NSF Personal Statement Essay

I have spent the majority of my biology career located between the macro world and the micro world. While majoring in Wildlife Ecology at the University of Wisconsin, Madison, I came to appreciate animal life histories and ecological and evolutionary principles. On the other hand, I filled my elective class schedule with courses that most wildlife ecology students would consider obscure, such as cell biology, endocrinology, immunology, and microbiology. With knowledge in these diverse fields, I developed an extreme curiosity in how different disciplines of biology can be integrated. Specifically, I have been drawn to the field of physiological ecology, which is the study of how organisms are physiologically adapted to various environmental conditions. This discipline integrates many areas of study, provides a better understanding of animal ecology and evolution, and results can have applications in wildlife management and conservation.

Personally, physiological ecology is the ideal field for me as it satisfies my interests in various levels of biological organization. As I learn the natural history of an animal, I often hypothesize about the physiological processes underlying these facts. Likewise, as I read the literature on physiology, I often speculate on the possible ecological implications of the information.

With these inquiries, I fit perfectly in to the lab of Dr. William Karasov, a physiological ecologist at University of Wisconsin – Madison. Instead of simply speculating, I was actually able to develop hypotheses and design experiments to test them. I spent three years conducting research on how diet and age affect modulation of digestive enzymes in song birds. Results from my experiments have allowed me to coauthor a paper which was published in the Journal of Experimental Biology, and give numerous presentations at national scientific meetings. Through my work here I have come to realize the integrated nature of biology, and realize that discoveries made in one area can have great relevance to other areas.

It is because of the integrative nature of biology that I have gained an appreciation for collaboration with peers. Collaboration allows different researchers to bring their own expertise, and together great scientific work can be done. During my time in the Karasov lab I enjoyed working with visiting researchers from Poland and Argentina, post-doctoral associates, and fellow undergraduates.

The most gratifying collaborative experience I have had was mentoring several students through their own independent research projects. In the summer of 2008 I mentored Lilly Pearson, a high school student through the High School Science Research Internship Program. I taught her basic lab techniques as well as biochemical enzyme assays that allowed her to develop her own independent project, titled “The effect of diet and age on pancreatic amylase activity in House Sparrow nestlings”. Lilly presented her findings at a poster session for the internship program in November 2008 and won the Gatzke Award for Poster Design. Additionally, during the 2008-2009 school year I mentored Krista Lessner, a junior majoring in biology. After teaching her lab techniques and enzyme assays, I assisted her with an independent project titled “Low plasticity in digestive physiology constrains feeding ecology in the diet specialist, Zebra finch (Taeniopygia guttata)”, which is currently being submitted for publication in the Journal of Experimental Biology. Mentoring these students allowed me to share what I knew with others, and to see these students develop and carry out successful research projects.
With the leadership, collaborative skills, and knowledge that I gained at UW-Madison, I received a job as a naturalist at Maywood Environmental Park in Sheboygan WI. Here, I used educational games and captivating lesson plans to teach K-12 children about ecological principles, such as how seeds move, how birds’ beaks are adapted to diet, and the effect of water chemistry on organisms. The most rewarding experience at Maywood was working with children from Salvation Army programs, which provide daycare for children of low-income parents. I like to believe that my work at Maywood helped to instill environmental ethics into children who might not develop them otherwise.

These past experiences have prepared me for life as a graduate student. Again located between the macro world and the micro world, I aimed to gratify my interest in how symbiotic microbes are important components of an animal’s physiology. I joined Dr. Denise Dearing’s lab at the University of Utah, where molecular and genomic techniques are used to investigate how mammals metabolize plant toxins. Additionally, studying at the University of Utah allows me to collaborate with Dr. Colin Dale, who researches the ecology and genome evolution of microbial endosymbionts. The unique opportunity to work with both these researchers will allow me to investigate the role microbes play in helping mammalian herbivores break down plant toxins in their diet, a largely unanswered question in plant-herbivore interactions.

As mentoring students was an extremely fulfilling experience in the past, I am certain I will want to incorporate high school and undergraduate students into my research plans in Dr. Denise Dearing’s lab. Specifically, I plan to take on students through the Bioscience High School Summer Research Program, which is an eight-week program where students receive lab training and research experience. Additionally, in January 2010, I will begin mentoring an undergraduate student through the ACCESS Program, which offers laboratory experiences for the brightest young women entering the science program. This competitive program has a high success rate at keeping women involved in science, and the Dearing lab has been heavily involved in this program by successfully hosting several students in the past.

My proposed research will train me, as well as the students I mentor, to connect the fields of digestive physiological ecology, and the rapidly evolving field of microbial metagenomics. I will take the tools I learn through this project to develop an exciting research career investigating how an animal’s ecology affect symbiotic microbes. After completing a Ph.D., I look forward to developing experimental systems to investigate how fasting between meals in snakes, temporal diet switching in birds, and body temperature in reptiles affects gene expression and function of symbiotic gut microbes. I am also interested in investigating how intestinal microbes affect the animal’s physiology and nutritional ecology, such as how microbial synthesis of essential amino acids or vitamins, or recycling of urea affect diet selection in wild vertebrates.

As a researching scientist I will be able to share my knowledge with new students, and perhaps inspire students to pursue science as a career. Again, as I was lucky enough to enter a lab as an undergraduate to gain experience, I know I will want to incorporate undergraduate and high school researchers in to my lab. Additionally, I have always enjoyed working with K-12 children, and understand that volunteering and outreach are important civic duties of scientific professionals. It is because of these experiences that I believe that if I am selected to receive the NSF Graduate Research Fellowship, the outcomes of my proposed research will extend beyond just the scientific community. The funding will aid towards yielding scientific results years in the future from myself and the students I involve.
NSF Previous Research Experiences

With knowledge in many levels of biological organization, I have always been extremely interested in how seemingly small molecular changes could influence an organism’s ecology or fitness. During my time at the University of Wisconsin – Madison, I was given the opportunity to be an undergraduate researcher in the lab of Dr. William Karasov. There, I was able to undertake several independent research projects investigating ecological and evolutionary aspects of modulating digestive enzymes in birds.

