

GRADUATE PROGRAM IN EVOLUTION, ECOLOGY, AND BEHAVIOR (EEB)

Department of Biology, Indiana University, Bloomington
Ph.D. and M.A. in Ecological and Evolutionary Biology
Ph.D. and M.A. in Zoology

Combined M.A. in EEB and Master of Science in Environmental Science

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GRADUATE PROGRAM IN EVOLUTION, ECOLOGY, AND BEHAVIOR GENERAL DESCRIPTION

The Master's (M.A.) and Doctoral (Ph.D.) degrees in the graduate program in Evolution, Ecology, and Behavior (EEB) may be obtained in a variety of concentration areas or in an individually tailored program.

In addition to the specific requirements of the EEB Program described below, students must meet the general requirements of the Department of Biology and those of the Graduate School, as described in the Bulletin of the University Graduate School. All new students and students approaching critical milestones (First Committee Meeting, Qualifying Examination, Finishing Thesis or Dissertation) should consult the Bulletin to be sure they are in compliance with relevant rules. It is the *student's responsibility* to make certain that her/his program meets her/his personal objectives and conforms to the regulations and requirements of the Graduate School, of the Department of Biology, and of the EEB Program.

Basic Requirements (all degrees). Students with diverse backgrounds who wish to engage in graduate study in EEB are encouraged to enter the program. Their Bachelor's Degree (or equivalent) need not have been in the biological sciences. Breadth in biological understanding, however, is important to graduate-level study. Students consequently are expected to have completed, prior to admission (with at least a B), one course in each of the following areas: genetics, cellular and/or molecular biology, organismal biology (e.g., physiology, development, systematics, or animal behavior), ecology or evolution, and calculus or statistics, and at least two courses in chemistry and two in physics or geology. A student who, in the opinion of her/his committee, has a deficiency in one or more of these areas will be required to remedy the deficiency, usually through equivalent course work taken during her/his first year in the Graduate Program. Courses taken to meet this requirement may be included as part of the student's Graduate Program only when graduate credit is normally offered for the course.

First Year Expectations.

Mentoring of First-Year Students

In an effort to ensure a smooth and successful transition to graduate school, the department has adopted a formal mentoring program for new students. During the first semester, the mentoring program requires that each new student meet once with his/her assigned faculty mentor at six to eight weeks into the semester and again at the end of the semester to discuss progress in courses and rotations and, where relevant, the Associate Instructor experience. In addition to these required meetings, the student is encouraged to meet with his/her mentor whenever it might be useful.

Research Area, Advisor, Committee Meeting

Both Ph.D. and M.A. students are required to make a preliminary choice of a thesis research area, select a faculty research sponsor, and form an Advisory Committee. ***Before the end of their second semester***, students are expected to have met with their Committee at least once to determine course work requirements, review the proposal for the preliminary (see page 7) or Master's research project (see page 11 & 14), and, for Ph.D. students, make plans for the Qualifying Examination (see pages 6–8). Students must have joined a lab before the end of May in order to remain in good standing in the program. Exceptions will be made in only the rarest of cases.

Research Grades. Passing grades in research courses for work done toward an M.A. thesis, M.A. alternative project, or Ph.D. dissertation will be graded R (= evaluation deferred) until the research project is complete. Grades for M.A. research will usually be assigned when the student completes the degree; those for Ph.D. research will usually be assigned at two points: first, after the Ph.D. qualifying examination; and second, when the student completes the Ph.D. degree.

+ **Annual Committee Meeting.** *EACH GRADUATE STUDENT IN THE DEPARTMENT OF BIOLOGY MUST HAVE A MEETING WITH HIS/HER FACULTY COMMITTEE AT LEAST ONCE EACH ACADEMIC YEAR.* Following that meeting, your faculty advisor must send a memo to the Graduate Office (Gretchen Clearwater) reporting the results of the meeting, with a copy to each committee member and to the student (students are advised to report the meeting to Gretchen so she can contact delinquent faculty advisors).

PH.D. IN ECOLOGICAL AND EVOLUTIONARY BIOLOGY *and* PH.D. IN ZOOLOGY

Advisor. The student must obtain the agreement of a faculty member in the Department of Biology to serve as the Ph.D. Advisor (see pages 15–17). Until the student chooses a Research Advisor, the EEB Program Director will serve in that role. The Advisor will help the student plan a coherent program of courses and research commensurate with the student's interests and the requirements of the program, and will oversee the formation of a Ph.D. Advisory Committee.

Advisory Committee. The Advisory Committee must consist of four or more members, at least two of which must be full members of the Graduate Faculty. The Committee must include at least two faculty from EEB and one from the minor area.

In practice the Advisory Committee is usually chosen by mutual agreement between the Advisor and the student, who then contact the potential Committee members and obtain their agreement to serve on the Committee. **Notify the Biology Graduate Office of the membership of this committee** as soon as it is formed, before the end of the student's second semester.

