Biology

Prof. Michael Caldwell

Department: Biology

Pre-requisite for a Summer Position:

Description of Research:

In the Caldwell Lab, we study the ways in which animals use vibrations traveling through surfaces, such as the ground or plant stems, to assess their world. Although we know far less about how animals use vibrations, as opposed to other sensory modalities like vision or hearing, we do know that vibrational information is important in the communication, foraging, and risk assessment behavior of hundreds of thousands of species.

Methods in our lab include the recording and playback of vibration and sound signals produced by animals, video analysis of behavioral responses to these signals, and the measurement of vibrations as they propagate through body tissues and the environment.

Current lines of research include:

- Teasing apart the communication roles played by airborne sound and plant vibrations produced by red-eyed treefrogs (Agalychnis callidryas) when they call to attract mates.

- Determining whether toe tapping behavior exhibited by some foraging frogs serves as a vibrational signal used to manipulate the behavior of termite prey.

- Measuring the physiological sensitivity of snakes to substrate vibrations, and testing whether snakes use vibrations to locate their prey.

Students joining the lab should expect a mix of theoretical discussions, intense fieldwork, software based data analysis, and fiddling with experimental technologies. While the main focus of the lab is vibrational communication in vertebrates, highly motivated students interested in pursuing projects in visual, chemical, or other modes of communication, or with non-vertebrate animals are also welcome.

Prof. Rebecca Eckert

Department: Biology

Pre-requisite for a Summer Position:

Students should have an interest in aquatic ecology and/or taxonomy, the ability to work with live insects/arthropods, the ability to use a microscope for long hours. They should be conduct organized, be familiar with precise work, and be a good communicator.

Description of Research:

My lab explores the connections between living organisms in streams, how they interact with their environment, and how changes in the surrounding terrestrial environment can impact them. These organisms, though often overlooked when walking near a stream, help regulate water quality and provide other important ecosystem services including leaf decomposition. The process of leaf decomposition ties the terrestrial and aquatic worlds together and recycles nutrients, as leaves from outside the stream enter and are broken down by physical, chemical, and biological mechanisms. The biological interactions that occur during this process are complex and not yet fully understood, and I specifically examine how interactions between leaves, microbes, and macroinvertebrates in streams vary with changes in the environment. My lab's grand challenge is to untangle these relationships and investigate how they are altered by continued human impacts on the environment like the cutting of streamside vegetation, nutrient inputs, salinization of freshwater, and global climate change. Having a better understanding of these impacts will allow us to protect water quality and biodiversity within streams. To answer these questions, students in my lab utilize a variety of techniques both within the field in streams and in the laboratory.

A recent project examined temporal changes in nitrogen and carbon associated with leaves (leaf plus microbial nutrient content) throughout the decomposition process. In this, we were interested in how carbon and nitrogen vary when macroinvertebrate shredders are present to aid in the decomposition process versus microbial contributions to nutrient content without macroinvertebrate shredders. Currently, we are examining leaf decomposition dynamics under varying salt concentrations to better understand what changes may occur with the input of road salt into streams after winter road applications. We have been examining how algal and bacterial communities change in response to salt additions, how salt may alter macroinvertebrate growth, and the impact on overall leaf decomposition, using an amphipod shredder in the lab and a range of salt concentrations. This summer we will be continuing to examine road salt impacts on leaf decomposition, the associated microbial communities, and macroinvertebrates.

Prof. Peter Fong

Department: Biology

Pre-requisite for a Summer Position:

Students should be interested in climate change, aquatic organisms, animal behavior, and pollution of the natural environment. Students should be comfortable being outdoors wearing waders and collecting animals in the summer heat and humidity of southern Pennsylvania, and have patience in observing small animals under the microscope.

Description of Research:

1. Projects will test the combined effects of water temperature, heat waves and human pharmaceuticals such as antidepressants on the release of snail embryos and on snail egg laying on native and invasive snails living in creeks 25 miles north of Gettysburg. Previous experiments from summer'24 and fall'25 showed that both embryo release and egg laying is accelerated at warmer temperatures. Heat waves may exacerbate the effect of warm temperature.

Thus, these projects will examine the impact of global climate change (and heat waves) on reproduction and behavior in both native snail species and species which have invaded both North America and Europe, causing significant ecological damage.

2. Aquatic invasive species are common in south-central Pennsylvania. The invasive Asian clam, Corbicula fluminea is abundant in lakes and streams throughout North America (including Marsh Creek at the Sachs Covered Bridge). Asian clams are invasive biofoulers which block the intake pipes of power plants and municipal water systems. These clams are themselves fouled by the tubes of native insect larvae (Neophylax sp.). My lab has documented attachment on Corbicula by Neophylax since 2021. This project will add a 5th year of data collection on frequency of attachment and mass of Neophylax on Asian clams in two local creeks (Marsh and Conewago).

