ECONOMY AND EVOLUTIONARY BIOLOGY

Director of undergraduate studies: Thomas Near, 370A ESC, 432-3002, karen.broderick@yale.edu, www.eeb.yale.edu

FACULTY OF THE DEPARTMENT OF ECOLOGY AND EVOLUTIONARY BIOLOGY

Professors Leo Buss, † Peter Crane, Michael Donoghue, † Vivian Irish, † Kenneth Kidd, Nancy Moran, Howard Ochman, Jeffrey Powell, Richard Prum, † Eric Sargis, † Oswald Schmitz, † David Skelly, Stephen Stearns, Paul Turner (Chair), J. Rimas Vaišnys, Günter Wagner

Associate Professors Suzanne Alonzo, Walter Jetz, Thomas Near, David Post

Assistant Professors Jeffrey Townsend, David Vasseur

Senior Lecturer Marta Martinez Wells

Lecturers Gisella Caccone, Mary Beth Decker

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

The Department of Ecology and Evolutionary Biology (EEB) offers broad education in the biological sciences. The subject matter includes molecules, cells, organs, organisms, and ecosystems and the evolutionary processes that shape them. The department offers a B.A. and a B.S. degree. The B.A. program is intended for students who are interested in ecology, evolution, and organismal diversity as part of a liberal education but do not intend to pursue graduate work in the discipline. The B.S. program is designed for students planning to attend medical or veterinary school or to pursue graduate study in ecology and evolutionary biology, other biological disciplines, or the environmental sciences. The two programs share the same prerequisite and core requirements but differ in elective and senior requirements.

Students majoring in EEB select one of two tracks. The requirements for Track 1 emphasize courses appropriate for careers in ecology, evolutionary biology, and environmental science; Track 2 is most appropriate for premedical and preveterinary students because it allows them to use as electives many courses required by medical schools. The EEB major offers opportunities for independent research in both laboratory and field.

Courses for nonmajors Several EEB courses have no college-level prerequisites and are suitable for nonmajors. These include all 100-level offerings as well as 200-level courses that deal with particular organism groups such as fish, mammals, birds, or insects.

Prerequisites The prerequisites for the major are intended to provide core scientific literacy; they include courses in biology, chemistry, physics, and mathematics. The introductory biology sequence BIOL 101, 102, 103, and 104 is required. Also required are CHEM 112, 113, or 114, 115, or 118, taken with their associated laboratories, and one term of organic chemistry with laboratory. CHEM 124, 125, with 222L, 223L, satisfies both chemistry requirements. Two terms of physics are required, PHYS 170, 171 or higher, and one term of mathematics, MATH 115 or higher or STAT 101–106. A different statistics course approved by the director of undergraduate studies may be substituted for the mathematics prerequisite.

Acceleration credit awarded in chemistry, mathematics, and physics, or completion of advanced courses in those departments, is accepted in place of the corresponding prerequisites for the EEB major. Students who have mathematics preparation equivalent to MATH 115 or higher are encouraged to take a statistics course (most often STAT 101–106) and/or additional mathematics courses such as MATH 120, 121, 222, or 225. Because chemistry courses are prerequisite to several EEB courses, students are strongly urged to take general and organic chemistry in the freshman and sophomore years. Students who place out of general chemistry should take organic chemistry during their freshman year. Finishing the prerequisites early allows for a more flexible program in later years.

Placement Students can place out of the introductory biology sequence (BIOL 101, 102, 103, 104) only by means of the biology placement examination administered jointly by the biological science departments, EEB, MB&B, and MCDB. See the EEB departmental Web site (http://www.eeb.yale.edu) for information about the placement examination.

Potential EEB majors are expected to take the mathematics placement test. Those who place above the level of MATH 112 may proceed to prerequisite courses for the EEB major; those who place into MATH 112 must take calculus before other prerequisites. The Chemistry department arranges placement in chemistry courses.

Requirements of the major Beyond the prerequisites, the B.A. requires three lecture courses and one laboratory, for three and one-half course credits, and the senior requirement. In Track 1, the required courses are E&EB 220, General Ecology; E&EB 225, Evolutionary Biology; and a lecture course on organismal diversity chosen from E&EB 246–272, along with its associated laboratory. Required courses in Track 2 include E&EB 290 and 291L, Comparative Anatomy and laboratory; E&EB 295, Comparative Physiology, (scheduled for fall 2014) or BENG 350, Physiological Systems; and MCDB 300, Biochemistry.