+ *The first meeting of the student's Advisory Committee must be convened before the end of the second semester of study in the Ph.D. Program.* This meeting is to discuss the student's goals and intended area of concentration, to review her/his past course work and plan additional course work, and to review the scope of the preliminary research project (page 7) the student will undertake for the qualifying examination. At this time the Committee will identify any deficiencies in course work that the student must make up. Deficiencies may include any basic requirements not already satisfied, as well as additional courses in biology, chemistry, or other academic areas, or the learning of ancillary skills such as statistics or computer science. The Committee will also decide the time for, and schedule of, the student's qualifying examination (page 6).

Course Requirements

Total Hours: A total of 90 graduate credit hours or the equivalent is required. Because the Ph.D. is a research degree, a substantial number of these credit hours will be in L800 Research.

Areas of Specialization: Students seeking a Ph.D. in Evolution, Ecology, and Behavior need to select an area of specialization from one of the following three.

Evolutionary Biology

- L567 Evolutionary Ecology
- Z620 Evolutionary Genetics
- Z540 Genetics of Structured Populations
- L533 Evolution of Genes and Genomes
- INFO 590 SNP Discovery and Population Genetics

Ecology/Population Biology

- L578 Population Biology
- L579 Community Ecology
- L575 Biodiversity and Ecosystem Functioning
- L577 Theoretical Ecology

Behavior/Physiology

- Z460 Ethology
- Z466 Endocrinology
- L581 Behavioral Ecology
- P548 Neuroethology
- L560 Physiological Ecology
- Z620 Sensory Ecology
- Z566 Laboratory in Endocrinology

Required Courses: Each student must take two courses listed under the area of specialization she/he selects. In addition, each student must take at least one course from one of the other two areas of specialization. Students are encouraged but not required to take a course from each area of specialization. Also required is a graduate level course in statistics (E538 or equivalent).

Beyond these basic requirements, students are expected to accumulate at least 26 graduate course hours of Biology (including the three course requirements in areas of specialization above, and, if the minor area is outside Biology, including the minor area [see below]). These hours may come from the lists of accessory courses and seminars (page 4), and other courses approved by the student's committee. The statistics requirement is over and above the 26 course hours described here.

Students are expected to participate in L570, Seminar in Ecology and Evolutionary Biology, or other biology seminars when these are offered. When available, students should plan to enroll in one of these courses at least once per year. First-year students enroll in L570 both semesters. In addition, students are expected to participate in a weekly or biweekly journal club or reading club during semesters when they are offered. In practice, one or more of these are often offered each semester in different areas (e.g., plant ecology, EEB Book Club, EEB Journal Club, etc.). Any club authorized by the program can fulfill this requirement.

Attendance at the EEB program's series of outside seminar speakers on Fridays is expected of all EEB graduate students.

Accessory Courses in Biology

Z466 Endocrinology

Z406 Vertebrate Zoology

P417 Neurobiology

N500 Neuroscience

B502 Research and Professional Ethics in Biology and Behavior Science

A501 Seminar integrative study of animal behavior

Z620 SPECIAL TOPICS IN ZOOLOGY

Z620 is offered frequently but on no set schedule. It provides faculty and students an opportunity to explore particular topics of interest in greater detail than is possible in a survey class. The following list is fluid but designed to give students an idea of the kinds of subjects that might be covered in the next couple of years and the faculty member who might be in charge.

The Origin of Species – Moyle

Speciation – Moyle

Science and Society – Reynolds

Genomic Approaches to Ecology, Evolution, and Behavior – Hahn

Developmental Plasticity and Evolution – Moczek

TBA - Watson

Seminars in Related Areas:

B560 Seminar in Systematics

B573 Special Topics in Plant Physiology

Minor for EEB Students: Each student will choose a minor outside of EEB in consultation with her/his Research Advisor and subject to approval by her/his Advisory Committee. Minors typically require 6 graduate credits of courses, seminars, or readings. The minor can be in a separate department, in an interdepartmental program, or in another graduate program in the Department of Biology. The designation of course work required for the minor is entirely the prerogative of the minor faculty member (acting under guidelines of the minor area's department or program and the Graduate School). A minor in the interdepartmental Program in Animal Behavior is particularly suitable for students whose major area of specialization is Behavior/Physiology (page 4). In all cases, a faculty member from the minor discipline must be a member of the student's Advisory Committee and will participate in the designation of required course work and in the qualifying examination.

