MOLECULAR, CELLULAR, AND DEVELOPMENTAL BIOLOGY

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Biology is one of the most dynamic and wide-ranging sciences, spanning everything from molecules and cells to entire organisms and ecosystems. It seeks to answer some of the most fascinating questions in science: How do living systems work? How do they develop? How have they evolved over time? And how can we apply biological knowledge to improve human health and understand the natural world?

Students majoring in Molecular, Cellular, and Developmental Biology (MCDB) receive a rigorous and flexible education that prepares them for a wide range of professional paths. MCDB provides a strong foundation for careers in medicine, biotechnology, pharmaceuticals, basic and applied research, education, and many other life science fields. From developing new therapies and biologic drugs to uncovering the mechanisms that shape development and disease, the applications of modern biology are both powerful and far-reaching.

The MCDB program is ideal for students who want to explore molecular and cellular biology, genetics, and cutting-edge approaches to understanding life. The major offers opportunities to pursue interdisciplinary interests through concentrations in Biotechnology, Neurobiology, and Quantitative Biology, allowing students to tailor their studies to their goals and passions.

A hallmark of the MCDB major is its emphasis on discovery through hands-on research. Students are strongly encouraged to participate in independent laboratory research, working closely with faculty mentors across Yale. With approval, research can be conducted in various departments, giving students the chance to contribute directly to the advancement of biological science.

PREREQUISITES

Students are held to the prerequisite requirements in effect when they declared their major. However, with approval from the DUS and/or course instructors, these updated prerequisite requirements, effective for the 2026-2027 academic year and beyond, may be fulfilled by students who declared the major in a prior term.

BIOLOGY: Most MCDB courses require prior preparation in biological science. First-year students intending to major in MCDB are suggested to take BIOL 1010, 1020, 1030, and 1040. See *Placement Procedures* below or contact the DUS for information about placing out of the Biology modules.

- Students with a score of 5 in AP Biology or equivalent may place out of BIOL modules by passing the BIOL placement exams offered in the summer before entering Yale. Alternatively, the DUS may give permission to place out. NOTE: Students who receive DUS permission to place out of the Biology modules must substitute every two modules with one MCDB core course or special elective

advanced MCDB lecture or seminar course (MCDB 2000 level or above). The approval from the MCDB DUS to waive the entire or part of the BIOL sequence applies to MCDB majors only.

MATH: All MCDB majors must complete a mathematics prerequisite from one of the following options: MATH 1150 or higher, or S&DS 1000, 1080, 1090, or 2380. Other statistics courses taken at Yale with approval from the MCDB DUS, excluding S&DS 1600.

CHEMISTRY: Students must take a two-term lecture sequence in Chemistry, usually in their first year. Because required chemistry courses are prerequisite to several MCDB courses, students are strongly encouraged to take general and organic chemistry in the first and/or sophomore years. Students who place out of general chemistry may want to consider taking organic chemistry during the first year. Finishing the prerequisites early allows for a more flexible program in later years. The Chemistry placement exam is administered by the Chemistry department in July.

- B.A. degree: CHEM 1610 and CHEM 1650, or placement in CHEM 1700, or placement out of CHEM requirement
- B.S. degree: CHEM 1610 and CHEM 1650 and associated laboratories CHEM 1340L and CHEM 1360L, or placement in CHEM 1700 and associated lab CHEM 1710L, or placement out of CHEM requirement. B.S. students must also take a term course in organic chemistry (CHEM 1740, CHEM 1750, or CHEM 2200) and associated lab, usually in their sophomore year.

PHYSICS: The Physics placement exam is administered by the Physics Department in July.

- B.A. degree: PHYS 1700 or higher, usually in the junior year, or placement out of the Physics requirement
- B.S. degree: two-term lecture sequence, numbered PHYS 1700 and PHYS 1710; PHYS 1800 and PHYS 1810; PHYS 2000 and PHYS 2010; or PHYS 2600 and PHYS 2610, or placement out of the Physics requirement. Note: a Physics laboratory is not required for the B.S. degree, but might be a prerequisite for graduate or medical school applicants.

