MOLECULAR, CELLULAR, AND DEVELOPMENTAL BIOLOGY

Director of undergraduate studies: Valerie Horsley (valerie.horsely@yale.edu), 121 YSB, 432-3839; MCDB undergraduate registrar, (mcdb.ureg@yale.edu) 231 YSB, 260 Whitney Ave., 432-3839; mcdb.yale.edu/

The science of biology is extremely broad, ranging across the domains of molecules, cells, tissues and organs, organisms, and ecosystems. Moreover, biology explores questions of evolutionary history and the processes of evolutionary change, as well as the mechanisms by which cells, organisms, and ecosystems function. Students majoring in Molecular, Cellular, and Developmental Biology receive a thorough yet varied liberal education and preparation for professional careers in a diverse array of fields. Practical applications of biology include the development of biologicals and pharmaceuticals, the practice of medicine, and the pursuit of the scientific bases for understanding the development and function of biological systems.

Molecular, Cellular, and Developmental Biology (MCDB) offers programs for students wishing to concentrate on molecular and cellular biology and genetics, with applications to problems in cell and developmental biology, neurobiology, and various aspects of quantitative biology. Interdisciplinary opportunities are available within the major in the Biotechnology, Neurobiology, and Quantitative Biology tracks.

The MCDB major offers many opportunities for independent laboratory research. With approval, research can be conducted under the supervision of faculty members in any Yale department.

PREREQUISITES

The foundational biology courses required of all MCDB majors are BIOL 101, 102, 103, and 104. All majors must also complete a course in mathematics numbered MATH 115 or higher or a statistics course taken at Yale and approved by the director of undergraduate studies (DUS).

For the B.A. degree, additional prerequisites are a two-term lecture sequence in chemistry, and a term course in physics numbered PHYS 170 or higher.

For the B.S. degree, additional prerequisites are a two-term lecture sequence in chemistry, with associated laboratories; a term course in organic chemistry with its associated laboratory; and two term courses in physics numbered PHYS 170 or higher.

PLACEMENT PROCEDURES

Placement in MCDB courses is determined by examinations administered at Yale. A student may place out of one or more courses in the BIOL 101–104 sequence. One or more of these foundational biology courses (or equivalent performance on the corresponding biological sciences placement examination) may be explicitly required as prerequisites for upper-level MCDB courses.

Placement in chemistry courses is arranged by the Department of Chemistry. 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.

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 115 or higher are encouraged to take additional mathematics courses, such as MATH 120, 222, or 225, or ENAS 151 or 194. 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

B.A. degree program The B.A. degree requires a minimum of five and one-half course credits beyond the prerequisites, including five lecture or seminar courses and one laboratory, as follows:

1. Two core courses selected from MCDB 200, 202, 205, 210, 290, 300 (or MB&B 300)
2. Two general electives selected from MCDB courses numbered 250 or above, or two additional core courses from the list above. Two laboratory courses, either MCDB 342L and 343L or MCDB 344L and 345L, 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 350 or higher
4. One laboratory from the biological sciences. Laboratories may be selected from MCDB, Molecular Biology and Biophysics, 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, including eight lecture or seminar courses and two laboratories, as follows:

1. Two core courses selected from MCDB 200, 202, 205, 210, 290, 300 (or MB&B 300)
2. Two general electives selected from MCDB courses numbered 250 or above, or two additional core courses from the list above. Two laboratory courses, either MCDB 342L and 343L or MCDB 344L and 345L, 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 350 or higher
4. One laboratory from the biological sciences. Laboratories may be selected from MCDB, Molecular Biology and Biophysics, 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)
1. Three core courses selected from MCDB 200, 202, 205, 210, 290, 300 (or MB&B 300)
2. Two general electives selected from MCDB courses numbered 250 or above. Additional core courses from the list above, a second term of organic chemistry, and courses in statistics may be used as general electives. Two laboratory courses, either MCDB 342L and 344L or MCDB 344L and 346L, 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 350 or higher
4. Two laboratories from MCDB
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).

**Independent research courses before senior year** The only independent research course available to students prior to the senior year is MCDB 474. 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. No independent research course satisfies a lab requirement for the MCDB major.

**Independent research courses during senior year** The research courses MCDB 475, 485, 486, and 495, 496 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 counted toward the MCDB major, including prerequisites.

