Department of Ecology and Evolutionary Biology
University of Michigan

5-Year Plan
Submitted 17 November 2003

<u>Executive Summary</u>

- ***The goal of this plan is to establish the Department of Ecology and Evolutionary Biology in the top five departments in the country for research, graduate training, and undergraduate training in the biodiversity sciences, within the next five years.*** We are already ranked in or near the top ten and therefore this goal is quite attainable with the resources requested.

- The biodiversity sciences include understanding the origin of organismal diversity (**evolutionary history**), accounting for their features (**evolutionary processes**), analyzing the function of organismal characteristics (**functional organismal biology**), and understanding how organisms affect and are affected by environmental factors, including other organisms (**ecology).** The hiring plan in this document is designed to maintain our current great strength in evolutionary history, to rejuvenate our strong, but aging, program in ecology, and to add strength in evolutionary processes. Because we cannot do everything well, we have chosen to do minimal hiring in the last major area of biodiversity sciences, functional organismal biology, despite its importance.

- The EEB faculty currently has 27 professorial and curatorial positions (19.75 FTE) distributed currently among 10 ecologists, 17 evolutionary biologists, 1 organismal biologist, and other "0" fraction appointments. Almost half (12) of these faculty are jointly appointed with the Museum of Zoology, the Museum of Paleontology or the Herbarium. This close integration with the museum units has been and continues to be a major source of our international reputation and our capability for research and graduate education.

- The Department also benefits from diverse interactions with various Departments in LS&A, (MCDB, Geology, Anthropology), other U-M Schools (SNRE, SPH, Medicine, Engineering) and other university units (University of Michigan Biological Station, Museum of Anthropology, Center for the Study of Complex Systems, International Institute). Over the next 5 years, we will increase our coordination with related groups on campus to increase interdisciplinary research and teaching at the intersection of ecology and evolutionary biology and the health and environmental sciences.

- EEB has the responsibility to teach and train undergraduate and graduate students in the broad areas of life sciences that include the study of evolution at all levels from molecules to species, the morphological, physiological, and behavioral traits of organisms, and the complex interactions among organisms and between organisms and their changing environment on earth. For undergraduates, our 5 year plan calls for the following: 1) an increased commitment to first year-seminars, 2) evaluation and modification as needed of our core concentration courses, 3) an increase in our overall educational impact by applying and evaluating innovative pedagogy and instructional technologies, 4) implementation of mechanisms to fulfill the junior-senior writing for our concentrators, and 5) renovation and expansion of our teaching laboratory facilities. For graduate students, our plan calls for improvement in mentoring to help reduce time to degree and initiation of more interdisciplinary programs through training grants and possible joint degree programs.

- While the graduate student body is equitable in terms of gender, women faculty are still strongly underrepresented, especially at senior levels, and African-Americans and Hispanics are strongly underrepresented at all levels in the department. We present initiatives to increase recruitment of underrepresented minority students and women faculty and to improve the climate overall in the department.

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I. Introduction

The subject matter of the Department of Ecology and Evolutionary Biology (EEB) embraces virtually all aspects of the study of organisms. It includes understanding the diversity of organisms, discerning their history and accounting for their characteristics (the main subject matter of **evolutionary biology**), analyzing the function of their features (**functional organismal biology**), and understanding how organisms affect and are affected by environmental factors, including other organisms (**ecology**). These several disciplines have often been referred to as "biodiversity science." Because most research in these disciplines analyzes organisms or their characteristics in broader contexts (organisms functioning in environments, molecular or anatomical features functioning within the milieu of the whole organism), they have also been collectively termed "integrative biology." Thus, in some universities, departments like ours bear names such as "Ecology, Evolution and Organismal Biology," "Ecology, Evolution and Behavior," or simply "Integrative Biology".

Research in these subjects is firmly grounded in "reductionist" biological disciplines, such as molecular biology, biochemistry, and studies of neural function, but focuses on integration and synthesis of these mechanisms as they operate in complex systems of interacting components or over long periods of time or large areas of space. The very diverse area of functional organismal biology is intimately related to physiology, biomechanics, neurobiology, developmental biology, and other biological disciplines. Evolutionary biology has strong connections to genetics, genomics, bioinformatics, geology, computer science, anthropology, and even linguistics, history, and philosophy. Ecology builds on all these biological disciplines, and reaches out to join geology, atmospheric science, oceanography, and geography in the larger field often called environmental sciences. Evolutionary biology and ecology include some of the most highly elaborated mathematical and computer modeling in the biological sciences, and theoreticians in these areas often collaborate with applied mathematicians, complexity theorists, and information scientists.

Evolutionary biology finds applications in plant and animal breeding, human genetics, disease epidemiology, and conservation biology. Ecological information, principles, and methods are indispensable in a great range of contexts, from pest management to conservation to predicting biological effects of the major environmental problems of our time, such as acid rain and climate change.

Before we describe the current status of the Department, we provide a fuller description of the major disciplines in biodiversity sciences, along with some of their most important contemporary research directions. More detailed descriptions of the key subdisciplines within these fields can be found in *Appendix A.*

II. Biodiversity disciplines

Evolution is the single most important unifying principle in biology, simply because every characteristic of every species - the DNA code, the nucleotide sequence of a particular gene, each of an organism's biochemical pathways, behavioral traits, anatomical features, ecological habits – has an evolutionary history. Both the historical origins of a trait and the ways it has been affected by natural selection are thus important parts of the explanation of most characteristics. Evolutionary biology therefore takes all biological phenomena as its subject. This discipline can be roughly divided into describing the *history* of diverse organisms and their characteristics, and determining the *processes* of evolutionary change and how they have shaped characteristics of interest.

Evolutionary history is inferred, to a very great extent, from comparisons among living species, although paleontological data, when available, provide the ultimate touchstone for these inferences. These comparisons enable us to infer phylogenetic (genealogical) relationships among species, which in turn provide a foundation for many inferences about the history of changes in their characteristics. Enormous progress in this area has occurred in the last decade or so, due to the development of new analytical algorithms, increased computing capability, and the ready production of DNA sequences as a major (but not sole) source of the requisite data. In principle, we can now develop a complete picture of the tree of life, a history of the origin of all species, which will provide the foundation for innumerable ecological and evolutionary studies – including deeper understanding of the rates and modes of evolution at the molecular level. An NSF "Tree of Life" initiative now supports major efforts in this direction. Moreover, the methods that enable us to infer the historical relationship among species are also used to infer relationships among genes within species and among different genes within a genome. Thus, phylogenetic comparisons among the genomes of different species are producing phenomenal progress in understanding the evolution of genomes. The original reports on the human genome, and the recent report on the completed mouse genome, include evolutionary interpretations on almost every page, and the authors of the latter paper concluded that "comparative genome analysis is perhaps the most powerful tool for understanding biological function" and that "it will play a crucial role in our understanding of the human genome and thereby help lay the foundation for biomedicine in the twenty-first century."

Evolutionary processes include genetic changes in populations, including changes that engender new species. The causes of genetic change include mutation, random genetic drift, and natural selection in its many forms. An important part of evolutionary biology therefore consists of population genetics, which analyzes the factors responsible for genetic variation within species. This subject includes mathematical theory, experimental laboratory studies that frequently employ model organisms such as colon bacteria and fruit flies, and analyses of patterns of variation in field samples of diverse organisms, sometimes in relation to ecological conditions. All these (and other) aspects of evolutionary study have seen phenomenal progress in recent years. For example, molecular tools now enable evolutionary geneticists to identify much more precisely the genes that may contribute to variations in a characteristic, and thus to determine the number and kind of genetic changes that have transpired in the evolution of two species from a common ancestor. One of the most exciting areas in contemporary biology is developmental biology, and evolutionary developmental biology is likewise one of the most dynamic subjects in our field. It is now possible to show the shared genetic underpinnings of characteristics, such as eyes, in organisms whose most recent common ancestor lived more than 500 million years ago, or to show how some genes' functions have changed during evolution, and to pinpoint some of the genetic changes that underlie major evolutionary transformations of body form. In the near future, profound and probably novel insights into the molecular details of evolutionary changes in adaptive characteristics will be forthcoming, and we will be much closer to understanding why lineages of organisms such as the human lineage took one pathway of evolutionary transformation rather than others.

Ecology embraces all aspects of the relationships between organisms and their environment, which includes both other organisms and the nonliving environment. As such, the field encompasses an enormous range of different questions and levels of biological investigation. Ecologists study phenomena at scales from the molecular (e.g., the effect of genetic relatedness on spread of disease in wildlife) to the global (e.g., the carbon budget of the earth and implications for global climate change), and at levels from the individual organism through populations and communities to regional ecosystems. The hallmark of these investigations is to understand the integrated functioning of the myriad interacting processes that influence the distribution and abundance of species, the patterns and maintenance of biodiversity, and the causes and consequences of biogeochemical cycles. Thus, the study of ecology is fundamental to understanding virtually all aspects of the natural world that include or are influenced by organisms, and on which we depend for sustenance. Consequently, ecologists are driven not only by the pure intellectual excitement generated by asking questions about how the natural world works, but by the urgency prompted from increasing awareness of the central role that ecological phenomena play in the welfare of the planet, from understanding emerging diseases to global climate change.

Functional organismal biology is an umbrella term for many subdisciplines that analyze the function of various characteristics, often with reference to natural selection and often including comparisons among species in which the feature differs. The term embraces fields such as evolutionary and ecological physiology, functional morphology, evolutionary and ecological aspects of animal behavior, and studies of biochemical traits, breeding systems, and life histories, all in the context of adaptation. Many researchers in these areas have a strong foundation in the systematics and biology of specific groups of organisms, and may identify themselves with taxonomically-organized areas such as microbiology, ornithology, or botany. A few of the many subjects of important contemporary research are the aerodynamics of flight in insects and birds, chemical defenses of plants against herbivores and fungal pathogens, the role of heat-shock proteins in temperature tolerances, and differences in brain structure among birds that differ in the complexity of their song repertoire. Many such studies are related to those pursued by molecular and cell biologists, but with a focus on differences among species and adaptation to differing environments and ways of life.

Integration with the museum units. An important part of all of these biodiversity disciplines is identifying the units of study. Just as human genomics will depend on its catalogue of mapped and annotated genes, almost all of biology rests on distinguishing and naming kinds of organisms, i.e., describing biodiversity. This is most obviously true in studies of evolutionary history, where the focus is on inferring the origin of diversity, and therefore students of evolutionary history are expert in describing and recognizing the diversity of the groups they study. However, this need is also true in all the other biodiversity disciplines. Most ecological studies, for example, depend on identifying the species that interact in an ecosystem, and on the literature that can be accessed only by knowing the species' names. Therefore much of research in the disciplines encompassed by EEB depends critically on collections of the organisms that are its subject. These collections provide the reference standards for identification, encompass the variation, both within and among species, that is the foundation of evolutionary analyses, and, with the labels on archived material, provide information on geographic and ecological distributions and changes over time (e.g., with climate change in recent decades). For many groups of organisms, archived specimens can also provide DNA, and thus constitute irreplaceable resources, especially as many of the specimens have been collected in places that today are prohibitively expensive, dangerous to visit, or the organisms themselves are now extinct or near it. For these reasons, the biological collections housed in the Museum of Zoology and the Herbarium and the taxonomic expertise of the curator-faculty of these collections are an absolutely essential part of EEB's international reputation and research and training capability. The taxonomic expertise of the curator-faculty with joint appointments between the Museum and EEB is, of course, only one of the many roles these faculty play. As is obvious from Table 1 and from the rest of this plan, joint appointments between the museum units and EEB are made based on scholarly contributions to the conceptual questions of the full range of the biodiversity sciences.

III. Current status of department

A. History

Until the latter half of the twentieth century, most biological sciences at most universities were organized into the traditional departments of Botany and Zoology. Increasingly, however, life science research has addressed questions and adopted concepts that apply generally to plants, animals, and other organisms, and the traditional departments often were merged into departments of Biology. However, biology became increasingly organized along "levels of organization," most conspicuously at the levels of molecules and cells, individual organismal function (e.g., physiology, development), and organismal diversity (evolutionary biology, ecology). But because competition and cultural differences often resulted in severe tension among these major interest groups, many universities, beginning in the 1960's, established different departments, now distinguished by level of organization. At the University of Michigan, this history was played out in 1974, when the venerable Departments of Botany and Zoology were brought under a Division of Biological Sciences, in 1986, when the Division became a single Department of Biology, and in July 2001, when the Departments of Molecular, Cellular, and Developmental Biology (MCDB) and Ecology and Evolutionary Biology (EEB) were established by fission of the Department of Biology.

This split was precipitated by the recommendations of an external review of the Department of Biology in Fall 2000, which was endorsed by former Dean Shirley Neuman. The split was ratified by a vote of the Department of Biology in January 2001. By June 2001, faculty members in Biology chose the department(s) in which they wished their appointment to reside. The division was anticipated in the former Biology Department by the existence of two interest groups: Ecology, Evolution and Organismal Biology, and Molecular, Cellular, and Developmental Biology, which separately administered their own graduate programs. The undergraduate Biology concentration and curriculum that existed under the former Department of Biology has been retained and is jointly administered by EEB and MCDB as an interdepartmental program.

During 2001, the incipient and then new Department of Ecology and Evolutionary Biology prepared a five-year plan that was submitted to the College, along with position requests, in September 2001 by then Interim Chair Deborah Goldberg. Due to some confusion, this plan was not evaluated and a new plan was begun with the arrival of an external chair in September 2002. Further changes in leadership led to further delays in completion of the plan until the present.

B. Current faculty profile

At this time, EEB has 19.75 FTE in the form of 27 tenured or tenure-track faculty members, with one additional assistant professor (0.5 FTE) scheduled to arrive on campus in September 2004. Of those currently in residence, 13 have 1.0-FTE appointments in the Department. Twelve faculty also hold joint appointments (0.5 FTE) as curators in one of the museum units, including 9 in the Museum of Zoology, 2 in the University Herbarium, and 1 in the Museum of Paleontology. One faculty member holds a 0.5-FTE appointment in SNRE, and one also holds a 0.75 appointment as Director of UMBS. There are also two Lecturers III (1 as a 1.0-FTE appointment, and 1 split with MCDB) and three Research Scientists who contribute teaching and research expertise. Individual faculty members are listed in Table 1, with information on their appointment, rank, physical location, and research areas.

Most EEB faculty are housed in the Kraus Natural Sciences Building (15) and the Ruthven Museums Building (10). The old Herbarium building was demolished in 2002 as part of the construction for the Life Sciences Institute; consequently the collection was moved to a spacious but very inconvenient site in the University Stores complex off of the main campus (approximately a 15-20 minute drive away). Of the faculty with Herbarium appointments, one is housed in Kraus, and the other (who will retire in December 2003) in the temporary herbarium facility. Despite the 2-block distance between Kraus and the Museum, there are healthy interactions among faculty and graduate students in the two buildings, but active work is constantly needed to counter

Table 1. EEB Faculty as of September 2003. ** indicates won't arrive until September 2004. Division within the Museum of Zoology (UMMZ), the Herbarium (HERB) or the Museum of Paleontology (UMMP) indicates the collection for which the individual has curatorial responsibility.

Name	Biodiversity Discipline	Research area	FTE	Shared unit (Division)
Professor				
Estabrook, George F	ecology, funct. biol.	Computational statistics, ethnobiology	1.00	
Fink, William L	evol. history	Phylogenetics, historical biology, ichthyology	0.50	UMMZ (fish)
Fogel, Robert D	evol. history, processes, ecology	Fungal evolution and ecology	0.50	HERB (fungi)
Futuyma, Douglas J	evol. processes, evol. history	Evolutionary biology	1.00	
Goldberg, Deborah E	ecology	Plant community ecology	1.00	
Hazlett, Brian A	ecology, funct. biol.	Behavioral ecology	1.00	
Kling, George W	ecology	Aquatic ecosystem ecology	1.00	
Lehman, John T	ecology, funct. biol.	Aquatic ecology	1.00	
Nadelhoffer, Knute	ecology	Ecosystem ecology and biogeochemistry	0.25	UMBS
Nussbaum, Ronald A	evol. history, ecology, funct. biol.	Evolution, ecology of amphibians, and reptiles	0.50	UMMZ (amph,rept)
OConnor, Barry M	evol. history, ecology	Host-parasite coevolution	0.50	UMMZ (insect)
Payne, Robert B	evol. history, processes, ecology, funct. biol.	Bird behavior and systematics	0.50	UMMZ (bird)
Vandermeer, John H	ecology	Theoretical, tropical, and agricultural ecology	1.00	
Webb, Paul W	funct, biol., ecology	Comparative physiology and biomechanics	0.50	SNRE
Werner, Earl E	ecology	Animal community ecology	1.00	
Wynne, Michael J	evol. history	evolutionary relationships and biogeography of marine algae	0.50	HERB (algae)
TOTAL PROFESSOR (16)		**11.75**		

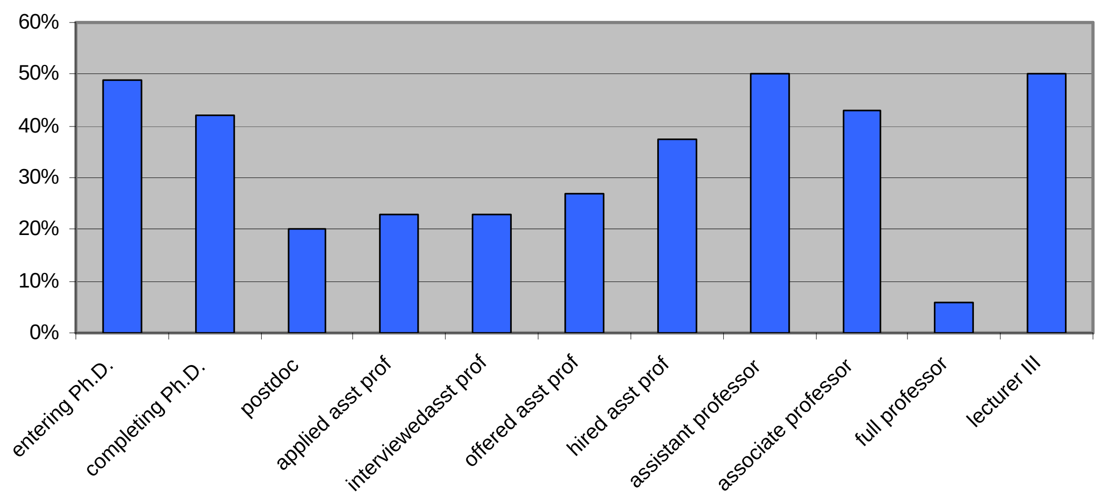
Associate Professor				
Burnham, Robyn J	evol. history, ecology	Tropical plant ecology; paleobotany	0.50	UMMP (plant)
Dunlap, Paul	evol. history, ecology, funct. biol.	Prokaryote biology	1.00	
Mindell, David P	evol. history, evol. process	Evolution of birds and viruses	0.50	UMMZ (bird)
Myers, Philip	evol. processes, ecology, funct. biol.	Mammalian systematics and ecology	0.50	UMMZ (mammal)
O'Foighil, Diarmaid	evol. history, evol. processes , ecology	Molluscan Biodiversity, molecular phylogeny	0.50	UMMZ (mollusks)
Rathcke, Beverly J	ecology	Plant-animal interactions	1.00	
Tucker, Priscilla K	evol. processes, evol. history	Mammalian evol. genetics/history	0.50	UMMZ (mammal)
TOTAL ASSOC PROFESSOR (7)		**4.50**		
Assistant Professor				
Duda, Thomas	evol. history, evol. processes, ecology, funct. biol.	Molluscan evolution	**	UMMZ (mollusks)
Knowles, Lacey	evol. history, evol. processes	Speciation and sexual selection	0.50	UMMZ (insect)
Pascual, Mercedes	ecology	Theoretical ecology	1.00	
Qui, Yin-Long	evol. history	Land plant evolution	1.00	
Zhang, Jianzhi	evol. processes	Molecular evol. genetics.	1.00	
TOTAL ASST PROFESSOR (5)		**3.50**		
Lecturer				
Ammerlaan, Marcus C	N/a	Science education, microbiology	0.50	MCDB
Kurdziel, Josepha	evol. processes, ecology	Science education, evol. ecology	1.00	
TOTAL LECTURER (2)		**1.50**		
Total Faculty (29)			***21.25***	
Total tenure-track (27)			***19.75***	

the effects of isolation. The distance between the new Herbarium and the campus has greatly decreased interaction and counteracting this impediment is a major challenge.

The age and rank distribution of EEB faculty is distressingly top-heavy: it includes 16 full Professors, 7 Associate Professors, and only 4 Assistant Professors, plus one more Assistant Professor scheduled to start in September 2004. The College has approved 5 open positions and 2-3 additional faculty are expected to retire in the next several years. Thus, a pronounced, rejuvenating change in the complexion of the Department can be anticipated as these positions are filled.

Filling these new positions also provides a tremendous opportunity to increase the diversity of the department. None of our faculty are members of underrepresented minorities and only 21% of our tenure-track faculty are women (6 out of 27), even though about 42% of graduating Ph.D.'s in EEB are women (Fig. 1), which is similar to the national average. As is also typical nationally, representation is better at the assistant professor level (50% women) but the small numbers (2 out of 4) mean that the proportional representation can change dramatically from year to year.

Fig. 1. Status of women in EEB.



Data on the percent of women at various career stages in EEB (Fig. 1) suggests that the key limitation to increasing the numbers of women in the faculty is in recruiting women to postdoctoral positions and to apply for assistant professor positions, rather than to any bias at the interview or hiring stage. On the other hand, the low proportion of full professors (1 or 6% of this rank), suggests there may also be significant issues in retention and promotion, although the numbers are too small for any statistical analysis. Strategies for increasing the diversity of our faculty are described in *Section V-J*.

Ten faculty members with "dry" appointments add to EEB's strength. The variety of units they represent exemplifies the breadth and reach of EEB's subject matter: MCDB

(Adams, Denver), School of Medicine (Foster), School of Public Health (Wilson), Geological Sciences (Blum), Museum of Paleontology (Fisher, Gingerich), Anthropology (Ford), and the School of Natural Resources and Environment (Foufopoulos, Zak).

The current faculty includes a large number of highly distinguished researchers with many past or current officers of professional societies (Presidents or Vice Presidents include: Fink, Futuyma, Lehman, OConnor, Werner, Wynne), Fellows of the AAAS (Fink, Futuyma, Kling, Pascual, Payne, Webb), as well as substantial service as members of editorial boards and NSF and NIH grant panels. UM internal awards to EEB faculty include Collegiate Professorships (Futuyma, Vandermeer), a Thurnau Professorship (Vandermeer), Faculty Recognition Awards (Kling), LS&A Excellence in Research Awards (Kling, Mindell, Payne), LS&A Excellence in Education Awards (Fink, Fogel, Hazlett, OConnor), the Sokol Award (Vandermeer), the Henry Russell Award (Lehman), and the Distinguished Faculty Governance Award (Lehman).

C. Research areas of current faculty and assessment of strengths and weaknesses

Many EEB faculty bridge two or more of the major disciplinary areas described in the introduction (Table 1). Since the days of the Zoology and Botany departments, ecology has been one of the strongest of the natural sciences within LS&A, and continues to hold high status. Ecology has long been primarily based entirely in EEB, but some of the most eminent ecologists in our Department's history have had appointments in the Museum of Zoology (e.g., Francis Evans, Nelson Hairston, and Don Tinkle) and many of the evolutionary biologists in the UMMZ include an ecological component in their research program (Table 1). Evolutionary history, including systematics and biodiversity expertise, is also exceptionally strong and highly ranked nationally. This ranking is primarily due to our joint appointments with the Museum of Zoology and the Herbarium. However, some of the most eminent systematists at the University of Michigan held appointments entirely in Biology (e.g., Warren H. Wagner, member of the National Academy for his work in plant evolution). From the areas listed in Table 1, it is clear that the two weakest components of the biodiversity sciences in EEB are in evolutionary processes and in functional organismal biology.

The University's preeminence in ***ecology*** extends back at least five decades; many of the leading ecologists in the United States were trained here. A major ongoing strength of the ecology group is its mixture of theoretical and empirical researchers. Our excellence in ecology has been significantly enhanced by the University's field facilities for research and teaching, especially the E. S. George Reserve in Pinckney and the Biological Station in Pellston, by faculty and graduate student access to the specimen collections in the Herbarium and the Museum of Zoology, and by the strong international component to the research of many of our students and colleagues, especially in Latin America and Africa. Despite our current strength in ecology, this is the area most in need of rejuvenation in the department, with only one assistant professor (being evaluated for tenure this year) and one associate professor. Without new faculty in the very near future to represent the many new and exciting areas in ecology, we run a great risk of losing our relevance in this field.

The Museum of Zoology and the University Herbarium have been the basis of the University's long-standing eminence in ***evolutionary history***. They have been home to individuals who immensely influenced their specialty areas in the United States, such as the ichthyologist Carl Hubbs and the herpetologist Alexander Ruthven, the president of the University for whom the Museums building is named. The reputation of Michigan in evolutionary history, which necessarily includes biodiversity expertise in many particular groups, has continued to attract outstanding graduate students, who have gone on to fill many positions in major universities and research museums in the U. S. and abroad. Some of the research within these units is based directly on the specimen collections; other research addresses questions in evolution, ecology, and behavior in ways that are based on or enriched by the expertise in biological diversity that resides here. Increasingly, research in these units uses DNA sequences and other molecular data, and includes analyses of molecular evolution and genome evolution, complementing the study of more traditional phenotypic features of organisms. Research in evolutionary history of animals has been maintained as a strong and vital program at Michigan, with the exception of work on insects. However, research in evolutionary history of plants has been decimated by recent retirements. The strength represented by the Museum and Herbarium distinguishes Michigan from all but two other highly-ranked universities (Harvard and Berkeley) with Yale just beginning to rebuild its program with quite substantial investments in faculty and facilities. This distinction is one on which we must continue to capitalize.

Research on ***evolutionary processes***, especially experimental and theoretical aspects of evolutionary genetics has been the weakest area of evolutionary biology in this department and its predecessors. The recent hiring of one senior faculty member (Futuyma) and two junior faculty (Zhang, Knowles) has improved our strength in this crucially important area, but our department is still far behind several others in this respect, and it is this subject area that needs the greatest strengthening if we are to rise to the top in our field as a whole.

The several subjects of ***functional organismal biology*** form something of a bridge between molecular and cell biology, on one hand, and the population-, community-, and ecosystem-level phenomena studied by most evolutionary biologists and ecologists on the other. As the polar realms of biology have grown, functional organismal biology has tended to wane at Michigan and many other universities. At present, the research of only one of our faculty (Webb, in functional morphology) is focused in these areas, although many faculty address some components of functional organismal biology in their programs (Table 1). No department can expect to develop strength in all the subjects of functional organismal biology, however no EEB department can afford to be entirely lacking in this broad area, even if only to support our research and teaching efforts in other aspects of biodiversity science.

Summary of challenges to faculty research area in EEB: 1) *maintaining our current strong program in evolutionary history of animals and reviving our program in evolutionary history of plants, which has been decimated by retirements*, 2) *addressing* *the dearth of junior faculty in ecology that restricts our expansion into some of the newest exciting parts of this field,* 3) *expanding our strength in evolutionary processes, and* 4) *maintaining a minimum level of expertise in functional organismal biology to cover teaching needs.*

D. The role of the Department of Ecology and Evolutionary Biology within the University

Research in EEB offers a unique perspective among the life science units on campus. Most research in other units takes a highly reductionist approach, studying suborganismal function in largely-isolated components in laboratory settings and using relatively few model systems (e.g., yeast, the nematode worm *C. elegans*, fruit flies, zebra fish, the wild mustard *Arabidopsis*, and the house mouse). Such research has been and will continue to be of enormous value in both understanding basic processes in biological systems and translating that understanding to medicine and biotechnology. However, EEB research on the great range of biological diversity beyond these few model organisms and on how entire organisms function in the complex environments of the natural world are essential complements to such approaches for two reasons.

