-level MB&B elective; and one quantitative reasoning elective (e.g., Math 120 or above, Stat 105 or 230 or above, CPSC 201 or above, or ENAS 130 or above). Students choose the elective courses in consultation with a faculty adviser (see below). Students may substitute Chem 335 for MB&B 302. The quantitative reasoning requirement may not be fulfilled by Advanced Placement test scores.

Senior requirement The senior requirement for both the B.S. and the B.A. is fulfilled by successful completion of MB&B 490, The Senior Project. 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. It is inappropriate for students to submit a revised version of a past research report or to resubmit a literature paper prepared for another course. The literature project for the senior requirement should be original work approved by the faculty member overseeing the senior colloquium.

The written report is expected to be 15–25 pages in length (double-spaced, twelve-point font exclusive of figures). A first draft of the paper is due two weeks prior to the date of the oral presentation. Faculty in charge of the program will review the draft and return it to the student with suggestions. A final draft of the paper is due the first day of the reading period in the student’s final term.

Students make a fifteen-minute oral presentation during the last three weeks of their final term in a general scientific forum open to the public. Other students in the series are expected to attend all presentations.

Credit/D/Fail Courses taken Credit/D/Fail may not be counted toward the requirements of the major.
Recommended courses All B.S. majors are encouraged to include MB&B 470 or 471 among their MB&B electives. Declared MB&B majors may take up to two credits of these independent research courses for a letter grade. The prerequisites in either general or organic chemistry should be taken in the freshman year.

Students with a strong interest in biophysics, including those planning to attend graduate school, are strongly encouraged to take courses beyond the basic requirements of the major. Such students are advised to take mathematics through differential equations (ENAS 194, MATH 246, or PHYS 301) and a full year of physical chemistry (CHEM 328 or 332, and 333). In place of one term of biophysics (MB&B 302) they may elect a full year of upper-level biophysics (MB&B 420 and graduate courses in optical spectroscopy and macromolecular interactions). Such revisions to the basic curriculum must be made in consultation with the faculty adviser.

Graduate courses in molecular biophysics and biochemistry, biology, and the biomedical sciences that may be of interest to undergraduates are listed in the bulletin of the Graduate School (http://www.yale.edu/printer/bulletin/htmlfiles/grad), and many are posted on the Biological and Biomedical Sciences Web site (http://bbs.yale.edu). Additional information is available from the directors of undergraduate and graduate studies. Undergraduates with an appropriate background may enroll with the permission of the director of graduate studies and the instructor.

Typical programs Programs with the minimal number of science courses required of B.A. and B.S. majors are shown below. Students whose scores on the Advanced Placement tests make them eligible for advanced courses are urged to replace the elementary science courses with more advanced ones in their freshman year, and to complete the required biochemistry and physics courses by the end of their sophomore and junior years, respectively. Students are permitted to take the biochemistry sequence (MB&B 300, 301) after one term of organic chemistry (CHEM 220).

### Freshman
- BIOL 101, 102, 103, 104
- CHEM 161, 165, 134L, 136L

### Sophomore
- CHEM 220, 230, 222L, 223L
- MATH 112, 115
- And, for the B.A. major: MCDB 221L

### Junior
- MB&B 300, 301
- One quantitative reasoning elective
- PHYS 180, 181
- And, for the B.A. major: MB&B 251L
- And, for B.S. major: MB&B 360L

### Senior
- CHEM 328
- MB&B 302
- One MB&B elective
- MB&B 490
- And, for B.S. major: One science elective and a second MB&B elective

Combined B.S./M.S. degree program Exceptionally able and well-prepared students may complete a course of study leading to the simultaneous award of the B.S. and M.S. degrees after eight terms of enrollment. See "Simultaneous Award of the Bachelor's and Master’s Degrees" under Special Arrangements (http://catalog.yale.edu/ycps/academic-regulations/special-arrangements) in the Academic Regulations. Interested students should consult the director of undergraduate studies prior to the sixth term of enrollment for specific requirements in Molecular Biophysics and Biochemistry.

MB&B Faculty Committee on the Undergraduate Major Committee members are available for consultation throughout the year and are the only faculty advisers eligible to approve and sign MB&B majors’ course schedules at the beginning of each term. Members acting as faculty advisers are:

- **Class of 2016:**
  - M. Hochstrasser, 224 BASS (432-5101)
  - W. Königshaus, CE 14A SHM (785-4599)

- **Class of 2017:**
  - L. Regan, 322 BASS (432-9843)
  - M. Simon, 220 BASS (432-5158)

- **Class of 2018:**
  - K. Neugebauer, C 123 SHM (785-3322)
  - J. Berro, 309C JWG (737-3285, 432-5437)

- **Class of 2019:**
  - J. Howard, 334A BASS (432-7245)
  - C. Schlieker, 236A BASS (432-5035)

REQUIREMENTS OF THE MAJOR

**Prerequisites**
- **B.S.**
  - BIOL 101, 102, 103, and 104; CHEM 161, 165, or CHEM 163, 167 (or CHEM 112, 113, or CHEM 114, 115, or CHEM 118); CHEM 134L, 136L (or CHEM 116L, 117L, or CHEM 119L); CHEM 174 (or CHEM 124), or PHYS 170, 171, or PHYS 170, 171, or PHYS 180, 181, or PHYS 200, 201; B.A. – same, with MCDB 221L or E&EB 223L (or MCDB 121L or E&EB 123L)

**Number of courses**
- **B.S.** – 9 term courses beyond prereqs, incl senior req
- **B.A.** – 7 term courses beyond prereqs, incl senior req

