Chuck Norris, Ph.D.
Very Excellent Research Foundation Postdoctoral Fellow
Department of Biochemistry and Biophysics
Prestigious University
City, USA
Phone: (000) 000-0000
Agreatemail.address@email.edu

September 15, 2017

Dear State College Department of Biology search committee,

I am writing to express my interest for the position of Assistant Professor of Biochemistry. My career goal is to teach at a liberal arts college where I can continue to conduct high-quality research while teaching and mentoring undergraduates. I am excited about the prospect of being a part of State College's diverse community.

I received my Ph.D. in Molecular and Cell Biology from University of Anywhere in 2013, where my doctoral work focused on structural and biochemical studies of telomeres in the lab of Prof. C.D. Parker. As a Very Excellent Research Foundation postdoctoral fellow in the lab of Prof. Alex Cahill at Prestigious University (PU), I study the structure and function of membrane calcium channels. My proposed research program is explicitly designed to be performed by undergraduates at a liberal arts college, combining elements of structural biology, biochemistry, and genetics to probe the structure and function of membrane transporters. I am a strong supporter of a broad liberal arts education and the creative thought it fosters, having earned my B.A. in History in addition to my B.S. in Biochemistry from James Trivette University. I am prepared to teach Introduction to Biological Chemistry, as well as introductory biology and advanced electives such as Molecular Biology and Advanced Cell Biology. Additionally, I would be excited to participate in State's tutorial course, given that close interaction with students is a major reason I am pursuing faculty positions exclusively at liberal arts colleges.

I am passionate about teaching science to students from all backgrounds, and I have continuously developed my teaching skills from the time I was an undergraduate. My interest in teaching undergraduates extends back over a decade: as an undergraduate at James Trivette University, I served as a Teaching Assistant in introductory chemistry lab courses. As a graduate student at University of Anywhere, I twice taught Anywhere's diverse student population as a teaching assistant, once in a lecture course designed for those majoring in biochemistry, and once for a lecture course designed for those outside the biochemistry concentration. On the basis of student evaluations and professor nominations, I received Anywhere’s Outstanding Graduate Student Instructor award. As a postdoc at PU, I continued to develop my teaching skills by attending the Coastal City Postdoc Workshop on Scientific Teaching at Firewalker University. Additionally, I participated in the Teaching preparation program at PU. These courses and workshops have taught me strategies based on education research that are designed to accommodate all learners. Because of my training, I am prepared to create a classroom environment in which students from all backgrounds can achieve their potential and learn to think as scientists. In particular, I adopt teaching strategies that are conducive to active learning, which has been shown by research to result in superior outcomes for students from underrepresented backgrounds.

Chuck Norris - Cover Letter

I am excited to involve undergraduate students in my research program as I investigate the structure and function of calcium channels. At University of Anywhere, I developed my background in structural biology and biochemistry through X-ray crystallographic studies and biochemical assays of telomeres. My work yielded new insights into the conserved mechanism of XYZ, and resulted in two first-author publications published in *Nature* and *Nature Structural & Molecular Biology*. At PU, I proposed to take my structural biology expertise and apply it to a new challenge of calcium channels in the lab of Alex Cahill. I study protein ABC that is essential for plant growth, and determined its first crystal structure. Structural comparisons with related proteins DEF, the most abundant membrane protein in my favorite cell type and a key driver of an important process, allowed me to propose a transport mechanism for ABC, DEF, and several related families. A manuscript reporting these results has been published in *Proceedings of the National Academy of Sciences*. I entered the Cahill lab with the intention of determining the structure of a calcium channel, and then leveraging that structural data into a research program designed to be performed by undergraduates. Thus, I have used the structure of ABC as a platform to develop simple yet informative biochemical and genetic assays that test aspects of the ABC transport model, using experiments that are well-suited to being performed by undergraduates at State. My work in the Cahill lab was funded by a fellowship from the Very Excellent Research Foundation, which includes a research stipend that I partly placed into a fund to be disbursed upon starting my independent research career as a professor. As a result, I have accrued $10,000 to serve as a mini-grant and supplement start-up funds as I set up my new lab. My expertise in structural biology and biochemistry, development of experiments well-suited to undergraduates, and acquisition of external funding have placed me in a strong position to launch my independent research career at a liberal arts college.