First, model organisms represent a minute fraction of the diversity of living organisms (e.g., the standard laboratory fruit fly is just one of several million species of insects). Because of the unique evolutionary history and genetic makeup of different groups of organisms, not even the same gene will necessarily function the same way in organisms with different evolutionary histories. A well-known metaphor in evolutionary biology is that of natural selection as a “tinkerer,” altering organisms in ways that are highly contingent on what genetic and phenotypic variations are available at various times in their history. Hence, each species has an evolutionary legacy that affects both its current function and its future evolution. Evolutionary biology seeks to understand the historical relationships of organisms and the processes by which their functions have evolved (and continue to evolve); without such understanding, we simply do not know how to extrapolate from processes studied in model organisms to the rest of the biological world. At every level, from molecular processes and genome structure to brain structure and function, the extraordinary diversity of species presents both instances of broad commonality and profound differences. DNA replication is much the same in all species, and Hox genes may govern the development of the body plan throughout the animal kingdom. However, the model species from which we learn so much cannot tell us how organisms survive extremely cold, hot, dry, saline, or otherwise apparently inhospitable environments; how some species can orient by echolocation, by self-generated electric fields, or by the earth's magnetic field; how some plants can be used to reclaim land ruined by toxic metals, or some bacteria to metabolize great arrays of pollutants. It is only through the study of evolutionary biology and ecology that we can understand the full range of how organisms live on earth. This role is underlined by increasing requests from health and life science researchers for collaborations with evolutionary biologists in our department.

Second, it is an enormously complex matter to scale up an understanding of processes at the molecular and cellular level in highly-controlled laboratory systems to the functioning of entire organisms that are living with diverse other organisms in highly spatially and temporally heterogeneous environments. Just as physics may predict all biological phenomena in principle but not in practice, molecular and cell biology alone cannot predict the physiological, developmental, and behavioral features of organisms, much less the dynamics of their populations or their paths of evolution in response to changing environments. The science of ecology is dedicated to understanding how organisms function and interact in this highly complex world. As an academic discipline, ecology is an enormously challenging and fascinating study and it also has immense practical applications. It is in the complex real world, not the laboratory, that humans must grow their food, obtain their resources for other necessities, and cope with disease and injury. This point is underscored by the increasing collaborations between basic ecology and the applied fields of public health, sustainable agriculture, natural resource management, and conservation.

Because of these complexities of scale and diversity, and because of the broad scope of ecology and evolutionary biology, research in EEB is highly interdisciplinary. This is most obvious within the life sciences, where research occurs along a seamless continuum from studies of the structure and function of molecules to those of entire ecosystems and information and concepts flow in both directions. Thus, EEB has natural bridges to MCDB and to many basic science units in the Schools of Medicine and Public Health, especially in the Departments of Human Genetics, Microbiology and Immunology, and Epidemiology.

A second, perhaps less obvious, continuum is between study of organisms and study of the physical environment. This dimension is based on the many inevitable feedbacks between organisms and their environment. This is now widely recognized in the case of human organisms, who have had drastic effects on the global environment, but is equally important and has a much longer history for all other organisms, starting with the very oxygen we breathe and the soil on which we build. Thus, EEB has important bridges to units in the physical sciences, most importantly Geological Sciences in LS&A and AOSS in the College of Engineering.

A third continuum on which EEB sits is between the natural and social sciences. New fields are emerging that are direct mergers of biodiversity disciplines and social sciences, such as ecological economics and sustainable development policy. Few EEB faculty are actively engaged in such research and this is not our highest priority for expansion, but this interface represents a fertile area for possible future joint appointments with SNRE or with social sciences within LS&A.

Related to all three of the dimensions above, is the relationship between empirical and theoretical research. Mathematical theory is a key element in much of research in ecology and evolution and therefore EEB has important bridges to the Department of Mathematics and the Center for the Study of Complex Systems.

Finally, EEB sits on the key continuum between basic and applied research. While all of our faculty have their major focus on basic research, as is appropriate for an LS&A department, many of us also conduct some research or collaborate with others on applications including agroecology and sustainable development (Vandermeer), noxious gases and “killer lakes” (Kling), global carbon cycle (Kling and Nadelhoffer), invasive species (Lehman, Rathcke, Goldberg), epidemiology (e.g., Pascual’s work on cholera) and even forensics (e.g., Mindell’s phylogenetic work tracing the source of the AIDS virus in a criminal case). This dimension also gives us numerous interactions with other schools in the university, most importantly SNRE, SPH, and, at least currently to a lesser extent, the School of Medicine and the Life Sciences Institute.

Consistent with the multiple dimensions of research in which EEB faculty are involved, faculty with "dry" appointments in EEB have their primary home in two other departments in LS&A (Geological Sciences, Anthropology) and in three other Schools of the University (SNRE, SPH, SOM). In turn, EEB faculty members hold dry appointments in SNRE and Geological Sciences, and hold Faculty Associate appointments in the Center for the Study of Complex Systems (CSCS), the Michigan Consortium on Theoretical Physics, and the Programs in American Culture and in Latin American and Caribbean Studies. EEB faculty participate in the multi-departmental Genetics Training Grant and in the Genome Science Training Grant, and have active research collaborations with faculty in SNRE, CSCS, School of Public Health, School of Education, Geological Sciences, Engineering, Human Genetics, and Cell and Developmental Biology. The Director of the University of Michigan Biological Station is a member of the EEB faculty and a number of our faculty conduct research and/or teach at UMBS during the summer, where they have the further opportunity to collaborate with faculty from other universities.

E. Research funding

Opportunities. A few decades ago, much of ecological and evolutionary research could be conducted on shoestring budgets, using very simple methods. Simple methods and experiments still have a role to play, but they have largely given way to technologically much more sophisticated (and correspondingly more expensive) methods. For example, much of evolutionary biology and, increasingly, parts of ecology, rely on molecular tools such as DNA sequencing. Many ecological studies, especially at the ecosystem level, rely very heavily on chemical analyses of the environment and of organisms and on monitoring of environmental parameters on scales from microclimate to the global atmosphere. Even research that is not equipment-intensive usually requires teams of knowledgeable data collectors to take measurements, set up or take down experiments, process samples, often in remote field sites (cf. the Arctic research programs in NSF). Modestly funded NSF grants often provide about $100,000 per year, representing considerable growth over the last decade or so, and some funding through NIH and other agencies is considerably greater.

Funding opportunities in ecology and evolutionary biology are continuing to increase in quantity and breadth. Major research and funding directions in ecology include spatial and "large scale" ecological patterns and dynamics, ecosystem-level and global processes, and complex dynamics of populations of pathogens and other organisms, owing to interactions with other species and with climatic factors. In addition to NSF, other federal agencies, such as NASA, USDA, NOAA, DOE, and EPA, all support ecological research. The crucial importance of evolutionary biology is seen in the increasing extent to which evolutionary genetics and genomics are supported within NIH, and in NSF programs in areas such as the evolution of developmental mechanisms. Major programs in taxonomic expertise, microbial diversity, biodiversity inventories, and, especially, phylogenetic studies of the tree of life underscore the importance of studying biological diversity as the foundation of ecological and evolutionary understanding. As a major part of evolutionary biology, such programs are largely supported by NSF. Specific programs and funding opportunities are described in *Appendix B.*

Current status. In analysis of research funding and potential by faculty in EEB, it is important to include grants by jointly appointed faculty in the museum units, who usually submit their grants through those units, on the principle that indirect costs should accrue to the unit that provides most physical and administrative facilities. Much of the scholarly interaction and all of the undergraduate and graduate teaching and training by joint EEB-museum unit faculty is done through EEB and our success as a department is inextricably linked with that of these units. Therefore we include data on grants for all faculty, regardless of their fractional appointment in EEB and the unit through which the grant is administered.

Table 2. External funding in Department of Ecology and Evolutionary Biology, including all faculty with joint appointments regardless of the administrative home for the funding. These data come from the DRDA data bases, which do not distinguish between funds allocated to PIs and CO-PIs within the University and which only give total dollar amounts over the duration of the grant. Therefore, these are somewhat of an overestimate of total funds in the department and a considerable overestimate of the annual funds available. The data for the base year include substantial grants involving Jim Teeri administered through UMBS and grants involving Mark Wilson administered through SPH. Their departures at the end of FY01 and FY 02, respectively, are responsible for the apparent slight decline in research funding; in fact, without their contributions, research funding has increased substantially since the base year.

	Research	infrastructure	graduate training	education	TOTAL
FY 01 (Base)	$14,876,205	$663,774	$143,571	$4,583,578	$20,267,128
FY 02	$14,101,877	$902,224	$109,571	$4,676,109	$19,789,781
FY 03	$14,087,553	$1,366,974	$1,623,030	$4,676,109	$21,753,666

The total amount of sponsored research funding of our faculty has not changed substantially since the initiation of the Department (Table 2). Similarly, between 2001 and now, the percentage of tenure-track faculty with substantial external funds for research has remained about 60%. This lack of large change so far in the new Department is not surprising as the total number of faculty has decreased over this period (from 30 in July 01 to 26 in July 03), which also included the departure of two faculty with very substantial grants but minimal appointments in EEB. We also note that almost all of the faculty without major research grants continue to have active research programs, to publish (sometimes prolifically), and to mentor graduate students. Nevertheless, the department is clearly under funded; addressing this is a top priority of the department.

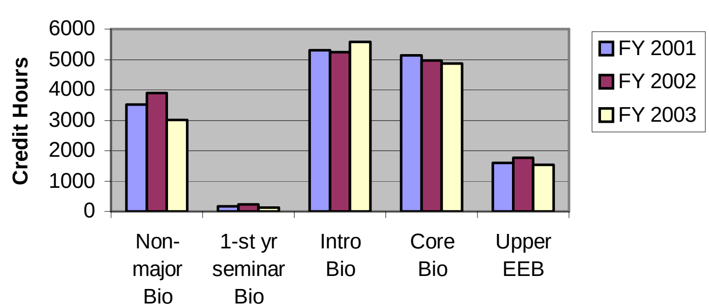
Summary of challenges to external research funding in EEB: 1) *increase research funding rate of faculty in the department and 2) take greater advantage of new initiatives from funding agencies for large, collaborative research programs*. Initiatives to address these challenges are described in *Section V-F*.

F. Undergraduate Teaching and Training

EEB faculty serve three main constituent groups of undergraduates: LS&A students taking distribution courses, students working towards careers in health-related professions and students working towards careers in biology and the environmental sciences. Our courses are, of course, essential to concentrators in the Program in Biology, our major undergraduate program, but, increasingly, also to the Program in the Environment (PitE).

EEB provides most of its teaching in terms of student credit hours via the Program in Biology, that part of the curriculum that preserves the structure from the previous Department of Biology (Fig. 2). When the department was divided, a major concern was maintenance of an undergraduate curriculum that reflects the breadth of modern biology, and the solution was to maintain the "introductory" part of the curriculum as a joint enterprise. The Program in Biology includes 100-level courses for non-majors, first-year seminars, the large Introductory Biology course, and the "core" concentration courses (Fig. 2). The latter include a series of ten 200-level courses from which concentrators must choose one course in EEB areas and one course in MCDB areas, and four 300-level courses that are required for the Biology and General Biology concentrations (Genetics, Biochemistry (two versions), and Evolution) (*Appendix C*). All other courses 300-level and higher are taught in the new departments but serve as electives for the Program in Biology concentrations (Biology, General Biology, and, in planning, Microbiology) and minor (Biology) and for the Program in the Environment concentration. The 400-level courses are also important for graduate students in EEB and other units, especially SNRE and Paleontology students within Geological Sciences. In the sections below, we first describe the current status and challenges for the non-

Fig. 2. Student Credit Hours FY 2001 - 2003 EEB Faculty



concentration courses, then the concentration programs and curriculum (for background, individual courses and recent enrollments are listed in *Appendix D*), and then a series of issues that cut across the curriculum, including undergraduate research, the honors program, pedagogy, scientific communication, field courses and facilities for students, laboratory facilities, and involvement in the Program in the Environment and the Microbiology concentration.

The Curriculum for Non-scientists. The United States citizenry is insufficiently literate about ecology and evolution to make informed decisions about many of the issues facing the country, and ultimately, the world. The ongoing explosion of information on science and technology in the popular press ranges from the environmental effects of human activity to the consequences of manipulating genes. The University of Michigan has responded, in part, to these developments by establishing the Program in the Environment and EEB contributes heavily to this concentration (see below). However, we are also firmly committed to contributing to science literacy within the Biology Program.

To do this, EEB faculty now offer eight 100-level courses for non-concentrators that can be used to satisfy the natural science distribution requirement and that meet our goals of increasing scientific (specifically, biological and environmental) literacy and of providing a basic understanding of the process of critical thinking and scientific discovery. These courses are: *Biology for Non-Scientists, Biology and Human Affairs, Practical Botany, Biology of Human Nutrition, Animal Diversity, Animal Behavior, Global Change,* and *Ecological Knowledge and Environmental Problem Solving* (*Appendix D*). Collectively, these courses are popular (accounting for 3000-4000 student credit hours per year, Fig. *2*). While we would like to increase this amount still further, stabilizing our teaching in core concentration courses (see below) is a higher priority given limited faculty.

While most non-major courses are fairly specific (and, we feel, appropriately so), EEB faculty also offer a general course on Biology for Nonscientists (Bio 100) that consistently enrolls about 200 students. This course has historically not had a laboratory component, but we have agreed with PitE to develop a laboratory course to complement the existing general lecture course so that students on an environmental studies (rather than environmental sciences) track within PitE can use Bio 100 instead of Bio 162 (the introductory course for Biology concentrators) to satisfy one of the core requirements of the Environment concentration. The laboratory course will be taught starting in Fall 2004.

First –year seminars. Although they reach far fewer students than the large lecture classes, the benefits of small classes and the opportunity for close contact with a faculty member need no elaboration. Over the last two years, only one first-year seminar per year has been taught by EEB faculty (although this semester, Fall 03, we have two). *We aim to increase that to at least 3 per year on a regular basis within the next five years.*

Concentrations in Biology and core courses. The Program in Biology offers two concentration programs: Biology (ca. 250-280 graduates /year) and General Biology (25-30 graduates/year), as well as a minor in Biology (ca. 30-35 students/yr) started in 2000.

Starting next year, it will also be the administrative home for the newly-designed cross-college Microbiology concentration.

The Biology Concentration was redesigned in January 1999 and continues to be administered jointly by EEB and MCDB as the Program in Biology (*Appendix C*). This redesign involved two major changes: first a switch from a two semester introductory sequence to a one semester introductory sequence and the addition of a discussion section as well as the existing lab to this course. Second, we shifted the level and content of some courses to produce a set of 200-level "gateway" courses; concentrators are required to take one of 5 possible gateway courses in MCDB areas and one of five possible in EEB areas (see *Appendix C*). The basic motivation was to allow students to take courses beyond introductory biology earlier and to give more structure to the curriculum by more explicitly building upon prior knowledge. The latter has proved to be problematic because we lacked a mechanism to enforce prerequisites and many students simply left the 200-level requirements until their senior year. The new MPathways capability to enforce prerequisites should improve this greatly. The third key component of the concentration did not change with this redesign: all concentrators are required to take three 300-level courses: biochemistry, genetics, and evolution—these and the 200-level gateway courses are grouped as "Biology core courses" in Fig. 2.

Of the required courses for the concentration (all part of the Program in Biology), EEB faculty contribute by teaching half of the basic introductory course (Bio 162), more than half of the gateway courses (one MCDB area course, in microbiology, is actually taught by an EEB faculty member, Paul Dunlap); and by teaching in whole (Evolution) or in part in some years (Biochemistry and Genetics) three of the required 300-level courses. Current enrollment in this group of core courses in biology (excluding Bio 162 and any separate lab courses) is about 5000 student-credit hours each year (Fig. 2).

We have two major challenges in this component of our undergraduate curriculum. First, is to *evaluate the 1999 redesign of the Biology curriculum*: has it been successful in its aims? Are changes needed in course structure, content, or sequencing? If so, what faculty and other resources would be needed? EEB and MCDB have charged a committee to conduct this evaluation and their report is due in winter term 2004.

The second challenge is to *stabilize teaching of our offerings*, especially of the core courses. Given the 9 retirements/departures over the last five years but only 5 hires, and the increased involvement of EEB faculty in administrative roles, we have been shorthanded in covering some of our core teaching. For example, our introductory course in Ecology, taught both fall and winter terms (and spring/summer term at UMBS), was taught by a Lecturer II in winter term last year and will be again this year and probably into the next several years until we hire a new ecologist. This is because Goldberg, the current Chair, had been expected to teach it and all other suitable ecology faculty are involved in other large core courses. Similarly, EEB has not been able to cover its half of Genetics in either term for the last two years, although a new hire, Zhang has begun teaching half of Genetics this term (Fall 03). We will not have another faculty member available for winter term until we fill our evolutionary genetics position (searching currently). Similarly, we only have one faculty member who can teach the EEB component of Animal Physiology even though this course is taught both terms and essential to the concentration.

Upper division curriculum. EEB faculty teach in approximately 20 advanced 300-400 level courses that contribute to the Biology concentration but are listed under EEB (Fig. 2, *Appendix D*). Many of our 400-level courses are also taken by graduate students. In most cases, the mix of graduate and undergraduate is highly stimulating to the undergraduates in these courses but requires constant vigilance to assure that undergraduate needs are carefully considered.

The vast majority of biology concentrators (and non-concentrators who take our core courses) plan to go into the health professions. We are especially concerned that these students receive training in the functioning of entire organisms (physiology, anatomy), the role of interactions between organisms and their environments in human health, and the evolution of disease organisms. As medical sciences are increasingly aware, prevention and treatment of infectious disease cannot focus exclusively at the sub-organismal level but needs to consider the evolutionary and ecological context of disease organisms and their hosts. EEB-taught or co-taught courses particularly important to pre-health professionals include Comparative Anatomy (Biology 252), Animal Physiology (Biology 225), Microbiology (Biology 207)), Parasitology (EEB 341), and a new course, Ecology and Evolution of Infectious Disease (EEB 315).

Beyond ensuring that all biologists know the fundamentals of ecology and evolution, it is essential that the university system produce individuals with skills necessary for professional work in modern biology and in society's efforts to stem environmental degradation and the associated loss of biotic diversity. Our current 300-400 level curriculum includes two groups of courses that address this need. First is a wide array of courses that cover “conceptual areas” cutting across particular ecosystems or groups of organisms, an approach that uses the comparisons between systems and taxa as a tool for discovering generalities, patterns, and underlying principles. Such courses include our sequence in advanced ecology courses (Population Ecology, Community Ecology, and Ecosystem ecology, Plant-animal Interactions) and advanced evolution courses (Population and Quantitative Genetics, Phylogenetic Systematics, Molecular Systematics).

Although we have been able so far to maintain coverage of the most basic conceptual areas in ecology and evolution, *our greatest challenge in the upper division section of the curriculum is to fill in a number of conspicuous gaps*. These fall into two groups. First are core courses in fields that are well established but rapidly evolving as a result of new technologies. These have been taught in the past by faculty who have either left or retired and include, most conspicuously, physiological ecology and evolutionary ecology; these are particularly important because they bridge the sub-disciplines in EEB (ecology and organismic function in the former case, and ecology and evolution in the latter). Second are courses in areas that have developed or expanded only in the last ten years or so; these include Biodiversity Informatics, Landscape and Spatial Ecology, Macroecology, Evolution of Development, Metazoan-Microbial Symbioses, Microbial Ecology, Evolutionary Genomics, and Ecology of Infectious Diseases (at a more advanced level than the one new course we have developed). Our mission of providing cutting-edge excellence in training to our large number of concentrators is dependent on such courses being offered.

The curriculum also includes courses that teach students about the details of certain ecosystems (e.g., Oceanography, Limnology (=fresh water systems) or groups of organisms (e.g., algae, flowering plants, mammals, fishes). Other ecosystems, notably forest ecology and soil ecology, are taught in PitE and cross-listed in EEB. Such detailed knowledge is essential whether students go on to work directly in environmental fields or go to graduate school. These courses typically integrate across the conceptual areas we described earlier, with a focus on how basic concepts in ecology, evolution, and organismal function apply to particular groups or ecosystems. Because of the EEB-associated Museum units, we maintain an exceptionally thorough educational coverage of the biodiversity of the earth, approached in similar breadth and depth only by a few other institutions (most notably, UC Berkeley and Harvard). Our most important gaps in recent years have been in entomology (insects) and in flowering plants—the two most important of all groups in terms of their diversity, their roles in ecosystem function, and economic impact. Two recent hires have started teaching courses in basic insect biology (EEB 442, Knowles) and plant biology (Biology 230, Qiu) but we do not yet have the capability to teach the evolutionary history and relationships within these groups after the retirements of the last five years. Given that these are the most important organisms worldwide in ecosystem functions and in agriculture and therefore sustainable development, this expertise remains a serious gap for both EEB and PitE-oriented undergraduates, as well as our graduate program.

Undergraduate research. We view undergraduate involvement in research as one of the most important experiences of an undergraduate program and most faculty are involved in such efforts through multiple means. First, many of our courses at all levels involve some research experience. For example, the Biology 100 non-major's course requires students to research a topic in biology, develop a poster, and present that poster at an evening session to which all the faculty of the department are invited. Biology 282 (ecology laboratory) requires an independent study project involving original field data collection and both oral and written reports on the results. Many of our 400-level courses (e.g., EEB 484, 481) involve more substantial independent research efforts and some of these end up as publications in peer-reviewed journals. Second, we offer undergraduate research experiences through the UROP program (ca. 5-10 students per year), through independent study courses (EEB 300 and 400, involving 30-40 students per year), and as research assistants to faculty (ca. 30 students per year). Thus, on average, our faculty have slightly over one student conducting research for credit and one student research assistant. This can and should be increased somewhat (especially the UROP program), although we do want to maintain the heavy involvement of faculty in many of these research experiences, rather than have supervision done largely by graduate students or postdoctoral fellows.

Honors in Biology. The number of students in the Biology Honors program has dropped precipitously in recent years, in response, we think, to changes that were implemented in 1998 in an attempt to increase the rigor of the program but that ended up being quite restrictive. After the Biology Program was initiated, these restrictions were retracted and the honors program is now much more flexible. However, the word is clearly not getting to potential Honors students (only 15 students in Biology Honors as of Fall 2003). We intend to remedy this by having faculty sign up as prospective mentors and to make that list available to the students through the Biology Program office as well as in individual counseling sessions. In addition, we will encourage Biology counselors to talk up the honors track and the new procedures.

Pedagogy. A number of EEB faculty have obtained major external funding for incorporating new pedagogical techniques into their courses. Professor Kling, as part of the Global Change Program has received two NSF grants for developing innovations in undergraduate education, and currently has a Hewlett Foundation grant to continue these advances, especially in the area of evaluation of teaching goals and success (done in conjunction with the U-M School of Education). Professor Myers has obtained major funding from a variety of sources (including NSF in collaboration with School of Education faculty) to develop the Animal Diversity Web (http://animaldiversity.ummz.umich.edu/) for inquiry-based learning both for college courses and K12 education. Professor Fink has greatly increased the use of creative visualization techniques and inquiry-based laboratories in teaching comparative anatomy. Faculty in many of our courses use Powerpoint presentations for lectures, and these are often made available online. Nonetheless, the majority of our courses still are in standard lecture format, with direct student participation mostly taking place in separate sections taught by GSI's. Pedagogical research has made it very clear that use of more active learning techniques improves engagement and enthusiasm about the material and often also improves retention of material. We address this absolutely critical *challenge of improving our pedagogy by adding more active learning and appropriate technological innovation to our classes in Section V-G.*

Scientific communication. The ability to communicate scientific ideas effectively is, of course, a critical goal for our students, both concentrators and non-concentrators. A majority of our upper division courses include a substantial writing component (e.g., regular laboratory reports, periodic essays and/or term papers and oral presentations). However, the faculty and GSIs in these courses now do not have the time or training to incorporate more writing pedagogy into these courses and thus to allow these courses to fulfill the LS&A upper division writing requirement. Until 2001, the Department of Biology had a single course, *Writing for Biologists*, that focused explicitly on developing communication skills in biology and it did fulfill the upper-division writing requirement. In 2001, the two new departments decided to develop separate plans for incorporating writing into our curricula. During the first two years of EEB, the spate of retirements and the relatively slow pace of new faculty arriving on campus and picking up their full teaching efforts made it impossible to plan and staff new efforts in writing. However, over the last year, we have been talking with the Sweetland Writing Center about improving this aspect of our program and increasing opportunities to satisfy the LS&A

upper level writing requirement within EEB. We address this *challenge in improving our teaching of scientific communication in Section V-G.*

Field courses. Both ecology and evolutionary biology are heavily field-oriented and therefore teaching and training of students must involve substantial field experience. This is difficult to achieve during the academic year on campus, although the Matthaei Botanical Gardens, the E.S. George Reserve, and other nearby university properties enable at least a minimal level of field work in some courses during fall terms (e.g., the laboratory sections of Biology 102 and 282 are taught entirely at Matthaei; EEB 477 has been taught entirely at E.S. George Reserve and the Patterson Lake Facility). Buses to Matthaei and other field sites have been supplied by the University and we hope to continue at least this level of field course activity during the fall.

Nevertheless, most field experiences by our undergraduates are either through the University of Michigan Biological Station (UMBS) or through individual research experiences with faculty. UMBS field courses provide small-group, intensive and problem-oriented classes, both as a substitute for the much larger versions of core courses on campus (introductory level Ecology and Evolution courses) and to provide education in particular ecosystems and taxonomic groups so that students gain the expertise needed to actually work with those groups. We strongly encourage all Biology concentrators to spend a summer at The University of Michigan Biological Station (UMBS) in Pellston—currently 40-45 of our concentrators do exactly that each year. In recent years, enrollment in UMBS courses has dropped, as it has in other such programs around the country. Professor Knute Nadelhoffer, the new Director of UMBS, has as a priority the revitalization of the undergraduate curriculum there, and we plan a much greater integration of EEB and UMBS courses in the coming years than has been true in the past by involving the EEB curriculum committee in annual discussions of UMBS curriculum.

Laboratory facilities. "Laboratory" experiences are often the most active part of learning in science courses. Teaching in EEB disciplines requires laboratory facilities as well as field sites and facilities. Courses that focus on biological diversity (at least of macroscopic organisms) usually do not require highly sophisticated technical equipment (other than microscopes) but do have specialized needs for storing and displaying specimens and for culturing and observing live specimens. Other courses require highly sophisticated technology for chemical and molecular analyses (e.g., Limnology, planned courses in molecular phylogenetics) and /or computer labs (e.g., Population Dynamics and Ecology; Comparative Anatomy).

EEB offers a total of 23 laboratory courses, either as participants in the Program in Biology or in EEB higher level courses; 7 of these are taught only at UMBS. Annually, about 850 students take the EEB-taught laboratory courses taught on campus (excluding Introductory Biology, which is taught in 3 laboratory classrooms in "old" Chemistry).

The main EEB laboratory teaching facilities are 4 classrooms in the old Chemistry building and 3 classrooms in the Kraus building. However, two of the latter are completely inadequate for current needs. One classroom on the third floor is problematic because it is actually two quite small rooms connected by a narrow hallway making it very difficult to teach effectively with one instructor. Room 1023, which is attached to the greenhouse on the south side of Kraus, is arguably the single worst laboratory classroom in LS&A; discussions are currently underway on renovation of this room. Laboratory classes are also currently taught in one room in the Ruthven building, although this room is needed for collection space in the near future. Two other laboratory classes (Ecology, *Biology 282*, and Practical Botany, *Biology 102*) are taught at the Matthaei Botanical Gardens because of their routine need of field sites and greenhouse space. Finally, we make substantial use of the Science Learning Center in the Chemistry Building for particular sessions of laboratory courses that require computers. All available laboratory space, adequate and inadequate, is currently fully occupied. Therefore, we have no space to put any new courses we would like to develop (e.g., the new laboratory course to be associated with *Biology 100*, as needed for the Program in the Environment concentration, and courses to be developed by our new faculty in new research areas). However, the construction of the new Undergraduate Science Building (USB), due to open in September 2005, gives us substantial opportunities to meet this *challenge of insufficient and inadequate laboratory teaching space as discussed in Section V-G.*

Involvement with Program in the Environment (PitE). Our courses are an integral part of the new LS&A/SNRE concentration in the Environment. In fact, more courses from Biology (almost all taught by EEB faculty) are included in the requirements and recommendations for PitE then from any other LS&A department. A representative of EEB serves on the advisory board of the program and the chair of EEB consults regularly with the Director of the Program. We also expect increased enrollments in EEB course offerings at the University of Michigan Biological Station (UMBS) as PitE students will have the option of fulfilling their *Field Experience* requirement by taking courses in residence at UMBS. In the first two years of PitE, 7 and then 13 concentrators took courses at UMBS during the summer; we expect this number to rise considerably as students who declared a PiteE concentration in their early years take more upper division courses and as the total number of PitE concentrators continues to grow (now at 96, with 28 minors). During Fall 2003, a total of 29 PitE concentrators were enrolled in Biology or EEB courses on campus.

