<u>Personal, Background, and Future Goals Statement</u>

Introduction: I discovered an interest in neuroengineering research merely by accident. During my sophomore year in college, I stumbled across a neuroengineering poster. It had beautiful pictures of neurons and microdevices with students in lab coats conducting research. It looked like something straight from a medical brochure, a jarring contrast to the typical research in the electrical engineering department to which I belonged. My classes did not expose me to how biology correlated with electrical engineering and this absence culminated into a sense of curiosity on the subject.

I first met Dr. Anja Kunze when I showed remarkable interest in joining her lab. She offered me guidance to shape my curiosity and accepted me in her lab, quickly becoming my mentor. The learning curve was steep: I sought out journal papers involving neurons, neurological diseases, and researched information relating to the field of neuroengineering. The deficit of research solutions between electrical engineering and neuroscience led me to piece together the implications of neuroengineering research. Driven by this, I became passionate to uncover the crossover between biology and electrical engineering.

<u>I am drawn to developing a deeper understanding of how the intricate circuits in our brain work and look towards developing exciting bioelectronic devices to do so.</u> The cross-discipline of engineering devices for biological applications has led me to pursue a PhD at Purdue University under Dr. Krishna Jayant where I continue to explore the field of neuroengineering and neuroscience.

<u>Intellectual Merit:</u> My undergraduate research in Dr. Kunze's research lab focused on developing miniaturized devices to understand neuronal morphology and neurotherapeutic approaches for neurological diseases. Fueled by the papers I read; I developed a scalable cell assay using soft hydrogel to investigate the effects of curvature forces on neurons **–** work that was subsequently **published in Lab on a Chip with me as the first author.** This device revealed precise mechanical interactions between neuronal network growth within degrees of confined curvatures, a relevant aspect since curvature changes occur during neurological disease states. This work **awarded me funding from the NIH INBRE program**, a cross-discipline collaborative program aimed to fund highly motivated undergraduate students through the summer. Working closely with biological and chemical engineers, we discovered that intracellular components of calcium and mitochondria are directly affected under different curvature microenvironments. The novelty of the scalable cell assay awarded me an **invited presentation at the National Science Foundation National Nanotechnology Coordinated Infrastructure (NSF NNCI)** convocation hosted at Cornell University**.** Here**,** I highlighted the emergence of distinct neuronal calcium networks shaped by curvature forces**.** The development of my device was valuable to the neuroengineering field as it provided a systematic approach to look at localized synapses by generating over 140 distinct microenvironments. **This breakthrough awarded me an oral presentation at the annual Biomedical Engineering Society (BMES) conference**. With several thousand abstracts, obtaining an oral presentation is rare, even more so as an undergraduate. I delivered my talk titled *<u>"Soft gel microchannels to study curvature effects in neuronal calcium signaling"</u>* in a track session called Micro and Nano Tools for Neuroscience. In this talk, I highlighted the implications of how this device can be used as a tool for scalable neurological drug screening, which I now hold a provisional patent on**.**

My experience in Dr. Kunze's lab was profound and strengthened my passion to pursue higher education in academic research. Gaining an understanding in neuroengineering and device fabrication solidified my interest in pursuing a PhD in biomedical engineering – the intersection of both these fields.

Interested in further developing tools to investigate challenging neuroscientific questions, I joined Dr. Jayant's Nano Neurotechnology lab at Purdue University under the **Stephen Ash Fellowship**, an award given to only two incoming doctoral students in our department. With Dr. Jayant's guidance, *<u>I am ambitiously researching novel neurotechnologies to map how memory circuits function in awake behaving animals.</u>* This project, funded by the Human Frontiers Science Program (HFSP), promises a cutting-edge technological solution to unravel memory encoding and recall during spatial navigation.

My first foray into the world of memory circuits and neuroscience was building a closed-loop virtual reality (VR) system to control the sensory experiences of mice – the first of its kind in our lab. Using my background as an electrical engineer, *I developed a close-loop microcontroller system* that neatly interfaced with a game-engine rendering software, and existing electrical and optical tools used by neuroscientists. Through the development of this system, I linked virtual experiences to the population activity of hippocampal neurons in real-time. **This work landed me a 2-year NIH T32 Fellowship** in which I proposed to record multisensory experiences to investigate neural circuit functions mapped through the VR system.

One hallmark of conducting neuroscience research in awake behaving animals is data acquisition and analysis, which scales immensely when using multi-model imaging and electrophysiology approaches paired with behavioral readout. This facilitates a demand to create sophisticated programming pipelines to interpret the massive amounts of data generated from these experiments. Following my efforts in building the VR system, *I spearheaded efforts to create a custom multi-model programming pipeline in MATLAB to concomitantly analyze optical and electrophysiological data.* After a thorough review of existing literature, I researched and applied various high-dimensional analyses including singular value decomposition, greedy correlation algorithms, and functional connectivity matrices on our data. The creation of this pipeline, in addition to my own work, has found widespread use including a Parkinson's project that our lab contributes to. Using algorithms that enabled precise spatial and temporal accuracy, I made a striking discovery of how pathogenic proteins–upregulated in Parkinson's–affect the neural syntax of cortical circuits in awake behaving mice. After discussing with my advisor, **I am currently preparing a manuscript for submission to *Neuron*,** a leading journal in our field.