PLACEMENT PROCEDURES

Placement in MCDB courses is determined by examinations administered at Yale or by permission of the DUS. The Biology, Chemistry, and Physics departments administer placement exams in July. For more information, visit the Placement Exams and Information webpage.

Acceleration credit awarded in chemistry, mathematics, or physics, or completion of advanced courses in those subjects, is accepted in place of the corresponding prerequisites for the MCDB major. Students who have mathematics preparation equivalent to MATH 1150 or higher are encouraged to take additional mathematics courses, such as MATH 1200, 1210, 2220, or 2250, or ENAS 1510 or 1940. Students in the B.A. degree program who have satisfied one or more prerequisites with advanced placement must still complete three term courses in chemistry and physics at Yale, including at least one from each department.

REQUIREMENTS OF THE MAJOR

The same course cannot be used to satisfy both a prerequisite and a core or elective requirement.

B.A. degree program The B.A. degree requires a minimum of five and one-half course credits beyond the prerequisites (the same course cannot be used to satisfy both a prerequisite and a core or elective requirement), including five lecture or seminar courses and one laboratory, as follows:

1. Two core courses selected from MCDB 2000, 2020, 2050, 2100, 2900, 3000 (or MB&B 3000)
2. Two general electives selected from MCDB courses numbered 2500 or above, or two additional core courses from the list above. Two laboratory courses, either MCDB 3420L and 3430L or MCDB 3440L and 3450L, can be paired for a single elective credit. If used as an elective, these laboratories cannot also fulfill the laboratory requirement
3. One special elective selected from MCDB courses numbered 3500 or higher
4. One laboratory from the biological sciences selected from MCDB, MB&B, or Biomedical Engineering, *or with permission of the DUS*, from Anthropology or Ecology & Evolutionary Biology
5. The senior requirement (senior essay option does not carry course credit)

B.S. degree program The B.S. degree requires a minimum of nine course credits beyond the prerequisites (the same course cannot be used to satisfy both a prerequisite and a core or elective requirement), including eight lecture or seminar courses and two laboratories, as follows:

1. Three core courses selected from MCDB 2000, 2020, 2050, 2100, 2900, 3000 (or MB&B 3000)
2. Two general electives selected from MCDB courses numbered 2500 or above. Additional core courses from the list above, *or* a second term of organic chemistry, *or* a statistics course may substitute for an MCDB general elective. Two laboratory courses, either MCDB 3420L and 3430L or MCDB 3440L and 3450L, can be paired for a single elective credit. If used as an elective, these laboratories cannot also fulfill the laboratory requirement
3. One special elective from MCDB courses numbered 3500 or higher
4. Two MCDB laboratories from MCDB 2010L, 2030L, 2210L, 2310L, 2510L, 2910L, 3030L, 3210L, MCDB 3410L, 3420L, 3430L, 3440L and 3450L
5. The senior requirement (2 course credits), described below

The B.S. degree program, intensive major Requirements for the B.S. degree program, intensive major, are the same as those for the B.S. degree except for the senior requirement (see below). This degree requires eleven course credits beyond the prerequisites (the same course cannot be used to satisfy both a prerequisite and a core or elective requirement), including 6 courses, 2 half-credit labs, and 2 senior research courses, each worth two credits.

Independent research courses before senior year The only independent research course available to students prior to the senior year is MCDB 4740. This course is

graded Pass/Fail and contributes to the thirty-six course credits required for the bachelor's degree, but it does not substitute for any MCDB major requirement, including the senior requirement. Independent research courses do not substitute for the senior lab requirement for the MCDB major.

Independent research courses during senior year The research courses MCDB 4750, 4850, 4860, and MCDB 4950, 4960 exist primarily to fulfill the senior requirement, and do not satisfy any other requirement for the major. Note that Yale College limits the number of independent study or independent research courses that students may take; see Academic Regulations, section C, Course Credits and Course Loads. Any independent study course, regardless of its number, is included in the total. No independent research course satisfies a lab requirement for the MCDB major.

