

Molecular Biophysics and Biochemistry

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For class of 2026 and beyond. Earlier class years are encouraged to opt-in.

Alternatively, students may use the descriptions specific to their class year (<http://catalog.yale.edu/ycps>)

MB&B on one page

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.

The core elements of our discipline are:

Biophysics 3 credits for BA, 4 credits for BS and BS/MS

Biochemistry 3 credits

Science & Society 1/2 credit

Additional requirements in MB&B serve to:

- support the core elements as prerequisites or accompanying labs
- teach advanced topics that make use of these underpinnings
- teach the technology that enables scholarship in our discipline
- give opportunity to seniors to demonstrate mastery of the discipline in writing

Practical Skills 1 credit for BA, 2 credits for BS and 1 for BS/MS

Electives 1 credit for BA, 2 credits for BS and 6 for BS/MS

Senior Thesis 1 credit for BA and BS, 4 for BS/MS

Three quarters of MB&B 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 1-2 years of public service, entered secondary education or joined the US armed forces as officers.

To directly engage students' interests and career goals, several concentrations are available to students. In MB&B, concentrations are named sets of electives, curated by the faculty, that count towards our elective requirements and appear on your official Yale transcript. MB&B students may concentrate in Biophysics and Structural Biology, Chemical Biology, Computational Biology, Medicine or Molecular Biochemistry.

Molecular Biophysics & Biochemistry

Degrees Offered	BA	BS	BS/MS
Introductory Courses	INTRODUCTORY PREPARATION Typically the following: CHEM 174 or CHEM 220 with lab MATH 115 or MATH 116 BIOL 101&102		
Requirements for each degree	9.5 course credits including senior requirement	12.5 course credits including senior requirement	18.5 course credits 10 of which at 500+ including senior req
	BIOPHYSICS (three terms) MB&B 275 and PHYS 170 &171	BIOPHYSICS (four terms) MB&B 275, PHYS 170&171 1 x 300+ in Physical Sci, MATH, CPSC or S&DS	BIOPHYSICS (four terms) MB&B 275 PHYS 180/181 CHEM 332
	BIOCHEMISTRY (three terms) MB&B 300 and MB&B 301 CHEM 175 or any CHEM 200+		
	SCIENCE & SOCIETY (1/2 term) MB&B 268 or MB&B 107 or others		
	PRACTICAL SKILLS (1 credit) (2 credits) (1 credit) enrollment in 2 or 3 of these categories: <u>Physics Lab</u> <u>Biochem/Bio Lab</u> <u>Critical Tools</u> 1/2 credit or more from MB&B Physics Lab: PHYS 165L, MB&B 101L, MB&B 364 or ... Biochem Lab: MB&B 470, 251L, CHEM 355L or ... Critical Tools: S&DS 105, CPSC 100, MB&B 435 or ...		
Concentrations (optional)	SEMINAR AND LECTURE ELECTIVES (one term) (two terms) (six terms) 1 x MB&B at 200+ level 1 x MB&B at 200+ level 2 x MB&B at 500+ level 1 x STEM at 200+ 1 x STEM at 500+		
	CONCENTRATIONS Faculty curated sets of classes that fulfill the above electives. Five available: <u>Medicine</u> <u>Biochemistry</u> <u>Computational Biology & Bioinformatics</u> <u>Biophysics & Structural Biology</u> <u>Chemical Biology</u> Between 0-3 additional credits depending on placement or DUS waiver. For BA & BS, one upper level elective can be taken Cr/D/F Concentration name appears on your Yale Transcript.		
Senior Requirements	SENIOR PROJECT (1 term) MB&B 490		RESEARCH (4 credits) MB&B 570a and 571

Introductory Courses

Students are encouraged to declare their major long before completion of coursework we have flagged as “prerequisites”. This greatly improves academic advising. Changing major at Yale requires no approvals and are non-binding.

The courses below total 7.5 credits. Students may alternatively receive acceleration credits from previous studies, take relevant exams to place out, receive instructor approvals to take coursework without a prerequisite. After a declared student is assigned an academic advisor, they may also petition to have courses waived (see **DUS approval** below). .

