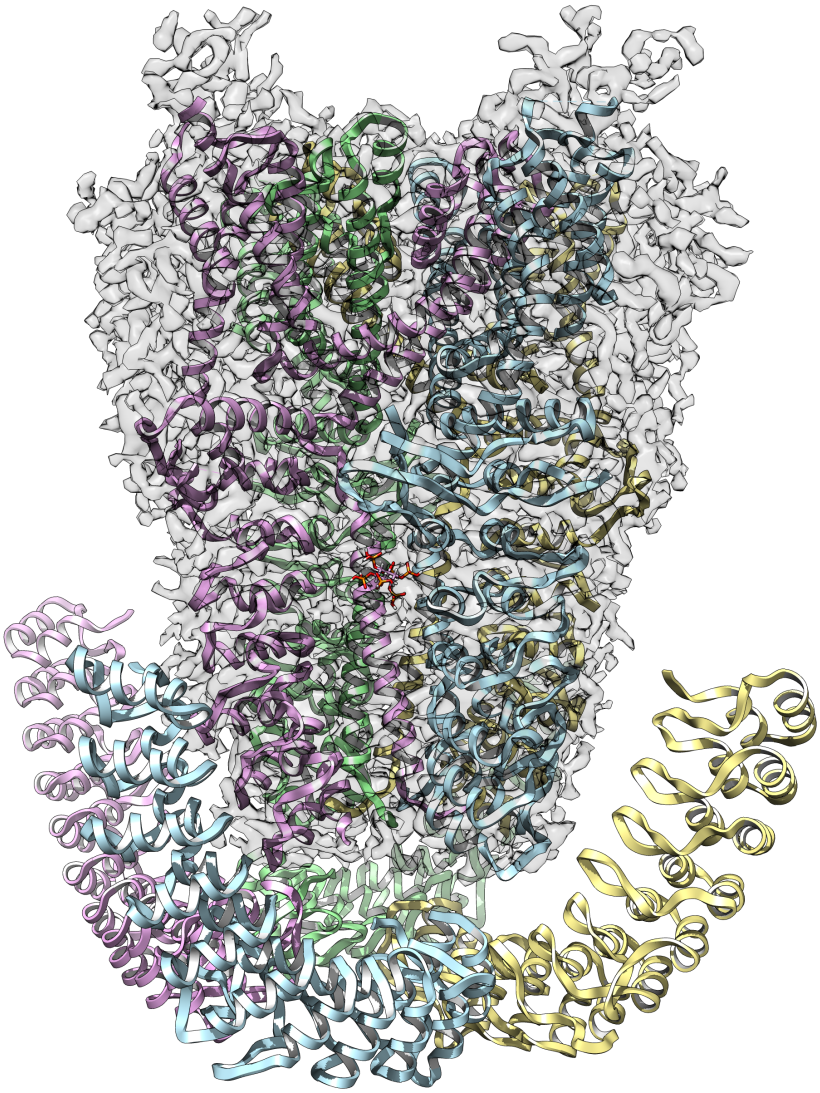
Molecular Biophysics & Biochemistry



Undergraduate Studies 2018-2019

Quick Facts about Majoring in Molecular Biophysics & Biochemistry*
The molecular basis of life

MB&B is for students interested in applying the tools of chemistry and physics to gain a mechanistic understanding of biology and medicine at the molecular level. Most of our majors go on to careers in medicine or scientific research after earning an advanced degree. We also have graduates working in teaching, journalism, and many other careers.

Features of the major

Faculty Advising: Two MB&B faculty members serve as academic advisors for each graduating class (see below for the current list of advisors). Majors can pick one of the advisors for their year and continue to see that same advisor regularly until they graduate. MB&B undergraduates should consult one of their Faculty Advisors for current information, advice, reference letters, and signing of their course schedules.

'19 Jonathon Howard (334 BASS) studies motor proteins and cytoskeletal systems.

'19 Christian Schlieker (235A BASS) studies molecular mechanisms underlying nuclear envelopathies.

'20 Enrique De La Cruz (336A BASS; Head of Branford College) studies actin and myosin regulation, RNA helicases, and signaling enzymes.

'20 Chuck Sindelar (CE25 SHM) studies the structure and function of molecular motors using cryoelectron micrsoscopy.

'21 Wendy Gilbert (C-127 SHM) studies the post-transcriptional gene regulation in eukaryotic cells.

'21 Andrew Miranker (318 BASS) studies the formation of amyloid fibers using kinetic, structural, and thermodynamic approaches.

'22 Michael Koelle (CE28A SHM) studies the mechanism of neurotransmitter signaling.

Curriculum:

- Core required sequence: MB&B 300, 301 and 302 (Biochemistry and Biophysics)
- MB&B majors can take **two** terms of Research for Credit for a letter grade (MB&B 470/471)!
- This research for credit can be expanded on for your senior requirement, MB&B 490.
- Option to pursue a 4-year BS/MS degree
- For our required lab (MB&B 251L) is 0.5 credit, premed students can take with an MB&B # for this to count in medical school admissions as a chemistry lab credit or an MCDB# to count as a biology lab credit.
- Electives: *Pick two!*
  MB&B 107a Being Human in STEM; MB&B218La Art and Biomolecular Recognition Laboratory; MB&B 330a Introduction to Dynamical Systems in Biology; MB&B 420a Macromolecular Structure and Biophysical Analysis; MB&B 425a Basic Concepts of Genetic Analysis; MB&B 435a Quantitative Approaches in Biophysics and Biochemistry; MB&B 443b Advanced Eukaryotic Molecular Biology; MB&B 445b Methods and Logic in Molecular Biology; MB&B 449a Medical Impact of Basic Science; MB&B 452b Biomedical Data Science: Mining and Modeling; MB&B 459a Writing about Science, Medicine, and the Environment

Working in a Research Lab

You can opt to volunteer, do a summer research internship, do work study, or take Research for Credit (MB&B 470/471) in any biomedical research lab at Yale. For tips on finding a lab and contacting the PI, see page 20 of our handbook*!

Activities:

- Study halls during reading week attended by Profs and faculty advisors. Refreshments served!
- Monthly dinners with other majors, including our student advisory committee; Peer advising system.
- Undergraduate Research Symposia for summer, fall and spring (participation optional).

DUS and Undergrad Registrar

Fall-Michael Koelle
CE28A SHM (737-5808) MBBUndergrad@yale.edu
Spring-Karla Neugebauer
C123 SHM (785-3322) MBBUndergrad@yale.edu
DUS Registrar: Elizabeth Vellali, CE26A SHM (737-2060) MBBUndergrad@yale.edu
Assoc Dean for Science Education, MB&B Prof Sandy Chang, advises on pursuing the MD/PhD s.chang@yale.edu

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FRONT COVER

Three-dimensional structure of the ion channel, TRPA1, which is activated by many environmental and endogenous irritants including the active ingredients in wasabi, mustard, onions and garlic to initiate pain sensations. TRPA1 assembles as a homotetramer (each subunit is shown in a distinct color for clarity) in the plasma membrane of a subset of sensory neurons. During her postdoctoral studies, Prof. Paulsen (Yale, MB&B) used a biophysical method called electron cryo-microscopy to solve this first-ever structure of the TRPA1 ion channel. The structure is docked in the density map (grey) to illustrate the high-resolution portion of the ion channel. TRPA1 contains 16 ankyrin repeats, a common protein fold, 11 of which were poorly resolved in the density, but are docked below the core of the channel for completion. The structure revealed, for the first time, the binding site of a necessary cofactor, InsP6 (chemical structure near center).

Candice Paulsen
Assistant Professor
Department of Molecular Biophysics & Biochemistry

A Brief Introduction to the Program

The undergraduate programs offered by the department of Molecular Biophysics & Biochemistry (MB&B) are for students interested not just in what life is, but also in how it works. We seek to understand life at a mechanistic level by studying how the extraordinarily complex molecules found in living organisms create structures, carry out chemistry, and store and utilize information to generate the remarkable properties of living organisms. The term "Biochemistry" in our name refers to the discipline that identifies and studies the molecules and chemical reactions in biological organisms. "Molecular Biophysics" uses the methods of physics to determine how the molecules identified by biochemists actually work by determining their three-dimensional structures and mechanisms of action. For example, biochemistry was used to discover DNA and the fact that it carries genetic information, while biophysics was used to discover its double-helix structure. Biochemistry and biophysics are rapidly advancing areas of science that underlie the current dramatic progress in medicine.

