PRIMER
National Science Foundation
Graduate Research Fellowship Program (GRFP)

Preface

Ostensibly, this primer is about how to produce a benchmark application for the National Science Foundation (NSF) Graduate Research Fellowship Program (GRFP). At its core, however, it's a proxy for clicking-in around the foundational pillars of **Initiative**, **Leadership**, **Impact**, and **Scholarship**, and using these 4 pillars to benchmark any fellowship, scholarship, research proposal, or graduate school application.

The primer will help you put on the lens of the reviewer. Without this lens, without understanding how reviewers will evaluate you, you're writing blindly and scribbling wildly in the dark. Reviewers are guided by specific review criteria. Take time to thoroughly understand the very first page of the primer, which presents the GRFP goals, the Merit Review Criteria of Intellectual Merit and Broader Impacts, and the six Merit Review Criteria Elements. This is what guides the reviewers in evaluating your application. Use this to guide you too!

You'll develop two statements (a 3-page Personal, Relevant Background, and Future Goals statement; and a 2-page Graduate Research Plan) as the core of your application. Using the 4 pillars of Initiative, Leadership, Impact, and Scholarship you'll create narratives that respond to the Goals of the GRFP and its six Merit Review Criteria Elements at a benchmark level—at a level by which all other applications are compared to.

Knock-your-socks-off letters of reference can often tip the scale. The primer will provide you with insights on how to orchestrate your three reference letters so they not only address the GRFP criteria, but they do so in ways that personalizes, corroborates, and benchmarks your unique qualities, your fit for the Graduate Research Fellowship, and your future potential as a scholar and leader in advancing knowledge and benefitting society.

Prewriting is essential for quality writing and gives you a mental jump start. Before you begin writing, the primer will take you through a recasting of your CV and through some prewriting exercises to get you warmed up, to get you to map out your narrative, and to get you to storyboard the structure, flow, and messaging of your statements.

A big chunk of the primer is dedicated to writing samples from three 2020 GRFP applicants. Early drafts show how we all grapple to get our ideas onto the page, and the final statements illustrate clicking-in using the pillars of Initiative, Leadership, Impact, and Scholarship. These writing samples are illustrative, not prescriptive, and are intended to provide grist for your writing mill as you develop your unique narratives.

NSF's $138k Graduate Research Fellowship is an investment in <u>you</u> and in your potential to soar! It's flexible (i.e. it provides three years of support that you can use within five years of your graduate study; you can change the scope of your proposed research plan and adjust your broader impacts initiatives; and you can choose a different graduate advisor and graduate program), portable (i.e. you can use it at any accredited US institution of higher education), and unrestricted (i.e. there is no service requirement after completion).

The primer is packed with information to help you put together a competitive and benchmark GRFP application. It will also give you a solid foundation on how to use the 4 pillars of Initiative, Leadership, Impact, and Scholarship to click-in to other high stakes opportunities, which your life as a graduate student and scholar will be centered around. The time you invest now will pay off in dividends during your illustrious career!

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GRFP Goals, Merit Review Criteria, and Merit Review Criteria Elements

The National Science Foundation Graduate Research Fellowship Program (GRFP) is a $138k **investment in you and your potential for grand achievements as a scholar and leader in your field and beyond!**

The GRFP has **two goals:**

1. Select scholars early in their careers who have significant potential to advance scientific knowledge (*Intellectual Merit*).
2. Select scholars who have significant potential to benefit society, particularly in broadening participation of underrepresented groups in STEM fields (*Broader Impacts*).

NSF Merit Review Criteria

Two overarching NSF **Merit Review Criteria** frame the scope of the GRFP:

- **Intellectual Merit:** *The potential to advance knowledge.*
- **Broader Impacts:** *The potential to benefit society and contribute to the achievement of specific, desired societal outcome.*

These Intellectual Merit (IM) and Broader Impacts (BI) Merit Review Criteria frame the scope of the fellowship and the Merit Review Criteria Elements below form the specific criteria that guide the GRFP reviewers in their applicant evaluations. They should guide you too! ***Burn these Merit Review Criteria Elements into your thinking and your narrative:***

NSF Merit Review Criteria Elements

Six Merit Review Criteria Elements guide the GRFP Reviewers:

1. What is the potential for the proposed activity to **Advance Knowledge** and understanding within its own field or across different fields (Intellectual Merit)?
2. What is the potential for the proposed activity to **Benefit Society** or advance desired societal outcomes (Broader Impacts)?

Note: Review Criteria 3-6 ***apply equally*** *to Intellectual Merit and to Broader Impacts*

3. To what extent do the proposed activities **suggest and explore creative, original, or potentially transformative concepts?**
4. Is the plan for carrying out the proposed **activities well-reasoned, well-organized, and based on a sound rationale**? Does the plan incorporate a **mechanism to assess success**?
5. **How well qualified** is the individual, team, or organization to conduct the proposed activities?
6. Are there **adequate resources** available (either at the home organization or through collaborations) to carry out the proposed activities?

Note: *Broader Impacts outcomes may include, but are not limited to: increasing participation of underrepresented groups, women, students with disabilities, and veterans in STEM; mentoring; improving STEM education and educator development at any level; community outreach and service; increasing public scientific literacy and public engagement with STEM; potential to impact a diverse, globally competitive STEM workforce; increasing partnerships between academia, agencies, industry, and others; and enhancing infrastructure for research and education.*

GRFP Website and Purpose of this Primer

Explore the GRFP website for a rundown of the GRFP. At the top of the home page click on the Applicants, Reference Writers, and Resources tabs and drill down into each category to get an understanding of the background, benefits, and requirements of the GRFP. Also, carefully review the GRFP Program Solicitation, which provides specific application guidelines. The purpose of this primer is not to repeat that information, but to offer you insights on how to put on the reviewer's lens, how to use the GRFP Merit Review Criteria Elements as your guide, and how to click-in using the pillars of Initiative, Leadership, Impact, and Scholarship to produce a benchmark application.

GRFP Application Sections

The GRFP reviewers evaluate each application holistically – considering individual interests, initiative, leadership, impact, scholarship, and future plans. Five main sections guide the reviewers:

1. Education and Work Experience
2. Personal, Relevant Background, and Future Goals Statement
3. Graduate Research Plan Statement
4. Three Reference Letters
5. Academic Transcripts

Download the GRFP application screenshots to grasp how each section is framed and how the application is structured.

Education and Work Experience

Look at this section as the CV (see Appendix A—Crafting Your CV) part of your application and use it to summarize your distinction in Intellectual Merit and Broader Impacts. This is the first major section that reviewers see and they use it to get a sense of the caliber of the applicant.

Populate this section with your 1) educational history; 2) relevant teaching, research, work, and leadership experiences; and 3) honors and awards, fellowships and scholarships, and publications and presentations. List them in reverse chronological order – most recent first – and put careful thought into your titles and formatting.

1. In the **"Educational History"** field list the colleges/universities you've attended, and the dates, degrees, fields of study, and cumulative GPAs in the provided format.

2. In the **"Teaching and Work Experience"** field be sure to also **include Research and Leadership experiences**. Reviewers will pay particular attention to the "Titles" of your experiences so take time crafting them. Here are some examples of what to include:

- Research Experiences (academic year and summer research experiences)
- Laboratory Assistantships
- Teaching Assistantships
- Curriculum Development Positions
- Relevant Work Experiences
- Tutoring Positions
- Mentoring Positions
- Outreach Positions
- Officer in student clubs, STEM professional organizations, etc.
- Volunteer Positions
- Field Courses

3. The **"Academic Honors, Fellowships, Scholarships, Publications, and Presentations"** field does not allow for easy formatting (e.g. you can't underline, bold, italicize, etc.). Think carefully about how to format this field so it still has *oomph*. Here's a suggested format:

- Honors and Awards (include the year of the honor or award)
- Fellowships and Scholarships (include the year of the fellowship or scholarship)
- Publications (use a full citation format and include publications that are in preparation or in review)
- Oral Presentations (use a full citation format and include any upcoming oral presentations)
- Poster Presentations (use a full citation format and include any upcoming poster presentations)

Below is an example of an undergraduate student's Education and Work Experience section and Proposed Field of Study section. Pay particular attention to titles, content, and formatting in the Education and Work Experience section and carefully choose your Proposed Field of Study.

NSF Graduate Research Fellowship Program

Program Year 2020

EDUCATION AND WORK EXPERIENCE

List academic institutions attended and your enrollment details.

Academic Institution	Location	Start Date	End Date	Degree Granting Program	Degree	Degree Cmpl.	Grad. Date	Field of Study	Cum. GPA	GPA Basis
University of California-Santa Cruz	SANTA CRUZ, CA, United States	09/2015	06/2020	Yes	BS	No, still enrolled in program		Geosciences - Marine Biology	3.30	4.0
University of California-Santa Cruz	SANTA CRUZ, CA, United States	09/2015	06/2020	Yes	BA	No, still enrolled in program		Computational Science and Engineering	3.30	4.0

List teaching and work experiences relevant to your field of study since you began undergraduate studies. Experiences do not have to be limited to the academic realm.

Title	Institution/Organization	Start Date	Other Experience Ongoing	End Date
Secretary	Women in Science Society, University of California, Santa Cruz	09/2019	Yes	
Undergraduate Researcher	University of California, Santa Barbara	06/2019	No	08/2019
Founder & President	Marine Science Club, University of California, Santa Cruz	04/2019	Yes	
Research Consultant & Collaborator	Ocean of Influence, University of California, Irvine	04/2019	No	06/2019
K-12 Curriculum Designer	Seymour Marine Discovery Center	09/2018	Yes	
Undergraduate Researcher	University of California, Santa Cruz	09/2017	Yes	
Exhibit Docent	Seymour Marine Discovery Center	09/2017	No	09/2018
Co-advisor	Project AWESOmE, University of California, Santa Cruz	09/2016	No	01/2017

List any significant academic honors, fellowships, scholarships, publications and presentations.

ACADEMIC HONORS:
Dean's List (2016)

FELLOWSHIPS AND SCHOLARSHIPS:
Student Research and Education Award (2018)
Koret Scholar (2018)
STEM Diversity IMSD Scholar (2018)
Women Diver Hall of Fame: Ella Jean Morgan Memorial Dive Training Grant (2018)

PUBLICATIONS:
Jarman CN, Smith JG, Carr MH. Dietary Preference of Meso-Predators in the Wake of an Herbivore Outbreak. Marine Ecology Progress Series. June 2020. (in prep)

Smith JG, Dealmonte J, Jarman CN, and Bott O. UrchinPy: A automated machine-learning sea urchin diet classification program. Marine Technology Society Journal. June 2020. (in prep)

ORAL PRESENTATIONS:
Jarman CN, Smith JG, Carr MH. Dietary Preference of Meso-Predators in the Wake of an Herbivore Outbreak. Western Society of Naturalists. Nov. 2019.

POSTER PRESENTATIONS:
Jarman CN, Smith JG, Carr MH. Dietary Preference of Meso-Predators in the Wake of an Herbivore Outbreak. Koret Foundation Research Symposium. University of California, Santa Cruz. June 2019.

Jarman CN, Smith JG, Carr MH. A visual approach to sea urchin diet characterization Western Society of Naturalists. Tacoma, WA. Nov. 2018.

Jarman CN, Smith JG, Carr MH. A visual approach to sea urchin diet characterization. Western Society of Naturalists. Tacoma, WA. Nov. 2018.

Jarman CN, Smith JG, Carr MH. A quantitative approach to urchin gut content analysis. STEM Diversity Summer Research Symposium. Santa Cruz, CA. Aug. 2018.

Jarman CN, Smith JG, Carr MH. Visualizing kelp forest species interactions. Broadening Participation in Visualization. Indianapolis, Indiana. June 2018.

PROPOSED FIELD OF STUDY

Field of Study: Geosciences - Marine Biology

Is your proposed graduate study interdisciplinary? No

Note: *Give careful consideration to the "Proposed Field of Study" and "Sub-Field" you choose, as they determine the expertise of your reviewers and the composition of your review panel. For example, since the applicant will be pursuing a Ph.D. degree in marine science she chose "Geosciences" as her Field of Study and "Marine Biology" as her Sub-Field.*

GRFP Statements

The GRFP application requires two statements that form the guts of your application: 1) ***Personal, Relevant Background, and Future Goals***; and 2) ***Graduate Research Plan***.

Format these statements on standard 8.5' x 11" page size and use no smaller than 11-point Times New Roman font for all text (including references), Cambria Math font for equations, Symbol font for non-alphabetic characters, single-line spacing, one-inch margins on all sides, and no headers, footers, or page numbers.

Personal, Relevant Background, and Future Goals Statement

Statement prompt: *Please outline your educational and professional development plans and career goals. How do you envision graduate school preparing you for a career that allows you to contribute to expanding scientific understanding as well as broadly benefit society? Page limit: 3 pages*

NSF's explanation of the statement prompt: *Describe your personal, educational and/or professional experiences that motivate your decision to pursue advanced study in science, technology, engineering, or mathematics (STEM). Include specific examples of any research and/or professional activities in which you have participated. Present a concise description of the activities, highlight the results and discuss how these activities have prepared you to seek a graduate degree. Specify your role in the activity including the extent to which you worked independently and/or as part of a team. Describe the contributions of your activity to advancing knowledge in STEM fields as well as the potential for broader societal impacts.*

NSF Fellows are expected to become globally engaged knowledge experts and leaders who can contribute significantly to research, education, and innovations in science and engineering. The purpose of this statement is to demonstrate your potential to satisfy this requirement. Your ideas and examples do not have to be confined necessarily to the discipline that you have chosen to pursue.

Overview on Crafting the Personal, Relevant Background, and Future Goals Statement

Look at how the two underlined sentences in the above prompt emphasize a "future tense." Keep this "future tense" in the forefront as you construct your narrative. Remember that NSF is investing in you and your future potential to significantly advance knowledge and to benefit society.

Organize your Personal, Relevant Background, and Future Goals statement into these four main sections: 1) Personal Statement, 2) Intellectual Merit (Relevant Background, 3) Broader Impacts (Relevant Background), and 4) Future Goals and Action Plan. NSF requires you to use headers to distinguish your different sections to enable reviewers to navigate the statement.

Craft an opening "Personal" section that portrays a past, present, and future image of you that's worth investing in. Create a visual lens of who you are for the reviewer.

Then construct "Relevant Background" sections in Intellectual Merit (IM) and Broader Impacts (BI) that establish your merit around these 4 benchmark pillars:

- **Initiative** (e.g. creative, original, innovative, risk-taking, thinking outside of the box, etc.),
- **Leadership** (e.g. translate vision into reality, inspire and influence the practice of others, leave something that lives beyond you, produce more leaders, etc.),
- **Impact** (e.g. scope and magnitude of significance, far-reaching, lasting, transformative, etc.)
- **Scholarship** (e.g. publications, oral presentations, poster presentations, performances, exhibits, workshops, panels, etc.)

Use your Intellectual Merit and Broader Impacts experiences as exemplars of the 4 pillars of Initiative, Leadership, Impact, and Scholarship. These are the qualities reviewers are looking for. These are the qualities that give reviewers assurances that going forward, no matter what initiatives you engage in, you'll make *"significant contributions*" in IM and BI.

Culminate in a Future Goals and Action Plan section that is visionary and purposeful in IM and BI, and that is ambitious and achievable. Use the 4 pillars to create a memorable vision of your future that meets the GRFP's expectation of becoming ***"a globally engaged knowledge expert and leader who can contribute significantly to research, education, and innovations in science and engineering, and to advancing broader societal impacts."*** It's this vision that NSF is investing in.

Organizing Your Personal, Relevant Background, and Future Goals Statement

1. **Opening Personal Statement Paragraphs** – (~1/2 page) *(note: a header is not required but you could create one)*
   - Develop an opening paragraph that **captures the reviewers' attention and that conveys an image of you**. Give some personal background (e.g. first to attend college, underrepresented, Community College transfer, overcame hardships, other relevant background), and shed light on the experiences (e.g. personal, educational, research, professional, leadership) that have inspired and prepared you for your graduate and career pathway.
   - Develop a second short paragraph that has a **future tense** to it and that includes why you chose your (proposed) graduate program and potential career path. Include ongoing commitments to Intellectual Merit and to becoming a leader in Broader Impacts initiatives.
   - Think of the opening two paragraphs as a 'story within a story' that **creates a personal lens for the reviewers.** Present an exciting **visual image** of you and your future contributions to science and society. Make the reader want to read on because they have a vibrant picture of you and who you want to become. Remember that the **GRFP funds you – the researcher and leader – so let your passion and personality show!**

2. Header: **Intellectual Merit (Relevant Background)** – (~3/4 page) *(note: feel free to develop a more creative header but make sure that this section focuses on IM, Relevant Background)*
   - Use this section to develop a **theme of your Intellectual Merit that describes your scholarly development, provides evidence of your achievements and scholarship, and that logically leads to your Future Goals section.**
     - Present your **Intellectual Merit evolution** and describe how your various experiences have given you the insights, skills, and drive to complete a graduate program and make significant contributions to advancing scientific knowledge.
   - **Emphasize elements of your Initiative, Leadership, Impact, and Scholarship in each of your paragraphs.**
     - Discuss how your **achievements demonstrate Initiative and Leadership, and how they explore creative, original, or potentially transformative concepts.**
     - Discuss the **Impact** of your research and its significance.
     - Provide **evidence of your Scholarship** (e.g. peer-reviewed publications, oral presentations, poster presentations, honors and awards) and cite your publications.
     - **Be sure to include upcoming conference presentations and publications in preparation or review** (ask at least one reference writer to corroborate this).

3. Header: **Broader Impacts (Relevant Background)** – (~3/4 page) (*note: feel free develop a more creative header but make sure that this section focuses on BI, Relevant Background*)

- Use this section to present your Broader Impacts (BI) achievements. **Focus on Initiative, Leadership, Impact, and Scholarship rather than activities.** For example, instead of stating that you tutored or mentored students, TA'd a course, or participated in educational outreach, frame your discussion around initiative, leadership, impacts, and products such as developing tutoring or mentoring materials, revising/developing course curriculum or lab modules, or improving STEM K-12 outreach materials. If you've worked with agencies or community organizations discuss the lasting impact your contributions have made (e.g. developing outreach materials, sharing data with other agencies, implementing organizational improvements, etc.). If you've had leadership positions with campus or community organizations describe how your contributions helped the programs become more successful than they were before and how you've contributed to the longevity of the organizations.
- Connect your BI achievements to a **theme of what motivates you** to engage in these BI endeavors. What is it that inspires you to keep giving back to the research community, students, and the public, and what is it that will propel you to continue along this pathway?
- Include upcoming BI initiatives (e.g. curriculum development, improving tutoring or mentoring materials, outreach, workshops, etc.), conference presentations, or planned publications. **Reviewers want to know about the BI initiatives you'll complete before starting your fellowship the following fall.** Don't leave this crucial segment out and have at least one reference writer corroborate and support these BI initiatives.
- For a concise overview of the principles and expectations of Broader Impacts review the *BI Guiding Principles* published by the National Alliance for Broader Impacts.

4. Header: **Future Goals and Action Plan** – (~3/4 – 1 page) (*note: feel free to develop a more creative header that fits the theme(s) of your statement*)
   - This ***going forward* plan is critical** –the GRFP is investing in your future so don't short-shrift this section. Include your graduate school, postdoctoral, and career plans and back them up with concrete IM and BI action plan initiatives. **This section is the proposal part of your statement; this is what NSF is investing in; make it memorable and impactful!**
   - Begin this section by presenting a **statement of why** your (proposed) graduate program and faculty advisor are good fits for you and your proposed plan of research.
     - Explain how the graduate program, advisor, and potential collaborators have the appropriate **qualifications**.
     - Identify the **resources** (e.g. computing, laboratory, equipment, ship time, field resources, etc.) available for you to complete your proposed research.
     - Describe the **skills you'll develop** to complete your research and analyses.
       - e.g. modeling skills, analytical skills, laboratory skills, field skills, etc.
   - Take a look at the GRFP Fellow programs (**GRIP and GROW**) that **are available only to GRFP recipients** and, if appropriate, include one in your graduate plan. Don't fall into the trap of just saying that you'll participate in these programs, rather give sound and purposeful reasons. Don't include them if they don't fit your narrative.
     - The Graduate Research Internship Program (**GRIP**) expands opportunities for Graduate Research Fellows to enhance their professional development by working with partner agencies (e.g. NOAA, US Dept. of Agriculture, US Geological Survey, Smithsonian, Environmental Protection Agency, Office of Naval Research, and others). Participating in GRIP would be particularly beneficial if you have a future goal of working with a federal agency.