The B.S. requirements are the same as those for the B.A., with the addition of at least two electives, for two course credits, in either Track 1 or Track 2. At least one of the electives must be a lecture or a seminar. Most EEB, MCDB, or MB&B courses numbered 200 or above qualify as electives, as do most research courses and laboratories in a biological sciences department or in the Medical School. Courses from other departments may qualify with permission of the director of undergraduate studies.
Substitutions permitted  Two upper-level courses in Geology and Geophysics (excluding G&G <315>), Mathematics, Computer Science, or Engineering and Applied Science can be substituted for the required term of organic chemistry and laboratory. The second term of organic chemistry and laboratory and up to two terms of physics laboratories are allowed as electives. Courses from other departments may also be suitable as electives. All substitutions require the permission of the director of undergraduate studies. College seminars may not be counted toward the requirements of the major.

Senior requirement  Students in the B.A. degree program fulfill the senior requirement either by completing one term of independent study in E&EB 470 during the senior year or by writing a senior essay. 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. Students intending to write a senior essay must obtain an approval form from the office of the director of undergraduate studies and have it signed by the essay adviser before the end of the course selection period. Essays must be submitted to the director of undergraduate studies by the last day of classes.

Students in the B.S. degree program fulfill the senior requirement by completing one term of original research in E&EB 475 or 495 in the senior year. Additional research courses may be taken as electives and may be taken before the senior year, but any research course intended to satisfy the senior requirement must be taken during the senior year.

Credit/D/Fail  No course taken Credit/D/Fail may be counted toward the EEB major, including prerequisites.

Limit on research courses  While independent research courses may be taken multiple times for credit, there are restrictions on the number of such courses that can be included in a student’s curriculum. See "Course Credits and Course Loads" in the Academic Regulations.

Graduate courses of interest to undergraduates  Graduate courses in the biological and biomedical sciences that may be of interest to undergraduates are listed in the online bulletin of the Graduate School, and many are posted on the Biological and Biomedical Sciences Web site (http://bbs.yale.edu). Additional information is available from the director of undergraduate studies and the director of graduate studies. Undergraduates with an appropriate background may enroll with the permission of the director of graduate studies and the instructor.

Advising  Freshmen considering a major in Ecology and Evolutionary Biology are invited to consult with the director of undergraduate studies. After the freshman year, students should choose an adviser from the department faculty who has interests comparable to their own and/or is a fellow of their residential college. For additional information, visit the EEB departmental Web site (http://www.eeb.yale.edu). The course schedules of all EEB majors (including sophomores intending to major in EEB) must be signed by a faculty member in EEB; the signature of the director of undergraduate studies is not required. Students whose regular adviser is on leave can consult the director of undergraduate studies to arrange for an alternate.

Study abroad  Participation in study abroad field programs is encouraged. Credit for such programs may apply toward the major; interested students should consult the director of undergraduate studies prior to going abroad.

Combined 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. In addition to the three lecture courses and one laboratory specified for the standard major, four courses are required, all of which must be graduate-level courses. One of these must be a graduate seminar selected with the approval of the director of undergraduate studies. Grades below B in graduate courses are not accepted.

2. In addition to the courses specified above, students must complete two graduate research courses for six course credits: (a) EEB 585, a two-credit course typically taken in the second term of the junior year. At the start of the course, each student forms a committee comprised of the adviser and two faculty members that meets to discuss the research project. Two of the members of this committee must be members of the EEB 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; (b) EEB 595, a four-credit, yearlong course that is similar to EEB 495, 496 and is taken during the senior year. In the first term of the course, the student gives an oral presentation describing the work. At the end of the course, the student submits a master’s thesis and gives an oral 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. Summer research between the junior and senior years is often required to obtain sufficient results for a credible master’s thesis.

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 course credits as well as in all of the course credits directly relating to the major, including prerequisites.
2. Students must apply in writing to the director of undergraduate studies and obtain departmental approval no later than the last day of classes in their fifth term of enrollment in Yale College. Students must have the approval of both the director of undergraduate studies and the director of graduate studies to receive graduate credit for the graduate courses they select.