**Roadmap** See visual roadmap of the requirements.

**SENIOR REQUIREMENT**

**For the Class of 2022**, if it is problematic to fulfill the senior research requirement in person due to outside circumstances, students seeking the MCDB B.S. degree (only) should consult the MCDB website and may appeal to the DUS for MCDB course substitutions. No accommodations will be allowed for the B.S. Intensive degree and B.S./M.S. degree.

In addition to the course requirements described above, all students must satisfy a senior requirement undertaken during the senior year. A booklet listing the senior requirements of each track and degree is available in the office of the DUS (111 YSC). All students must fill out a checklist of requirements and go over it with the MCDB undergraduate registrar (mcdb.ureg@yale.edu) 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 475). 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 adviser’s written approval 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 should obtain an approval form from the office of the DUS.

**B.S. degree program** For the B.S. degree, the senior requirement is usually fulfilled by completing a yearlong research course, MCDB 485, 486. The senior requirement must be completed during the senior year. Yale College does not grant academic credit for summer research unless the student is enrolled in an independent research course in Yale Summer Session. 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 495, 496 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.

**REQUIREMENTS OF THE NEUROBIOLOGY, BIOTECHNOLOGY, AND QUANTITATIVE BIOLOGY TRACKS**

**Neurobiology track** In addition to the core courses for the B.A. degree or the B.S. degree programs, the Neurobiology track requires MCDB 320. One elective is selected from MCDB courses numbered 350 or above and one is selected from BENG 410, CPSC 475, MCDB 250, 310, 415, 425, 430, 440, MCDB 461, PSYC 376, or S&DS 101. Other courses may be substituted with the approval of the student's track adviser. (Students should note that PSYC 110 is a prerequisite for many psychology courses but does not substitute as an elective in the Neurobiology track.) The laboratory requirement and the senior requirement are the same as those for the B.A. degree or the B.S. degree programs. Students interested in the Neurobiology track should consult an adviser for the track.

**Neurobiology track advisers**
P. Forscher, 120 YSB (432-6344)
H. Keshishian, 228 YSB (432-3478)
R. Wyman, 139 YSB (432-3475)
W. Zhong, 225 YSB (432-9233)

**Biotechnology track** In addition to the core courses for the B.A. degree or the B.S. degree programs, the Biotechnology track requires MCDB 370. One elective is selected from MCDB courses numbered 350 or above and one is selected from MB&B 420, 421, 443, BENG 351, 352, 410, 435, 457, 463, 464, CENG 210, 411, 412L, CPSC 437, 445, 470, or 475. The laboratory requirement and the senior requirement are the same as those for the B.A. degree or the B.S. degree programs. Students interested in the Biotechnology track should consult an adviser for the track.

*Biotechnology track advisers*
R. Breaker, 311 YSB (432-9389)
C. Crews, 250 YSB (432-9364)
F. Isaacs, 141 YSB (432-3783)
K. Nelson, 137 YSB (432-5013)
J. Wolenski, C112 YSB (432-6912)

**Quantitative Biology track** In addition to the core courses for the B.A. degree or the B.S. degree programs, the Quantitative Biology track requires MCDB 330. One elective is selected from MCDB courses numbered 350 or above and one is selected from MCDB 320, 361, 461, BENG 463, 467, CPSC 440, 475, MB&B 302, 435, 452, 523, PHYS 402, MATH 246, 251, or CPSC 475. The laboratory requirement and the senior requirement are the same as those for the B.A. degree or the B.S. degree programs. Students interested in the Quantitative Biology track should consult an adviser for the track.

*Quantitative Biology track advisers*
M. Acar, West Campus B-31 (737-3255)
D. Clark, C148 YSB (432-0750)
T. Emonet, C169 YSB (432-3516)
D. Kankel, 111 YSB (432-3532)

**ADDITIONAL INFORMATION AND ADVISING**

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.

**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 upper-level elective with permission of the DUS.

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.

**Advising** First-year students considering a major in Molecular, Cellular, and Developmental Biology are invited to consult with the DUS and/or a faculty member in MCDB who is a fellow of their residential college. For assistance in identifying a suitable adviser, students should contact the departmental undergraduate registrar. (mcdb.ureg@yale.edu) Students in the Biotechnology, Neurobiology, or Quantitative Biology tracks should consult an adviser for their track (listed above). The course schedules of all MCDB majors (including sophomores intending to major in MCDB) must be signed by a faculty member in the department with a primary appointment in MCDB. The signature of the DUS is required only for students who are fulfilling the requirements of two majors or who have been admitted to the simultaneous B.S./M.S. degree program. Students whose regular adviser is on leave can consult the office of the DUS to arrange for an alternate.