Minor in EEB for Students in Other Programs: Students in other departments or in other programs in the Department of Biology who wish to minor in EEB are subject to the following guidelines. A faculty member whose primary affiliation is with EEB (see pages 15–17) must be a member of the student's Advisory Committee and will participate in designating required course work. Minors typically require 6 credits of graduate courses. The EEB minor, like the major, may concentrate in one of the three areas of specialization discussed on pages 3–4 by selecting two or more courses from the chosen area. A course may not simultaneously satisfy both major and minor requirements. In

special cases, the minor advisor may approve a single course from one of the three areas of specialization and the other course(s) from the other areas or from the list of Accessory Courses in Biology on page 5.

Grades: An overall average of B (3.0) or better is required. If a student's average falls below 3.0, the student will be placed on academic probation. Failure to raise the overall average to at least 3.0 during the next semester will result in dismissal from Graduate School. Courses for which a student receives a grade lower than B- cannot be used to fulfill any of the course requirements for the Ph.D. but do count in the overall grade average. Passing grades in research courses are assigned first after the completion of the qualifying examination and again upon completion of the degree.

Qualifying Examination: The purpose of the Ph.D. qualifying examination is to determine whether the student is prepared to undertake independent research. The ability to do creative, rigorous research is difficult to assess. The Committee will look for: a solid background in basic biology and the physical sciences; familiarity with and ability to manipulate important concepts in EEB, especially the ability to derive from them a significant question for research; the ability to structure experiments or observations in such a way as to answer questions unambiguously; the ability to analyze correctly and to interpret creatively the results of experiments or observations; the ability to derive the next step in the process of investigation; and the ability to communicate effectively with other scientists orally and in writing.

Structure of the Qualifying Examination

- Part I. Breadth of Knowledge:** A written examination with an oral defense.
 - This part allows the student to demonstrate mastery of the major ideas and research strategies appropriate to the concentration area, as well as mastery of effective written and oral communication.
 - Questions are formulated by the Committee members and given to the student *six weeks in advance of the written examination*.
 - This part must be passed prior to the 13th week of the student's fourth semester* in the EEB program. See details on page 7.

- Part II. Research Skills:** A preliminary research project report, a proposal for dissertation research, and an oral defense of both.
 - This part assesses the student's ability to engage in active research and to appropriately analyze and interpret the data that she/he derives. In addition, it is the point at which the committee must approve the dissertation proposal.
 - This part must be passed prior to the fifth week of the student's sixth semester* in the EEB program. See details on pages 7–8.

- Retake Option:** In the event of failure prior to the deadline, a student may retake each component of the examination only once. This retake must be completed before the deadline specified for that component. *Failure to complete either part satisfactorily within the allotted time will result in dismissal from graduate study.* Students who fail the examination must be reexamined by the same committee unless the student has changed advisors. In that event, a majority of the new committee must have been members of the original committee.

Schedule for Taking the Qualifying Examination

- Part I. Breadth of Knowledge:

Format: Students will research and prepare written answers on 4 questions chosen by their advisory committee during a 6-week period of study. The written answers to each of the 4 questions are to contain full text citations and to be 4-6 double-spaced pages in length (not to exceed 2000 words). A References Cited section must accompany each written answer and shall not count toward the page/word limit. Answers should exhibit the student's proficiency at synthesizing the literature and at staking out their own intellectual positions, rather than being a simple summary of all literature and ideas relevant to the question. The 4 written answers will be turned in to the major advisor on the day following the 6-week period. An oral exam will be scheduled within 1 week of the end of the 6-week study period. After a question and discussion period during the oral exam, the major advisor will facilitate discussion among the faculty examiners about the student's performance and the committee will decide the exam outcome.

Breadth: The 4 exam questions shall encompass at least three different areas relevant to the student's research scholarship, including the student's core area (e.g. Evolution, Ecology or Behavior) and the minor. Appropriate areas include but are not limited to ecology, evolution, behavior, physiology, neuroscience and development. Any given question may bridge more than one area.

Although the questions are designed to assess breadth of knowledge, they can be related to the student's specific research project(s). As one example, an evolution question for a plant ecology graduate student working on plant-microbe interactions might focus on coevolution between plants and microbes. Likewise, a behavior question for the same student might address some aspect of plant 'behavior', such as mechanisms of information exchange between or within plants or between plants and other organisms. Such questions can be tailored so that the student also needs to explore and articulate general concepts in the area (e.g. Wright's adaptive landscapes, levels of selection, Tinbergen's 'Four Questions'). This approach will foster well-rounded graduate students who are able to think outside the box of their own specialty, understand the relevance of other major disciplines to their own research interests, and synthesize knowledge across fields.

Role of major advisor: The major advisor will be responsible for writing no more than 1 question and soliciting 2 exam questions from each of the 3 other committee members, for a total of 7 questions. Questions should be solicited sufficiently in advance of the exam period. The major advisor will lead the decision-making about which areas each committee member provides questions on and should review the questions and suggest or request modifications as necessary, including the possibility of merging questions to create more synthetic questions. The major advisor will have the responsibility of arriving at 4 exam questions from the original 7 questions that encompass at least 3 different areas and the committee as a whole will have final approval of the 4 questions. The major advisor shall provide a written copy of the questions to the graduate examinee on the first day of the 6-week exam period.