Involvement with the Microbiology Concentration. Over the last year, a committee formed by the Provost's Office has been investigating re-establishing a cross-college concentration program in microbiology; the concentration requirements and curriculum have now been decided and final budget arrangements are being discussed. EEB teaches some essential components of this new concentration, including half of Introductory Biology, all of Microbiology (both required of all concentrators) and two of the seven courses that satisfy the requirement for a core basic biology course (Microbial Diversity, *EEB 4XX* (proposal submitted to the LS&A curriculum committee), and Ecology and Evolution of Infectious Disease, *EEB 315*). The microbiology concentration planning committee has also stated that a 400-level Microbial Ecology course is needed; we agree, but while this research area is in our hiring plan (see below), it will likely be several years before we can commit to teaching this course.

Summary of challenges to undergraduate education in EEB. The discussion above describes seven major issues of concern for our undergraduate programs: 1) *increase offerings to non-science concentrators and first-year students,* 2) *evaluate introductory and core courses of the concentration and modify if needed,* 3) *improve pedagogy,* 4) *improve scientific communication skills,* 5) *stabilize teaching participation in core courses,* 6) *fill in major gaps in upper division curriculum,* 7) *renovate and expand teaching laboratory space.* We address these challenges below in *Section V-G.*

G. Graduate Training

The great majority of our graduate students are in the Ph.D. program and the descriptions below of the graduate program refer to these students, unless the masters program is explicitly mentioned.

Current status. As of September 2003, 67 students were in the EEB Ph. D. program, including 31 women and 36 men. One U.S. student is a member of an underrepresented minority group, and 13 are international students. The total numbers in successive year-classes are 10 (first-year), 12, 12, 7, 7, and 9; 16 students have been here more than six years. Of the 48 EEB-oriented students who have finished their degree in the last five years, the median time to completion of the Ph. D. was 6.8 years, and the mean time 7.3 years. Six students are currently enrolled in the Master's program.

Our students are highly qualified in terms of their numerical records (GRE mean scores of 2100 for combined verbal, quantitative, and analytic tests and grade point averages of ca. 3.55 over the last five years) and, even more importantly, in the letters of recommendation and the records of accomplishment, including previous publications, they bring to our program.

Recruiting. In 2002-3, we received 90 applications to the Ph. D. program, slightly fewer than has been typical in recent years. Of the 90 applicants, 55 were domestic and 35 were foreign applicants.

As is typical of most elite graduate programs, we attract applicants based on the reputation of the program and of individual faculty members. In addition, for many students of evolution and systematics, the collections of the Museum of Zoology and the Herbarium and the expertise of the curators on various groups of organisms are a major reason for coming to Michigan. Domestic applicants we anticipate admitting are invited to visit the department, with most expenses covered by the department. For the last two years, most such applicants have visited during a "recruitment weekend" in which almost all faculty and older graduate students participated. International applicants we anticipate admitting are called by a faculty member who is not the potential mentor for a preliminary screening on English proficiency and later by the potential advisor for a phone interview.

We make offers to about 25% of applicants overall and about half of these offers of admission to the Ph. D. program are accepted. Twelve to 14 students have been admitted annually to the Ph.D. program over the last 5-10 years. Under the full-funding plan for graduate support that came into effect in AY 2002-3 (see below), we expect to admit 12 students on average (but see below).

Graduate student diversity: Because our entering class of Ph.D. students has been about 50% female for the last 10 years or so, the Department's efforts to enhance the diversity of the pool of applicants have focused on underrepresented minorities. Our subject area attracts very few applicants from underrepresented minority groups, and we only have one at this time. In our first year as a department, we sent a representative with the Rackham delegation to four recruiting fairs at schools with large minority populations; this effort was unsuccessful and, we felt, rather inefficient. Last year, we developed a new EEB departmental brochure and distributed it to a list of institutions having programs in biological sciences with a large percentage of underrepresented minorities. Further efforts are described in *V-G*.

While recruitment of women into the program has been equitable, retention of women in the Ph.D. program has been significantly lower than that of men and the time-to-degree of students who do finish has been longer by 0.75 years on average over the last five years and 1.5 years longer for graduates during the last year. A series of focus groups and individual interviews with current and past EEB graduate students conducted by ADVANCE staff in Fall 2002 suggested, not surprisingly, that one of the key causes of differential retention for women was the perception that it is impossible to have a balanced family life and be successful in academia, fueled in part by the relatively few women faculty in the department. Increasing the proportion of woman faculty will certainly help with this issue, as will more explicit discussion of the balance between work and family within the department. The reasons for longer time to degree for women are less clear (although apparently also true nationally); because relatively few women students in our program have children at this stage of their careers, this is unlikely to be a major cause.

Goals of graduate training. The goal of the EEB Ph.D. program is to train independent scientists for positions in research- or teaching-oriented universities and colleges, research museums, governmental or independent research agencies, and other such institutions. Ideally, our students will acquire knowledge of the subject matter of our area and the ability to devise and carry out independent research (including design and data analysis), to find and obtain research support, and to communicate effectively, verbally and in writing. They should also acquire the ability to teach effectively, as well as self-confidence and a sense of membership in the community of their scientific peers. Career goals vary among students, and these differences are respected. Although all faculty advisors have similar aspirations in student training, methods differ. Some feel the goals can best be achieved by acting as resources for students who they encourage to be highly independent, while others work much more closely with their students, and play a larger part in shaping their dissertation research. Relatively few of our faculty follow an apprenticeship model, with students working almost entirely on aspects of their advisor's research program with general directions set by existing grants.

Current positions of past graduates. Many of our students take positions in leading universities in our fields (e.g., University of Arizona, University of California-Berkeley, University of California-Irvine, University of Kansas, Michigan State University, Yale University) and in the major research museums in the country (e.g., at American Museum of Natural History, Florida State Museum, Los Angeles County Museum, Philadelphia Academy of Natural Sciences). Because of our ability to train students in curation (in part through GSRA's in the museum units), the qualifications of our students for curatorial positions are virtually unmatched. The great majority of our students find academic or other positions in the fields in which they were trained.

The graduate training program. *Appendix E* describes the Ph.D. policies and procedures. We expect our students to complete a qualification exam by their third term, achieve candidacy with a complete dissertation proposal by their fourth term, and complete and defend a dissertation by the end of five years. While the great majority of our students now meet the first two deadlines, our average time to degree remains longer than 5 years (6.0 years for students completing their Ph.D. in AY 2003). However, the students finishing now (and for the next 2-3 years) are those who have been funded almost entirely on GSI's and without guarantees of summer support. Before candidacy, students are advised by an initial advisor and co-advisor, chosen by the student, and the progress of each student is discussed by the entire faculty at an annual meeting. After candidacy, students meet with their committee at least once a year, with a required report submitted to the Graduate Affairs Committee.

All EEB students are expected, in principle, to acquire a strong background in all four biodiversity disciplines, although a student typically concentrates in one of these areas. To help students achieve this goal, this year, we are instituting two new courses to provide an advanced-level overview of these disciplines, Principles of Evolution (covering both evolutionary processes and evolutionary history) and Principles of Ecology. (Unfortunately, we do not currently have the faculty expertise to have a similar core graduate-level course in functional organismal biology.) These courses are not required, to allow some flexibility for our diverse student population, but almost all of our new students (and many older students) are enrolled in these courses. Most students also take some of our more specific courses within these broad disciplines, plus courses in other units in areas such as statistical methods.

To prepare our students for teaching as a component of their career, we require all our students to act as a Graduate Student Instructor for at least one year and offer an extensive GSI training program before and during the fall term each year; the program is run under the auspices of the Program in Biology and shared with MCDB. First-time GSIs attend a series of evening seminars and workshops to prepare them to teach. Early sessions tackle first day issues, course policies and lesson planning; later sessions address more subtle subjects such as grading, learning styles, and professional responsibilities. Two observations and mid-semester feedback from students are incorporated into the training program. Overall, the philosophy is learn by doing.

EEB students tend to be highly dedicated and effective teachers—we regularly nominate students for Rackham's Outstanding GSI Award and in many years have had 2 of our students win out of only 20-25 awarded throughout the entire University each year.

Nature of graduate student research. The dissertation research undertaken by most graduate students in ecology and evolutionary biology, both in our department and on other American campuses, differs in important respects from that of most Ph.D. students in molecular biology and many other fields in the natural sciences.

First, although some students devise research projects very closely related to, or even derived from, their advisor's research program, the culture of American ecology and evolutionary biology strongly encourages independence at the graduate student stage, to a considerably greater extent than is common in some other fields of biology. At Michigan and elsewhere, most students devise their own project, which can be quite independent of the advisor's research, although usually thematically related to the advisor's interests. This cultural emphasis unquestionably fosters the maturation of students into independent scientists, who have been challenged to exercise their imagination, creativity, and ability to learn techniques and analytical approaches that their advisor may know little about. There are tradeoffs, though, the most salient of which are that the student's research often cannot be supported by the advisor's grant, and that the student, exploring *terra* that is somewhat *incognita* to the advisor, may experience obstacles that require effort, imagination, and especially time to surmount or circumvent.

A second distinction of graduate student research in ecology and evolutionary biology is that it frequently involves field work and/or "non-model" organisms, the biology of which is only moderately, or sometimes very poorly, known. This contrasts enormously with the situation faced by a student who uses laboratory cultures of yeast or another model organism, with well understood properties, dependable behavior in a constant environment, and well-established protocols. However, much of ecological and evolutionary research has meaning only if conducted in the field, and important conceptual questions may require that the fieldwork be in diverse environments, often distant, and sometimes under trying conditions. Likewise, many students choose to study particular non-model organisms because they have qualities particularly apt for addressing certain conceptual questions or because their biology should be better known. Fieldwork and studies of non-model species pose special problems that often depend on the system. Weather, predators, vandals, and many other unforeseen events can cause setbacks; the results of an experiment may depend on site or time of year, requiring more replication than the student had expected; the species may have quirks of behavior or life history that the student needs to understand (or to discover) before meaningful data can be obtained. An advisor can caution a student to anticipate such problems, but the problems nonetheless need solution that may entail trial and time.

The consequences of these aspects of dissertation research in our fields are twofold: first, in some cases, the time to the Ph.D. may be unavoidably extended beyond the expected five years; funding this extra time was a major problem under the former graduate funding model but has become much more manageable with the new full funding package described in the next section. Second, in addition to the need for stipends, graduate students often need significant funding to carry out their research that cannot be met from their advisor's grants, which are often on a different topic. Our graduate students become proficient at finding and applying to a remarkable variety of funding agencies and we strongly encourage and support these efforts. We also hold internal competitions to distribute endowment funds (ca.$50-60,000/yr) and Rackham block grants ($25-30,000/yr) for research support and for summer funding for students not on the full-funding package.

Graduate student support. As part of the Department of Biology, most graduate students in the EEB program were supported as GSI's, with an academic-year stipend considerably lower than the norm at some competing institutions. Summer support was inadequate, although we used our annual block grant awards from Rackham and much of our endowment support for competitively-awarded summer stipends. Only about 5% of students in their first five years were typically supported as GSRA's on faculty research grants, while a much higher proportion (50%) of students in their 6th or 7th year were supported in this way. The high cost of tuition, especially for pre-candidates, has made it difficult to increase this number. Given typical NSF funding in our fields of ca. $100,000 per year of total (direct + indirect) costs—supporting a single pre-candidate GSRA for a year would use about 75% of such a grant. Even supporting a single candidate GSRA uses almost half of a typical NSF grant for a 12-month appointment.

When the Biology department was divided, the College, recognizing that the low stipend severely compromised Michigan's ability to attract outstanding students, made a commitment to both new departments of a competitive funding package, beginning with the AY 2002-3 entering cohort of students. The plan provides that 12 new students per year will receive a twelve-month stipend of $20,000 plus benefits and tuition with support as follows:

Year in program	Fall	Winter
1	GSI	GSI
2	Fellowship	Fellowship
3	GSI	GSI
4	GSI	Fellowship
5	GSRA	GSRA

The fellowship support was assumed to be in the form of Regents, Rackham Merit, Rackham One-term, and Rackham Dissertation fellowships, as well as incremental funds through LS&A. GSRA's will include positions supported by faculty research funds and college-funded positions in the Museum of Zoology used for assistance to the curators and to train students in curation. The graduate funding package is part of the Provost's and College's initiative to transform Biology at the University of Michigan.

Funding limitations. As the department has implemented the full-funding package, several critical issues have come up concerning both how this package is financed over the long-term and, in the short-term, how the package for new students has changed the funds available for older students who entered before the new department. Although discussions with Rackham are not complete, it is likely that that insufficient funds will be available to maintain the package in its current form for the target 12 students per year. In addition, the complications of the funding package from LS&A and changes in Rackham funding have made it difficult to even maintain funding of our older students at their previous level; the resulting strong inequities have understandably led to some resentments between cohorts in the program.

In addition, even twelve students per year is too few for a critical mass in a department of our size and nature. This is especially important for new faculty who are developing their research program and who do so with the help of graduate students. Including only current faculty, authorized positions, and the replacements of retirees guaranteed under the original commitment from then Dean Neuman, we would have 35 faculty, or an average of 1.7 students/faculty at steady state of 60 students total. The incremental positions we are requesting would bring this to an average of <1.5 students/faculty. While no quantitative data are available, based on the many seminar visits our faculty make to peer departments, a more typical number is 2-4 Ph.D. students per faculty in our field.

In *Section V-H*, we discuss possible changes in the form of our graduate funding plan and in the number of students we target.

Summary of challenges in graduate program. 1) *shorten the time to candidacy and to degree for all students, although we do insist that some students will need more than five years because of the nature of their research,* 2) *eliminate the differential in retention and time to degree between male and female graduate students,* 3) *increase the number of graduate students entering each year so that new faculty can develop their research programs more fully, and* 4) *stabilize funding for graduate students*.

H. Governance and procedures

By-Laws. The rules of governance of the Department of Ecology and Evolutionary Biology set guidelines for the administration of the department, including obligations of the Chair, Associate Chairs and faculty. The rules of governance also provide for the election of the Executive Committee and standing committees, and for formation of *ad hoc* committees at the Chair's discretion. All committees except those having to do with faculty tenure and promotion have graduate student members elected by the graduate student body and with full voting rights.

There are currently two Associate Chairs, one for research and facilities and one for undergraduate curriculum. The latter also serves as the co-Director of the Program in Biology, along with the parallel associate chair from MCDB. The Associate Chair for Research and Facilities will have an increasingly heavy load as we begin the detailed planning process for renovation of Ruthven and Kraus. The current governance and committee structure in the Department works very well with one important exception: we now have two separate committees with different committee chairs that deal with graduate student affairs, one on admissions and one that oversees all activities after students arrive to the Department. This has turned out to be a very heavy load for the chair of the latter committee, as well as somewhat inefficient as we have increased the coordination of the work of these two committees. We propose to merge these two committees and raise the status of the joint chair of these committees to an Associate Chair of Graduate Studies. Support from the college for a third Associate Chair (currently one summer ninth or equivalent amount of teaching release for each associate chair) would enable this new Associate Chair to devote more effort to overseeing our graduate program and ensure the success of the initiatives we propose (see *Section V-H*).

The Chair, Associate Chairs and Key Administrator meet together weekly to ensure full communication and efficient operation on all important issues in the department.

Departmental procedures. At its initiation, the department formulated new procedures for mentoring of junior faculty, tenure and promotion, appointing and evaluating research scientists, and equitable distribution of teaching effort. All procedures are explicit about how they apply to faculty with joint appointments in the Museum of Zoology and the Herbarium and those units have independently approved these procedures for their joint faculty with EEB. These procedures are all working smoothly, with the possible exception of the junior faculty mentoring procedures. Currently, the chair discusses possible mentors with each new junior faculty member on their arrival and then assigns a senior faculty member as mentor. The intensity and frequency of interaction between mentor and “mentee” is then left entirely up to the faculty involved and is variable among our faculty. Follow-up occurs during the junior faculty member’s annual meetings with the Promotion and Merit Committee and then with the Chair. While we do not feel that it is necessary or desirable to impose a more rigid structure on this relationship, we do need to encourage more interaction. To this end, we will suggest at least a monthly lunch meeting between “mentee” and mentor, to be paid for by the department.

Departmental climate and interactions: The formal organization and procedures described above do not fully capture the functioning of the EEB department. It is important to note some informal aspects and activities that are critical for maintaining unity and the kind of intellectual and collegial atmosphere that we believe is essential in a properly functioning department.

One crucial aspect is a conscious effort, to which all members of the Department contribute, to maintain unity and communication between faculty in the Kraus Building and in the museum units (Museum of Zoology and Herbarium). It is understood that faculty committees will include representatives from both groups, and the ballot for candidates for the Executive Committee is structured to assure such representation. Likewise, departmental functions such as faculty meetings and the "EEB Lunch" (a weekly seminar meeting, usually with EEB faculty or graduate students as speaker) are held alternately in the Kraus and Ruthven buildings.

Faculty meetings are called on all matters of general concern, such as faculty development, prospective appointments, and proposed changes in department policies. An annual retreat for the entire department is held at the Biological Station in Pellston, at which extensive discussion of directions and possible initiatives occurs. The proposals in this document for faculty development are based on several meetings of major groups of faculty, followed by long discussions in a series of meetings of the faculty as a whole. The departmental culture, which is characteristic of our field almost everywhere, views the department as a *demos*, in which important decisions are arrived at by democratic procedures.

Departmental unity, mutual respect, and intellectual interchange within the department are fostered by formal and informal activities that provide opportunities for interaction among faculty and graduate students. These include the EEB Lunch mentioned earlier, Museum and Kraus coffee hours, seminars by visiting speakers and receptions for the speakers, and numerous ongoing discussion groups (e.g., on plant/animal interactions, or phylogenetic methods).

Summary of challenges in faculty governance and departmental climate: 1) *improve mentoring of junior faculty by more incentives for interaction with mentors and by closer monitoring by the Chair and the Promotions and Merit Committee*, 2) *improve coordination of graduate program by appointing an Associate Chair for Graduate Studies*.

I. Staff support

We currently have 9 staff members in EEB and 11 shared with MCDB. In addition, the Herbarium and Museum have staff who support faculty in those units for many aspects of their work. The EEB staff handles all of the administrative aspects of the department, including financial, personnel, sponsored research submission and administration, travel, seminar series, computing, photography, and graphics. The EEB graduate program is also coordinated by the EEB staff. The shared Biology staff work mainly in the undergraduate Biology program, with 3 staff handling all administration and secretarial support for the program (including all GSI assignments and paperwork for both Departments as well as the Program) and 4 staff providing technical support to the laboratory courses. In addition, two shared staff members handle facilities and maintenance in Kraus and one shared staff member handles safety, purchasing, shipping and receiving for the two Biology departments. The current staffing level of both the EEB staff and the shared staff appear to be adequate at this time.

The EEB, UMMZ, and Herbarium staff cooperate routinely, especially on grants administration, with the business manager and grants administrator in EEB often providing assistance in preparation and submission of grants for faculty with joint appointments in one of the museum units. The staff of the three units also now routinely provide backup when one of the units is short-handed, for example, due to medical emergencies.

J. Space and facilities

Research and training in EEB requires individual laboratory facilities, common equipment facilities for molecular (DNA) and chemical analyses, computing, collections of specimens for reference and resource material, animal care and plant growth facilities, and access to field sites. In this section, we describe the major facilities we use on and off campus and any current limitations.

Laboratory and office space for faculty and students

The 27 EEB tenure-track faculty and their graduate students, postdocs and laboratory personnel are distributed among four buildings: Kraus (15), Ruthven (10), Dana (1) and the temporary Herbarium facility on Varsity Drive (1, who will retire in December 2003). Kraus is shared with MCDB and Ruthven is shared with the Museums of Anthropology and Paleontology (including one EEB faculty member) and with the Exhibit Museum of Natural History. Limitations on the amount of space, the quality of current space, and, the way in which the faculty are distributed over space are all highly significant impediments to faculty productivity and to recruiting the best new faculty.

<u>Quantity of space</u>: Because the Herbarium facility is meant to be temporary and is at an impossible distance for routine interactions with undergraduate and graduate students, no faculty laboratories have been or are planned to be built there. Therefore, all new EEB faculty with joint appointments in the Herbarium (two already authorized, one additional one approved this year, funded by the Wehmeyer endowment), must be fit into the already limited space in Kraus (although they will, of course, also have office and collection space at the Herbarium). Two other positions already authorized (in evolutionary genetics and evolutionary ecology) are 1.0 FTE in EEB and will be housed in Kraus. By the agreement of LS&A to transform some classrooms in Kraus to EEB laboratories, some consolidation of existing EEB space in Kraus, and assigning smaller laboratories than are optimal, we can provide space for all of these already authorized positions and for replacement of any current faculty in Kraus who retire. This is the absolute limit for housing faculty in Kraus and therefore the incremental positions we request and any special recruiting we do to increase diversity in the department will require new space. The situation in Ruthven is similarly near its limit. Although we are not requesting any incremental positions jointly with the Museum of Zoology, incremental space is necessary because retiring faculty rarely used molecular tools and focused much of their research activities in the collections themselves and at field sites. The new faculty we hire to be housed in Ruthven will inevitably use molecular tools as well as the collections and field sites and thus require more extensive and sophisticated laboratory facilities than previous faculty, while having similar access to the collections, animal care facilities, and field sites.

<u>Quality of space:</u> Ruthven and Kraus are recognized, along with Frieze (which does not house natural scientists), as the buildings in LS&A most in need of drastic renovation. External reports commissioned by LS&A in 2001 and 2002 conclude that in their current state they cannot support modern science laboratories. Some of these problems can be dealt with by major renovation (e.g., electrical infrastructure) but others are intractable given the age of the buildings, including weight-bearing limits and lack of head space between floors for adequate air-handling. The Kraus report further concluded that complete renovation of Kraus could do no better than an upgrade to 1995 levels of science laboratories and thus would be 15 years out of date by completion. The central

administration of the University has recognized these limitations by initiating planning for a new building for MCDB, which shares Kraus with EEB. This need for improved space is no less urgent for EEB, whose faculty increasingly use molecular tools and chemical analyses to address questions in both ecology and evolutionary biology.

Distribution of space: The third key challenge in terms of our physical facilities is our dispersal across and even off campus. Most critical is the location of the Herbarium off campus—this is disastrous for the incorporation of the collections into our teaching and graduate training and for the research programs of faculty we hire jointly with the Herbarium. Housing these faculty on campus and a considerable distance from the collections is a major problem for the research programs of these faculty and, we already know from efforts over the last several years, a critical stumbling block in recruiting. On the other hand, these faculty play a central role in teaching undergraduates and graduate students and in the overall intellectual life of both the Department and the Museum of Zoology on campus, and it is obvious this role could not be fulfilled adequately by having their major office and laboratory off campus. Thus, we have no choice but to house new Herbarium faculty in Kraus at present, but recruiting and retaining outstanding faculty will depend critically on a long-term plan to bring the Herbarium back to campus. Recruiting a joint Director of the Herbarium and the Museum of Zoology, as we all agree is the ideal intellectually because of the commonality of research questions and approaches, will also be greatly facilitated by having those units co-located or, at least, an explicit commitment to having them co-located in the near future.

As we have reiterated throughout this plan, the long-term success of EEB depends critically on intellectual integration across all the fields of ecology and evolution and on cooperation in teaching and graduate training. Therefore, we view it as absolutely essential that all the faculty of EEB, those with 1.0 FTEs in the Department and those jointly appointed with the Museum of Zoology, the Herbarium, and the Museum of Paleontology, eventually be in the same building with each other and with the collections. The interactions among faculty and students that take place by daily meetings in the hall and the mailroom, or the easy visiting between offices and laboratories simply cannot be duplicated by any formal mechanisms of interaction imposed on inhabitants of different buildings.

In the final section of this plan, we describe briefly a vision of how this integration could be achieved. A more detailed version of this plan is in preparation as a joint project of EEB, UMMZ, and the Herbarium and will be submitted to the College by January.

General facilities: on campus

DNA core facility on the medical school campus. LS&A currently covers a subsidy of $35,000 per year for use by EEB faculty of the DNA core facility in the medical school, which results in considerably lower costs of DNA sequencing. This has meant we have not needed to purchase sequencers for most of our new hires, even as common departmental equipment, resulting in considerable savings for the College. Thus it is essential that this subsidy be continued at this minimum level. This subsidy has already had positive effects on faculty recruitment and retention, as well as facilitating research efforts.

Genome Diversity Laboratory (UMMZ) and Herbarium Laboratory: The UMMZ houses a general laboratory for DNA work, that is designed to enable use of molecular tools by graduate students of faculty (and the faculty themselves) who have not had these tools as part of their long-term research programs and therefore do not have facilities for such work. The temporary Herbarium facility has a similar laboratory that is used by students doing DNA work in plants and fungi; the latter in particular can be a source of contaminants so that it has been necessary to have a separate facility. The Herbarium laboratory has adequate space and basic facilities, but its distance makes it impractical for many students.

Animal care facilities: In Kraus, MCDB supervises the animal care facilities and EEB faculty have access on the same basis as MCDB faculty. In Ruthven, the aquarium facility has been decommissioned pending renovation and the insect facility has been reduced in size to accommodate new faculty and is now too small for experimental work on live animals.

Growth chambers: Growth chambers are an important resource for experiments under controlled conditions with plants and with small animals such as insects and plankton. While many faculty have small chambers in their laboratories, access to walk-in chambers for larger-scale experiments is very limited--EEB currently has five chambers in a common equipment room in Kraus; these are quite old, relatively small, and break down frequently (too often with an ongoing experiment).

Ecosystem research facility: Such a facility does not exist currently but is badly needed. Many of our faculty and graduate students routinely need to conduct chemical analyses of soil, water, or tissue, including inorganic nutrients, organic chemical composition, and isotopic (stable and radioactive) tracers. Currently, this kind of work is all conducted in laboratories of individual faculty, who are generous in granting access to technicians and graduate students of other faculty who do not have fully equipped laboratories for these kinds of analyses. Particularly critical to many faculty and students in EEB have been Kling’s laboratory in aquatic chemistry, Zak’s laboratory (in SNRE) in soil chemistry, and Blum’s laboratory (in Geological Sciences) in stable isotopes. These laboratories are almost entirely supported by individual research grants to those faculty. We need to explore ways of finding funds to help support faculty labs that devote considerable effort to a diversity of research and training outside of the faculty member’s research programs and/or making more common facilities available (including technical staff for training researchers in techniques and maintenance of equipment and supply base). While we have discussed joint proposals among these units for such a facility, there is simply no space where such a facility could be built at the current time.

General facilities: off campus

Matthaei Botanical Gardens: The Matthaei Botanical Gardens consists of a 350-acre site on Dixboro Road, along with two other research and teaching areas comprising an additional 250 acres (Mud Lake Bog and Horner-McLaughlin Woods). The Dixboro site includes four large greenhouses for research and teaching, a laboratory-classroom building and service and utilities buildings. The Botanical Gardens is a critical component of EEB research, especially in plant ecology and evolution. Many EEB faculty and students routinely use the greenhouses for small-scale pot experiments (with excellent support by the Gardens horticultural staff) and protected areas of the grounds are used for common garden experiments, e.g., in the NSF-supported wetland mesocosm facility developed by Goldberg. The Botanical Gardens also represents a rich diversity of habitats for field research close to the Ann Arbor campus.

