Personal, Relevant Background, and Future Goals Statement

My classmates and I were hiking up a narrow trail in the Andes, a few hours from our study abroad center in Mérida, Venezuela. We were on a field trip to perform plant biodiversity transects. As our path leveled out, I paused and surveyed the landscape. I was struck by an undeniable pattern across the slopes of the opposite mountains: each altitude had its own set of endemic flora. While I knew the history of biogeography on those slopes, it fails to convey the imposing magnitude of life's diversity that I felt standing on that mountain, an impression that stays with me to this day. As I continued my study abroad experience in Venezuela, I found myself reflecting on that moment and the developing country around us. At the time, there was a shortage of medical supplies, leading to outbreaks of infectious disease. I began to recognize that the same evolutionary forces that shaped the physiology of those mountain plants also drove successful pathogens, reinforcing to me that a greater understanding of how microorganisms evolve could be leveraged to improve our responses to infectious disease.

Two years earlier, when I entered the University of Minnesota, I had no idea that I would end up fascinated with microbial evolution. I was interested in many fields, but none of them captivated me. I found that passion by surprise, walking out of my morning physics class freshman year. As part of an activities fair, an undergraduate was showing his research project experimentally evolving *Escherichia coli* in the laboratory of Dr. Mike Travisano. This demonstration of real-time evolution challenged my notion of evolutionary biology as solely historically based, piquing my curiosity, and I soon began volunteering in Dr. Travisano's laboratory. Working with guidance from that same undergraduate, I designed an assay to determine how the *E. coli*'s swimming behavior had evolved and quickly jumped into running it. That was when I learned my first lesson: always pilot any assay or experiment, so you can discover any unnoticed flaws in your design before investing lots of effort. Although discouraged, I revised, ran the assay on a small scale, then retested everything. The moment when I saw the first results, I felt a rush knowing I had discovered something no one else had. This experience inspired me to prepare an undergraduate research grant proposal, extending my current project. As I wrote my application, I found myself reading the literature and synthesizing their ideas into something new with relish. These experiences had ignited an interest in biological research, in microbial ecology and evolution, and in experimental evolution. I was proud of the proposal I had produced, so when I learned that it had been rejected as poorly-defined, I was deeply disappointed. Determined to continue, I began thinking about work on the coevolution of bacteria and bacterial viruses (bacteriophages, phages).

While I was gaining interest in microbial ecology and evolution, I was also continuing to study Spanish. I believe a second language is a robust tool that opens countless doors, both enabling personal international travel and relationships, as well as facilitating professional collaborations. Spanish is especially relevant because it will prepare me to build connections with the rapidly expanding number of scientists in Latin America. This contributed to my interest in studying biology abroad, and the Venezuelan program was exactly what I wanted: Spanish immersion courses in field botany and tropical ecology. My time abroad exposed me to new ecosystems, while my work on a field project comparing plant biodiversity helped me realize the merits of both field and laboratory approaches, as well as my personal preference for more laboratory-based inquiry.

When I returned to Minnesota, wanting to explore other research interests and laboratory cultures, I sought out a summer laboratory technician position studying age-related macular degeneration, which causes progressive vision loss in old age. In contrast to my previous experiences, this research group was intimately organized and managed by the principal investigator, who worked closely with everyone to direct their work. Realizing this difference spurred self-reflection and helped me realize that I want to be a more hands-off mentor. This experience also gave me the opportunity to learn new molecular biology skills, useful tools for me in the future. One of my responsibilities was managing the laboratory's tissue bank database. As the summer progressed, I found myself enjoying this task more and more, even taking it upon myself to learn and write Excel scripts to manage it more efficiently. By the end of the summer, I had realized that I wanted to incorporate more computational approaches into my own research, and that microbial ecology and evolution was a much more personally captivating field.