Our undergraduate degree programs are well suited for students planning to attend medical and/or graduate school in biochemistry, molecular biology, genetics, genomics, or biophysics. The MB&B major differs from the major in Molecular, Cellular, and Developmental Biology (MCDB) in that MB&B places its central focus on studying biology using the tools of chemistry, physics, and biochemistry. MB&B students thus carry out more in-depth coursework in these areas, and typically take less coursework in other areas such as organismal biology, cell biology, and genetics.

MB&B majors first acquire a broad foundation in chemistry, mathematics, physics, and biology, and then, starting in the sophomore or junior year, focus intensively on biochemistry and biophysics. Seniors choose among a wide range of opportunities: independent research projects, courses at the Graduate School or the Medical School, and advanced elective classes in Yale College.

Designed for students with a strong interest in research, the B.S. degree program provides an extensive 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. degree requires 2 fewer courses than the B.S., but still provides the intellectual discipline of biochemistry and biophysics for students who also want to have sufficient time to pursue in-depth studies outside the major. The four-year B.S./M.S. involves graduate-level coursework and intensive research similar to that carried out in the first year of a Ph.D. program. The B.S./M.S. is particularly suited for students who will not pursue a Ph.D. in the sciences, but who are going on to careers (e.g. business or legal aspects of the biotechnology industry) in which they will benefit from advanced scientific training.

Of the seniors majoring in MB&B each year, about two-thirds go to medical school. Of the other third, some enter graduate school, others seek employment in university labs or in the biotechnology industry, and some attend law or business school. Our alumni include many distinguished leaders in science and medicine.

Director of Undergraduate Studies (DUS)
Fall-Michael Koelle
CE28A SHM (737-5808) MBBUndergrad@yale.edu
Spring-Karla Neugebauer
C123 SHM (785-3322) MBBUndergrad@yale.edu

Other contact information
The MB&B undergraduate Web site
http://mbb.yale.edu/
has additional information, course registrations forms, etc.

DUS Registrar
Elizabeth Vellali, CE26A SHM (737-2060) MBBUndergrad@yale.edu

MB&B Faculty Advisor System

The idea behind MB&B's faculty advising system is that all majors should get to know more than one faculty member well. All undergraduates, including entering freshmen (who should also meet with their college advisor), should consult one of the MB&B Faculty Advisors assigned to their class for current information, advice, and signing of their course schedules. Faculty Advisors are assigned according to year of study, as listed below:

Class of 2019

Christian Schlieker, 236A Bass (432-5035) *christian.schlieker@yale.edu*

Christian Schlieker majored in Genetics and Biochemistry at the University of Bonn, earned his PhD from the University of Heidelberg in 2004 and worked as postdoctoral fellow at Harvard Medical School and the Whitehead Institute for Biomedical Research/MIT. He joined the Yale faculty in 2009 and is now an Associate Professor in Molecular Biophysics & Biochemistry, where he investigates molecular mechanisms underlying nuclear envelopathies, using biochemical, cell biological and biophysical/structural methods. Click here to visit his lab webpage.

Joe Howard, 334A Bass (432-7245) *jonathon.howard@yale.edu*

Joe Howard studied Mathematics (B.Sc., 1979) and Neurobiology (Ph.D. 1983) at the Australian National University. His interest in mechanics at the cellular and molecular scale began during postdoctoral studies in Bristol, UK and San Francisco (hair cells and hearing) and continued as a Professor at the University of Washington Medical School in Seattle (motor proteins) and as Director of the Max Planck Institute of Molecular Cell Biology & Genetics in Dresden, Germany (cytoskeletal systems). Joe's research combines theory and experiment. He joined the Yale MB&B faculty in 2013 and holds a secondary appointment in Physics. Click here to visit his lab webpage.

Class of 2020

Enrique De La Cruz, 336A Bass (432-5424) enrique.delacruz@yale.edu

Enrique M. De La Cruz, Ph.D. is a Professor in the Department of Molecular Biophysics and Biochemistry at Yale University. He is a first generation Cuban-American who was raised in Newark, NJ. Dr. De La Cruz earned his Ph.D. degree in Biochemistry, Cell & Molecular Biology (BCMB) with Dr. Thomas D. Pollard at Johns Hopkins University School of Medicine and received postdoctoral training in the laboratories of Dr. H. Lee Sweeney and E. Michael Ostap at the University of Pennsylvania School of Medicine. Dr. De La Cruz has published extensively in the areas of actin and myosin regulation, RNA helicases, and signaling enzymes, for which he has received a number of awards and honors. Click here to visit his lab web page.

Chuck Sindelar, CE25 SHM (737-4752) Charles.sindelar@yale.edu

Chuck Sindelar's group uses high-resolution structural tools, with a special emphasis on cryo-electron microscopy,(cryo-EM) to unravel the mechanism of vital biological processes. The fundamental question that drives our work is how complex formation triggers the elaborate functional activity of molecular motors and other proteins associated with biological filaments. In our cryo-EM work, we apply state-of-the-art image-processing techniques to chemical intermediates and mutant forms of enzyme complexes in order to directly visualize key conformational changes. We synthesize such data with other biochemical and biophysical data to derive mechanistic models that explain how these molecular machines work. We devote significant effort toward developing novel image-processing methods to visualize never-before-seen details of motility and other vital processes. For example, a recent breakthrough from our laboratory has allowed us to produce the first 3D reconstruction of a dimeric kinesin molecule poised in mid-step along the microtubule. This challenge was previously insurmountable due to the fact that this configuration of kinesin violates helical symmetry, combined with the small size of the kinesin. This work builds on methods which I developed during my postdoctoral studies, to identify and characterize the microtubule seam, a

symmetry-violating feature of the microtubule helical lattice itself, which obstructed previous efforts to solve high-resolution cryo-EM structures of microtubules. Combining these tools along with additional innovations by ourselves and other groups, my group has worked to progressively refine our understanding of the force-generating mechanism of kinesin. We work with a number of collaborators ((Enrique De La Cruz, Albert Ko, James Rothman, David Calderwood) on other diverse processes including actin cross-linking and dissembly, flagellar motility in spirochete bacteria, SNARE-mediated fusion of synaptic vesicles and many others.

Class of 2021

Wendy Gilbert, C127 SHM (785-4857) wendy.gilbert@yale.edu

Wendy Gilbert studied Molecular Biology at Princeton (AB 1994) and Biochemistry at UCSF (PhD 2004). After postdoctoral training at UC Berkeley, she joined the faculty at MIT (2008). In 2017 she moved to Yale as an Associate Professor of Molecular Biophysics and Biochemistry. Wendy is passionate about RNA Biology and about increasing diversity and inclusiveness in STEM fields. Wendy's lab combines systems approaches, molecular genetics, and biochemistry to understand post-transcriptional gene regulation in eukaryotic cells. Click here* to visit her lab webpage.

Andrew Miranker, 318 Bass (432-8954) Andrew.miranker@yale.edu, Asst: Lisa Adams@yale.edu

Andrew Miranker studied Biology at Carnegie Mellon University, earned his PhD in Biophysics from Harvard, and did his postdoc in Biophysics at Oxford. At Yale he currently teaches MB&B 420a/720a Macromolecular Structure and Biophysical Analysis. Sporadically, he teaches MB&B 107 Being Human in STEM and MB&B 218 Art and Biomolecular Recognition. Miranker studies protein folding, misfolding and aggregation as it relates to diseases such as Alzheimer's, Parkinson's and Diabetes Click here to visit his webpage.