Edwin S. George Reserve: The E. S. George Reserve (ESGR) is a 1400-acre tract of land located 25 miles northwest of Ann Arbor and administered by the Museum of Zoology since 1930 as a nature reserve and biological research station. The ESGR includes a wide variety of natural habitats, an extensive experimental pond facility used by Professor Werner's research program, living quarters, laboratory and storage space, and a weather station. Other than the experimental pond facility, which was constructed in 1986, most of the infrastructure in ESGR is badly in need of renovation and a more regular maintenance schedule. The main portion of the ESGR is fenced to permit the safe conduct of experimental programs that otherwise would be sensitive to public intrusion. The ESGR has become internationally famous for studies of plant succession, white-tailed deer biology and management, ecology of amphibians, insect biology and the demographic studies of turtles, with more than 437 research papers and books published from research conducted on the ESGR (an average of 6.4 papers per year through the present), as well as 28 Master's and 74 PhD. theses. The ESGR is becoming increasingly important to our faculty and students as a research facility as undisturbed sites for ecological research near Ann Arbor diminish and interest in biodiversity research increases.

The University of Michigan Biological Station (UMBS): The UMBS, near Pellston in northern lower Michigan, is a unit of the College of Literature, Science, and the Arts with close links to EEB that is dedicated to education and research in field biology and environmental science. The new Director, Knute Nadelhoffer, is a professor in EEB. The UMBS is effectively a small campus consisting of 150 buildings, including 16 classrooms/teaching laboratories, a winterized dormitory with a kitchen and meeting room, 10 winterized homes, 90 summer cabins, a large research laboratory, an auditorium, a large library, a dining center, and maintenance and storage facilities; many of these facilities are in need of upgrading and discussions are ongoing between UMBS and LS&A about these needs. About 280 students, faculty, staff, scientists and families can be accommodated in summer, and 40 people in winter. Five current EEB faculty have major components of their field research programs centered at UMBS (Nadelhoffer, Goldberg, Hazlett, Myers, Webb) and 5-10 EEB graduate students are conducting all or most of their dissertation research there.

The UMBS administers approximately 10,000 acres of mostly forested land that includes, several first-order streams, wetlands and ~7 miles of undeveloped shoreline on Douglas and Burt Lakes. It also has easy access to various habitats on public lands (state and county forests) and Great Lakes shorelines. The UMBS also administers the ~3,000 acre Chase Osborne Preserve on Sugar Island, which provides access to shoreline habitats in the straits between Lake Superior and Lake Huron. Research facilities at UMBS include greenhouses, a soil Biotron for study of belowground environments, towers for measuring forest-atmosphere gas exchanges (CO_2, ozone, oxides of nitrogen, volatile organics), an experimental stream laboratory allowing for manipulation of stream substrate, flow rate, chemistry, light levels, etc., an analytical chemistry facility with an isotope ratio mass spectrometer, and a well-equipped stock room with field and laboratory supplies.

Summary of challenges for space and facilities: 1) *add space for new faculty*, 2) *bring the Herbarium back to central campus and house all of EEB, the Museum of Zoology, the Herbarium, and the Museum of Paleontology in a single building that is fully up to modern science laboratory standards*, 3) *construct or expand common facilities for molecular (DNA) work and chemical analysis, plant growth, and animal care*, and 4) *improve infrastructure at University-supported field sites, especially ESGR and UMBS.*

Section V-K addresses these challenges both on a short-term basis (without new construction or major renovation) and a long-term basis (our ideal form of new construction and renovation).

IV. Goals and assessment

A. Goal

Our goal is to establish EEB in the top five departments in the country for research, graduate training, and undergraduate training in the biodiversity sciences, within the next five years. With sufficient support from the College for faculty and facilities, this is a quite attainable goal; among the natural science departments in LS&A, only the EEB group within Biology has long been ranked in or very near the top ten of their peer units. Our ranking is a reflection of our near-unique combination of great strength in ecology (through 1.0 FTE appointments in EEB) and in evolutionary biology, often through joint appointments with the museum units (Museum of Zoology [UMMZ], Herbarium, and Museum of Paleontology [UMMP]). Thus, these units are a critical component of our distinction in our field and the basis of our ability to integrate among all the biodiversity sciences. While other universities exceed us in some aspects of evolutionary biology, especially in evolutionary processes, and in some aspects of ecology, especially other than community ecology, the breadth of our unit, combined with the great depth in some of the most critical areas, gives us an already exceptional department that can quickly become one of the top five.

B. Current national standing

Overall, EEB has an excellent reputation, and is ranked highly in ratings of graduate programs. Although U.S. News and World report does not distinguish our subject area from the biological sciences as a whole, *Science Watch* (a publication of the Research Service Group of the Institute for Scientific Information) in 1998 ranked Michigan fifth in "Ecology/Environment", a category that may include applied environmental sciences in units other than EEB (which at that time was included within the Biology department). The most appropriate ranking of Ph.D. programs in our field, although somewhat dated, was published in 1993 by the National Research Council/National Academy of Science. In "Ecology, Evolution, and Behavior," the University of Michigan ranked ninth (of 129) in "effectiveness ratings" and twelfth in "faculty quality ratings." The ranking of "Ecology, Evolution, and Behavior" considerably surpassed all other biological disciplinary areas at the University of Michigan.

C. Informal internal assessment

In our own informal assessment of how we compare to other departments at this time, we are pleased with our progress, but not at all complacent.

Ecology, as we conceive the field, is stronger overall at the University of California at Davis, which has enormous breadth as well as depth. The Ecology Group at Davis cuts across departments and schools and involves over 100 faculty. Princeton and Stanford are also both extremely strong in ecology, especially theoretical approaches. The University of Minnesota is nearly our equal in overall strength at this point as it is building rapidly in ecology; we lost an outstanding junior candidate to Minnesota last year, in part because of the lack of prospects for new hiring in ecology in EEB. University of Wisconsin at Madison and Cornell University have maintained strong overall programs in ecology, especially in aquatics at Wisconsin. Within specific subdisciplines in ecology, when EEB is combined with faculty in SNRE and Geological Sciences, UM is probably equally ranked with Duke and the University of Georgia in ecosystem ecology after Stanford. Community ecology is probably in the top five in the country (along with UC-Davis, Minnesota, Princeton, Wisconsin), but we have no junior faculty in this area. We are weakest in evolutionary ecology—none of our ecology faculty view this as their primary field, although most include an evolutionary perspective. In addition, as noted earlier, our age-structure in ecology is very top-heavy and we have not been able to keep pace with the newest developments within even the subdiscipline of community ecology, where we are strongest.

Over the full scope of evolutionary biology, including both evolutionary processes and historical patterns, we may be surpassed only by UC-Davis and by the University of Chicago (by virtue of its several departments with evolutionary biologists, and by a program that includes the Field Museum). The only other universities with comparable strength in systematics and evolutionary history are Harvard and Berkeley with their major museum collections and curatorial faculty (although both of these have been weakened by recent departures and retirements). Despite our breadth, we have a serious weakness: we are only now developing strength in evolutionary processes, especially evolutionary genetics and evolutionary ecology. In these all-important areas, we are surpassed by Chicago, UC-Davis, and University of Texas, and by vigorous recent hiring at Indiana University. Small groups of excellent faculty in evolutionary biology are also at Stanford, Cornell, Harvard, and Washington University, and offer very good graduate programs. On the other hand, of these institutions, only Chicago has a strong program in evolutionary history in systematics and only Davis has a strong program in ecology. **Thus, if we can maintain and rejuvenate our current strengths and add depth in evolutionary processes as we propose in this plan, we are uniquely poised to integrate across the biodiversity disciplines in a way that no other institution can do.** UC-Davis comes closest, but because it lacks substantial museum collections, it can never approach our scholarship and ability to train students in evolutionary history.

In functional organismal biology, we are currently quite weak. However, no department can do everything and so we have reluctantly come to a consensus to hire in this area only to the extent absolutely essential to maintain core teaching needs (animal physiology, comparative anatomy).

V. Strategies for the next five years

The most important component of any strategy for a successful department is, of course, faculty hiring, because this is the ultimate determinant of undergraduate and graduate training, as well as research reputation and productivity. Therefore we begin our plan for the future with faculty hiring and then proceed to discuss specific initiatives for the undergraduate curriculum, graduate training, increasing departmental diversity, and outline a plan for long-term facilities development. A more detailed long-term space plan is in preparation as a joint effort by EEB, UMMZ, and the Herbarium and will be submitted by January 2004.

When the EEB department was formed, the faculty and Interim Chair Goldberg developed an initial five-year plan (submitted to LS&A on 20 September 2001). That plan included an overall set of research priorities for the department and a strategy for hiring that have been our guiding principles during the subsequent two years. The plan presented below represents the next phase of hiring based on that plan, with some modifications stimulated by the vision of Doug Futuyma during his year as Chair (AY 02-03).

In the sections below, we first describe our overall priorities and then the four general conceptual areas and the five taxonomic groups in which we plan to hire, along with information on the recent hires, currently authorized positions and planned positions in each area. We follow this by a summary of the specific positions we request for the next five years and a proposed timetable for searching for these positions. The timetable assumes that unconstrained hiring of authorized positions can be resumed by next year; if this is not the case the time table will need substantial modification and the plan would obviously extend beyond the five years proposed.

A. Faculty development priorities

Based on our evaluation of the current status of the research strengths and weaknesses in the Department (*Section III-C*), we have agreed that our priorities in faculty development over the next five years will be:

1) maintaining our current strong program in ***evolutionary history of animals and reviving our program in evolutionary history of plants, which has been decimated by retirements***,

2) addressing the dearth of junior faculty in ***ecology*** that restricts our expansion into some of the newest exciting parts of this field,

3) expanding our strength in ***evolutionary processes,***

4) hiring one person with expertise in ***functional organismal biology*** in an evolutionary or ecological context to replace retirements/departures; combined with our very few current faculty in this area, this will give us a minimum level for basic teaching needs and broad graduate training, although certainly not enough to build a strong national reputation.

We will achieve these goals by a combination of refocusing some positions in evolutionary history to evolutionary processes or (in one case) functional organismal biology and by requesting a total of six incremental positions beyond replacement of all retirements or other departures over the next five years as guaranteed by former Dean Neuman under the original plan for the new EEB Department. This would add to the two incremental positions we have received over the first two years of the department that were also part of the original commitments of LS&A to EEB (*Appendix G*). Together with the currently authorized positions and replacements of retiring faculty, this would give a total 31.75 FTE and 42 individual tenure-track and tenured faculty and an additional 1.5 FTE and 2 individual Lecturer III's.

B. Search and hiring strategy

We will use two complementary searching strategies to attain these goals. As in any field, a successful research program depends both on research questions that are motivated by a broad theoretical context and a detailed knowledge of particular research systems in which to address these questions. In EEB, research systems tend to be taxonomically focused (e.g., reptiles or fungi), while in social sciences or humanities, research systems are often geographically and/or temporally constrained (e.g., medieval France). The intellectual challenge for any particular research program is to combine these approaches, by comparing the theoretical context across systems or integrating different theoretical constructs within a system to generate new understanding of how that system functions as a whole.

We argue that, at a departmental level, this challenge is best met by having two types of searches: those defined in somewhat-constrained conceptual research areas that are needed in the department but broadly open in terms of organismal focus, and others focused on organismal expertise needed in the department but broadly defined in terms of conceptual focus. It is important to note that we are NOT trying to fill in a matrix of all conceptual areas for all organisms; rather we aim to ensure that we have expertise in most of the important and innovative conceptual areas in the biodiversity disciplines, regardless of organisms, and in the biology of the most important organisms on earth, regardless of what particular aspect of the organism is studied. In practice, this strategy means that positions that are 1.0 FTE in the department will usually be requested and advertised in terms of a broad conceptual area, with the specific system of expertise left open. Positions that are 0.5 FTE in the UMMZ, Herbarium or UMMP will be requested and advertised in terms of a specific group of organisms but usually with the conceptual area left open or broadly defined. But again, the successful applicant will focus on a particular conceptual area that is a priority for the department. For example, if we search for someone working with insects and the successful candidate is an evolutionary ecologist (currently, one of our priority areas), this will mean that evolutionary ecology is no longer a high priority conceptual area and we can focus our attention elsewhere in the next search.

We plan to maintain the historic balance of joint positions between EEB and the museum units at an equal split of 0.5 FTE in each unit even though the close integration of these units means that such joint appointments typically contribute more than a half load in teaching and service to EEB. The equal FTE split is essential to maintain the long-term viability of all our interacting units, which have complementary, but distinct missions. Shifting the balance towards either EEB or a museum unit has the potential of weakening the unit with the smaller FTE share. As we have emphasized throughout this plan, recruitment of faculty and students in EEB and their productivity and success relies critically on the reputation and the resources in the museum collections. However, EEB has no direct responsibility for the curation of these collections and their maintenance and continual expansion as resources not only for UM but for the international community of researchers in the biodiversity disciplines. These are, however, essential components of the mission of the Museum units, as will be elaborated in their parallel long-term plan.

C. Research areas--conceptual

The four biodiversity disciplines discussed above are defined as broad conceptual areas . They are not, of course, sharply delimited, and individuals who bridge them are and will be important elements of the intellectual structure of our Department. More detailed descriptions of the subdisciplines within each broad area and their current and future research potential are in *Appendix A*. Funding potential in these broad areas is described in *Appendix B.*

1. Evolutionary processes. This area includes the subdisciplines of evolutionary developmental biology, evolutionary genomics, processes of evolutionary divergence, evolutionary theory, and the study of phenotypic evolution (*Appendix A*). This broad area grades into evolutionary history and comparative biology, evolutionary ecology, evolutionary physiology, and behavioral ecology, so that hiring in our other three areas will also strengthen our program in evolutionary processes. We have made three recent hires in these areas: Doug Futuyma (phenotypic evolution in insects, arrived Sept. 02), Lacey Knowles (evolutionary divergence in insects, arrived Jan. 03), Tom Duda (phenotypic evolution in mollusks, will arrive Sept. 04). Both Knowles and Duda are jointly appointed with UMMZ. In addition, last year the LS&A EC approved a broadly-defined position in evolutionary genetics and genomics that could cover any of these areas (02-21); the Department has agreed that this will be the single general-fund position for which we will search in AY 03-04. While these four new hires, together with our current faculty of Jianzhi Zhang (evolution of genes and genomes) and Priscilla Tucker (evolution of genes and the genetic architecture of species divergence) will make a highly respectable program in evolutionary processes, we are still lacking almost entirely three subdisciplines that have become absolutely critical for an outstanding program in evolutionary biology: evolution of development, evolutionary theory, and the use of experimental genetics in studying evolutionary processes. These are all areas in very high demand around the country and successfully competing for the very best new faculty means having a substantial program. Therefore we require at least three more people for a truly stellar program with real depth. We expect no retirements in this field in the next five years but expect that at least one person hired jointly with the Museum of Zoology or Herbarium under a search based on an organismic group will be in this conceptual area. **Therefore we request two incremental positions in the general area of evolutionary processes, in addition to our already authorized position in this area**. Joint positions with other units in some of these areas are possible, especially in MCDB (in evolutionary development) or Mathematics (evolutionary theory).

2. Ecology. This area focuses on the study of the interactions between organisms and their physical and biological environments at various levels of organization and spatial scales. It includes the subdisciplines of evolutionary ecology and behavioral ecology (both focused on individuals), population dynamics, community ecology, landscape ecology, ecosystem processes, disease ecology, microbial ecology, spatial ecology, biocomplexity theory, and conservation biology (*Appendix A*). It grades into the areas of physiological or morphological ecology and therefore into functional organismal biology, as well as into evolutionary processes through the subdiscipline of evolutionary ecology. EEB is currently particularly strong in community ecology (Goldberg, Rathcke, Vandermeer, Werner), although the last person hired in community ecology in EEB was Werner as a senior hire in 1985! We have long had only one faculty member in ecosystem ecology (Kling), but made a significant increase in our strength with the arrival of Knute Nadelhoffer this summer. In addition, the presence of Don Zak, Dave Ellsworth, and Bill Currie of SNRE and Joel Blum of Geological Sciences (Zak and Blum are dry appointments in EEB) make the overall program in ecosystem ecology at University of Michigan fairly strong. We are weak in population ecology, with this area being a partial focus of Myers in the UMMZ, but the major focus of a relatively recent hire in theoretical ecology (Pascual).

Ecology has the most problematic age structure in the Department with only one assistant professor (being evaluated for tenure this year) and one associate professor. We have identified evolutionary ecology, spatial ecology, microbial ecology, disease ecology, biocomplexity theory, and the interface between basic and applied ecology as areas that have developed enormously in sophistication and excitement in recent years but where we have minimal expertise at the current time. While many of our faculty have developed their programs at least partially into these six areas (e.g., Vandermeer works in agroecology; Goldberg and Rathcke work on the basic ecology underlying problems of invasive species; Werner, and Kling now incorporate spatial ecology as an important component of their research programs), only Pascual (in disease ecology, hired in 2001) has any of these areas as a central focus. Therefore, we argue we will need at least five more positions in ecology to restore our position to the cutting edge of ecology programs nationally. We expect one retirement in ecology over the next five years. Last year, the LS&A Executive Committee approved one position in evolutionary ecology (02-22), which we will fill as soon as budgets permit. Evolutionary ecology has been our first priority because it represents an explicit bridge between the two major components of our program, ecology and evolution; this is a diverse and rapidly developing field because of the revolution in molecular technology. While most EEB departments have several people working within this subdiscipline, we have none.

We therefore **request three new positions in ecology over the next five years beyond replacement or those already approved as the minimum needed to keep us in the top five ecology groups in the country.** We are in ongoing discussions with Geological Sciences, Psychology, the Center for the Study of Complex Systems, SNRE, and SPH about potential joint positions in many of the subdisciplines in ecology and the new positions we request could be in this context to minimize the burden on the College of these additional positions.

3. Evolutionary history and comparative evolutionary biology. This entails study of the patterns of evolutionary change across all life forms and across all character types, from molecular sequence traits to behavioral characters. Sub-disciplines include phylogenetics, which aims to reconstruct the history of diversification for taxa and for their traits, evolution of development, comparative genomics and bioinformatics. All of these are integrated with the study of evolutionary processes, described above. The nature of this work demands broad expertise within taxonomic groups and most positions in this area are associated with one of the museum units. Therefore positions requested in this area will usually be developed with a taxonomic focus and will incorporate the widest possible definition of conceptual disciplines. This general area has long been exceptionally strong at the University because of the museum units but multiple retirements in both UMMZ and the Herbarium make it urgent that we rejuvenate the area. Some of these retirements have been or will be replaced by researchers with a focus on evolutionary processes (e.g., new faculty already hired: Knowles, Duda) or functional organismal biology (in one case). However, new developments in this field, including rapidly developing molecular and computational techniques, make it imperative we continue to hire new faculty in this area. We have made only one new hire in this area since the inception of EEB, Yin-Long Qiu (plants, 1.0 FTE in EEB), who arrived in January 2003. We currently have two authorized positions jointly with the Herbarium (plants; 01-12, 02-23) and we expect at least one of these will be in this broad area (the other we anticipate will be in evolutionary processes). The College has just approved another position in the Herbarium (fungi, Wehmeyer Professorship). **As part of this**

plan, we are requesting two replacement positions in the UMMZ (one in "lower" vertebrates, one in insects). While these organismal-focused positions will be searched relatively broadly in terms of conceptual area, we will be especially interested in candidates whose research includes at least some component of studying evolutionary history.

We anticipate at most 1-2 additional retirements of faculty in this discipline; both have joint positions with the Museum or Herbarium and we would expect to replace their taxonomic expertise, but not necessarily the same conceptual foci to their research. Because we have no specific information on any further retirements in this area, we do not specify either organismal expertise or conceptual areas that will be needed.

4. Functional organismal biology. This area includes a number of subdisciplines that analyze the function of various characteristics of whole organisms and including comparisons among species in which the feature differs. Consistent with the focus of our department overall, we are especially interested in the **evolution** of organismal functions and how these functions influence **ecological patterns and processes**, i.e., in fields such as evolutionary and ecological physiology, evolutionary functional morphology, evolutionary and ecological aspects of animal behavior, and studies of biochemical traits, breeding systems, and life histories. We have made no new hires in functional organismal biology in EEB and only one in Biology for the last twenty years or so (R. Denver, now in MCDB), although MCDB has many biologists who work on function of organisms at a suborganismal level. Our current faculty in this area are either just retiring (Larry Nooden, plant physiology, 0.5 FTE in EEB), quite senior (Brian Hazlett, Bob Payne, both in behavior and at the interface of ecology and of evolutionary history, respectively), or have major duties elsewhere (Paul Webb, functional morphology, 0.5 in SNRE and currently Associate Director of Program in the Environment). In addition, Karen Ocorr (0.5 FTE in EEB), a lecturer III who taught in animal physiology for EEB, has just left the University.

Despite the importance of functional organismal biology and our current weakness in this area, we cannot do everything well and have reluctantly decided that we will not build a major research group in this area, at least over the next five years. However, a minimal presence in this area is essential for both basic graduate training and undergraduate teaching. As we noted earlier, an organismal perspective on animal function is essential for pre-health professionals, yet we do not have the tenured/tenure-track faculty to teach regularly in comparative anatomy or the EEB half of animal physiology. We propose to solve this problem by using one of our replacement positions to search for a single person in functional organismal biology within an ecological or evolutionary context, i.e., the evolution of organismal function or how organismal function determines ecological interactions (see *Appendix A*, page 71 for examples of research questions). Depending on exact research area, such a person would thus be part of our major research clusters in ecology, evolutionary processes, or evolutionary history, rather than isolated intellectually but would still provide us with the teaching expertise we need. We will specifically search for a functional organismal biologist working with "lower" vertebrates, i.e., fishes, amphibians, and reptiles, as an exception to our general strategy outlined above. These are by far the most diverse groups of vertebrates and have a large community of innovative researchers in diverse areas of functional organismal biology. This plan allows us to continue our taxonomic expertise in these groups, maintain expert curation, while filling a critically important gap in our program.

D. Research areas -- organisms

For reasons developed earlier in this document, we are committed to maintaining the University of Michigan's tradition of expertise in the biology and diversity of major groups of organisms and to appointing individuals with that expertise primarily in the Museum of Zoology or the Herbarium, where they will also hold 0.5-FTE appointments as curators. These units house collections that have inestimable value for teaching and for research not only within the University, but also on a national and international scale. It is also crucially important, therefore, that at least some of the faculty appointed as curators not only have expertise in organisms, but also know how to manage collections and have vision regarding their use. Faculty curators do not do the everyday work of collection maintenance or databasing, but they have the intellectual perspective on the kinds of research for which the collections have value and therefore only they can provide proper guidance for the overall development of the collections. Curatorial efforts and the collections themselves will be defined in more detail in the forthcoming plans for the Museum of Zoology and Herbarium.

1. **Plants**. Plants are the ultimate source of food and oxygen for all other organisms on earth, including humans, and the focus of studies ranging from the origins of life on earth, to food production, to sources of medicines to fight human diseases. No ecological system can be understood without knowledge of plants. Plant biologists have seized the new tools of molecular biology to trace the evolution of plants and their traits, including a well-funded multi-institutional, multi-investigator project called “Deep Green.” This project has been a model of scientific collaboration and is providing the basis for the next steps of mapping traits onto a tree of life. This new knowledge is causing plant scientists to rethink many traditional ideas about plant development (such as the origin of flowers), nitrogen fixation, defenses against herbivores, pollination, speciation, and hybridization, to name but a few areas. Many of these traits are key to ecological interactions, and the potential for collaboration between plant ecologists and plant evolutionary biologists has never been greater. EEB is currently very strong in plant ecology and thus we expect productive and stimulating collaborations between primarily evolutionary biologists housed in the Herbarium and ecologists.

The collections in the UM Herbarium include over 3 million specimens, making it the third largest university herbarium in the U.S. (the non-university institutions of the Smithsonian, the New York Botanical Garden, and the Missouri Botanical Garden are also larger). The Herbarium has been the center of plant evolutionary biology at UM, but recent retirements and a department-level denial of tenure have decimated its strength, with only a single faculty curator remaining after December 2003. A major step toward rebuilding our strength was made with the appointment of Professor Qiu, who arrived in January 2003 (1.0 FTE in EEB) and we currently have two open and authorized lines in plant evolution that are joint with the Herbarium and for which we are anxious to search.

2. Fungi. Fungi are one of the three crown eukaryotic (nucleated) lineages in the tree of life. Together with plants (the primary producers) and animals (the consumers), they form much of the entire multicellular eukaryotic landscape. Fungi inhabit virtually every environment on earth, they control global-scale carbon dynamics through their role in decomposition, and they also can be important plant and animal pathogens. Each year, fungal pathogens cause more death in humans than HIV, and inflict tremendous damage to crops and livestock. Fungi are also important partners in mycorrhizae, a nearly ubiquitous symbiosis in which fungi living on plant roots supply nutrients to plants and, in return, receive carbon from plant photosynthesis. In fact, it is thought that evolution of land plants was facilitated through a mutual symbiosis between early plants and beneficial fungi that inhabited their roots.

The study of fungi has been revolutionized in recent years by the ability to assess diversity using molecular techniques rather than the laborious and difficult task of isolating and culturing each species separately. This, in turn, is revolutionizing the study of the influence of fungi on ecological processes. The study of fungal evolution and the interface between evolution and ecology is therefore undergoing a renaissance; while the number of senior people in this field is relatively small, large numbers of students are being trained and a exciting cadre of relatively young scientists in this area is emerging. Last year, in the first round of competition in NSF's newly established Tree of Life Program, one of the half-dozen successful proposals was devoted to reconstruction of an all-fungi-phylogeny. We envision that the integration of fungal molecular systematics with microbial ecology can unlock our understanding of the dynamics of microbial communities and their function in a wide range of habitats and therefore we are particularly interested in hiring a fungal evolutionary biologist who integrates evolution with ecology either in their own work or through collaborations with ecologists. Developing this intellectual capability would place the University of Michigan at the forefront of using molecular approaches to understand evolutionary and ecological processes.

The fungal collection in the UM Herbarium is among the five largest in North America and includes approximately 287,000 specimens of fungi. Many of these specimens can be used for DNA sampling, which makes them a treasure trove for researchers on any aspect of evolutionary biology of fungi. We therefore anticipate an outstanding pool of researchers for this position.

3. Insects. Insects account for nearly two-thirds of all described species of organisms. Their ecological importance as herbivores, parasites, or food for other organisms cannot be overstated, and they have enormous direct impacts on human health as vectors of infectious diseases and on economic health as major consumers of crops and forest products. Furthermore, insects play an overridingly important role, probably second only to vertebrates, as subjects of biological research, especially in ecology and evolutionary biology. Most conspicuous is the fruit fly *Drosophila melanogaster*, the vehicle for major advances throughout the history of genetics and, more recently, developmental biology, but many other insects have become exemplars for the study of particular evolutionary or ecological phenomena.

In many groups of vertebrates and other animals, most of the species have been described, and many are biologically reasonably well known. That is not the case with insects, because of their immense diversity: it is quite certain that the ca. one million described species are less than half, and possibly less than ten per cent, of those that exist. Moreover, the biology and the evolutionary relationships of many insect groups are poorly understood. The significance of this relative lack of knowledge becomes alarmingly apparent when unfamiliar pest species appear and threaten crops, shade trees, or timber. Even determining whether or not the new pest is a described species – and thus being able to find out if anything is known about its geographic origin and its life history - can be a major challenge, requiring individuals familiar with the insect group and the relevant literature. Likewise, ecological and evolutionary research on insects depends on a systematic foundation, and researchers in these areas very frequently rely on insect systematists for aid and collaboration. For this reason, we propose to hire, jointly with the UMMZ, a biologist who focuses on evolutionary history and phylogenetics of insects. This is an exception to our general strategy of having completely open searches in terms of conceptual areas for our taxonomically-oriented searches, but the need for expertise in the evolutionary history and relationships in insects is so strong, and the field is so large, that we feel the exception is well justified. Areas of very active research that fit into this subdiscipline include a host of basic questions in evolutionary biology such as the causes of differences in rates of diversification (production of new species and higher-order evolutionary lineages) or of the evolution of complex ecological relationships, such as those between insects and plants, between parasitic insects and their hosts, and between insects and the symbiotic fungi, bacteria and viruses that play extraordinarily important roles in their life histories.