The first required course in MB&B is **MB&B 275 Biology at the Molecular Level**. Professors in MB&B 275 assume these courses, or equivalent, have been completed:

CHEM 161	General Chemistry I
CHEM 134L	General Chemistry I lab
CHEM 165	General Chemistry II
CHEM 136L	General Chemistry II lab
MATH 112	Calculus
BIOL 101	Biochemistry and Biophysics (taught by MB&B Profs!)*
BIOL 102	Cell Biology and Membrane Physiology*

Note: BIOL 103 and BIOL 104 are encouraged for all students who are uncertain about their major. For some of our concentrations, described below, BIOL 103 and BIOL 104 are requirements, but these may be taken in later years as best suits students’ schedules.

These courses, or equivalent, support upper level MB&B coursework in physics and biochemistry.

CHEM 220 or 174	Organic Chemistry
CHEM 222L	Organic Chemistry Lab
MATH 115 or 116	Calculus II

*Can be taken concurrently with MB&B 275 with instructor permission.

Core elements

Biophysics:

All Majors: A two (BS and BS/MS) semester sequence or one (BA) semester of biophysical chemistry. **MB&B 275 “Biology at the Molecular Level”**, is strongly recommended and ideally taken in the fall of year 2.
There is no accompanying lab requirement.

Alternatives to MB&B 275 are CHEM 332, CHEM 328, CENG 300, APHY 420, MENG 211. MB&B 275 cannot be taken after these courses.

BS majors: An additional 300+ elective in the physical sciences, engineering, math, statistics & data science or computer science.
Accompanying labs are not required.

BS/MS majors: An additional 300+ elective emphasizing thermodynamics, statistical mechanics, quantum mechanics and/or spectroscopy, for example, CHEM 332, CHEM 328, CENG 300, APHY 420, MB&B 431.
Accompanying labs are not required.

All majors: A two semester sequence PHYS 170/171 or higher (BA and BS), or PHYS 180/181 or higher (BS/MS).
Accompanying labs for these classes are not required, but can be used to fulfill **Practical Skills** requirements described below.

Biochemistry:

MB&B 300/301 is a two semester, comprehensive sequence that defines MB&B’s perspective on biochemistry. It is required of all majors.

Course substitutions for **MB&B 300/301** are not permitted.

The prerequisites for MB&B 300/301 is one semester of organic chemistry with lab, BIOL 101 and BIOL 102. While we recommend this course sequence be taken in year 3, about 1/3 of majors take this course sequence in year 2. MB&B 300 may be taken concurrently with organic chemistry.
There is no accompanying lab to MB&B 300 or 301.

A second semester of any 200+ level course in Chemistry, or CHEM 175, is required of all majors to further support understanding of Biochemistry. Majors typically take a second semester of organics chemistry, or inorganic chemistry. Accompanying lab is not required.

Science & Society:

The intersection of Molecular Biophysics & Biochemistry with human identity and society is critically important to your training. Matters of personal and group identity underpin the history of our discipline's development, the lived experience of its practitioners, the achievement of excellence by diverse cultures co-working in our labs and the interaction of faculty and graduates with the public in secondary schools, businesses, hospitals and government.

All majors take a ½ credit of coursework in this area. One mechanism is to take the initiative and independently explore this interface by taking MB&B 268, "Society, Identity and STEM". This half-credit course meets in the second half of term and is taken simultaneously with any humanities course with significant focus on race, ethnicity, gender, sexuality, disability, veteran status, religion or any other aspect of human identity. MB&B 268 may be taken up to two times for a letter grade.

An alternative approach to fulfilling this requirement is to take one of many courses at Yale that directly address this topic. This includes MB&B 107, HSHM 206/241/406/424/436/475/425/481, SOCY 127/351 or WGSS 457. Petitions for **course substitutions** (see below) are encouraged.

Additional Requirements

Practical Skills:

Many practical skills are vital to effective bench and computer-based research in biology and physics. Other practical skills benefit our ability to generate and test hypotheses and establish rigor when performing statistical analyses of data sets large and small. The juxtaposition of concepts and practical implementation in coursework results in lasting understanding.

BA majors take one credit and BS majors take two credits: across at least two of three categories: **Physics Lab**, **Biochemistry Lab** and **Critical Tools**. One or more courses (at least ½ credit) must be from MB&B. Courses that can be used to satisfy more than one category may not be double counted.