    - The Graduate Research Opportunities Worldwide (**GROW**) program provides Graduate Research Fellows with an international travel allowance to engage in research collaborations with investigators in partner countries. Consider including **GROW** if your research might have an international element.
- Present a solid and compelling **Broader Impacts Plan** that you'll lead while in graduate school. **Scout out BI programs** on the websites of your (proposed) graduate school, graduate program, and graduate advisor. Check out university programs that support STEM diversity and inclusion such as the McNair Scholars Program, the Louis Stokes Alliances for Minority Participation Program, the Millennium Scholars Program, and Educational Opportunity Programs; programs that work with community colleges; K-12 STEM education outreach programs; Undergraduate Research Centers; etc. And review the websites of your (proposed) graduate program and faculty advisor to see what BI initiatives they are engaged in.
- After completing this scan, and after considering the GRFP societal goal to *"broaden participation in STEM,"* **strategically consider the BI initiatives you will focus on in graduate school that demonstrate initiative and leadership, and that will have significant and lasting impacts.** Present a Broader Impacts action plan that is concrete, well supported, ambitious, and achievable.
- The Broader Impacts comments from this GRFP reviewer of an undergraduate applicant highlight the importance of well thought-out initiatives that demonstrate leadership and impact:
    - *"The applicant already has a **strong record of leadership**, for example by serving as president in the Society for Advancement of Chicanos and Native Americans in Science, and as an ambassador with the Undergraduate Research Opportunities Center. The applicant has additional **well thought-out and concrete broader impact plans** to lead a mentoring program through the MARC and LSAMP programs, and to develop citizen science curriculum as she progresses through her doctoral research. In addition, **references are highly supportive of her proposed broader impact initiatives**, and show that the **foundations are in place for the applicant to succeed and have significant impact.**"*
- Check if your (prospective) graduate school has opportunities for training in professional development, Preparing Future Faculty, leadership, and diversity and inclusion that you can link into your statement. For example, UC Santa Cruz provides graduate students with a cluster of these opportunities through the Institute for Scientist & Engineer Educators' Professional Development Program, the Center for Innovations in Teaching and Learning, a Graduate Student Leadership Certificate, and a Diversity and Inclusion Certificate. **Carefully investigate development and training opportunities at your (proposed) graduate institution and weave a development plan into your statement.** Demonstrate to the reviewers that you'll get trained and calibrated to conduct BI initiatives at a benchmark level. Give the reviewers confidence that no matter what you choose to do, you'll do it with impact.
- Consider discussing how, as a graduate Teaching Assistant, you plan to use your experiences in these development and training programs to craft inclusive teaching practices to meet the needs of diverse student learners. **Reviewers will appreciate concrete plans you present to develop and practice your pedagogy of teaching and learning to meet a GRFP goal of broadening participation in STEM fields.**
- **Discuss the appropriateness of a postdoctoral trajectory with your faculty advisor and check out the National Postdoctoral Association** and their online publications and resources. If appropriate, include a short statement about pursuing a postdoctoral position

after your doctoral degree, and how the research and professional development you'll receive as a postdoc will prepare you for your career goal.

- **Present a vision of your career goal** (e.g. university professor, government agency, non-profit sector, private sector, etc.) and, based on themes you developed in your statement, **weave in proposed plans for Intellectual Merit and Broader Impacts initiatives**. For example:
    - If you plan to be a university professor give the reviewer a glimpse of what that might look like.
        - Weave in themes from your statement into a vision of teaching, research, inclusion, and Broader Impacts service as a faculty member.
    - If you plan to work in a government agency, the non-profit sector, or the private sector give a glimpse of what that might look like.
        - Describe what you envision your role might be (e.g. researcher, entrepreneur, science/policy advisor, etc.) and the impacts you'd like to make.
- Create a **memorable closing** that wraps up your statement and that re-affirms your passion and vision of how your trajectory will prepare you for a ***"career that allows you to contribute to expanding scientific understanding as well as broadly benefit society."***

Graduate Research Plan Statement

Graduate Research Plan Prompt: *Present an original research topic that you would like to pursue in graduate school. Describe the research idea, your general approach, as well as any unique resources that may be needed for accomplishing the research goal (e.g., access to national facilities or collections, collaborations, overseas work, etc.). Include important literature citations. Address the potential of the research to advance knowledge and understanding within science as well as the potential for broader impacts on society. The research discussed must be in a field listed in the Solicitation. Page limit: 2 pages*

Overview On Crafting the Graduate Research Plan

Reviewers are expecting a well-thought out and well-supported research plan that meets all of the Merit Review Criteria Elements and that addresses ***"the potential of the research to advance knowledge and understanding within science as well as the potential for broader impacts on society."*** You're asked to pack a lot into 2 pages! You can do it!!

If you're not currently in the lab where you'll conduct your proposed research (e.g. undergraduate applicant, Master's student moving on to a Ph.D. program) there are a number of strategies you can use to find mentors to help you develop your proposed Graduate Research Plan. See Appendix B for advice on these strategies and for an example of how to contact a prospective graduate school advisor to ask for mentoring support.

Organizing Your Graduate Research Plan

Put careful thought into formatting your research plan and how you'll proportionate your sections. Below is a Graduate Research Plan format oriented toward Life and Physical Science fields. Other fields may have different format norms. Regardless, all formats need to meet the six Merit Review Criteria Elements and IM and BI must be addressed individually under separate headings.

Research Title:

- Develop a clear, informative, scientifically valid, and memorable title that concisely describes the core of your research plan.

- Your reviewers will not necessarily be experts in your field so don't use too much jargon.

Background/Problem Statement:

- What's the problem or big question and why should we care?
  - Describe its importance to science and society.
  - Cite key studies that have addressed the question (see citation guidelines in the next section).
  - If this is an expansion of your prior research include what you've accomplished so far.
- What critical basic science gap(s) must be filled to move the field forward?
- What do you generally plan to do to address the gap(s)?
  - Provide a clear context that sets the stage for the aim/approach.

Aim/Approach:

- To set up your research question present a well-defined, non-technical, and memorable soundbite of the aim/approach of your research plan and how it will fill this pressing gap.

Research Question:

- State the key research question(s) you must answer to meet your aim.
  - Indicate how your research question moves the field forward.
  - This sets up your study system and hypotheses.

Study System or Organism(s) (if appropriate):

- Explain the study system or organism(s) you will use to address the question and why it's a "*model*" or the "*most appropriate*" system to use.
  - What is the advantage of this system over others?
- Reiterate your qualifications and the qualifications of your (proposed) advisor and collaborators, and that the needed resources (e.g. study sites, lab equipment, field equipment, computer facilities, etc.) are available to carry out your proposed activities.
  - ***Note:*** *If you don't have a study system section be sure to put qualifications and resources in another part of the text as they hit two Merit Review Criteria Elements*.

Hypotheses:

- Your hypothesis/hypotheses must be testable, and must clearly and concisely state the expected relationship between variables.

Methods: *(for each hypothesis include a separate methods and analysis section)*

- Your Methods section describes how you will test your hypotheses.
- Start with a very brief description of the overall methodological approach.
- Conceptualize your research plan as a 3-year project.
  - Describe what you will you do in Year 1, 2, and 3, and how your hypotheses and activities build on one another.
  - If appropriate, discuss specific collaborations you'll foster to hone your skills and accomplish your research.
- Describe the major steps you'll take to collect the data you need to test your hypotheses.
  - It's critical to link your methods to your research question(s) and hypotheses.
  - Think about your hypotheses building logically and chronologically (e.g. hypothesis 1 the first year, hypothesis 2 the second year, etc.).
  - It's ok to include more jargon in the Methods section to demonstrate expertise.
- Highlight creative, original, and innovative parts of your approach and why they are most appropriate.

- Discuss how you will assess success and how you might deal with difficulties that you might encounter.
- Include a figure or diagram if it can elucidate your proposed plan of research.
    - Remember that space is limited – if you use a figure make sure it's clear, concise, and impactful.

Analyses:
- Describe how you will analyze your data to test your hypotheses.
    - What statistical tests, or other tests, will you use to test your hypotheses?
- Will you develop or enhance a model, or develop other useful tools that can be used by others?
    - If you need to develop these analytical skills present the training you'll receive and the collaborations you'll seek to hone these skills.

Intellectual Merit:

Reviewers will pay particular attention to this IM summary section so carefully consider the following questions in creating strong soundbites that hit on the originality, significance, impact, and potentially transformative nature of your proposed research:
- How does your proposed research suggest and explore creative, original, or potentially transformative concepts?
- How does your proposed research advance knowledge and understanding within the field and across fields?
- What are the benefits and impacts of your proposed research within the field and across fields?
- How will you foster collaborations?
- How will you actively publish and present your scholarly findings within and across disciplines?

Broader Impacts:

Reviewers will also give this BI section close scrutiny. Consider the following questions in creating strong BI soundbites that hit on the societal impacts of your research and on the specific BI initiatives that you'll engage in:
- What are the benefits/impacts/applications of your proposed research to society?
    - Provide specific and realistic examples of this linkage (e.g. provide predictive models for resource management practices, provide insights on how diseases are regulated, improve ecosystem health through soil and pest management, provide insights on coral acclimation processes, develop microbial metrics for measuring reclamation success, etc.)
- What BI initiatives will you lead as a graduate student?
    - Keep this GRFP goal in mind: *"To broaden participation in science and engineering of underrepresented groups, including women, minorities, persons with disabilities, and veterans."*
    - Be specific and show initiative, leadership, and lasting impact.
    - Make sure that what you propose is reasonable for a graduate student and doable with the resources available to you.
        - Consider plugging into existing programs and describe your role.
    - Think about how you might collaborate with the university's assessment center to measure the effectiveness and impact of your BI initiative(s).
        - Assessment enables you to publish and present at conferences, which elevates impact.

In-Text Superscript Citations and References Format

In-text citations and the References section can take up gobs of space and the GRFP understands this. It's acceptable to **use superscript numbering for in-text citations** and to **include an abbreviated References section.** Remember that 11-point font is the smallest font you can use for your narrative **and** for your References section. Below are in-text superscript numbering citation and Reference section guidelines.

In-text superscript numbering format (adapted from the Council of Science Editors):

- Place the superscript next to the fact, concept, or quotation being cited.
- Use consecutive superscript numbers to cite material.
- If citing more than one reference at the same point, separate the numbers with commas and no spaces between (e.g. *Ecologists often use estimates of species interaction strengths to create network models that describe how changes in a species density alter the abundance of other community members*[1,2].)
- Place the superscript inside periods and commas (e.g. *Disruption of normal gene splicing patterns can cause or modify human disease[1], and these errors may lead to tissue-specific diseases or developmental defects*[2,3].*), and inside colons and semi-colons (e.g. Some coral species are sensitive to small changes in temperature and pH* [8]*; other species tolerant a broader range of shifts in temperature and pH* [9]*.),*
- When more than two references are cited at a given place in the manuscript, use hyphens to join the first and last numbers of a closed series; use commas without space to separate other parts of a multiple citation (*e.g. Our understanding of processes that structure ecological communities, and resulting management efforts, are dependent on accurate estimates of species interaction strengths*[1-5,9]*.)*
- If a reference is cited multiple times, use the original number throughout.

References Format:

Put a References section at the end of your text, and use 10-point font and an abbreviated format. Both format examples below are acceptable. The first example is a more complete reference format that includes volume number and page numbers. If space is tight the second example is a more abbreviated format and is still acceptable. Remember to **be consistent** in your formatting.

Example 1:

References: [1]Sunday JM et al. 2014. *PNAS* **111**:5610–5615. [2]Gilman, SE et al. 2010 Trends Ecol. Evol., **25**:325-331. [3]Huey RB et al. 2009. *Proc. R. Soc.* **276**:55-66. [4]Kroeker KJ et al. 2013. *Global Change Biol.* **19**:1884–1896. [5]Gunderson AR et al. 2015. *Annu. Rev. Mar. Sci.* **8**:12-22. [6]Stillman JH & Somero GN. 2000. *Physiol. Biochem. Zool*. **73**:200-208. [7]Jensen GC & Armstrong DA. 1991. *Mar. Ecol. Prog. Ser.**73:47-60.* [8]Stillman JH & Tagmount A. 2009. *Mol. Ecol.* 18:420-431. [9]Donahue MJ. 2004. *Mar. Ecol. Prog. Ser.* **267**:219-231. [10]Paganini AW et al. 2014. *J. Exp. Biol.* **217**:3974-3980

Example 2:

References: [1]Sunday JM et al. 2014. PNAS. [2]Gilman, SE et al. 2010 *Trends Ecol. Evol*. [3]Huey RB et al. 2009. *Proc. R. Soc. B.* [4]Kroeker KJ et al. 2013. *Global Change Biol*. [5]Gunderson AR et al. 2015. *Annu. Rev. Mar. Sci.* [6]Stillman JH & Somero GN. 2000. *Physiol. Biochem. Zool*. [7]Jensen GC & Armstrong DA. 1991. *Mar. Ecol. Prog. Ser.* [8]Stillman JH & Tagmount A. 2009. *Mol. Ecol***.** [9]Donahue MJ. 2004. *Mar. Ecol. Prog. Ser.* [10]Paganini AW et al. 2014. *J. Exp. Biol.*

Reference Letters

***Knock-your-socks-off* reference letters can tip the scale.** Your reference letters should personalize, corroborate, amplify, and benchmark your IM and BI achievements, your unique qualities, your future potential as a scholar and leader in serving science and society, and your fit for the Graduate Research Fellowship.

Reference letters have a two page limit and require 12-point Times New Roman font in the body of the letter. The letter should be on institutional or professional letterhead, include the name and title of the reference writer, and the name of the department and institution or organization. Two reference letters are the minimum required for an application to be reviewed. You can request up to five letters and you are asked to rank the letters. If more than three letters are received, only the top three will be considered for the application. **Make sure to get three *knock-your-socks-off* letters!**

Carefully orchestrate your letters so each letter complements the others and offers unique components that address the GRFP goals, the Merit Review Criteria, and the Merit Review Criteria Elements. Provide your letter writers with your CV, your transcripts, and your draft GRFP statements. **AND provide each letter writer with complementary bullet points of your value as a GRFP applicant that enables them to write compelling and persuasive reference letters**. You want to remind your writers of your leadership and achievements, of your outstanding potential as a future STEM research leader, and as a leader committed to advancing broader societal outcomes.

Engage with your letter writers early and provide them with the purpose of the GRFP and point out that the letters need to address NSF's Merit Review Criteria and Merit Review Criteria Elements. Ask your writers to review the GRFP Reference Writer resources at the following links:

- Reference Writer Requirements
- Reference Writer Tips
- Reference Writer FAQs

Below are two email examples from an undergraduate applicant to two GRFP reference writers. The first example is a complete email to a research mentor with bullet points for the mentor to consider in the reference letter, and the second example is an email to a faculty advisor that includes only the bullet points. Look at how the bullet points from each email complement one another.

Example 1: An email to a reference writer outlining the GRFP Review Criteria, reference letter guidelines, and personal bullet points to consider. This reference writer was a summer research mentor and a potential graduate advisor.

Dear Dr. Xxxx,

I've attached the final versions of my Personal, Relevant Background, and Future Goals statement, my Graduate Research Plan statement, and my CV. I am proud of my statements and I want to thank you for the pivotal role you played in providing me critical feedback to my Graduate Research Plan. I believe that my two statements present compelling and competitive evidence for the GRFP reviewers that I am capable of accomplishing my proposed plan of research, that I will succeed as a Ph.D. student and make significant contributions to science and society, that I will broaden participation of underrepresented groups in STEM fields, and that I will become a globally engaged scientist.

Thank you again for writing me a letter of reference in support of my GRFP application. Letters are due November 2 via NSF's FastLane portal, have a two-page limit, and need to be on letterhead with name, title, and signature of the reference writer. As we discussed, the reference letter should address NSF's Merit Review Criteria of ***Intellectual Merit*** *and* ***Broader Impacts*** *and the associated Merit*

Review Elements. Additionally, the GRFP homepage has a REFERENCE WRITERS tab where you'll find additional information on Reference Writer Requirements, Tips, and FAQs.

Your letter will provide evidence to the GRFP reviewers that my research has sound merit as a potential doctoral student at Carnegie Mellon University, that it fits within your research interests, and that it will have a broad impact on the global community. I would particularly like to ask that you address the following aspects of my value as a GRFP applicant:

- *The value of my GRFP proposed research and its fit in your lab's broader mission statement.*
- *My preparation before the summer in studying the research and software that allowed me to lead and guide my fellow summer scholars in developing code in the watercraft software.*
- *My rank compared to other undergraduate researchers that you have mentored.*
- *My ability to quickly learn new techniques (computer vision, OpenCv, and PID controller) and apply them to my research.*
- *My ability to work independently on a research project and work collaboratively in a team environment.*
- *My collaboration with international researchers during the summer and the international scope and impact of my proposed research in areas like China and Qatar.*
- *My passion and excitement for the research project and for learning.*
- *The innovative nature of my summer research, how I developed unique computer vision techniques to drive the watercraft, and that I will be the primary author on a paper that we will submit to a peer-reviewed journal.*
- *My presentation at the high school teacher's conference that focused on computer science and robotics career paths and skills development.*
- *My preparedness for graduate study and for conducting my proposed research at Carnegie Mellon University, and that there are adequate resources at CMU to carry out my research.*
- *My leadership in fostering broader research involvement for my fellow summer scholars through the Pittsburgh river experiment.*
- *My proposed graduate leadership involvement with the Western Pennsylvania Summer STEM academy and with the Computer Science for High School (CS4HS) program at Carnegie Mellon University.*

Thank you in advance for your time and consideration in writing this important letter. The opportunity you gave me to conduct research in your lab this past summer provided me with fundamental insights into the challenges of applied research, and it was your guidance and passion that helped me along the way. My time at CMU truly helped shape me into a confident and capable researcher. For this I am deeply grateful. Thank you for investing in me.

Sincerely,

Xxxx Yyyy

Example 2: The personal bullet points section from a letter of reference email to an on-campus faculty advisor. Notice how these bullet points complement the bullet points from Example 1.

In our previous meetings, we discussed some topics for my GRFP reference letter and I would like to formally lay them out in this email. I would particularly like to ask that you address the following aspects of my value as a GRFP applicant:

- *My potential to succeed at graduate school and my future as a research professor.*
- *My rank compared to other students you have taught and my academic performance.*

- *How I formed a mentorship with you and the Undergraduate Research Opportunities Center (UROC) and in the process brokered research positions at the Monterey Bay Aquarium Research Institute and at Carnegie Mellon University.*
- *My teamwork and leadership in the interdisciplinary Mathematics research group and the skills and knowledge (constraint-based solver, graph search algorithms, and C++ programming) that I brought to solving the Skyscraper puzzle.*
- *Our work in developing the curriculum for the "Introduction to Artificial Intelligence" class that we will co-teach this spring.*
- *My initiative in developing peer mentoring materials for UROC, and my mentoring of McNair and UROC Scholars.*
- *My commitment to serve my community by:*
    - *Developing hands-on high school computer science curriculum for CSUMB's Recruitment in Science Education (RISE) program.*
    - *Mentoring underrepresented high school students through the RISE program.*
    - *Building an open source web application for the Pacific Grove Museum of Natural History to store their Monarch butterfly research for California online (the data are openly accessible to any participating researcher or high school to add to or use the research data).*

Sample Reference Letter

Graduate Research Fellowship Program
National Science Foundation
Arlington, Virginia 22230

Dear Review Panel Members,

I write this letter in support of the application of Ms. Xxxx Xxxx for the National Science Foundation's Graduate Research Fellowship Program. I am giving Ms. Xxxx the highest possible recommendation I can give an undergraduate scholar because her skills, knowledge, and abilities are in the top 1% of undergraduate students I have known in the past 20 years. This is significant because I have mentored over 35 undergraduate scholars from 6 colleges and universities while a Research Plant Pathologist with the USDA Agricultural Research Service. I have won multiple awards for mentoring undergraduate students (including two at the national level and the highest award for service to the nation in agriculture) and my top students have been awarded NSF Graduate Research Fellowships for research they conducted in my laboratory. Ms. Xxxx is a rare student who gives the best of herself in every opportunity she afforded and has demonstrated that she is prepared for a stellar graduate education.

Ms. Xxxx began work in my laboratory in October 2014 as an intern from the competitive and esteemed Undergraduate Research Opportunities Center program at California State University, Monterey Bay. From the day she arrived it was clear that she was already technically astute and ready to conduct research. My technician and I were impressed with her ability to quickly learn new skills and procedures. After one demonstration or discussion she was able to work independently to conduct the projects in new research areas. For example, she independently planned, planted, rated, successfully isolated bacteria from diseased plants, and using rep-PCR completed Koch's postulates to demonstrate which pathogens from *Pseudomonas cannabina* (including model organisms previously identified as *P. syringae* pv. *maculicola*) are pathogens on beans. This required that she learn sterile technique, media preparation, and other general microbiology skills in addition to basic

plant pathology and PCR skills. She expanded our initial hypothesis by testing several different bean types. She prepared the data for publication in a research article we are writing for peer review. Although my students have published peer review literature in the past, no other student was able to master the work at this level of authorship in such a short period of time. She presented her research at the August meeting of the American Phytopathological Society.

Her ability to quickly master both theory and practice gave us confidence to encourage her to take on the multiple research projects her insatiable curiosity drove her to ask about. First, she used methods similar to those in her main project to evaluate the etiology of bacterial leaf spot on kale and to identify the pathogen as *P. syringae* pv. *tomato*. She then isolated and genotyped *Xanthomonas campestris* pv. *vitians* from diseased lettuce grown throughout the Salinas Valley of California. This is part of a larger project describing the genetic diversity (by MLSA) of this pathogen in order to target disease control. For her last project she demonstrated that despite conventional wisdom, the causal agent of bacterial blight of chives is caused by a pathogen of grains *Xanthomonas translucens.* The standard of evidence she needed to provide was high because this is the first report of this pathogen on chives. Her research will result in one co-authored full-length manuscript and two peer reviewed disease notes, including one for which she will be the first author.

Her scholarship has been recognized by others. She was selected to be a research scholar in the Undergraduate Research Opportunities Center (UROC) program at California State University, Monterey Bay. UROC has a proven track record of producing undergraduates prepared at the highest level for graduate school. She received an Honorable Mention from the exceptionally competitive Goldwater Scholar program. Finally, she was selected for the outstanding Summer Research Opportunities Program at Michigan State University in 2015 where her advisor trusted her with an extremely risky and ambitious project.

Ms. Xxxx has taken leadership within our laboratory. She helped to train new students who started in our laboratory in January 2015. Importantly, her level of preparation and ability to discuss her projects has served as a model for our new students. She was quick to volunteer to help with other experiments. She sought to help with the USDA/ARS outreach programs to Latino students in the community. Many of these students are the sons and daughters of vegetable field workers in the Salinas Valley. Xxxx not only volunteered to participate, she served as the coordinator for the Salinas USDA/ARS outreach program to Los Padres Elementary School. She coordinated the scientists' and teachers' schedules so that she and the scientists could teach the scientific method and conduct a plant based experiment with fifth grade students in 5 classrooms. In addition to coordinating she prepared classroom materials, organized data sheets, and outlined activities. She also organized the subsequent tour of the USDA/ARS research facility in which 10 scientists presented their work to the students in a rotation during 2 hours. These examples demonstrate her sense of community and willingness to work toward broader impacts. The USDA/ARS station in Salinas would not have had this outreach project this year if it weren't for Xxxx's dedication. The materials she left will ensure that the outreach program will continue.