This person would contribute curatorial oversight to the Museum's important (currently the collection is the 3rd largest after Harvard and Cornell) collection of 4 million arthropod specimens (insects and mites). This hire would be indispensable for any training grant (e.g., IGERT) on biodiversity, and would teach a course in insect diversity and a course in macroevolution or phylogeny. The Insect Division currently has two other curators, both of whom have joint appointments with EEB. Professor Barry OConnor actually studies another highly diverse and economically important group: the mites, which are related to spiders and not insects at all. Professor Lacey Knowles, who joined our faculty in January 2003, studies myriad aspects of the process of speciation in insects and has begun to teach insect biology and to curate the Insect Division’s outstanding collection of Orthopterans (grasshoppers and crickets; ca. 1 million specimens). However, no one person's research or curatorial activities could adequately cover the tremendous importance of insects in both ecological and evolutionary study.

4. “Lower vertebrates”: Fishes, amphibians and reptiles. Because fishes constitute the vast majority of vertebrate species, and are extraordinarily diverse in anatomy, physiology, behavior, and ecology, they have been the basis of many important studies on topics such as sexual selection, the evolution of parental care, speciation and adaptive radiation, clonal reproduction, sexual parasitism (using sperm to induce cell development, but ejecting the DNA of the male), the evolution of life span and other life history characteristics, and the maintenance of the extraordinary diversity of tropical reef fishes. We expect to attract applications from the most highly qualified and innovative young scientists in this field, both because of the reputation of the program in fish biology centered in the Division of Fishes in the Museum of Zoology and because of the quality of the collection, which is the most diverse fish collection associated with a university anywhere. Ranked second only to the Smithsonian Institution as an International Resource Center by the American Society of Ichthyologists and Herpetologists, the collection currently holds approximately 3.5 million specimens and about 9,500 species (constituting 95% of fish families). There are nearly 5000 specimens on which species descriptions have been based, including about 600 "primary type specimens" that are all-important for taxonomic purposes. The very large skeletal collections provide materials for morphological or functional studies and also supply tissues for DNA analyses.

Amphibians, with their dual life history, an aquatic juvenile phase and a terrestrial adult phase, and reptiles, as exemplars of an early terrestrial radiation, provide important models for research on many topics in ecology, evolution, and organismal functional biology. For example, the repeated, independent evolution of paedomorphosis in salamanders – sexual reproduction by morphologically juvenile species – provides a rich opportunity, using a conjunction of phylogenetic, genomic, and physiological approaches, to understand the evolution of drastic changes in development and life history. Our understanding of the evolution of life history features (e.g., reproductive rates, longevity) has been greatly advanced by past and continuing comparative studies of lizards and snakes (pioneered by D. W. Tinkle, a former curator in the Museum of Zoology). Comparative studies are shedding light on the evolution of novel, complex features, such as the evolution, in several lineages of lizards and snakes, of mammal-like viviparity (live birth) from oviparous (egg-laying) ancestors. Phylogenetic analyses are contributing to an understanding of the evolution of the biosynthesis of a wide range of skin toxins in frogs and toads (some of which are of pharmaceutical interest). Analysis of such phenomena is enormously facilitated by the herpetological collections at the University of Michigan, which are among the largest in the world. The collection contains nearly a half million specimens, with especially strong collections from the Americas and Africa, including the type specimens upon which the original descriptions of nearly 800 new species were based and 6,000 tissue samples available for DNA studies.

***5.* Microbes**: Microbes dominate life on earth and account for up to 50% of the Earth's biomass. These mostly single-celled organisms were the first life forms to evolve, and they have invaded and colonized each new habitat suitable for life as the Earth itself evolved: they live in boiling water, frozen ground, acid volcanoes, and at the bottom of the ocean. They can reproduce by doubling every 20 minutes, or survive for hundreds of years in a resting stage. They cause the most devastating diseases known to humans; they are winning the war we are waging against them with antibiotics, and yet we cannot live without them. Microbes recycle nutrients from dead material into forms usable by plants and enable herbivores to graze on poor quality food.

Despite the central biological roles of bacteria and other microbes, our ignorance of their diversity, activities, and interactions with each other and with other organisms is profound. Bacteria are probably many times more biologically diverse than higher organisms – some authorities suppose there are millions of species – but only a small fraction of species has been studied. However, molecular techniques are now leading to real breakthroughs in our understanding of microbes and their role in biodiversity, as we can now identify species in natural environments, define and quantify microbial activities, and identify the genes that control those activities. Because of their small size and fast generation times, microbes are ideal organisms for experimental studies of evolutionary processes and so this position could also add to our strength in this area. Finally, the study of ecology and evolution is perhaps more intrinsically linked in microbes than any other organisms both because of the need to use molecular genetic tools simply to describe the diversity of microbes and their functions in natural systems and because major evolutionary shifts in microbial function can occur so rapidly relative to the time scales of human activity and studies of ecological phenomena. We are at the threshold of extraordinary advances in understanding the biodiversity of microbes. Adding more expertise in microbial ecology and evolution to EEB would also increase our interaction with the research community in microbiology at the University of Michigan, which spans the Schools of Medicine (Department of Microbiology and Immunology), Public Health (Department of Epidemiology), and Natural Resources and Environment and would contribute to the new cross-school concentration in Microbiology.

E. Summary of positions requested and timetable

Table 4 lists the specific 17 positions (13 FTE) over the next five years that we have argued are necessary to achieve our goal of becoming one of the top five departments in the biodiversity disciplines. Five of these positions are already authorized by the LS&A Executive Committee. Another five are replacements of retirements already occurred (2) or expected to occur (3) before the end of FY 06; these were guaranteed to EEB as part of the new Department in 2001 (*Appendix G*). One more position is requested as a replacement for Richard Alexander (0.5 FTE in UMMZ), who retired in 2000. While Alexander's replacement was not guaranteed as part of the new department, we view this position as an essential component of maintaining our scholarly reputation, as described earlier (insects, evolutionary history). The remaining six positions in the table are all highlighted in bold and are all incremental beyond the original commitment from LS&A described in *Appendix G*.

We recognize that we are requesting a very major investment in EEB on top of the existing investment made as part of the original Transforming Biology Initiative. However, as we have argued throughout this plan, these new positions are essential to make the difference between a very good department hovering around the bottom of the top ten (as we are now) and one of the top five departments or even better in biodiversity disciplines. It is, of course, difficult to say exactly how many are necessary to move us to the goal of "top five" but it should be clear from our descriptions of the major changes occurring in these disciplines that we simply cannot get there without some further investment.

The new positions are listed and will be advertised very broadly in terms of one or more of the four disciplinary areas (and any taxonomic group) or one or more taxonomic group (and any disciplinary area). This is done deliberately to maximize the quality and diversity of the pool of applicants for any position, although advertisements will include a list of subdisciplines (see *Appendix A*) in which we are particularly interested, but which are not restrictive.

Table 4. Five-year hiring plan for EEB. Positions in bold are requested incremental positions **beyond** those guaranteed in the original plan for EEB (*Appendix G*). The proposed search year is based on resumption of unconstrained hiring in FY 05; the actual year obviously depends on budgetary considerations.

Research area	**Source**	**Position #**	**Status**	**Search yr (FY)**	**FTE**	**Shared unit**
Evolutionary genetics	Incremental	02-21	authorized	2004	1.0	
Fungi	Fogel	03-4	authorized	2004	0.5	Herb
Plants	Frohlich	01-12	authorized	2005	0.5	Herb
Plants	Anderson	02-23	authorized	2005	0.5	Herb
Evolutionary Ecology	Wilson/Osgood	02-22	authorized	2005	1.0	
-	Ocorr/Nooden		eliminated	-	-	-
Ecology	**Incremental**		**plan**	**2006**	**1.0**	
Lower vertebrates-functional biol.	Kluge/Smith		req 03	2006	0.5	UMMZ
Lower vertebrates-evol. history	Kluge/Smith		req 03	2006	0.5	UMMZ
Insects-evolutionary history	**Alexander**		**plan**	**2007**	**0.5**	**UMMZ**
Evolutionary processes	**Incremental**		**plan**	**2007**	**1.0**	
Ecology	Retirement		plan	2007	1.0	
Ecology	**Incremental**		**plan**	**2008**	**1.0**	
Focal group to be determined	Retirement		plan	2008	0.5	UMMZ
Microbes	**Incremental**		**plan**	**2008**	**1.0**	
Focal group to be determined	Retirement		plan	2009	0.5	Herb
Evolutionary processes	**Incremental**		**plan**	**2009**	**1.0**	
Ecology	**Incremental**		**plan**	**2009**	**1.0**	

F. External research funding initiatives

In our internal review of research funding (*Section III-E*), we documented that research funding and percent of faculty with external funding has not yet risen substantially since the formation of the new department two years ago. As we noted earlier, we do not find this surprising given that we have only just begun to hire new faculty to replace many retiring faculty who had not been externally funded and that we have actually declined in the number of tenured/tenure-track faculty since the beginning of the department (from 30 in July 2001 to 26 as of July 2003). Nevertheless, we need to and will address two distinct challenges in terms increasing external funding: 1) ensure that all new faculty are well-funded, 2) increase funding of faculty currently here but who have not been active in applying for (or successful in obtaining) external research grants.

The first is simply to continue to hire outstanding faculty as we have been doing over the last two years. All our new faculty have needed no special encouragement to submit grants; they have been doing so quite actively and successfully (3 out of 4 assistant professors are very well-funded already, the fourth, at UM less than 1 year, has a major CAREER proposal to NSF pending).

The second challenge is more complex: to increase the application and success rates for research funding of more senior faculty without major external research funding (although not necessarily any less active in publication). First, we already denote faculty as research active, semi-active, or in-active and adjust expected teaching efforts accordingly. We will be modifying the definitions of these research activity levels to encourage greater grant activity. If some faculty choose to focus more on teaching activity at their stage of career, this would allow us to be more flexible in assigning teaching efforts to other faculty with very large research programs. Second, we will be tying research grant activity and the number of graduate students mentored by faculty more closely. Third we will be actively looking for more collaborative projects that would involve multiple faculty members, such as the NEON initiative described in *Section V-I* below. With appropriate mentoring, the inclusion of less research-active faculty in such projects could be an effective way of restarting some research programs.

G. Undergraduate teaching initiatives

In our internal review on undergraduate education (*Section III-F*), we identified seven major challenges. Here, we describe initiatives to address each of those.

1) Increase offerings to non-science concentrators and first-year students. In response to faculty concern about public understanding of evolution, we are re-instituting "Evolution of Life" (Biology 107, Prof. Mindell). In addition, as part of increased teaching by faculty in the Museum of Zoology/Herbarium, EEB is committing to teach at least 3 sections per year of Biol. 120 (First Year Seminar in Biology); we have only been able to teach 1-2 a year for the last several years. We expect these seminars to be taken both by non-science concentrators and prospective biology (or other science) concentrators.

2) Evaluate introductory and core courses of the Program in Biology concentrations and modify if needed. In a cooperative effort with MCDB, a committee is being charged with evaluating the introductory course (Biol. 162) and the role of our 200-level courses in the concentrations. They will also be evaluating the use of pre-requisites in structuring the sequence of courses within the concentration and the effectiveness of the single term introductory course. The report is due in winter 2004 with implementation of any changes targeted for September 2005.

3) Improve pedagogy. We see this as a crucial challenge for EEB and other natural science departments. The increased importance of science and scientific thinking in our society makes science literacy a fundamental part of citizenship. Science teaching has not been as engaging and effective as it should be and we need to educate and stimulate faculty to incorporate proven-effective teaching innovations beyond a straight lecture format and to provide them with the resources for implementing these innovations as easily as possible. The latter is perhaps the more critical simply because time is undoubtedly the most limiting resource for our faculty.

We will implement two strategies to improve pedagogy in EEB courses. First, we will take advantage of the expertise of our new Lecturer III, Dr. Jo Kurdziel, in active learning methodologies to help other faculty implement these techniques in their classes. For example, Dr. Kurdziel has just submitted proposals to CRLT and LS&A-IT to incorporate and evaluate active-learning technology (including Personal Response Systems; PRS) and techniques in Biology 100 (our nonmajor's general biology course, enrollment ca. 200). The use of infrared technology in PRS allows each student (or group of students who have worked together) to send the results of their activity directly to the instructor's computer, which is then programmed to summarize student responses so the instructor can give immediate feedback. After Dr. Kurdziel has successfully integrated this approach into Biology 100, she will work with individual faculty to implement similar approaches in their classes, as part of her regular teaching effort. Because Dr. Kurdziel is a biologist herself, she can do a great deal of the work of designing such exercises and training other faculty to use them in class, making it much easier to adopt such innovations.

Second, we will encourage faculty to develop new approaches in their teaching by supporting their efforts in a way that feeds directly back to their research or teaching programs. Specifically, we already have instituted a "teaching bank" whereby faculty who teach significantly more than the standard expected effort in the department will be rewarded (when funds are available) with graduate student support (from our supplemental instructional budget). We will add to this program, rewards to faculty who seek funding for innovation in the classroom (e.g., from CRLT or LS&A-IT, or external sources). Faculty with this support will be able to apply it to research or to further teaching development.

4) Improve scientific communication skills. All Biology and EEB courses should have some writing component and instructors will be asked to provide explicit statements about the literacy goals expected to be achieved from those assignments. General class cohort goals that should be achieved are:

- 100-level: be able to understand and communicate clearly about broad issues, such as environmental change or evolution of diseases; be able to explain the scientific method and be able to interpret graphs.
- 200-level: be able to discuss such topics in greater depth, exhibit critical thinking; write clearly on these topics.
- 300-level: be able to write a 30-page paper on more narrow topics, exhibiting critical thinking and the ability to synthesize.
- 400-level: be able to give public presentations on scientific topics (including analysis of primary research literature).

Approximately half of the biology concentrators in a given year (ca. 125-150 students based on current concentrators) should have the opportunity to fulfill the LS&A upper-division writing requirement in EEB, consistent with our contribution to the Program in Biology. We are working with the Sweetland Writing Center to provide information on and assess resources necessary to meet these goals. During AY 2003-4, we will hold several workshops run by Sweetland staff on the kinds of writing exercises that meet the requirement and how to structure laboratory or classroom experiences so that a course could fulfill the requirement. All faculty who teach in 300-400 level courses will be asked to attend a workshop and then, if appropriate, to submit a plan on how their course could be modified to fulfill the requirement and what support (additional GSIs and/or GSI training) will be needed to implement this. The Associate Chair will coordinate efforts so that sufficient courses are modified to reach our goal.

5) Stabilize teaching participation in core courses, and 6) Fill in major gaps in upper division curriculum. This requires new faculty and will be achieved through the hiring plan summarized in *Section V-E*.

7) Renovate and add laboratory space. As described earlier, teaching laboratory space is currently the limiting factor for expanding our "hands-on" teaching, with several courses in substandard space and no place for several planned laboratory courses. However, the construction of the Undergraduate Science Building (due to open in September 2005) should enable us to remedy this situation both directly by opening up new laboratory classrooms for our use (on the third floor, studio lab space) and indirectly because of the planned move of all of MCDB's laboratory teaching to this building, thereby freeing up some space in old Chemistry. A more detailed proposal that lists all current and planned EEB laboratory courses and their proposed room assignments is being submitted to LS&A Facilities in November 2003.

First, we plan to consolidate all of our teaching in animal biodiversity in four of the new studio labs in USB, which will greatly increase the quality of teaching in those courses. Flexible lecture/laboratory space is ideal for courses where lecture and specimens go hand in hand and where student inquiry about the organisms involves close examination of the specimens themselves. Courses to be moved to this location are: Animal Diversity (Biology 288), Chordate Anatomy and Phylogeny (Biology 252), Parasitology (EEB

341), Biology of Mammals (EEB 451), Biology of Amphibians and Reptiles (EEB 450), Biology of the Insects (EEB 442), Ornithology (EEB 433), and Biology of Fishes (EEB 440).

Second, we will renovate the dilapidated laboratory in room 1023 Kraus into a state-of-the-art studio laboratory for teaching in plant sciences, with the adjacent greenhouse available to keep live material and for small-scale experiments. Two of our four plant courses will be taught there: Introduction to Plant Biology (Biology 230) and Plant Diversity (Biology 255).

These two moves will enable us to vacate the laboratory rooms on the 3rd floor of Kraus; this space has no windows and is ideal for a state-of-the-art lecture room for about 100-120 people. The room would have a Personal Response System installed (see earlier section on improving pedagogy) and would be used for intermediate size lecture classes, as well as a seminar room for the EEB and MCDB Departments.

Finally, our remaining classes would be taught in four laboratories on the first floor of the "old" Chemistry Building; two of these are already used by EEB courses and two would be made available when MCDB moves its laboratory teaching to the USB.

H. Graduate program

The challenges discussed in *Section III-G* for our graduate program fall into three categories: *recruitment* (increasing underrepresented minorities), *mentoring* of graduate students (time to candidacy and degree, gender differences in retention and time to degree), and *graduate funding* (increasing number of students in program and stabilize funding. Recruitment efforts are described in *Section J* below; here we focus on mentoring and departmental and university funding. Interdisciplinary training and new sources of external funding for graduate students is discussed in *Section I* below.

1) Mentoring: Current mentoring practices for graduate students differ widely among faculty in the department; we welcome this diversity and have no desire to impose a uniform mode on all faculty and students. On the other hand, it is imperative that there is a good match between mentoring styles needed and offered and that there are no systematic differences in the kind of mentoring received by students based on gender, research interests, or anything else. To this end, we are planning a number of changes including: a) all faculty will be asked to add a section on mentoring styles to their departmental web page and we will encourage prospective students to look at this. 2) we will develop more departmentally-run activities on aspects of professional development, including workshops on writing grants, applying for postdocs and jobs, balancing work and personal lives (some of these are part of our past and proposed ADVANCE activities), 3) have an annual meeting of all faculty where we discuss progress of all candidate graduate students and make suggestions for each student (we already do so for pre-candidate students).

2) Funding: As noted earlier, we need to re-evaluate our current graduate funding model (p. 30) both because we do not have sufficient funds to cover the target number of 12 students per year and because we need to increase this target number of students per cohort to have a critical mass of graduate students for our faculty. Options include increasing the number of GSRA terms relative to fellowship terms and/or increasing the number of GSI terms relative to fellowship terms. The exact form this will take depends on the outcome of discussions with Rackham on stabilizing their funding to EEB, on further faculty discussions on the optimal number of students in the program, and on discussions with Associate Dean Hanlon. We will have a final decision before admission of Ph.D. students for next year starts in February 2004.

I. Interdisciplinary initiatives

As noted throughout this plan, the ecologists and evolutionary biologists in EEB have scholarly interactions with many other units at the University. Most of these interactions involve pairs or small groups of faculty that have research or teaching collaborations, participate in dissertation committees or simply interact through seminars and informal discourse. Others are more formal, such as joint positions or participation of several of our faculty in NIH training grants in Genetics and in Genome Science. No other units have the study of ecology and evolution as their central mission and therefore EEB is uniquely poised to play a major role in facilitating greater interaction in these fields across campus, including for graduate training. Here we describe some potential interdisciplinary initiatives, some of which are already started and others which are only in early discussion stages.

Interdisciplinary graduate training in Biodiversity: The focus of EEB in its broadest sense is biodiversity science; we are developing a proposal for an interdisciplinary training grant to the NSF IGERT program that would integrate training in basic and applied aspects of ecological and evolutionary research, including training in communicating to the public through the media and museums. Discussions have begun with a number of potential partners, including the Program in Bioinformatics, SNRE, SPH, the Center for the Study of Complex Systems, the International Institute, the Exhibit Museum of Natural History, and the Museum Studies Program. We will submit a pre-proposal to NSF for this training grant in January.

Interdisciplinary graduate training in biogeochemistry: Biogeochemistry (a significant part of ecosystem ecology) has become increasingly strong at the University of Michigan over the last five years or so as new hires in EEB, Geological Sciences and SNRE have added to the existing strength in those units and in Atmospheric, Oceanic, and Space Sciences (in College of Engineering). We have already held informal discussions with faculty from these units on the possibility of a joint Ph.D. program in this area and plan to continue these in consultation with Rackham. This would likely involve expansion of the current NSF-funded interdisciplinary training grant (IGERT Program) on biosphere-atmosphere interactions that is based at UMBS.

Another important initiative in which EEB has taken the lead is the **National Ecological Observatory Network (NEON).** This is a major infrastructure project proposed by NSF and recently endorsed by a report from the National Academy of Science. NEON is in the current House of Representatives Budget, although not yet approved in the final Congressional budget. EEB has coordinated numerous meetings with colleagues at UM and other universities in Michigan, Wisconsin, and Indiana; these have led an agreement that UMBS would be the core site for a regional observatory for the Upper Great Lakes. Under the leadership of Professor Nadelhoffer of UMBS, we are now poised to develop a proposal for a NEON site, once Congress approves funding.

A related project is the **Coastal Long-Term Ecological Research (LTER) site**. LTER is an NSF program that funds long-term research in particular biomes; NSF has recently called for proposals for a coastal LTER site, with the Great Lakes as a prime candidate. EEB faculty have been in preliminary discussions with SNRE and other units on campus about developing a proposal, although the University has greatly decreased its effort in aquatic sciences in recent years, and it is unlikely that we would be strongly competitive in such a proposal at this time. Nevertheless, we will be carefully monitoring this and other opportunities for major initiatives in Great Lakes research and how EEB can contribute, including paying special attention to aquatic ecologists for some of our incremental ecology positions. This is both because aquatic systems provide some of the most exciting potential for addressing basic questions of “scaling-up” in ecology and because it would increase our interdisciplinary interactions with other aspects of aquatic sciences on campus and increase the ability of the University as a whole to restore its position as a major contributor to research on Great Lakes ecosystems. The Provost’s office and OVPR have recognized the overall decline and authorized a new initiative to rebuild large-scale aquatic research at U-M, beginning by hiring a director of the Michigan Sea Grant program (to be housed in SNRE).

J. Initiatives to improve departmental diversity and climate

To address concerns about equity and diversity for both graduate students and faculty in the department, in 2002, EEB established a Diversity Committee with the following mission: *Oversee development and implementation of a plan to increase diversity and excellence of the department faculty and graduate student body, by increasing recruitment and retention of women (especially in the faculty) and underrepresented minority groups at all levels.* As noted earlier, graduate student recruitment and entry into our program has been fairly equitable with regard to gender for at least the last ten years, but retention and time to degree have been poorer for women students, and the proportion of women applying for faculty positions in our department (and, anecdotally, nationally as well) is much lower. In contrast, the key current problem in increasing diversity in terms of minority groups is in recruitment to our graduate program—the application rate of underrepresented minority groups is vanishingly small. Efforts to improve this situation are discussed next, followed by a general discussion of the challenges regarding women.

1) Increase recruitment of under-represented minorities in graduate program. Starting last year, we routinely pull prospect data from MPathways, including a listing of underrepresented minorities from the CIC Name Exchange. We then send an email to those indicating an interest in our disciplines, introducing our program and encouraging them to apply. For future years, we plan to send faculty to institutions with substantial numbers of African-American and Hispanic students graduating in Biology (e.g., Wayne State University in Detroit and Fort Valley State University, Ft. Valley, Georgia).In each case, the faculty member will give a seminar and meet with undergraduate students to talk about the EEB graduate program and encourage applications. (Our attempts to implement this for this year were too late to be effective; we will organize this during late winter term 04 to ensure that our faculty are available at times suitable for the institutions we wish to visit in fall 04.) We recognize that more substantial efforts will be needed and will be asking our Diversity Committee to investigate additional approaches to take.

2) Improving climate and proportion of women at all stages. With help from a $15,000 grant from ADVANCE, the Committee has been focusing on women last year and this year. Accomplishments to date of the Committee include: 1) developed a set of guidelines for faculty searches that incorporate suggestions from the STRIDE committee, 2) sponsored a set of focus groups (conducted by ADVANCE staff) with graduate students to discuss issues of climate in the department and presented the resulting report to the faculty for discussion and proposed changes, 3) sponsored visits by four outstanding women for possible consideration as faculty recruits through the LS&A ADVANCE program (one of these resulted in an assistant professor offer that was unfortunately turned down in favor of U. Minnesota), 4) held three workshops for graduate students and postdocs, on how to obtain postdocs and jobs in academia, on work/life balance, and on career options in ecology, and 5) sponsored a visit by a couple who are both distinguished tropical ecologists, to talk about their research and how they balance their family life and their work. The focus group report and faculty discussion resulted in some changes in mentoring procedures as discussed in the section on Graduate Training Initiatives and, perhaps even more important, increased awareness by the faculty of problems perceived by many graduate students of limited options for balancing career and family and the particular perception by some women students that some faculty are insensitive to these issues. These are the issues that undoubtedly contribute to the lower retention rate of women graduate students, their longer time to degree, and the decreased rate of application to faculty position by women even after completing their degree. In addition, the Department’s efforts at further increasing the quality of mentoring of graduate students in the department (see Graduate Program Initiatives) should particularly help women graduate students, who are often cited as receiving less mentoring than men.

The Diversity Committee has submitted a second proposal to ADVANCE to continue these activities and add several new ones. Of the new activities, we are particularly excited about our proposal to initiate the “University of Michigan Young Scientists’ Symposium in Ecology and Evolution”. This would be an annual symposium held each spring on a different topic each year to which the most promising finishing graduate students, postdoctoral fellows, and early stage assistant professors in the field (national and international) would be invited to give lectures and posters in an a particularly exciting and innovative topic in our discipline. The topic to be chosen would be one in which we are particularly interested in recruiting faculty and the invitees would fully represent the diversity of the Ph.D. pool in this subdiscipline—national data suggests that this is over 50% women in most life science disciplines. We will also invite senior faculty in the subdiscipline field, not to give talks, but to participate in discussions and engage with the more junior speakers and our own faculty and graduate students. We expect this symposium to accomplish a number of goals; most important in terms of faculty recruitment, this would allow us to survey the potential recruits in an area both to increase our pool for formal searches and to allow us to make special offers to particularly exciting scientists just coming on the job market or currently "underplaced" in faculty positions, who might not be available when a regular search for that area is scheduled but who would increase the diversity and quality of our faculty. It would also increase the range of role models to graduate students from the relatively small number of women currently on the faculty in EEB. Finally, such a series of symposia would showcase both the academics and the climate of the University of Michigan's program in Ecology and Evolutionary Biology to the entire community of our discipline; this in turn would enhance our reputation and attract the best potential faculty and entering graduate students to apply to our department.

K. Facilities Development

Short term. Regardless of long-term plans for new construction or major renovation, we will need to continue to have at least adequate laboratory space for our new hires over the next five years. Of the 17 positions in Table 4, we currently have room for seven in Kraus and 3 in Ruthven, albeit in quite cramped conditions, especially for any senior hires. The remaining positions (and any possible hiring through the ADVANCE program or other target of opportunities) will have to be housed elsewhere. We propose that we use as temporary research space the five large teaching laboratories on the second floor of Chemistry that will be vacated when MCDB laboratory teaching is moved to the Undergraduate Science Building in 2005. These would require minimal renovation (since the infrastructure should be adequate) and provide for a minimum cluster for interaction of faculty, students, and postdocs. Even use of this space will not completely house all the faculty we request. However, the eventual move of MCDB to a new building and out of Kraus and the consequent reconfiguration of EEB physical space would enable us to expand while a long-term solution is developed (next section).