College faculty advisers available to first-year students are listed below.

| BF | D. Kankel |
| BK | V. Irish, J. Wolenski |
| BR | I. Dawson, T. Emonet, S. Hatzios, J. van Wolswinkel, D. Breslow |
| DC | S. Dellaporta, P. Forscher, W. Zhong |
| ES | |
| GH | M. Mooseker, R. Wyman |
| JE | R. Breaker, F. Isaacs |
| MC | H. Keshishian, T. Pollard |
| MY | S. Bahmanyar, D. Clark, C. Crews, J. Gendron |
| PC | J. Carlson, V. Horsley, N. Dimitrova |
| SM | J. Rosenbaum |
| SY | |
| TC | Y. Jacob, M. Moreno |
| TD | S. Holley |

**Simultaneous B.S./M.S. degree program** Exceptionally able and well-prepared students may accelerate their professional education by completing a course of study leading to the simultaneous award of the B.S. and M.S. degrees after eight terms of enrollment. Students may not enroll in Yale College for more than eight terms in order to qualify for the simultaneous award of both degrees. It is possible to earn both degrees in fewer than eight terms, but not by the use of acceleration credits. The requirements are as follows:
1. Candidates must satisfy the Yale College requirements for the B.S. degree. Students in the program must complete the core courses for the major and choose their 4 electives from graduate-level courses. One of the electives must be a graduate seminar selected with the approval of the DUS. Grades below B– in graduate courses are not accepted.

2. In addition to the courses specified above, students must complete three terms of graduate research courses for six course credits: (1) MCDB 585, a two-credit course taken in the second term of the junior year. At the start of the course, each student forms a committee comprised of the faculty adviser and two faculty members that meets to discuss the research project. Two of the members of this committee must be members of the MCDB faculty. At the end of the course, the student completes a detailed prospectus describing the thesis project and the work completed to date. The committee evaluates an oral and written presentation of the prospectus and determines whether the student may continue in the combined program; (2) MCDB 595, 596, a four-credit, yearlong course that is similar to MCDB 495, 496 and is taken during the senior year. During the course, the student gives an oral presentation describing the work. At the end of the course, the student is expected to present his or her work to the department in the form of a poster presentation. In addition, the student is expected to give an oral thesis defense, followed by a comprehensive examination of the thesis conducted by the thesis committee. Upon successful completion of this examination, as well as all other requirements, the student is awarded the combined B.S./M.S. degree.

Students must also satisfy the requirements of Yale College for the simultaneous award of the bachelor’s and master’s degrees, including the following:

1. To be considered for admission to the program, by the end of their fifth term of enrollment students must have achieved at least two-thirds A or A– grades in all of their courses as well as in all of the courses directly relating to the major, including prerequisites.
2. Students must apply in writing to the DUS and obtain departmental approval no later than the last day of classes in their fifth term of enrollment in Yale College.
3. Students must have the approval of both the DUS and the director of graduate studies to receive graduate credit for the graduate courses they select.
4. Graduate work must not be entirely concentrated in the final two terms, and students in the program must take at least six term courses outside the department during their last four terms at Yale and at least two undergraduate courses during their last two terms.
5. Students must earn grades of A in at least two of their graduate-level term courses (or in one yearlong course) and have at least a B average in the remaining ones.

For more information, see Academic Regulations, section K, Special Arrangements, “Simultaneous Award of the Bachelor’s and Master’s Degrees.”

STUDY ABROAD
Some programs for study abroad are available to MCDB majors; approved programs can fulfill some of the requirements for the major. Interested students should consult the DUS and the Center for International and Professional Experience.