I look forward to continuing to mentor undergraduate students. I have had the opportunity to mentor undergraduate and first-year graduate students during my training. I developed individual research projects for them, tailoring my guidance based on student experience and work habits. The students I mentored have gone on to further scientific accomplishments. A project I devised for a first-year rotation student developed into a paper we wrote together in which he assumed first authorship. I am keenly aware of the value of undergraduates performing research that leads to publications. Work I performed while I was an undergraduate researcher at Cordell Walker University led to my inclusion as an author on a paper. That experience helped start my career, and is an experience that I want to give back to undergraduates under my guidance. I would relish the opportunity to do so as member of the State College community. Thank you for your consideration.

Sincerely,

Chuck Norris, Ph.D.

Chuck Norris, Ph.D.

000 Address, Prestigious University, Location, USA,
Agreatemail.address@email.edu - (000) 000-0000

EDUCATION

2008 - 2013	University of Anywhere Ph.D. in Molecular and Cell Biology Thesis Adviser: C.D. Parker Graduation date: December 2012
2004 - 2008	James Trivette University B.S. in Biochemistry, B.A. in History, Minor in Mathematics Graduated with Highest Distinction, GPA: 3.93/4.0

RESEARCH EXPERIENCE

2013 - present (2017)	Prestigious University Very Excellent Research Foundation Postdoctoral Fellow Adviser: Alex Cahill *Name of research project here*
2009 – 2013	University of Anywhere Ph.D. dissertation research Adviser: C.D. Parker *Name of thesis project here*
2008	Cordell Walker University Undergraduate Research Program Adviser: Trent Malloy *Name of research project here*
2004 – 2008	James Trivette University Undergraduate Research Adviser: Carlos Sandoval *Name of research project here*

FELLOWSHIPS AND ACADEMIC HONORS

2014 - 2017	Very Excellent Research Foundation Postdoctoral Fellowship ($XXX,XXX award over three years)
2014 - 2016	Another Great Foundation Postdoctoral Fellowship ($XX,XXX award over two years – declined)

2010 - 2012	Institute Training Grant
2010	Graduate Research Fellowship Program Honorable Mention
2009	Graduate Research Fellowship Program Honorable Mention
2008	Graduating Senior Award - awarded by the James Trivette Department of Chemistry each year to a top graduating senior
2008	Phi Beta Kappa
2007	Sonora Scholarship Honorable Mention
2004 – 2008	Important Scholarship - only one scholarship awarded by James Trivette University to my incoming class of over 7,000 students; covers full tuition to a student who will perform research for four years

PUBLICATIONS

7. **Norris C** and Cahill A. Publication title. *Proc Natl Acad Sci U S A* (2017)
6. Name, Name, **Norris C**, Name, Name, and Name. Publication title. *Plos Biol* (2015).
5. **Norris C**, Name, and Parker CD. Publication title. *Nat Struct Mol Biol* (2013).
4. Name, **Norris C** Name, Name, and Parker CD. Publication title. *J Mol Biol* (2013).
3. Name, Name, **Norris C**, and Parker CD. Publication title. *Nat Rev Mol Cell Biol* (2012).
2. **Norris C**, Name, Name, Name, and Parker CD. Publication title. *Nature* (2011).
1. Name, Name, Name, **Norris C**, Name, Name, and Malloy T. Publication title. *Proc Natl Acad Sci U S A* (2008).

