It still shocks me that something that feels so irrevocable as identifying myself as a neuroscientist only happened a few years ago. In retrospect, it feels as inevitable as water freezing to ice – all my free-floating motivations and ideas looking for anchor locked into a single, orderly whole. I love so deeply those moments that you, I, and all our colleagues share: standing on the edge of human understanding, the breathless decision to build the scaffolding from which we can take another step. Describing my motivation for pursuing this project and graduate education in general is thus difficult, because to me it feels self-evident: here I stand at the edge of our understanding of speech perception; I can do no other.

Background & Preparation I've always been a tinkerer. The elements of my environment, physical and intangible, have never felt immutable – instead, I pick them apart and imagine how they could be. This tendency, with all the force of gravity, animates all my dearest projects: Still in high school, in the face of regressive education reforms I attempted to inspire my classmates to take control of the structure of their own education by giving speeches, interviews, and leading walkouts. At Willamette University, I worked in a shop building sets for the theater department. There I began to learn the carpentry and metalworking necessary to remove my dependence on the pre-fabricated – and felt firsthand that the limits of what exist are only those of one's imagination and skill. This extended into my work in technical sound production, where we rebuilt and rewired commercial speaker equipment to give the student music culture the tools to thrive. In life and in science, I continue to learn as many new skills and ideas as I can so that I have a wide array of tools to answer any questions I have.

Academically, before I found footing in science, I thought that this do-it-yourself ethic was properly situated in the study of politics and economics. I had been reading works like those of Hegel and John Stewart Mill that made the natural extension of individual autonomy to collective human dynamics. History and culture were dynamic systems, emergent from the churn of people and ideas cooperating and conflicting. When I began to translate these ideas into practice, however, I found that the methods of these disciplines were dismayingly static. It was the right instinct in the wrong system – culture moves too slowly to measure its flow, and experimental perturbation is impractical if not impossible. Expressing this to my history professor, he suggested that to investigate dynamic human systems I might consider studying neuroscience. He was right.

I lined up conversations with the faculty at Willamette clustered around neuroscience, but after speaking with Dr. Emma Coddington it became clear I could cancel the rest of my appointments. Her work with reproductive behavior in rough-skinned newts was a perfect fit: it was an elegant model to explore my intuition regarding dynamic systems. Her lab had linked a complex behavior to neural computation unfolding over a dramatic range of spatial and temporal scales, all exquisitely sensitive to context and history. This was at the end of my sophomore year, so a complete transition from social to biological science was a stretch. I was not to be deterred, however, because I had already started to feel an irresistible pull towards neuroscience. Neuroscience felt like an obvious extension of everything I had loved before, only instead of social or physical construction, we were building our understanding of basic material reality. After convincing the university that I was capable of catching up to my peers by doubling up on coursework and filling in any blanks with independent research, I made the switch.

Previous Research My project with Emma was to use whole-cell electrophysiology to characterize the intrinsic and synaptic electrical properties of a population of hindbrain neurons involved in gating the newt's reproductive behavior. Corticosterone released during stress had been observed to prevent mating by inhibiting these neurons, but the mechanism was uncertain. To tackle this problem, I spent all my waking hours practicing every part of my whole-cell technique from top to bottom: from studying biophysics and ion channel dynamics to the practicalities of tissue dissection and electrophysiology itself. Whole-cell electrophysiology is a heinously difficult technique, but my work paid off. My results suggest that what appeared to be inhibition from multi-unit recordings was actually the induction of a temporal filter that caused the neurons to only spike with rapid, coincident input. I began dissecting the changes in ion channel composition pharmacologically, and by modeling them as a system of partial differential equations came to the conclusion that the most likely mechanism was that corticosterone opened a tonic chloride current that kept transient sodium channels inactivated following an action potential. I left Willamette for University of Oregon with a few control experiments left unfinished, and am currently waiting for a researcher there to complete them to publish this result.

This project is the template for my approach to science: I was given a broad question and support when I needed it, but beyond that I worked to make the project my own. I fought to understand information from unlikely disciplines to inform my work, and challenged myself daily to improve my technique. I take ownership of my projects for three reasons: First, I want total mastery of every technique necessary for an experiment. My DIY ethic dovetails with my scientific rigor. By mastering every technique, I deepen my understanding of the problem while gaining technical flexibility for future experiments. Second, I want to get so deep into a project that it keeps me up at night. To know the whole of an ongoing project is to have a puzzle that invades every mental moment, begging for insight and investigation. Third, rather than learning as a student, I learn as a peer. This is a dual process that involves humbly requesting and taking the advice of those more experienced than myself, while also probing every experimental alley on my own to return whatever insight I can.

