Personal & Relevant Background:
Gasping for breath, I paused. I was on a field trip from my Venezuelan study abroad center to the Andes Mountains. We had been hiking up a steep mountainous trail, but it wasn't just the altitude and exertion that made me stop; as I looked around I was struck by the appearance of horizontal bands across the opposite slopes. Perplexed, I looked more closely, and realized the cause: each altitude had its own endemic plant community. It dawned on me that those plant communities had been evolving for millennia on every Andean slope, and I felt overwhelmed to be standing in the middle of it. This indelible impression has stayed with me since my time abroad, even as I have found myself drawn to a very different scale: microbial evolution.

Two years earlier, when I entered the University of Minnesota, **I had no idea microbial evolution was my destination**. During my first year, I explored a variety of interests, and became involved in political advocacy and outreach around local and state education policy. As a chapter president of Students for Education Reform, I helped draft and lead lobbying efforts for state legislation changing how disadvantaged undergraduates were billed for remedial courses. Further, I independently organized an on-campus forum between candidates for a Minneapolis School Board election. These experiences helped me realize how meaningful it is for me to help future generations of students, especially those who have the odds stacked against them.

Despite the meaningful impact of education policy, curiosity drew me back to science. Once there, a passion for research snuck up on me: I happened to converse with an undergrad studying evolution in response to environmental signals. In the laboratory of Dr. Mike Travisano, he had experimentally evolved motile *E. coli* in response to conflicting chemical signals. This demonstration of **real-time evolution hooked me**, and I quickly got involved. I designed an assay to measure the evolved swimming behavior and began running it. That was when I learned my first lesson: always pilot an experiment first. Despite this setback of unusable data, I pushed on, revising the protocol, running a pilot, then scaling up. When I saw the first results, I felt a rush knowing I had discovered something no one else knew, **sparking my interest in research**.

As I continued the next few semesters, I took many opportunities to **explore other areas of biology**. I served as a laboratory Teaching Assistant (TA) for a course using bacteria as a model for adaptive radiation. Because this was the first offering of the course, I had the opportunity to help shape course content and structure, an experience that kindled my interest in undergrad education. Then, when abroad in Venezuela, I participated in a project on plant biodiversity. The next summer, I worked as a technician in a molecular biology laboratory, and that fall, I joined a group studying microbial ecology. Through these experiences I gained new techniques and computational skills, and I realized that **microbial evolution is my deepest intellectual passion**.

Accordingly, I returned to the Travisano laboratory, where I devised a new project studying how antagonists, like predators or parasites, could drive diversification. I worked with bacteria and lytic bacteriophages (phages), parasitoids which kill their bacterial host when they replicate. Specifically, I hypothesized that differential phage selection over space could lead to bacterial diversification. To test this prediction, I evolved *E. coli* in response to a phage gradient. This produced incredible visually-striking results, where resistant bacteria were distinguishable on agar plates. Deeply curious, I began to further characterize and figure out the evolutionary outcomes. Unfortunately, this is where I hit a roadblock: the literature-based assays were not producing consistent results. Struggling to make progress, and feeling like nothing was working, **I sought a new perspective**. That spring, following my nascent computational interests, I took several courses in statistics and computer science. I loved how these classes challenged me to think differently, inspiring me to take new approaches in my research. In the end, I learned resilience to experimental failures. Furthermore, despite the fact that I didn't resolve my research question, I realized that I still found microbial evolution research deeply meaningful.

The following summer I participated in an NSF Research Experience for Undergraduates at Kansas State University, where I investigated the evolution of cooperation. I worked with *Agrobacterium*, a plant pathogen which expresses costly virulence genes that induce infected plants to release nutrients (public goods). We used experimental evolution to vary the costs and benefits of cooperating *in vitro*, then measured how long cooperation persisted. Additionally, during this time I had **my first mentorship experience** with a recent high school graduate. Working with him was a learning experience for both of us: I learned to balance my guidance and his independence, while at the same time he was developing autonomy and confidence. By the end, we were operating as an effective team. Furthermore, this experience helped him become an independent scientist, as he returned the next summer as a participant in the same REU program to continue work on our project. Together, we have found that bacterial cooperation rapidly declined when it was costly, regardless of the benefits. Reflecting on my work, I realized that ownership of the project's direction and excitement for the underlying questions had cultivated **a deeper passion for research in experimental microbial evolution**.