Following the oral exam, the major advisor will provide a detailed summary of the committee's decision, including an assessment of strengths as well as any areas for continuing progress. A written

communication of this summary should be sent to both the Graduate Office (Gretchen Clearwater) and directly to the student. This summary shall specify the 3 areas over which questions were drawn. The major advisor is also expected to have a more in depth one-on-one with the graduate examinee to discuss the student's performance on the written and/or oral portion of the exam when needed or if requested by the student.

—Part II. Research Skills:

- During the student's second semester* the student must submit to her/his Committee a written proposal for the **preliminary research project** and obtain the Committee's approval for the project (making whatever revisions may be required).
- The student then completes the project, making necessary design modifications with the approval of the Committee, and then analyzes the results and prepares a written report which must include *properly analyzed* data.
- By the middle of the fifth semester* the student submits to the Advisor and Committee a written report on the preliminary research project and a written proposal for dissertation research.
- An oral examination covering both the report on the preliminary research project and the proposal is held *during the 12th week of the fifth semester*.
- This chronology allows time for a retake before the departmental deadline(5th week of the student's sixth semester) if the first attempt is unsatisfactory.

Students who previously have completed a Master's thesis (or other substantial graduate individual research project with a written report) may propose that this previous research and the thesis or report be accepted in lieu of the preliminary research project component of the qualifying examination. The appropriateness of such a substitution will be determined by the student's Advisory Committee. If the substitution is accepted, both parts of the qualifying examination must be completed *prior to the 13th week of the student's fourth semester*.

Admission to Candidacy: Once the student has passed both parts of the qualifying examination **and has completed all required major and minor course work**, the student can be nominated to candidacy for the Ph.D. degree. The Thesis Research Committee is then selected by the student and Advisor. It must be made up of four or more members of the Graduate Faculty, at least two of whom must be full members. In practice, these members are often the same individuals who made up the student's Qualifying Examination Committee (= "Advisory Committee" on page 3); but changes in committee membership, if desired, can be made at this time. A nomination form designating the membership of the Committee (obtained from the Biology Graduate Office) is submitted to the EEB Program Director, the Director of Graduate Studies of the Department of Biology, and the Dean of the Graduate School for their approvals.

The candidate must submit a one- or two-page prospectus of the dissertation research to the Graduate School, after consultation with and approval by the student's Advisor and by the proposed Research Committee. Both the Research Committee and the dissertation prospectus must be approved by the Graduate School **at least six months before the final defense of the dissertation**.

Dissertation: To obtain the Ph.D., a candidate must submit a dissertation that is acceptable to the members of her/his Research Committee and to the Graduate School. Research for the dissertation usually occupies substantially more than half the student's graduate training. It is essential that the student obtain the Committee's advice and consent in formulating, pursuing, and writing the dissertation. If the dissertation topic is subsequently changed significantly, approval must be obtained from the Research Committee and, if the nomination to candidacy has been submitted, from the Dean of the Graduate School.

At least one month before the final examination, a complete, unbound copy of the dissertation must be submitted to each member of the candidate's Committee. At the same time, the student must submit to the Graduate School a one-page announcement of the final public examination. Specific guidelines for the preparation and submission of the announcement and dissertation are available in the Graduate Office of the Department of Biology.

Public Defense: The student must hold a public defense of her/his Ph.D. dissertation. This will take the form of a public seminar followed by open discussion. A meeting with the Committee and other interested faculty will follow.

Time Limits, Extensions, and Revalidation: The student must submit and have received acceptance of her/his dissertation within seven years after the date on which the qualifying examination is passed. Failure of a candidate to meet this requirement will result in the termination both of candidacy and of enrollment in the degree program.

To be reinstated in the Graduate School, the student must first take and pass a then-current Ph.D. qualifying examination and then petition for a reinstatement of candidacy which, if granted, will be valid for a period of three years. If at the end of the period of reinstatement the student has a dissertation accepted for defense by the Research Committee, but needs additional time for the defense, etc., the Graduate School may grant an extension of up to six weeks. However, no other extensions will be approved.

In addition, all course work that is to be counted toward the Ph.D. must have been completed or revalidated within seven years prior to the completion of the degree. Courses that were taken more than seven years prior to completion may be revalidated. The purpose of revalidation is to demonstrate that courses counted toward a degree (and the body of knowledge contained in them) are acceptable as current and adequate at the time of revalidation. For *each course* falling outside the seven-year period allowed for the Ph.D., students must demonstrate that they have remained current in the knowledge required by the course. This can normally be done by:

- passing an examination specifically on the material covered by the course;
- passing a more advanced course in the same subject area;
- passing a comprehensive examination (either an M.A. examination or a Ph.D. qualifying examination) in which the student demonstrates substantial knowledge of the content of the course;
- teaching a comparable course; or
- publishing scholarly research demonstrating substantial knowledge of the content and fundamental principles of the course.

