Biogeography: Combining Genetics and Geography to Unlock Species Origins

As a University Scholar I will create a rigorous program in biogeography and spatial statistics. Biogeography is concerned with mapping distributions of a particular taxonomic group and combining it with genetic and geological data to understand how species have arrived at their present distributions. This unique field incorporates many disciplines including molecular biology, evolution, ecology, systematics, geographical mapping systems, statistics, and geological sciences. With knowledge of a species' distribution, other larger issues can be investigated such as the influence of landscape and climate changes on population dynamics and the effect of natural and introduced populations on their environment .

Project Background

My interest in biogeography started in May of 1998 when I was chosen as a member of an National Science Foundation-sponsored a team of UConn researchers, led by Dr. Chris Simon of the Ecology and Evolution Department, conducting an extensive field and laboratory study of geographic variation and evolution of 13- and 17-year periodical cicadas. From May to August, I gained hands-on experience designing geographical surveys, conducting behavioral and hybridization experiments, and sequencing DNA. From these, I gained a better understanding of population dynamics and the process of speciation.

For the past two years, I have incorporated and expanded those experiences into an ongoing independent project investigating the species status and the genetic relationships present in 13-year and 17-year periodical cicadas. Under the guidance and supervision of Dr. Simon, I have been conducting a project to sequence the DNA of a number of nuclear genes (e.g. EF1-alpha and PGI) in 13- and 17-year cicadas. These DNA data will be compared to existing mitochondrial DNA data (mitochondrial DNA typically shows less genetic variation than nuclear genes) to help understand geographical variation, ecological distributions, and evolution of these unique species. Questions to be addressed include: (1) What are the evolutionary origins of 13-and 17-year

cicadas? (2) Is gene flow occurring between these different life cycles? (3) Can the distribution and interactions between different cicada species be explained by the current or paleo-geographical/climatological features of North America? All of these questions are fundamental to any kind of study investigating genetic and ecological relationships, evolutionary history, and species conservation. My goal this semester is to gain insight into the speciation of this unique group by combining the DNA data with behavioral studies performed in Dr. Simon's laboratory.

Preliminary genetic data from mitochondrial DNA and abdomen color polymorphisms suggest that at some point in the last glacial period a massive life-cycle-switching event occurred, converting some 17-year cicadas to a 13- year form. While genetic data was the key to discovering this strange event, its cause is still unknown. One of the candidates is resource scarcity in regionally specific niches of the Midwest. Also temporally and regionally specific climatic patterns, slow formation of landforms, rivers, and glaciers all could have caused this life-cycle-switching event. The periodical cicada system is an excellent example of how genetic data helps uncover strange patterns of distributions that only evolutionary, geographic, and geological theory can fully explain.

The periodical cicada system is only one of many examples where knowledge of the abiotic environment is vital for explaining many of the evolutionary/genetic trends connected with a particular population. Only when molecular knowledge is coupled with knowledge of the encompassing environmental systems can questions of evolutionary dynamics and conservation be answered.

As an MCB major, my strong molecular background is the foundation for the techniques used to obtain DNA sequence data from periodical cicada specimens. Even though my molecular biology training has enhanced this aspect of my research, my background in environmental and geographic sciences needs strengthening. Molecular techniques are tools to obtain genetic data. Knowing the DNA sequence of periodical cicadas cannot by itself make sense of the bizarre life-

cycle patterns or their peculiar geographic distribution patterns. Environmental features such as glacial movements, climate change, flooding patterns, and formations of landscape features (bluffs, rivers, valleys) could have influenced the unusually long life cycle of periodical cicadas. In addition, current geographic features are thought to affect the interactions between different species of periodical cicadas across North America.

University Scholar Plan of Study Description

In my University Scholar plan of study I have outlined several courses which would fill in the missing aspects of my research. The plan is centered around evolutionary biology. *Evolutionary Patterns and Processes* (Spring 2000), *Molecular Systematics* (Spring 2000), and *Populations Genetics* (Spring 2001) are the foundations of this program. A solid foundation in the biology of organisms is also important. *Applied Entomology* and *Invertebrate Zoology* are courses I have been unable to take previously that would provide the necessary background for my biogeographical studies. Invertebrates and insects in particular contribute most of the world's biodiversity and therefore are often the focus of major biogeographic studies.

To add the geological component necessary for my independent project, I have incorporated a field geology course which will give me experience in electronic, geological, and geophysical surveying. The rigorous nature of the course will equip me with skills to assess a variety of geological landscapes and to incorporate that information in my current genetic studies. In order to take *Field Geology* I need to take *Geology* 102, which I have scheduled for the Spring 2000. I have also scheduled *Principles of Geomorphology* for Fall 2000. The emphasis on casual processes of landscape genesis and paleoenvironmental patterns is applicable to my current project goal to understand how landscape changes and climate changes in geological history may have dictated current periodical cicada distributions.