Class of 2022

Michael Koelle, CE28A SHM (737-5808) Michael.koelle@yale.edu

Michael Koelle studied Mathematics and Biology at the University of Washington, earned his Ph.D. in Biochemistry from Stanford University, and received postdoctoral training in neuroscience and genetics at the Massachusetts Institute of Technology. At Yale he currently teaches MB&B 101a Biochemistry and Biophysics, as well as MB&B 300a Principles of Biochemistry I. His lab studies the mechanism neural signaling through G protein coupled receptors (GPCRs). Neurotransmitters, neuropeptides, as well as many addictive drugs act in the brain at at least in part through GPCRs that activate heterotrimeric G proteins to modulate the activity of neurons. The Koelle lab studies the molecular mechanism of such signaling. The lab also studies how such signaling is used to control neural circuits, with these studies focused on using genetics and microscopy to analyze the egg-laying circuit of the simple nematode worm *C. elegans*. Click here to visit the Koelle lab webpage.

Majors Accepted to the B.S./M.S. Program

Karla Neugebauer, C123 SHM (785-3322) MBBUndergrad@yale.edu

Fall 2018 Michael Koelle will advise.

The Bachelor of Arts Degree

The B.A. program provides the intellectual discipline of biophysics and biochemistry for students who want to have sufficient time for in-depth studies outside the major or who are interested in molecular biology as part of a liberal education and may not want to go on to graduate work in any of the natural sciences. B.A. program majors have an opportunity to carry out research in faculty laboratories after they have completed their required MB&B laboratory course. In the absence of Advanced Placement (AP) in any of the natural sciences or mathematics, completion of at least 19.5 science credits is required for the B.A. major.

Requirements for the B.A. program in the MB&B Major

The table shows the MB&B course requirements in the Basic Sciences (Part A) and in the Advanced Sciences (Part B) for the B.A. degree. Courses prefixed with a star (*) may be waived by receiving scores on AP tests or placement exams sufficient to earn acceleration credits in the particular subjects, even if the student does not choose to accelerate. Note that you can find a complete list of MB&B courses, including electives, at the end of this handbook.

Bold letters after the number of credits indicate footnotes.

Part A. Basic Sciences Credits	
Introductory Biology:	
*BIOL 101, 102, 103, and 104	2
Chemistry:	
*General: CHEM 161, 165, or 163, 167; and 134L, 136L	3**a**
Organic: CHEM 174, 175, or 220, 221, and 222L, 223L	3**b**
Physical: CHEM 328 (may substitute CHEM 332)	1**c**
Physics:	
*PHYS 170, 171, or 180, 181, or 200, 201	2
Mathematics:	
*Calculus: MATH 112 and either MATH 115 or 116	2**d**
Total Course Credits in Basic Science (Maximum)	13
Part B. Advanced Sciences and Senior Requirement	
MB&B:	
Biochemistry: MB&B 300, 301, and 251L (0.5 credit)	2.5**f**
Biophysics: MB&B 302 (may substitute CHEM 333)	1
MB&B Elective: One additional MB&B course	1
MB&B 490b (Senior requirement)	1**g**
Quantitative reasoning (QR) elective	1**e**
Total Course Credits in Advanced Science	6.5
Total Credits Required for B.A. Degree	**19.5**

a: (For class of 2018 and earlier, the previously offered general chem. courses will be accepted: 112, 113, or 114, 115, & 116L, 117L; or 118 & 119L)

b: Only students having AP for CHEM 113 are eligible for CHEM 174. By taking freshman organic chemistry (CHEM 174, 175) in the fall followed by organic chemistry (CHEM 221b) in the spring of the freshman year, a student is able to take MB&B 300a/301b in the sophomore rather than the junior year.

c: CHEM 328a is the standard one-term physical chemistry course that should be taken by most MB&B majors. A small number of students with especial interest in physical chemistry may want to take CHEM 332a instead of CHEM 328a. Taking CHEM 332a gives students the option to take a second term of physical chemistry, CHEM 333b, as a substitute for the biophysics course MB&B 302b. Aside from the more fundamental treatment given in Chem 332 (viz., trying to explain basic concepts and to demonstrate from where the venerable tenants/equations of thermodynamics actually originate), the primary difference between these two courses resides in the focus of applications (with Chem 328 obviously being more oriented towards biochemical applications).

d: MATH 115 and 116 are essentially equivalent in terms of calculus level. MATH 116 is a more intimate class, with readings grounded in biology and more use of differential equations to solve problems. Even if you place out of MATH 115, you may consider MATH 116 because of the unique topics presented. Please consult the instructors (e.g. John Hall) if you wish to discuss this further.

e: Several courses that fulfill this requirement and fit nicely with the interests of MB&B majors are as follows: MB&B strongly encourages all majors to strengthen their skills in statistics and data analysis. In particular, S&DS 110 (Introduction to R) and S&DS 220 (Intensive Intro Stats) include instruction in the R package for statistical computing, which is useful for all biologists. Some MB&B majors may be interested in S&DS 105 or 230, CPSC 100, 112, 201 or above. For those interested in computational or structural biology, multivariable calculus is advantageous **(**MATH 120 or ENAS 151). Linear algebra (Math 222 or 225) is highly recommended for computational biologists. Others with permission from academic advisor or DUS. AP credit cannot be applied toward the quantitative reasoning elective.

f: MB&B 251L is cross listed as MCDB 301L. This means that students could sign up for the class as "MB&B 251" if they need an additional chemistry lab for premed purposes. On the other hand, students who have already take at least three chemistry labs could instead register for "MCDB 301L" and thus complete both their MB&B biochemistry lab course requirement AND a premed "biology lab" course requirement at the same time.

g: The MB&B senior requirement for both B.S. and B.A. degrees is fulfilled by participation in MB&B 490b during the second semester of the senior year. This course will confer course credit for completion of the senior project in the department. Students prepare a written report and make an oral presentation on recent advances in research on a topic of their choice within biochemistry and biophysics. Students will meet with the faculty during the first two weeks of the spring term to agree upon a topic and approach.

Written presentation: The paper is expected to be 15–25 pages in length, and should critically review the literature on a scientific topic within biochemistry and biophysics. A first draft of the paper is due two weeks prior to the date of the oral presentation. It is inappropriate for students to resubmit a paper prepared for another course in fulfillment of the senior requirement. The literature project must be original new work approved by the faculty member overseeing the senior project. It is recommended that students who took research for credit earlier in their training write a new 15–25 page literature review on the topic of their research, and append to it the research report they previously completed for the research course. Faculty in charge of the program will provide suggestions for the paper and return it to the student. A final draft of the paper is due the first day of the reading period of the student's final term.

Oral presentation: Students will make a 15-minute oral presentation during the last three weeks of the student's final term in a general scientific format open to the public. Other students in the senior project course are expected to attend the presentations.

NOTE: MB&B 470/471 are independent research courses for MB&B majors only that may be taken during the sophomore, junior, or senior years. Students receive letter grades. MB&B B.A. degree majors may take up to two credits of these courses and count one of them as the "MB&B elective" toward their MB&B B.A. degree requirements. Students may take additional independent research for credit by registering for MB&B 472/473, which have identical requirements but are graded Pass/Fail. These additional credits do not count towards the MB&B degree requirements. Ideally students will take MB&B 251L to receive a grounding in practical laboratory skills prior to taking an independent research course.

Possible Course Programs for B.A. MB&B Majors Entering Yale Without Any Advanced Placement

This B.A. program provides the minimal number of science and non-science courses required of all MB&B majors. It earns a total of 36.5 course credits and assumes no AP credit. (Credits are indicated in parentheses). Students having AP in science are urged to replace introductory science courses by more advanced ones in their freshman year.