When I returned to Minnesota, I resumed my research on antagonist-driven diversity. After feedback from my mentor and labmates, I realized that my project lacked a clearly novel question and began to broadly search the literature. Consequently, my stomach dropped when **I read a paper very similar to my work.** However, I realized **I could build off their findings** by combining experimental evolution with their experimental treatments. My new hypothesis was that spatially limited phages would select for bacterial motility on agar plates as a means of escape. Unfortunately, I soon ran into a problem: the bacteria were spreading in uneven swarms. Frustrated by the delay, I began setting up new experiments with slightly different conditions each time the previous one failed. Eventually, I realized that **I needed to slow down to make faster progress**. I set up a broad assay to test a range of conditions, and was finally able to see a pattern: as the nutrient concentration increased, cell swarming increased. Sensing a breakthrough, I ran my evolution experiment and began to phenotype the evolved lineages.

As the project became more solidified, **I sought additional mentorship opportunities**. While working on my project, I had also reconnected with the professor I had worked with as a TA. Together, we incorporated my bacteria-phage system into their course curriculum. Through this connection, I reached out to the undergraduates who had worked with phage, and two of them began working with me. Building off of my previous mentorship experience, I gradually cultivated their independence inside and outside the lab. Together we made substantial progress, completing our experimental evolution and characterizing various phenotypes from one set of replicates. So far, the data fail to support our hypothesis: selection for increased motility did not differ between treatments. However, these experiences helped my mentees become independent scientists, as they continue to complete data collection with my close collaboration. All these findings will be included in **a manuscript we are currently drafting.**

This fall I moved to Yale University to begin my PhD in Ecology and Evolutionary Biology with Dr. Paul Turner, Elihu Professor and Acting Dean of Science. Dr. Turner is an expert in viral evolution, with ongoing projects ranging from phage to arthropod-borne viruses. His expertise will help me pursue broader and more meaningful work as a graduate student to understand bacteria-bacteriophage coevolution and its consequences.

Future Goals:
As a graduate student, I will contribute rigorous and impactful **scientific advances in viral and bacterial evolution**. Outside of my contributions, I will also learn valuable skills: through the Yale Center for Research Computing, I will continue to develop and utilize computational skills; and through the Yale Center for Genome Analysis, I will learn how to analyze complex genomic data. Both skills will enable my success during graduate school and for the rest of my career.

I will also continue to engage with mentorship, teaching, and outreach during my time in graduate school. For **mentorship**, as mentioned I will be continuing to work closely with the students in Minnesota, providing remote guidance as they complete data collection. Similarly, I will mentor undergraduates at Yale through my research projects. As I continue to grow as a mentor, I especially want to broaden my mentorship beyond the laboratory, guiding my mentees to use scientific literature, design experiments, analyze data, and communicate scientific findings. For **teaching**, I will supplement teaching requirements by pursuing Yale's Certificate of College Teaching Preparation. This certificate incorporates pedagogy instruction, teaching observations, and reflection to help graduate students learn how to plan and communicate effectively in the classroom. Finally, I will continue **political advocacy** with the Yale Science Diplomats, a graduate student organization which organizes legislative visits around public issues involving science. I will also organize and participate in their Science in the News public **outreach** events. At these events, Yale graduate students give short talks geared to "deconstruct complex scientific topics" for the public. Through these policy initiatives and outreach events, I hope to improve public awareness and policy implementation of scientific ideas.

After graduate school, I seek to enter a career in academia. Eventually, I hope to become a faculty member with both an extensive research program and teaching opportunities. In particular, my research will explore the nature and dynamics of viral evolution across a range of systems. These findings will inform how we respond to and pre-empt emerging pathogen outbreaks, discovering or suggesting novel treatments, vaccines, and public health policies.

Summary of Intellectual Merit:
My experiences have led me to my passion for experimental microbial evolution. At the same time, I have made various contributions. I developed computational skills and applied them to several research projects, measured the decline of cooperation in *Agrobacterium* populations, and observed evolution in response to phage selection. Meanwhile, I have gained valuable life lessons for the rest of my career: the importance of pilot experiments, novel questions, and resilience in the face of failure. Today, I am determined to continue to elucidate the nature of bacterial and viral evolution, processes that are central to our understanding of the natural world.

Summary of Broader Impacts:
My experiences with mentoring, teaching and outreach have shaped the scientist I have become, and continue to inform and motivate my work. As an undergraduate, I took several opportunities to mentor others through research, engage in teaching, and apply myself to policy and public communication. These pursuits remain central to my current involvement at Yale, and reflect a commitment to lifelong engagement. Through them, I hope to prepare future generations of students and scientists and to engage an ever-widening sphere of the public in scientific inquiry.