In order to acquire the technical skills necessary for this project, I have scheduled a two course sequence in Geographical Information Systems (GIS). This is a series of computer based

systems used to rapidly analyze and illustrate geographic data. I will use this knowledge of GIS to map current distributions of periodical cicadas all across North America. The versatile functions of GIS will allow me to synthesize and extract all the necessary information from current data on cicada distributions. I have also planned an Independent Study with Dr. Allen of the Geography Department for Fall 2000. In addition to Dr. Allen, I will work closely with two other biogeographers (Dr. Cromley and Dr. Cook) to find appropriate readings and exercises relevant to current research in biogeography. Such an intensive and individualized study will be an unparalleled academic experience in preparation for my future geographical studies.

Spatial Statistics (*Geog* 342) is scheduled for Fall 2000. A background in methods of spatial data analysis is necessary to find patterns in the genetic relationships of periodical cicadas across their geographic range.

Lastly, I will continue conducting my senior thesis research as an independent study (*EEB 299*) in each of my remaining three semesters. As I accumulate data from specific genes of interest, I will begin to answer the questions of evolution and geographical distribution outlined previously by integrating the geographic, geological, and statistical experience gained from other courses into my independent study.

University Scholar Plan of Study Justification

As a University Scholar I will have the necessary freedom to take courses which are administratively and logistically difficult under an MCB course of study. Under a normal course of study I would finish my Molecular and Cellular Biology requirements with *MCB* 240W. In addition, I still have three general education requirements to fill in the last three semesters: Class (4)-*Literature*, Class (4)-*Arts*, and Class (5)-*History*. While I am able to fulfill my literature requirement in the Spring 2001, scheduling the Art and History requirements would force me to remove *Spatial Data Analysis* (*Geog* 342) and *Invertebrate Zoology* (*EEB* 275) from Fall 2000 or to remove *Evolutionary Patterns and Processes* (*EEB* 462) and *Population Genetics* (*EEB* 310)

from Spring 2000 and Spring 2001 respectively. While I would still take some courses proposed in the plan of study, I would be forced to eliminate at least two of the courses mentioned above. These graduate level courses are especially important to the success of my independent project. These classes will expose me to material not available at the undergraduate level. Without these classes it will be impossible to achieve the depth necessary to excel in this field of study.

The status of University Scholar would give me the administrative latitude to pursue the courses outlined below. For instance, I have scheduled full course loads for my remaining three semesters, totaling 28 credits[1] (Spring 2000), 17 credits(Fall 2000), and 20 credits (Spring 2001). In addition, I have planned four graduate level courses over the next three semesters. While undergraduates are not always able to enroll for extra credits and graduate classes, University Scholar provides the necessary freedom for credit over-enrollment and guarantees my participation in each of the graduate level courses listed.

Even though my proposed plan of study is rigorous, my experience and success in credit over-enrollment and graduate level course work over the past three semesters has given me the confidence to take on a challenging and intensive academic path for my remaining time at UConn.

Career Goals

My coursework in Molecular and Cellular Biology has been invaluable. It has given me the theoretical background and laboratory experience to perform a wide range of techniques to extract genetic data from a variety of organisms. While this has been rewarding, finishing my undergraduate degree in Molecular and Cellular Biology will not allow me to pursue the central questions of my independent project. As a University Scholar, I can take my independent project to the next level and broaden my academic horizons across several disciplines.

[1] Field Geology (6 credits) is offered in the first four weeks of summer session 2. During the Spring I would be enrolled for 22 credits.

Over the past year and a half I have been exposed to graduate and professional studies in biogeography and population genetics. My experiences with my independent project to date have solidified my intention to study molecular and ecological biogeography in graduate school and beyond. As I look ahead towards a career in species conservation research and biodiversity studies, I hope to engage in coursework and research in my last three undergraduate semesters that will uniquely prepare me for my future profession. Only as a University Scholar will I be able to obtain this experience.

University Scholar Plan of Study	**MCB Plan of Study**
(course title, department and course number, credits)	(department and course number, credits)
Spring 2000:	
Computer Methods In Molecular Systematics, (EEB 372), (3)	EEB 372, (3)
Evolutionary Patterns and Processes (EEB 462), (4)	EEB462, (4)
Bacterial Diversity and Ecology (MCB 240W), (4)	MCB240W, (4)
Intro to Geology (Geol 102), (3)	
General Physics (Phys 132Q) , (4)	Phys 132Q, (4)
Senior Thesis Research (EEB299), (3)	EEB 299, (3)
Field Geology *summer 2000* (Geol 212), (6)	
Fall 2000	
Intro to Arc View Systems (Geog 246C), (4)	Geog 246C, (4)
Invertebrate Zoology (EEB 275), (4)	EEB 275, (4)
Independent Study: Biogeography (Geog 299), (3)	Class (4)—Arts req, (3)
Spatial Data Analysis (Geog 342), (3)	Class (5)—History 101, (3)
Senior thesis research (EEB 299), (3)	EEB 299, (3)
Spring 2001	
Population Genetics (EEB 310), (3)	EEB 310, (3)
Applications Geog Info Systems (Geog 248C), (4)	Geog248C, (4)
Principles of Geomorphology (Geol 220), (3)	
Applied Entomology (EEB 288), (4)	EEB 288, (4)
Shakespeare I (ENGL 230), (3)	ENGL 230, (3)