Freshman	**Sophomore**	**Junior**	**Senior**
BIOL 101-104 (2)	CHEM 220 and 221 (2)	MB&B 300a (1)	CHEM 328a (1)
	CHEM 222 and 223 (1)	MB&B 301b (1)	MB&B elective (1)
CHEM 161, 165 (2)	MATH 116 a or b (1)	MB&B 251L (0.5)	MB&B 302b (1) Biophysics
CHEM 134L, 136L (1)	Quantitative Reasoning (1)	PHYS 180a and PHYS 181b (2)	MB&B 490b (1) Senior Seminar
MATH 112a or b (1)	Non-science (4)	Non-science (5)	Non-science (5)
Non-science (3)			
MB&B requirements/Total 6/9	5/9	4.5/9.5	4/9
		TOTAL	**19.5/36.5**

Notes:

1. Majors who must begin their study of a foreign language after entering Yale are urged to do so in their freshman year. The foreign language requirement should be completed by the end of the junior year.

2. Half-credit courses such as BIOL 101-104 and MB&B 251L earn no course credit per se; one credit is awarded only after two such courses are completed. Additional half-credit courses include one-day-per-week lab courses offered by MCDB, Chemistry, Computer Science, Psychology, or Physics.

MB&B Coursework Planning Sheet for the B.A. Degree

REQUIREMENT	COURSE NAME	TERM TAKEN			
Introductory Courses	(When alternative courses are listed on one line, circle the name of the one taken)	Proposed	Enrolled	Completed	Grade
Introductory Biology	BIOL 101				
Introductory Biology	BIOL 102				
Introductory Biology	BIOL 103				
Introductory Biology	BIOL 104				
General Chem 1	CHEM 161 **or** 163 (previously offered versions of general chem. and labs will be accepted for the classes of 2018 and earlier)				
General Chem Lab 1	CHEM 134L				
General Chem 2	CHEM 165 **or** 167				
General Chem Lab 2	CHEM 136L				
Calculus 1	MATH 112a/b				
Calculus 2	MATH 116a/b or 115a/b				
Quantitative Reasoning	Specify course:				
Mid-level Courses					
Physics 1	PHYS 170a **or** 180a **or** 200a				
Physics 2	PHYS 171b **or** 181b **or** 201b				
Organic Chem 1	CHEM 174a **or** 220a/b				
Organic Chem Lab 1	CHEM 222La/b				
Organic Chem 2	CHEM 175b **or** 221a/b				
Organic Chem Lab 2	CHEM 223La/b				
Biochemistry 1	MB&B 300a				
Biochemistry 2	MB&B 301b				
Biochemistry Lab BS	MB&B 251La				
Upper-level Courses					
Physical Chem 1	CHEM 328a **or** 332a				
Biophysics	MB&B 302b or CHEM 333b				
MB&B Elective*					
Senior Seminar	MB&B 490				
Other courses					
Other courses					
Other courses					

*MB&B elective is any 200-level or above MB&B course, including any lecture, seminar, lab or research for credit course.

The Bachelor of Science Degree

The B.S. program is designed especially for students with a strong commitment to research. B.S. program majors have an opportunity to carry out research in faculty laboratories after they have completed their required MB&B laboratory course. This program is readily adapted to permit qualified majors to enter the combined B.S./M.S. program that leads to the simultaneous award of the two degrees at the end of four years in Yale College.

In the absence of AP in any of the natural sciences or mathematics, and depending on the specific courses taken, completion of 21.5 credits of science courses are required for the completion of the B.S. degree.

Requirements for the B.S. Program in the MB&B Major

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Part A. Basic Sciences Credits	
Introductory Biology:	
*BIOL 101, 102, 103, and 104	2
Chemistry:	
*General: CHEM 161, 165, or 163, 167; and 134L, 136L	3**a**
Organic: CHEM 174, 175, or 220, 221, and 222L, 223L	3**b**
Physical: CHEM 328	1**c**
Physics:	
*General: PHYS 170, 171, or 180, 181, or 200, 201	2
Mathematics:	
*Calculus: MATH 112 and either MATH 115 or 116	2**d**
Total Course Credits in Basic Science (Maximum)	13
Part B. Advanced Sciences and Senior Requirement	
Biochemistry: MB&B 300a, 301b and 251 (.05)	2.5**f**
Biophysics: MB&B 302b (may substitute CHEM 333b)	1
MB&B Electives: *Two* additional MB&B courses	*2***g**
Additional science elective	*1***h**
MB&B 490b Senior Project	1**i**
Quantitative reasoning (QR) elective	1**e**
Total Course Credits in Advanced Science	8.5
Total Credits Required for B.S. Degree	**21.5**

a: (For class of 2018 and earlier, the previously offered general chem. courses will be accepted: 112, 113, or 114, 115, & 116L, 117L; or 118 & 119L)

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c: CHEM 328a is the standard one-term physical chemistry course that should be taken by most MB&B majors. A small number of students with especial interest in physical chemistry may want to take CHEM 332a instead of CHEM 328a. Taking CHEM 332a gives students the option to take a second term of physical chemistry, CHEM 333b, as a substitute for the biophysics course MB&B 302b. Aside from the more fundamental treatment given in Chem 332 (viz., trying to explain basic concepts and to demonstrate from where the venerable tenants/equations of thermodynamics actually originate), the primary difference between these two courses resides in the focus of applications (with Chem 328 obviously being more oriented towards biochemical applications).

d: MATH 115 and 116 are essentially equivalent in terms of calculus level. MATH 116 is a more intimate class, with readings grounded in biology and more use of differential equations to solve problems. Even if you place out of MATH 115, you may consider MATH 116 because of the unique topics presented. Please consult the instructors (e.g. John Hall) if you wish to discuss this further.

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f: MB&B 251L is cross-listed as MCDB 301L. This means that students could sign up for the class as "MB&B 251" if they need an additional chemistry lab for premed purposes. On the other hand, students who have already take at least three chemistry labs could instead register for "MCDB 301L" and thus complete both their MB&B biochemistry lab course requirement AND a premed "biology lab" course requirement at the same time.

g: One of the two must be an MB&B lecture or seminar course. The other can be another MB&B lecture course, research for credit, or the upper level lab course MB&B 460L. **Only two course credits of MB&B 470, 471 and 478, 479 may count towards the B.S. degree requirements – one as an "MB&B elective" and the other as the "additional science elective".**

h: This elective is chosen, with the approval of the major's MB&B Faculty Advisor, from among courses with the Sc designation. Students may also use graduate courses offered by MB&B and other science departments, including Cell Biology, Human Genetics, Neuroanatomy, Pharmacology and Physiology. Courses must be at a higher level than those already required for the major. This elective can be an introductory course if no other course in that field is required.

i: The MB&B senior requirement for both B.S. and B.A. degrees is fulfilled by participation in MB&B 490b during the second semester of the senior year. This course will confer course credit for completion of the senior project in the department. Students prepare a written report and make an oral presentation on recent advances in research on a topic of their choice within biochemistry and biophysics. Students will meet with the faculty during the first two weeks of the spring term to agree upon a topic and approach.

Written presentation: The paper is expected to be 15–25 pages in length, and should critically review the literature on a scientific topic within biochemistry and biophysics. A first draft of the paper is due two weeks prior to the date of the oral presentation. It is inappropriate for students to resubmit a paper prepared for another course in fulfillment of the senior requirement. The literature project must be original new work approved by the faculty member overseeing the senior project. It is recommended

that students who took research for credit earlier in their training write a new 15–25 page literature review on the topic of their research, and append to it the research report they previously completed for the research course. Faculty in charge of the program will provide suggestions for the paper and return it to the student. A final draft of the paper is due the first day of the reading period of the student's final term.

Oral presentation: Students will make a 15-minute oral presentation during the last three weeks of the student's final term in a general scientific format open to the public. Other students in the senior project course are expected to attend the presentations.

NOTE: MB&B 470/471 are independent research courses for MB&B majors only that may be taken during the sophomore, junior, or senior years. Students receive letter grades. MB&B majors may take up to two credits of these courses and count them as electives toward the MB&B B.S. degree requirements. Students may take additional independent research for credit by registering for MB&B 472/473, which have identical requirements but are graded Pass/Fail. These additional credits do not count towards the MB&B degree requirements. Ideally students will take MB&B 251L to receive a grounding in practical laboratory skills prior to taking an independent research course.