TEACHING EXPERIENCE, AWARDS, AND TRAINING

Fall 2017	Guest instructor for Virus Environments, Prestigious University. I have led discussion sections for a graduate-level course for first year Ph.D. students at PU. My primary responsibility was to lead group discussion of journal articles.
Spring 2017	Participated in PU's Teaching Preparation Program This four-session training course taught how to define learning objectives for a course, track learning by using formative assessment, and adopt learning strategies that promote active learning.
Spring 2017	Attended the Coastal City Postdocs Workshop on Scientific Teaching at Firewalker University. This workshop taught different strategies, rooted in education research, for achieving active learning in the classroom.
Spring 2011	Biochemistry and Molecular Biology, led two discussion sections, Anywhere University - Department of Molecular and Cell Biology. Course responsibilities included leading weekly lecture and discussion activities, holding office hours, and grading exams.
Spring 2010	Outstanding Graduate Student Instructor Award, Anywhere University. Selected on the basis of student evaluations and faculty nomination.
Fall 2009	Survey of Biochemistry and Molecular Biology, led two weekly discussion sections, Anywhere University - Department of Molecular and Cell Biology. Course responsibilities included leading weekly lecture and discussion activities, designing and grading weekly quizzes, holding office hours, and grading exams.
Spring 2006	General Chemistry, led one lab section, James Trivette University - Department of Chemistry. Led a weekly lab section in which I gave a short lecture over that week's lab, oversaw student performance of the lab, and graded lab write-ups.
Fall 2005	Elementary Chemistry, led one lab section, James Trivette University Department of Chemistry. Led a weekly lab section in which I gave a short lecture over that week's lab, oversaw student performance of the lab, and graded lab write-ups.

MENTORSHIP

Summer 2012	Served as a Graduate Assistant for the Anywhere University Biotech company Scholars Program. The Biotech company Scholars Program brings undergraduates from around the nation to perform

research in labs at Anywhere University over the summer. As a Graduate Assistant to the program, my role was to have weekly meetings with a group of seven students to see how their research was progressing, meet with each student's research mentor to ensure the goals of the program were achieved, advise the students in the preparation of writing abstracts, making poster presentations, and giving oral presentations, and lead workshops designed to prepare the students to applying to graduate school.

Spring 2012 — Mentored a first-year graduate rotation student, Name Here. I partnered with a first-year student for 10 weeks and devised an independent project for him to work on. The work developed into a paper reporting the structure of human insert protein here on which he assumed first-authorship and on which I was second author.

Summer 2011 — Mentored an undergraduate, Name here, for 10 weeks. He visited the lab during the summer after his freshman year in college. He had not taken any college coursework in biology, nor had he worked in a lab before. I devised an independent project for him on developing a high-throughput assay for monitoring enzyme A activity. He is currently a graduate student at Elite University.

DEPARTMENT SERVICE

2011 - 2012 — Served on MCB graduate admissions committee. I was elected to this position, which participates fully in the selection of the following year's entering class. I was one of three people (the other two being faculty) to review and rate applications for admission.

2010 - 2012 — Seminar Series Organizer. I was elected to this position to invite and organize the visit of student-nominated faculty speakers to Anywhere University to give research seminars.

2010 - 2012 — Organized Monthly Meeting, a monthly meeting in which speakers from two research groups present data to the other Anywhere University structural biology research labs.

2009 - 2011 — Department divisional representative. I was twice elected to this position, whose responsibility is to attend and participate in the monthly faculty meetings for the academic year.

2008 - 2009 — First year class representative, MCB Department. I was elected to this position, whose responsibilities include organizing multiple components of prospective graduate student recruitment campus visits.

List of References

Alex Cahill, Ph.D.
Professor
Department of Biochemistry & Biophysics
Prestigious University
City, USA
Phone: 000-000-0000
Email.address@email.edu

C.D. Parker, Ph.D.
Professor
Department of Biophysics and Biophysical Chemistry
Francis Gage Medical Institute
City, USA
Phone: 000-000-0000
email.address@email.edu

Sydney Cook, Ph.D.
Associate Professor
Department of Science
Prestigious University
City, USA
Phone: 000-000-000
email@email.com

Teaching Statement

My primary goal as an instructor is to create a classroom environment in which students from all backgrounds can achieve their potential and learn to think as scientists. To accomplish this goal, my teaching philosophy relies on the following principles:

(1) Teach all types of learners by using active learning strategies: This is the most important aspect that underlies my teaching philosophy. I believe the traditional lecture is an important component of any class I teach. However, I also believe lecturing must be combined with other methods of instruction, because not all students learn best from lectures. Critically, research shows that incorporating active learning improves learning outcomes for all students[1], and that it especially improves outcomes for women and underrepresented minorities[2]. To learn more about active learning and effective examples of how to use it in the classroom, I attended the Teaching preparation program (TPP) at PU, as well as the Coastal City Postdocs Workshop on Scientific Teaching at Firewalker University. Because of my training, I have learned a diverse array of methods to incorporate active learning in my classroom. For example, while learning glycolysis, I once handed students cards identifying them as a specific enzyme, substrate, or co-factor, and instructed them to move about the room, find their interacting partners, and line up in order to complete the full glycolytic pathway. From listening to students as they walked about and discussed what they were looking for, it was clear that they were engaged with the material. Students who were more comfortable with the material got the opportunity to teach their classmates, while other students were able to work through what they were unsure about. In student evaluations that semester, multiple students wrote that it stood out as one of the most memorable and effective discussion sections.

(2) Understand the diverse backgrounds students bring to the classroom: By using a combination of traditional lectures and active learning, my teaching style is designed to accommodate all types of learners. Beyond that, however, it is important to be aware of other ways I can ensure an inclusive classroom environment in which students from diverse backgrounds can excel. In my TPP training, I have learned about perceived stereotype threats, imposter syndrome, and how to be sensitive to these concerns and avoid situations that are hostile to student learning. Additionally, when discussing discoveries and experiments relevant to class topics, I will highlight examples of women and minority scientists so that students can see all groups as important contributors to science. By serving as a compassionate and empathetic instructor, I will create a welcoming learning environment for all my students.

(3) Teach students to think like scientists: I believe that at the outset of any course, an instructor must first decide what learning outcomes they want students to achieve by the end of the course. Furthermore, it is important to me that the chosen learning outcomes depend on higher-order cognitive skills, as opposed to rote memorization. For example, while a certain amount of memorization in a biochemistry course is unavoidable, such as knowing the names

and structures of the 20 standard amino acids, merely recalling the amino acids is a lower cognitive skill. An example of a higher order skill I would hope to elicit from my students would be to predict and explain which amino acids one would expect to see on the binding surface of a protein that interacts with the phosphate backbone of DNA. Particularly in upper division coursework, one of my learning outcomes would be the ability to read and explain primary scientific literature. For example, I would assign my students with presenting a figure from a paper to their peers in a discussion section. Only after I've decided on learning outcomes and how I will test student achievement of them can I proceed with the critical task of deciding what material to cover during class and how I will teach it.

(4) I take the same rigorous, evidence-based approach I use with my research and apply it to my teaching: Exams will be designed to assess whether students have achieved my learning outcomes. However, even in a class with several midterm exams in addition to a final, that creates only a handful of opportunities to receive quantitative information about how the class is performing. To better monitor student learning, I will use formative assessment, which is the use of formal and informal methods to gather data on how students are learning during a course, and modify the teaching strategy accordingly. One effective way to use formative assessment is by using clickers. I might ask my students a question at the beginning of class, and again at the end of class, to see if they learned what I wanted them to over the course of the lesson. If not, that suggests that my strategy for the day might need to be modified, or perhaps I need to spend more time covering a particular topic. I could also ask them the same question again in a future class meeting, to see how well the lessons are retained. In the event that clickers are not readily available, there are other alternative methods of formative assessment I would use, including short-ungraded exercises that students hand in at the end of class, or active learning methods such as think-pair-shares, which I assess by walking around the classroom and listening.

At State, I would be prepared to teach Introduction to Biological Chemistry, as well as introductory biology and advanced electives such as Molecular Biology and Advanced Cell Biology. Additionally, I would be excited to participate in State's tutorial course, given that close interaction with students is a major reason I am pursuing faculty positions exclusively at liberal arts colleges. By adhering to the above principles, I will teach my students to become critical thinkers trained in the scientific method. Such skills will serve my students well in their futures, because whether they become professional scientists or not, it is critical that all of them enter their careers as citizens educated in the sciences and the critical thinking they promote.