With those realizations I pursued two research experiences in my junior year. The first was a research fellowship in the laboratory of Dr. Satoshii Ishii, as well as returning to the Travisano laboratory. Working with Dr. Ishii was an opportunity to explore microbial ecology. We came up with a project to measure and model the rate of denitrification, an important biogeochemical process in the nitrogen cycle, in real-time. Spurred by my computational interests, I wrote several scripts to automate data organization and analysis, a process that I enjoyed and that further confirmed my interest in computational tools. At the same time, I was beginning a new microbial evolution project in the Travisano laboratory working with bacteria and phages. Phages attach to bacteria, replicate inside the cell, and then lyse their host. Bacteria can evolve resistance to phages through mutational changes in cell-surface proteins. I hypothesized that, in an environment where both resistance or motility could provide protection from phages, there would be a tradeoff between them. I developed simple procedures, always piloting them before committing to any large-scale assays. These preliminary efforts produced visually striking results, where differentiation between resistant and non-resistant bacteria was plainly visible. Enthralled, I prepared another undergraduate research grant proposal extending the work I had already done. Determined to have my proposal accepted, I made sure to clearly state my hypothesis, the predictions it generated, and the experiments to directly test those predictions. As I continued to work, I received the fantastic news that my proposal had been accepted, and that my research would be funded for the spring semester of 2016.

Almost immediately however, I started to run into obstacles. The assays in the literature did not translate well to my organisms, providing inconsistent results. Concurrently, the microbial ecology project began to stall, as measurements proved far more challenging to standardize than expected. I also began to struggle academically, having registered for several challenging courses. The confluence of these experiences led me to fear that my poor performance meant that I was headed in the wrong direction, and that microbial evolution and ecology was not my calling. I began to wonder whether I could be successful in active biological research, and starting looking to shift my academic experiences away from the biological sciences. Following that desire, the spring of my junior year I took three courses outside of my major which emphasized computation and bioinformatics. I enjoyed the challenges these classes provided to develop my computer programming skills, and continued to gain a hands-on appreciation of their utility as I applied what I learned to my ongoing research projects. While I didn't make as much progress on those experiments as I would have liked, I learned to never trust the experiments to turn out exactly how they did in the literature, and to appreciate the small successes while expecting and working through the unexpected. I also solidified my confidence to work without direct guidance. Finally, as I continued to be preferentially drawn to my work on bacteria phage coevolution, I narrowed my research interests specifically to microbial evolution.

This past summer I participated in the National Science Foundation Research Experience for Undergraduates at Kansas State University, where I carried out an independent project on the evolution of cooperation in *Agrobacterium*, a plant pathogen. *Agrobacterium* expresses costly virulence genes that induce infected plants release nutritious compounds, creating an opportunity for cheating phenotypes that consume the nutrients without paying the cost. We carried out experimental evolution, and then phenotypically characterized the outcomes. During this time, I had the chance to mentor a recent high school graduate, teaching him laboratory techniques and directing our efforts conjointly. At first, I did not provide enough guidance and teaching, and we wasted some time when he made mistakes because of my lack of instruction, something I am determined to prevent next time. However, by the end of the summer we were operating smoothly, and my guidance, when needed, was limited. Throughout this experience, I was motivated by my ownership of the project's direction and outcomes, and by my excitement for the underlying questions. I learned how to manage my time and various projects when working on research full-time, and realized that my winding journey had cultivated a sustained passion for research in experimental microbial evolution.

Intellectual Merit: From my first exposure to evolutionary biology research to my current focus on experimental microbial evolution, my interests have developed and been shaped by my experiences. Similarly, the phenomena I am most interested is have also changed. Today, I am most passionate about studying the evolution of pathogens, especially through the use of model systems that allow evolutionary change over short time scales. Research on these systems can reveal broad, fundamental evolutionary paradigms, as well as being used to inform and develop direct applications on human pathogens. Finally, the scientific tools I wish to utilize have also changed, especially as my interest in computational, bioinformatic, and mathematical techniques has grown. With the rapidly expanding availability of genomic and phenotypic data, such tools are becoming more and more powerful, and will be a central part of my graduate school research, as well as a vital part of the rest of my research career. My experiences and achievements demonstrate my potential for significant research achievements.

Broader Impacts: My graduate school education will broadly benefit society both during and long after my experience. During graduate school, I will engage with the public over disputes where scientific reasoning and evidence can provide clarity and an objective answer. Issues like climate change, genetically modified organisms, and evolution are all topics where public opinions differ greatly from scientific truths. Because of that disparity, there is an opportunity for scientists who are interested in public communication to help inform the public debate. This engagement will only expand as I move further along in my career. As a faculty member, I will continue speaking out and communicating scientific evidence that is underrepresented in the public discourse.

I will also engage in mentorship of others throughout my time in graduate school and beyond. My experience as a mentor this past summer has opened my eyes to the impact I can have on others, as well as the opportunities I can help provide. I will continue to create and engage in mentorship opportunities where I can positively shape the lives of others, while also growing personally and professionally.