Possible Course of Study for the MB&B B.S. Major

Examples of course selections are provided below for the MB&B B.S. major, depending on the placement status of the incoming freshman. Note: you can major with a B.S. in MB&B even if you do not place out of any classes. In that case, please consult the example given on page 8 and note that some of the "non-science" credits would then be allocated to the additional MB&B requirements (2 credits). Note that taking MB&B 300/301 in the sophomore year frees up the junior year to finish other requirements and MB&B electives in the junior and senior years. Nevertheless, it is still possible to complete the requirements for a BS major in MB&B, taking 300/301 in the junior year, as shown on page 8.

The following example assumes that the student has acceleration credit for two semesters of math based on performance on the math AP exam.

AP	**Freshman**	**Sophomore**	**Junior**	**Senior**
Math (2)	BIOL 101-104 (2)	CHEM 220, 221 (2)	PHYS 180a PHYS 181b (2)	CHEM 328a (1)
	CHEM 161, 165 (2)	CHEM 222La/223Lb (1)	MB&B elective (1)	MB&B 302b (1)
	CHEM 134L, 136L (1)	MB&B 300a/301b (2)	Science elective (1)	MB&B elective (1)
	Non-science (4)	MB&B 251La (.5)	QR elective (1)	MB&B 490b Senior Seminar (1)
		Non-science (3)	Non-science (4)	Science or non-science (4)

MB&B requirements/Total

2/2	5/9	5.5/8.5	5/9	4/8
			Total	**21.5/36.5**

MB&B Coursework Planning Sheet for the B.S. Degree

REQUIREMENT	COURSE NAME	TERM TAKEN			
Introductory Courses	(When alternative courses are listed on one line, circle the name of the one taken)	Proposed	Enrolled	Completed	Grade
Introductory Biology	BIOL 101				
Introductory Biology	BIOL 102				
Introductory Biology	BIOL 103				
Introductory Biology	BIOL 104				
General Chem 1	CHEM 161 **or** 163 (previously offered versions of general chem. and labs will be accepted for the classes of 2018 and earlier)				
General Chem Lab 1	CHEM 134L				
General Chem 2	CHEM 165 **or** 167				
General Chem Lab 2	CHEM 136L				
Calculus 1	MATH 112a/b				
Calculus 2	MATH 116a/b or 115a/b				
Quantitative Reasoning	Specify course:				
Mid-level Courses					
Physics 1	PHYS 170a **or** 180a **or** 200a				
Physics 2	PHYS 171b **or** 181b **or** 201b				
Organic Chem 1	CHEM 174a **or** 220a/b				
Organic Chem Lab 1	CHEM 222La/b **or** 226La				
Organic Chem 2	CHEM 175b **or** 221a/b				
Organic Chem Lab 2	CHEM 223La/b **or** 226Lb				
Biochemistry 1	MB&B 300a				
Biochemistry 2	MB&B 301b				
Biochemistry Lab BS	MB&B 251La				
Upper-level Courses					
Physical Chem 1	CHEM 328a **or** 332a				
Biophysics	MB&B 302b (or CHEM 333b)				
MB&B Lecture Elective#					
MB&B Elective*					
Senior Seminar	MB&B 490				
Science Elective					
Other courses					
Other courses					
Other courses					

*MB&B elective is any 200-level or above MB&B course, including any lecture, seminar, lab or research for credit course.

MB&B Lecture elective is any 200-level or above MB&B course **EXCEPT** a lab or research for credit course

MB&B Combined
Bachelor of Science/Master of Science Degree

To provide exceptionally able undergraduates an opportunity to accelerate their professional education, the MB&B department offers a combined B.S. and M.S. program usually requiring eight terms to complete.

1. The candidate must satisfy the requirements of Yale College for Yale's combined bachelor's and master's degree program. These rules are outlined in the Yale College Programs of Study, and are incorporated into the requirements described here.

2. The candidate normally must complete the core requirements of the B.S. degree during his/her first three years in Yale College. Specifically, he/she must:

(a) Enter Yale College as a freshman with AP (or have received acceleration credit) equivalent to at least one *year* of college-level courses in biology, chemistry, mathematics, or physics;

(b) Complete all of the following (or their equivalents) by the end of his/her fourth term in Yale College: Introductory Biology, CHEM 221/223L, the required Quantitative Reasoning course, PHYS 180a, and 181b;

(c) Complete the following by the end of his/her sixth term in Yale College: MB&B 300a/600a, 301b/601b, and 360Lb/660Lb (or its equivalent), CHEM 328a, and either MB&B 302b or CHEM 333b; and

(d) Complete one semester of Research in Biochemistry and Biophysics (MB&B 470a or 471b) or equivalent in the laboratory where the M.S. thesis project will be carried out.

3. The candidate must apply in writing to the Director of the B.S./M.S. Program for admission no later than December 1 of their junior year, and have achieved at that time grades of A or A- in at least two-thirds of all courses as well as in courses directly related to the MB&B major. It is not required that the student maintains these grade standards after he/she joins the B.S./M.S. program in order to successfully complete the degrees, although most students do maintain such grades.

4. In lieu of the electives required of B.S. majors, B.S./M.S. candidates must complete the graduate-level work described below. Courses qualify as graduate level if they have course numbers of 500 or higher. Some 400-level undergraduate courses are cross-listed as graduate-level courses and do qualify as counting toward the M.S. elective requirements.

(a) During the senior year, two semesters of Intensive Research in Biochemistry and Biophysics (MB&B 570a and 571b).

(b) Two graduate-level MB&B lecture electives. Possibilities include the following:

Fall term: MB&B 420a/720a *Macromolecular Structure and Biophysical Analysis*, MB&B 449a/749a *Medical Impact of Basic Science*, MB&B 452b/752bu *Bioinformatics: Practical Application of Simulation and Data Mining,* MB&B 602a *Molecular Cell Biology*, MB&B 750a2 *Biological Membranes*. **Note:** MB&B 730a *Methods and Logic in Molecular Biology* is not open to B.S./M.S. students.

Spring term: [MB&B 421b/721b *Macromolecular Interactions & Dynamic Properties*], MB&B 443b/743b *Advanced Eukaryotic Molecular Biology*, MB&B 630b *Biochemical & Biophysical Approaches in Molecular and Cellular Biology*, MB&B 710b4 *Electron Cryo-Microscopy for Protein Structure Determination*, MB&B 760b3 *Advanced X-ray Crystallography*, MB&B 761b4 *X-ray Crystallography Workshop*, MB&B 465b/765b *Enzyme Mechanisms*.

(c) Four graduate-level electives in MB&B or in other biological or physical sciences.

5. Students must complete the graduate courses listed above under item 4 with grades of Honors (A or A-) in at least two courses and with and at least a High Pass (B) average in the remaining courses.

6. At least one of the graduate-level elective lecture courses taken to fulfill requirements 4b and 4c above should be oriented toward biology (as opposed to biophysics or other physical sciences). Suitable courses include MB&B 625a *Basic Concepts of Genetic Analysis*, MB&B 449a/749a *Medical Impact of Basic Science*, MB&B 602a *Molecular Cell Biology,* MCDB 430a/530a *Biology of the Immune System,* MCDB 310a/BENG 350a/MCDB 550a *Physiological Systems*, MCDB 415b/560b *Cellular and Molecular Physiology*, MCDB 677b *Mechanisms of Development*, MCDB 685b *Evolutionary Developmental Biology*, MCDB 720a *Neurobiology,* NBIO 501a *Principles of Neuroscience,* BIO 642a *Roles of Microorganisms in the Living World,* MBIO 685b *Molecular Mechanisms of Microbial Pathogenesis*.

7. During the final four terms, the candidate must earn at least six credits in courses outside the major (typically courses not designated Sci or QR). Two of these six courses can be CR/D/F. Only under the most extenuating circumstances can a Distributional Group IV class be used for this requirement. At least two undergraduate courses must be taken during the last two terms. A 20-minute oral thesis presentation is also required. This presentation will be open to all MB&B faculty, postdoctoral fellows, and students. The presentation will be scheduled toward the end of the spring term.