References:

1. Freeman, S. *et al.* Active learning increases student performance in science, engineering, and mathematics. *Proc. Natl. Acad. Sci. U. S. A.* **111,** 8410–5 (2014).
2. Snyder, J. J., Sloane, J. D., Dunk, R. D. P. & Wiles, J. R. Peer-Led Team Learning Helps Minority Students Succeed. *PLoS Biol.* **14,** 1–7 (2016).

Investigating the structure and function of calcium channels

How do calcium channels pass their substrates across a biological membrane? What hypotheses about an ion channel's transport mechanism can we make and test based on structural data? How does the structure of ABC relate to its transport activity? These are fundamental questions that undergraduates in my lab at State will address, using interdisciplinary approaches at the intersection of structural biology, biochemistry, and genetics. My lab will investigate a membrane protein ion channel named ABC, essential for calcide transport in plants. The projects proposed here are purposefully designed for participation by undergraduate researchers, and will teach them essential biochemistry methods as they learn to think as scientists and answer questions concerning ABC structure and function.

Summary of Proposed Research

Project 1: Determine whether oligomerization is necessary for transport by calcide transporters
ABC is a calcium protein transporter that transports calcide, an essential plant nutrient that is toxic in excess. My previous work in determining the crystal structure of ABC showed that it displays a dimeric architecture that is conserved among several protein families. It is unclear if its dimeric status is critical for function, or whether its dimeric architecture anchors two independently functional monomers. My lab will make obligate monomers, and then test them for function to determine whether dimerization is essential for activity.

Project 2: Identify and characterize the substrate pathway through ABC
I have developed a yeast genetic complementation assay for ABC function, which I have previously used to identify several residues that likely interact with calcide in the binding site. The transport model I proposed makes specific predictions about other regions of ABC that are likely to be important. My lab will test those predictions, and perform a thorough investigation that will identify other, possibly unexpected amino acids critical for transport activity.

Project 3: Determine why plant ABC cannot complement for yeast ABC
A curious result in the yeast complementation assay is that *S. cerevisiae* ABC, but not *A. thaliana* ABC, can rescue yeast growth when challenged with calic acid. *A. thaliana* possesses seven calcide transporters, named ABC through ABF, and they have not been examined in detail. I propose that the seven calcide transporters in *A. thaliana* function over a range of calcide concentrations. To test this hypothesis, my lab will assay each of them in the complementation assay, and also measure their binding affinities for their substrate. These experiments may help explain why plants have multiple calcium transporters, and how they function over a range of calcide concentrations.

Introduction

The most fundamental property of cells is that they have an inside and an outside. The barrier that delineates the inside from the outside is the plasma membrane, and it possesses limited permeability to most substances. Determining what crosses the membrane is critical for processes ranging from regulation of genes to removal of toxic substances. A diverse array of membrane proteins called transporters play key roles in controlling the passage of molecules through the membrane. The GHI group comprises 52 transporter families classified based on function and sequence homology[1]. The GHI family is termed the bicarbonate transporters, and includes the ion channel subclass. The archetypal GHI ion channel is DEF, the most abundant membrane protein in human red blood cells[2], which reversibly exchanges bicarbonate and chloride ions. In tissues, CO_2 diffuses into red blood cells and is