Ms. Xxxx demonstrates the highest level of scholarship and genuine scientific talent I have seen in an undergraduate. Ms. Xxxx has the professionalism, research acumen. and innate ability to be the type of scientist that the NSF will be proud to have supported. I cannot give a higher recommendation.

Sincerely,

Yyyy Yyyy, Ph.D.
Professor and Department Head

Thanking Your Reference Writers and Other Mentors

Your GRFP reference writers and other mentors who helped you put together your GRFP application all played a pivotal role, and thanking them would mean the world. You can, of course, thank them via email, text, and social media shout-outs, but in this digital age a handwritten note or card means more than ever. Take time to write a note that speaks from the heart. It leaves a bit of you with them.

Beyond the GRFP, surprise your other mentors by sending them a message or card of appreciation. Brighten their day! Be authentic and think about what would be meaningful to them. It doesn't have to be long, just heartfelt.

Pre-Writing

Often the hardest part of writing is getting started. We all wrestle with finding the right word or idea, or we crowd our head with so many ideas that we create mental traffic jams. To clear the congestion start by pre-writing. Pre-writing is a secret sauce that can give you a mental jump start to transform writing into writing well. It can help you brainstorm and organize ideas, find weak points and gaps, develop the structure of your statements, and respond to the criteria at a benchmark level.

To set up for pre-writing, first pull out your CV and look at how you might revise it using the 4 pillars to guide you:

- **Initiative** (e.g. creative, original, innovative, risk-taking, thinking outside of the box, etc.)
- **Leadership** (e.g. translate vision into reality, inspire and influence the practice of others, leave something that lives beyond you, produce more leaders, etc.)
- **Impact** (e.g. scope and magnitude of significance, far-reaching, lasting, transformative, etc.)
- **Scholarship** (e.g. publications, oral presentations, poster presentations, performances, exhibits, workshops, panels, etc.)

For example, visit Appendix A *(Crafting Your CV)* and examine how the authors integrate elements of the 4 pillars throughout their CVs. Revise your CV to also incorporate elements of the 4 pillars. Don't worry about having all 4 pillars in each achievement.

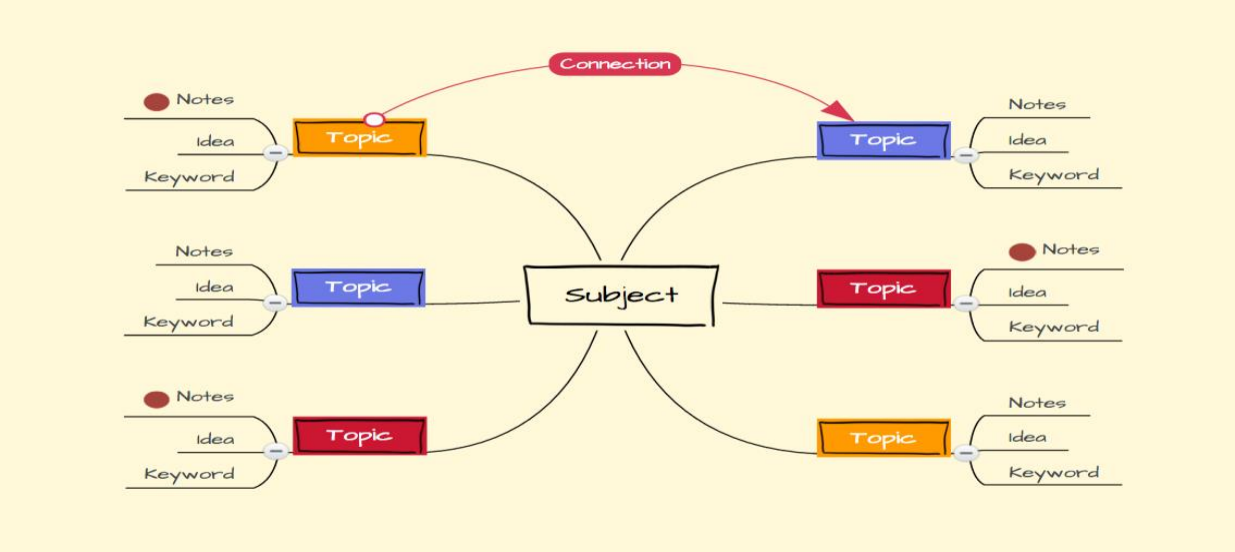
After you've revised your CV, do a gap analysis and, using the 4 pillars to guide you, build-out another CV with a vision of what you'd like to achieve by the time you start your fellowship. There may be areas you want to shore up or new initiatives you want to undertake. For example, in Intellectual Merit you may have a research manuscript that you'll submit for review, or a conference presentation lined up, etc. For Broader Impacts, you may focus on BI initiatives (e.g. curriculum development, mentor training, workshops, outreach, etc.) that are important to you, and that will have deep and lasting impacts. Remember that you have close to a year between your application submittal and the start of your fellowship. Don't let that be a gap in your application. Reviewers want to know about the initiatives you'll complete during this period.

Once you've built-out your CV, there are lots of productive ways to launch into pre-writing that include freewriting, mindmapping, storyboarding, diagramming, bubbling, outlining, and so on. Explore different techniques and find ones that work for you. I've found that a sequence of freewriting, mindmapping, and storyboarding work best for me. I start with freewriting as a warmup, and then create mindmaps that form core themes that I build my storyboards around.

To get started on freewriting, pull out your built-out CV and, using the 4 pillars as idea triggers, write about your Intellectual Merit and Broader Impacts. Don't think about what you're going to write and then write; think as you write! Follow the flow of your ideas but don't pressure yourself to

fully tease out everything. Don't be concerned about exactness or quality and don't censor your ideas. AND, most importantly, don't stop!! After this initial freewriting, loop back and circle topics, ideas, phrases, or sentences that you find interesting. Then freewrite again using one or a set of the circled areas as a starting point and drill down using the 4 pillars as triggers. Looping multiple times enables you to hone in on key ideas while discovering important themes.

Then use mindmaps to link the ideas you generated in your freewriting to central themes. Mindmapping is a visual technique to organize your thoughts, generate new ideas, and stimulate creativity. It incorporates words, images, numbers, and colors to link and group concepts to a central theme through natural associations. Here's an example of a basic mindmap template:



To get started on mindmapping, begin with two blank horizontal pages. Circle IM (Intellectual Merit) in the middle of one page and BI (Broader Impacts) in the middle of the second page. These are your central subjects. Draw branches that radiate out from these central subjects and add basic topics, ideas, keywords, and notes that you garner from your freewriting. Organize your information with the most important topics closer to the central subject, and the more minor elements further away. Don't worry about including a lot of detail; maintain organization and linkages by using keywords, short phrases, illustrations, colors, etc. This link has terrific examples of mindmaps.

Now drill down with more detailed mindmaps that focus on the two GRFP statements. For example, your Personal, Relevant Background, and Future Goals statement has four main sections: 1) Introductory Personal Statement; 2) Intellectual Merit (Relevant Background); 3) Broader Impacts (Relevant Background); and 4) Future Goals and Action Plan. Using the NSF Merit Review Criteria Elements as your guide (see page 1 of the primer) and the 4 pillars of Initiative, Leadership, Impact, and Scholarship as your benchmarks create mindmaps for each of these sections. Wander down related lines of thought using ideas to spur more ideas. The web of connections you make will allow you to map out related ideas and themes, which you can select, connect, and arrange into a plan for your statement. Take the same approach for mindmapping the different sections of your Graduate Research Plan.

Pulling from your mindmaps, develop storyboards that create the architecture, sequence, and flow of your two GRFP statements. Look at storyboarding as a more structured way to flesh out the specifics of your writing and to put a logical order to your paragraphs and to the flow of your narrative. Visualize a storyboard as a series of information boxes much like a comic strip. Think of each box as a separate paragraph for your statement and order your storyboard from beginning to end.

For example, start by breaking the four sections of your Personal, Relevant Background, and Future Goals statement into these paragraphs:

- Personal Background: 2 paragraphs
- Intellectual Merit (Relevant Background): 3-4 paragraphs
- Broader Impacts (Relevant Background): 3-4 paragraphs
- Future Goals and Action Plan: 4-5 paragraphs

Start out by drawing 12-15 boxes with 2 boxes per page (you'll be posting these on a wall so make them big and visible). Pulling from your mindmaps put one controlling idea/soundbite/theme in each box that corresponds to the respective paragraph of your statement. Remember that a paragraph develops and supports one central theme.

Go back and add key words, phrases, soundbites, drawings, etc. that support the themes of your paragraphs. Compose inside or outside the boxes; don't feel constrained! Use the GRFP Merit Review Criteria Elements as a guide and the 4 pillars as benchmarks in constructing and supporting your paragraphs. Initially, you'll be able to fill in some boxes easier than others and that's ok. You'll build-out additional paragraph boxes as your storyboard evolves. Take this same approach to storyboarding your Graduate Research Plan.

Don't stick your storyboards in a drawer — post them on a wall or door so they're visible and alive. Ruminate on themes, and on the structure and flow that emerges. Be dynamic with the architecture of your storyboards. Move ideas around, toss old ones and post new ones. Link the 4 pillars to your central themes.

After you've gone through this prewriting phase take a breather and let it percolate. After this intermission you'll often have fresh insights, ah-ha moments, and clearer and deeper ways to undertake your writing. You'll begin your writing at a higher level, reduce your actual time of writing, produce benchmark statements, and enjoy writing them!

Writing Your GRFP Statements

Again, at its core, writing for the GRFP is a proxy for clicking-in around the foundational pillars of **Initiative**, **Leadership**, **Impact**, and **Scholarship** and using these principles to benchmark any fellowship, scholarship, research proposal, or graduate school application.

The best way to illustrate clicking-in around the 4 pillars is by example. Following are three 2020 GRFP statements (one from an undergraduate student who received Honorable Mention and two from second year graduate students who received fellowships) along with early drafts of Personal, Relevant Background, and Future Goals statements.

Start by reading the <u>early</u> <u>drafts</u> of the Personal, Relevant Background, and Future Goals statements. Don't worry about the details—focus on the voice and flow and impact of the writing.

Now read the <u>final</u> versions of the Personal, Relevant Background, and Future Goals statements. Take time to explore the differences between the early drafts and the final versions. Look at how the final versions have stronger messaging, how bolding highlights these messages, how the statements address the GRFP criteria with greater clarity and impact, and how the writing style improves with a clearer and more active voice that personalizes the themes. Look at how the opening 1-2 paragraphs create a story within a story that paints engaging and visual portraits of the applicants. Look at how the Relevant Background sections of Intellectual Merit and Broader Impacts are packed with the pillars of Initiative, Leadership, Impact, and Scholarship that synthesize rather than list. Look at how the Future Goals and Action Plan sections present robust, ambitious, and achievable Intellectual Merit and Broader Impacts initiatives, and how they end with clear and compelling career goals that persuade the reviewers of a bright future for these scholars and leaders. Look at how all of these

elements work together to create remarkable and memorable statements.

Now read the final versions of the Graduate Research Plan statements. Look at how the titles are clear and descriptive, how the introductory background sections establish the context and the importance of the research questions, and how the research fills pressing gaps. Look at how the statements reiterate the qualifications of the investigators and the availability of appropriate resources. Look at how the methods clearly address the hypotheses/aims of the research and how they highlight creative, original, and innovative approaches. Look at how the IM sections emphasize the significance and impact of the research, and how the BI sections hit on the societal impacts of the research and how the applicants present specific BI initiatives they will undertake.

Begin your writing by carefully consider the purpose of each paragraph. Revisit your storyboards and **draft bolded sentences that capture the message of each paragraph — what you want the reviewer to remember.** Then build-out each paragraph using the GRFP Merit Review Criteria Elements as your guide and the 4 pillars of Initiative, Leadership, Impact, and Scholarship as your benchmark support structure.

As you develop your paragraphs pay attention to how the ending of each paragraph connects to the first sentence of following paragraph. If the transition seems missing or strained, improve the transition by clarifying your logic or rearranging the paragraphs. Create transitions that help your readers track your ideas, tie up loose ends, and build forward momentum.

To check the overall arc of your statement, read just the bolded sentences in each paragraph. Do they collectively express what you want the statement to convey? Do they have the impact you want them to have? Is there a flow and cohesion to your narrative communicated through your bolding? Ultimately, you'll decide if you want to keep bolded text in your final statements. Effective bolding can provide reviewers with memorable messaging; however, bolding can be distracting if it's not carefully crafted.

Gather a solid group of people to consistently review your drafts. They should be calibrated to what the GRFP reviewers are looking for, familiar with the GRFP goals and Merit Review Criteria, and who you trust will give you constructive and critical feedback. Your review group could include faculty mentors, undergraduate and graduate students, writing center associates, and others who might have served as a GRFP reviewer or be familiar with your proposed research or Broader Impacts. Keep the number of reviewers manageable (3-6) so you're not overwhelmed by everyone's feedback. As you reach the finish line, consider condensing your reviewers down to those who can give you the most substantive feedback.

How GRFP Applications Are Reviewed

Each GRFP applicant receives three reviews and the reviewers give each application a holistic review that allows for individualized assessments of the Merit Review Criteria of Intellectual Merit and Broader Impacts. Reviewers assign separate ratings (*Excellent, Very Good, Good, Fair*, or *Poor*) for Intellectual Merit and Broader Impacts and provide summary statements. You need to be compelling in <u>both</u> Merit Review categories of Intellectual Merit and Broader Impacts, and ratings of Excellent and Very Good are generally required to be competitive for a fellowship. For example, if an applicant receives *Excellent* ratings for Intellectual Merit and *Good* ratings for Broader Impacts from the reviewers it's unlikely that the applicant would receive a fellowship.

EARLY DRAFT

Cheyenne Jarman **Personal, Relevant Background, Future Goals** GRFP 2020

In the field before sunrise, shivering in the crisp dawn, I intently observed a peregrine falcon dive through the thin air to attack its prey. Growing up, my mother would take me from our urban home to the rural vineyards, where she would practice her falconry. It was here I developed my innate curiosity for the natural world. This curiosity drove me to defy the odds against my socioeconomic status as a first-generation female student in STEM and pursue undergraduate education. Through my undergraduate journey I have experienced tides of unprecedented highs and devastating lows. The multiple scholarships I have received, including a Dean's List honor, and my active leadership in school clubs during my first year is testament to my relentless pursuit of knowledge. However, the unexpected loss of my father that summer broke my academic stride and performance. Pulling myself up I acquired the personal skills of an academic entrepreneur – perseverance, grit, risk taking, and vision. These have shaped my identity and I am now soaring academically, in my independent undergraduate research, and in my leadership. I now have a clear vision to complete a Ph.D. degree in Community Ecology with the goal of becoming a research professor.

Intellectual Merit (Relevant Background):

Becoming a STEM Diversity Fellow at the University of California, Santa Cruz (UCSC) was a pivotal point in my academic career. Not only has this been an amazing opportunity for me to develop my abilities as a researcher but has proven to me that the selection panel saw the potential in me to pursue and succeed in research. Armed with this fellowship and a fresh scientific scuba diving certification I was eager to dive into some field work. I procured a highly coveted spot in the Raimondi-Carr Lab at UCSC, learning and experiencing first-hand the mechanisms driving my local kelp forest ecosystem. The central coast of California is in the midst of an urchin outbreak and seeing the deforestation events that these small herbivores are capable of was both alarming and intriguing. That summer was also the first time I combined my computational skills with my biological skills through an automated urchin diet analysis project (paper in progress). I presented the beginnings of this research at the 2018 Western Society of Naturalists.

Having those images of deserted urchin barrens and lush kelp forests running through my head, I started to pursue a senior thesis. I wanted to know, if sea otters aren't eating this abundant population of urchins from barrens, then who will? I shifted down a trophic level and decided to focus on the impact mid-level predators may have. From previous studies, we know that sea otters exhibit a preference of urchins from forests (healthy) over urchins from barrens (starved), but does this preference exist in mid-level predators as well?

I tested the prey preference of the two most abundant mid-level predators within the central coast of California's kelp forests through feeding trials in a wet lab. I was awarded the Seymour Marine Discovery Center's Student Research and Education Award and named a Koret Scholar, which provided funding my thesis work. Being in the midst of an urchin outbreak it is crucial we identify predators that may consume this abundance of starved urchins. The results from this research will help us better understand predator-prey dynamics and may aid in the understanding of ecological shifts in the kelp forest. I will be presenting the results through an oral presentation at the 2019 Western Society of Naturalists and will be publishing my senior thesis in a peer-review journal by the end of my undergraduate career.

Since my first field season, I have had this desire within me to explore more of our underwater world and to learn how the same ecosystem (kelp forests) and its interactions can vary

across large spatial scales. This led me to a position in the Caselle lab at the University of California, Santa Barbara (UCSB). Through this position I learned the importance of long-term monitoring and what these large-scale data sets can reveal. Similar to the central coast, Southern California is comprised of a mosaic of kelp forest and urchin barren patches and many of the same dynamics are at play. Both regions lost a major predator, the sunflower star (*Pycnopodia helianthoides*), and have been impacted by major warming events (i.e., the 2014 blob), however, these regions have major differences in their community compositions. These observations have left me ruminating on the resiliency mechanisms of kelp forests in the different coastal regions of California and have inspired me to pursue a Ph.D at UCSB.

Broader Impacts (Relevant Background):

Early in my academic career I realized the importance of community and continually sought out my niche, an environment where I could thrive. At this time, I was strictly pursuing computer science (CS) and a majority of my classes were male dominated. I didn't have any colleagues I could relate to. This led me to Project AWESOmE, a club dedicated to promoting and supporting women pursuing computer science. I was an active member throughout my freshmen year where I learned about navigating the world of CS and established strong connections with my peers. The following year I took on a leadership role as a co-advisor. In this position I led weekly meetings that focused on a variety of topics like dealing with imposter syndrome, building a network, and prepping for technical interviews. As co-leader, I also further established the framework for the club's peer mentorship program. This program pairs underclassmen with upperclassmen and allows for one-on-one peer mentorship, allowing students to receive academic and career advice they need in a casual setting. Project AWESOmE and the mentorship program continue to be an active presence on the UCSC campus, providing support for women in CS.

During my second year I volunteered with the Seymour Marine Discovery Center (SMDC). As a volunteer I disseminated scientific research to the general public and helped bridge the knowledge gap that exists between these two communities. My time as a volunteer helped me realize my passion for public outreach and led me to pursue a position designing curriculum for the SMDC's school program, which educates k-12 students about their marine backyard. Working with the existing curriculum, I made the lesson presentations compatible with the center's iPads, making the information and images clearer and allowing for instant sharing via the cloud. As I updated the old curriculum and after meeting with the youth programs manager, I saw sections of the curriculum that could be expanded upon and made to fit more active learning methods. I started working on further developing a module exploring the trophic cascade that exists in kelp forests and how the recent urchin outbreak has significantly altered this ecosystem. I wanted to take a tactile approach and wrote a proposal to fund the printing of 3D urchin models, which would show the cross sections of an urchin from a forest (healthy) and an urchin from a barren (starved). The project did not receive the necessary funding this past year, but I intend to re-apply this upcoming school year and complete the project.

Finding a community as a woman in STEM has been difficult. To foster this community, I pursued a leadership position with the Women in Science Society (WSS). The chapter at UCSC is new, so as an executive board officer I will help further establish the club's foundation. As a leader, I also get to help these women co-leading professional development workshops covering how to build a strong CV, finding the right career path, and writing a competitive application for graduate school. In order to connect with the community, WSS plans to partner with the local Girl Scout troop to host educational events to inspire the next generation of women in science.

Realizing the lack of community for marine science students on UCSC's campus I decided to co-find the Marine Science Club (MSC). Pulling from my previous experiences with Project AWESOmE and WSS has really helped the start-up process progress. However, establishing this club to be recognized by the university has not been an easy feat. My executive board and I are still building

the infrastructure. We have been attending the necessary workshops on budgeting, maintaining an organization, and collaborating, and working with the appropriate university offices to ensure MSC will support marine scientists for generations to come. MSC's mission is to provide a supportive and inclusive environment for marine scientists and help them develop the necessary skills to establish a successful career. I envision the MSC community as a space that provides academic, emotional, and career support.

In order to achieve MSC's mission my e-board and I will address the mission in two main parts, (1) providing professional development workshops to members and (2) creating a space for peers to communicate and receive academic, emotional, and career support from colleagues. The professional development workshops will cover a wide range of topics to suit the needs of members at all stages of their academic career. Topics will include how to apply to REUs, talks on different career paths available, and applying to graduate school. Each of these workshops will be developed through a collaborative effort between the MSC e-board and undergraduate students, graduate students or faculty members who have experienced success in that specific area. To tackle the second part of MSC's mission, of creating a supportive environment, I will establish a peer-to-peer mentorship program. Utilizing my skills from working on the Project AWESOmE's mentorship program, I will establish a similar framework of pairing underclassmen with upperclassmen.

Throughout my undergraduate career I have been fortunate enough to receive amazing mentorship from upperclassmen, graduate students, and faculty members. As a result, I want to be able to give that back. Serving in these leadership positions and being able to create a lasting impact in my undergraduate communities is just the beginning.

Future Goals and Action Plan:

I will be the first in my family to have pursued and completed undergraduate education and to continue on to a Ph.D. Upon the completion of my Marine Biology B.S. and Computer Science B.A. I intend to enter the Ecology, Evolution, and Marine Biology (EEMB) program at the University of California, Santa Barbara (UCSB) under the co-advisement of Dr. Jennifer Caselle and Dr. Cherie Briggs. As a budding community ecologist with a heavy computational background, Dr. Caselle and Dr. Briggs are the ideal mentors. Dr. Caselle works on predator-prey dynamics, larval dispersal, and the success rates of marine protected areas in kelp forest and coral reef ecosystems. Dr. Briggs's lab places a heavy emphasis on combing theoretical and empirical work while looking at community and population dynamics. This co-advisement will help me create a cohesive story of the interactions of an ecosystem and successfully pursue my doctoral thesis, examining and modeling food web dynamics within a kelp forest.