REQUIREMENTS OF THE MAJOR
Prerequisites B.A. – BIOL 101, 102, 103, 104; a two-term lecture sequence in chem; one term of PHYS 170 or above; MATH 115 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 170 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 major – 8 courses and 2 labs, totaling at least 11 course credits beyond prereqs
Specific courses required Biotechnology track – MCDB 370; Neurobiology track – MCDB 320; Quantitative Biology track – MCDB 330
Distribution of courses B.A. – 2 core courses from MCDB 200, 202, 205, 210, 290, 300 (or MB&B 300); 2 electives numbered MCDB 250 or above (or 2 addtl core courses); 1 elective numbered MCDB 350 or above; 1 biology lab; B.S. – 3 core courses from MCDB 200, 202, 205, 210, 290, 300 (or MB&B 300); 2 electives numbered MCDB 250 or above (or 2 addtl core courses); 1 elective numbered MCDB 350 or above; 2 MCDB labs; Biotechnology, Neurobiology, and Quantitative Biology tracks – same as B.A. and B.S. degree programs, with a specific req (track dependent) in place of one general elective
Senior requirement B.A. – MCDB 475 taken in senior year, or senior essay; B.S. – 2 consecutive terms of independent research in senior year, MCDB 485, 486; B.S., intensive major – MCDB 495, 496 in senior year

The major in Molecular, Cellular, and Developmental Biology (MCDB) offers programs for students interested in molecular biology; neurobiology; cell biology, genetics, and their applications to problems in cell and developmental biology; and various aspects of computational biology. Tracks concentrating in biotechnology, neurobiology, and quantitative biology offer interdisciplinary opportunities.

Students have the opportunity to carry out independent research, which may consist of laboratory or field work. Those who are particularly interested in research can elect either a standard B.S. degree or a B.S. degree with an intensive major, in which research occupies up to half of the senior year. Programs to study abroad that fulfill some MCDB requirements are available. The MCDB major provides excellent preparation for medical school and the health professions as well as for a wide range of professional careers in the biological sciences, biotechnology, law, conservation, and science writing.
Prospective majors and other students who would like a thorough basis in biology should take the foundational sequence BIOL 101–104, which provides a solid grounding in modern biological science. These courses are prerequisite to all majors in the biological sciences; students who take them along with chemistry courses during the first year will have more flexible programs in later years. The sequence consists of the following half-term, half-credit courses:

- BIOL 101, Biochemistry and Biophysics
- BIOL 102, Principles of Cell Biology
- BIOL 103, Genetics and Development
- BIOL 104, Principles of Ecology and Evolutionary Biology

The department also offers courses with no college-level prerequisites that are intended for non-science majors:

- MCDB 040, The Science and Politics of Cancer
- MCDB 050, Immunity and Microbes
- MCDB 065, The Science and Politics of HIV/AIDS
- MCDB 070, Human Biology
- MCDB 103, Cancer
- MCDB 105, Biology, the World, and Us
- MCDB 106, Biology of Malaria, Lyme, and Other Vector-Borne Diseases
- MCDB 109, Immunity and Contagion
- MCDB 175L, Exploring the Microbial World

Students in the first year should consult with their faculty adviser or a faculty member in the Molecular, Cellular, and Developmental Biology department for advice on which courses to take. For additional information, visit the department website, or contact Valerie Horsley (valerie.horsley@yale.edu) or the MCDB undergraduate registrar (mcdb.ureg@yale.edu).

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

**Professors** Ronald Breaker, John Carlson, †Lynn Cooley, Craig Crews, Stephen Dellaporta, Thierry Emonet, Paul Forscher, †Mark Hochstrasser, Scott Holley, Valerie Horsley, Vivian Irish, †Akiko Iwasaki, Douglas Kankel, †Paula Kavathas, Haig Keshishian, Mark Mooseker, Thomas Pollard, Anna Pyle, Joel Rosenbaum, †Hugh Taylor, Robert Wyman

**Associate Professors** Damon Clark, Joshua Gendron, Farren Isaacs, †Megan King, †Kathryn Miller-Jensen, Weimin Zhong

**Assistant Professors** Shirin Bahmanyar, David Breslow, Nadya Dimitrova, Stavroula Hatzios, Yannick Jacob, Sigrid Nachtergaele, Michael O’Donnell, Josien van Wolswinkel, Jing Yan

**Professor Adjunct** Robert Bazell

**Lecturers** †Meghan Bathgate, †Alexia Belperron, Francine Carland, †Surjit Chandhoke, Iain Dawson, †Seth Guller, Amaleah Hartman, Ronit Kaufman, Rebecca LaCroix, Thomas Loreng, †Elizabeth Luoma, Maria Moreno, Kenneth Nelson, †Aruna Pauwashe, Joseph Wolenski

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

View Courses