Chuck Norris - Research Statement

converted to bicarbonate, which is exported by DEF in exchange for chloride ions. In lungs, the partial pressure of CO_2 is lower and the process is reversed, thus driving cellular respiration. In addition to bicarbonate transporters, the GHI ion channels include calcide transporters, originally discovered in plants[3]. Calcium is an essential plant micronutrient that is taken up from the soil and participates in the formation of calcide esters that contribute to stability of plant cell walls[4,5]. In excess levels, however, calcide is toxic to plants. The transport and regulation of calcide levels is regulated partly by ABC, a calcide ion channel that loads xylem, such that calcide is transported from roots to shoots and leaves[3]. ABC is active in plants under limiting calcide conditions, but is degraded under high concentrations of calcide to avoid accumulation of toxic calcide levels in plant shoots[6]. The regulation of calcide by transporters is important for plant viability and has implications for worldwide agriculture. Our understanding of the mechanism of transport by GHI ion channels has been limited by a lack of structural data, for the GHI family in general and for ABC in particular. ABC shares 26% sequence identity with human DEF, and thus studies of ABC have significance for DEF and the entire GHI family. Recently, the first crystal structure of an GHI protein, human DEF, was reported in an outward-open state[7]. To better understand the structural transitions that control substrate translocation by GHI transporters, as a postdoc I determined the crystal structure of *A. thaliana* ABC in a state previously unobserved for its family (**Fig. 1A**)[8]. Like DEF, ABC is a dimer, with each monomer comprised of two domains, the Core and the Gate, and dimerization mediated by the Gate domains. Unlike DEF, however, ABC in an occluded configuration, in which the Core domains have rotated inward towards the Gate domains. Structural comparisons between the ABC and DEF structures helped define the conformational landscape utilized by GHI transporters in the course of a transport cycle (**Fig. 1B**); however, the structure of ABC created as many questions as it answered. To set up my independent research lab at a liberal arts college, I have used the ABC structure as the basis for designing projects that probe the calcide transport mechanism and are specifically designed to be successful in an undergraduate research setting.

Figure 1 here

Fig. 1 - Structure and mechanism of ABC. (*A*) Crystal structure of ABC dimer, with one monomer shown in gray. In the other monomer the Gate domain, responsible for dimerization, is shown in teal. The Core domain, responsible for transporting calcide, is shown in orange. (*B*) A cartoon schematic illustrating the proposed "elevator" transport mechanism. In the inward-open state, substrates (red stars) have access to the binding site in the Core domain. The Core domains vertically pivot through an occluded state to an outward-open state, at which point the substrate may leave the cell. The Gate domains (teal) remain rigid. Interpreting the structure of ABC, making predictions about its transport mechanism, and testing these predictions through biochemical and genetic assays will be the foundation of the experimental approach taken by undergraduates in my lab.

Project 1: Determine whether oligomerization is necessary for transport by calcide transporters

The structure of ABC revealed it to consist of a dimeric architecture found in DEF and related protein families. Each ABC monomer is composed of two domains, the Gate and the Core. The Gate domain is a rigid module that provides the dimerization interface between monomers. It is not known whether individual monomers are capable of transporting substrate by themselves, or whether the dimerization mediated by the Gate domain is necessary for activity. To determine the importance of dimerization for

function, students will design and establish obligate ABC monomers and test them for function in a yeast complementation assay. To design obligate monomers, we will analyze the structures of ABC and DEF and introduce point mutations designed to destabilize the dimerization interface. A strategy of mutating selected amino acids to the bulkiest amino acid, tryptophan, has been shown previously to disrupt dimers in the unrelated ClC transporter family[9]. We will adopt that strategy to design and perform site-directed mutagenesis to make tryptophan mutants in ABC. To test whether the point mutants behave as dimers or monomers, proteins will first be recombinantly expressed in *S. cerevisiae* and purified using established protein purification protocols. Oligomerization status will be determined using a chemical cross-linking assay. Incubation with glutaraldehyde cross-links dimers but not monomers, which can be detected on an SDS- PAGE gel. As a proof of principle, I have performed this experiment with three different calcide transporters, which shows that it is sensitive to detect whether the species is dimeric. To test whether obligate monomers are functional calcide transporters, we will use a simple yet informative yeast genetic complementation system to assay I developed as a postdoc[8]. Yeast samples containing a *abc* deletion are plated on media that contain calic acid, and only if they express a functional calcide transporter can they grow. We will test if the monomeric mutants we identify can complement the *abc* deletion. If yeast expressing the monomers can still grow on calcide this result suggests dimerization is not required for function. If the monomers do not complement then dimerization is likely required for function. Because it is not known whether dimerization is required for calcide transport function, either positive or negative results in this experiment will illuminate a previously unknown aspect of calcide transport in particular and GHI transporter mechanism in general.