Continuous Enrollment: After admission to candidacy the student must enroll each semester, excluding summer sessions, for any remaining required course work, dissertation, or research credit. If 90 hours have been completed, and if the student has been admitted to candidacy, the student must enroll for at least one hour of research or dissertation credit in *each* semester until the degree is completed. A candidate who will graduate in June, July, or August must enroll for at least one hour of credit in either of the two summer sessions.

M.A. IN ECOLOGICAL AND EVOLUTIONARY BIOLOGY *and* M.A. IN ZOOLOGY

Advisor: The student must obtain the agreement of a faculty member in the Department of Biology to serve as the student's Research Advisor.

Advisory Committee: The M.A. Advisory Committee must include three faculty members, including at least two from the EEB Program and may include one or two additional faculty members from any department at Indiana University. An Advisory Committee for the Ph.D. in EEB can also function as the Advisory Committee for an M.A. in EEB. An Advisory Committee for a Ph.D. in another program in Biology can also function as the Advisory Committee for an M.A. in EEB *if* the student has also been admitted to the EEB Program for an M.A. *and if* the Program Director of EEB approves.

In practice, the Advisory Committee usually is chosen by mutual agreement between the Advisor and the student, who then contact potential committee members and obtain their agreement to serve on the Committee. A nominating form (from the Biology Graduate Office) designating the proposed membership of the Committee is submitted to the EEB Program Director, the Director of Graduate Studies of the Department, and the Graduate School for approval.

Course Requirements: *The Advisory Committee must meet before the end of the student's second semester of M.A. work* and approve a proposed plan of course work and a proposed topic and scope for the thesis or alternative project. The nature of these two components is determined by the student's Advisory Committee subject to the following constraints:

1. **Graduate Credits.** The student must take a minimum of 30 hours of graduate credit; at least 20 of which must be in the Department of Biology. At least 21 must be in courses and seminars and at least 6 must be in graduate research.
2. **Focus.** The courses and research that each student pursues must have a coherent focus within the general field of EEB. Examples of appropriate foci are the Ph.D. areas of specialization (page 4). A focus in Genetics or in Molecular, Cellular, and Developmental Biology may be proposed for the M.A. in Zoology.

Grade Average and Time Limits: A "B" average (3.0) is required for the degree. If a student's average falls below 3.0, the student will be placed on academic probation. Failure to raise the overall average to at least 3.0 during the next semester will result in dismissal from Graduate School. The M.A. degree must be completed within five semesters of full-time study or its equivalent (within five calendar

years if enrollment is part-time or episodic). Students in Ph.D. Programs in the Department of Biology who decide to leave IU during or after the fifth semester may petition the EEB Program Director *and* the Director of Graduate Studies for a single additional semester to complete the M.A. Such petitions will be considered on their individual merits.

Thesis or Alternative Project: The M.A. in EEB must include a **research project**. Before the research is begun the student must obtain the approval by her/his Advisory Committee of a written proposal for the M.A. research project. The brief proposal should include a statement of the research problem, a brief analysis of the most relevant literature, a tentative experimental design, and a plan for the data analysis. The scope of the project should be such that the project could reasonably be completed in no more than nine credit hours of effort. Once the design is agreed upon by the student and the Committee, the student proceeds with the research, making necessary design modifications in consultation with her/his Committee. After the research is completed, a written report is prepared that usually includes revised material from the original proposal as well as *properly analyzed* results and discussion. The research project must be orally defended before the Advisory Committee. The initial part of this defense may be a public seminar. It is not necessary that the results of the research adequately support or refute the initial hypothesis. Rather, the examination and written report will be evaluated on the student's mastery of the skills of problem delineation, research design, research techniques, data analysis, elucidation of the significance of results, and written and oral presentation. (Students who plan to pursue the Ph.D. in EEB or MBG may request permission to use the preliminary research project component of their qualifying examinations as the M.A. project and examination.)

The scope (6 to 9 credit hours) and the relative success of the research will vary among projects. More extensive projects producing positive, publishable results will usually be designated theses. Briefer projects and those producing primarily negative results will be designated alternative projects. Students completing a thesis should consult the Graduate School Bulletin for information on format, number of copies, etc.

Certification: Satisfactory completion of the program of course work, the thesis or alternative project, and the M.A. degree as a whole must be certified by the Advisory Committee on the appropriate form. Subsequent approvals by the Director of the Graduate Program in EEB, the Director of Graduate Studies of the Department, and the Graduate School are also required.