Long term. Our ideal scenario for the long term is that all EEB, all of UMMZ, and the Herbarium be housed together in a single large building, comprised of a completely renovated and expanded Ruthven Museums Building. This plan would entail moving the Exhibit Museum, and possibly the Museum of Anthropology to other sites. The expansion would involve two phases: First, the Herbarium would be returned to central campus by excavating under the current parking lot for space for the collections (which must be on a ground floor because of the weight of the specimens) and building an atrium above it that could become a 'public', glass-domed entrance and commons area with displays of faculty and graduate student research; this commons area would have new auditoria nearby and adjacent open space for meetings and workshops. The second phase would involve construction of a new wing that would connect the wings of the current Ruthven Building; this wing would house modern laboratories for the faculty moved from Kraus and for new faculty, as well as common laboratory facilities for work in ecology and evolution (e.g., DNA, soil and water chemical analysis, stable isotope tracer work).

Renovations of the older part of the existing Ruthven Building would include newly designed or reconfigured collection facilities for the UMMZ, UMMP, and Herbarium, incorporating compactors for museum cases and fire-safety features for rooms with specimens in alcohol as needed. The "new wing" of Ruthven (completed about 1965) is the current location of most laboratory space in Ruthven and needs substantial renovation and upgrading as well. A compelling model for the physical plan is the University of California at Berkeley's Valley Life Science Building on their main campus, which houses an integrative biology department's faculty, as well as their museum of vertebrate zoology, museum of paleontology, herbarium, and associated libraries.

It would also be desirable to connect the north side of Ruthven with the new MCDB building planned to occupy the current site of NUBS and to the Undergraduate Science Building where EEB will be teaching a substantial part of its courses. Connecting the renovated Ruthven complex to these buildings would greatly facilitate interactions, intellectual exchange and equipment sharing between EEB, MCDB and LSI researchers, providing a mini- life science corridor on Washtenaw Avenue extending from North University to the Medical School campus. This entire package, keeping the two new LS&A biology departments in physical proximity, would facilitate interactions, and administrative flexibility, thereby enhancing LS&A biology for a long time to come.

Given the recent decision to initiate planning for a new MCDB Building, EEB, UMMZ, and the Herbarium have begun to collaborate on a detailed plan for co-housing our units over the long term, to be submitted to the College during early Winter 2004.

Appendix A: Sub disciplines in ecology and evolutionary biology

The text describes the broad disciplines of evolutionary history, evolutionary processes, ecology, and functional organismal biology. Searches will be conducted at this disciplinary level or even more broadly in the case of organism-focused searches. In this appendix, we describe some of the most exciting new subdisciplines within these disciplines.

Evolutionary processes

1. *Evolutionary developmental biology*. The morphological (anatomical) features of organisms are acquired during the ontogeny, or development, of each individual, as a result of processes specified by genes and affected by environmental factors. Each cell of an organism has the same set of genes, but certain genes are "turned on," i.e. transcribed into RNA and hence translated into protein, in only certain cell types or tissues, at certain times during development. Consequently, groups of cells acquire the chemical and structural features of different tissues and organs. Until quite recently, this regulation of gene action was little understood, and the "genetic algorithms" that govern development were almost a black box. One of the most important accomplishments of recent biology has been to learn how these processes, in which genes regulate other genes in complex ways, transpire. Developmental biology has undergone a revolutionary change, and is one of the most exciting areas in contemporary biology.

Evolution of organisms' features, including the evolution of differences among species, consists of changes in the genetic program that is realized during development. Because of progress in developmental biology, it is now possible to determine the changes in "genetic algorithms" that are responsible for some of the differences among species. Until recently, evolutionary biologists could describe the genetic basis of morphological differences within and between species in general terms (i.e., the pattern of inheritance, the approximate number of gene differences responsible for variation in a characteristic), but were ignorant of the biochemical and developmental roles of the genes in question. They could not describe the evolution of the genetic algorithms of development. That has now changed, and "evolutionary developmental biology" ("evo-devo" in informal discourse) is a vibrant field, one of the most exciting in evolutionary biology. We are learning that some genes have had much the same developmental role for more than 500 million years, operating in much the same way in insects, nematode worms, and mammals. Some genes regulate the activity of different "lower-level" genes, and thus have acquired different functions, in different organisms. Substantial differences between species can be traced to evolutionary changes in a single key gene in some instances, and to the collective effects of several or many gene differences in others. A deeper understanding of developmental processes offers hope that we can understand not only what kinds of evolutionary changes are possible for a species, but also what imaginable alterations are unlikely to be realized because of internal developmental constraints.

Evolutionary developmental biology is studied both by comparisons of gene expression patterns in distantly related organisms, and by detailed molecular and genetic analyses of variation within species or among very closely related species. The first, macroevolutionary, approach sheds light on what changes in developmental pathways actually underlie "large" differences that have accrued over long periods of evolutionary time. The second, microevolutionary, approach enables us to understand the processes of evolution of development at a finer, mechanistic level by, for instance, finding the DNA sequence changes in a gene's control region that underlie differences in its expression between related species. Many investigators take both tacks.

Depending on the individual's background and research approach, an appointment would be suitable either within the Department only, or joint between the Department and the Museum or Herbarium.

2. *Evolutionary genomics*. The DNA sequence of the entire genome has been determined for more than 100 species (including human); complete genome sequencing is underway or anticipated for many more species; and sequences of significant portions of the genome are or will be available for many more. Some interesting inferences can be made from patterns discerned within raw sequence data; far more conclusions issue from determining the functions of the individual genes. Many important insights into the evolution of genes and genomes can be gained by studying variation within a single species. Many others are obtained from comparative genomics (a part of the larger field of evolutionary genomics). One of the most powerful tools for inferring the function of genes in one species (say, human) is comparison with DNA sequences of genes with known functions in other species. The team that published the mouse genome concluded that "comparative genome analysis is perhaps the most powerful tool for understanding biological function. Its power lies in the fact that evolution's crucible is a far more sensitive instrument than any other available to modern science…comparative analysis …will play a crucial role in our understanding of the human genome and thereby help lay the foundation for biomedicine in the twenty-first century" (Nature 420:557). Indeed, a year before, the reports on the human genome sequence used such comparisons as the most prominent method for making sense of the extraordinary amount of data they confronted.

Comparing genomes (or anything else) among species involves inferences from differences that have evolved between them. Furthermore, powerful inferences can be made about the origin of the diverse genes in a single species' genome, and the functional significance of these genes, by molecular signatures of evolutionary change. The analytical methods by which such comparisons and inferences are made have been developed almost entirely by evolutionary biologists, especially those concerned with inferring phylogenetic relationships and history and those concerned with modeling population-level processes of genetic change. Thus, molecular biologists have increasingly recognized that training in molecular evolution is essential to their work, and researchers in functional genomics are even more aware of the crucial importance of an evolutionarily informed perspective. Conversely, genomic databases and the sequence data that evolutionary biologists amass on species of special interest are the basis of unprecedented insights into processes of molecular and genomic evolution. Evolutionary genomics now includes studies of natural selection for gene sequences with novel functions; studies of the role of selection on "junk" DNA sequences that had been thought to lack function; the origin and functional divergence of new genes within the genome, and hence in increases in genomic complexity; rates of mutation and the role of deleterious mutations in evolution and extinction; the meaning of the structural organization of the genome, including linkage relationships among genes; changes in regulatory sequences that affect the time and place of gene activity and many other topics.

A hire in this research area could well be suitable as a joint appointment with MCDB, Human Genetics, Bioinformatics, and the Life Sciences Institute.

3. *Evolutionary theory*. Mathematical (analytical) theory and computer simulation have played a leading, guiding role in evolutionary biology since the 1930's. Indeed, the population geneticists R. A. Fisher and Sewall Wright are identified as statisticians by those who are more familiar with analysis of variance and path analysis than with evolutionary biology, and evolutionary theory has been adopted by information scientists, in the form of evolutionary algorithms, as a powerful tool for solving complex problems. Theoretical evolutionary biologists develop both models for understanding the behavior of evolving systems and methods for data analysis and hypothesis testing. The best theoreticians know biology well, understand the questions, methods, and frustrations of empirical evolutionary biologists, and can interact and collaborate with them. Theoreticians continue to play a major role in shaping both the conceptual framework and the analytical framework of our field, and include in their number some of the most influential evolutionary scientists.

Major areas of contemporary work in evolutionary theory include methods for inferring phylogenetic and other aspects of evolutionary history, especially from comparative molecular data; models for adaptive evolution of various classes of phenotypic features such as breeding systems and mating behaviors; the evolution of features of genomes; and population and quantitative genetics, which is the foundation of most evolutionary theory but continues to expand in many directions as new kinds of data enable more refined models to be developed and tested. For example, the last few years have seen stimulating development of new theory on subjects such as genetic processes of speciation, the role of small- and large-effect mutations in adaptive evolution, the evolution of characteristics that are based on complex gene interactions, and inference of various modes of natural selection from data on DNA sequence variation.

There is much opportunity for fruitful interactions with and/or a possible joint appointment of such an individual with units such as the Center for Complex Systems, the Department of Human Genetics, the Center for Statistical Genetics, the Program in Bioinformatics, and with mathematical biologists in the Department of Mathematics.

4. *Genetic basis of phenotypic evolution*. Most of evolutionary biology concerns the evolution of phenotypic traits, i.e. morphological, physiological, behavioral, or life-

history characteristics. Increasingly, such studies are informed by insights at the molecular level, but they are nonetheless motivated by the need to understand the phenotypic characteristics that express the relationships between organisms and environments. Two of the most important aspects of this enterprise are understanding the genetic basis of variation in phenotypic characteristics and understanding how they are subject to natural selection stemming in part from environmental factors. Often, and ideally, these two aims are integrated into a single research program. The questions posed may pertain to one or more characteristics in a single population or species, or to the evolutionary divergence between two or more populations or species.

The many questions in contemporary research in this area include these: How many genes contribute to the variation in a characteristic that we observe within a population? Does the variation at these gene loci consist of mutations with small or large phenotypic effects? Do these genes interact in complex ways in specifying differences among individuals? Do most such genes simultaneously affect multiple characteristics, resulting in such complex integration of the organism that a change in one characteristic causes nonadaptive side effects on other features? Are most characteristics, then, parts of highly complex genetic-developmental systems, or are they free to evolve more or less independently? How does such genetic variation interact with direct effects of environmental factors in shaping the actual pattern of variation among individuals and populations? What effect does the process of new mutation have on the amount and pattern of variation? Is mutation solely responsible for the existence of the genetic variation we observe, or do other factors help to maintain it? Are the differences between closely related populations or species based on the same mutational differences that contribute to variation within species, or does the evolution of such differences require unusual new mutations? How rapidly, therefore, can populations evolve in response to changes in environmental factors, and what genetic conditions make extinction more likely than adaptation?

This is now a flourishing field of inquiry, partly because of the continuing development of new theory, partly because of clever new experimental approaches, and partly because of new methods that have made refractory old questions accessible to answer. For example, the variation in phenotypic characteristics includes direct environmental component and a genetic component that is usually polygenic, i.e. based on many genetic loci, many of which have allelic variations with small individual effects on the phenotype. Until recently, the genetic basis of such variation could be characterized only by coarse statistical description. Now, however, abundant molecular markers can be used to map, and ultimately to identify and determine the function of, each of the genes that contribute to the variation within a species or to the difference between species. This approach ("QTL mapping") is among several methods that have become overridingly important in plant and animal breeding, in analyzing human characteristics, and in understanding variation and evolution in many other species.

Research on phenotypic evolution is closely related to research in evolutionary developmental biology, genomics, and population genetic theory, but takes different approaches and employs somewhat different methods.

This faculty member would interact with and possibly be suitable as a joint appointment with the Center for Statistical Genetics, the Department of Human Genetics, and others.

Evolutionary History

5. *Macroevolution and comparative evolutionary biology*. Many phenomena in evolution cannot be studied at the level of genetics within species, because they emerge only over very long spans of time. These "macroevolutionary" phenomena include, for example, the origin and subsequent adaptive refinement of new characteristics, such as the origin of flowers from aggregates of leaf-like sporophylls in ancient nonflowering plants, and the subsequent modification of the flower into many forms, some of them very highly modified, in different groups of flowering plants. Similar phenomena can now be studied at the genomic level, such as the origin and diversification of the genes that govern the development of the body plan in various animal groups. Macroevolutionary studies include analysis of such character evolution, including factors that have influenced rates and directions of evolutionary change. Other macroevolutionary phenomena include patterns displayed by sets of species in aggregate, such as directional evolutionary trends versus diversification, the history by which taxa have achieved their current geographic distributions, or changes in rates of species origination and extinction in relation to environmental changes or key evolutionary innovations.

Research in macroevolution has seen a renaissance in the last decade, owing to great improvement in phylogenetic inference (see below) and advances in evolutionary developmental biology (as described above). The limitations on progress in this very active field are now most likely to consist in insufficient knowledge. Data on the morphological, ecological, or behavioral features of some or many of the species that should be included in a macroevolutionary study are frequently lacking, and for many groups of organisms, there exist few authorities with expertise on the group's diversity or biology, or even the ability to identify different species. This is one context in which university museums and herbaria assume overriding importance.

6. Phylogenetics. The revolution in molecular sequencing technology and computing is resulting in the production of more accurate phylogenies and gene genealogies, which are enabling astonishingly rapid advances in knowledge of the tree of life, that is the grand project of deciphering the history of the evolution of all of biodiversity. Accurate reconstruction of phylogenies from these emerging masses of molecular data involves developing models of the evolutionary process and applying highly complex algorithms to these models to compare alternative trees from the masses of molecular data that are being generated. Phylogenetic theory is still an evolving and rapidly developing field but is critical to assembling the tree of life.

In addition to the sheer intrinsic interest of reconstructing the history of life, these much more accurate phylogenies are being used to enhance understanding of many biological processes in a newly emerging field called applied phylogenetics. A few examples of exciting new applications for new phylogenies include: (1) using phylogeny to illuminate the origins, evolution, and epidemiology of disease and the pathogens (viruses, bacteria, protozoans) implicated; (2) using phylogeny to better understand horizontal transfer of molecular sequences between different species, conferring new capabilities such as disease resistance; (3) comparing phylogenies for hosts and parasites to learn about patterns and processes of coevolution at the level of both molecules and whole organisms; and (4) using molecular-based phylogenies to diagnose and quantify genetic diversity among and within species to inform and prioritize conservation efforts. Many of these applications are just beginning, and this is an increasingly fertile area for interdisciplinary collaboration and research.

Another exciting field rooted in phylogenetics is biodiversity informatics, which harnesses the power of computational and information technologies to organize, integrate and analyze biological data from research collections for purposes of research, resource conservation, and education. An important component of biodiversity informatics databases is the integration of ancillary data associated with a specimen, including digital images and technical descriptions. Geographic Information Systems incorporating these databases are being developed to provide visual output for research on the spatial and temporal relationships of specimen data to changes in land use, climate, and range extensions of exotic species. Biodiversity informatics is integral to studies of species distributions, extinction, habitat loss, invasive species effects, consequences of global climate change, and the potential development of products that are beneficial to science and society from plants and animals. Scientists with the training to bridge the computational and museum collections disciplines are rare, and we see this as an opportunity to provide exciting new career possibilities for both undergraduate and undergraduate students. Biodiversity informatics faculty will provide national leadership in forging new collaborations among computer scientists, conservation biologists, systematic biologists, molecular biologists, educators and students.

Ecology

7. *Large-Scale ecology*. Ecologists now understand a great deal about how ecological processes play out between small subsets of organisms and at local scales. One of the major frontiers where ecologists now work is using this understanding to “scale up” to the increased complexity and much larger spatiotemporal scales representative of natural systems. This scaling up is required to further both basic understanding and to effectively confront pressing environmental issues. The fields of ecology that address questions at larger scales are ecosystem ecology, landscape ecology, global ecology, and macroecology. These are rapidly expanding fields, and combine complex intellectual challenges with critical implications for human activities and the global environment. Our world's ecosystems are changing rapidly on many fronts. Understanding the causes and consequences of this complex web of global change is a critical issue for sustaining and improving the quality of life and environment on the planet. It is also a major intellectual challenge because of the large scale and complexity of interactions involved in understanding and predicting the dynamics of entire systems. Large-scale ecologists ask such questions as: How do different ecosystems interact? How do species function in an ecosystem, and what is the level of biological redundancy? How does species

diversity contribute to ecosystem services? What properties control the response times, trajectories, and resilience of ecosystems to gradual disturbances such as climate warming or deforestation, compared to rapid disturbances such as violent storms or disease outbreaks? It is already evident that the answers will come from an integration of knowledge across many different levels of biological organization – an integration that links nearly all studies in ecology and evolution and is guided by an evolving theory of complex adaptive systems (which is the foundation of research in *Biocomplexity,* as described below).

Faculty in this area would interact and possibly be suited for joint appointments with Geological Sciences, Center for the Study of Complex Systems, SNRE, and AOSS.

8. Spatial ecology. In the past, ecological models implicitly excluded space and the spatial relationships among organisms from consideration, thus simplifying nature in order to study it. However, recent work has emphasized that ignoring space has distorted our view of the world and that the inclusion of space as an explicit component of ecological study is now required for a realistic understanding of communities, ecosystems, and entire landscapes. Work in this area has been enhanced by increases in computing power, tools for analyzing spatial relationships, application of molecular techniques, and remote sensing. The recognition that local changes have regional and even global consequences also has led to the rapidly expanding fields of landscape ecology and global ecology. One component of this active subject area is metapopulation ecology. Metapopulations are composed of many spatially distinct subpopulations connected by migration and subject to local extinction. The study of metapopulations has rapidly grown in use and usefulness over the past ten years, in terms of both more realistic models and a better understanding of the natural groups that exhibit this kind of population dynamics. Landscape ecology is another field that has developed strongly in the last ten years, partly in concert with metapopulation research (which posed such questions as how organisms disperse through different kinds of habitats on the landscape and what, exactly, controls their movement). Landscape ecologists have also helped pioneer the research on how fragmentation of natural environments by human development affects everything from the local dynamics of a community of organisms, to the global impact that our biosphere has on the atmosphere, to the limits on species migration in response to climate change.

Faculty in this area would interact with and possibly be suitable for joint positions with Center for the Study of Complex Systems, SNRE, and AOSS.

9. *Microbial Ecology*. Microbes dominate life on earth, and account for up to 50% of the Earth's biomass. These single-celled organisms were the first life forms to evolve, and they have invaded and colonized each new habitat suitable for life as the Earth itself evolved: they live in boiling water, frozen ground, acid volcanoes, and at the bottom of the ocean. They can reproduce by doubling within 20 minutes, or survive for millions of years in a resting stage. They cause the most devastating diseases known to humans, they are winning the war we are waging against them with antibiotics, and yet we cannot live

without them. Microbes generate oxygen, recycle nutrients from dead material into forms useable by plants, and enable herbivores to graze on poor quality food.

Despite the central biological roles of bacteria and other microbes, our ignorance of their diversity, activities, and interactions with each other band with other organisms is profound. Bacteria are probably many times more biologically diverse than higher organisms – some authorities suppose there are millions of species – but only a handful of species have been studied. However, molecular techniques are now leading to real breakthroughs in our understanding of microbes, since we can now identify species in natural environments, define and quantify microbes' activities, and identify the genes that control that activity. Major advances in microbial ecology lie ahead, when microbes' physiological functions and ecological interactions are studied in depth, whenevolutionary relationships and genomic diversity among microbes are better understood, and when their genetic and ecological dynamics are analyzed as an integrated system. In all of ecology, advances in this field may have the broadest impact, because so little is currently known about these extraordinarily important organisms.

The University of Michigan, mainly through EEB, can and must be a full participant in this emerging area by hiring individuals using the modern technical approaches of microbial ecology within the conceptual and intellectual paradigms of microbiology and ecology. This view is reflected widely in the University. For example, current efforts to reestablish the undergraduate Microbiology Concentration, mandated by the Provost in response to strong student interest, involve a cross-college working group of faculty from EEB, MCDB, Epidemiology, and Microbiology and Immunology who have been directed to develop a strong, academically balanced concentration that fulfills the training and professional needs of our undergraduates. This faculty group has identified microbial ecology as the single largest gap in the microbiology commitment; EEB is the obvious home for this course and faculty expertise, but we have not been able to commit to filling this gap.

Faculty hired in this area will interact with and possibly be suitable for joint appointments with faculty in Geological Sciences (role of microbes in geochemical processes), SNRE, SPH (Epidemiology) and Medicine (Immunology and Microbiology).

10.   *Biocomplexity.*   Biological systems, from cells to ecosystems, invariably consist of large numbers of parts or “players” that interact in complex ways. However, we still lack a quantitative understanding of the behavior of virtually all complex biological systems. For example, we are only beginning to understand how the immune system works, how organisms develop, what determines the rates and directions of evolution, or how ecosystems interact and function. More importantly, we cannot confidently predict how these systems will change their function as the players or their environments are altered. Understanding these aspects of life sciences in the terms of mathematical modeling and theoretical applications of universal laws and principles is a major and consummately important challenge. Several universal principles are already apparent: **(a)** Biological systems show hierarchical structures (e.g., enzymes-cells-organisms-societies-ecosystems); **(b)** These complex systems show ubiquitous features of control processes and feedback mechanisms that operate in both directions across the levels of hierarchy;

and **(c)** Biological systems are able to adapt and change over time. Moreover, the "complex systems" revolution has been driven strongly by the realization that the response of whole systems or their components is often non-linear, resulting in non-linear and chaotic dynamics. This realization has required a reformulation of some of the most classical ecological models, and has welded ecology to the study of complex systems.

The study of "biocomplexity" is the study of these complex adaptive systems in all disciplines of biology. By its nature, the study of biocomplexity is interdisciplinary within the life sciences and will engage researchers in mathematics, physics, and computer science as well. Although the Report of the U-M Life Sciences Commission proposed an initiative in studies of Biocomplexity, this part of the Life Sciences Institute was never formed. Both large-scale ecology (as an empirical example, described above) and theoretical biology are important parts of EEB's biocomplexity initiative. Ecology and evolutionary biology in particular have a long and rich history of mathematical theory, which has played a central role in advancing these fields. Theory in both of these areas is in great ferment these days because of advances in computing power (making possible analysis of spatially-explicit models, for example) and in the sheer volume of data available (e.g., in phylogenetic systematics). Particularly exciting questions in theoretical ecology, for example, concern the influence of spatially-distributed interactions on population and community dynamics, how to integrate ecosystem processes across complex landscapes, the role of variation among individual organisms in the evolution and dynamics of populations, and the nature and consequences of the non-linear interactions as described above. These questions highlight the complex nature of biological systems, and the need to understand this inherent biocomplexity in both empirical and theoretical studies. To hold pace with our peer institutions in ecology and evolution, and to be among the leaders in life sciences that are competing for funding in large new initiatives at NSF and NIH, it is essential that we build strength in biocomplexity at the University of Michigan.

11. *Applied Ecology*. Applied ecology studies the application of ecological principles to conservation, natural resource management and sustainability. While not a primary goal of our department (it is indeed the central goal of the School of Natural Resources and Environment, the School of Public Health, and several other units on campus), applied studies rely on the science of ecology to provide the underlying basis of environmental management, much as physics underlies most of mechanical engineering. The move from "theoretical" to "practical" is rarely discrete, and it should be obvious to all that we currently face the need for a bridge that uses and further develops general ecological principles and relates them to urgent applied problems. Below we describe two such bridges (possibly two positions) in the areas of sustainable development and disease ecology.

A newly emerging and highly interdisciplinary field of scientific study relates ecology, economics, and various aspects of social and political science to the conservation and sustainable development of our environment. Universities across the country are responding to this new challenge of integrating science into a post Cold War world defined by increased internationalism. Economic and social systems are larger than ever before, more interconnected than ever before, and sometimes obey rules that did not exist before. Myriad factors loom large as we seek to understand the machinery of this new society, and it is imperative that the University engage in the struggle for that understanding. From our perspective this struggle centers on how the environment and its complex manifestations is part and parcel of this new world. Indeed, the centrality of the environment is magnified in many quarters as the world has internationalized; from global warming, to tropical deforestation, to biodiversity loss, to air and water pollution, to the apportionment of risky production in less affluent regions of the world.

Intertwined environmental and economic issues are also responsible for diverse attitudes in various regions. In the "northern, affluent regions", income levels and standards of living are high, and maintaining them seems to be the primary goal. Awareness of the severity of environmental problems has matured, and even in venues formerly suspicious of "extreme environmentalism" it is now part of the conventional wisdom to be concerned about the fate of the Earth. Nations of the "south" have a very different perspective in almost every regard. Grinding poverty and great economic inequity convey an enormous need for economic development, which in turn has frequently encouraged a devaluation of environmental matters. These distinct views of and pressures on the environment are common, and despite widespread recognition that many, if not most, current development efforts are unsustainable in the long-term, the pressure to meet the needs or wants of people is nearly irresistible. As a consequence, nations and their economies are forced into development modes that are ecologically disastrous in the long term, and rich and poor nations alike are in need of an environmental accounting that recognizes their dependence on sustainable resource use. What is desperately needed is an understanding of the role that ecology and natural resources play in determining the productivity of nations, and whether or not particular tracks are sustainable in the long run.

While Michigan presently has a few faculty with strength in this rapidly emerging area, there are several initiatives with the U-M International Institute, SNRE, and SPH that signal the need for increased cooperation and contributions from ecologists and this remains a potential source of joint appointments.

12. Disease Ecology and evolution. The field of disease ecology and evolution was recently founded in part by the recognition that while both micro- and macro-parasites are ubiquitous in nature, their study is often limited to identification and classification instead of research into their population or community interactions and evolution. This field now primarily represents the study of how human populations interacting with their environments affect and are affected by pathogenic parasites. However, it also concerns the study of infectious diseases in plants and animals in nature and their importance in a variety of ecological and evolutionary processes, including population regulation, the establishment of invasive species, animal behavior and sexual selection, and their interplay with the functioning of the immune system. Researchers are asking basic and applied questions about the impact of parasites in conservation, the evolution of virulence and antibiotic resistance, the connection between disease outbreaks and climate variability, and the two-way influences between species diversity and disease. This exciting new area of interdisciplinary inquiry brings together researchers from the natural and environmental sciences, public health, the social sciences, and medicine. Recent federal initiatives involving biocomplexity, infectious disease ecology, climate variability, and environmental change all target understanding the complex web of interactions that govern the properties of environment-health systems. They also recognize the important role that theory and mathematical modeling play in generating new knowledge and understanding. Research into the ecology and evolution of infectious diseases holds the promise of producing major breakthroughs in our understanding of the origin, spread, emergence, and resurgence of pathogenic microbes of humans. While there is an obvious practical side to such research, there also are important theoretical issues, ranging from natural control of populations to the mechanisms of how large numbers of species coexist in different environments. In an era of massive global environmental changes, unprecedented population growth, increasing antibiotic resistance, and overnight transport of people and products throughout the world, such research has taken on special importance.

Functional organismal biology

13. Evolutionary and ecological functional organismal biology. Perhaps most of biology is concerned with understanding how organisms function. Fields such as molecular biology, biochemistry, and cell biology pursue such understanding at low levels of biological organization. At higher organizational levels, physiology, endocrinology, functional morphology, and behavior are among the disciplines that ask how whole organisms, or major organs, function. In each area, important and intriguing advances are being made by addressing the subject from ecological and/or evolutionary perspectives. Thus, an evolutionary physiologist may ask what mechanisms enable different species to tolerate different temperatures, and how such differences have evolved; an endocrinologist might ask how sex hormones influence plumage and behavior in species of birds that show "sex role reversal"; some neurobiologists analyze sensory and central nervous mechanisms that cause different insect species to respond to the characteristic chemical differences among plant species; a functional morphologist might analyze the structural features that make some plant species more drought-resistant than others.

These subdisciplines continue to be paramountly important. All have progressed because of various advances in molecular biology and in computation and other technologies. Several of them have also experienced a renaissance by explicitly adopting the conceptual framework and analytical methods of evolutionary biology and ecology. For example, evolutionary physiologists now use phylogenies, quantitative genetics, and studies of natural selection on physiological characteristics. Some functional morphologists combine bioengineering or biophysics with the phylogenetic comparative method.