Project 2: Identify and characterize the substrate pathway through ABC

I have used the yeast complementation assay described in Project 1 to identify amino acids in the purported cacide binding site that are critical for transport activity[8]. My lab will perform a more thorough investigation that will identify other, possibly unexpected amino acids critical for transport activity. I have proposed that ABC uses an elevator transport mechanism that has been observed for other, unrelated transporter families. One prediction of the elevator transport model is that only residues in the Core domain interact directly with substrate during transport. To test this hypothesis, students will mutate residues near the purported calcide binding site in the Core domain to further define the path that cacide takes during transport. Additionally, proximal residues in the Gate domain will be mutated to test whether they fail to disrupt transport as predicted. Students will interpret the crystal structure to design which mutants to test, and perform the cloning to make the mutants. Mutants that fail to complement will not immediately be concluded to be important for the transport mechanism; rather, those mutants will be overexpressed and purified under identical conditions as the wild-type protein and examined by size- exclusion chromatography. These experiments are important to show that the loss of complementation displayed by mutants is not due to defects in expression, folding, aggregation, or sorting to the plasma membrane. If a mutant meets that threshold, then we can conclude that it likely directly disrupts the transport mechanism.

Project 3: Determine why plant ABC cannot complement for yeast ABC

A curious result in the yeast complementation assay is that *S. cerevisiae* ABC, but not *A. thaliana* ABC, can rescue yeast growth when challenged with calic acid. *A. thaliana* possesses seven calcide transporters, named ABC through ABF, and the reason for the expansion of the protein family is not understood. I propose that the seven calcide transporters in *A. thaliana* function over a range of cacide concentrations. To test this hypothesis, my lab will assay each of them in the complementation assay, and also measure their binding affinities for calcide. These experiments may help explain why plants

have multiple calcide transporters, and how they function over a range of calcide concentrations. Measuring the binding affinity between calcide and each of the seven *A. thaliana* transporters poses challenges because the ligand is small (under 100 Daltons), and because there are no radioactive or fluorescently labeled analogs available. Thus, the best option is to use isothermal titration calorimetry (ITC). To perform ITC experiments, one possibility is to collacacide and use existing infrastructure at Prestigious University or University of Anywhere, where I know labs that have the necessary equipment. Another possibility I would be excited about is to apply for a grant to bring ITC to State. In addition to aiding my lab's research, I think an ITC apparatus would be useful to other labs at State. Additionally, my lab will assay each of the seven *A. thaliana* calcide transporters in the yeast complementation assay described in Projects 1 and 2. My hypothesis is that ABC has the tightest binding affinity, because its function is to load calcide into xylem under limiting conditions, while other calcide transporters will have weaker affinities, as I predict their function is to operate at higher, toxic calcide concentrations and export calcide out of the organism to alleviate its toxicity. Because the plating assay requires a relatively high concentration of 20mM calic acid to be toxic to yeast, I predict that the calcide transporters with weaker affinities, which consequently operate at higher calcide concentrations, will complement and rescue growth.

Undergraduate Research Considerations

The projects proposed here are well-suited for an undergraduate research environment for several reasons. The necessary equipment is minimal, and what is not present in-house will be available through new and existing collaborations. I will fund my research by applying for external awards, such as the NIH AREA R15 Program award. I have previously demonstrated success in securing external funding. Through working in my lab, students will master a host of experimental biochemical techniques. I have specifically designed research projects that draw on skills that are accessible at the undergraduate level, and I have successfully trained students under my guidance in several of these techniques. The students I mentor will gain experience developing their own research plan, generating hypotheses, evaluating data, and preparing posters, talks, and papers. My proposed research will complement existing research at State and offer exciting projects for undergraduates to perform research in biochemistry.

References

1. *Mol. Aspects Med.* (2014).
2. *Biochemistry* (1972).
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4. *Plant Physiol.* (1997).
5. *Science* (2002).
6. *Proc. Natl. Acad. Sci. U. S. A.* (2006).
7. *Science* (2016).
8. *Proc. Natl. Acad. Sci. U. S. A.* (2017).
9. *Nature* (2011).