MOLECULAR BIOPHYSICS AND BIOCHEMISTRY

Director of undergraduate studies: Andrew Miranker (andrew.miranker@yale.edu) [Sp 2022], 318 BASS, 432-8954, MBBUndergrad@yale.edu; mb&b.yale.edu

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 322).

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), 470 and 471*, PHYS 165L, 166L, CHEM 355L, other 200+ level lab courses with DUS approval.

* Biochemistry Lab options include MB&B 251L, 364, 470 and 471*, CHEM 355L, other 200+ level lab courses with DUS approval.

* Critical Tools options include MB&B 435, 470 and 471*, S&D 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.

The following changes to the major requirements for the Class of 2026 and subsequent classes may be fulfilled by students who declared their major under previous requirements.

The major requirements for the Class of 2025 and previous classes degree program requires a total of 12.5 course credits including the senior requirement.

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 322).

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.

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* Physics lab options include MB&B 101L (available spring 2023), 470 and 471*, PHYS 165L, 166L, CHEM 355L, other 200+ level lab courses with DUS approval.

* Biochemistry Lab options include MB&B 251L, 364, 470 and 471*, CHEM 355L, other 200+ level lab courses with DUS approval.

* Critical Tools options include MB&B 435, 470 and 471*, S&D 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.A. 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, S&DS 230, or higher
- **Psychology**: PSYC 110 or higher or PSYC 312
- **Physics labs** (1 credit): MB&B 101L (available spring 2023), PHYS 165L, PHYS 166L, MB&B 364, or others as approved by the DUS
- **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, MCDB 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 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, MCDB 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+ course 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, MATH 225, S&DS 100+, or CPSC 112

**Computer Science, Math, Statistics** (for B.S. degree): one from MATH 120, MATH 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&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 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; 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 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.; 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 PHYSICS 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 Kolesar, William Konigsberg, †Mark Lemmon, †Patrick Loria, †I. George Miller, Andrew Miranker, ‡Peter Moore (Emeritus), Karla Neugebauer, ‡Thomas Pollard, Lynne Regan (Emeritus), ‡Karin Reinitz, ‡David Schatz, Robert Schulman (Emeritus), ‡Frederick Sigsworth, 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

Courses

* MB&B 090b, 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 090b / MCDB 090b / MENG 090b / PHYS 090b / SCIE 090b, Introduction to Research Methods in Physics and Biology: Preparing for a First Research Experience  Staff
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 104a or b / MCDB 104a or b, Biology, the World, and Us  Staff
Biological concepts taught in context of current societal issues, such as emerging diseases, genetically modified organisms, green energy, and the human brain and its disorders. Emphasis on biological literacy to enable students to evaluate scientific arguments.  SC 0 Course cr

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

* MB&B 200a / MCDB 300a, Biochemistry  Ronald Breaker
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 0 Course cr

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

* MB&B 251La or b / MCDB 301La or b, Laboratory for Biochemistry  Aruna Pawashe and Staff
An introduction to current experimental methods in molecular biology, biophysics, and biochemistry. Limited enrollment. Prerequisite: BIOL 101.  SC ½ Course cr

* MB&B 268b, Identity, Society, and STEM  Enrique De La Cruz and Andrew Miranker
Matters of personal and group identity underpin the development of science as a discipline, the lived experience of its practitioners, and the achievement of excellence by diverse cultures collaborating on research, teaching in schools, treating the sick, promoting business, and setting government policy. Yale STEM students who are actively engaged in the study of any aspect of identity and society, whether contemporary or historical, learn how STEM is intertwined with these interests. To achieve this goal, students in this course must be simultaneously enrolled in a full-credit, humanities course at Yale. Instructor permission is required and is based on a proposal (250 words) that makes a compelling case for exploring STEM’s engagement with the concurrent humanities course. Students use knowledge from the humanities course to develop a unique project that can include anecdotal sources, but must also include elements of form...
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. After BIOL 101; after or concurrently with CHEM 175 (or CHEM 125) or 220. sc o Course cr

MB&B 301b, Principles of Biochemistry II Christian Schlieker, Karla Neugebauer, 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 Staff 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). Q8, sc o Course cr