Admission from Other Programs: The EEB program offers an M.A. in Ecological and Evolutionary Biology and an M.A. in Zoology. Students admitted to the Ph.D. Program in MBG also may wish to apply for admission to the EEB Program for an M.A. degree. (Note that in the Department of Biology, M.A. programs also are offered in Plant Sciences and Microbiology.)

Transfer to the Ph.D. Program: Full-time students in an M.A. Program in the Department of Biology at Indiana University (Bloomington) who wish to transfer to a Ph.D. program in EEB should apply for admission to the Ph.D. Program **no later than their third semester of M.A. study**.

COMBINED M.A. IN EEB AND M.S. IN ENVIRONMENTAL SCIENCE (M.S.E.S.)

Description: This is a three-year, 60 credit-hour program that qualifies the student for two Master's degrees: M.A. in Ecological and Evolutionary Biology and M.S. in Environmental Science. A student must apply to and be accepted by SPEA, the School of Public and Environmental Affairs, for study toward the Master of Science in Environmental Science (MSES) degree and by the program in Evolution, Ecology, and Behavior of the Department of Biology and the University Graduate School for study toward the M.A. or Ph.D. degree. The student must select an advisory committee of at least three faculty members representing both EEB and SPEA. The composition of the committee must be approved by the director of the EEB program and by the director of the MSES program in SPEA.

Requirements: Students in the combined MA/MSES Degree Program must fulfill the following requirements. The SPEA components of the following lists, somewhat out of date, should be revised. Contact the EEB Program Director if this impacts you. Consult Dr. John Mikesell in SPEA (855-9485) for the current listing.

1. Environmental Science Courses (12 cr.)
 - SPEA E526 Applied Mathematics for Environmental Sciences
 - SPEA E527 Applied Ecology
 - SPEA E536 Environmental Chemistry
 - SPEA E552 Environmental Technology

2. Environmental Management and Policy Courses (10 cr.)
 - SPEA V517 Public Management Economics or
 - ECON E463 Environmental and Resource Economics
 - SPEA E680 Seminar in Environmental Science and PolicyAnd two of the following courses:
 - SPEA V520 Environmental Policy Analysis
 - SPEA E549 Environmental Planning
 - SPEA V540 Law and Public Affairs
 - SPEA E620 Environmental Analysis Workshop
 - LAW B660 Environmental Law

3. Ecology Graduate Courses (6 cr.). Two courses selected from the following:
 - BIOL L560 Physiological Ecology
 - BIOL L578 Advanced Population Biology
 - BIOL L579 Community Ecology
 - BIOL L575 Biodiversity and Ecosystem Functioning

4. Ecology Electives (18-20 cr.). Additional courses from group #3 (above) may be elected here; alternatives may be selected from the following
 - B364 Summer Flowering Plants
 - Z406 Vertebrate Zoology
 - M420 Environmental Microbiology
 - M460 Biology of the Prokaryotes
 - Z460 Ethology
 - L465 Advanced Field Biology

L473 Ecology
L474 Field and Laboratory Ecology
L479 Evolution and Ecology
Z508 Advanced Ornithology
B555 Special Topics: Phylogeny and Families of Flowering Plants
B555 Special Topics: Speciation
B560 Seminar in Systematics
L567 Evolutionary Ecology
L570 Seminar in Ecology and Environmental Biology
L591 Plant Population Biology—An Experimental Approach
Z620 Special Topics in Zoology

5. Environmental Science Electives (6-9 cr.). Selected from the following:

CHEM C310 Analytical Chemistry
GEOG G335 Photogrammetry and Remote Sensing
GEOG G405 Hydroclimatology
GEOG G435 Cartography and Remote Sensing
GEOG G477 Advanced Climatology and Meteorology
GEOL G415 Principles of Geomorphology
GEOL G451 Principles of Hydrogeology
GEOL G551 Advanced Hydrogeology
SPEA E431 Water and Wastewater Treatment
SPEA E452 Air Pollution and Control
SPEA E440 Fisheries and Wildlife Management
SPEA E441 Fisheries and Wildlife Management Laboratory
SPEA E450 Process Analysis for Environmental Engineering
SPEA E470 Elements of Fluid Mechanics
SPEA E528 Applied Ecology Laboratory
SPEA V537 Environmental Chemistry Laboratory
SPEA E539 Aquatic Chemistry
SPEA E542 Hazardous Waste Management
SPEA E547 Applied Earth Science
SPEA E548 Applied Earth Science Laboratory
SPEA E538 Statistics for Environmental Science
SPEA E549 Environmental Planning
SPEA E552 Environmental Engineering
SPEA E553 Creation and Solution of Environmental Models
SPEA E554 Groundwater Flow Modelling
SPEA E555 Topics in Environmental Science
SPEA E560 Environmental Risk and Decision Analysis
SPEA E570 Soils Engineering and Science
SPEA E620 Environmental Analysis Workshop