Credit/D/Fail No course taken Credit/D/Fail may be applied toward the requirements of the major, including prerequisites.

Outside credit Courses taken at another institution approved by Yale College or during an approved summer or term-time study abroad program may count toward the major requirements with DUS approval.

SENIOR REQUIREMENT

In addition to the course requirements described above, all students must satisfy a senior requirement undertaken during the senior year. All students must fill out an MCDB worksheet of requirements and go over it with the MCDB undergraduate registrar by the spring term of the junior year.

B.A. degree program For the B.A. degree, the senior requirement can be met either by submitting a senior essay of 15–20 pages evaluating current research in a field of biology, or by successful completion of one term of individual research (MCDB 4750). A senior choosing to fulfill the requirement with a senior essay must consult with a faculty adviser on the scope and literature of the topic and submit the approved Senior Essay Form to the DUS no later than the course selection period of the term in which the paper is due. The senior essay may be related to the subject matter of a course, but the essay is a separate departmental requirement in addition to any work done in a course and does not count toward the grade in any course. The senior essay must be completed and submitted to the office of the DUS by the last day of classes. Students electing this option can obtain a Senior Essay Form from the MCDB website, under Undergraduate Forms. Students who select this option should be aware it carries no credit or course registration. A grade of A/A- in the senior essay is required for students to be considered for distinction in the major.

B.S. degree program For the B.S. degree, the senior requirement is usually fulfilled by completing a yearlong research course, MCDB 4850, 4860. The senior requirement must be completed during the senior year. Seniors working toward the B.S. degree are expected to spend at least ten hours per week in the lab conducting individual research.

B.S. degree program, intensive major Requirements for the B.S. degree with an intensive major are the same as those for the B.S. degree except that students fulfill the senior requirement by taking MCDB 4950, 4960 for four course credits. Seniors

in the intensive major are expected to spend at least twenty hours per week in the lab conducting individual research.

ADVISING

First-year students considering a major in Molecular, Cellular, and Developmental Biology are invited to consult with the MCDB undergraduate registrar and/or the MCDB Peer Mentors. The prerequisites for the B.S. degree fulfill most of the usual premedical science requirements. Students who choose the B.A. degree can also prepare for medical school by taking additional premedical courses.

Once a declared MCDB major, students are required to contact the MCDB undergraduate registrar to be assigned to a faculty adviser. Students are strongly encouraged to meet with the MCDB Undergraduate Registrar (andrea.chamba@yale.edu) once per term and prior to registration. Students who have an MCDB faculty adviser on leave can consult the MCDB Undergraduate Registrar to arrange for an alternate.

Selection of courses A relevant intermediate or advanced course from another department in science, engineering, mathematics, or statistics may be accepted as an elective with permission of the DUS. Many courses in other departments have prerequisites; such prerequisites can be substituted for an MCDB elective with permission of the DUS.

Note: Residential College Seminars cannot be substituted for electives and do not count toward the requirements of the major. The MCDB major should not be taken as one of two majors with Molecular Biophysics and Biochemistry, Ecology and Evolutionary Biology, or Neuroscience.

Concentrations Students in the Biotechnology, Neurobiology, or Quantitative Biology concentrations should consult an adviser familiar with their concentration. For specific concentration requirements, see the Concentrations section.

Simultaneous B.S./M.S. degree program

Well-qualified students may be able to structure their undergraduate programs to become eligible for a simultaneous master's degree in selected graduate programs. Students must successfully complete relevant graduate course requirements and earn qualitative grades of Honors, High Pass, or Pass. At least two grades of Honors are required, and all grades must average High Pass in order to fulfill requirements for the master's degree.

Interested students should consult with both the DUS and DGS prior to submitting the online application, which is due no later than the last day of classes in their fifth term of enrollment in Yale College. Students should also review the GSAS Degree-Granting Departments and Programs page and select the relevant program for specific requirements and application information

STUDY ABROAD

Some programs for study abroad are available to MCDB majors. Approved Yale Study Abroad and Summer Programs can fulfill some of the requirements for the major. Interested students should email the DUS (mcdb.dus@yale.edu) with the course

syllabi and indicate which MCDB requirement the course will fulfill. Petitions must be submitted at least two weeks before the relevant deadline.