Integrated study of organismal function provides a mechanistic basis at the organismal level for phenomena that ecologists and evolutionary biologists study at higher levels, such as the abundance and habitat associations of species, or patterns of evolutionary change and adaptation. It constrains theory, and enforces realism, by calling attention to the features that may prevent organisms from attaining a theoretical ideal. It provides a bridge between processes at the supraorganismal level (populations, species, communities, ecosystems) and processes at the suborganismal level of molecular structure and biochemical pathway. At the same time, studies of organismal function are enriched both by molecular and biochemical biology and by the theory, hypotheses, andmethodologies of evolutionary biology and ecology.

Appendix B: Research Trends and Funding Opportunities in Ecology and Evolutionary Biology

We describe here some contemporary funding emphases at the agencies that support most basic research in ecology and evolutionary biology. These funding patterns and initiatives provide an indication of some national trends in ecological and evolutionary biological research.

Ecology

Ecological research is supported at NSF mostly by the sections of Ecology, Ecosystems, and Population Biology within the Division of Environmental Biology (DEB). Of particular note is the Long Term Ecological Research (LTER) program, which supports 24 LTER research sites throughout the U.S. with an annual budget of about $18 million. About $44 million in LTER-related research is funded annually. On a smaller scale, the program in Long Term Research in Environmental Biology funds studies of ecological or evolutionary phenomena that require data extending for more than six years. DEB funds many individual investigators' research on population dynamics, community ecology, and evolutionary ecology, all of which have seen renewed vigor in recent years.

Much of this work interfaces with advances in mathematical and computer-aided analyses of complex ecological systems, including analyses of the ecology and evolution of diseases. NSF's program on Biocomplexity in the Environment has recently targeted such themes as dynamics of coupled natural and human systems, coupled biogeochemical cycles, and "Genome-Enabled Environmental Studies and Engineering." A recently announced category of proposals, Quantitative Environmental and Integrative Biology, encourages proposals at the interface of mathematics and environmental biology. NSF has joined NIH in a joint program on Ecology of Infectious Diseases, and together with NOAA, EPA, NASA, and EPRI administers a Joint Program on Climatic Variability and Human Health (which supports some of Professor Pascual's work on cholera and Professor Mark Wilson's research on influenza). Some ecological funding is also available through such private foundations as the Mellon Foundation and the James S. McDonnell Foundation (which supports Professor Pascual's research in complex ecological systems).

Research in ecosystem ecology usually is carried out by rather large collaborative groups, and is correspondingly well funded. Such research is funded not only by the Ecosystems Program within DEB, but also by NSF's Biocomplexity Initiative, by the Arctic System Science program (which contains several large, interdisciplinary programs that focus on ecosystem processes and interactions of processes at different scales), by NSF's Arctic Natural Sciences program (which has handsomely supported Professor Kling's research), and by the Microbial Observatories program (which funds research on microbial biodiversity and the role of microbes in ecosystem processes at several observatories, at about $1-2M per grant). A new NSF program (EROC – Ecological Rates of Change) is oriented toward both ecosystem and community ecology, focusing especially on global change. NSF's Water and Energy: Atmospheric, Vegetative, and Earth Interactions

(WEAVE) Initiative, integrating geosciences and ecosystems ecology, seeks to improve understanding of the Earth's hydrologic and energy cycles to support better assessments of the potential impact of human activities on those cycles and on climate. Within NSF, finally, we must note the NEON (National Ecological Observatory Network) initiative, which would fund a number of sites for ecological and evolutionary field studies. Professor Goldberg has been active in efforts to establish the University's Biological Station as a NEON site. This initiative still requires Congressional approval.

NASA has several programs that together provide up to $1 billion annually on environmental science, especially ecosystem research *sensu lato*. Much of the work is on spatial processes and scaling, which includes landscape and regional approaches to understanding ecosystems using remote sensing and modeling tools. NOAA funding in ecology is concentrated in aquatic fields, especially coastal, Great Lakes, and ocean research. Ecological research is funded by DOE via programs such as the Program for Ecosystem Research and the Terrestrial Carbon Processing Program (which funds about 10 proposals at $0.5-2M per year). The USDA has competitive grants programs in many areas of ecology, such as soil biology and plant biology.

Evolutionary biology

NSF funds evolutionary research largely through the Division of Environmental Biology sections on Population Biology and Systematics. Population Biology funds a great variety of evolutionary studies of natural populations, including analyses of natural selection and other evolutionary processes, genetic variation, and speciation. In addition to grants on phylogenetic studies of evolutionary relationships and long-term evolutionary patterns, the Systematics section oversees the Partnerships for Enhancing Expertise in Taxonomy (PEET) program, which provides 10 to 20 awards annually, totalling about $3 million, to support research and training in the basic systematics of understudied groups of organisms (e.g., mites, for which Professor OConnor holds a PEET grant). The initiative in Biodiversity Surveys and Inventories funds projects such as "botanical surveys in Madagascar" and "arthropod biodiversity from rainforest to cloud forest." Some evolutionary studies are also supported by the Plant Genome Research Program, part of the interagency National Plant Genome Initiative. Individual, small group, and large-scale collaborative efforts are supported for topics such as comparative evolutionary genomics and the genomic basis of the evolution of resistance to diseases, salt stress, and drought. The Division of Integrative Biology and Neuroscience funds research in areas such as ecological and evolutionary physiology, animal behavior, and the evolution of developmental mechanisms.

A major new initiation at NSF is “Assembling the Tree of Life", a cooperative program of the Directorates of Biological Sciences, Computer and Information Science and Engineering, Geosciences, and Social, Behavioral and Economic Sciences. The announced goal of this program is to estimate evolutionary relationships among the approximately 1.7 million described species of organisms, chiefly by analysis of molecular data. Awards totaling about $12 million per year include support of research on data analysis and computational phylogenetics and phyloinformatics.

NIH has long been a major source of funding of research in genetic aspects of evolutionary biology, such as population genetics, molecular evolution, and now evolutionary genomics. At NIGMS (Institute of General Medical Sciences), an initiative on Genetic Architecture, Biological Variation, and Complex Phenotypes emphasizes research on "variation in basic biological systems, including sequences, structures, and pathways that direct metabolism and development; variation in these systems within individuals, among individuals, among populations, and among species with the goal of learning how these complex systems interact and evolve; determination of the extent to which genetic architecture is shared across populations and among species; effects of admixture, population history, recombination, mutation, population structure, selection, and drift on the organization of variation." (This describes much of the research program of evolutionary genetics.) Another initiative, on Evolution of Genome Properties, notesthat "an emerging area of research focuses on how properties of genomes arise inevolutionary history. Such research has important consequences for understanding genome organization and for interpreting data on genetic and phenotypic variation. Such research could include the evolution of haplotypes, selection for genetic interactions, and the evolution of recombination and methylation patterns."

NIH-supported research has usually been restricted to a few species of model organisms, so it is particularly interesting to note a new interest in "Extensions to Other Organisms." The guidelines for applications note that "Many organisms have been studied for their value in agriculture or ecology. Thus, there is considerable information about the population structure, natural history, and genetics of these systems. It will be valuable to take advantage of this wealth of information to study variation in the natural settings in which it evolved." It is clear that evolutionary and comparative approaches are rapidly becoming widely appreciated as indispensably important components of genomic science. In this same vein, NIGMS funds work in Bioinformatics, noting that "the study of biological variation depends heavily on rich data sets; researchers need the ability to access many kinds of information (e.g., DNA sequence, protein structure, development, natural history, and phenotype) in organisms from different habitats, from different populations, or from different species. This initiative supports development of tools to help researchers use data from many databases to address research questions."

The National Human Genome Research Institute, likewise, has issued a call for proposals on major themes in evolutionary genetics, including many of the subdisciplines we describe under evolutionary processes in *Appendix A.*

Appendix C: Concentrations in the Program in Biology

PROGRAM IN BIOLOGY

RECORD OF CONCENTRATION IN BIOLOGY AND GENERAL BIOLOGY

Name____________________________ **Uniqname**_________________________

Student Number ___________________ Expected Date of Graduation ______________

Students interested in one of the biology concentrations should consult with a general counselor during their freshman year and with a concentration advisor by the middle of the second term of their sophomore year. Concentration advisors are assigned through the Biology Program Office (1111 Nat. Sci.). Questions about the content or appropriateness of particular courses should be directed to counselors or the appropriate instructor. The office staff will be pleased to answer general questions about the biology concentration programs.

PREREQUISITES (5 lab courses)
It is not necessary to complete every prerequisite before declaring a concentration in biology.

Introductory Biology (5 hours, 1 lab)

	CR	TERM	YEAR	COMPLETED
Biology 162	5	_____	_____	____________

Introductory Physics (10 hours, 2 labs)

	CR	TERM	YEAR	COMPLETED
Physics 125 or 140	4	_____	_____	____________
Lab 127 or 141	1	_____	_____	____________
Physics 126 or 240	4	_____	_____	____________
Lab 128 or 241	1	_____	_____	____________

Mathematics* (8 hours)

	CR	TERM	YEAR	COMPLETED
Math. 115	4	_____	_____	____________
Math. 116	4	_____	_____	____________

***Students with AP credit for Math. 120 should enroll in Math. 116; students with AP credit for Math. 120 and 121 will have fulfilled the mathematics prerequisite requirement.**

Chemistry (10 hours, 2 labs)

	CR	TERM	YEAR	COMPLETED
Chem. 210	4	_____	_____	____________
Chem. 211	1	_____	_____	____________
Chem. 215	3	_____	_____	____________

Chem. 216		2	_____	_____	____________

REQUIRED COURSES WITHIN THE BIOLOGY CONCENTRATION

Concentrators must take a minimum of **33** hours, which must include three courses with laboratory. Library "research" and introductory biology laboratories do not qualify. Biology counselors will help you narrow your course selections in accordance with your interests and career aspirations. A **maximum** of three hours of independent research under the direct supervision of a faculty member (EEB or MCDB 300 or 400), or on approval of a biology program counselor, three hours of independent research under a faculty member of another University of Michigan department, may be used as one of the three laboratory experiences.

REQUIRED COURSES IN GENETICS, BIOCHEMISTRY, AND EVOLUTION

TITLE	NUMBER	CR	TERM	YEAR	COMPLETED
Introduction to Genetics	305	____	_____	_____	_____
Introductory Biochemistry	310 **OR**				
Biochem. by the Keller Plan	311 **OR**				
Biol. Chem. (Med. School)	415	____	_____	_____	_____
Evolution	390	____	_____	_____	_____

DISTRIBUTION WITHIN THE BIOLOGY CONCENTRATION

Select at least one course from group I and one course from group II. (See Course Listings I-II for the available courses in each group.)

	CR	TERM	YEAR	LAB	COMPLETED
I. Molecular, Cell, and Developmental Biology					
____________________________	___	_____	_____	____	____________
II. Ecology, Evolution, and Organismal Biology					
____________________________	___	_____	_____	____	____________

III. Select one course in EEB or MCDB at the 300 or 400 level (except EEB 302, or MCDB 302 or 412)

	CR	TERM	YEAR	LAB	COMPLETED
____________________________	___	_____	_____	____	____________

IV. Additional Course Selections by Biology Concentrators

Select additional Biology, EEB, or MCDB courses at the 200 level or above (except Biology 262, EEB 302, MCDB 302, or MCDB 412) to bring your concentration total to at least 33 hours. You may use **two** counselor-approved cognate courses toward your concentration. Introductory science courses and prerequisites are excluded.

	CR	TERM	YEAR	LAB	COMPLETED
____________________________	___	_____	_____	____	____________
____________________________	___	_____	_____	____	____________
____________________________	___	_____	_____	____	____________
TOTAL HOURS IN CONCENTRATION	___				

REQUIRED COURSES WITHIN THE GENERAL BIOLOGY CONCENTRATION

Concentrators must take a minimum of **27** hours, which must include two courses with a laboratory. Library "research" and introductory laboratories do not qualify. A minimum of three hours of independent research (EEB or MCDB 300 or 400) under the direct supervision of a faculty member in the EEB or MCDB Departments may be used to fulfill the required laboratory experience.

REQUIRED COURSES IN GENETICS, BIOCHEMISTRY, AND EVOLUTION

TITLE	NUMBER	CR	TERM	YEAR	COMPLETED
Introduction to Genetics	305	___	_____	_____	____________
Introductory Biochemistry	310 **OR**				
Biochem. by the Keller Plan	311 **OR**				
Biol. Chem. (Med. School)	415	___	_____	_____	___________
Evolution	390	___	_____	_____	___________

TWO REQUIRED LABORATORY COURSES

	CR	TERM	YEAR	LAB	COMPLETED
_________________________	___	_____	_____	____	____________
_________________________	___	_____	_____	____	____________

DISTRIBUTION WITHIN THE GENERAL BIOLOGY CONCENTRATION

Select one course from group I and one course from group II. (See course listings I-II for the available courses in each group.)

	CR	TERM	YEAR	LAB	COMPLETED
I. Molecular, Cell, and Developmental Biology					
________________________	___	_____	_____	____	____________
II. Ecology, Evolution, and Organismal Biology					
________________________	___	_____	_____	____	____________

REQUIRED COGNATE COURSE

Select one course from the **General Biology Cognate List**, which is attached, to fulfill this requirement.

	CR	TERM	YEAR	COMPLETED
_______________________	___	______	______	____________

ADDITIONAL COURSE SELECTIONS

SELECT ADDITIONAL BIOLOGY, EEB OR MCDB COURSES (EXCEPT BIOLOGY 262, EEB 302, MCDB 302, OR MCDB 412) TO BRING YOUR CONCENTRATION TOTAL TO AT LEAST 27 HOURS.

	CR	TERM	YEAR	COMPLETED
____________________________	___	_______	_______	______________
____________________________	___	_______	_______	______________

TOTAL HOURS
IN CONCENTRATION ___

ACADEMIC MINOR IN BIOLOGY

Name ____

Student Number ______________________ **Date of Graduation** _______

An academic minor in Biology is not open to students with a concentration in Biology, General Biology, Plant Biology, Cell & Molecular Biology, or Biochemistry, nor to students electing an academic minor in Environmental Studies or Global Change.

PREREQUISITE

	TERM	YEAR	COMPLETED
Biology 162	_____	______	____________

MINOR PROGRAM

Courses totaling a minimum of 17 credits at the 200-level or higher in BIOLOGY, EEB, or MCDB including:

1. Choose 2 courses from:
   - Biol. 281 (General Ecology)
   - Biology 305 (Genetics)
   - Biol. 310 or 311 (Biochemistry)
   - Biol. 390 (Evolution)

	CR	TERM	YEAR	COMPLETED
____________________________	__	_____	_____	____________
____________________________	__	_____	_____	____________

2. One laboratory or field course in BIOLOGY, EEB, or MCDB at the 200-level or higher (EEB 300 or 400, or MCDB 300 or 400, independent study, elected for a minimum of 3 credits may be used to fulfill this requirement):

____________________________	__	_____	______	___________

3. One additional BIOLOGY, EEB, or MCDB course at the 300-level or higher (except EEB 302, MCDB 302 or MCDB 412). A third course from those listed in Group 1 may be used to satisfy the requirement:

____________________________	__	_____	______	___________

4. Elective courses in BIOLOGY, EEB, or MCDB at the 200-level or higher to bring academic minor credits to at least 17 hours:

____________________________	__	_____	______	___________

Appendix D: Courses taught by EEB faculty in the Biology Dept. (AY 1999, AY 2000, AY 2001) and in the Program in Biology and EEB (AY 2002, 2003, 2004).

Values are enrollments (* indicates taught 2 terms, ** indicates taught 3 terms). For cross-listed courses, the first number is the number of enrollments through Biology or EEB and the second number is the total course enrollment.

Dept.	#	Course Name	98-99	99-00	00-01	01-02	02-03	03-04
Biology	100	Biology for Non-Scientists	362*	171	189	175	171	130
Biology	101	Biology and Human Affairs	144	215	207	211	202	195
Biology	102	Practical Botany	99	125	122	129		
Biology	103	Ecology: Prin. & Applications			13		23	16
Biology	105	Biology of Human Nutrition			60	121		194
Biology	108	Animal Diversity		33	65	54	81	
Biology	109	Eco Know & Env Prob Solving			114		172	
Biology	110	Global Change (x listed)	124	133	64*135	63*163	47*147	29*116
Biology	120	First Year Seminar	49*	75*	56*	80*	40*	52
Biology	130	Animal Behavior		150		161		144
Biology	162	Introductory Biology	585*	1187**	1059**	1050**	1116**	445
Biology	163	Honors Introductory Biology				25	33	36
Biology	195	Intro to Biology	64					
Biology	200	Undergraduate Tutorial	23*	21*	3**	3*	10**	5*
Biology	201	Research in Life Sciences	54*	42*	36*	30*		
Biology	207	Intro Micro	216	205	229	200	204	216
Biology	215	Spring Flora	33	27	29		25	
Biology	225	Animal Physiology (325)	198	347*	416*	457*	539**	204
Biology	230	Plant Biology		18	28	35		40
Biology	252	Chordate Anat & Phyl	58	45	65	49	50	60
Biology	255	Plant Diversity	32		37	34		
Biology	262	Evol. Bio. & Human Disease (x-listed)				53* 78	40*99	
Biology	275	Plant Development	11					
Biology	281	General Ecology	172*	148*	180**	174*	165*	99
Biology	282	Ecology Lab	31	36	53*	46	48	54
Biology	288	Animal Diversity			31	48	54	51
Biology	300	Biology-Undergraduate Research	112**	123**	117**	116**		
Biology	301	Writing for Biologists	66	100	117			
Biology	305	Genetics	632**	619**	559**	649**	638**	272
Biology	310	Intro Biochemistry	320**	320**	367**	271**	491**	155
Biology	311	Intro Biochemistry	548*	523*	322*	349*	188	245

Dept.	**#**	*Course Name*	**98-99**	**99-00**	**00-01**	**01-02**	**02-03**	**03-04**
Biology	390	**Evolution**	181*	197*	288*	280*	275*	116
Biology	400	Biology Advanced Research	118**	135**	115**	127**		
Biology	401	Biol. Topics	24	54	45	7		
EEB	300	EEB-Undergraduate research					23*	13
EEB	315	Ecol & Evol Infec. Dis.					45*49	
EEB	341	Parasitology	57	55	54	57	57	
EEB	355	Woody Plants (x listed)	90	80	14*64	13*55	6*70	9*51
EEB	380	Oceanography	49	49	22	39	20	
EEB	400	EEB Advanced Research					10*	4
EEB	401	Biol. Topics EEB					14	
EEB	433	Ornithology (x listed)	20		9*36		10*25	
EEB	437	Biology of Invertebrates		9				
EEB	440	Biology of Fishes (x listed)	44	48	11*30	19*43	16*35	8*28
EEB	441	Biology of Fishes Lab (x listed)	20	25	4*15	10*25	7*15	1*8
EEB	442	Biology of Insects						12
EEB	445	Biogeography (x listed)	30		18* 21			
EEB	450	Bio of Amphib & Reptiles	15		9	12	13	8
EEB	451	Biology of Mammals (x listed)		76		44*63		
EEB	458	Algae		5			5	
EEB	459	Systematic Botany	19	12	16		15	
EEB	463	Neotropical Plants				13		8
EEB	468	Mushrooms and Molds		19	16		17	
EEB	472	Plant-Animal Interactions		10	8	18		
EEB	473	Aquatic Ecology Lab					6	
EEB	476	Ecosystem Ecology (x list)		11* 29		13* 38		
EEB	477	Field Ecology Lab (meet w/NR)	9	8	9*14	9*18		
EEB	479	Rainforests	2	2		3	1	
EEB	480	Computer-Aided Inferences	7	6	9	14		3
EEB	481	Pop. Dynamics & Ecology	13	10	9	7	15	14
EEB	483	Limnology	27	34	36	46	16	
EEB	484	Limnology Lab	7	8		9		
EEB	487	Ecol of Fishes (456 xlist)	51	8* 32	2* 22	6* 18	6*18	
EEB	488	Microbial Ecology	28			31	22	
EEB	489	Soil Prop & Proc (x listed)	33	52	6*39		3*26	1*8
EEB	490	Pop. & Quant. Genetics				21	18	
EEB	491	Phylogenetic Systematics	15		8			
EEB	492	Behav. Ecol (Ethology)	19	28				
EEB	496	Pop Ecology (x list)	17	0* 15	2	1* 17	2*17	
EEB	497	Community Ecology	11		13	12	20	

Dept.	#	Course Name	98-99	99-00	00-01	01-02	02-03	03-04
EEB	498	Agroecosystems		10		13		11
EEB	499	Dynamic Syst.	2		5		3	
EEB	514	Molecular Evolution		12		11		
EEB	516	Principles of Evolution						21
EEB	532	Birds of the World	6		4		5	
EEB	685	Ecol., Evol. & Organ.	16		12	13	17	

Appendix E: Graduate Policies

THE UNIVERSITY OF MICHIGAN
Department of Ecology and Evolutionary Biology

Ph.D. Policies and Procedures

1. Focus
Faculty and graduate students in the EEB Department include ecologists, evolutionary biologists, organismal biologists and systematists who analyze such topics as behavior, biogeochemistry, population dynamics, community structure, environmental physiology, disease ecology, biogeography, life history evolution, selection, speciation, species interactions, and phylogenetics. Their techniques include comparative and experimental approaches in ecology, ethology, genetics, molecular biology, morphology, paleontology, physiology, biochemistry and cytology. Many members of this group are specialists on particular groups of organisms.

2. Orientation/Advising
The Department holds an orientation for new graduate students prior the beginning of the fall semester. All new students meet with a counseling committee for general counseling. At this meeting the counseling committee (1) advises the student on course selection, (2) reviews Departmental requirements, (3) selects EEB 700-730 advisors, and (4) discusses with the student various approaches for achieving his/her goals within the disciplinary framework provided by EEB.

An initial counseling report of this meeting is prepared by the counseling committee and submitted to the Graduate Coordinator for inclusion in the student's permanent file.

The student is expected to meet with the EEB 700 advisor during the first week of the fall term to discuss the student's background, interests and plans and to establish a schedule of activities leading up to Evaluation and Candidacy. The student should meet with the secondary advisor at least once during the fall term to discuss their progress and to keep abreast of any changes in plans. The student may change advisors; if so they must notify the Graduate Affairs Committee of any change in a memo.

3. Courses
a) EEB 685: All students are required to register for EEB 685, "Current Topics in EEB" for fall term for one credit. In this course students will meet faculty and learn about current research being done in the department.
b) EEB 700-730: All students are required to register for EEB 700 (Fall) and EEB 730 (Winter) during the first academic year of enrollment and to write at least one paper. Copies of the paper must be submitted to his/her advisor and permanent file in the Graduate office. Students may have different advisors for each term. Students should consult the document "EEB Requirements and Guidelines for EEB 700-730" for further information concerning the role that these courses play in the graduate program.
c) Seminars: Many seminars are offered within the Department and students are expected to attend and participate in seminars.

4. Preliminary Examination
Students must demonstrate that they are qualified to proceed in the Ph.D. program by passing the EEB Evaluation. Students undergo this evaluation in the fall term of their second year.

For information on the evaluation procedure, see "EEB Evaluation Procedure Guidelines".

5. Dissertation Committee
Once a student has passed the EEB Evaluation, he/she should form a Dissertation Committee. The student should notify the Graduate Affairs Committee of the composition of his/her Dissertation Committee during winter term of the second year. Before the winter break, the student will hold an initial meeting with the Dissertation Committee to discuss research plans and the requirements for the proposal. Before the end of the second year, the student must hold a candidacy meeting and present a research proposal (see below).

The student, in consultation with her/his major professor, selects the members of the Dissertation Committee (see below). This committee has a minimum of four members and must include a chair (or two co-chairs), two members of the EEB Department, and one cognate member from a different research area that satisfies Rackham's requirement. If you have a member that does not have an appointment with the University of Michigan, please see the Rackham Dissertation Handbook at www.Rackham.umich.edu/OARD/pdf/disscommittee.pdf. The Dissertation Committee is responsible for (1) certifying that the student has met all requirements of Candidacy, (2) providing advice concerning the conduct of the thesis research, (3) monitoring progress in research, (4) providing advice on other aspects of professional development, (5) administering the final oral thesis defense, and (6) certifying that the completed thesis meets the requirements for the Ph.D. degree.

The student must meet with their Dissertation Committee at least once a year before April 2nd to assure satisfactory progress in the program. After each meeting, a progress report signed by both the Committee Chair and the student will be placed in the student's permanent file and will be reviewed by the Graduate Affairs Committee. "Satisfactory progress" is one criterion for continued financial support.

Additional information concerning the functions and responsibilities of the Dissertation Committee is found in the Rackham Student Handbook (http://www.rackham.umich.edu/StudentInfo/Publications/GSH/html/contents.html).

6. Candidacy
All students who pass the evaluation are expected to achieve candidacy by the end of the following term. Typically, this will be by the end of the fourth term. Candidacy is achieved when the student has met all of the requirements for the Ph.D. except for the dissertation, has met the minimum fee requirements, has taken four credits of cognate courses (courses outside the EEB Department), and has been approved for subsequent dissertation work by the Dissertation Committee. The Dissertation Committee meets with the student to evaluate the thesis proposal and to determine the student's readiness to proceed. The thesis proposal, often written in the format of a grant proposal, must be

submitted to committee members at least one week before the meeting. A copy of the approved proposal must be placed in the student's permanent file in the Graduate Office. On the basis of the thesis proposal and the meeting, the Dissertation Committee may recommend (1) advancement to Candidacy, (2) revision of the proposal, to be evaluated by the committee in a second meeting, or (3) termination of the student status. The recommendation of the Dissertation Committee is reported to the Graduate Affairs Committee.

Under extraordinary circumstances students may petition the GAC for an exception to this schedule.

Because Rackham requires 36 fee-credit hours to achieve Candidacy, students must take an average of 9 credits per term during their first two years.

Additional information concerning Candidacy is provided in the Rackham Student Handbook (http://www.rackham.umich.edu/StudentInfo/Publications/GSH/html/contents.html).

7. Thesis Defense

The last step in the process of earning a Ph.D. is the oral thesis defense. You must schedule your pre-defence meeting with Rackham (OARD.questions@umich.edu) at least ten working days prior to your oral defense.

The student must arrange a date for the oral defense acceptable to all members of the Dissertation Committee and must advertise it in public postings. Copies of the thesis and a Rackham Evaluation form must be presented to the members of the Dissertation Committee at least two weeks before the oral defense.

The doctoral thesis is defended in a public seminar open to all faculty and students in the University. Following the public portion of the defense, the Candidate defends his/her thesis before the Dissertation Committee, plus any other member of the EEB Department who wishes to attend. After the oral defense, the Dissertation Committee decides upon the acceptability of the dissertation. The Committee may accept or reject the dissertation or recommend further work and re-examination.

Additional information about the dissertation and the oral thesis defense is provided in the Rackham Student Handbook and the Dissertation Handbook.

8. The Role of the Graduate Coordinator and the Graduate Affairs Committee
The Graduate Coordinator in the EEB office is available to provide information and assistance to graduate students and is responsible for coordination, administration and tracking of all matters pertaining to the graduate program. The Graduate Affairs Committee is responsible for monitoring, evaluating, and facilitating the progress of students in the program. Students should feel free to consult the Committee and/or the Graduate Coordinator with any questions or concerns**.**

Year 1	Fall	Winter
	Orientation (1st week)	Meet with 730 advisor
	Meet initial advisor (1st week)	Register for EEB 730
	Meet with 700 advisor	Meet with secondary advisor
	Meet with secondary advisor	Complete paper for the student file
	Register for EEB 685 & 700	Meet with Evaluation Committee
Year 2	Fall	Winter
	Submit evaluation	*Meet with Dissertation Committee*
		Achieve candidacy

Subsequent years
Have your yearly meeting before April 2nd.

Please note: Under extraordinary circumstances students may petition the GAC for an exception to this schedule.

05/03

THE UNIVERSITY OF MICHIGAN
DEPARTMENT OF ECOLOGY AND EVOLUTIONARY BIOLOGY

Evaluation Procedure for the Ph.D. Program

1. RATIONALE

The rationale of the evaluation process is to help you develop the skills that are necessary in a scientific career. These skills include building a comprehensive base of background knowledge, the developing and testing of hypotheses, and communicating your findings in formal oral and written formats as well as in an informal discussion of scientific matters with colleagues. These areas are represented by the three parts of the evaluation - the review paper, the seminar, and the oral exam.