- **Physics Lab:** MB&B 101L, 364, **470/471***, PHYS 165L, 166L, CHEM 355L and others with **DUS approval** (see below).
- **Biochemistry Lab:** MB&B 251L, 364, **470/471***, CHEM 355L, others including MCDB/EEB/BENG 200+ lab courses with **DUS approval**.
- **Critical Tools:** MB&B 435, **470/471***, S&DS 105, 238, CPSC 100+ and others with **DUS approval** (see below).

BS/MS majors: Practical Skills are incorporated into the senior requirement

*This is research for credit coursework. Up to two credits may be taken for a letter grade. Categorization of the coursework into one of the three skills is dependent on your project and/or the lab in which your project is conducted.

Electives

Seminar or lecture-based coursework as follows:

BA majors: one 200+ level in MB&B

BS majors: one 200+ level in STEM and one 200+ level in MB&B

BS/MS majors: six credits at the graduate level, 500+. Two of the six from MB&B. Many graduate courses are ½ semester modules. It is common for more than six courses to be used to reach six credits.

Courses holding both 300+ undergraduate and 500+ graduate course number can be retroactively converted to graduate course numbers to fulfill this requirement after admission to the BS/MS program.

Senior Requirements

BA and BS majors: MB&B 490 is a one credit course that culminates in the writing of a thesis in the spring term of senior year.

BS/MS majors: Completion of 5 credits of research for credit: MB&B 470 or 471 is required by the end of fall semester of junior year. MB&B 570 and 571 is taken during senior year. All 5 credits of research are expected to take place within the same lab and culminate in a 50-page thesis and a public oral defense during the reading period of your final semester.

Concentrations

Concentrations in MB&B are sets of electives, curated by faculty, designed to focus attention onto specific subfields of Molecular Biophysics and Biochemistry. Concentrations appear on a student's official Yale transcript and are currently available in **Biophysics and Structural Biology**, **Chemical Biology**, **Computational Biology and Bioinformatics**, **Medicine** and **Molecular Biochemistry**.

Electives for concentrations can be used to fulfill the above elective options for the major which total 3.5 credits for BA majors, 6.5 credits for BS and 8.5 credits for BS/MS majors:

- CHEM 175 or CHEM 200+
1 credit BA, BS and BS/MS
- 300+ in physical sci, engineering, math, statistics & data sci. or computer sci.
1 credit BS
- 300+ elective in thermodynamics, statistical mech, quantum and/or spectroscopy
1 credit BS/MS
- Science and Society
½ credit BA, BS, BS/MS
- Practical Skills
2 credit BS, 1 credit BA
- STEM elective at 200+
1 credit BS
- MB&B elective at 200+
1 credit BA, BS
- MB&B elective at 500+
2 credits BS/MS
- STEM elective at 500+
4 credits BS/MS

For example, a BS major concentrating in **Medicine** must fulfill one course in statistics. S&DS 220 can fulfill the concentration's requirement and also count as a 200+ level STEM elective for the major. Sample schedules for each concentration for BS students are provided below.

Students can take up to one credit of upper level requirements as **Credit/D/Fail** (details below). For example, a BS major concentrating in **Medicine** and fulfilling their 300+ physical science requirement using CHEM 332 may take this class Cr/D/Fail and still have it count toward the major.

Placement exams and acceleration credits **do not** count towards completion of concentration-specific requirements. E.g. A BS Major who places out of 100-level statistics and is pursuing a concentration in **Computational Biology and Bioinformatics** is still expected to complete the concentration's requirement for 3 courses in MATH/S&DS/COMP.

Concentration in **Medicine**

The MB&B concentration in **Medicine** is designed for students with strong interests in the molecular basis of physiology and disease. MB&B offers a unique lens on these subjects as it was formed as a merger of the Yale Medical School Department of Biochemistry and the Yale College Department of Molecular Biophysics. MB&B faculty maintain labs in both schools (as well as West Campus) and instructs both Yale undergraduates and Yale medical school students. Majors aspiring to graduate studies in biomedical sciences, work in biotechnology or enter medical school are particularly encouraged to fulfill this concentration:

Requirements

Genetics and Development and Ecology and Evolution (1 credit): BIOL 103 and BIOL 104

Organic Chemistry (1 credit): Second term organic chemistry, CHEM 175 or CHEM 221
Accompanying lab is not required.