8. SENIOR REQUIREMENT. The candidate must submit a master's thesis, based on the MB&B 570a, 571b research project, by the last day of the reading period in the spring term. The thesis should be 50–60 double-spaced pages (approximately 12,000 words) and in a format specified by instructions available from the DUS Registrar's office. Copies of the thesis must be submitted to the Research Supervisor and DUS Registrar's office. Students are encouraged to submit their thesis to their advisor in advance of the deadline so they can receive critical review of the work prior to final submission to the Registrar's office. At the end of the spring term the candidate must also present a 20-minute talk on the thesis research to the DUS, their research supervisor, and the other BS/MS students.

NOTE: MB&B 470/471 are independent research courses for MB&B majors only that may be taken during the sophomore, junior, or senior years. Students receive letter grades. MB&B majors may take up to two credits of these courses and count them as electives toward the MB&B B.S. degree requirements. Students may take additional independent research for credit by registering for MB&B 472/473, which have identical requirements but are graded Pass/Fail. These additional credits do not count towards the MB&B degree requirements. Ideally students will take MB&B 251L to receive a grounding in practical laboratory skills prior to taking an independent research course.

Possible Course of Study for the MB&B BS/MS Major

A course schedule satisfying the course credit requirements in the combined BS/MS program is shown below. This schedule assumes that the student has AP credit in math and biology, and enrolls in freshman organic chemistry based upon his/her AP chemistry score and the Chemistry department placement examination. It also assumes that the student is awarded a waiver for the MB&B 251L requirement based on gaining equivalent research training in the research courses (MB&B 470a or 471b, 570a, and 571b) and/or summer research internships. Eight graduate-level elective courses are required. The six credits outside the major in the final four semesters are identified with double daggers (‡).

AP	**Freshman**	**Sophomore**	**Junior**	**Senior**
Math (2)	CHEM 175 (2)	MB&B 300a (1)	CHEM 328a (1)	MB&B 570a (2)
Chem (3)	CHEM 126L (1)	MB&B 301b (1)	MCDB 302b (1)	MB&B 571b (2)
Biology (2)	Quantitative Reasoning (1)	PHYS 180a (1)	MB&B Grad Electives (2)	Grad Science (3)
		PHYS 181b (1)	Grad science Elective (1)	
			MB&B 470a (1) or 471b	
	Non-science (5)	Non-science (5)	Non-science (3)‡	Non-science (3)‡
Science/Total				
7/7	4/9	4/9	6/9	7/10

Notes:

1. Students who want to participate in the BS/MS program are strongly encouraged to take freshman organic chemistry with lab and to complete the MB&B 300/301 series during their sophomore year.

2. It is also possible for students with fewer AP credits to complete the BS/MS degree, but particular effort must be made to complete the prerequisite courses during the freshman and sophomore years.

MB&B Coursework Planning for the B.S./M.S. Degree – classes of 2016 and later
Courses Used toward the Degrees

REQUIREMENT COURSE NAME TERM TAKEN
(or write "AP" under "completed" if you received AP credit)

Courses to be completed in the first four terms	When alternatives are listed, circle the one taken. If a different course is used, specify.	Proposed	Enrolled	Completed	Grade
Introductory Biology	BIOL 101-104				
General Chem 1	CHEM 161 **or** 163 (previously offered versions of general chem. and labs will be accepted for the classes of 2018 and earlier)				
General Chem Lab 1	CHEM 134L				
General Chem 2	CHEM 165 **or** 167				
General Chem Lab 2	CHEM 136L				
Organic Chem 1	CHEM 174a **or** 220a/b				
Organic Chem Lab 1	CHEM 222La/b **or** 126La				
Organic Chem 2	CHEM 175b **or** 221a/b				
Organic Chem Lab 2	CHEM 223La/b **or** 126Lb				
Calculus 1	MATH 112a/b				
Calculus 2	MATH 116 a/b or 115a/b				
Quantitative Reasoning	Specify course:				
Physics 1	PHYS 180a **or** 200a				
Physics 2	PHYS 181b **or** 201b				
Courses to be completed by the end of the 6th term					
Biochemistry 1	MB&B 300a				
Biochemistry 2	MB&B 301b				
Biochemistry Lab BS	MB&B 251L				
Physical Chem 1	CHEM 328a **or** 332a				
Biophysics	MB&B 302b (**or** CHEM 333b)				
Research for Credit	MB&B 470a **or** 471b				
Graduate-level courses					
MB&B grad elective					
MB&B grad elective					
Science grad elective					
Science grad elective					
Science grad elective					
Science grad elective					
Research: MB&B 570a					
Research: MB&B 571b					

Premed Curriculum
Advice for MB&B Majors with Advanced Placement Credit

The MB&B department allows AP credit to substitute for the introductory courses we normally require of our students. However, many medical schools do not. Premed students majoring in MB&B must be aware of how medical schools will treat their AP credit. Policies vary at different medical schools. Students are urged to contact the Yale Premedical Advisory Program (55 Whitney Avenue, 3rd Floor 203-432-0818) for information regarding specific schools. Also, see their Web site at http://ocs.yale.edu/content/premedical-studies-yale-college. Some general trends in medical school admissions requirements are described below. **Note that premedical requirements are changing and students should consult the premedical advisory program for the most up-to-date information**.

1. Biology. Most medical schools require students to take two semesters of biology, with lab, in college. AP credit cannot be used to substitute for this requirement. However, students with AP credit may usually take more advanced biology electives (with lab) instead of introductory biology. This fits nicely with MB&B's B.S. requirements, which ask students to take at least one advanced biology elective anyway (although MB&B does not require labs with advanced courses). Appropriate biology electives would include courses in areas such as genetics, microbiology or cell biology.

2. Chemistry. Most medical schools require two terms of general chemistry, with lab, and two terms of organic chemistry, with lab. However, students with AP credit for introductory chemistry will satisfy most medical school admissions requirements by taking one year of organic chemistry, with lab, followed by one term of biochemistry, with lab. MB&B asks students with AP credit for introductory chemistry to take a year of organic chemistry, with lab, followed by two semesters of biochemistry. The half credit lab MB&B 251L is the only MB&B lab requirement for the major.

3. Physics. This is the most difficult area for MB&B students with AP credit to negotiate. The MB&B department allows students to substitute AP credit for introductory physics. Some medical schools also allow this. Many do not. Also, medical schools require physics lab, while the MB&B major does not require any physics lab. The safest bet for a premedical MB&B student with AP physics credit is to take two semesters of introductory physics at Yale, with labs, or to take two semesters of more advanced physics courses, with labs.

4. Math. The Yale Premedical Advising Office finds that medical schools will accept students who use AP credit to skip MATH 112 and MATH 115/116 to satisfy their calculus requirement. A course in statistics is recommended, and there are many excellent options in S&DS (e.g. 105, 110, 220, etc) to consider. Some schools strictly require two semesters of college math, which can be satisfied by taking courses in computer science, statistics, or other quantitative disciplines

Frequently Asked Questions

What courses should I take as a freshman to best enable me to complete the MB&B major?
Freshman should take the highest-level chemistry courses for which they are eligible. Depending on their previous preparation in chemistry, freshmen should complete: 1) general chemistry (CHEM 161 and 165 or 163 and 167, along with the associated labs); or 2) organic chemistry (CHEM 174, 175, and the associated labs). The sooner students can complete at least one term of organic chemistry, the sooner they can take the biochemistry core course (MB&B 300a/301b) at the heart of the MB&B major. This course, in turn, is required for many upper-level MB&B electives. The other course should try to complete (or place out of) as a freshman is BIOL 101, Biochemistry and Biophysics, which is also a prerequisite for MB&B 300a/301b. Beyond this, the other introductory biology modules (BIOL 102-104) and calculus (MATH 112a or b and MATH 115a or b) are also good choices for freshmen.