Entering into my Ph.D. program I intend to jump straight into developing my ecological modeling skills. In my first year I will enroll in a statistical and dynamic modeling course and other computational biology courses to further intertwine my computer science skills into my research. Skills from these courses paired with my computational background will serve as a strong foundation for me to enter the world of modeling; not only preparing me to pursue the modeling chapter of my dissertation, but a career full of integrating computation with ecology.

To further my modeling skills and expand my range of research I intend to apply to the Graduate Research Opportunities Worldwide (GROW) program under the auspices of the GRFP. Within the GROW program I will collaborate with Dr. Craig Johnson at the University of Tasmania on modeling kelp bed dynamics in South Australia. In addition to modeling work, Dr. Johnson looks at kelp forest resiliency against natural sources (herbivory) and anthropogenic sources (climate change and pollution) in forests throughout Australia and Tasmania. This internship will help my understanding of kelp forest dynamics on a cross-continental spatial scale.

Ultimately, I foresee myself becoming a research professor at a public university; In order to properly prepare myself I will pursue pedagogical and leadership programs as a doctoral student.

UCSB offers a variety of these trainings, such as the Certificate in College and University Training (CCUT) course and a Supervisory Certificate Program, which includes a diversity and inclusion certificate program. Through the CCUT program I will develop a diverse teaching portfolio that includes TA-ing, developing curriculum, and teaching a course. Complementing the CCUT, the Supervisory Certificate Program will help me develop leadership skills, interpersonal skills, and the ability to create an inclusive work environment. These programs and experiences will help me foster an inclusive and productive lab and class environment as a professor.

In order to bolster my mentorship skills, I intend to work with programs that focus on helping first-generation and students from underrepresented groups to pursue advance degrees. Programs like the McNair Scholars Program and UC LEADS at UCSB offer mentorship programs where a graduate student mentors an undergraduate and helps them navigate the world of academia and research. Pulling from my past experiences with Women in Science Society and the Marine Science Club (MSC), I intend to pursue a "super mentor" position where I can work with graduate students to develop their mentorship skills. I also want to help undergraduate students develop their own mentorship skills by spearheading a peer-to-peer mentorship program similar to the program I established for MSC. The program will require the upperclassmen to partake in mentorship workshops and diversity and inclusion training courses to ensure they are equipped with the proper mentorship tools. This program will equip students with strong mentorship skills that they can carry throughout their careers.

Following my Ph.D. I will pursue a postdoctoral position with Dr. Craig Johnson at the University of Tasmania (UTAS). As a postdoc, I want to explore the interactions at the intersection of kelp forests and coral reefs. Being familiar with the university and ecosystem from my time in the GROW program, I will dive straight into a new research area and broaden my abilities as a community ecologist.

Harnessing all the experiences and knowledge I gained throughout my higher education I intend to pursue a professoriate position at an R1 public university. As a researcher, I envision my laboratory as an inclusive and collaborative environment that studies community dynamics across multiple systems with the goal to create a comprehensive story of how communities affect one another. As a professor, I view my role as one of strong mentorship to not only my graduate students, but also undergraduates. Throughout my schooling, I have had the fortune of working with amazing mentors and my goal is to continue that legacy.

In the field before sunrise, shivering in the crisp dawn, I intently observed a peregrine falcon dive through the thin air to attack its prey. Growing up, my mother would take me from our urban home to the rural vineyards where she would practice her falconry. It was where I discovered my innate curiosity for the natural world. Such curiosity drove me to overcome my socioeconomic status as a first-generation Latina student in STEM pursuing undergraduate education. Throughout my undergraduate journey, I have experienced tides of unprecedented highs and devastating lows. The multiple scholarships I have received (Koret Scholar and STEM Diversity Fellow) and my active leadership in school clubs (co-advisor of Project AWESOmE, secretary of Women in Science Society, and founder and president of the Marine Science Club) are all a direct testament to my academic ambition. However, the unexpected loss of my father in the first summer of my undergraduate education broke my academic stride and performance. **Rallying, I acquired the skills of an academic entrepreneur—perseverance, grit, risk-taking, and vision.** These experiences have shaped my identity and I am now soaring academically in both my independent undergraduate research and leadership with the goal to complete a Ph.D. degree in community ecology and to become a research professor.

Intellectual Merit (Relevant Background):

A pivotal point in my academic career occurred when I became a STEM Diversity Fellow at the University of California, Santa Cruz (UCSC). It was here my untamable desire to pursue research was affirmed by an academic selection panel who saw the potential in me to succeed. Armed with this fellowship and a fresh scientific SCUBA diving certification, I was eager to delve into research and I procured a coveted spot in the Raimondi-Carr Lab at UCSC. **Applying my computational skills, I co-developed a machine-learning program that identifies algae particles in sea urchin stomachs to generate a quantitative understanding of sea urchin grazing behavior.** I presented this research at the 2018 Western Society of Naturalists Conference and will co-author a publication that will be submitted to the *Marine Technology Society Journal* in June 2020.

Throughout my time in the field collecting urchin samples, **I was particularly drawn to interactions between grazers and their predators.** I swiftly dove into a senior thesis investigating predator-prey dynamics. From 2013 to present, an unprecedented outbreak of herbivorous sea urchins has transformed central California kelp forests into a mosaic of forest patches and sea urchin 'barrens' that are void of kelp. The urchins are healthy in the forest patches, but starved in the barrens. **This phenomenon led me to investigate whether the quality (i.e., health) of sea urchins influences their vulnerability to predation.** I received two grants, the Seymour Marine Discovery Center's Student Research and Education Award and the Koret Scholarship, to investigate whether the two most locally abundant meso-predators (*Cancer productus* and *Dermasterias imbricata*) preferentially target healthy sea urchins and how predator preferences may inform the recovery of kelp forests. I designed an experiment to test for the effects of prey preference in a controlled laboratory seawater flow-through system and found that while *D. imbricata* had a preference for healthy urchins, *C. productus* did not. The results from this research will help to better understand predator-prey dynamics and improve ecological network models. **I will give an oral presentation of my results at the 2019 Western Society of Naturalists Conference, and in June 2020, I will submit the results of my thesis to the journal *Marine Ecology Progress Series*.**

To increase the breadth of my understanding of community dynamics, I brokered a research position in Dr. Jennifer Caselle's lab at the University of California, Santa Barbara (UCSB). Dr. Caselle directs a large-scale field-based monitoring program of kelp forests in the California current system. Despite the persistence of this ecosystem for over tens of millions of years, climate change,

overexploitation, and other anthropogenic disturbances are ravaging California's underwater forests. Therefore, long term monitoring is critical to advance understanding of ecological dynamics for developing effective conservation and management strategies. Through extensive subtidal kelp forest surveys, I expanded the long-term monitoring data set of the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO). These data are currently being summarized into a report that will be issued to the State of California for developing adaptive ecosystem-based management practices. **Through this position, I learned the rigors of conducting SCUBA intensive field work, expanded the PISCO long-term monitoring data set, and honed my vision to pursue my Ph.D. at UCSB.**

Broader Impacts (Relevant Background):

Early in my academic career, I realized the importance of community and continually sought out my niche where I could thrive. I was solely pursuing computer science (CS) and it was difficult finding colleagues I could relate to in such a male dominated major. This led me to Project AWESOmE, a club dedicated to promoting and supporting women pursuing computer science. I was an active member throughout my freshmen year where I learned to navigate the world of CS. The following year, I became a co-advisor where I led weekly meetings that focused on a variety of topics like dealing with imposter syndrome, building a network, and prepping for interviews. **I also established the framework and protocols for the club's peer mentorship program where upper and lower division students are paired for one-on-one peer mentorship.** This enabled students to receive academic and career advice they needed while in a supportive setting. Project AWESOmE and the mentorship program remain an active campus resource for supporting women in CS.

The advancement of human knowledge fundamentally depends on our ability to heighten public appreciation of science and nature. During my second year at UCSC I served as a marine science docent at the Seymour Marine Discovery Center (SMDC). **My year as a docent helped me realize the importance of public outreach and led me to secure a position designing curriculum for the SMDC's K-12 education program.** At the end of my term, I met with the youth programs manager and offered to convert their paper lesson curricula into a digital format compatible with the center's iPads to improve informational accessibility. While digitally converting the material, I identified informational gaps in the kelp forest module and proposed to incorporate findings from my senior thesis into this module. Complementing the revised module, I wrote a proposal to fund the printing of 3D urchin models, which would showcase cross sections of a healthy urchin versus a starved urchin, giving the students a more visceral understanding of mechanisms that underpin trophic interactions. While the project did not receive funding the first round, I will reapply after completing the appropriate modifications.

Throughout my many experiences in leadership positions and real-world research, I have observed that diversity in the STEM workforce is not yet reflective of society's diversity. One explanation is the low retention rates of first year undergraduate and transfer students in STEM due to generational economic struggles inherent amongst many minorities. The lack of guidance and mentoring inhibits their potential to develop their scientific skills (e.g., experimental design and data analysis) and engage in research beyond the classroom—which are fundamental in increasing students' opportunities and retention rates within STEM. **In 2019, I founded the UCSC Marine Science Club (MSC) to fill this void in diversity outreach and to increase retention rates of underrepresented students in marine science.** To achieve this, I structured the MSC mission around three fundamental objectives: (1) to demystify the academic pathway; (2) to prepare students to pursue a career in marine science; and (3) to create a space for mentorship among upper and lower division students (building upon my experience from Project AWESOmE). I am also registering MSC as a university recognized student organization (i.e., establishing a constitution, developing mentorship trainings,

and creating an informational website) to ensure MSC's continued presence on campus after my departure.

Future Goals and Action Plan:

Upon completing my Marine Biology B.S. and Computer Science B.A. degrees, I intend to enter the Ecology, Evolution, and Marine Biology program at the University of California, Santa Barbara (UCSB) under the co-advisement of Dr. Jennifer Caselle and Dr. Cherie Briggs. **As an aspiring community ecologist with an extensive computational background, Dr. Caselle and Dr. Briggs will greatly strengthen my capacity as an interdisciplinary community ecologist.** Dr. Caselle works on trophic interactions within kelp forests and Dr. Briggs places a heavy emphasis on combing theoretical (i.e., modeling) and empirical work towards community and population dynamics. With Dr. Caselle's guidance, I will elevate my ability to tease apart species interactions and comprehensively evaluate their relative strengths within a community, while under Dr. Briggs's mentorship, her vast knowledge in ecological network models will allow me to cultivate my modeling skills through her guided expertise.

To broaden my range of research and modeling skills, I will apply to the Graduate Research Opportunities Worldwide (GROW) program under the auspices of the GRFP. Within GROW, I intend to collaborate with Dr. Craig Johnson at the University of Tasmania modeling kelp bed dynamics in South Australia. **The GROW internship will enhance my understanding of kelp forest dynamics on a cross-continental spatial scale and enable me to establish an international network.** I later intend to pursue a postdoctoral position in the Johnson Lab exploring the interactions at the intersection of kelp forests and coral reefs.

While a doctoral student, to prime and optimize my pedagogical and leadership skills as a professor, I will complete UCSB's Certificate in College and University Training (CCUT) course. Through the CCUT program, I will construct an expansive teaching portfolio that will include TA training, developing curriculum, and teaching a course. Broadening my teaching portfolio, I will develop interactive modules for UCSB's Research Experience and Education Facility (REEF; see Graduate Research Plan). To perpetuate continued best teaching practices, I will establish a community of TAs who will meet monthly to share curriculum design techniques while focusing on the importance of fostering inclusive and productive labs and classrooms.

Elevating my lasting impact at UCSB, I will work with the McNair Scholars and UC LEADS programs which focus on helping first-generation and underrepresented students pursue advanced degrees. **Working in conjunction with the program directors, I will develop graduate student mentorship materials based off of my previous leadership success while at the helm of Project AWESOmE and the Marine Science Club (MSC).** I will also spearhead a peer-to-peer mentorship program in the same vein as the one I established for the MSC to encourage more undergraduate students to develop their mentorship skills, so they may perpetuate an ongoing tradition of mentoring the next generation of undergrads.

Harnessing all the experiences and knowledge I will have gained throughout my higher education, I look forward to joining the professoriate at an R1 public university. **I envision creating environments teaching about community dynamics while providing a learning climate that is diverse, inclusive, and collaborative.** As a professor and researcher, I will provide strong mentorship guidance and ideals to graduate and undergraduate students alike, ensuring my students are well-equipped to become impactful future leaders within their respective fields.

Title: *The landscape of fear: how non-consumptive interactions underpin community dynamics and ecosystem function*

Introduction: Species interactions define the structure and function of communities that scale-up to entire ecosystems[1,2]. Indeed, trophic interactions have fundamental implications for conservation and management[3]. However, empirical estimates of interaction strengths are difficult to measure because of the large number of species in natural ecosystems, multiple pathways of effects, non-linear responses, and diversity of interactions (e.g., competition, predation, symbiosis, etc.)[4]. Most of these trophic-based interaction networks emphasize direct consumptive interactions. However, trait-mediated non-consumptive interactions can be equally influential in structuring communities[5,6]. Thus, to better understand and predict the consequences of changes in composition and relative abundance of species on the functioning and resilience of communities requires knowledge of both consumptive and non-consumptive interactions.

Species interactions can be assigned to three core modes: competition, predation, and symbiosis. While many direct consumptive interactions (i.e., the impact of one species eating another) have been well quantified in the species interactions literature[7], fewer studies have quantified more nuanced non-consumptive interactions amongst predators, prey, and competitors (i.e., the behavioral response of one species reacting to another)[8,9]. For example, current food web models do not consider how non-consumptive interactions are involved in *per capita* species interaction strengths. These unaccounted modes of interaction strengths are amplified throughout interaction network models, which may misinform predictions in changes in species composition on community processes. Although competition and predation are typically well accounted for in these models, behavioral interactions are often not included because of the difficulty in quantifying consumptive versus non-consumptive behavioral interactions. Therefore, I propose to develop an empirical approach to evaluate how changes in species composition within a community are manifest through non-consumptive effects and how these interactions ultimately underpin food web dynamics and community function.

Study System: Throughout the Channel Islands of California, herbivorous sea urchin grazers (*Strongylocentrotus purpuratus* and *Mesocentrotus franciscanus*) cause mass kelp deforestation events[10]; however, two locally abundant urchin predators (California sheephead *Semicossyphus pulcher* and spiny lobster *Panulirus interruptus*) may elicit important behavioral responses that regulate the capacity of sea urchins to overgraze forests. Whether these altered behaviors are a result of predation (i.e., death of conspecific or heterospecific) or the mere presence of a predator (i.e., chemical cues) is unknown, making the islands the ideal study site to examine non-consumptive interactions and their relative strength between multiple species. I will conduct this study under the auspices of the University of California, Santa Barbara (UCSB), which is fully equipped with a dive locker and dive boats to support the field operations.

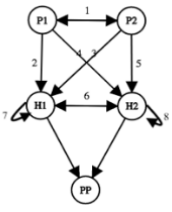


Figure 1. 2 predators, 2 prey interaction network. Each edge between the predators (P) and prey (H) denotes a non-consumptive interaction.

Hypothesis 1: *The separate and combined presence of different predators and different prey species will have non-consumptive effects on the productivity of a primary producer.* **Methods:** In year one (2021) I will deploy an experimental cage array in the sand adjacent to the rocky reef in Prisoner's Harbor, Santa Cruz Island, CA. Each cage (1x1x0.4m) will be constructed from rebar and mesh and placed at a depth of 7m, spaced 5m apart to avoid cue dispersal between treatments. To calculate the relative *per capita* non-consumptive interaction strengths in edges 1-5 (Fig. 1), I will

orthogonally manipulate the presence of one or two predator species (*S. pulcher* or *P. interruptus*) across three combinations of grazers (20 *S. purpuratus*, 20 *M. franciscanus*, or 10 *M. franciscanus* and 10 *S. purpuratus*), each with 1kg (wet weight) of *Macrocystis pyrifera* (9 treatment levels, 3 predator-absent controls). To prevent predators from consuming urchins, I will remove lobster palps and will use 30cm sheephead, which are too small to effectively prey on urchins. Daily rates of algal depletion will be recorded by wet weighing algae over a week-long period, each replicated eight times. The results of this experiment will yield a *per capita* interaction strength function based on the presence of a predator or predators in a community.

Hypothesis 2: *A direct consumptive interaction will have indirect effects on the behavior of other prey (i.e., flee response to death of a conspecific or heterospecific) that will influence the productivity of a primary producer.* **Methods:** Building on H1, I will examine non-consumptive interactions 6-8 (Fig. 1) by measuring the indirect behavioral response of grazers to a consumptive interaction. A single urchin will be crushed (mimicking a predation event) within each combination of grazers (three treatment levels) to quantify the behavioral response of prey to the death of a conspecific and heterospecific, each replicated eight times. Results from this experiment will be compared to H1 to determine whether predator scent cues or predation cues (i.e., death of an individual) elicits stronger behavioral response interaction strengths.

Hypothesis 3: *The development of a non-consumptive interaction model with varied interaction strengths will markedly advance our ability to accurately predict ecological networks.* **Methods:** In 2023, I will develop a dynamic 4-species network model that evaluates the sensitivity of trait-mediated effects on the productivity of a foundational species (kelp). A simulated Lotka-Volterra stochastic community model derived from the empirical interaction matrix (Fig. 1) will be used to identify extinction risk of kelp under varying degrees of trait mediated interaction strengths. The model will be validated through a combination of UCSB's long-term monitoring data paired with ecosystem surveys designed to evaluate model robustness. These results will be used to predict multispecies community function and dynamics across trophic levels.

Intellectual Merit: The empirical evaluation of non-consumptive interaction strengths will reveal how trait mediated responses underpin community function and food web dynamics. The dynamic network model derived from this study will substantially improve predictive capacities of ecosystem resiliency by increasing the accuracy in predictions of interaction strengths.

Broader Impacts: The broader impacts of this research are three-fold: (1) Advancing understanding of the mechanisms that underpin food web dynamics and providing a robust framework for future studies to accurately predict how trait-mediated responses manifest throughout ecological networks; (2) Increasing public engagement in science through interactive modules at UCSB's Research Experience and Educational Facility's (REEF) education and outreach center. I will design interactive learning modules at the center that explore direct and indirect species interactions. A digital learning station will feature an interactive trophic network program that will allow users to manipulate species interaction strengths to explore how changes are manifest throughout the entire ecosystem; and (3) Promoting interdisciplinary education by partnering with the National Center for Ecological Analysis and Synthesis (NCEAS) at UCSB to develop ecological modeling workshops and short courses targeted for undergraduate students to enhance their computational skillset. The single disciplinary scientific approach is antiquated; to continue the advancement of science we must start training the next generation of scientists to become multifaceted and well-versed in interdisciplinary knowledge.

References: [1]Terborgh et al. 2001. *Science.* [2]Power et al. 1992. *Ecology*. [3]Terborgh & Estes. 2010. *Trophic Cascades.* [4]Sih et al. 2003. *Anim Behav*. [5]Gaynor et al. 2019. *TREE.* [6]Brown et al. 1999. J Mammal. [7]Estes et al. 2011. *Science*. [8]Schmitz et al. 1997. *Ecology*. [9]Pessarrodona et al. 2019. *Ecology.* [10]Graham MH. 2004. *Ecosystems.* [11]Wootton, JT. 1997. *Ecol Monogr*.

EARLY DRAFT

Nolan Smyth **Personal, Relevant Background, and Future Goals** GRFP 2020

Opening Paragraphs

I was homeschooled from day one. During the brief interludes between playing guitar and exploring the woods behind my house, I found time to teach myself math from pre-algebra to calculus. My first day of school was at Middlesex Community College where I pursued an associates in Liberal Arts and Sciences and founded the Math Club. After two years, I applied for transfer and was accepted as a Benton Scholar at Colgate University. Coming from a rural, isolated town where the vast majority of my education was self-directed, I couldn't believe how many opportunities I was suddenly exposed to. In my first year, I took a class on the atomic bomb. The Benton Scholars program provided the funding to travel to Japan and talk firsthand with Hibakusha, atomic bomb survivors. This experience left me with a deep appreciation for the power of physics to shape our world in ways that are both awesome and terrible.

Up until this point I had never so much as drawn a free-body diagram. Now I was ravenous. I took every physics class I could. In my junior year, I studied abroad at King's College in London where I took a General Relativity course and had my first genuine encounter with black holes and dark matter; I had found my calling. I returned to Colgate my senior year to find the department had hired its first professor to specialize in dark matter research. Without hesitation, I chose to do my senior project with the new hire, professor Walter Tangarife.

Early in my research, I encountered a book titled *An Introduction to Particle Dark Matter* by professor Stefano Profumo. I found it invaluable. A quick search revealed he was a professor at the University of California - Santa Cruz. I knew of UCSC's fantastic reputation for space science, and found out that its research influence is tied with that of Stanford. Recognizing the incredible potential for mentorship and research impact, UCSC became my top choice graduate program. With one year behind me, I've already had the opportunity to work with some of the best minds in dark matter research and I couldn't feel better about my decision to study at UCSC.

Intellectual Merit

My first exposure to research in physics was over the summer after my 2nd year at Colgate. I worked with professor Jonathan Levine on the development of an in-situ mass spectrometer capable of spaceflight which can determine the age of rocks on the surface of other planetary bodies. My goal in particular was to improve the accuracy of our dates. I approached this by writing clustering algorithms, isolating qualitatively distinct groups of points in our data. This led me to discover instrumental error in the laser ablation process which was skewing our data. After correcting this error, we were able to obtain our most accurate results to date. My research was presented at the 48th Lunar and Planetary Science Conference[1]. I also presented the same research in the form of a poster at the NY6 Undergraduate Research Conference[2]. That summer, I gained valuable coding, data analysis, and presentation skills. But I also realized that I wanted to explore other branches of physics.