Statistics (1 credit): S&DS 105, S&DS 230 or higher.

Psychology (1 credit): PSYC 110 or higher, PSYC 312.

Physics lab (2 courses totaling 1 credit or more): **MB&B 101L**, PHYS 165L, PHYS 166L or **MB&B 364** and others

Biomedical Research (1 credit): Research for credit on a project focused on basic biological or biomedical research, **MB&B 470 or 471**. Alternatively, course-based undergraduate biomedical research experience (CURE), **MB&B 251L**, **MCDB 291L** and others.
See **course substitutions** policy below.

Advanced (300+) Biomedical Lecture or Seminar (1 credit):

MB&B 449 Medical Impact of Basic Science
MB&B 445 Methods and Logic in Molecular Biology
MB&B 452 Biomedical Data Science, Mining and Modeling
MCDB 315 Pathobiology
MCDB 450 The Human Genome

Other choices for the above are encouraged and possible by petition.
See **course substitutions** policy below.

Note: The core BS major requires 12.5 credits while the core BA major requires 9.5 credits. For students with no advanced preparation in STEM, the concentration in **Medicine** (see sample schedules) can be completed with 2 additional credits over the core BS major and 3 additional credits over the core BA requirements.

Computational Biology & Bioinformatics

The MB&B concentration in **Computational Biology & Bioinformatics** is designed for students with a combination of 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:

Requirements

Genetics and Evolutionary Biol (1 credit, BA): BIOL 103 and BIOL 104

Genetics and Evolutionary Biol (1 credit, BS): A 200+ elective in genetics, molecular biology or evolutionary biology. This elective may be used in place of MB&B's requirement for a 200+ elective in Chemistry: MCDB 200, MCDB 202, MCDB 310, **MB&B 330** and others. (and prerequisites in BIOL 103/104 if needed)

Computer Sci, Math, Stats (2 credits, BA): CPSC 201 (and one prerequisite if needed) and S&DS 100+

Computer Sci, Math, Stats (3 credits, BS): CPSC 223, CPSC 201 (and one prerequisite if needed) and S&DS 238 (and the one prerequisite if needed). CPSC 223 may be used to fulfill the 300+ elective requirement in physical sci, engineering, math, statistics & data sci. or computer sci.

Advanced (300+) Computational Biology & Bioinformatics (1 credit):

MB&B 452 Biomedical Data Science, Mining and Modeling

CPSC 453 Unsupervised Learning for Big Data

Other choices for the above are encouraged and possible by petition.
See **course substitutions** policy below.

Note: The core BS major requires 12.5 credits while the core BA major requires 9.5 credits. For students with no advanced preparation in STEM, the **Computational Biology & Bioinformatics** concentration (see sample schedules) can be completed with 3 additional credits over the core BS major and 3 additional credits over the core BA requirements.

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:

Requirements

Organic Chemistry II (1.5 credits):

Second semester of organic chemistry with accompanying ½ credit lab.

Cell Biology and Chemistry (3 credits for BS):

2 x 200+ and 1 x 300+ electives in Chemistry or Cell Biology.

At least one of the credits must come from Cell Biology or Chemistry.

Cell Biology (1 credit for BA):

1 x 200+ electives in Cell-based biology

Research in Chemical Biology (1 credit): Research for credit on a Chemical Biology project (broadly interpreted), **MB&B 470 or 471**. Alternatively, **MB&B 364** or course-based undergraduate chemical biology research experience (CURE) by petition to DUS. See **course substitutions** policy below.

Advanced (300+) Chemical Biology Lecture or Seminar (1 credit):

MB&B 443 Advanced Eukaryotic Cell Biology

CHEM 419 Foundations of Chemical Biology I

Other choices for the above are encouraged and possible by petition.

See **course substitutions** policy below.

Note: The core BS major requires 12.5 credits while the core BA major requires 9.5 credits. The concentration in **Chemical Biology** (see sample schedules) can be completed with one additional credit requirement over the core BS major and two additional credits over the core BA requirements.