3. 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.

4. Students must earn grades of A in at least two of their graduate-level term courses or in one year course.

For more information, see "Simultaneous Award of the Bachelor’s and Master’s Degrees" in section K of the Academic Regulations.

REQUIREMENTS OF THE MAJOR

Prerequisites  BIOL 101, 102, 103, 104; CHEM 112, 113, or 114, 115, or 118 with labs; 1 term of organic chem with lab (CHEM 124, 125 with 222L, 223L satisfies both chem requirements); PHYS 170, 171 or higher; MATH 115 or higher or STAT 101–106

Number of courses  B.A. – 3½ course credits (not incl senior req); B.S. – 5½ course credits (not incl senior req)

Specific courses required  Track 1 – E&EB 220, 225; 1 from E&EB 246–272, with lab; Track 2 – E&EB 290, 291L; E&EB 295 or BENG 350; MCDB 300

Distribution of courses  B.S. – 2 electives

Substitutions permitted  Senior requirement  B.A. – E&EB 470 taken in the senior year or senior essay; B.S. – E&EB 475 or 495 taken in senior year

Introductory Courses

E&EB 115a / F&ES 315a, Conservation Biology  Jeffrey Powell and Linda Puth
An introduction to ecological and evolutionary principles underpinning efforts to conserve Earth’s biodiversity. Efforts to halt the rapid increase in disappearance of both plants and animals. Discussion of sociological and economic issues.  sc

*E&EB 125b / G&G 125b, History of Life  Derek Briggs and Pincelli Hull
Examination of fossil and geologic evidence pertaining to the origin, evolution, and history of life on Earth. Emphasis on major events in the history of life, on what the fossil record reveals about the evolutionary process, on the diversity of ancient and living organisms, and on the evolutionary impact of Earth’s changing environment.  sc

E&EB 210a / STAT 101a, Introduction to Statistics: Life Sciences  Jonathan Reuning-Scherer and Walter Jetz
Statistical and probabilistic analysis of biological problems, presented with a unified foundation in basic statistical theory. Problems are drawn from genetics, ecology, epidemiology, and bioinformatics.  QR

E&EB 246a, Plant Diversity and Evolution  Michael Donoghue
Introduction to the major plant groups and their evolutionary relationships, with an emphasis on the diversification and global importance of flowering plants. To be taken concurrently with E&EB 247L. Prerequisite: a general understanding of biology and evolution.  sc

E&EB 247La, Laboratory for Plant Diversity and Evolution  Michael Donoghue
Hands-on experience with the plant groups examined in the accompanying lectures. Local field trips. To be taken concurrently with E&EB 246.  sc ½ Course cr

E&EB 250a, Biology of Terrestrial Arthropods  Marta Martínez Wells
Evolutionary history and diversity of terrestrial arthropods (body plan, phylogenetic relationships, fossil record); physiology and functional morphology (water relations, thermoregulation, energetics of flying and singing); reproduction (biology of reproduction, life cycles, metamorphosis, parental care); behavior (migration, communication, mating systems, evolution of sociality); ecology (parasitism, mutualism, predator-prey interactions, competition, plant-insect interactions).  sc

E&EB 251La, Laboratory for Biology of Terrestrial Arthropods  Marta Martínez Wells
Comparative anatomy, dissections, identification, and classification of terrestrial arthropods; specimen collection; field trips. Concurrently with or after E&EB 250.  sc ½ Course cr

*E&EB 272b, Ornithology  Richard Prum
An overview of avian biology and evolution, including the structure, function, behavior, and diversity of birds. The evolutionary origin of birds, avian phylogeny, anatomy, physiology, neurobiology, breeding systems, and biogeography. Enrollment limited to 50.  sc

*E&EB 273Lb, Laboratory for Ornithology  Richard Prum
Laboratory and field studies of avian morphology, diversity, phylogeny, classification, identification, and behavior. Enrollment limited to 12.  sc ½ Course cr

Intermediate and Advanced Courses

Prerequisites for all intermediate and advanced E&EB courses are BIOL 101, 102, 103, and 104, or permission of the instructor.
E&EB 220a / EVST 223a, General Ecology  David Vasseur and David Post
The theory and practice of ecology, including the ecology of individuals, population dynamics and regulation, community structure, ecosystem function, and ecological interactions at broad spatial and temporal scales. Topics such as climate change, fisheries management, and infectious diseases are placed in an ecological context. Prerequisite: MATH 112 or equivalent. SC