The General Relativity and Cosmology class I took my junior year first sparked my interest in dark matter and black holes. My fascination only grew as I started working with professor Tangarife on my senior project: Fuzzy Cold Dark Matter. This was my first exposure to quantum field theory, a course which is not offered at Colgate, and a great opportunity to expand my research toolkit. Using the skills I developed through this project, we showed that this model was able to successfully solve the outstanding "cusp vs. core" problem in dark matter. I presented this research in talks at Colgate

University[3,4], the University of Rochester[5], and Syracuse University[6]. My achievements were recognized with the Amato and Aveni Award for excellence in scientific research and I was invited to develop my project into an honors thesis. Along the way, I was given the Dean's Award with Distinction every semester, managed to improve my GPA *every single semester*, received the Benton Scholars Award, was inducted into the Sigma Pi Sigma Physics Honor Society, and graduated Summa Cum Laude with Honors in Physics.

After graduating, I interned at NASA's Goddard Space Flight Center. I worked with Dr. Lynn B. Wilson III researching the mechanism for electron acceleration in the Earth's foreschock. My role was to analyze large data sets taken from the THEMIS mission. At first I was able to get by with the coding experience I gained during my research at Colgate, but the work was tedious. This completely changed in the middle of my internship**.** I attended a coding bootcamp and a workshop on machine learning that completely revolutionized my approach. I had used basic machine learning principles before, but I realized I had only been scratching the surface as I began applying my newfound skills. Soon after, I could automatically identify all of the events we were searching for within a given data set. A process that had previously done by hand (at the expense of many previous interns) could now be done in seconds. Along the way, I was able to convince several of my fellow interns to implement these ideas into their own research with equally fantastic results. I presented my research in the form of a poster at the NASA Goddard Summer Research Symposium[7] and left with another tool in my kit.

My latest research began in my first quarter at UCSC. While attending Dr. Profumo's weekly group meetings, I learned of a paper which placed constraints on primordial black holes as dark matter. My interest was piqued and I started meeting with Dr. Profumo to discuss this work. We quickly realized that the results of the paper couldn't be correct so I set out to do the calculation properly. Using the techniques I learned during my time at NASA, and many new skills I developed through this research, I was able to address the critical omissions of the previous work. My preliminary results have already been presented at high-impact dark matter workshops[8,9] and I have a first-author publication in review with Physical Review Letters showing the most up-to-date constraints on primordial black holes as dark matter[10].

Broader Impacts

In my senior year at Colgate, I decided I wanted to build a stronger community within the physics department. Until that point, the physics club had been inactive for years and I decided to revive it in full force. In my year as president, we held meetings to share opportunities for undergraduate research, hosted GRE and grad school application help sessions, had weekly tea where students had the space and audience to present their latest research, and scheduled time for the weekly colloquium speakers to talk with club members. We also hosted larger events for the school and community as a whole. The General Relativity course that first sparked my love of black holes and dark matter was taught by one of Sean Carroll's former graduate students. Using this connection, I reached out to numerous STEM departments, the philosophy department, and student affairs and was able to raise the money to bring Sean himself to Colgate. Sean gave an interdisciplinary talk on the value of physics to hundreds of students and community members. I also scheduled meals where students could talk with Sean in an intimate setting. Of course, during his visit, I took every opportunity to pick his brain about all things black holes. Seeing the benefits of a thriving physics club, I resolved to not simply leave it in pieces that may not be reassembled in future years. I set up the infrastructure for the club to continue to grow, holding elections for necessary positions and scheduling events for the following year. I'm proud to say that the club is still going strong.

That same year, I worked with professor Karen Harpp on revamping the atomic bomb course I took my first year at Colgate. I wrote assignments, designed and built hands-on demonstrations, and gave lectures on the physics behind the bomb. But perhaps my biggest contribution was developing

an online component to the course. We created a space where alumni could watch the course lectures, follow along with assignments, and most importantly, engage in truly meaningful discussion with the students. I recruited over 70 alumni and acted as their liaison as they discussed and debated with the class throughout the semester. The students talked about the Doolittle Raid with General Doolittle's cousin, discussed the impact of Chester Nimitz's strategy in the pacific with the Admiral's own grandson, and debated the role of nuclear weapons with scientists who worked at Los Alamos and Hanford. I also helped organize a field trip to Washington DC to meet with nuclear weapon engineers at the National Nuclear Security Administration and directors of the Arms Control Association. It was for this work that I received the Benton Scholars award for outstanding global awareness, leadership, and academic achievement. I also worked with my friend on designing a program which scraped the website for all of the content and surrounding discussion any given student or alumnus produced. All of this information was then compiled and available for that student to download. This gave them ownership of their data and a record of their work which they could reference long after the course ended.

At UCSC, I have truly dedicated myself to improving the physics experience. My first quarter, I took a pedagogy course which trained me in the topics of classroom climate, inclusivity, and active learning. I make a point to know all of my 44 students by name each quarter, rework laboratory experiments to maximize understanding, and create a space where students feel like *they can do physics*, especially if they're accustomed to feeling like it's out of reach. This year, we made a website where physics graduate students share the assignments and materials they've created. This allows me to share the best of all the thought and effort I've put into my teaching with all current and future physics TAs.

I am a strong advocate for improving the presence of underrepresented groups in physics. This year at UCSC, the APS was invited to conduct an on-site evaluation to address the lack of diversity and climate of the department. After meeting with the committee and encouraging all of my fellow students to do the same, we received a report containing specific actionable steps to take. One of the primary recommendations was to improve our prospective graduate student visit day. I was part of a group of students that met with our graduate program coordinator, rethinking every aspect of the visit. Rather than simply scheduling hours of lectures, we organized a poster session where prospectives could talk with their potential peers about what the graduate experience is really like. Instead of hiding our lack of diversity, we acknowledged the state of our demographics and explained the steps we were taking to make lasting improvements. The outcome was phenomenal. The year above me had no female physics grad students. My year had one. This year we have ten female graduate students and the best showing of underrepresented economic and ethnic groups in the department's history.

Future Goals and Action Plan

I genuinely believe that anyone who wants to do physics can do physics. My goal is to give students of all backgrounds the tools they need to succeed. At the same time, I care deeply about my own growth; I have and will always have the drive to learn more, to understand more deeply, to confront my own convictions viciously and repeatedly. To meet both of these needs, one path stands out above the rest. I will become a professor so that I may work with the most extraordinary objects in the universe: dark matter, black holes, and people.

To help me achieve this goal, I am currently enrolled in UCSC's Diversity & Inclusion Certificate Program. Through the program, I'm developing practical skills to promote equity and inclusion both in and out of the classroom. This year, I will take part in UCSC's Professional Development Program where I will further develop my project management and pedagogical skills while strengthening my application to postdoctoral and professorial positions. I will also complete the

Graduate Student Leadership Certificate Program which will enhance my abilities in leadership, conflict resolution, and collaborative teamwork. In the following year, after completing the Personal Development Program, I will have a very competitive application for the Graduate Pedagogy Fellows program. Through this program, I will have the opportunity to design a TA training program for my peers, fostering an entire department staffed with effective and inclusive teachers.

UCSC is the perfect place for me to grow as a researcher. Our department boasts the highest citation rate of any physics department in the United States. I also regularly work with professors and grad students from UCSC's top-ranked astronomy department. And the proximity to Stanford, UC-Berkeley, and the SLAC national laboratory makes UCSC a hub for collaboration.

The GRFP would allow me to focus all of my effort on research, mentorship, and personal development. Without the considerable time commitment of a teaching assistantship, I can fully dedicate myself to the programs listed above without sacrificing my research. This, in turn, means that my research will have the depth needed to generate more projects for mentees and more high-impact papers.

References: [1]F.S. Anderson, Jonathan Levine, **Nolan Smyth**, Michelle Tebolt, and T.J. Whitaker, *Multianalytical Science with the CODEX In-Situ Dating Spectrometer* [2]Nolan Smyth, *Supporting the development of an in situ dating mass spectrometer*. Poster presented at: New York Six Liberal Arts Consortium Undergraduate Research Conference. 2016, September 17; Hamilton College, Clinton, NY [3]Nolan Smyth, *Fuzzy Cold Dark Matter*, Talk given at: Colgate University Department of Physics and Astronomy Senior Research Symposium. 2017, December 13; Colgate University, Hamilton, NY [4]Nolan Smyth, *Aspects of Fuzzy Cold Dark Matter*, Talk given at: Colgate University Department of Physics and Astronomy Honors Research Symposium. 2017, December 13; Colgate University, Hamilton, NY [5]Nolan Smyth, *Aspects of Fuzzy Cold Dark Matter*. Talk given at: Rochester Symposium for Physics Students. 2018, April 7; University of Rochester, Rochester, NY [6]Nolan Smyth, *Fuzzy Cold Dark Matter*. Talk given at: Syracuse University Undergraduate Research Day. 2017, November 4; Syracuse University, Syracuse, NY [7]**Nolan Smyth**, Lynn B Wilson III, *Unsupervised machine learning as a tool for understanding foreshock acceleration*. Poster presented at: 2018 Summer Intern Poster Session. 2018, August 1; NASA's Goddard Space Flight Center, Greenbelt, MD [8]Stefano Profumo, **Nolan Smyth,** *Asteroid-mass primordial black holes as dark matter*. Talk presented at: Search for Dark Matter Workshop. 2019, September 11; Galileo Galilei Institute for Theoretical Physics, Firenze Fl, Italy [9]Stefano Profumo, **Nolan Smyth,** *Asteroid-mass primordial black holes as dark matter*. Talk presented at: Leaving No Stone Unturned Workshop. 2019, August 7; University of Utah, Salt Lake City, UT [10]PRL PAPER GOES HERE

I was homeschooled from day one. During the brief interludes between playing guitar and exploring the woods behind my house, I found time to teach myself math from pre-algebra to calculus. At 16, I had my first day of school. I started taking classes at Middlesex Community College where I founded the Math Club. After two years, I applied for transfer and was accepted as a Benton Scholar at Colgate University on a Pell Grant. Coming from a rural, isolated town where the vast majority of my education was self-directed, I couldn't believe how many opportunities I was suddenly exposed to. In my first year, I took a class on the physics and politics behind the development of the atomic bomb. That summer, the Benton Scholars program provided me with the opportunity to travel to Japan and talk firsthand with Hibakusha, atomic bomb survivors. **I was left with a deep appreciation for the power of physics to shape our world and its inhabitants in ways that are both awesome and terrible.**

Though I had never so much as drawn a free-body diagram, I was suddenly ravenous. I took every physics class I could, including a cosmology course where I had my first real encounter with black holes and dark matter; I had found my calling. **Eager to learn more, I chose to do my senior thesis on dark matter.** Early in my research, I encountered a book titled *An Introduction to Particle Dark Matter* by Prof. Stefano Profumo. I found it invaluable. A quick search revealed Prof. Profumo taught at the University of California, Santa Cruz. Recognizing the incredible potential for mentorship, research impact, and resources to help me become a professor in the UC system, UCSC became my top choice graduate program. Now with one year behind me, I've already had the opportunity to work with some of the best minds in dark matter research and I couldn't feel better about my decision to study at UCSC.

Intellectual Merit (relevant background)

Before I fully immersed myself in dark matter research at UCSC, I explored several avenues of physics and honed my research skills. My first research experience was at Colgate where I worked on improving the accuracy of a mass spectrometer capable of determining the age of rocks on other planetary bodies. I approached this by writing clustering algorithms, isolating qualitatively distinct groups of data points. I discovered instrumental error that was skewing the data, corrected the error, and obtained the most accurate ages ever achieved by this type of mass-spec. **I presented a poster of my findings at the NY6 Undergraduate Research Conference and I co-authored our results that were presented and published at the Lunar and Planetary Science Conference[1].** That summer, I gained valuable coding, data analysis, and presentation skills. But I also realized that I wanted to explore other branches of physics.

As part of this exploration, I took a General Relativity and Cosmology course where I made one of my most important discoveries to date: I'm obsessed with dark matter. This obsession turned into my senior thesis. Working with Prof. Walter Tangarife, I showed that the Fuzzy Dark Matter model successfully solved the outstanding "cusp vs. core" problem. **I shared my findings through oral presentations at three undergraduate research conferences and was invited to develop my project into an honors thesis, for which I received the Joseph C. Amato and Anthony F. Aveni Award for excellence in scientific research.**

After graduating s*umma cum laude*, I interned at NASA's Goddard Space Flight Center with Dr. Lynn B. Wilson III. We searched for events in the Earth's magnetosphere that produce electrons with enormous energies. This involved tedious analysis of very large data sets, a process done by hand at the expense of many interns. Early on, I attended a workshop on machine learning that completely revolutionized my approach. Applying my newfound skills, I could automatically identify all the events we were searching for. Days of work could now be done in seconds. I helped many of my

fellow interns implement these ideas into their own research with equally fantastic results. **I presented my research in the form of a poster at the NASA Goddard Summer Research Symposium and left with another tool in my kit.**

At UCSC, I returned to my dark matter obsession. While meeting weekly with Prof. Profumo, I read a paper that placed constraints on primordial black holes as dark matter. I quickly realized that the results of the paper couldn't be correct, so I set out to address the critical omissions. By creating accurate stellar population models and addressing the finite size effects of microlensing, I showed that their constraints were off by *three orders of magnitude*. Prof. Profumo has presented my results at high-impact dark matter workshops and **I have a first-author publication submitted for review with Physical Review Letters showing the most up-to-date constraints on primordial black holes as dark matter[2].**

Broader Impacts (relevant background)

Atomic bombs are merely abstract scientific achievements until you hear what it's like to have one detonate above your hometown. While this is an extreme example, it illustrates a simple but profound message: **physics changes lives.**

To spread this message and build a stronger physics community, **I took the Colgate physics club, which had been inactive for years, and revived it in full force.** As president, I organized weekly meetings with colloquium speakers and created opportunities for students to share their research. I also created the infrastructure for the club to sustain and grow in future years, which I'm proud to say it has. And at every step, I connected physics and people's lives. For example, I brought bestselling author and theoretical physicist Prof. Sean Carroll from CalTech to give a talk to hundreds of students and town members on how physics shapes the human experience.

Working with Prof. Karen Harpp, I revamped the atomic bomb course I took my first year at Colgate. I designed hands-on demonstrations that connected the science, politics, and ethics of the bomb and how it shapes nuclear policy today. I created an online platform for the course, recruited over 70 influential alumni, and acted as their liaison as they conversed with the class. The students discussed the impact of Chester Nimitz's strategy in the pacific with the Admiral's own grandson and debated the role of nuclear weapons with engineers at the National Nuclear Security Administration on a trip to D.C. that I organized. **It was for this work that I received the Benton Scholars award for leadership and outstanding global awareness.**

At UCSC, I continue to connect physics and people at UCSC through exceptional teaching and leadership. My first quarter I took a pedagogy course that trained me in classroom equity and active learning. I compile the assignments and materials I create as a TA and upload them to the department website so current and future TAs can benefit from the thought and effort I've put into my own teaching. **I will continue building this collection as I gain more pedagogical experience with the goal of making it a resource that TAs can draw from and contribute to as an integral part of the TA workshop series I will design (see future goals).**

This year, the American Physical Society conducted an on-site evaluation to address the lack of diversity in the UCSC physics department. Their major concern was that the prospective student visit day seemed unwelcoming, especially to diverse groups. I joined a small team of grad students and the grad program coordinator, rethinking every aspect of the visit. Rather than scheduling hours of lectures, we organized a poster session where prospectives could talk with their peers about what the graduate experience is really like, and I also arranged a beach walk where visitors had a chance to make connections with current students and each other. These changes made the visit more personal, more welcoming, and led to a phenomenal outcome. The year above me has no female physics grad students. My year has one. **The incoming year has ten female graduate students - more than doubling the program's number - and the best showing of underrepresented economic and ethnic groups in the department's history.**

Future Goals and Action Plan

UCSC is the perfect place for me to become an expert in the field of dark matter. The physics department boasts the highest citation rate of any in the US and I conduct research with Prof. Profumo, who literally wrote the book on particle dark matter. But I also understand the importance of broader collaboration. If selected as a GRFP fellow, I will take advantage of the GROW program and intern at the Kavli Institute at the University of Tokyo, which produces cutting edge dark matter research, including the work that sparked my most recent paper.

While growing as a researcher, I want to develop my pedagogy and give students of all backgrounds the tools they need to succeed. That is why I enrolled in UCSC's Diversity & Inclusion Certificate Program. Through the program, I'm developing practical skills to promote equity and inclusion. This year, I will also complete the Graduate Student Leadership Program and the Professional Development Program (PDP), further cultivating my leadership skills. **After completing the PDP, I will have a competitive application for the Graduate Pedagogy Fellows program (GPF) thorough which I will develop series of TA training workshops.**

Prior to my year, incoming physics grad students received absolutely no TA training. Although my class was the first to receive a series of TA workshops, the information was vague and inapplicable to first year TA positions. Using my leadership and pedagogical training, I will take advantage of the existing infrastructure and create a TA workshop series for incoming physics grad students. **Through these workshops, I will help TAs design assignments, rubrics, and feedback metrics that are particular to their position and are based on active learning and inclusive practices.** They will then contribute their best work to the online collection I've created. This will foster a department staffed with effective and inclusive teachers who have access to a shared resource of meaningful and specific pedagogical material.

When I started community college, I didn't expect to earn a bachelor's degree, but I had strong mentors who encouraged me to advance to higher levels of education. To ensure this path is available to all students who wish to take it, I'm joining the Cal-Bridge initiative, mentoring CSU and community college students. In this role, I will advance the Cal-Bridge mission of increasing the number of students from underrepresented groups graduating with a physics degree. I've also joined the Society of Physics Students (SPS) mentoring program, which creates support and research opportunities for students from diverse backgrounds by pairing grad students with undergrads. However, there aren't enough mentors to meet the current demand, and the ones who join receive no mentorship training. **That is why I will develop mentorship training workshops through SPS that will fill the gap by training upper division undergrads and grad students.** These peer mentors will learn how to provide pedagogically minded support and craft projects that are both achievable and beneficial for their mentees. Many senior undergrads are already involved in research and thus have opportunities to involve other students. In addition to helping the mentees, the mentors will gain valuable experience that will greatly benefit them when applying to grad school or other employment.

After completing a postdoc at a UC with a strong dark matter focus and exceptional future faculty development programs, such as UC Irvine where I already have collaborators, I aspire to return to the UC system in a professorial role. The UC system provides some of the finest public higher education in the world, produces high-impact research, and has the best track record of graduating first-generation and low-income students. **It is here that I hope to continue working with the most extraordinary objects in the universe: dark matter, black holes, and people.**

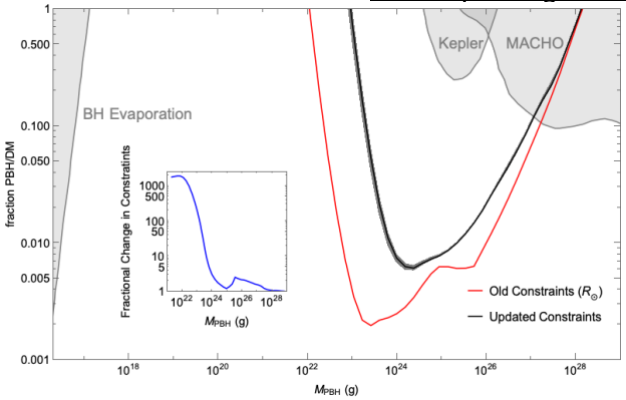
References: [1]Anderson FS, Levine J, **Smyth N**, Tebolt M, Whitaker TJ. 48th Lunar and Planetary Science Conference. 2017; The Woodlands, TX. [2]**Smyth** et al. arXiv:1910.01285. Physical Review Letters (in review).

Ignoring the Dark Elephant in the Room - Microlensing Constraints of Primordial Black Holes

Despite the fact that dark matter (DM) accounts for 5 times more of the universe than does baryonic matter, we know far less about the former than we do the latter. Countless models have been proposed, the most notable being the Weakly Interacting Massive Particle (WIMP), that attempt to explain DM. **But after decades of fruitless searches for the WIMP and other similar particles, it is necessary to explore more promising DM candidates.** Primordial Black Holes (PBHs), black holes that formed from density perturbations in the early universe, are compelling candidates because they could account for DM without invoking beyond-standard-model physics (except for gravity) and their existence is motivated by various inflation models[1,2].

It is possible that PBHs make up 100% of the dark matter if massive enough to survive Hawking radiation[3]. But previous constraints of PBHs have been found to be inaccurate[4,5]. **This must be remedied because it is necessary to have accurate constraints when deciding how we design, build, and point our telescopes.** Without this knowledge, we could be ignoring the most worthwhile areas of research in this field. And with breakneck advancements in instrumentation, we will soon be able to probe PBHs in ways that were previously unfeasible, making this the perfect time to take a new approach to studying this promising model.

Aim: Updating and Innovating Microlensing



Improvements in cadence and resolution make it possible to simultaneously observe millions of individual stars, almost the entirety of Andromeda (M31). **Using such observations from the Hyper Suprime Cam (HSC) and accurately modeling the stellar population of M31, I have placed the most up-to-date constraints on PBHs as dark matter, as shown in the included figure[6].** These constraints come from gravitational lensing, the phenomenon of light bending through spacetime curvature, which is a powerful tool for observing dark, massive objects. When an asteroid-mass PBH passes in front of a star, its gravity will cause that star to be temporarily magnified. This type of event, called microlensing, can be detected by monitoring the change in magnitude of a light source over time. But there is much more to uncover.