6. Research (6 cr.).

A student must complete a minimum of six hours of research in: SPEA E625 Research in Environmental Science or in BIOL L500 or L800 Research. **Before the research is begun the**

student must obtain approval by her/his Advisory Committee of a written proposal for the research project. The proposal should include a statement of the research problem, a brief analysis of the most relevant literature, and a tentative design for execution and for analysis of the data. The scope of the project should be such that the project could be completed reasonably within the credit hours allowed. After a design is agreed upon by the student and the Committee, the student proceeds with the research, making necessary design modifications in consultation with her/his Committee. After the research is completed a written report is prepared that usually includes revised material from the original proposal as well as properly analyzed results and discussion. The research must be orally defended before her/his Advisory Committee. The initial part of this defense may be a public seminar. It is not necessary that the results of the research adequately support or refute the initial hypothesis. Rather, the examination and written report will be evaluated on the student's mastery of the skills of problem delineation, research design, research techniques, data analysis, elucidation of the significance of results, and written and oral presentation.

The research report must be acceptable to the student's Committee, to the Director of the EEB Program (as a thesis or an alternative project for the M.A.), and to the Director of the MSES Program (as appropriate for the MSES Professional Experience requirement).

FLEXIBILITY IN DEGREE REQUIREMENTS

The requirements for the M.A. and Ph.D. degrees outlined above may be modified in several ways to take account of the student's background and career objectives. Any required course may be waived upon presentation of adequate evidence showing that the student already has acquired substantially the same knowledge either from previous courses or independently. Students may petition for a modification or waiver of requirements that seem inappropriate in their particular case. Such petitions must have the approval of the student's Faculty Advisor and Committee. Petitions must be approved by the Director of EEB and by the higher unit, if any, responsible for the particular requirement (often, the Director of Graduate Studies of the Department of Biology, or the Graduate School).

Transfer of Graduate Credit: Graduate work taken elsewhere may qualify for transfer credit toward the Ph.D. and, when appropriate, may be substituted for required or elective courses. The appropriateness of proposed substitutions will be determined by the student's Advisory Committee. No more than 30 hours of credit by transfer can be accepted for the Ph.D., and none can be accepted for the M.A.

Students who have previously completed a Master's thesis or other substantial individual research project with a written report may propose that this previous research and the thesis or report be accepted in lieu of the "preliminary research project" component of the preliminary examinations (see page 7).

ALTERNATIVE CAREER OBJECTIVES

Students are encouraged to consider courses or training beyond the formal requirements of the programs described here as possible preparation for careers in areas outside traditional academia. Students may wish to elect courses in such areas as computer science or information technology, technical writing, applied ecology, etc. It is possible in some instances for a student to complete the

M.S. in Environmental Science (MSES) degree in the School of Public and Environmental Affairs (see above) while satisfying the requirements for the Ph.D. in EEB. Research in applied areas of biology may be proposed for the Ph.D. or M.A. degree. Other alternatives may be available to students who have interests in mathematics, programming and data analysis, or geology.

FACULTY AND THEIR RESEARCH INTERESTS

Core Faculty

James D. Bever (Ph.D., Duke University, 1992; Professor)
Ecology and evolution of plants and fungi.

Keith Clay (Ph.D., Duke University, 1982; Professor)
Microbial Interactions: Ecology, Symbiosis, Disease.

Lynda F. Delph (Ph.D., University of Canterbury, 1988; Professor)
Evolutionary ecology, plant reproductive biology.

Gregory E. Demas (Ph.D., Johns Hopkins University, 1998; Associate Professor)
Behavioral endocrinology; neuroendocrine-immune interactions; biological rhythms; seasonality; aggression.

Gerald J. Gastony (Ph.D., Harvard University, 1971; Professor EMERITUS)
Systematics and evolution of vascular plants; isozyme and DNA-level studies of populational biology and phylogenetic relationships in plants.

Jim Goodson (Ph.D. Cornell University, 1998, Associate Professor) *Neural/neuroendocrine mechanisms of social behavior; comparative neuroanatomy; evolution of avian sociality.*

Matt Hahn (Ph.D., Duke University, 2003; Assistant Professor) *Computational and Evolutionary Genomics; Evolution of Transcriptional Regulation; Molecular Population Genetics.*

Spencer Hall (PhD, University of Chicago, 2003; Assistant Professor) *Ecology of infectious disease and food web interactions in freshwater environments.*

Charles B. Heiser (Ph.D., University of California, Berkeley, 1947; Distinguished Professor EMERITUS) *Angiosperm systematics; ethnobotany.*

Laura M. Hurley (Ph.D., University of Washington, 1997; Assistant Professor) *Neuromodulation of the auditory system; modulator-induced plasticity in neural circuits underlying behavior..*

Ellen D. Ketterson (Ph.D., Indiana University, 1974; Distinguished Professor)
Behavioral, physiological, and population ecology; avian biology.