During development, many birds experience a shift in the composition of nutrients fed to them by their parents. For example, newly hatched House Sparrows (*Passer domesticus*) are initially fed protein-rich insects, but are gradually fed an increasing amount of carbohydrate-rich seeds through fledging. Ideally, the activities of the animal’s digestive enzymes would correlate with the amount of substrate in the diet, as to not waste biosynthetic energy or cell-membrane space on unnecessary enzymes [1]. Interestingly, previous studies have indeed found that as carbohydrates become a larger part of the nestlings’ diet, the activity of carbohydrate-digesting enzymes in their small intestine (such as maltase) increases as well [2].

However, it was unknown whether this increase in maltase was a response to the increasing amount of carbohydrates present in the individuals’ diet, or if it was genetically programmed within the animal. Studies in newly hatched and adult individuals of precocial bird species (chickens) show that individuals raised on a high carbohydrate diet express significantly higher activities of maltase when compared with those fed a carbohydrate free diet [3]. Curiously though, studies in adult altricial species, e.g., the House Sparrow, have not found the same results [4]. That is, experiments in adult birds of several species found that individuals fed high-carbohydrate diets showed no increase in maltase activity compared with individuals fed low-carbohydrate diets [4].

These results inspired the design of the first experiment ever to investigate the effect of diet on intestinal enzymes in altricial nestlings, which became my first independent research project. To test whether the maltase activity in house sparrow nestlings was influenced by diet or genetically determined, nestlings were collected at 3 days of age, and brought into the lab where they were fed either a 0% or 25% starch diet. The nestlings were euthanized at 12 days of age, at which point their intestines were removed and saved for later analysis. I determined activities of maltase and aminopeptidase-N (APN, an intestinal enzyme that breaks down peptides) by adding specific substrates and measuring the concentration of the products. Aminopeptidase-N assays were performed in order to test if any response seen in maltase was specific. This research gave me experience in animal husbandry, dissections, and biochemical assays.

Interestingly, I found that diet influenced maltase activity in nestlings. Birds fed on a 25% starch diet showed significantly higher activity of maltase when compared to birds given a 0% starch diet. Nestlings showed no difference in APN activities, showing that the increase in maltase was specific to the increase in dietary starch. My results show that unlike adult house sparrows, nesting house sparrows are able to modulate the activities of intestinal maltase in response to dietary carbohydrates.

The results from my independent project became part of a larger manuscript in collaboration with Dr. Karasov, Dr. Pawel Brzek (a postdoctoral associate from Poland), as well as Dr. Enrique Caviedes-Vidal (a faculty member from the National University of San Luis, Argentina) [5]. Continuing with this study system I also investigated the effect of lipid and age
Kevin Kohl

on enzyme activities, and presented results at 2008 and 2009 Society for Integrative and Comparative Biology (SICB) meetings [6,7,8].

The fact that adults were unable to modulate enzyme levels caused me to question whether evolutionary shifts in diet preferences are paired with changes in constitutive enzyme activities. I designed my own project, for which I received funding through the competitive Hilldale Undergraduate Research Fellowship. To test this hypothesis, I captured wild individuals of six different bird species with natural diets varying from almost exclusively insects, to primarily seeds. To characterize each species diet, I used historical literature on diet preferences, and average chemical composition of foods to determine percent starch and protein. I also measured stable isotopic composition of blood and collagen to characterize diets. Enzyme assays were conducted on intestinal (measuring maltase, sucrase, APN) and pancreatic (amylase, chymotrypsin, trypsin) tissue samples. Although the overall goal was to test for correlation between enzyme levels and dietary substrates, phylogeny had to be taken into account to avoid overestimating degrees of freedom in the statistical analyses, which occurs when species are phylogenetically related and thus not entirely independent units. I used the independent contrast method which takes into account differences in measured variables as well as phylogenetic tree branch lengths between species.

Results suggest that correlation trends differ depending on an enzyme’s substrate. For example, I found no correlation between protease activities (APN, trypsin, chymotrypsin) and dietary protein as determined by the literature or isotopic composition of tissues. However, all carbohydrate digesting enzymes studied (maltase, sucrase, amylase) were significantly positively correlated with the percentage of dietary starch. This result is especially interesting as short term modulation of carbohydrases in response to dietary starch has not been documented in studies on passerine birds [4]. Thus, my findings preliminarily suggest the idea of evolutionary matching between the activity of digestive enzymes and the prevalence of their specific substrate in an animal’s diet. Natural selection may favor a constitutive level of enzymes that reflects average intake of dietary substrates, especially those mainly supplying energy, such as carbohydrates.

I published these findings in a senior honors thesis at UW Madison [9]. Additionally, I am also preparing this study for publication in Physiological and Biochemical Zoology and will be presenting my data at the 2010 Society for Integrative and Comparative Biology meeting in order to share it with the greater scientific community.

Since starting at the University of Utah this August, I have developed projects to analyze digestive enzymes in woodrats (Neotoma spp.), and in Southern right whales (Eubalaena australis) in collaboration with Dr. Vicki Rowntree. However, I now look forward to taking my research in a new direction by investigating the role of intestinal microbes in animals’ physiologies. This will allow me to build on past experiences as a nutritional physiologist, and conduct exciting research in the quickly developing field of microbial metagenomics.

References