2. EVALUATION COMMITTEE

The Evaluation Committee consists of three members of the faculty, two of whom are members of the standing EEB Evaluation Committee. The third member is selected by the student. A student may petition the Chair of the EEB Evaluation Committee to add a fourth member to the committee.

3. REVIEW PAPER

Preparing the review paper is intended to develop a student’s skills in analytical thinking, in formulating research ideas, and in preparing manuscripts and research proposals. The paper topic is the student’s choice, but it should address an issue of broad ecological or evolutionary interest. A hypothesis-testing framework which comprehensively reviews and provides a synthesis of your topic and its likely future development is required; papers that are merely catalogues of the literature or factual knowledge are not acceptable. The Evaluation Committee will expect some creativity and original insights in your review paper.

The paper should be prepared in a format appropriate for submission as a manuscript for publication in a review journal, such as the Quarterly Review of Biology or Biological Reviews. The paper should have an abstract of 150-200 words in which the questions, general approach, specific results and major conclusions are succinctly described. The introduction should describe the general context of the study, the specific questions posed, and the reasons why the questions are significant and interesting. The maximum length is 25 typed double-spaced pages of text.

Before beginning the paper, a student should discuss the suitability of possible topics with his/her advisor and a member of the EEB Evaluation Committee. Papers written earlier, such as Master's or Honor's theses, are not acceptable, although material from such papers may be incorporated into the Review Paper if approved by the student's evaluation committee. The paper cannot be on the exact, same topic as the seminar, but the seminar can address some specific aspect of a broader topic discussed in the paper. Students are encouraged to circulate draft copies of the review paper for comments from other students and faculty, except for faculty on the standing EEB Evaluation Committee. Writing style, organization, grammar, spelling and punctuation also will be evaluated. Preparation of the review paper should be initiated during the Winter Term preceding evaluation.

4. SEMINAR

The seminar is intended to develop a student's skills in organizing concepts and results and preparing visual materials for use in an oral presentation. The seminar also develops skill in speaking in front of an audience of interested and knowledgeable peers. The seminar should deal with a specific research project and should have a narrower focus than the review paper. The seminar is typically based on a student's own research, but if this is not possible, other research results may be presented. Seminars must place the specific project or topic into a broader scientific context, and at the end should place the results within the framework of future research. The seminar must present hypotheses, explain the experimental approach for testing those hypotheses, present the data and their analysis clearly, and finally interpret the data with respect to the hypotheses within the broader scientific context originally put forth.

Seminars are open to the public and consist of a 40-minute presentation followed by a 10-minute question period. It is imperative that you keep within this time limit. The seminar must be given before the oral exam, and the seminar and oral exam cannot be on the same day. The student is responsible for publishing an announcement of the time and place of the seminar in the Department Newsletter during the week preceding the presentation. Students wishing to receive credit for presenting the seminar may sign up for Bio 800.

5. ORAL EXAMINATION

The oral examination is intended to develop the student's ability to discuss science in an informal way with interested and knowledgeable peers. Typically, the first half of the exam is based on the student's review paper and seminar, while the second half ranges widely into other areas. We expect that a student will demonstrate a general knowledge of biology, a good understanding of contemporary ecology and evolutionary biology, and expert knowledge in the topic area of the review paper.

Oral exams typically last about 2-3 hours. It is the responsibility of the student to arrange the date and time of the oral exam in consultation with members of his/her evaluation committee.

6. SPRING PRE-EVALUATION MEETING

At the end of the Winter Term of the student's first year there is a "spring meeting" with the Evaluation Committee. This meeting is designed to give the student a "feel" for what the oral exam will be like in the coming Fall Term, and to highlight any areas of concern that the student or the Committee may have in the student's preparation for the oral exam or the overall evaluation process. There is a list of general readings (attached to the end of this document) in ecology and evolutionary biology that can serve as starting points for students with deficiencies in particular areas. At this time the student may also discuss topics for the review paper and seminar with the Evaluation Committee. Starting in April of the Winter Term the student provides the Evaluation Committee with a 1 page CV and 1 page written description of their background and research interests. This background material is given to the Evaluation Committee at least one day before the meeting; the time and place of the meeting are arranged by the student.

7. THE EVALUATION PROCESS

Each member of the student's evaluation committee independently writes an evaluation of the review paper, seminar, and oral exam, and ranks each as "acceptable" or "unacceptable". Based upon these evaluations, the Evaluation Committee formulates a recommendation concerning each student. The Committee can recommend that a student (1) proceed to establish a Dissertation Committee, (2) undertake remedial action and retake all or a portion of the Evaluation at a later date, or (3) be separated from the Ph.D. Program. These recommendations are presented to the entire EEB Faculty at a meeting in early December, at which time they are discussed along with other aspects of the students' performance since entering the program. The EEB Faculty may accept, reject, or amend the recommendations of the EEB Evaluation Committee. The recommendations of the Faculty are then communicated to the students, and to the Departmental Graduate Affairs Committee for consideration and action. Students are informed of the final, official outcome of the Evaluation Process by the Graduate Affairs Committee. Students may appeal the final decisions, and the appeal process is initiated by writing a letter to the Departmental Graduate Affairs Committee.

8. SCHEDULE, DATES, DEADLINES, and STUDENT RESPONSIBILITIES

(a) March-April (before end of Winter Term of first year). Submit the name of the faculty member chosen to serve as the third member of your Evaluation Committee.

Arrange a time for the "spring meeting" with your Evaluation Committee, and distribute a 1 page C.V. and a 1 page description of your background and research interests to your committee members at least 1 day before the meeting.

(b) September 15 (beginning of Fall Term of second year). Confirm or note changes in the composition of your Evaluation Committee and the topics for your review paper and seminar.

<u>(c) Mid-October</u> (Fall Term, second year). Submit copies of your review paper to your Evaluation Committee and to the Graduate Program Coordinator in the Department Office. At the same time give each member of your Evaluation Committee an evaluation form, which is available in the Department Office. The exact deadline date for submission of all the papers will be determined by the Evaluation Committee.

<u>(d) October-November</u> (Fall Term, second year). Schedule your seminar and your oral exam during this period with the Evaluation Committee (the seminar may be given in September if your evaluation committee agrees). The seminar must be given before the oral exam, and the seminar and oral exam cannot be on the same day. The oral exam must be scheduled a minimum of 5 days after the review paper is submitted to your committee. The Graduate Program Coordinator will inform you how to reserve rooms for the seminar and oral exam. Publish your seminar notice in the Department Newsletter at least one week prior to your seminar date.

Revised 5/2002

Appendix F: Faculty mentoring and promotion procedures

Department of Ecology and Evolutionary Biology

Junior Faculty Mentoring and Reviews

Constructive mentoring and reviewing of tenure-track faculty work to help faculty meet high standards of rigor, depth and innovation in scholarship and to realize their full potential as scholars, teachers and members of the academic community. The College has established a set of principles and best practices involved in mentoring and reviewing tenure-track junior faculty. The Department of Ecology and Evolutionary Biology (EEB) has used these to develop the specific procedures described below that will be followed in our department, including for faculty with joint appointments with the Herbarium, Museum of Zoology, or Museum of Paleontology (henceforth, Museum units). All references below to “Chair [and Director]” refer to a) the Chair of EEB for assistant professors with appointments only in EEB or b) the Chair of EEB and the Director of the appropriate Museum unit for assistant professors with joint appointments with a Museum unit. For faculty with joint appointments with other units, the specific mentoring and annual/third-year review procedures for each case will be specified in a joint letter to the new faculty member from the Chairs or Directors of all units involved.

First year: During the first term of the assistant professor's first year, the faculty person will receive from the Department: a copy of the College's statements on “Tenure Proceedings: Best Practices” and "Principles and Best Practices: Junior Faculty Mentoring and Third-Year Reviews", a copy of this document, and a copy of the department’s procedures for tenure review. Before the end of that term the assistant professor will meet with the Chair [and Director]. The meeting(s) will include a thorough explanation of the schedule and procedures of the review process. The conversation will include an explicit reminder than neither a renewal of the contract after three years nor an eventual granting of tenure is guaranteed.

Also during the first term of the assistant professor’s first year, the faculty person will be assigned a senior faculty member as a mentor. The choice of the mentor will be made by the Chair [and Director] in consultation with the new faculty member. It is up to the new faculty member and the mentor to define the format and approaches for meeting, but the relationship should involve discussion of the expectations for research, teaching, and service to the Department, the University, and the larger academic community.

Each year: During the winter semester of each year, the assistant professor will meet with the Chair [and Director]. The meetings will review their teaching and research in relation to their progress towards tenure, and in the case of joint appointments with a Museum unit will review their curatorial contributions. The meetings should address areas of strength and areas for improvement in teaching, research and service, and (as appropriate) curatorial activities. The meetings should offer advice and encouragement to the candidate and should seek constructive ways of addressing any emerging problems. The discussion should then be summarized by the junior faculty member in a letter to the Chair. The Chair will respond to this letter by either confirming the accuracy of its summary or by noting any amplifications to the understanding it conveys. In the case of a joint Museum appointment, the discussions should be summarized in a joint letter from the untenured faculty member to the Chair and the Director of the Museum unit to ensure a consistent set of advice to the candidate. The Chair and Director should then also respond jointly. In all cases, a copy of the final letter summarizing the discussions with the appropriate administrative head(s) should be sent to the departmental-assigned mentor of the untenured faculty member.

Third year: During the Fall semester of the assistant professor's third year, the chair of the Promotions and Merit Committee will send the assistant professor a letter requesting the following information, with deadlines:

1. Lists of University of Michigan colleagues and current and former students who can be asked to comment on the assistant professor's performance in the areas of scholarship, teaching, and/or service as appropriate. In the case of Museum appointments, names should also be provided of individuals who can comment on the area of curatorial performance. The Chair [and Director] may add names to this list, in consultation with the Promotions and Merit Committee. Candidates should indicate to the Chair [and Director] the names of persons they consider inappropriate to assess their work by reason of conflict of interest, or kinship or domestic relationship, and should indicate why they consider these persons inappropriate. In such cases, the Chair [and Director] should not ask these persons to provide internal assessments.

2. A current candidate’s form, a current curriculum vitae with a complete list of publications, research and teaching statements, CRLT scores and other evidence of teaching performance during the assistant professor's time at the University of Michigan, and copies of the most significant publications. In the case of joint appointments with a Museum unit, curatorial statements should also be provided.

3. A schedule for the Promotions and Merit Committee to meet with the assistant professor during that term.

The current file including the letters provided by the colleagues and students will be read by all members of the Promotions and Merit Committee before meeting with the assistant professor. For assistant professors with joint positions with a Museum unit, if the Promotions and Merit Committee does not include a member of the appropriate Museum unit, an ad hoc member from the unit will be appointed by the Chair and the Director of the Museum unit as an additional member of the Promotions and Merit Committee, for the purposes of review of that faculty member only.

The meeting will discuss all aspects of the assistant professor's progress to date. This will include explicit comments on both strengths and weaknesses of the record, and the expectations of the Department and, if appropriate, the Museum unit, with respect to improvements of the record. The committee should determine that the candidate is not being unduly burdened by excessive new course preparations, large classes, or excess service assignments, and that the candidate has the opportunity to teach at the senior undergraduate and graduate level in the candidate's area of research. The assistant professor will receive a description of the procedure for promotion.

Before the end of the same term, the Promotions and Merit Committee will submit to the Chair [and Director] a summary of their review and recommendations. That report will be a clear, accurate and constructive commentary and will include:

1. A recommendation concerning whether the assistant professor's contract should be renewed for a second three-year period.

2. In the case of a positive recommendation, specific suggestions for changes both by the assistant professor and by the Department and, as appropriate, the Museum unit, that might improve the assistant professor's prospects to gain tenure.

3. In the case of a negative recommendation, specific reasons for the Committee's conclusion that the assistant professor is unlikely to meet the standards for promotion with tenure and any other bases for its recommendation that the assistant professor's contract not be renewed.

After receiving the report from the Promotions and Merit Committee, the Executive Committee will discuss the recommendation and vote on whether to accept that Committee's recommendation. For an assistant professor with a joint department/museum appointments, if the recommendation from the Promotions and Merit Committee is negative, the voting membership of the Executive Committee should be supplemented for this discussion and vote to ensure that: a) half of its voting faculty members are from any of the Museum units and at least one voting member is from the same Museum unit as the assistant professor. By the end of February of the winter term of the 3rd year, the Chair and, as appropriate, the Director of the Museum unit will meet with the assistant professor. In that meeting the Chair [and Director] will give the assistant professor a copy of the recommendation and will tell the assistant professor of the decision of the Executive Committee. For those who are granted a renewed contract, the discussion will include the Department's and, as appropriate, the Museum unit's expectations over the next three years. The assistant professor and the Chair [and Director] will initial the appropriate items in the "Third-Year Review Checklist." This checklist will include statements that the discussion included (a) expectations concerning research and publications, (b) expectations concerning teaching, (c) expectations concerning service, (d) in the case of museum appointments, expectations concerning curatorial contribution, (e) a statement that the written summary of the Promotions and Merit Committee has been given to the candidate by the Department Chair [and Director], (f) the Chair [and Director] has communicated and explained to the Candidate the decision of the Executive Committee respecting a second three-year contract, and (f) it is understood that the Candidate's conversations with the Promotions and Merit Committee and with the Chair [and Director] are meant to guide but do not guarantee promotion. After that meeting with the Chair [and Director], copies of the initialed checklist will be distributed to the assistant professor, the Department, the Museum unit if appropriate, and the LS&A Dean's Office.

Approved by the Executive Committee 11/27/01

Department of Ecology and Evolutionary Biology

Procedures for Evaluation for Tenure and Promotion to Associate Professor

The College has established a set of principles and best practices involved in evaluating junior faculty for tenure and promotion to associate professor. The Department of Ecology and Evolutionary Biology (EEB) has used these to develop the specific procedures described below that will be followed in our department, including for faculty with joint appointments with the Herbarium, Museum of Zoology, and Museum of Paleontology (henceforth, Museum units). All references below to "Chair [and Director] " refer to a) the Chair of EEB for assistant professors with appointments only in EEB or b) the Chair of EEB and the Director of the appropriate Museum unit for assistant professors with joint appointments with a Museum unit. For faculty with joint appointments with other units, the specific procedures for evaluation for tenure and promotion for each case will be specified in a joint letter to the new faculty member from the Chairs or Directors of all units involved.

I. Selection of external and internal assessors.

1. By April 1 in the academic year preceding the Department's recommendation to the College regarding tenure, candidates are to provide the Chair [and Director] with a list of at least 8 scientists and scholars whom they consider appropriate to assess their work. With each name, the candidate should provide complete contact information and a brief biography indicating the research area and professional stature of the potential reviewer.

   i) Candidates may include their dissertation and/or post-doctoral fellowship supervisors in this list; otherwise, the names should not include scientific collaborators or co-authors.

   ii) Candidates should indicate to the Chair [and Director] the names of persons they consider inappropriate to assess their work by reason of conflict of interest, or kinship or domestic relationship, and should indicate why they consider these persons inappropriate. In such cases, the Chair [and Director] should not ask these persons to provide external assessments. Intellectual disagreements do not constitute conflict of interest and are not grounds for exclusion as a potential assessor.

2. The Chair [and Director] will consult with the Promotions and Merit Committee for additional names of potential reviewers for a total list of at least 16 reviewers. This list will be shown to the candidate to ensure that no inappropriate candidates are chosen (as in 1.ii. above). From this list, the Chair [and Director] will choose 8-10 names from whom to request letters of evaluation, assuring that at least three external assessments are from persons suggested by the candidate. When at least three such external assessments are not provided because the persons suggested declined to write or did

not respond to requests, these exceptions shall be documented at the end of the list of assessors in the file that goes to the Tenure Panel and the College.

3. By September 1 of the year in which tenure will be considered, the candidate should provide lists of University of Michigan colleagues and current and former students who can be asked to comment on the assistant professor's performance in the areas of scholarship, teaching, and/or service as appropriate. In the case of Museum appointments, names should also be provided of individuals who can comment on curatorial performance. The Chair [and Director] may add names to this list, in consultation with the Promotions and Merit Committee. Candidates should indicate to the Chair [and Director] the names of persons they consider inappropriate to assess their work by reason of conflict of interest, or kinship or domestic relationship, and should indicate why they consider these persons inappropriate. In such cases, the Chair [and Director] should not ask these persons to provide internal assessments.

II. Candidate submission of materials for consideration by external assessors, the Tenure Panel and the College.

By May 1 of the year preceding consideration for tenure, the candidate will provide to the Chair [and Director] the following: the candidate’s form, a current curriculum vitae with a complete list of publications, research and teaching statements, CRLT scores and other evidence of teaching performance, and copies of the most significant publications, including any manuscripts that have been accepted for publication along with letters indicating such acceptance. In the case of joint appointments with a Museum unit, curatorial statements should also be provided.

III. Departmental responsibility for preparing and reviewing the completed tenure file

1. The Chair [and Director] will be responsible for requesting external and internal letters of assessment. The letters for external assessment should be requested no later than July 1 of the year preceding consideration for tenure. The letters for internal assessment should be requested no later than 30 September of the year in which the candidate will be considered for tenure.

2. The Promotions and Merit Committee of the Department will be responsible for preparing the completed tenure file, with all documents listed in II above and the external letters of assessments.

3. Evaluation of the tenure file will be done by a Tenure Panel, appointed, as described below, in September of the year in which the candidate will be considered for tenure.

    i) For candidates with 100% appointments in the Department, the Tenure Panel will be composed of eight faculty members. Three of the members shall be the members of the Promotions and Merit Committee. A fourth will be a member of the tenured faculty with expertise in the subfield of the candidate. The rest of the membership of the Tenure Panel will be composed of all tenured professors on the

Executive Committee plus a number of appointed members necessary to bring the total voting membership up to eight. Appointments will be made by the Chair in consultation with the Promotions and Merit Committee. The Chair and Associate Chair will be non-voting members of the Tenure Panel, for a total of 11 members. A quorum for any meeting of the Panel shall consist of 7 of the 8 voting members of the Panel.

ii) For candidates with joint appointments with one of the Museum units, the Tenure Panel will consist of eight faculty members. Three of the members shall be the members of the Promotions and Merit Committee, with at least one of them having a joint Department/Museum appointment. A fourth will be a member of the tenured faculty with a joint Department/Museum appointment with expertise in the subfield of the candidate. The rest of the membership of the Tenure Panel will be composed of all tenured professors on the Executive Committee plus a number of appointed members necessary to bring the total voting membership up to eight, including four members with joint appointments in the appropriate Museum unit. If these procedures do not result in four members of the Tenure Panel with joint appointments in the appropriate Museum unit, members of the Executive Committee or Promotions and Merit Committee should be replaced to ensure four members from that unit on the Tenure Panel. If the appropriate Museum unit does not have four members of appropriate rank, those slots on the Tenure panel should be filled with faculty with joint appointments in one of the other Museum units. Appointments will be made by the Chair of the Department and the Director of the appropriate Museum unit in consultation with the Promotions and Merit Committee. The Chair and Associate Chairs of the Department and the Director of the appropriate Museum unit will be non-voting members of the Tenure Panel, for a total of 12 members. A quorum for any meeting of the Panel shall consist of 7 of the 8 voting members.

iii) For candidates with appointments that are joint with units other than one of the Museums listed above, the Tenure Panel will consist of 5 members of the other unit plus five voting members from the Department. The Department component will include 2 members of the Promotions and Merit Committee, one additional member of the tenured faculty with expertise in the subfield of the candidate, and two tenured members of the executive committee. Appointments will be made by the Chair in consultation with the Promotions and Merit Committee. The Chair and Associate Chair will be non-voting members of the Tenure Panel, for a total of 8 members from the Department on the joint Tenure Panel. Four voting members from each of the participating units shall constitute a quorum for any meeting of the joint Panel. The details of the tenure procedure will be spelled out in a joint letter from the Chairs (or Chair and Director) of the two units written to the candidate in her/his first year in the Department

iv) The candidate shall have the opportunity to review the membership of the Tenure Panel to ensure that the candidate's field and methodology are represented on the group and to challenge the faculty person designated as most closely associated with the candidate's research specialty. Any conflicts over the composition of the Tenure Panel may be brought to the Associate Dean for Academic Affairs in consultation with the Chair [and Director].

4. Review of the Tenure file

The Tenure Panel will receive from the Promotions and Merit Committee the tenure file concerning the achievements and external evaluations of the candidate being considered for tenure. Members of the Tenure Panel are expected to fully participate in the evaluation of each candidate for tenure, including the examination of all relevant documents. After thorough discussion by the Tenure Panel, the Department Chair [and Director] will designate a member of the Promotion and Merit Committee to develop a full and frank summary of these deliberations in a draft report.

5. Disclosure to the candidate and response:

i) By the Tenure Panel: Before the Tenure Panel makes a decision about recommending promotion, it shall forward to the candidate the draft summary report, including what it sees as the strengths and weaknesses of the record in relation to tenure and shall invite the candidate to respond to any inaccuracies, misunderstandings of the work, or problems in contextualizing the work.

ii) Maintaining confidentiality in the summary to the candidate: This summary must protect absolutely the identity of the external assessors. While the strengths and weaknesses this summary enumerates will be consistent with those described in the report that the tenure panel prepares for discussion by the College, the summary for the candidate must not quote directly from letters of assessment, and it must not include any markers that would enable the candidate to identify who wrote the letters of assessment.

iii) Candidate's response to the summary:

a) The candidate for tenure shall have up to two weeks to respond.

b) The summary and the candidate's response shall be taken into account in the Tenure Panel's report to the College.

c) The candidate may choose to modify the teaching, research, and, as appropriate, curatorial statements in response to this summary; if done the modified statements shall be the ones included in the file that is forwarded to the College.

6. Making a recommendation on tenure and promotion to the College of LS&A.

i) The Tenure Panel will prepare a final report to the College, based on the draft summary report and taking into account the candidate's response.

ii) A positive vote by at least 2/3 of the panel's members will constitute a positive recommendation. Abstentions will be counted as negative votes.

iii) The numerical vote shall be reported by the Chair [and Director] to the College, along with the detailed report by the Tenure Panel.

Appendix G: Commitments from LS&A to the Department of Ecology and Evolutionary Biology

November 21, 2001

Professor Deborah Goldberg, Chair
Department of Ecology and Evolutionary Biology
1127 Natural Science Building - 1048

Dear Deborah,

The purpose of this letter is to detail components of the package worked out between the Dean of LS&A and the Provost to support the initiative to tranform Biology within LS&A. In this letter, I will also outline some quantitative metrics that the College will use to measure success of this initiative and I will discuss some expectations of the EEB Department as we move forward with this initiative.

I will begin with resources and will divide the discussion amongst the three components of support – faculty, graduate student support, and staff.

FACULTY: The College commits faculty resources both through the renewal of faculty who resign or retire and by the creation of three FTE of incremental faculty lines. Specifically,

a) The LS&A Executive Committee agrees to replace faculty lines (replace in accordance with their fraction authorized in EEB) for all faculty who resign or retire from EEB in FY02 – FY06.

b) The College agrees to add three FTE of incremental faculty lines to EEB according to the following schedule:
   - one senior line will be authorized in FY02 (this is the line for the Chair).
   - one junior line will be authorized in FY03.
   - one senior line will be authorized in FY04.

Please note that the year of authorization is the year when the search commences. The faculty will not be in place until September of the following year (at the earliest).

GRADUATE STUDENT SUPPORT: LS&A agrees to support a five year funding package for graduate students in EEB. This plan calls for an entering class of twelve students per year. Each student will be supported according to the following plan:

YEAR	Fall	Winter
1	GSI	GSI
2	Fellowship	Fellowship

3	GSI	GSI
4	GSI	Fellowship
5	GSRA	GSRA

Students will receive a twelve month stipend of $20,000 plus benefits as part of this support package. In addition, their tuition will be paid by the department. The plan will commence with the students who are admitted next academic year, i.e., students starting their graduate studies in the Fall of 2002.

As part of this plan, the College agrees to continue allocation of six LS&A 1-year Regents Fellowships to EEB. The plan assumes that on average .5 student in every class will hold a Rackham Merit Fellowship, that six students each year will be awarded Rackham One-term Fellowships, that one student per year will be supported by a Rackham Dissertation Fellowship and that one students per year will be supported by an external fellowship.

Since this funding model calls for GSI support in the first year, the Department will receive no incremental graduate student support in its FY03 budget. Then, the Department will receive, in its FY04 and FY05 budgets, enough support for eleven second-year fellowship students after the assumptions of other sources of support are taken into account. Beginning in FY06, the Department will receive in its budget fellowship support for eleven second-year students and ten fourth-year students (supported according to the mixed GSI-fellowship model) after the assumptions of other sources of support are taken into account.

In accepting this plan, the Department bears the responsibility to support all students in its PhD program according to this model. If the Department decides to systematically admit more than twelve students per year, then the Department must bear the added cost of supporting these students from its own resources.

<u>STAFF</u>: The Provost has committed $230,000 in incremental support to fund the added costs of operating separate offices of EEB and EEB. This funding has been incorporated into the FY02 staff budgets for the two departments. In addition, EEB will receive an allocation of $75,000 per year for each of four years to support research secretaries.

<u>FACILITIES</u>: The Dean recognizes that the Kraus Building is inadequate to support the research needs of the Departments of MCDB and EEB going into the future. It will be a high priority of the College to address this major facility need.

The above paragraphs outline the commitments that the Provost and College are making to support the transformation of Biology. As the Department of EEB transforms its faculty and research activities, we will want measures to determine our success in achieving the goals of this initiative. In a recent letter to the Provost and President, Dean Neuman committed that the Department and College would track (at least) the following quantitative metrics over the next five to ten years as a means to measure the success of the Biology transformation initiative:

Research Excellence

M1. National rankings of EEB by the NRC and by U.S. News and World Report.
M2. Level and growth of sponsored research funding.
M3. Percent of faculty with external funding.
M4. Number of department faculty in the National Academy of Sciences.
M5. Number of citations of articles authored by department members.
M6. Number of first-round offers accepted by prospective graduate students (to be separated by domestic and international students).
M7. Average GPA and GRE scores of incoming graduate students.
M8. Number of department faculty awarded prestigious research recognition (to be tracked by type of award, eg., PECASE Awards, major invited addresses, MacArthur Fellowships, etc.).

Climate

M9. Number of faculty at each rank who are women and number of faculty at each rank who come from underrepresented groups.
M10. Number of graduate students who are women and number of graduate students who come from underrepresented groups.
M11. Fraction of female faculty who achieve tenure and fraction of female graduate students who finish with a Ph.D.
M12. Success rate in recruiting women and underrepresented minorities into faculty and graduate student ranks.
M13. Number of complaints of unprofessional conduct within the department handled by the Dean's Office.

Interdisciplinarity

M14. Number of faculty who have wet appointments with other units.
M15. Number of grants which have multiple PI's, one in EEB and at least one in another unit.
M16. Number of faculty who are affiliated with the Life Sciences Institute.
M17. Number of EEB faculty who team teach a course with faculty from another unit.

As mentioned, those are quantitative metrics which the Department and Dean's office will collect on a regular basis to evaluate the success of the initiative to transform Biology. This list does not preclude the use of other metrics, both quantitative and qualitative and I would welcome suggestions by EEB of metrics that the Department feels would be particularly valuable as indicators of success.

Let me make two points in closing. First, although the Department of EEB faces a difficult challenge, it also have been presented with a significant opportunity. To take full advantage of this opportunity, it will be crucial that the Department engage this initiative with energy and positive spirit. This is particularly true when recruiting an external chair.

Second, EEB should engage in long-range planning over the coming academic year. Although there are advantages to waiting for new leadership before finalizing a plan, a great deal of valuable initial work can be done this year. Please call on me for any advice or assistance during this process.

Yours truly,

Phil Hanlon
Associate Dean of Planning and Finance
College of Literature, Science and the Arts