SUMMARY OF MAJOR REQUIREMENTS

Prerequisites *B.A.*—BIOL 1010, 1020, 1030, 1040 or placement exam, or one MCDB core course for placement out of every two BIOL modules; a two-term lecture sequence in chem; one term of PHYS 1700 or above; MATH 1150 or above or a Yale statistics course approved by the DUS; *B.S.*—same as for the B.A. degree, in addition to labs associated with a two-term lecture sequence in chem; 1 term of organic chem with lab; two terms of physics, PHYS 1700 or above

Number of courses *B.A.*—5 courses and 1 lab, totaling at least 5½ course credits beyond the prereqs; *B.S.*—8 courses and 2 labs, totaling at least 9 course credits beyond the prereqs; *B.S., intensive*—8 courses and 2 labs, totaling at least 11 course credits beyond prereqs

Specific courses required (see the Concentrations section) *Neurobiology* MCDB 3200; *Biotechnology* MCDB 3700**;** *Quantitative Biology* MCDB 3310

Distribution of courses *B.A.*—2 core courses from MCDB 2000, 2020, 2050, 2100, 2900, 3000 (or MB&B 3000); 2 electives numbered MCDB 2500 or above (or 2 addtl core courses); 1 elective numbered MCDB 3500 or above; 1 biology lab, as specified

B.S. and B.S. intensive—3 core courses from MCDB 2000, 2020, 2050, 2100, 2900, 3000 (or MB&B 3000); 2 electives numbered MCDB 2500 or above (or 2 addtl core courses); 1 elective numbered MCDB 3500 or above; 2 MCDB labs from MCDB 2010L, 2030L, 2210L, 2310L, 2510L, 2910L, 3030L, 3210L, MCDB 3410L, 3420L, 3430L, 3440L and 3450L

Biotechnology, Neurobiology, and Quantitative Biology concentrations—same prerequisites as B.A. and B.S. degree programs, with a specific req (MCDB 3200, 3310, or 3700) and 1 addtl concentration-related elective in place of 2 general electives

Senior requirement *B.A.*—MCDB 4750 taken in senior year, or senior essay; *B.S.*—2 consecutive terms of independent research in senior year, MCDB 4850, 4860; *B.S., intensive major*—MCDB 4950, 4960 in senior year (each course is worth 2 credits)

CONCENTRATIONS

In addition to the requirements for the B.A. or B.S. degree programs, students who wish to pursue one or more concentrations within the MCDB major must complete the designated required course and one concentration#related elective from the approved list below. A single course may not be applied to more than one concentration. Courses taken for a concentration will fulfill the general elective or special elective requirement, as applicable.

For a summary of the MCDB major requirements, see the Overview page

NEUROBIOLOGY CONCENTRATION

The Neurobiology concentration focuses on understanding how the nervous system develops, functions, and gives rise to behavior. Students explore the molecular and cellular mechanisms that underlie neuronal signaling, neural circuit formation, and brain plasticity, while also examining how these processes contribute to cognition,

sensory perception, and neurological disease. The concentration integrates coursework in neuroscience with opportunities for hands-on laboratory research. Through this interdisciplinary approach, students gain a mechanistic understanding of the brain from molecules to circuits to behavior, preparing them for careers and advanced study in neuroscience, medicine, and related biomedical fields.

Concentration Course Requirement:

In addition to the core courses required for the standard MCDB major, students pursuing the Neurobiology track are required to complete MCDB 3200 (Neurobiology) and one concentration-related elective course selected from: BENG 4410, CPSC 4391, 4750, MCDB 2500, MCDB 3100, 3150, 3290, 3620, 4150, 4250, 4300, or 4400.