I've taken some AP classes in math and science during high school. How does that affect the courses I will need to take to fulfill requirements for the major?
Students who scored 5 on the AP biology exam can take the placement exams for BIOL 101-104 and potentially place out of certain of these half-semester introductory biology courses. Acceleration credit in math and physics is accepted for fulfillment of the introductory courses in their respective departments. AP in chemistry is arranged by the Chemistry department and includes AP test scores as well as a departmental placement exam given at the beginning of the freshman year. **Note:** Most medical schools have requirements in each of the basic sciences and mathematics. AP credit does not satisfy these since most schools require the applicant to take a course (either introductory or advanced) in each of these areas while enrolled in college. Contact the Career Service Office (Premedical Advisory Program, 203-432-0818) for further information.

I have received full acceleration credit for biology, chemistry, or physics. Does this include the laboratory course requirements in these sciences?
The AP credit applies to both the lecture course and the laboratory. However, pre-medical students are advised that medical school regulations call for two chemistry, one biology, and one physics laboratory taken in college. The MB&B 251L lab usually is counted as a chemistry laboratory. Therefore, it is recommended that the student take an advanced biology elective that has a laboratory associated with it.

Can I use credits for courses taken at other universities toward the science or math requirements of the MB&B major?
Courses in math, biology, chemistry, or physics at other universities may be substituted for the prerequisite courses in these subjects required of MB&B majors at Yale, provided the courses taken are equivalent to the Yale courses for which they will be substituted. We are unlikely to allow courses at other universities to substitute for MB&B 300a, 301b, 302b, or the required MB&B electives. Official course credits should be transferred to Yale, but in rare cases students will be exempted from a course required for the MB&B major even if Yale College does not grant transfer credit for the course. In these cases, students may be asked to complete a higher-level course at Yale College as a substitute. To obtain a waiver, students should obtain a waiver form from the MB&B DUS office or the MB&B undergraduate Web site. This form must be signed by the MB&B faculty advisor and the MB&B DUS. To allow the advisor and DUS to evaluate the courses taken, the student should provide a copy of the course syllabus and contact information for the course instructor.

What is the Senior Project requirement for the major?

- B.A. and B.S. requirement: Participation in MB&B 490b, which includes a written paper and oral presentation
- B.S./M.S. requirement: BS/MS Thesis

My Research Report/Senior Requirement Report is due the last day of the reading period. What can I do if I need an extension of time to complete my report?

You need permission from your College Dean and have him/her call the DUS Registrar's office to indicate his/her permission. However, remember that your grade will be reported incomplete and you cannot graduate until the report has been completed.

What math courses should I take as an MB&B major?
All MB&B majors are required to complete basic calculus (MATH 112 and 115 or 116). We recommend MATH 116, which is tailored to students interested in biology. They must also take one additional quantitative reasoning course, which can be an upper-level math course, or could also be a lower-level course in a discipline such as statistics or computer science. One additional semester of upper-level math can be counted toward the MB&B BS degree requirements as the "additional science elective". The MB&B faculty strongly recommend that students interested in a research career take as much upper-level mathematics as possible, including studies of differential equations, linear algebra, and other applied math topics. This mathematical training will strongly enhance students' ability to perform well in the physical chemistry and biophysics courses that are required for the MB&B major, and will provide training that will be beneficial for the rest of their scientific careers.

Many MB&B students take MATH 120, which is a pure math course, and thus only indirectly relevant to the applied math used by scientists. However, MATH 120 is a prerequisite for the applied math courses offered at Yale that are of greatest benefit to MB&B students. The applied math courses we recommend include ENAS 151a, ENAS 194a or b, PHYS 301a, MATH 222 a or b, and MATH 225b. In certain years MB&B offers a math course—MB&B 435a1 "Mathematical Methods in Biophysics & Biochemistry". This half-credit course is for students who have completed both MB&B 300a and MATH 120, and is designed to expose MB&B students to just the applied math concepts most needed by biophysicists.

ENAS 151a is designed for engineering students, and covers some of the same topics as MATH 120, but is oriented toward applied math and includes some additional applied math topics. Enrollment in ENAS 151a will be limited to a small number of MB&B students, at the discretion of the Bioinformatics instructor.

I am interested in doing research for credit. How do I find a research advisor and select a research project?
Turn the page!

Getting your hands wet: finding a research lab at Yale

Doing research in a lab is the ultimate way to experience the excitement of discovery, deepen your understanding of the scientific method, use the biophysical and biochemical tools you have been learning about, and appreciate the beauty of life's molecules in action. All MB&B majors are encouraged to work in a research lab during the semester and/or over the summer. During the semester, you have several options for getting involved in a research project: you can simply volunteer for the number of hours you think is reasonable for you, you can take research for credit (e.g. MB&B 470/471) that anticipates a minimum of 10hrs/week in the lab, or you can organize/respond to an ad for student employment in a lab. Summer research can be supported by a fellowship:
http://science.yalecollege.yale.edu/yale-science-engineering-research/fellowship-grants) Arrange summer research early in the spring term, to give you time to apply!

When you do research in the lab, you'll be asking a question that has never been answered before. Getting the right or wrong result is not the point of research. Taking MB&B 251L is an opportunity to find out the kinds of research you might enjoy and gain real skills you can use in any research lab. But there are so many fascinating unanswered questions, you may not know which interests you the most before getting started.

In choosing a lab, there are three main considerations:
1. Pick a lab that studies something that really interests you! It could be a broad goal (how do cells move?), a more focused goal (how do proteins bind RNA?), or a technical interest (how does X-ray crystallography or RNA-Seq work?).
2. You will have the chance to get to know the professor (PI) of the lab really well. Although the PI may not supervise your every move, he/she will want to get to know you, discuss your experiments with you and help you set new goals in and out of the lab. Consider working in the lab of a professor who has inspired you in the classroom. Or, meet with a professor you have never heard of and decide if you have a good rapport.
3. The lab is also a social and learning environment. You will have the chance to get to know other undergrads, graduate students, technicians, and postdoctoral fellows. When you talk to the professor, peek into the lab and even chat with some of the lab members if possible. Does the lab environment feel exciting and welcoming to you?

MB&B encourages students to take advantage of all ~350 biomedical research labs at Yale. Keep in mind that most biological research is medically relevant. Although you need not restrict yourself to MB&B, reading the blurbs the ~50 MB&B faculty members have written about their research on our web site is a good place to start.
MB&B faculty from A-to-Z: http://medicine.yale.edu/mbb/faculty/facultyaz.aspx
MB&B faculty by research area: http://medicine.yale.edu/mbb/faculty/research/
For all 350 labs, see Biological and Biomedical Sciences Faculty: http://bbs.yale.edu/people/
Another resource is your MB&B advisor; he or she will be full of tips.

To approach a profess about working in their lab, just write an email. He or she will love to hear from you! Here is the sort of information you can write in your email to introduce yourself and your goals:
a. Say who you are (Yale college undergrad, what year, what major, what science courses you have completed, what you long term career goals are). Tell them if you have taken MB&B 251L!
b. Explain why you are specifically interested in that professor's research. For example, you are interested in the research topic, you read a paper by the professor, your academic advisor suggested the professor, etc.
c. Explain that you want to do an independent research project. State when you would like to work in the lab (e.g. this semester, next semester, next summer).

Requirements for Graduating with Distinction in the Major

As described in the Yale College Programs of Study, graduation with distinction in the major requires that students earn an A or A- in 3/4 of the credits taken for the major. Students must also receive an A or A- in the senior project course, MB&B 490b. Finally, the MB&B department requires students receive A or A- in at least 2/3 of the MB&B core courses: MB&B 300a, 301b, and 302b. To calculate if you have earned an A or A- in ¾ of the credits taken for the major, we count up how many A/A- credits you received in courses taken for the major (numerator), divide by the total number of credits you took for the major (denominator), and look for a ratio of ≥0.75. Half credit courses count half as much as full credit courses both in the numerator and denominator for this calculation. "Courses taken for the major" means all courses required for the major, including prerequisites in math, physics, chemistry, biology, not just courses from the MB&B department. Grades of F are included as non-A grades. Courses for which acceleration credits are received are not included in the calculation. No courses used toward MB&B degrees may be taken using the Credit/D/Fail option.