MB&B 361b / BENG 465b / MCDB 361b / NSCI 325b, Modeling Biological Systems II Jonathan Howard, Thierry Emonet, and Damon Clark 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. Q8

* 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, iP and ZP 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, 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, MB&B 301, MB&B 200, or permission of the instructor. sc

**MB&B 420a, Macromolecular Structure and Biophysical Analysis**  Yong Xiong and Jonathan 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  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 431b, Illuminating Biomolecular Mechanism with Structure**  Charles Sindelar, Julien Berro, and Nikhil Malvankar
This class focuses on methods for observing biomolecular structure and dynamics on the atomic and near-atomic length scales. Upon completion of the class, students have a working understanding of the theory that underpin methods such as cryo-electron microscopy and optical spectroscopy. All methods introduced are anchored to fundamental processes in biology and to biomedical advances through guided discussion of ground-breaking studies in contemporary primary literature. Prerequisite: MB&B 275, 301, or permission of the instructor. Enrolled students should have an introductory level understanding of Fourier transforms, linear/matrix algebra and multivariate calculus, but note, portions of class time are used to review the small subset of relevant mathematics essential for this course. QR, SC

**MB&B 435a, Quantitative Approaches in Biophysics and Biochemistry**  Julien Berro, Nikhil Malvankar, 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, and Matthew Simon
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, Julien Berro, and Mark Hochstrasser
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, Sandy Chang, 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 452b / MCDB 452b / S&DS 352b, Biomedical Data Science, Mining and Modeling**  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 459b / ENGL 459b / EVST 215b, Writing about Science, Medicine, and the Environment  Carl Zimmer
Advanced non-fiction workshop in which students write about science, medicine, and the environment for a broad public audience. Students read exemplary work, ranging from newspaper articles to book excerpts, to learn how to translate complex subjects into compelling prose. Admission by permission of the instructor only. Applicants should email the instructor at carl@carlzimmer.com with the following information: 1. One or two samples of nonacademic, nonfiction writing. (No fiction or scientific papers, please.) Indicate the course or publication, if any, for which you wrote each sample. 2. A note in which you briefly describe your background (including writing experience and courses) and explain why you'd like to take the course. WR RP

* MB&B 460Lb, Biochemical Analytics Laboratory  Staff
This is a project-oriented lab based around DNA aptamer design and microfluidics. Often referred to as lab-on-a-chip, these are mainstays of contemporary efforts in biomedical and environmental diagnostics. Students learn cutting-edge molecular evolution techniques to optimize DNA structures that can recognize and bind selectively to a molecular target. Students further learn from each other as they each report on their progress. Useful and transferrable skills include biomolecular engineering, next generation DNA sequencing, and assays using microfluidic devices built in collaboration with the Yale Center for Engineering, Innovation, and Design. Prerequisite or taken concurrently: MB&B 251L/MCDB 301L or equivalent. SC ½ Course cr
* MB&B 470a and MB&B 471b, Research in Biochemistry and Biophysics for the Major  Staff
Individual laboratory projects under the supervision of a faculty member. Students must submit an enrollment form that specifies the research supervisor by the date that course schedules are due. Students are expected to commit at least ten hours per week to working in a laboratory. Written assignments include a research proposal, due near the beginning of the term, and a research report that summarizes experimental results, due before the beginning of the final examination period. Students receive a letter grade. Up to 2 credits of MB&B 470/471 may be counted toward the MB&B major requirements. Enrollment limited to MB&B majors. Prerequisite: MB&B 251L or permission of the instructor.  SC

* MB&B 472b and MB&B 473b, Research in Biochemistry and Biophysics  Staff
Individual laboratory projects under the supervision of a faculty member. Students must submit an enrollment form that specifies the research supervisor by the date that course schedules are due. Students are expected to commit at least ten hours per week to working in a laboratory. Written assignments include a research proposal, due near the beginning of the term, and a research report that summarizes experimental results, due before the beginning of the final examination period. Students 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.  SC

* MB&B 478a and MB&B 479b, Intensive Research in Biochemistry and Biophysics for the Major  Staff
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 490b, The Senior Project  Dieter Soll and Nikhil Malvankar
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.