In sixth grade, I was up late to glue tiny beads from my family's junk drawer onto the cardboard cell model that I had traced out. While I struggled to place the small plastic pieces onto my model, I also struggled to link the simplistic descriptions of organelles we had learned into an understanding of the cellular whole. Because every piece of the cell depends on others, I felt I could not truly understand any piece in isolation. That experience stoked a glimmer of curiosity that grew into a love of thinking about and experimenting with abstractions of the **astonishing complex structures and mechanisms embedded at every level of biological organization**. Today, **computational experiments** are my vehicle for this endeavor.

When I started to develop an interest in biology, I also began playing the oboe. Like science, band culture is built on **mentoring relationships, cooperative competition, and friendly warmth between peers**. Without this community, we could not develop extensive technical skills, push ourselves to do our best work, and accomplish goals far beyond the capabilities of any single individual. The willingness to help, high expectations, and mutual respect scientists hold for their kind inspired me to pursue a career in science.

As a scientist, I aspire (1) to **develop fundamental theory and applications for bio-inspired approaches to AI** and (2) to **promote an inclusive and intellectually vibrant science community through mentoring relationships and STEM outreach**.

Research History I began gaining research experience as a high school student through an **Apprenticeships in Science program** at Oregon State University. I worked with Dr. John Folwer to investigate the exocyst protein complex in plants. Using genetic assays and phenotypic measurements, I screened 25 populations of *Arabadopsis thaliana* for synergistic interactions between a known exocyst mutation and a mildly deleterious mutation at an independently-assorting locus. The group went on to isolate a novel Golgi-localized protein confirmed to interact with the exocyst [1]. I took away a strong impression of what a friendly, supportive, and inclusive scientific community looks like. This personal experience with STEM outreach motivates my desire to make similar opportunities available to others.

As an undergraduate, I worked at the interface of science and industry at the **USDA small fruits breeding laboratory**. I spent two summers working full time with Dr. Chad Finn to develop berry cultivars for the fresh fruit and processed food markets. Achieving widespread production of our cultivars requires buy-in from our partner growers. To build these relationships, we hosted regular symposiums with brief and actionable presentations on best practices and actively involved growers in our scientific experiments. I gained further experience making connections between the real word and science through three bouts in the **Mathematical Competition in Modeling** (MCM). These four-day sprints emphasize pitching insights gained by developing and analyzing mathematical models to business executives and policy makers. In 2017, my three-person team developed a model of highway traffic in the greater Seattle area and showed that in the near future designating lanes exclusively for autonomous vehicles will reduce commuter travel delays. We **ranked among the top 11 of over 1,500 participating teams**. I will continue to use my experience building collaborative partnerships and gearing science toward a professional audience to translate my research into real-world innovations.

As a sophomore, I built my computational skill set **developing methods for automated isolation of mouse ultrasonic vocalizations (USVs) from noisy recordings** with Dr. Adam Smith at University of Puget Sound (UPS). I sought outside funding and was **awarded a NASA space grant of $3,250** through a competitive application process. USVs are an important quantitative assay for the affective and social state of mice in biomedical research, but existing software tools were readily confounded by background noise. I developed and tested filtering algorithms inspired by the Sobel Edge detection method that use human-annotated spectrograms to learn to distinguish between true mouse vocalization signals and background noise. My approach achieved 75% accuracy at 25% recall from noisy recordings. I presented these results at the 2015 UPS summer research symposium [2]. From this experience, I gained computational research skills including data management, version control, and visualization techniques.

I brought my biological and computational interests together studying ant foraging behavior at the **NJIT Swarm lab** in the summer after my junior year. I was recruited by Drs. Simon Garnier and Jason Graham through the Mathematical Biosciences Institute REU. For ants on flat terrain, the shortest-distance foraging path, the most energy-efficient foraging path, and the quickest foraging path are all identical. However, on uneven terrain an obstacle may make the most direct path take longer than a trip that circumvents it. In the absence of an absolute "best" path, the question of how ants make trade-offs is of great interest to biologists and engineers studying swarm robotics. Thus, I extended computational models of ant foraging to consider uneven terrains. My differential-equations based model predicts that severe inclines cause ants to favor a more direct, less variable foraging path. I presented my work at the **2017 Joint Mathematics Meetings** [3]. During my time at the Swarm lab, I was empowered by the autonomy entrusted to me and found the opportunity to answer open biological questions with practical applications rewarding. After this REU, I saw graduate school as the best way to continue engaging in such self-directed, impactful work.