There is strong evidence to suggest that dark matter is "clumpy," yet the current literature assumes a smooth density profile that we know to be incorrect in many cases[7]. Additionally, the previous constraints assume the same source position for every star in M31. Considering the radius of M31 is ~70 kpc and the distance to M31 is ~700 kpc, this could result in as much as ~20% error in the distance estimation of each star. **I intend to correct the constraints even further by considering a more realistic density distribution and using the Panchromatic Hubble Andromeda Treasury catalog to determine significantly better estimates for the distance to source stars.**

By accurately accounting for the instrumental limitations of the HSC and constructing the first representative distribution of stars conducive to microlensing detections, I have shown in my recent paper that PBHs are currently completely unconstrained in a large region of parameter space[6]. **Constraining PBHs in this region will require a novel and creative approach to microlensing, which I propose to do by observing new sources with new methods.**

Current microlensing searches are most sensitive to large, high-luminosity, off-main-sequence stars. But when the size of a source in the plane of a lens is larger than the Einstein radius of that lens, the maximum magnification is severely diminished, making present searches incredibly inefficient. Moreover, the wave nature of light also restricts current observations[8]. This is because the magnification of a source is acutely limited when the wavelength of light being lensed is comparable to the Schwarzschild radius of the lensing PBH[9]. By isolating sources that emit high-frequency light, such as X-ray binaries and pulsars, we can more effectively probe low-mass PBHs. The difficulty arises from the low number density of these objects compared to that of main sequence stars. **Making significant constraints from such objects requires long duration observations so selecting the optimal survey method is crucial.**

One promising avenue is the Large Synoptic Survey Telescope (LSST). Once operational, LSST will completely map the sky every three nights with the largest digital camera ever constructed, the development of which is being led at UCSC[10]. With first light of LSST expected in 2021, this is the perfect time for me to contribute to the determination of the most advantageous observation strategies and be primed to take full advantage of the ~1.3 petabytes of data LSST will collect each year. LSST will observe each patch of sky over 1000 times during the 10-year survey, providing the long duration observations needed to make significant constraints. These aspects make LSST ideal for cataloging transient events, such as microlensing. I will also take more observations with the HSC using a shorter wavelength filter. This will mitigate the wave effect described above by preferentially selecting white dwarfs, which emit shorter wavelength light. These stars are quite small and thus the finite size effect would also be lessened. **By addressing both the wave and finite size effects simultaneously, I will fill the existing void in microlensing constraints.**

Intellectual Merit

My research in microlensing not only advances our knowledge of PBHs, but applies to other macroscopic, compact dark matter candidates, such as dark stars, strangelets, and axion mini clusters. It also informs the cosmological simulations that impact the entire fields of astronomy, cosmology, and high energy theory. **This, in turn, influences DM model building and determines what phenomena we search for in our astronomical observations.**

The previous literature on PBHs is considerable but does a poor job of correctly merging theory and observation. By accounting for the true stellar population and DM density profile of our targets and calculating the corresponding finite size and wave effects, **I will innovate our microlensing models and accurately apply theoretical calculations to realistic systems for the first time.** Armed with this knowledge, I will pursue new observation strategies and pave the way for future work.

Broader Impacts

Advancing our knowledge of the cosmos has always been one of humankind's greatest endeavors. **An explanation for dark matter would shake the core of every person, scientist or not, because understanding the universe is a crucial part of appreciating our place in it.**

Black holes are among the most mysterious objects in the universe. They can captivate a wide audience and spark a fascination in young scientists. **I will use this fact in my outreach to create interest and opportunities for students of all backgrounds to conduct their own research through my initiatives with Cal-Bridge and the Society of Physics students, which I describe in my personal statement.**

References: [1]Inomata et al. Phys. Rev. D 2018. [2]Katz et al. J. Cosmol. Astropart. Phys. 2018. [3]Carr et al. Phys. Rev. D 2010. [4]Montero-Camacho et al. arXiv:1906.05950, 2019. [5]Niikura et al. Nat Astron, 2019. [6]**Smyth et al.** arXiv:1910.01285. [7]Kuhlen et al. J. Phys. Conf. Ser. 2008. [8]Nakamura T, Deguchi S. Prog Theor Phys 1999. [9]Matsunaga N, Yamamoto K. J. Cosmol. Astropart. Phys. 2006. [10]Ivezic et al. ApJ 2019.

EARLY DRAFT

Theresa-Anne Tatom-Naecker **Personal, Relevant Background, and Future Goals** GRFP 2020

Introduction

In 2006, Al Gore released 'An Inconvenient Truth' and, at eleven years old, I became aware of the damage humans were inflicting on our planet. The collapse of Earth under the weight of climate change, pollution, and other anthropogenic threats felt very imminent and almost impossible to stop, and as an eleven year old already prone to anxiety, I felt helpless and terrified. I was especially worried about changes in the ocean and the effects on the animals living within it, animals that had fascinated me since I was young. My terror lessened as the immediate impact of the film faded, but my concern and my feeling of helplessness continued until, during 9th grade Biology, I learned how scientists were using research and education to address anthropogenic effects. I was determined to join them, to combine my persisting curiosity about marine animals and my concern for the ocean, and that goal has driven my actions and informed the opportunities that I have sought ever since.

Now, as a second-year Ph.D. student at the University of California Santa Cruz (UCSC), I am studying feeding and foraging behavior in bottlenose dolphins (*Tursiops trauncatus*) in order to ensure the health of wild and managed animal populations and inform resource management and policy concerning commercial and recreational fishing, pollution runoff, and climate change. I am honing the skills necessary for my intended career as a marine scientist in a government agency or a non-profit and a university-affiliated researcher and lecturer. During my Ph.D. and afterwards, I will work to educate, inform and inspire through my research, public outreach, and teaching and mentoring in order to fulfill my ultimate goal of working to conserve the world's oceans.

Developing Intellectual Merit: *Getting my feet wet*

Driven by my goal of being a research scientist and following my persisting interest in animal behavior and the marine environment, I joined Dr. Mark Westneat's lab at the University of Chicago (UChicago) during my sophomore year of undergraduate, remaining until I graduated. I studied the biomechanics, kinematics, and associated morphology of sand-diving behavior in wrasses (family Labridae). Sand-diving fish use a quick and forceful headfirst plunge into the substrate followed by undulatory body movements to conceal themselves beneath the surface, to avoid predators and rest under the sand at night. Following field and laboratory observations of sand-diving, I hypothesized and showed that the behavior is composed of two distinct phases; the fish fluidizes the substrate in the first phase with high frequency, low amplitude undulations and then enforces itself into the bottom with low frequency, high amplitude movements. I compared labrid fish specimens and found trends in morphological features that could contribute to burrowing ability, and used an ancestral state reconstruction made by members of Dr. Westneat's lab to show the evolutionary history of sand-diving behavior. I compiled this research in my senior thesis, and in September 2018, I published my findings with Dr. Westneat in the Journal of Fish Biology[1]. I also presented my findings on several occasions, most notably at the Society for Integrative and Comparative Biology's January 2016 meeting. This research experience increased my familiarity with the experimental process, analyzing animal behavior, and writing and speaking clearly and with impact.

In order to experience research in an aquarium setting and participate in public outreach educating and inspiring passion for conservation and the ocean, I worked as an Animal Husbandry and Education intern at the Woods Hole Science Aquarium the summer after my junior year. Daily husbandry of fish, invertebrates, and two harbor seals familiarized me with caring for managed

animals, evaluating behavior, and conducting small research projects, while working in a team of interns strengthened my ability to be both a leader and a team member. Concurrently, I led aquarium tours and twice-monthly beach collecting walks and interpreted at the touch pool, developing my capacity for public communication and educating audiences diverse in age and background. The most transformative part of the internship, however, came during our whale-watching trip. For the first time outside of books and nature documentaries, I saw humpback whales bubble-net feed and dolphins disband and regroup in synchrony, and I was filled with questions. Afterwards, I spoke to National Oceanic and Atmospheric Administration (NOAA) scientists who described marine mammal-human conflict—in shipping lanes and on beaches, over food and habitat—and how research on marine mammal behavior was informing policy and education efforts. I had found animals whose behaviors inspired me to think and question and whose charisma garnered public attention and concern, and I saw that I could contribute to my goal of broader ocean conservation by focusing on research and education to alleviate conflict between marine mammals and humans.

With my research goals focused on marine mammals, I knew that I needed to develop my skills in marine mammal research before pursuing the Ph.D. that would provide the experience, knowledge, and credentials necessary to fulfill my goals. Accordingly, the year after I graduated from UChicago, I worked as a research intern with the Sarasota Dolphin Research Program (SDRP) and the Pacific Whale Foundation. In the former, I contributed to long-term projects monitoring local dolphins and studying dolphin prey fish through boat-based photo-ID surveys and purse seine fishing; in the latter, I studied how boat traffic impacted humpback whale behavior using land-based theodolite surveys. During the internships, I improved my observational and camera skills, gained experience in marine mammal research methodologies and relevant computer programs like ACDSee and MS Access, and honed my ability to work accurately and collaboratively under pressure. Equally important, I saw close contact between dolphins, whales, and humans, and the potential for conflict—over boat traffic and human pollution of the oceans, and over prey fish and feeding areas—but also clear evidence of research into animal behavior informing management of marine mammal-human interactions.

Making a Broader Impact: *Inclusive and equitable teaching to spread passion and knowledge*

Entering UChicago with a core belief in the importance and power of education, I was determined to share the privilege of my education with others, spreading my passion for learning and for science. From the spring of my freshman year until my graduation in June 2017, I worked as a tutor and teaching assistant for science, math, and reading in a local Chicago public school, through the UChicago Neighborhood Schools Program. Navigating and adapting to the students' different learning styles, backgrounds, and motivations challenged me to think broadly and creatively in my communication and teaching methods, preparing me for a career educating diverse audiences. Simultaneously, I was driven to continue working in education by the students' perseverance in the face of racial and socio-economic challenges, their excitement for new ideas, and the joy and satisfaction brought by learning.

The students and my experience with them inspired me to participate in the UCSC Diversity and Inclusion Certificate Program (DICP) and the Institute for Science and Engineering Education Professional Development Program (ISEE PDP) during the first year of my Ph.D. Through the DICP, I explored the concepts of class, race, disability and sexual orientation, in relation to myself and to others, and considered their intersections with power, privilege and oppression, determining how I could support and create diverse, equitable environments. I built on those ideas and began acting on them during the ISEE PDP, where I discussed how to create inclusive and equitable environments focused on inquiry-based learning, how to design assessments that meaningfully evaluate my impact so that I can be more effective in the future, and how to adapt my teaching to different audiences and

situations. I put those ideas into practice in the spring of 2019, when I worked with two other graduate students to design and teach a two-day inquiry-based activity for undergraduates from underrepresented minorities to prepare them for a summer lab research experience. We focused on guiding the students in recognizing themselves as "STEM people," which research shows is a key component of persistence in STEM fields (e.g., Carlone and Johnson, 2007), and happens as students gain a sense of, and are recognized for, their competency in STEM practices, and when they can see how their existing abilities and interests are applicable and represented in the STEM field (Carlone and Johnson, 2007; Hazari et al., 2010). We facilitated an activity on antibiotics and the central dogma of biology in which students, working in small groups, carried out all the parts of the scientific process—making and testing hypotheses, interpreting data and making logical, clearly communicated conclusions, and presenting their findings in posters. Our students had the opportunity to feel and perform competency with scientific practices and to receive recognition for that from both their peers and us, the facilitators. In the surveys after the activity, students described "feeling like a scientist" and how much they enjoyed working through the steps of the scientific method and having to think and collaborate rather than being provided with the answers. I will continue to employ the skills and understanding that I developed during the ISEE PDP and the DICP as I work as a graduate student teaching assistant and lecturer for courses about ecology, evolution, and marine science, and a mentor for undergraduates (see Research Statement).

Combining Intellectual Merit and Broader Impacts: *Looking to the future*

My experience researching marine mammals and their interactions with humans, teaching in the Chicago Public Schools, through the ISEE PDP, and during public outreach, and learning from the DICP, has cemented my belief that carrying out solid scientific research and communicating it in equitable, inclusive environments to students of all ages is key for the future of our planet. It informs regulation by policy makers, motivates the public to care about and work to conserve the natural environment, and, most importantly, inspires students to see themselves as scientists, creating the next generation of problem solvers. My commitment to doing that research and communication work represents the foundation of my Ph.D. and my future career.

Under the direction of Drs. Dan Costa and Randy Wells, I am studying foraging and feeding in the population of resident bottlenose dolphins (*Tursiops truncatus*) that SDRP has studied since 1970. I am benefitting from the immense body of research and resources (e.g. power boats, audio recorders, equipment for tracking and fatty acid analysis) and extensive marine mammal research experience available to SDRP, Dr. Wells, and Dr. Costa and the facilities, coursework, and community of other students and researchers at UCSC. My research will contribute to the health of wild and managed dolphin populations and inform resource management and policy concerning commercial and recreational fishing, pollution runoff, and climate change.

For the last year, I have been a docent at UCSC's Seymour Marine Discovery Center, where I lead hour-long public tours for diverse visitors of all ages and interpret and discuss aquaria of local species and interactive dry exhibits, always working to highlight the role of research and education in understanding and protecting the marine environment. I will use my connection with Seymour Center staff and experience with the institution to collaborate with their School Programs department to develop an outreach program about marine mammals and the challenges they face as they come into conflict with humans with hands-on lab activities that can be tailored for different ages, sparking interest in marine science and conservation and the experience of doing the kinds of hands-on research that a scientist does. I would provide this program through the Seymour Center's Discovery Labs, which serve school groups of K-12 students from schools across Santa Cruz county, especially the primarily Hispanic-serving school districts outside of the city of Santa Cruz. I will continue to

refine the program following assessments derived both my own experience from the ISEE PDP and from collaboration with UCSC's Center for Innovations in Teaching and Learning.

From my research, internship, and educational experiences, I have learned the key role of both research and education in informing management of animal-human interactions and conservation of marine animals and the ocean environment. The NSF-GRFP Fellowship would allow me to contribute to both elements, as I conduct research on bottlenose dolphin feeding and foraging behavior that has implications for the health of wild and managed animal populations and resource management and policy concerning commercial and recreational fishing, pollution runoff, and climate change. In turn, my graduate education and experiences at UCSC will be the platform for a career as a marine scientist in a government agency or a non-profit and a university-affiliated researcher and lecturer, where I will work to educate, inform and inspire through my research, public outreach, and teaching and mentoring in order to fulfill my ultimate goal of working to conserve the world's oceans.

References: [1]Tatom-Naecker and Westneat. 2018. *Journal of Fish Biology*.

"The great aim of education is not knowledge but action," writes biologist and philosopher Herbert Spencer. Yes, it is the type of cliché statement found on motivational posters, but it hits home for me. In middle school, fascinated with marine life and angry over ocean degradation, **I set my sights on being a scientist whose marine research and teaching mitigated anthropogenic threats.** That goal in mind, I excelled as a student, amassing vast quantities of knowledge and vital skills in research and education. However, as I finished my junior year at the University of Chicago (UChicago), my efforts felt hollow. My impact as an educator had been limited, and I had no clear plan for turning my knowledge and skills into action.

I formulated that plan the summer after my junior year when I saw my first wild whales and realized cetaceans' dual role. As long-lived predators, cetaceans shape the marine ecosystem and are indicators of its health; as charismatic megafauna, they inspire conservation action. I realized that I could harness that dual role through a career as a scientist in a government agency like NOAA, at the interface of research, education, and policy. **By conducting cutting-edge cetacean research, I will inform policies that conserve cetaceans and their marine environment. Combining cetaceans' charisma with equitable and inclusive education, I will broaden STEM participation and motivate conservation action by the public and policymakers.** With my plan set, since graduating from UChicago I have sought opportunities, as a research assistant and now as a Ph.D. student, to prepare for a career where my pioneering research and equitable and inclusive teaching will have a lasting impact.

Intellectual Merit: Getting my hands and feet wet with innovative research

As an undergraduate at UChicago, I joined Dr. Mark Westneat's lab to build my research abilities. While studying sand-diving behavior in labrid fish, **I learned to turn my questions into testable hypotheses, to design innovative experiments, and to rigorously analyze and clearly present my results.** I used trigonometry and linear regressions to analyze high-speed video of sand-diving and showed that the fish fluidize the substrate, a biomechanical feat, before burying themselves. I revealed multiple evolutions of sand-diving behavior using an ancestral state reconstruction and identified shared morphological features that enhance sand-diving ability. **My research demonstrated the biomechanical capacities of labrid fish and sand-diving's widespread ecological significance.** I presented my findings at the Society for Integrative and Comparative Biology's 2016 meeting and in my senior thesis. **In September 2018, I was first author on the publication of my research in the Journal of Fish Biology[1].**

After graduating from UChicago, I focused on developing my cetacean research skills. As a research assistant with the Sarasota Dolphin Research Program (SDRP), which runs the world's longest continuous study of bottlenose dolphins, and the Pacific Whale Foundation (PWF), which studies five species of whales and dolphins, I gained research experience with multiple cetacean species. Collecting data on social and foraging behavior, and human interactions, I acquired photo identification and database management skills central to studying cetaceans. **My behavioral research augmented the SDRP and the PWF's long-term data sets, which are the focus of multiple publications each year and inform conservation policy worldwide.**

My insightful questions, productivity, and quick learning impressed Dr. Randall Wells, the SDRP's director, and he suggested I conduct my Ph.D. research with the SDRP, co-advised by Dr. Wells and his long-time collaborator Dr. Daniel Costa at UC Santa Cruz (UCSC). Drs. Wells and Costa are leaders in marine mammalogy, and the SDRP and UCSC are globally recognized for marine mammal research. **I knew that their guidance and resources would help me accomplish innovative and significant research, and I was accepted to UCSC that spring.**

As a first-year Ph.D. student, I immediately began conducting my thesis research and cultivating crucial research skills. **My dissertation will be the first validation in cetaceans of quantitative fatty acid signature analysis, a new diet determination method, advancing the study of cetacean diet and disturbance vulnerability worldwide** (see Research Statement). In spring and summer 2019, I collected key cetacean blubber and prey fish samples and applied biochemical analysis techniques (e.g., lipid extraction, FAME derivatization, GC-FID) to determine the samples' fatty acid signatures. I will analyze this first set of results this fall, and I will present my findings at the American Cetacean Society conference next year. As I conduct novel cetacean research, I am turning my knowledge and skills into actions with lasting impacts.

Broader Impacts: Advancing STEM participation through equitable and inclusive teaching

As an undergraduate at UChicago, I knew that education was vital to igniting a passion for learning, broadening STEM participation, and motivating conservation action, and I sought to build my teaching skills. For four years, I taught science, math, and reading at Bret Harte Elementary School, a Chicago public school where enrollment is 88% Black and only 40% of students meet state assessment expectations. As I advanced from tutor to teaching assistant (TA), I learned to ask questions instead of passively providing information, guiding students to talk through their confusion and actively deduce answers. My junior year, I was the only undergraduate TA for an upper-division biodiversity course, advancing my teaching experience to the collegiate level. While leading weekly labs, I used what I learned at Bret Harte to guide my students through formulating and testing hypotheses, deepening their understanding of the material. **Through these experiences, I developed active facilitation and inquiry-based teaching techniques, central elements of equitable and inclusive pedagogy.** However, my impact felt limited. I lacked the skills to fundamentally change student's learning practices, and though the contrast between UChicago's privilege and Bret Harte's struggle was striking, I was not equipped as an educator to diminish that gap.

Not satisfied with my impact, as soon as I started at UCSC, I honed my knowledge of equitable and inclusive pedagogy and the skills to turn that knowledge into action. **In the Diversity and Inclusion Certificate Program, I developed techniques to build inclusive environments that counteract disadvantages in power and privilege due to race, class, ability, or sexual orientation.** To supplement that learning and enhance my teaching abilities, I also participated in the UCSC Institute for Science and Engineering Education's Professional Development Program. **There, I learned to design inquiry-based curricula, to meaningfully assess student and teacher performance, and to adapt my teaching to diverse audiences.**

I applied my pedagogical knowledge and skills when I designed and taught a two-day inquiry-based workshop for undergraduates from underrepresented minorities in UCSC's Maximizing Access to Research Careers (MARC) program. While analyzing real data to determine how different antibiotics were targeting bacteria, students learned how genetic information is transcribed and translated into proteins and carried out key research practices, from making hypotheses to presenting posters. **In the assessment survey, students described feeling more confident using scientific practices and inspired to pursue research opportunities, demonstrating the workshop's value.** I provided the workshop curriculum to the MARC program to use again, and, this winter, I will work with UCSC's biology department to integrate the curriculum into lower division undergraduate classes like Cell and Molecular Biology, and Experimental Biology. As others teach this curriculum, it will educate and encourage STEM participation in more students than I could teach on my own. As I turn my pedagogical knowledge into action, I have begun maximizing my impact as an educator.

Looking to a Multi-Coastal Future: Combining Intellectual Merit and Broader Impacts

As a second-year Ph.D. student at UCSC co-advised by Drs. Costa and Wells, I am based in California but carry out my research in Florida with the SDRP. My ties to two coasts provide

unique access to the expertise and connections of two leaders in marine mammalogy, the resources and collaborative learning environments of two globally recognized marine mammal research institutions, and diverse teaching and outreach opportunities.

My Ph.D. research, the first-ever validation and application of quantitative fatty acid signature analysis in cetaceans, combines fieldwork, biochemical analyses, and quantitative modeling. During my Ph.D., I will build on my field- and lab-based skills and expand my expertise in statistical analysis, programming, and computer modeling. My graduate coursework will include Quantitative Ecology, and Experimental Design & Data Analysis, which teach advanced statistical analyses and methods for building quantitative models.