Students interested in the Neurobiology concentration should consult an adviser:

John Carlson, YSB 206

Damon Clark, YSB C148

Thierry Emonet, YSB C169
Haig Keshishian, YSB 228
Michael O'Donnell, YSB 110
Weimin Zhong, YSB 225

BIOTECHNOLOGY CONCENTRATION

The Biotechnology concentration turns your discovery and mechanistic knowledge from core courses into real-world impact. This track blends biology, chemistry, genetics, and engineering to teach you how living systems can be harnessed to solve humanity's grand challenges, which span developing life-saving therapies and vaccines and creating sustainable biofuels and cutting-edge agricultural innovations. Students will emerge with knowledge and appreciation for the biotechnology revolution fueling the emerging bioeconomy.

Concentration Course Requirement:

In addition to the core courses required for the standard MCDB major, students pursuing the Biotechnology track are required to complete MCDB 3700 (Biotechnology) and one concentration-related elective course selected from: BENG 3600, 4350, 4475, 4611, 4690, CENG 2100, 4110, CHEM 3190, 4210, 4240, 4920, 5200, MB&B 3520 or MB&B 4490.

Students interested in the Biotechnology concentration should consult an adviser:

Ronald Breaker, YSB 311

Gregory Craven, YSB 431/MIC 243

Craig Crews, YSB 250

Farren Isaacs, YSB 234/ISTC 333

Yannick Jacob, YSB 416

Anna Pyle, YSB 306
Joseph Wolenski, YSB C112

QUANTITATIVE BIOLOGY CONCENTRATION

The biological sciences are undergoing a rapid transformation, integrating knowledge from the physical sciences, mathematics, and engineering into the quantitative analysis of complex living systems. Mathematical models are replacing cartoon models, automation and miniaturization are transforming experimental design, and advanced concepts from mathematics, physics, and computer science are used to analyze data. Students in this concentration will gain interdisciplinary quantitative skills to model, analyze, and experimentally investigate biological processes.

Concentration Course Requirement:

In addition to the core courses required for the standard MCDB major, students pursuing the Quantitative Biology track are required to complete MCDB 3310 (Modeling Biological Systems I) and one concentration-related elective course from: BENG 4630, 4767, CPSC 4750, MATH 2460, 2510, MB&B 3520, 4350, 5230, MCDB 3200 or 3620.

Students interested in the Quantitative Biology concentration should consult an adviser:

Damon Clark, YSB C148
Thierry Emonet, YSB C169
Douglas Kankel, YSB 111
Harry McNamara, YSB 235/WTI 1042
Jing Yan, YSB C144
For a summary of the MCDB major requirements, see the Overview page.

FACULTY OF THE DEPARTMENT OF MOLECULAR, CELLULAR, AND DEVELOPMENTAL BIOLOGY

Professors Ronald Breaker, John Carlson, Damon Clark, †Lynn Cooley, Craig Crews, Stephen Dellaporta, Thierry Emonet, †Mark Hochstrasser, Scott Holley, Valerie Horsley, Vivian Irish, Farren Isaacs, †Akiko Iwasaki, Douglas Kankel, †Paula Kavathas, Haig Keshishian, †Megan King, †Kathryn Miller-Jensen, Mark Mooseker, †Jon Morrow, Anna Pyle, †Hugh Taylor

Associate Professors Shirin Bahmanyar, David Breslow, Nadya Dimitrova, Joshua Gendron, Stavroula Hatzios, Yannick Jacob, Josien van Wolfswinkel, Weimin Zhong

Assistant Professors Alex Canto-Pastor, †Hattie Chung, Gregory Craven, Harry McNamara, Kirstin Meyer, Binyam Mogessie, Jacob Musser, Sigrid Nachtergaele, Michael O'Donnell, Jing Yan

Professor Adjunct Robert Bazell

Lecturers †Alexia Belperron, Edgar Benavides, †Surjit Chandhoke, †Seth Guller, Amaleah Hartman, Ronit Kaufman, Thomas Loreng, †Jennifer Marlon, Maria Moreno, Freya Wencker, Joseph Wolenski

†A secondary appointment with primary affiliation in another department or school.