Prof. Kazuo Hiraizumi

Department: Biology

Pre-requisite for a Summer Position:

Completion of Biology 211 (Genetics) by the end of the Spring Semester of 2026 would be most helpful. An alternative qualification would be completion of Biology 212 (Cell Biology). Laboratory experience working with Drosophila would be a plus but not a requirement.

Description of Research:

Dipeptidases belong to a class of digestive enzymes and are found ubiquitously among organisms in every kingdom. These enzymes hydrolyze peptide bonds to provide amino acids for various metabolic and physiological processes. The level of catalytic activity of dipeptidases is a quantitative phenotype that varies between individuals in a continuous distribution within a natural population for any species. The genetic, molecular, and biochemical basis for such variation could be differences in the number of enzyme molecules that are produced (related to transcriptional or translational efficiency) or in the structure of the enzyme molecule (related to amino acid composition or sequence). Research projects focus on the characterization of genetic variation for gene regulation using the dipeptidase genes in Drosophila melanogaster as a model system. Identification and understanding of genetic factors that affect regulation of these enzyme-coding genes has relevant medical applications, given that reduction in enzyme levels of certain dipeptidases in humans is associated with disorders such as Huntington Disease, Alzheimer Disease, Crohn's Disease, and Celiac Disease.

Three of the Drosophila dipeptidase enzymes are encoded by independent genes (Dip-A, Dip-B, Dip-C). Each gene transcribes multiple forms of mRNA. Dip-B and Dip-C each produces mRNA isoforms that contain the same coding sequence (amino acids) for the primary structure of the enzyme but differ in the number and composition of nucleotide bases in the upstream non-coding portion of the mRNA (5' Untranslated Region or 5' UTR). For Dip-A (Drosophila homologue to human CNDP2, a carnosinase enzyme), mRNA isoforms encode polypeptides of different amino acid sequences. How these molecular differences contribute to the expression of enzyme function is one of the primary research questions. Some of the ongoing and future research projects include: 1) molecular characterization of new mRNA isoforms of dipeptidase genes and transcriptional profile between genetic strains that differ in enzyme activity; 2) characterization of tissue-specific and developmental expression of mRNA isoforms for the three dipeptidase genes; 3) quantitative analysis of dipeptidase proteins at various developmental stages using antibodies; 4) comparison of DNA sequence and amino acid composition of dipeptidase isoforms between genetic strains that differ in enzyme activity; 5) knockout and knockdown modification of dipeptidase genes using CRISPR-Cas9 approaches; 6) development of biochemical assays to distinguish carnosinase and DIP-A activity; and 7) bioinformatics strategies for the identification of potential mRNA isoforms in other peptidase and proteinase genes. The summer internships offer an opportunity to contribute to one or more of these areas of research.

Prof. Ryan Kerney

Department: Biology

Pre-requisite for a Summer Position:

Description of Research:

The Kerney lab is offering three hands-on summer research projects that explore how animals develop and interact with their environments. One project studies why some spotted salamander egg clutches appear milky white, focusing on a crystallizing protein that may help protect the eggs. Another project examines whether certain local fish briefly develop a simple version of a swim bladder (an organ similar to a lung) while they are still embryos. The third project looks at how salamander embryos safely host symbiotic algae inside their cells, even though the algae produce potentially harmful oxygen as they photosynthesize.

Students in these projects will gain broad experience in both fieldwork and lab work. Depending on the project, students may help collect eggs or embryos from local streams and ponds, prepare and image tissues under the microscope, and run chemical and molecular assays. All students will learn how to read and summarize scientific articles, keep a detailed lab notebook, write clear experimental protocols, participate in weekly lab meetings, and contribute to a collaborative lab environment.

Prof. Jennifer Powell

Department: Biology

Pre-requisite for a Summer Position:

Highly motivated students who love genetics and plan to continue their research project in the Powell lab during the school year. Preference given to rising sophomores and juniors.

Description of Research:

So much stress! Cells experience many different types of stress, including the stress of being attacked by pathogens, endogenous stresses such as the production of toxic metabolites or the accumulation of unfolded proteins, and environmental stresses such as changing temperature or salinity. The Powell lab focuses on how cells recognize stress, respond to stress, and integrate signals from multiple stressors. The tiny nematode C. elegans is an outstanding model system to answer these fundamental biological questions using powerful molecular genetic techniques.