I am committed to broadening STEM participation through equitable, inclusive, and inquiry-based education, and I know that it requires teachers with pedagogical knowledge and the skills to implement it. Through the UCSC Center for Innovations in Teaching and Learning Graduate Pedagogy Fellowship, I will learn to create teaching trainings for graduate student TAs. Combining this preparation and my experience in equitable and inclusive pedagogy, I will design a workshop on recognizing privilege and power inequalities, and creating equitable and inclusive environments. With my department's support, I will integrate the workshop into existing yearly graduate student teaching trainings. **By helping others broaden STEM participation through their teaching, I will extend my impact and enhance my pedagogical knowledge and skills.**

Expanding my impact into the community, I will partner with UCSC's Seymour Center, where I am a docent, and Florida's Mote Aquarium, where the SDRP is based, to implement inquiry-based curricula informed by my research and tailored for K-12 students. Students will analyze how real cetacean diet data changes with disturbances, making science accessible and engaging, and fostering interest in conservation. I will train Seymour and Mote educators to teach the curricula in existing in-house outreach programs, which each year serve over 30,000 students from diverse communities. I will also provide the curricula in mobile classroom kits. I will refine the program following educator and student feedback from a formal assessment. **Combining cetaceans' charisma and inquiry-based education, I will reach diverse students on two coasts, motivating the next generation to pursue science and conservation.**

To complete my career preparation, I will conduct research in a government agency, learn how that research informs policy and conservation, and expand my professional network. Through the GRIP Program, I will conduct research with a marine scientist at NOAA like Dr. Elliot Hazen, a colleague of my co-advisor Dr. Costa, who studies the climate change vulnerability of top predators. After my Ph.D., I will obtain a government agency post-doc through the NOAA Sea Grant State Fellowship or the NRC Research Associates Program.

Obtaining a Ph.D. and completing a postdoc will hone my skills in innovative cetacean research and equitable and inclusive teaching, and prepare me for a career in a government agency like NOAA. As a government scientist studying cetaceans, I will conduct pioneering research, informing policy that conserves cetaceans and the marine ecosystem. I will also broaden STEM participation and motivate conservation action by combining cetaceans' charisma, effective education, and programs like NOAA's Education Outreach Center and their Educational Partnership Program with Minority Serving Institutions. **By harnessing cetaceans' dual role, I will finally turn my knowledge and skills into actions with lasting impacts.**

Reference: [1]Tatom-Naecker, T.M., & M.W. Westneat. 2018. Burrowing fishes: kinematics, morphology, and phylogeny of sand-diving wrasses (Labridae). *Journal of Fish Biology.* 93: 860-873.

Title: *Advancing the study of diet and disturbance vulnerability for cetaceans worldwide*
Background: Cetaceans increasingly face disturbances that disrupt their access to prey and have impacts ranging from changes in prey choice and feeding behaviors to diminished body condition, decreased fitness, and mortality[1,2]. Disturbance sources include harmful algal blooms, commercial and recreational fishing, and climate change, among others. To evaluate cetacean vulnerability and mitigate disturbance effects, it is critical to understand both baseline diet variation, which occurs under undisturbed conditions due to differences in demography (e.g., age, sex, maternal lineage, and habit use patterns[3]), and how current disturbances impact diet.

Since cetaceans are underwater predators, directly observing feeding is difficult and diet must often be estimated indirectly. However, traditional indirect methods like stomach content and stable isotope analyses have systemic weaknesses, such as determining only the most recent meal or revealing prey trophic level only[3,4]. Quantitative fatty acid signature analysis (QFASA) is a new indirect method that uses the fact that prey fatty acids are deposited in predator blubber with minimal structural change. QFASA estimates diet over several months and identifies prey species and their proportions in predator diet[5,6]. The QFASA model estimates diet by minimizing the statistical divergence between the actual fatty acid signature (FAS) of a predator's blubber and model FASs constructed from a "library" of prey fish FASs[5,6]. However, though the chemical analyses and modeling protocols are the same across species, QFASA requires taxon-specific calibration coefficients (CCs) to account for minor *in vivo* fatty acid modification due to predator metabolism[4,7]. CCs are estimated via controlled feeding studies lasting at least 5 months. Due to this constraint, cetacean CCs have never been calculated. Accordingly, QFASA has been used in pinnipeds and other marine animals but has never been validated or applied in cetaceans.
Objectives: To validate QFASA in cetaceans for the first time, significantly expanding its potential application, I will **(O1)** determine the first-ever cetacean CCs and **(O2)** validate that the QFASA model accurately estimates cetacean diet. To elucidate cetacean vulnerability and response to disturbance and inform studies of cetacean diet worldwide, I will **(O3)** use QFASA to determine baseline diet variation in common bottlenose dolphins (*Tursiops truncatus*, hereafter "dolphins") and how existing harmful algal bloom disturbances impact dolphin diet.
Study system: The long-term resident community of free-ranging dolphins in Sarasota Bay, Florida, and the dolphins under the joint care of the US Navy and the National Marine Mammal Foundation (NMMF) present ideal study systems. The Sarasota Dolphin Research Program (SDRP), directed by my co-advisor Dr. Wells, has studied the Sarasota dolphins since 1970. Over 90% of the dolphins are of known age, sex, maternal lineage, and/or habitat use patterns[2,8]. The quantity of different prey consumed by the Navy/NMMF dolphins is recorded every day, equivalent to a controlled feeding study. Dr. Wells regularly collaborates with the NMMF, and they have agreed to donate blubber and fish samples. The SDRP is fully equipped for fieldwork (e.g. boats, nets for dolphin and prey fish sampling). Animal handling occurs under active NMFS permits and with IACUC approval. All chemical analyses will occur at Baylor University in the lab of Dr. Steve Trumble, a QFASA expert and regular collaborator of my co-advisor Dr. Costa.
Hypotheses: **(H1)** *QFASA will accurately model free-ranging bottlenose dolphin diet.* **(H2)** *In undisturbed conditions, dolphin diet will vary predictably with age, sex, maternal lineage, and/or habitat use patterns.* **(H3)** *In disturbed (harmful algal bloom) conditions, variation in diet will decrease as prey becomes limited and/or patterns of prey species use will change.*
Methods: *Collect dolphin blubber and prey fish:* In June 2019 (study year 1), I collected blubber samples (n=17) during yearly capture-releases of free-ranging Sarasota dolphins[8]. I will sample from

different dolphins during capture-release efforts in spring 2020 and 2021 (years 2&3). In July 2019 (year 1), the NMMF donated Navy/NMMF dolphin blubber samples (n=3) and prey fish. In spring 2020 and 2021 (years 2&3), Sarasota prey fish will be collected for me during the SDRP's monthly purse-seine net fishing. *Determine fatty acid signatures (FASs):* In August 2019, at Baylor, I used lipid extraction via Soxtec apparatus, FAME derivatization, and GC-FID to determine the FASs of the Navy/NMMF blubber and prey fish and the Sarasota blubber[5,6]. I will return to Baylor in summer 2020 and 2021 (years 2&3) to determine the FASs of that field season's Sarasota blubber and prey fish (the latter establishes the prey "library"). *Determine correlation coefficients (CCs)* **(O1)**: During fall 2019 (year 1), using the Navy/NMMF blubber and prey fish FASs, I will calculate the first-ever cetacean CCs following established protocols[6]. *Validate the QFASA model* **(O2)***:* In year 3, with the CCs, Sarasota dolphin FASs, and the prey "library," I will use the QFASA model to determine the proportion of different prey species in Sarasota dolphin diet[6]. To validate the model's accuracy (**H1)**, I will compare QFASA results to existing Sarasota dolphin diet estimates from stomach content, fecal matter, and stable isotope analyses[4,9,10]. *Determine diet variation* **(O3)**: I will analyze the relationships between QFASA-determined diet, sampled dolphin demographics (age, sex, maternal lineage, and habitat use patterns), and harmful algal bloom (HAB) severity at sampling. This will elucidate baseline diet variation under undisturbed and disturbed (HAB) conditions (**H2&3)**. HAB timing and severity data will come from the Florida Fish and Wildlife Conservation Commission.

Intellectual Merit: My calculation of the first-ever cetacean CCs and validation that the QFASA model accurately determines dolphin diet will make the QFASA method available for use in cetaceans for the first time. This will allow researchers to determine diet and disturbance vulnerability in cetaceans around the world. Furthermore, my findings on diet variation can inform the direction of research in other bottlenose dolphin populations, found worldwide[1]. QFASA is especially useful for studying rare or endangered cetaceans whose feeding behavior is seldom observed. While many traditional diet determination methods are difficult to apply without capturing the animal, QFASA requires only a minimally invasive blubber sample that can be acquired remotely via dart biopsy[6]. To expand the use of QFASA and establish future collaborations, I will publish my findings in peer-reviewed journals and present at conferences.

Broader Impacts: Wildlife managers can mitigate disturbance effects by applying my findings and those of researchers who use QFASA to investigate cetacean diet. Knowing which species are important prey and how disturbances disrupt diet helps managers create targeted and justified responses, such as limiting specific fisheries or reducing nutrient run-offs that exacerbate harmful algal blooms, with a higher likelihood of public compliance and success.

My research can also improve the health of dolphins under human care. Studies by the SDRP and the NMMF link chronic health conditions in Navy/NMMF dolphins to aspects of their diet, including deficits of certain fatty acids[11]. Understanding standard diet variation in Sarasota dolphins, which are the same coastal-feeding ecotype as both NMMF dolphins and many of the 900+ managed dolphins worldwide[1,11], can inform the optimal diet for managed dolphin health.

Finally, to broaden STEM participation and motivate the next generation to pursue conservation action, I will partner with UCSC's Seymour Marine Discovery Center, where I am a docent, and Florida's Mote Marine Aquarium, where the SDRP is based, to implement inquiry-based curricula informed by my research and tailored for K-12 students (see Personal Statement).

References: [1]Wells & Scott. 2018. *Encyclopedia Mar Mams.* [2]McHugh et al. 2011. *Mar Mam Sci.* [3]Rossman et al. 2015. *Mar Mam Sci.* [4]Rosen & Tollit. 2012. *Mar Eco Prog Ser.* [5]Iverson et al. 2004. *Eco Mono.* [6]Budge et al. 2006. *Mar Mam Sci.*[7]Meynier et al. 2010. *J Mam.* [8]Wells. 2014. *Primates and Cetaceans.* [9]Berens-McCabe et al. 2010. *Mar Bio.*[10]Dunshea et al. 2013. *Bio Letters.*[11]Venn-Watson et al. 2015. *PloS One.*

APPENDIX A

Crafting Your CV

The term CV is an abbreviation of the Latin word *Curriculum Vitae*, which means "the course of your life." While a resume is a concise and targeted 1-2 page summary of your qualifications, skills, and experiences, a CV has no page limit and details the course of your academic career. The goal of a resume is to construct a professional identity, while the goal of a CV is to construct a scholarly identity and it's widely used in the academic arena. Your CV is a living document and you'll update it frequently to reflect your scholarly development.

By carefully crafting a polished CV you're investing in yourself and in a future that you'll proudly build on it!

Format, Layout, and Content

The first thing that a reader will notice about any CV is the format and layout. Is the format well-organized with clear and distinct sections so everything is easy to find in one glance? Is it carefully and logically laid out? Are the headings and text font clear and consistent? Are the margins and white spaces between the text designed so the whole document is easy on the eyes?

A well-designed CV with an eye-catching format and layout will draw the reader into the guts of your CV. Craft headings and concise text (1-2 sentences) that use the 4 pillars of Initiative, Leadership, Impact, and Scholarship to illuminate achievements. Use parallelism in your phrasing to add consistency and enhance the flow and rhythm of your CV. Vigilantly sustain concise and compelling writing that is flawless and clear of any and all grammatical and spelling errors. You'll destroy the impact of your CV with lengthy descriptions and with flawed writing.

Format Option

Name and Contact Information:

- Center and bold your **Name** (15-16 point font)
- Below your name put your contact information in 11-12 point font
    - Email address
    - Personal Website (if you have a website, provide it as a hyperlink)
    - Phone number

Guts of your CV:

Consider organizing your sections in the following order and present your information in reverse chronological order with dates aligned along the right margin. Your section headings should be bolded in 13-14 point font and your supporting text should be in 11-12 point font. Don't use a crazy font. Keep it clean and professional looking.

1. **Education**
    a. Educational institutions and dates of attendance
    b. Degrees and majors (include minors)
    c. Overall GPA
    d. Major GPA optional
2. **Research Interests**
    a. Create a succinct and strong soundbite of your key research interest(s)
3. **Research Projects**
    a. Title (e.g. Undergraduate Researcher, Big Data 2 Knowledge Scholar)
    b. Institution
    c. Project title

    d. Principal Investigator of the project or the name of your mentor(s)
    e. Concise description of the project, its significance, and your role
    f. List the relevant skills that you acquired
4. **Honors and Awards**
    a. List your honors, awards, fellowships, scholarships, etc.
    b. Concise description of the award and its significance
5. **Publications**
    a. Include manuscripts 'in preparation' or 'in review' and list these first
    b. Full citation format and bold your name in the author list
6. **Oral Presentations**
    a. Include upcoming oral presentations and list these first
    b. Full citation format and bold your name
7. **Poster Presentations**
    a. Include upcoming poster presentations and list these first
    b. Full citation format and bold your name
8. **Teaching Experience**
    a. Title
    b. Institution
    c. Concise description of your role, pedagogy products, and impact
9. **Leadership**
    a. Title
    b. Institution
    c. Concise description of your leadership role and impact
10. **Professional Experience**
    a. Title
    b. Institution
    c. Concise description of responsibilities, products, and impact
11. **Volunteer Experience**
    a. Title
    b. Institution
    c. Concise description of responsibilities, products, and impact
12. **Technical Skills, Training, and Certifications**
    a. List your technical skills, training, and certifications
    b. Put the highest impact ones first
13. **Memberships**
    a. List memberships in science societies and other relevant organizations

Note: *Insert page numbers starting on page 2 on the bottom center of the page and include your name as a footer on the bottom right margin starting on page 2.*

Following are two CV examples from rising senior undergraduate students that are well-constructed, laid out in a clear and engaging format, and that concisely incorporate elements of the 4 pillars of Initiative, Leadership, Impact, and Scholarship to highlight achievements. Look at these examples not as models to follow in every detail but rather as strategies for how you can present your information most effectively.

CV Example 1

Samantha Miller

samamiller@csumb.edu
samanthalmiller.weebly.com
xxx-xxx-xxxx (telephone number)

EDUCATION

California State University, Monterey Bay (CSUMB) *August 2017 - May 2021*
B.S. Molecular Biology
Overall GPA: 3.65

RESEARCH INTERESTS

- *Archaeogenetics*: Use of information derived from ancient DNA to study historical pathogens, pandemics, adaptation, and social development and interactions, particularly in relation to early hominin evolution.
- *Paleopathology*: The role of genetics in immunity with a focus on reemerging historic pathogens.

RESEARCH PROJECTS

- **Undergraduate Researcher** *March 2019 - present*
  California State University, Monterey Bay
  Project 1: Functional Genomics of Pesticide Remediating Bacteria
  Principal Investigator: Dr. Nathaniel K. Jue
  Description: Determine the remediation capacity of pesticide remediating bacterial strains and identify the genes and mechanisms involved in remediation.
  Relevant Skills: Protocol development, bacteria culturing, large-scale TECAN growth assays, bacterial DNA extraction, PCR, Illumina MiSeq sequencing and maintenance, R-based data analysis, genome assembly, and genome annotation.

  Project 2: Evolution of Sex Changing Fishes
  Principal Investigator: Dr. Nathaniel Jue
  Description: Determine the genes involved in hermaphroditism of three species of *Serranidae*.
  Relevant Skills: Relational database construction, ortholog identification, detection of differentially expressed genes, and positive selection analysis.

- **Undergraduate Researcher and Big Data 2 Knowledge Scholar** *June 2020 - August 2020*
  University of California, Santa Cruz
  Principal Investigator: Dr. Russ Corbett-Detig
  Project: Evolutionary Analysis of the CTCF Gene
  Description: Conduct phylogenetic and evolutionary analyses on metazoan orthologs of the highly conserved CTCF gene.
  Relevant Skills: Ortholog identification, phylogenetic tree development and analysis, and dN/dS estimation.

- **Undergraduate Researcher** *May 2019 - January 2020*
  American Museum of Natural History, New York City

Project 1: Metagenomic Analysis of Myxozoan Parasites in Amazonian Fishes
Principal Investigator: Dr. Mark Siddall
Description: Developed a methodology for targeted amplification of myxozoan DNA from host tissue and characterized the community structure of myxozoans present in fish gills from three Amazonian rivers.
Relevant Skills: DNA extractions using modified kit protocols, PCR, carboxylated bead clean-up, Sanger sequencing, Bioanalyzer electrophoresis, dissection, and command line data analysis.

Project 2: Transcriptomic Characterization of Antimicrobial Peptides Secreted by *Dermatobia hominis* (human botfly)
*Principal Investigator***:** Dr. Mark Siddall
Description: Identified the physiological location of antimicrobial peptide (AMPs) secretion in *D. hominis* larvae and characterized the AMPs through transcriptome sequencing.
Relevant skills: Larval dissection and phenol-chloroform RNA extraction.

Project 3: Archival Crocodile Reclassification
Principal Investigator: Dr. Evon Hekkala
Description: Identified species of Crocodilia for taxonomic reclassification based upon high-throughput DNA sequencing of samples from archival crocodilian specimens.
Relevant Skills: Sample collection from historic crocodilian specimens, historic DNA extraction, PCR, and gel electrophoresis.

- **Course-Based Undergraduate Research Experience** *August 2019 - December 2019*
  California State University, Monterey Bay
  Project: Metagenomic Analysis of Monterey County Bat Fecal Microbiomes
  Principal Investigators: Jennifer Kato and Dr. Arlene Haffa
  Description: Determined the species of bacteria present in bat guano from Monterey County through metagenomic sequencing.
  Relevant Skills: Biochemical microbiological tests, bacterial DNA isolation, fecal DNA isolation, PCR, carboxylated-bead cleanup, and gel electrophoresis.

HONORS AND AWARDS

- **Barry Goldwater Scholar** *March 2020 - present*
  The Goldwater Foundation awards this prestigious scholarship to undergraduates in STEM fields who intend to acquire a graduate degree and pursue a career in research. I was 1 of 396 scholars selected from a pool of over 5,000 applicants, and 1 of 2 scholars selected from the California State University system.

- **California State University Agricultural Research Institute** *May 2020*
  Data Intensive Fellowship
  Amount: $6,500
  I was 1 of 3 undergraduate students awarded this fellowship for research involving big data. I was selected for my proposed research on the functional genomics and transcriptomics of pyrethroid remediating bacteria with Dr. Nathaniel Jue.

- **California State University Council on Ocean Affairs,** *March 2020*
  Science, and Technology Award (CSU COAST)
  California State University, Monterey Bay
  Amount: $500

I was 1 of 5 undergraduate researchers who received this award from the CSUMB COAST chapter. I was chosen for my proposed work on the functional genomics and transcriptomics of pyrethroid remediating bacteria with Dr. Nathaniel Jue.

- **Chevron Graduate Record Examinations (GRE) Award** *May 2020*
  Amount: $205
  Stipend provided by the Chevron Corporation to cover the costs of the GRE.

- **Undergraduate Research Opportunities Center Scholar** *December 2018 - present*
  California State University, Monterey Bay
  The UROC Scholars program is a competitive, two-year, mentor-influenced research program that provides professional development opportunities, graduate school preparation, and research courses for students who intend to attend graduate school.

- **School of Natural Sciences Dean's List** *Spring 2018 - Spring 2020*
  California State University, Monterey Bay

PUBLICATIONS

- **Miller, S. L.**, Williams, K. M., Crampton, W., Calegari, B. B., Siddall, M. E. *Metagenomic Analysis of Myxozoan Parasites in Amazonian Fish Gills*. Manuscript in preparation for submission to the Journal of Parasitology.

- **Miller, S. L.**, Williams, K. M., Siddall, M. E. *Transcriptomic Analysis of Antimicrobial Peptides Secreted by Dermatobia Hominis.* Manuscript in preparation.

- **Miller, S. L.** *Accommodating Diverse Learning Styles Using Metacognitive Strategies.* Manuscript in preparation.

ORAL PRESENTATIONS

- **Miller, S. L.** "Evolution of the CTCF Protein in Metazoa" *to be presented at* the Max Planck-Harvard Research Center for the Archaeoscience of the Ancient Mediterranean Young Investigator Symposium. October 2020. Webinar.

- **Miller, S. L.** "Functional Genomics of Pyrethroid Remediating Bacteria" *to be presented at* the World Congress and Expo on Applied Microbiology. September 2020. Webinar.

- **Miller, S. L.** "Evolution of the CTCF Protein in Metazoa" *to be presented at* the Big Data 2 Knowledge Symposium. August 2020. Webinar.

- **Miller, S. L.** "Developing Student Leaders" *panel member* for the Association of Colleges for Tutoring and Learning Assistance Tutor Forum. November 2019. Webinar.

- **Miller, S. L.** "Metagenomic Analysis of Myxozoan Parasites in Amazonian Fishes" *presented at* the Western Society of Naturalists Annual Meeting. November 2019. Ensenada, BC, Mexico.

- **Miller, S. L.** "Metagenomic Analysis of Myxozoan Parasites in Amazonian Fishes" *presented at* the American Museum of Natural History Summer Research Symposium. July 2019. New York City, NY.

POSTER PRESENTATIONS

- **Miller, S. L.**, Williams, K. M., Siddall, M. E. "Metagenomic Analysis of Myxozoan Parasites in Amazonian Fishes" *presented at* the California State University Program for Education and Research in Biotechnology Annual Symposium. January 2020. Santa Clara, CA.

TEACHING AND PEDAGOGY

- **Instructional Student Assistant** *August 2018 - May 2021*
  Cooperative Learning Center, California State University, Monterey Bay
  Tutor for Precalculus, Calculus I, Calculus II, Molecular and Cell Biology and Animal Physiology, and Genetics
    - Develop pedagogical strategies to serve diverse populations of my peers, create lesson plans that future tutors can utilize, and construct exercises to help tutors develop metacognitive abilities and enhance adaptability during mandatory tutor training sessions.
    - Tutor drop-in sessions, group sessions, and Peer-Led Undergraduate Study (PLUS) sessions. Devise session plans and strategies that are shared with other tutors and adapted to other courses.