*E&EB 223Lb, Evolution, Functional Traits, and the Tree of Life  Marta Martínez Wells
Study of evolutionary novelties, their functional morphology, and their role in the diversity of life. Introduction to techniques used for studying the diversity of animal body plans. Evolutionary innovations that have allowed groups of organisms to increase their diversity. SC ½ Course cr

E&EB 225b / EVST 226b, Evolutionary Biology  Michael Donoghue and staff
An overview of evolutionary biology as the discipline uniting all of the life sciences. Reading and discussion of scientific papers to explore the dynamic aspects of evolutionary biology. Principles of population genetics, paleontology, and systematics; application of evolutionary thinking in disciplines such as developmental biology, ecology, microbiology, molecular biology, and human medicine. SC Psychology: AdvSci NeuroTrk

E&EB 226Lb, Laboratory for Evolutionary Biology  Gisella Caccone
The companion laboratory to E&EB 225. Patterns and processes of evolution, including collection and interpretation of molecular and morphological data in a phylogenetic context. Focus on methods of analysis of species-level and population-level variation in natural populations. Concurrently with or after E&EB 225 or with permission of instructor. SC ½ Course cr

*E&EB 230a / EVST 221a / FR&ES 221a, Field Ecology  Linda Puth
A field-based introduction to ecological research, using experimental and descriptive approaches, comparative analysis, and modeling for field and small-group projects. Weekly field trips explore local lake, salt marsh, rocky intertidal, traprock ridge, and upland forest ecosystems. Includes one Saturday field trip and a three-day trip during the October recess. Concurrently with or after E&EB 220 or with permission of instructor. SC

E&EB 240a, Animal Behavior  Suzanne Alonzo
An introduction to the study of animal behavior from an evolutionary and ecological perspective. History and methods of studying animal behavior. Topics include foraging, predation, communication, reproduction, cooperation, and the role of behavior in conservation. Enrollment limited to 15 per section. WR, SC

*E&EB 275b / EVST 400b, Biological Oceanography  Mary Beth Decker
Exploration of a range of coastal and pelagic ecosystems. Relationships between biological systems and the physical processes that control the movements of water and productivity of marine systems. Anthropogenic impacts on oceans, such as the effects of fishing and climate change. Includes three Friday field trips. Enrollment limited to 15. SC

*E&EB 280a / ANTH 310a, Mammalogy  Eric Sargis
The evolution and diversity of mammals, including primates. Origins, evolutionary history, systematics, morphology, biogeography, physiology, behavior, and ecology of major mammalian lineages. Accompanying laboratories focus on diagnostic morphological features of mammalian groups through examination of specimens from the Peabody Museum. SC

E&EB 290b, Comparative Anatomy  Günter Wagner
A survey of the structure, variation, and evolution of major vertebrate groups. Topics include the microanatomy of major organ systems, the embryology of the vertebrate body plan, and the structure and evolution of the major organ systems such as the locomotory system, sensory organs, digestive tract, reproductive tract, and nervous system. SC

*E&EB 291Lb, Comparative Anatomy Laboratory  Günter Wagner
Microscopic examination of histological and embryological preparations. Dissection of selected vertebrate species including shark, bony fish, frog, lizard, and rat. To be taken with E&EB 290. SC ½ Course cr

*E&EB 342b / ANTH 335b, Primate Diversity and Evolution  Eric Sargis
The diversity and evolutionary history of living and extinct primates. Focus on major controversies in primate systematics and evolution, including the origins and relationships of several groups. Consideration of both morphological and molecular studies. Morphological diversity and adaptations explored through museum specimens and fossil casts. Recommended preparation: ANTH 116. SC

E&EB 426a, Phylogenetics and Macroevolution  Thomas Near
Theory and methodology of phylogenetics and the application of phylogenetic trees to the comparative study of biological variation observed in living and fossil organisms. Topics include biogeography, speciation, adaptive radiation, estimation of divergence times and "molecular clock" methods, rates of lineage diversification, and phylogeny of genes, species, and higher taxa. Prerequisite: E&EB 225 or permission of instructor. SC