Future work – Intellectual Merit My current work in phonetic perception (described in my project proposal) with Dr. Mike Wehr at the University of Oregon is a perfect continuation of my scientific and creative interests. Being at the cutting edge of a new question in a relatively young field requires one to both build the microscope as well as look through it – as a lab, we innovate and invent new instruments and techniques that let us answer our questions. This project harnesses the deeply interdisciplinary potential of neuroscience by asking a question that is inextricably linked to physics, biology, theoretical neuroscience, psychology, and linguistics. It is my belief that real breakthroughs in neuroscience will come only through projects like these that combine insights from multiple fields and perspectives. This is an area where University of Oregon excels: we are in active collaboration with Dr. Kaori Idemaru, a linguist who has been invaluable to our understanding of phonetics. In the future I hope to collaborate with Dr. Cris Niell and his lab to do calcium imaging of auditory cortex with their two-photon microscope; and to model my data with Dr. Yashar Ahmadian, a theoretical neuroscientist studying dynamic stability and computation in neural networks.

In pursuing this project in conjunction with our collaborators, I hope to not only develop a mouse model for phonetic perception, but a model that can be used to study dynamic neural computation more generally. How a population of independent agents operates together as an emergent whole is one of the deepest open scientific questions. Mathematically, the difficulty we face understanding dynamic neural networks is precisely that faced by those attempting to understand behavioral economic models. We know that a system with relatively simple individual behavior can yield stunningly complex collective behavior, but we still lack the intuition to derive those rules and draw meaningful conclusions from our observations of complex systems. In neuroscience, many of our models are still static. Computation is the linear combination of different receptive field properties, rather than a collective computation unfolding through time.

The phonetic model is the first auditory model, to our knowledge, based on a class of stimuli that are temporally complex and nonlinear while still being well-studied perceptually in humans. I hope that with it I will be able to contribute to our understanding of phonetic processing, auditory processing, and more generally to dynamic computation. My future work will continue along this path, though because I am not bound to a system, I would like to branch into other disciplines. Specifically combining nonlinear dynamics and graph theory to broaden my grasp of the problem.

Future work – Broader Impact The two ways that I think I can best extend my work to help others are by making scientific tools, and by making scientific teaching tools that align with how modern students learn. I am deeply inspired by open science initiatives like the Allan Brain Institute, and open hardware initiatives like Open Ephys. This summer I wrote a set of programs to automate our behavioral training as well as manage and analyze the resulting data. These programs are hardware and stimulus-agnostic, and allow work that would previously have cost tens of thousands of dollars to be done for less than $100 using inexpensive microcontrollers. Tools like these can powerfully augment the types of questions that any lab, but particularly small, young, or otherwise poorly-funded labs can ask. As I continue my research, I plan to continue to publish all my tools open source, and make them in such a way that they can be flexibly adapted by other labs. I am also committed to openly sharing the raw data of my publications. Openly sharing scientific data has the promise of fundamentally changing the single-lab-based architecture of science. Two of the greatest challenges to realizing that promise are that the raw data summarized in publications is still difficult to share and standardize. I manage several decentralized data-transfer systems with friends and colleagues. These systems work by leveraging the combined bandwidth of individual computers that all have the same data. I will attempt to adapt these systems to overcome the problem of sharing data by allowing smaller labs to distribute their data without needing large, expensive servers. The problem of standardization is essentially that of matching file formats and metadata, both of which can be solved by simple file conversion tools and well-designed user interfaces. Once it is possible to pull the raw data for a particular experiment from other labs, the need for redundant experiments will plummet while opening up the possibility for big-data research that would be impossible for a single or even group of labs to accomplish.

Scientific teaching will have to adapt to the fact that digital natives interact with information differently than past students: rather than getting their information from books or lectures, most get it from interactive online media. When teaching a course on music and the brain this summer, I noticed that my students would often tune out the lecture portion of class, but would sit in rapt attention while I was demonstrating the lecture concepts with a computer model or animation. I then spent the rest of the term making these models and animations so that the students could interact with them on their own. Students would come to my office hours having explored the models until they found something they couldn't explain – with the right teaching tools, they were self-motivated to ask and answer their own questions. Open publication, and free online courses all have the promise of democratizing scientific knowledge, but at present do not reach the vast majority of the non-scientific world because they aren't presented in a way that lay audiences find engaging. I plan to teach the same course again next summer, and will package the models that I have made into a freely released guided tour of the auditory system. If this project is successful, it would serve as a viable replacement to textbooks and even paid courses, as students can engage with the content on their own terms in a way with which they are familiar. I view it as my responsibility as a scientist to fulfill the promise of Diderot's encyclopedia: as I continue to teach I will package each of my classes similarly, attempting to leave behind a preserved, approachable edifice of scientific knowledge.