For my **senior thesis project** at UPS, I worked with Dr. America Chambers to synthesize a conceptual framework for evolvability, the potential for adaptive change to occur in an organism's descendants. Evolvability has been connected to a wide array of causal factors ranging from gene duplication to phenotypic plasticity. I organized this constellation of causal factors into three larger classes and analyzed their broad relationships [4]. Building off my thesis, I conducted a **capstone project** to empirically investigate how environmental influence on the phenotype relates to evolvability in a gene-regulatory network model. I found that populations subjected to stochastic perturbations during the development process evolved a higher incidence of silent mutation. Further, populations pressured to respond to environmental signals by activating alternate developmental pathways were more sensitive to mutation. I presented my findings at the 2016 NW Honors Symposium, two campus seminars, and the 2017 NSF BEACON Congress [5]. For my thesis and capstone work, I received the **MacArthur Award for an Outstanding Thesis Presentation** and the **Goman Outstanding Math/CS Senior Award**. This fall, I have published my thesis work as an illustrated blog series aimed at both the general public and other scientists. Uniting experiments and theory in my thesis and capstone projects was extremely rewarding; this work inspired me to continue conducting research that tightly couples these domains.

<u>Broader Impacts</u> I developed educational outreach skills as **a subject tutor, an academic consultant, an AP tutor, a classroom assistant, a musical coach, and an after-school club leader**. In these capacities, I worked with high school and college students on a weekly basis over three and a half years. I see these mentoring relationships among the most important accomplishments of my undergraduate career. I was caught off guard by an alternative high school student I tutored in math who, out of the blue, asked, "What's so great about college?" I almost launched into why *I* liked college, but instead asked, "What's your favorite thing to talk about?" She took a moment, then replied, "Books, I guess." "What's so cool," I told her, "is that you can take classes in whatever you want. You can take classes about literature with other people who also love books." She took notice when I mentioned how well she would get along with my humanities friends. This experience made me realize the impact of making a personal connection and showing a student they belong. I went on to **lead a CS mentoring initiative** in my senior year. We organized three department-funded meet-ups to develop social connections between class cohorts and build skills like professional networking and programming in IDEs. Each was attended by approximately fifteen students.

By showing me the difference *I* can make, my outreach work led me to define making higher education and STEM more welcoming and accessible as a key priority of my scientific career. As an LGBT person, I know that identity is not baggage to be checked at the door. I believe recognizing and respecting diversity makes STEM stronger. I strive to use my own experiences to reach across barriers to inclusivity experienced by others in the scientific community.

Career Goals My current research interests stem directly from my undergraduate thesis and capstone work. **I am pursing a doctoral degree with Dr. Charles Ofria at BEACON**, an NSF Science and Technology Center for the Study of Evolution in Action at Michigan State University. BEACON offers access to **high performance computing resources** and a **uniquely interdisciplinary research community**. Working with biologists on *in vivo* work and with evolutionary computing practitioners will allow me to apply novel biological concepts to evolutionary computing. In particular, I am interested in understanding what critical nuances are missing from simple algorithmic implementations of evolution built on bare bones selection, variation, and inheritance. My specific focus is on **evolvability and environmental influence on the phenotype**. Understanding the relationship between these phenomena will help biologists answer questions about the evolution of complex traits like human intelligence and will help evolutionary computing researchers develop powerful applied evolution techniques to solve practical problems like automating deep learning architecture design.

By probing the algorithmic principles of biology, I hope to contribute to the **development of more capable, versatile AI systems** with direct human impact. I am inspired by my father, who volunteers for Dial-A-Bus to serve individuals whose disabilities would otherwise limit their ability to fully participate in the community. I hope that, through applications that counteract disability and free us from dangerous or simply menial tasks, stronger AI will enable people to more fully exercise their human capabilities. My work with the Swarm lab, with Dr. Chambers, and in the Ofria lab helps lay the groundwork for this future. I will leverage my outreach skills build industrial collaborations that apply my research to real-world AI problems.

I am committed to **continuing to foster community among scientists and perform STEM outreach**. I currently volunteer four hours a week as a teacher's assistant in special and general education classrooms in East Lansing. In my fourth period classroom, my work is specially targeted at engaging minority students. As I progress in my graduate studies, I look forward to welcoming new graduate students and taking advantage of BEACON funding support to mentor undergraduates on summer research projects.

Ultimately, I aspire to lead an academic research group and build an inclusive community that will allow myself and others to accomplish our outreach, technological, and scientific goals. GRFP support will help me conduct **cutting-edge research at the intersection of biology and computer science** and lead in the conversation about the **intrinsic value of outreach, mentorship, and community in science**.

References [1] Cole *et al. Plant J* (Submitted for publication), [2] MAM. *UPS Summer Research Symp* (2017), [3] MAM. *JMM 2017* (2017), [4] MAM. *UPS Honors Theses* (2017), [5] MAM. *BEACON Congress Poster S* (2017)