- **Teaching Assistant** *June 2020 - May 2021*
  Department of Biology and Chemistry, California State University, Monterey Bay
  Teaching Assistant for Practical Computing for Scientists
    - Develop and adapt pedagogical methodologies for use in an online setting, create and populate a collection of supplementary resources that can be implemented by future teaching assistants.
    - Lead weekly online discussion sessions and provide assistance to students during scheduled class time to minimize preventable coding errors.

  Instructional Student Assistant for summer Genetics course
    - Constructed structured lesson plans to support students in an online summer genetics course, created and populated a repository of materials for use by current and future teaching assistants.
    - Taught daily 2-hour discussion sessions during a month-long accelerated genetics course and provided students with supplementary materials to aid in understanding.

LEADERSHIP

- **Cofounder of the Linux Users Group (CSUMBLUG)** *April 2020 - May 2021*
  California State University, Monterey Bay
  Founded and established the Linux Users Group in the Monterey community
    - Cofounder: Provide an environment for community discourse and contribution of ideas to the Linux Project to proliferate the ideals of the Open Source movement as they apply to computing and academia as a whole.

- President of Outreach: Organize computational outreach events targeted both towards the Monterey community and towards youth programs dedicated to improving STEM education, establish a framework and session plans for future coding-based educational events that the club may hold after my departure.

- **Workshop Developer and Facilitator**
  California State University, Monterey Bay
  "Introduction to Git: Command Line Collaboration" *July 2020*
  - Developed and facilitated an interactive workshop for undergraduate and graduate researchers that provided participants with an introduction to command line interfacing with GitHub. Compiled the lesson plan and supplementary resources in the CSUMBLUG's publicly accessible GitHub account for use by future facilitators and learners.

  "GitHub: An Introduction to Cloud Computing" *July 2020*
  - Developed and facilitated an interactive workshop for undergraduate and graduate researchers that introduced participants to collaborative computing on GitHub. The lesson plan and supplementary resources are accessible on the CSUMBLUG's GitHub account for use by future facilitators and learners.

  "Python: An Introduction for Big Data" *June 2020*
  - Co-facilitated a workshop that introduced undergraduate researchers to the fundamentals of Python programming and big data analytics. Compiled the lesson plan and supplementary resources in the CSUMBLUG's publicly accessible GitHub account for use by future facilitators and learners.

PROFESSIONAL EXPERIENCE

- **Lab Assistant** *March 2020 - present*
  Tulare County Public Health Lab
  - Process patient samples for COVID-19 testing, organize and prepare RNA extractions using QiaCube, EZ1, MagNA Pure machines, and prepare large scale RT-PCR runs using ABI 7500 Fast Dx instrument.

TECHNICAL SKILLS AND TRAINING

- Advanced Python programming and shell scripting experience
- Proficient R statistical analysis and figure production skills
- Archival DNA extraction
- DNA and RNA Isolation (Kits and Phenol-Chloroform)
- Bioanalyzer electrophoresis
- Sanger sequencing
- PCR, RT-PCR
- TECAN use and maintenance
- Illumina MiSeq use and maintenance
- Family Educational Rights and Privacy Act certified
- College Reading and Learning Association Certification Level 1
- CITI Responsible Conduct in Research Training in Biological/Biomedical and Physical Sciences

CV Example 2

Selina Espinoza

seespinoza@csumb.edu
https://seespinoza.wixsite.com/mysite
xxx-xxx-xxxx (telephone number)

EDUCATION

California State University, Monterey Bay (CSUMB) *August 2018 - present*

B.A. Psychology
Minor in Statistics
Overall GPA: 3.20
Major GPA: 3.41

Hartnell Community College

A.A. Psychology *August 2016 - May 2018*
A.A. Art *August 2011 - May 2013*

RESEARCH INTERESTS

● *Cannabis Use and Perceptions*: Explore cannabis use and perceptions among vulnerable subpopulations (e.g. college students, veterans with post-traumatic stress disorder), and conduct research to inform policy.

● *Community Engagement and Advocacy*: Apply my research knowledge and skills to serve community members and improve public health. Facilitate youth participatory action research and empower young people to engage in action that supports community wellness.

RESEARCH PROJECTS

- **Undergraduate Researcher** *January 2019 - present*
- ***California State University, Monterey Bay***

Project 1: Cannabis Use and Perceptions Among College Students and Veterans
Mentor: Dr. Jennifer Lovell
Description: Develop an anonymous self-report survey with scales that measure cannabis use disorder, cannabis consumption, and well-being. Descriptive statistics and t-tests will be used to analyze quantitative questions, and thematic analysis will be used to answer qualitative questions.
Relevant Skills: IRB protocol development, survey design and administration via Qualtrics & CSUMB Sona-Systems, data collection, study advertisement with self-made flyer, participant recruitment via email, and manuscript preparation.

Project 2: Gonzales Youth Council (GYC) Mental Health Action Project
Mentor: Dr. Jennifer Lovell
Description: An anonymous self-report survey was designed to gather information about how middle school and high school students in Gonzales were handling COVID-19. The survey data will be used by the GYC to create online content (e.g. creation of online videos, social media posts, hashtags) for the youth and present the results to the Gonzales City Council and Gonzales Unified School District.
Relevant Skills: Assisted in creating and inputting the mental health survey in Qualtrics, data collection and analyses, collaborative student-led research initiatives, and facilitated the Qualtrics Data Quantitative Analysis Workshop.

- **Undergraduate Researcher** *June 2020 - August 2020*
  Washington State University
  Project: Acute Effects of Cannabis on Everyday Life Cognition
  Mentor: Dr. Carrie Cuttler
  [Note: Accepted for summer research in Dr. Cuttler's lab, but this research opportunity was canceled due to public health concerns related to COVID-19.]

- **Undergraduate Researcher** *June 2019 - August 2019*
  University of Colorado Boulder
  Project 1: Cannabis Use and Perceptions Among Veterans with Post-Traumatic Stress Disorder
  Mentor: Raeghan Mueller
  Description: Conducted an exploratory study that investigated symptom relief from cannabis vs. non-cannabis treatments/medications among veterans with post-traumatic stress disorder (PTSD). Compared military veterans with and without PTSD on typical product and strength by archival survey data collected by the CU Change lab.
  Relevant Skills: Data organization, SPSS-based analysis, project development (research paper, poster, and oral presentation), active collaboration, and presentation of results at a national symposium.

  Project 2: Cannabis Observational Study on Mood, Inflammation, and Cognition (COSMIC)
  Mentor: Dr. Kent Hutchison
  Description: This study observes the mental and physical effects of legal market cannabis in a naturalistic setting by using a mobile laboratory sprinter van that is fully equipped to collect all the research data. The van allows researchers to examine the acute effects of before and after cannabis use. Participants partake in self-report questionnaires, cognitive tasks, and blood draws. The goal of this study is to further understand the risks and benefits associated with different strains of legal market cannabis, specifically varying ratios of cannabidiol (CBD) and delta-9-tetrahydrocannabinol (THC).
  Relevant Skills: Phone screen procedures, data management and collection, shadowed CU Change lab members, independently ran baseline appointments (Session 1), and assisted with van appointments (Session 2) by conducting cognitive tests.

- **Undergraduate Researcher** *August 2018 - November 2018*
  California State University, Monterey Bay
  Project: Many Things Matter for College Success
  Mentor: Dr. Kevin Grobman

Description: A longitudinal study to predict college student success, particularly for first-generation students, based on non-cognitive abilities (e.g. grit and creativity) in addition to traditional cognitive abilities (e.g. GPA). I attended a two-day research training workshop, assisted in administering cognitive tests in-person, and transcribed participants' verbal answers in explaining their idea of an ideal society.
Relevant Skills: Conducted experiments (independently and with lab partner), data collection and entry, coded results, and CITI training (Human Subjects in Research Training & Responsible Conduct of Research: Social and Behavioral RCR).

HONORS AND AWARDS

● **CSU Sally Casanova Scholar** *May 2020 - present*
Amount: $3,000
The California Pre-Doctoral Scholarship is awarded to CSU undergraduate and graduate students who excel in academics, experience economic or educational disadvantages, and are committed to a career in teaching and research at the college or university level. Funding is provided for graduate school preparation and participation in summer research in 2021. I am one of 77 highly qualified California State University students who were chosen from 250 applications.

● **CSUMB UROC Scholar** *December 2018 - present*
The CSUMB Undergraduate Research Opportunities Center (UROC) Scholars Program is a competitive two-year program that facilitates a four-semester Undergraduate Research Seminar Series and professional development workshops. Scholars are mentored by a CSUMB faculty member and receive two years of summer research and academic funding.

● **McNair Scholar** *December 2018 - present*
The Ronald E. McNair Postbaccalaureate Achievement Program is embedded within the UROC Scholars program and supports low-income, first generation undergraduate students who plan to pursue a doctoral degree by giving them opportunities to engage in research and other scholarly activities.

● **Suzanne Dewar Memorial Undergraduate Research Scholarship** *January 2019 - present*
Amount: $1,000
This scholarship supports two CSUMB UROC scholars who conduct research under the arts, humanities, and social sciences. I received two-years of funding that will support my undergraduate research, scholarship, and creative activity.

● **2nd Place Winner at the CSU Student Research Competition 2020** *April 2020*
Amount: $250
The 34th Annual California State University Student Research Competition was hosted by Cal State East Bay. Due to COVID-19, the competition was virtual and students submitted an oral presentation video and participated in a Q&A session via Zoom. I placed second in the Health, Nutrition, and Clinical Sciences category with "Cannabis Use and Perceptions Among Veterans with Post-Traumatic Stress Disorders" (Espinoza & Mueller, 2019).

● **6th Place Winner, Anastasi Research Paper Award** *July 2018*
Amount: $100
Psi Beta, a community college national honor society in psychology, holds this scholarship

competition to commemorate Anne Anastasi's enduring and lasting contribution to psychology and psychometric theory and procedures. My lab partners and I wrote an original research paper and my team and I placed 6th in the nation.

● **Marcelle Villani Memorial Scholarship** *July 2018*
Amount: $1,031
I used this scholarship to defray my tuition.

● **Stanford Phoenix Scholar** *April 2017*
The organization assists low-income and/or minority students in applying to and deciding on the college of their dreams by providing free college counseling and mentorship with experienced university students.

● **President's Honor Roll** *2016-2017*
Hartnell Community College

PUBLICATION

Espinoza, S. & Lovell, J. *Cannabis use and perceptions among college students and veterans*. Manuscript in preparation.

ORAL PRESENTATION RESEARCH COMPETITION

Espinoza, **S.** & Mueller, R. (2019). *Cannabis use and perceptions among veterans with post-traumatic stress disorder.* CSU Monterey Bay Delegate for the 34th Annual CSU Student Research Competition. Virtual. CSU East Bay, CA. April 24, 2020. [Note: Competition format offered in response to COVID-19].

ORAL PRESENTATION NATIONAL SYMPOSIUM

Espinoza, **S.** & Mueller, R. (2019). *Cannabis use and perceptions among veterans with post-traumatic stress disorder.* Leadership Alliance National Symposium (LANS), Hartford, CT.

POSTER PRESENTATIONS

Espinoza, **S.** & Lovell, J. (2020). *Cannabis use and perceptions among college students and veterans.* Abstract accepted for a poster presentation at the Western Psychological Association Convention, San Francisco, CA.

Espinoza, **S.** & Mueller, R. (2019). *Cannabis use and perceptions among veterans with post-traumatic stress disorder.* Student Multicultural Access to Research Training (SMART) Poster Symposium at the University of Colorado Boulder, Boulder, CO.

Espinoza, **S.**, Sanchez, D., Lopez, M., & Duarte, J. (2018). *Perceptions of sexual harassment by gender of the perpetrator.* Psi Beta Research Symposium at the American Psychological Association Annual Convention, San Francisco, CA.

Espinoza, **S.**, Sanchez, D., Ramirez-Perez, O., & Avila, X. (2018). *What's in a name? A partial replication study of predictive power of personalities vs. situational labels in game moves.* Psi Beta Research Symposium, Western Psychological Association Convention, Portland, OR.

TEACHING EXPERIENCE

- **Psychology Supplemental Instruction Leader** August 2017 - May 2019
  Hartnell Community College
  ○ I was a SI Leader for four consecutive semesters (three sections per semester) for General Psychology at Hartnell College and held SI sessions three times a week and office hours twice a week. I have tutored over 50 students, the majority of whom identify as Hispanic. I used a variety of pedagogical approaches that included differentiated instruction, experiential learning, and cooperative learning. I supported students by creating practice quizzes, reviewing notes using whiteboard note mapping strategies, and collaboratively discussing readings and concepts.

LEADERSHIP

- **Students for Sensible Drug Policy (SSDP)** *August 2019 - December 2019*
  California State University, Monterey Bay
  ○ Vice-President: Attended the Executive Officer Retreat, assisted in member recruitment, assisted in meeting presentations, facilitated War on Drugs open conversation, and led club meetings.

- **Psychology Society** *August 2019 - December 2019*
  California State University, Monterey Bay
  ○ Vice-President: Assisted in member recruitment, helped facilitate and participated in the Meditation and Coloring Workshop, and engaged in meeting conversations with members.

- **Psi Beta** *January 2018 - May 2018*
  Hartnell Community College
  ○ Chapter President: Led research projects by assigning poster sections to lab members and practicing poster presentations speeches (WPA & APA 2018), assisted new, incoming members, planned agenda for meetings, and assigned tasks for meetings and club activities.

- **Psychology Society** August 2017 - *May 2018*
  Hartnell Community College
  ○ President: Facilitated meetings, set and monitored club goals, trained new members in orientation, led fundraising initiatives, coordinated club activities (e.g. poster sessions, mental health awareness events, fundraising events).

  January 2016 - May 2017
  ○ Secretary: Created and sent club emails, organized meetings, recorded meeting notes and minutes, maintained club records, created and posted meeting flyers, participated and assisted in club activities (e.g. club elections, spring carnival, mental health resource fair).

PROFESSIONAL EXPERIENCE

- **Admissions and Records Technician** November 2015 - January 2016
  Hartnell Community College
  ○ Processed admissions applications and registered students, phone and written communication, updated student information, and maintained confidentiality.

- **Student Enrollment Ambassador** July 2011 - May 2013
  Hartnell Community College

  ○ Provided assistance to new, returning, or transferring students in completing forms either in paper or online, maintained filing systems, managed office equipment, and held on-campus tours with students.

VOLUNTEER EXPERIENCE

- **Sally Casanova Pre-Doctoral Info Session Facilitator** *June 2020*
  California State University, Monterey Bay

  ○ Assisted in facilitating a virtual information session by sharing my experience in the application process and by providing tips for potential applicants.

- **Boys and Girls Club Volunteer** *August 2019 - December 2019*
  Santa Cruz, California

  ○ Created art with the children, read books aloud to the younger children, and assisted in preparing snacks and in picking up children from various schools.

- **College Readiness Workshop Participant** *April 2019*
  Gonzales High School

  ○ Shared my college experiences, and explained the financial and scholarship resources I used in higher education.

- **National Alliance on Mental Illness (NAMI) Conference Volunteer** *June 2018*
  Monterey, California

  ○ Assisted in conference logistics and in certifying students' documents for earning continuing education credits.

- **Supportive Programs & Services Notetaker** *August 2017- December 2017*
  Hartnell Community College

  ○ Notetaker in Biological Psychology and Theories of Personality courses as part of a service provided by Hartnell College's support program for students with disabilities.

TECHNICAL SKILLS AND TRAINING

- Collaborative Institutional Training Initiative (CITI) Ethics Training
  - ○ GCP for Clinical Trials with Investigational Drugs and Biologics (ICH focus)
  - ○ Social and Behavioral Responsible Conduct of Research
  - ○ Social and Behavioral Research Investigators and Key Personnel
  - ○ Human Subjects in Research Training
  - ○ Responsible Conduct of Research: Social and Behavioral RCR
- Statistical Package for the Social Sciences (SPSS)
- Mental Health First Aid
- Indiana University Certificate on Recognizing Plagiarism

MEMBERSHIPS

- Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS)
- Research Society on Marijuana (RSMj)
- National Latinx Psychological Association
- American Psychological Association Division 38 (Society of Health Psychology)
- American Psychological Association of Graduate Students (APAGS)

APPENDIX B

Contacting a Prospective Graduate School Advisor to Help Guide the Development of Your GRFP Graduate Research Plan

If you're an undergraduate student, or a Master's degree student who may use the NSF Graduate Research Fellowship to pursue a Ph.D. degree at another university, there are a number of approaches you can take to find mentors to help you develop your proposed Graduate Research Plan that fit the university you're targeting. If you don't tie your proposed Graduate Research Plan to a specific lab it's unlikely that it will receive a favorable review because you'd be missing two key Merit Review Criteria Elements:

- *How well qualified is the individual, team, or organization to conduct the proposed activities?*
- *Are there adequate resources available (either at the home organization or through collaborations) to carry out the proposed activities?*

Targeting an appropriate university and lab for your Graduate Research Plan can be approached in three primary ways:

- First, you may have already developed a relationship with a prospective graduate school faculty advisor (e.g. through a summer research experience in the faculty member's lab, networking at conferences, or other means) who would be willing to provide you with guidance and feedback as you develop a Graduate Research Plan.
- Second, if you've identified a lab you're interested in targeting for your Graduate Research Plan, but you don't have a relationship with the faculty member you could reach out with an email query asking if she/he, or a graduate student or post-doc in the lab, would be willing to provide mentoring as you develop your Graduate Research Plan.
- Third, you may be unable to secure a commitment from the lab you're targeting, but you have mentoring at your current university and elsewhere that would still enable you to develop a solid research plan aimed at the graduate program and lab you're targeting. For example, you could consider expanding on research that you've done or are doing and connect its relevance to the lab you're targeting. The mentor who helps you develop your Graduate Research Plan could write a reference letter about the robustness of your research plan, the fit of your plan to the university you're targeting, and how that university has the resources to enable you to successfully conduct your proposed research. It's not required that you secure a letter of reference from a faculty member of the university you're targeting in your GRFP application.

It may at first seem daunting to reach out to a prospective graduate school faculty advisor, but if it's approached properly your prospective advisor will appreciate your initiative and interest in the program. Even if the faculty member does not have the bandwidth to assist you, you will had made a positive and memorable impact that will serve you well when you apply to the program for graduate study. If you're unsure of a prospective lab that you may want to target for your Graduate Research Plan speak with your current faculty mentor and others to get recommendations.

Once you've identified a lab that you'd like to target do some homework on the faculty member and the lab, and craft an email that contains these elements:

- Introduce yourself and explain why you're interested in the research that's occurring in the lab.
- Provide a brief background of your achievements and the experiences and skills that would be beneficial to the research that is conducted in the lab.
- State that you've attached your CV to further detail your achievements and skills.
- Ask if the faculty member is accepting graduate students in Fall 2021.
- State that you will be applying to the GRFP this fall and that you would like to write a proposed Graduate Research Plan statement centered around the research that the lab conducts.
- State that this would not serve as a commitment to being accepted into the faculty member's lab, that NSF GRFP applicants have portability if awarded a fellowship and there is no obligation from potential graduate school mentors.
- Ask if it would be possible to collaborate with the faculty member, or a graduate student or post-doctoral fellow in the lab, in developing your proposed Graduate Research Plan.
- Ask if you could set up an opportunity to discuss the prospect.

Following is an email example that contains the above elements and that provides useful ideas for how you might craft your email. Again, your prospective graduate school advisor will appreciate your initiative, your interest in the program, and the quality of your query and CV. Go for it!

Sample email to a Prospective Graduate School Advisor

Subject line: Query from a Prospective Graduate Student

Dear Dr. Xxxx,

I hope this email finds you well. My name is Xxxx Xxxx and I am a third-year molecular biology student at California State University, Monterey Bay and a 2020 Barry Goldwater Scholar. I am interested in applying to the University of Xxxx's Anthropology Ph.D. program for Fall 2021. Because of my avid interest in paleopathology and archaeogenetics, I have quite enjoyed your research on anthropological genetics, particularly your papers on xxxxx and xxxxx. After reading your publications and reviewing your lab website, I am very interested in pursuing my Ph.D. degree in your lab.

I'm engaged in a variety of projects to advance my research, scientific writing, and computational skills. I currently conduct research on the functional genomics of pesticide remediating bacteria with Dr. Xxxx Xxxx in my university's Genomics, Genetics, and Bioinformatics lab — research for which I received the Barry Goldwater scholarship, a CSU Council on Ocean Affairs and Technology grant, and the CSU Agricultural Research Institute Data Intensive Fellowship. I am also writing two first author manuscripts with Dr. Xxxx Xxxx in the Invertebrate Zoology department of the American Museum of Natural History on the transcriptomics and metagenomics of parasites and their communities. This summer I am working with Dr. Xxxx Xxxx at UC Santa Cruz to conduct phylogenetic and evolutionary analyses on metazoan orthologs of the CTCF gene through the NIH's Big Data to Knowledge program.

After reading through your papers, I believe that my experiences with bacteriology and computational genomics provide me with skills that would be beneficial for the microbial ancient DNA research that your lab conducts. Specifically, I have advanced experience with python programming, shell scripting, phylogenetic analysis, positive selection analysis, and R statistical analysis. I have attached my CV to this email to further detail my research and experience.

I know that we are in uncertain times, but are you planning on accepting graduate students into your lab for Fall 2021?

Additionally, I am currently writing my application for the National Science Foundation Graduate Research Fellowship Program (GRFP) and I would like to write the required two page proposed Graduate Research Plan statement centered around the research that your lab conducts. This would not serve as a commitment to being accepted into the Xxxx University's graduate program or your lab. NSF GRFP applicants have portability if awarded a fellowship and there is no obligation from potential graduate school mentors. I can collaborate with you, a graduate student, or a post-doctoral fellow in your lab in whatever capacity you deem appropriate in developing my proposed Graduate Research Plan. If this is something that you would be willing to consider, please let me know and we can arrange a virtual meeting to discuss the prospect further.

Thank you for your time and consideration,
Xxxx Xxxx