**Specific courses required**
- **B.S.** – MB&B 300, 301, 302, 360L
- **B.A.** – MB&B 251L, 300, 301, 302

**Distribution of courses**
- **B.S.** – 2 addtl MB&B electives, 1 quantitative reasoning elective, and 1 science elective, all as specified
- **B.A.** – 1 addtl MB&B elective and 1 quantitative reasoning elective, as specified
Substitution permitted CHEM 333 for MB&B 302
Senior requirement Senior project (MB&B 490)

Courses

* MB&B 050a, 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 freshmen with a strong background in biology and/or chemistry, typically demonstrated by a score of 4 or 5 on Advanced Placement examinations. Preregistration required; see under Freshman Seminar Program. SC

MB&B 105a or b / MCDB 105a or b, An Issues Approach to Biology  Staff
Biological concepts taught in context of current societal issues, such as emerging diseases, genetically modified organisms, green energy, stem cell research, and human reproductive technology. Emphasis on biological literacy to enable students to evaluate scientific arguments. SC

* MB&B 110a, Current Issues in Biological Science  William Summers
Students identify a scientific problem and then plan and execute a program of individualized learning aimed at the particular scientific knowledge required to understand and analyze the chosen problem. Intended to help students develop self-education skills as applied to scientific understanding, apply those skills to acquire some specific scientific knowledge, and understand the process by which scientific knowledge and understanding are achieved. For non-science majors. SC

* MB&B 200a / MCDB 300a, Biochemistry  Ronald Breaker, Nicole Clay, and Donald Engelman
An introduction to the biochemistry of animals, plants, and microorganisms, emphasizing the relations of chemical principles and structure to the evolution and regulation of living systems. Prerequisites: BIOL 101 or equivalent performance on the corresponding biological sciences placement examination; one term of organic chemistry; or with permission of instructor. SC

[ MB&B 218L, Art and Biomolecular Recognition Laboratory ]

[ MB&B 230, Rain Forest Expedition and Laboratory ]

* MB&B 251La / MCDB 301La, Laboratory for Biochemistry  William Konigsberg and Aruna Pawashe
An introduction to current experimental methods in molecular biology. After or concurrently with MB&B 200 or 300. Limited enrollment. Requires preregistration by e-mail to Aruna Pawashe and William Konigsberg prior to the first week of classes. SC

½ Course cr

MB&B 300a, Principles of Biochemistry I  Michael Koelle and Matthew Simon
Discussion of the physical, structural, and functional properties of proteins, lipids, and carbohydrates, three major classes of molecules in living organisms. Energy metabolism, hormone signaling, and muscle contraction as examples of complex biological processes whose underlying mechanisms can be understood by identifying and analyzing the molecules responsible for these phenomena. After BIOL 101; after or concurrently with CHEM 175 (or CHEM 125) or 220 SC

MB&B 301b, Principles of Biochemistry II  Christian Schlieker and Karla Neugebauer
A continuation of MB&B 300 that considers the chemistry and metabolism of nucleic acids, the mechanism and regulation of protein and nucleic acid synthesis, and selected topics in macromolecular biochemistry. Prerequisite: MB&B 300 or permission of instructor. SC

MB&B 302b, Principles of Biophysics  Charles Sindelar and Donald Engelman
An introduction to the theoretical basis of biophysical concepts and approaches with selected examples and applications. Prerequisites: MB&B 300 and CHEM 328. SC

* MB&B 360Lb, Laboratory for Biochemistry and Biophysics  Alan Garen, William Konigsberg, and Aruna Pawashe
An intensive introduction to the principles and applications of experimental techniques currently used in biochemistry, biophysics, and molecular biology. Recommended to be taken with or directly after MB&B 301. Limited enrollment. Preregistration required during the first week of November using a sign-up sheet outside 157 OML. SC

MB&B 420a, Macromolecular Structure and Biophysical Analysis  Andrew Miranker, Yong Xiong, and Jonathon 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: MB&B 301 and 302. SC

* MB&B 425a / MCDB 425a, Basic Concepts of Genetic Analysis  Tian Xu
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 200 or equivalent. SC
Applied mathematical methods relevant to analysis and interpretation of biophysical and biochemical data. Statistics and error analysis, differential equations, linear algebra, and Fourier transforms. Analysis of real data from research groups in MB&B. Prerequisites: MATH 120 and MB&B 300 or equivalents, or with permission of instructors. Q8, SC

MB&B 443b, Advanced Eukaryotic Molecular Biology  Mark Hochstrasser, Matthew Simon, Patrick Sung, and Karla Neugebauer
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 449a, Medical Impact of Basic Science  Joan Steitz, Thomas Steitz, I. George Miller, Andrew Miranker, David Schatz, and Karla Neugebauer
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 RP

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

* MB&B 470a and MB&B 471b, Research in Biochemistry and Biophysics  Alan Garen
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. A required organizational meeting will be held at the beginning of each term. 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. No more than two course credits count as electives toward the B.S. degree. Enrollment limited to junior and senior MB&B majors. Prerequisite: MB&B 251L or 360L. 2 Course cr per term

* MB&B 478a and MB&B 479b, Intensive Research in Biochemistry and Biophysics  Alan Garen
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. A required organizational meeting will be held at the beginning of each term. 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 490b, The Senior Project  William Konigsberg, Alan Garen, and Karla Neugebauer
Colloquium for fulfillment of the senior requirement. The course involves a written and an oral presentation of a senior paper in an area of biochemistry or biophysics. The topic is selected in consultation with the faculty members in charge of the course.