Biochemistry

The MB&B 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:

Requirements

Genetics and Development and Ecology and Evolution (1 credit): BIOL 103 and BIOL 104

Molecular, Cellular or Organismal Biology 200+ (1 credit): MCDB 205, MCDB 202 and others

Research in Biochemistry (1 credit): Research for credit on a project with biochemical emphasis (broadly interpreted), **MB&B 470 or 471**. Alternatively, course-based undergraduate research experience (CURE) in biochemistry by petition to DUS.

Advanced (300+) Biochemistry Lecture or Seminar (2 credits for BS, 1 credit for BA):

MB&B 365 Biochemistry and our Changing Climate

MB&B 339 Modeling Biological Systems

MB&B 445 Methods & Logic in Molecular Biology

MB&B 449 Medical Impact of Basic Research

MB&B 443 Advanced Eukaryotic Cell Biology

Other choices for the above are encouraged and possible by petition.
See **course substitutions** policy below.

Note: The core BS major requires 12.5 credits while the core BA major requires 9.5 credits. For students with no advanced preparation in STEM, the concentration in **Biochemistry** (see sample schedules) can be completed with two additional credit requirements over the core BS major and 3 additional credits over the core BA requirements.

Biophysics and Structural Biology

The MB&B concentration in **Biophysics and Structural Biology** 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.

Requirements

Comp. Sci, Math, Statistics (1 credits, BS): MATH 120/225 or S&DS 238 or CPSC 112

Comp. Sci, Math, Statistics (1 credits, BA): MATH 120/225 or S&DS 100+ or CPSC 112

Biophysical Chemistry (1 credit, BS): CHEM 332 or **MB&B 431** or any 300+ elective in thermodynamics, statistical mech, quantum mechanics or spectroscopy.

Research in Biophysics and Structural Biology (1 credit): Research for credit on a solution biophysical or structural biology project (broadly interpreted), **MB&B 470 or 471**. Alternatively, CHEM 355, or course-based undergraduate biophysical or structural biology research experience (CURE) by petition. See **course substitutions** policy below.

Tools and Quantitative Analysis (1 credits, BS): 200+ course with emphasis on measurement and/or modeling of energy, kinetics, or structure relevant to the molecular length scale. **MB&B 330/420/431/435**, CHEM 333/406/492 and others

Advanced Biophysics and Structural Biology Lecture or Seminar (1 credit):

MB&B 420 Macromolecular Structure and Biophysical Analysis

MB&B 431 Illuminating Biomolecular Mechanism with Structure

MB&B 529 Structural Biology and Drug Discovery

Other choices for the above are encouraged and possible by petition.
See **course substitutions** policy below.

Note: The core BS major requires 12.5 credits while the core BA major requires 9.5 credits. For students with no advanced preparation in STEM, the concentration in **Biophysics and Structural Biology** (see sample schedules) can be completed with one additional credit requirements over the core BS major and 2 additional credits over the core BA requirements.

Policies and Procedures

Course Substitutions: Students may petition for **DUS approval** (see below) for course substitutions by assembling the relevant syllabi and writing a short justification (<300 words). Thoughtful requests in line with MB&Bs teaching goals are always welcome.

Credit/D/Fail: To encourage BA and BS majors to explore more challenging coursework, students are welcome to complete one credit requirement as Credit/D/Fail. This will not affect your 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 BS/MS students, all required coursework must be taken for a letter grade.

MB&B Academic Advisors: Students are assigned a member of MB&B faculty for academic advising as soon as they declare their major. Requests for change in advisor should be sent to the registrar via direct email (elizabeth.vellali@yale.edu). Justification is not required nor is **DUS approval**.

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** (see above). 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. Very important: one-on-one meetings by majors with their **MB&B academic advisor** during every registration period are logged. Failures to schedule meetings and missed meetings are factored into the DUS approval process.

Sample Schedules

Available online are sample student schedules for hypothetical students who arrive at Yale with no advanced preparation.

1/3 of MB&B students place out of General Chemistry

4/5 students place out of first semester calculus.

Students can take BIOL 101/02 in fall or spring terms. BIOL 103-104 is not required, but is integrated into some of the concentrations. BIOL 103/104 can be taken at any time during a student's four years.