Sigler Prize for Undergraduates

Paul Sigler, 1934-2000
Founded in 2001, by a friend and colleague, in memory of Paul Sigler, who was a distinguished member of the faculty in the Department of Molecular Biophysics and Biochemistry. Paul Sigler was one of the world's leading structural biologists on the mechanisms by which gene expression is controlled, transmembrane signaling is accomplished, and correct folding of proteins is assisted by chaperonins. The Sigler Prize is awarded to a graduating Molecular Biophysics and Biochemistry major who has demonstrated excellence in scholarship and research.
The recipients are:

2018 James Diao and Charlotte Herber
2017 Paul Chung and Laura Goetz
2016 Charlie Kinzig
2015 Maria Christina Passarelli
2014 Connie Zhao
2013 Max Valenstein and Jonathan Liang
2012 Durga Thakral
2011 Eugene Serebryany and Julia Rogers
2010 Susan Scanlon
2009 Valerie Gordon
2008 Bennett Harrison Lane and Aaron Michael Ring
2007 David Weinberg and Rebecca Voorhees
2006 Eleanor Marshall
2005 Sara Koenig
2004 Srinivas Viswanathan
2003 Ruey Ho and Michael Gong
2002 Stanley Lo
2001 Yoomi Lee

Course Listing 2018-2019

MB&B 050b, 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. SC
MW 1pm-2:15pm

MB&B 060a, Molecular Medicine
Sandy Chang
The main purpose of this course is to use benign and malignant hematological disorders to introduce fundamental concepts in molecular and cellular biology. Students emerge from this course with a firm understanding of the molecular pathways perturbed in various hematological disorders and the therapeutics currently used to exploit these pathways for disease treatment. Through lectures and reading of primary scientific literature, students learn about landmark discoveries in hematology and how these discoveries contribute to understanding of the normal hematopoietic system, and when perturbed, how diseases arise. Students also learn to (1) read primary scientific literature, (2) synthesize this material to present to the class and (3) learn how to write a short grant proposal. These skills are essential for any successful scientist or physician, and it's important to master them early. Enrollment limited to first-year students. Preregistration required; see under First-Year Seminar Program. Prerequisite: score of 5 on the AP Biology exam or AP Chemistry exam. SC
MW 1pm-2:15pm

MB&B 105a or b / MCDB 105a or b, Biology, the World, and Us
a (fall term) John Carlson, Anthony Koleske and Joshua Gendron
b (spring term) Don Engelman, Scott Strobel, Shirin Bahmanyar, Yannick Jacob, Candie Paulsen
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
MW 11:35 am-12:25 pm

MB&B 107b / EDST 107b / PHYS 107b, Being Human in STEM
Helen Caines and Andrew Miranker
A collaboratively-designed, project-oriented course that seeks to examine, understand, and disseminate how diversity of gender, race, religion, sexuality, economic circumstances, etc. shape the STEM experience at Yale and nationally, and that seeks to formulate and implement solutions to issues that are identified. Study of relevant peer-reviewed literature and popular-press articles. Implementation of a questionnaire and interviews of STEM participants at Yale. Creation of role-play scenarios for provoking discussions and raising awareness. Design and implementation of group interventions. SO
F 9:25am-11:15am

MB&B 200a / MCDB 300a, Biochemistry
Ronald Breaker 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
MWF 9:25am-10:15am

MB&B 251La or b / MCDB 301La or b, Laboratory for Biochemistry
Aruna Pawashe and William Konigsberg
An introduction to current experimental methods in molecular biology, biophysics, and biochemistry. Limited enrollment. Requires preregistration by e-mail to aruna.pawashe@yale.edu and william.konigsberg@yale.edu prior to the first week of classes. Meets for first half of the term. After BIOL 101. SC ½ Course cr

MB&B 300a, Principles of Biochemistry I
Michael Koelle, Matthew Simon, Enrique De La Cruz, and Candice Paulsen
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
TTh 11:35am-12:50pm

MB&B 301b, Principles of Biochemistry II
Christian Schlieker and Karla Neugebauer
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
TTh 11:35am-12:50pm

MB&B 302b, Principles of Biophysics
Enrique De La Cruz and Charles Sindelar
An introduction to the theoretical basis of biophysical concepts and approaches with selected examples and applications. Prerequisites: MB&B 300 and CHEM 328. SC
MW 1pm-2:15pm

MB&B 330a / MCDB 330a / NSCI 324a, Introduction to Dynamical Systems in Biology
Damon Clark, Kathryn Miller-Jensen, and Jonathon Howard
Study of the analytic and computational skills needed to model genetic networks and protein signaling pathways. Review of basic biochemical concepts including chemical reactions, ligand binding to receptors, cooperativity, and Michaelis-Menten enzyme kinetics. Deep exploration of biological systems including: kinetics of RNA and protein synthesis and degradation; transcription activators and repressors; lyosogeny/lysis switch of lambda phage and the roles of cooperativity and feedback; network motifs such as feed-forward networks and how they shape response dynamics; cell signaling, MAP kinase networks and cell fate decisions; bacterial chemotaxis; and noise in gene expression and phenotypic variability. Students learn to model using MatLab in a series of in-class

hackathons that illustrate biological examples discussed in lectures. Prerequisites: BIOL 101 and 102, and PHYS 170 and 171 or equivalents, or with permission of instructors. QR, SC
TTh 2:30pm-3:45pm

MB&B 361b / BENG 465b / MCDB 361b / NSCI 325b, Dynamical Systems in Biology
Thierry Emonet and Jonathon Howard
Advanced topics related to dynamical processes in biological systems. Processes by which cells compute, count, tell time, oscillate, and generate spatial patterns. Time-dependent dynamics in regulatory, signal-transduction, and neuronal networks; fluctuations, growth, and form. Comparisons between models and experimental data. Dynamical models applied to neurons, neural systems, and cellular biophysical processes. Use of MATLAB to create models. Prerequisite: MCDB 330 or equivalent, or a 200-level biology course, or with permission of instructor. QR
TTh 2:30pm-3:45pm

MB&B 420a, Macromolecular Structure and Biophysical Analysis
Andrew Miranker and Yong Xiong
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: MBB 301 and 302. SC
TTh 9am-10:15am

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
MW 11:35am-12:50pm

MB&B 435a, Quantitative Approaches in Biophysics and Biochemistry
Julien Berro, Yong Xiong, and Jonathon Howard
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
TTh 11:35am-12:50pm

MB&B 443b, Advanced Eukaryotic Molecular Biology
Mark Hochstrasser and Wendy Gilbert
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
TTh 11:35am-12:50pm

MB&B 445b, Methods and Logic in Molecular Biology
Wendy Gilbert, Mark Hochstrasser, and Christian Schlieker
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
Th 2:30pm-4:20pm

MB&B 449a, Medical Impact of Basic Science
Joan Steitz, Thomas Steitz, I. George Miller, David Schatz, Daniel DiMaio, Karla Neugebauer, and Wendy Gilbert
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
MW 1pm-2:15pm

MB&B 452b / MCDB 452b / S&DS 352, 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
MW 1pm-2:15pm

MB&B 459a / ENGL 459a / EVST 215a, 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
T 9:25am-11:15am

MB&B 460Lb, Advanced Laboratory for Biochemistry
Aruna Pawashe and William Konigsberg
An advanced laboratory in biochemistry, molecular biology, and biophysics. Students perform experiments on an individual basis that have unknown outcomes using techniques currently used in research labs. MB&B 251L or permission of the instructor. SC ½ Course cr
T 1:30pm-5:30pm

MB&B 470a and MB&B 471b, Research in Biochemistry and Biophysics for the Major
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. 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. No more than two credits of MB&B 470/471 may be taken. These courses do count toward the degree requirements. Enrollment limited to MB&B majors. Prerequisite: MB&B 251L or permission of the instructor. SC

MB&B 472a and MB&B 473b, 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. 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 degree 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
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. 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 Söll, Karla Neugebauer and Mark Solomon
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.