The experiences this past year have helped me gain an invaluable understanding of complex neuroscience concepts. This spans biophysics of computation, neuroanatomy, and behavior. The combination of the close-loop VR behavioral system and multi-scale analysis pipeline has provided me with a platform to springboard into the world of memory circuits. The HFSP is based on an international collaboration between Dr. Krishna Jayant and Dr. Laura Ewell (formally at University of Bonn, Germany now at UC-Irvine).

This collaborative project focuses on creating a unique neuroprobe which facilitates both optical access and electrophysiological readout in the awake hippocampus. Achieving this is a difficult feat as the hippocampus resides subcortically, rendering it a challenging problem for neuroscientists. Working alongside Dr. Daniel Gonzalez – a postdoctoral researcher – we successfully developed a proof-of-concept flexible and transparent multi-electrode array. I was given the opportunity to travel to the University of Bonn to learn the intricate hippocampal surgery required for the implantation of my array. When I arrived at the medical center, I was surrounded by neuroscientists, psychologists, and medical experts well-versed in hippocampal and epileptic research. Not only was I able to learn the surgery well; *I implanted my proof-of-concept platform into the hippocampus for simultaneous optical and electrical recordings*–a feat performed for the first time. This success was made possible by the numerous discussions with my advisor, surgeons, and fellow neuroscientists. I experienced, first-hand, the ground-breaking discoveries that could be made when bridging the gap between engineering and neuroscience. I also understood the breadth of scientific success achieved when collaborating with others in differing areas of studies.

This success led my advisor to nominate me for an honors college mentoring program. I now mentor Maia and Fahad, mechanical and electrical engineering honor students, who work on *mechanical* insertion methods for flexible microprobes and behavioral recording *electronics*. I find it incredibly rewarding to watch the independent and critical thinking that comes from their experiences and personal growth. Their contributions will be invaluable as we ambitiously push forward in creating new neuroelectronic devices for the neuroscience field. This experience is motivated by my passion for teaching and mentoring, and that I find academia extremely exciting and personally enriching.

Broader Impacts: Much of my accomplishments as a researcher would not be possible without the mentorship of students and professors around me. I strive to offer the same experience to young students, including underrepresented minorities, navigating their way through college. At Montana State University, I joined a mentoring program tailored to help incoming students integrate into their college environment. Aptly named Sophomore Surge, this program centered on helping students *surge* into their sophomore year. Initially, I joined this program's pilot group to investigate how to increase retention rates in our university. With fourteen other mentors, our program was small but proactive. I received training in community building, leadership, and response to emergencies. I assisted incoming students on registration, classes, and how to access various academic resources across campus. We coordinated closely with the assistant provost, *aiming to broaden our community impact*.

By my senior year, our program spanned across three departments, included more than 80 mentors, and assisted more than 1000 incoming students. Our work gained recognition as a program that directly reduced dropout rates in our university. Through this experience, I discovered the importance of proximity to build understanding and communication - the cornerstones of successful mentorship. Mentoring requires patience and empathy to set expectations for students to understand what I can do for them. With this approach, *I helped more than 100 students successfully transition into higher education*. I carried this similar mindset to other mentoring opportunities as well, including becoming a graduate teaching assistant for Fundamentals of Bioelectricity, a core course in Purdue's biomedical engineering department taught by Dr. Jayant. I graded quizzes, helped with assignments, and held office hours. *These experiences taught me the importance of having a diverse perspective to successfully communicate, a skill that undoubtedly became valuable for community and societal outreach.*

I am also extremely passionate about transferring technologies from the lab to the public. Prior to starting graduate school and during the pandemic, *I helped co-found a company* that used nanomagnetic particles as a shuttle for therapeutic drugs in neurodegenerative diseases. Having established a device that uses nanoscale forces for neural modulations, I recruited a team of engineers for commercialization as part of our CAPSTONE project. Aimed at increasing transparency and impact of our work to the public, we set out in taking our scientific platform from the engineering bench to the commercial market. Throughout the year, we continuously worked on packaging the device, minimizing technical requirements, and maximizing *broader and more practical health impacts*. Our team joined a seed venture competition with a cumulative prize of $50k startup venture. After spending several weeks perfecting our presentation delivery, myself and Paul, a mechanical engineer who led efforts packaging our device, delivered the business pitch to potential investors. We secured $6k for startup funding, and the company of Nanomagnetic Solutions LLC. was founded. Having established a foothold in scientific entrepreneurship, our newly minted company participated in the *NSF I-corp program at University of Washington*, where Paul and I met various investors, gained valuable insight in startup entrepreneurship, and delivered business pitches to other companies and ventures.

Until then, I did not consider the commercial breadth of our technologies, but quickly became fascinated with scientific entrepreneurship. Crafting a compelling story for a broad audience was challenging but extremely rewarding. This realization ignited a new avenue of research exploration that I intend to continue throughout my academic career.

Future Goals: My goal is to advance novel neurotechnologies in the field of neuroscience and neuroengineering through my doctoral degree in biomedical engineering. The impactful experience of undergraduate mentors, collaborations, and entrepreneurship has driven me towards broadening scientific discoveries be it a startup, scientific collaboration, or mentoring. To tackle the immense challenges within the neuroscience field, a highly skilled and diverse team is only effective through proactive collaboration. The **NSF GRFP will allow me to build new and impactful technologies for pressing neuroscience questions, looking beyond what does exist to what can exist.** Through collaborative effort, I endeavor to bridge the gap between engineering and neuroscience. I aim to extend this mindset to the future when I set out to begin my academic lab as a professor, ushering the next generation of engineers looking to shape the field.