Eric Knox (Ph.D., University of Michigan, 1993: Director, Indiana University Herbarium)

Plant evolution; speciation; phylogenetic systematics; chloroplast genome evolution; horizontal gene transfer; flora of Indiana.

Curtis M. Lively (Ph.D., Arizona State University, 1984; Professor)
Population biology, predator-prey and host-parasite interactions.

Michael Lynch (Ph.D., University of Minnesota, 1977; Distinguished Professor)
Evolution and quantitative genetics.

Emília P. Martins (Ph.D., University of Wisconsin, 1992; Professor)
Evolution of complex behavioral traits; phylogenies and the comparative method.

Armin Moczek (Ph.D., Duke University, 2002; Associate Professor)
Evolutionary developmental biology, phenotypic plasticity, morphological and behavioral diversity in arthropods.

Kristi Montooth (Ph.D., Cornell University, 2005; Assistant Professor)
Evolutionary physiological genetics; population genetics; biochemical adaptation.

Leonie Moyle (Ph.D., Duke University, 2002; Assistant Professor) *Genetics of speciation and adaptation, Comparative genomics, Evolutionary ecology, Plant reproduction.*

Craig E. Nelson (Ph.D., University of Texas, 1966; Professor EMERITUS)
Community and population ecology and evolution; vertebrate systematics.

Jeffrey D. Palmer (Ph.D., Stanford University, 1981; Distinguished Professor)
Chloroplast DNA evolution and function, coevolution of chloroplast and nucleus, plant molecular systematics.

Richard Phillips (Ph.D.) Cornell University, 2005: Assistant Professor)
Plant-Soil-Microbial Interactions and Carbon and Nutrient Dynamics. Ecosystem Ecology and Biogeochemistry: Consequences of Human-Accelerated Environmental.

Rudolph A. Raff (Ph.D., Duke University, 1967; Distinguished Professor)
Evolution of development; molecular phylogeny.

Heather L. Reynolds (Ph.D., University of California, Berkeley, 1995; Associate Professor)
Plant community ecology; plant-microbe interactions.

Gerald Troy Smith (Ph.D., University of Washington, 1996; Associate Professor)
Neural and hormonal control of reproductive and communication behavior; ion channels and membrane excitability; motor pattern generation.

Michael R. Tansey (Ph.D., University of California, Berkeley, 1970; Associate Professor)
Mycology.

Gregory Velicer (Ph.D., Genetics, Michigan State University, 1997; Associate Professor)

Ecology and evolution of bacterial social behavior.

Michael J. Wade (Ph.D., University of Chicago, 1975; Distinguished Professor)
*Evolution in metapopulations; Genetic basis of speciation in Tribolium; Epistasis;
Evolutionary genetics of maternal effects; Sexual selection and alternative male mating
strategies; Coevolution of arthropod hosts and Wolbachia endosymbionts.*

Maxine A. Watson (Ph.D., Yale University, 1974; Professor)
Population biology, physiology and development of clonal plants.

Adjunct and Associated Faculty

Clay Fuqua *Multicellular interactions of bacteria.* Primary affiliation with MBG graduate program.

Roger Hangarter *Plant physiology: Environmental sensory-response systems and plant development.* Primary affiliation with MBG graduate program.

Elizabeth Houseworth Statistical genetics. Department of Mathematics

Arthur L. Koch (Ph.D., University of Chicago, 1951; Professor EMERITUS)
Microbiological ecology; evolution of bacteria. Primary affiliation with MBG graduate program.

Elizabeth Lloyd *Units and levels of selection; the evolution of female orgasm; history and philosophy of biology.* Department of History and Philosophy

Vicky Meretsky (Ph.D., University of Arizona, 1995; Assistant Professor)
Conservation biology. School of Public and Environmental Affairs

Todd Royer *Biogeochemistry and water quality in streams and rivers.*
School of Public and Environmental Affairs

Dale Sengelaub *Neural development; neural plasticity; hormones and behavior.*
Department of Psychology

Roderick A. Suthers (Ph.D., Harvard University, 1964; Professor) *Sensory ecology, animal orientation, bioacoustics, and neurophysiology.* Medical Sciences Program

Bill Timberlake *Analysis of the perceptual-motor, regulatory, rhythmic, and neurophysiological structures and processes that underlie behavior.* Department of Psychology

Meredith J. West (Ph.D., Cornell University, 1975; Professor)
Development of communicative behavior. Department of Psychology

Donald R. Whitehead (Ph.D., Harvard University, 1958; Professor EMERITUS)
Conservation ecology (factors influencing neotropical migrant landbirds).