E&EB 427La, Phylogenetics Laboratory  Thomas Near
Introduction to methods of phylogeny reconstruction and evolutionary comparative analysis. Computer lab-based exercises and lessons in obtaining genetic data from Internet resources and building phylogenetic trees. Additional topics and methods include biogeographic analyses, estimating divergence times with molecular data, and independent contrast analysis. Prerequisite: E&EB 225 or permission of instructor. SC ½ Course cr
*E&EB 460b / HLTH 480b, Studies in Evolutionary Medicine I  Stephen Stearns and staff
Principles of evolutionary biology applied to issues in medical research and practice. Lactose and alcohol tolerance; the "hygiene hypothesis"; genetic variation in drug response and pathogen resistance; spontaneous abortions, immune genes, and mate choice; the evolution of aging; the ecology and evolution of disease; the emergence of new diseases. Students develop proposals for research to be conducted during the summer. Admission by competitive application; forms are available on the EEB Web site (http://www.eeb.yale.edu).

*E&EB 461a / HLTH 481a, Studies in Evolutionary Medicine II  Stephen Stearns and Paul Turner
Continuation of E&EB 460. Prerequisite: E&EB 460 or permission of instructor.

*E&EB 470a or b, Tutorial  Marta Martínez Wells
Individual or small-group study for qualified students who wish to investigate an area of ecology or evolutionary biology not presently covered by regular courses. A student must be sponsored by a faculty member who sets requirements and meets weekly with the student. One or more written examinations and/or a term paper are required. To register, the student must submit a written plan of study approved by the faculty instructor to the director of undergraduate studies. Students are encouraged to apply during the term preceding the tutorial. Proposals must be submitted no later than the end of the second week of the term in which the student enrolls in the tutorial. The final paper is due in the hands of the director of undergraduate studies by the first day of reading period in the term of enrollment. In special cases, with approval of the director of undergraduate studies, this course may be elected for more than one term, but only one term will count as an elective for the major. Normally, faculty sponsors must be members of the EEB department. Fulfills the senior requirement for the B.A. degree if taken in the senior year.

*E&EB 475a or b, Research  Marta Martínez Wells
One term of original research in an area relevant to ecology or evolutionary biology. This may involve, for example, laboratory work, fieldwork, or mathematical or computer modeling. Students may also work in areas related to environmental biology such as policy, economics, or ethics. The research project may not be a review of relevant literature but must be original. In all cases students must have a faculty sponsor who oversees the research and is responsible for the rigor of the project. Students are expected to spend ten hours per week on their research projects. Using the form available from the office of undergraduate studies or from the Classes server, students must submit a research proposal that has been approved by the faculty sponsor to the director of undergraduate studies, preferably during the term preceding the research. Proposals are due Friday, September 6, for the fall term and Tuesday, January 21, for the spring term. The final research paper is due in the hands of the director of undergraduate studies by Friday, December 6, for the fall term and Friday, April 25, for the spring term. Fulfills the senior requirement for the B.S. degree if taken in the senior year.

*E&EB 495a and E&EB 496b, Intensive Senior Research  Marta Martínez Wells
One term of intensive original research during the senior year under the sponsorship of a Yale faculty member. Similar to other research courses except that a more substantial portion of a student’s time and effort should be spent on the research project (a minimum average of twenty hours per week). A research proposal approved by the sponsoring faculty member must be submitted to the instructor; forms are available from the office of undergraduate studies or from the instructor. For the fall term, approval is encouraged during the spring term of the junior year and must be done by Friday, September 6; for the spring term, submission of the research proposal is encouraged during the fall term and must be done by Tuesday, January 21. Students who wish to take both E&EB 495 and 496 under the sponsorship of the same faculty member may submit a single proposal by the fall deadline; in this case, the grade assigned at the end of the spring term applies to all four credits. Students who take 495 and 496 under the sponsorship of different faculty members complete an interim oral report and submit a final paper in each term; a separate grade is assigned in each term. The due date for papers in E&EB 495 is Friday, December 6; the due date for E&EB 496 only or for 495 and 496 is Friday, April 25. One term fulfills the senior requirement for the B.S. degree. 2 Course cr per term.