The immune response is a special type of cellular stress response to infection by pathogenic microorganisms. Stressful cellular damage occurs as a result of the infection and/or the cell's own immune response to that infection. One example is oxidative stress – both from the Reactive Oxygen Species (ROS) produced by pathogens to attack the host cell, and by ROS produced by the host cells to fend off the pathogen. We are interested in understanding how infected cells manage the dual assault of an infection and the accompanying oxidative stress by identifying and characterizing regulators of both response processes. We have identified a list of candidate dual regulators, genes that appear to regulate the expression of an oxidative stress response gene and an infection response gene. This summer we will use qRT-PCR to test whether any of these candidates is indeed a dual regulator of the oxidative stress and innate immune response pathways and begin to dissect the cellular pathways involved.

We also study the response to a brief extreme cold exposure. Following cold stress, we discovered that worms face a decision to allocate resources toward repairing the cold-induced damage or to provide those resources to their offspring. The choice to transfer lipids from their normal storage location in the somatic intestine to their germline is a reproductive strategy called terminal investment. Lipid reallocation results in a survival advantage for the resulting progeny if they experience a subsequent severe cold shock, but it comes at the expense of the life of the parent. This summer we will determine the identity of the lipids that are responsible by measuring embryo survival following dietary supplementation with lipids or blocking lipid synthesis via RNAi.

Prof. Paula Trillo

Department: Biology

Pre-requisite for a Summer Position:

Successful applicants will be highly motivated, be eligible for travel abroad, and be comfortable with intense tropical field-work. Preference will be given to students who have spent some time doing research in the Trillo Lab and have taken Animal Behavior

Description of Research:

Research in the Trillo lab integrates the fields of behavior, ecology, and evolution. We do a lot of field work and collect much of our data in the tropics, in affiliation with the Smithsonian Tropical Research Institute. Next summer, we will start a new project examining the role that mixed-species aggregations of frogs have on vector attraction and disease transmission.

Vector attraction and disease transmission in mixed-species chorus assemblages:

When signaling to attract mates, animals often form mixed-species assemblages. These mixed assemblages can attract disease vectors that exploit sexual signals to identify and locate hosts. How the behavior of these eavesdropping vectors shapes the dynamics of wildlife disease is, however, poorly understood. Work in my lab has demonstrated that frog species vary greatly in their attractiveness to eavesdropping frog-biting midges in the genus Corethrella, and that calling in proximity to heterospecific signalers can strongly increase or decrease the risks experienced by individual frogs. These frog-biting midges are thought to be the key vector in the transmission of trypanosomal infections, nearly ubiquitous to anurans worldwide. Furthermore, our initial efforts to model the effects of differential vector attraction within mixed-species assemblages suggest that it is major factor in determining disease dynamics. This summer, we will start the process of examining trypanosome infection and transmission patterns in Panamanian frogs by characterizing trypanosome diversity, prevalence, and host overlap in natural breeding aggregations. We have two objectives: (a) to characterize trypanosome species, infection prevalence, and host overlap in breeding aggregations of frogs in Soberanía National Park; and (b) to confirm trypanosome transmission from frog-biting midges to relevant frog species and determine the mode of infection.

Student researchers that work on this project are involved in experimental design, equipment handling, and will be trained in frog sampling techniques, sound playbacks, as well as trypanosome identification in the lab.They will also be trained in experimental techniques, bioacoustics software, behavioral analysis software, and methods in tropical fieldwork. The study will be carried out at the Smithsonian Tropical Research Institute in Panama.

Chemistry & Biochemistry

Prof. Katherine Buettner

Department: Chemistry

Pre-requisite for a Summer Position:

Students should have taken general chemistry to work in the lab.

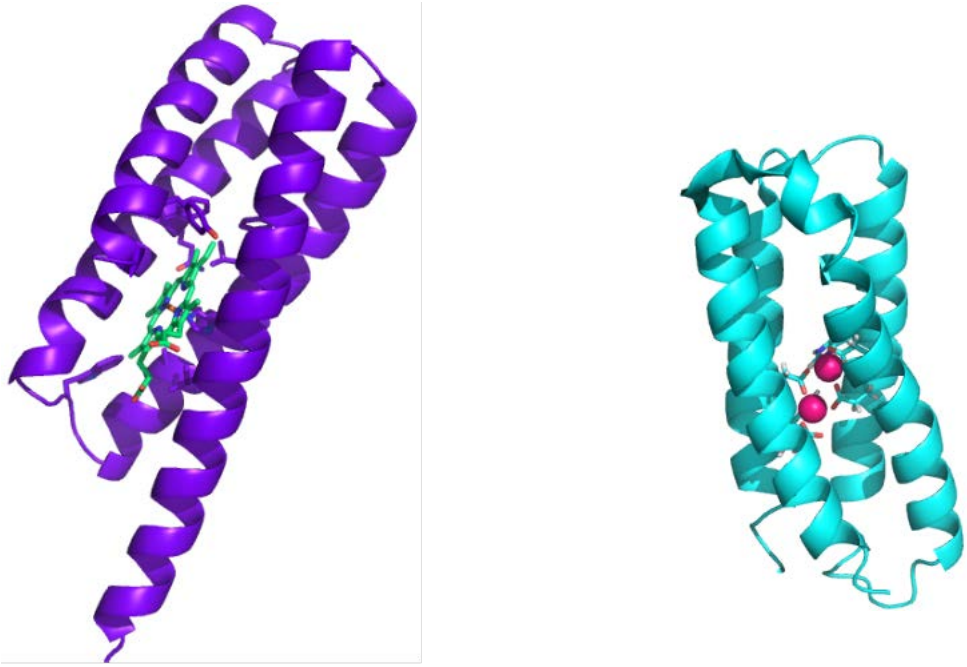
Description of Research:

Using biology's toolkit to control metals

Biology has developed lots of ways to control the reactivity of metals, using an impressive level of selectivity to prevent unwanted reactions, particularly with water, while maintaining more desirable metal activity. Nature does this with incredible specificity despite its limited toolbox, and the Buettner lab uses this toolbox in de novo designed proteins to both model and hijack natural systems. There are two current focuses in the Buettner lab that use different protein scaffolds to accomplish both of these goals.

The first uses the Due Ferri single chain (DFsc) protein scaffold to directly coordinate metal ions like zinc, titanium, manganese, and cobalt to capitalize on their ability to activate water molecules for reactivity. We are able to use metal bound DFsc proteins to cleave DNA, and we have observed that changing the metal identity or single amino acids in and near the active site changes reactivity. This summer, we will continue to characterize a set of proteins that have a single amino acid substitution and show significant differences in metal binding preference as well as reactivity. This system allows us to understand better the structure function relationships in natural proteins, as well as functionalize metals that are underused by nature to make potential therapeutics and more environmentally friendly catalysts. This project is in collaboration with the Reig lab at Ursinus College.

The second uses a new class of de novo proteins, named NovoChromes, designed to bind macrocyclic metallocofactors, like heme. Our first steps in this project are to bind vanadium in a variety of porphyrin scaffolds (the type of ring the organic part of heme is), and then determine the ability of these enzymes to carry out chiral reactions when bound to the scaffolds. These reactions will move current catalytic processes into more environmentally conditions, and add selectivity that is hard to achieve with small molecules. This work will be done in collaboration with Dr. Funk. Additionally, in collaboration with the Shafaat lab at UCLA, we will send these new complexes and enzymes to UCLA for further characterization to understand their potential to be used at quantum information systems.



Left: A Due Ferri protein bound to two zinc ions (pink). Right: Heme bound NovoChrome protein

Prof. Emily Dieter

Department: Chemistry

Pre-requisite for a Summer Position:

Description of Research:

Methanogenic archaea ("methanogens") produce ~70% of the world's methane, the second most abundant greenhouse gas after carbon dioxide. The ability to produce methane makes methanogens an enticing source of bioenergy; however, fundamental questions about their biology remain, due to the difficulty of culturing them in the laboratory. One group of proteins that is thought to be particularly important to methanogen survival is the radical S-Adenosyl-L-methionine (SAM) enzyme family. Radical SAM (RS) enzymes represent the largest known enzyme superfamily, and these enzymes use iron and sulfur to perform a variety of diverse chemical reactions; however, about half of the RS enzymes in methanogens have no established functions. Projects in the Dieter group will use biochemical techniques to elucidate and catalog the functions of these methanogenic enzymes. Enzymes will be expressed in Escherichia coli (E. coli), organisms that are more amenable to growth in a laboratory environment, then purified from the E. coli. This approach will allow us to biochemically characterize our proteins without the need to culture methanogens. Once the enzymes have been characterized, future work will focus on the role of these proteins in the native organism. A more thorough understanding of these proteins is expected to uncover novel chemical transformations, natural products, and biosynthetic pathways, which has the potential to contribute to strategies to both mitigate methane production and harness methane as a source of bioenergy.

Last summer, we received ~150 plasmids that contain the genes of unannotated RS enzymes from methanogens. During the academic year, my group has worked to start screening these proteins for suitability of expression in E. coli. Summer X-SIG students will each be responsible for 1-2 proteins, and will work to express and purify their protein, reconstitute the protein with iron and sulfur, and then characterize the protein (determine purity, iron and sulfur content, and enzymatic activity). Ultimately our goal is to first experimentally demonstrate that these proteins are RS enzymes, rather than rely on the bioinformatics characterization, then determine the biological function of each of these proteins, using different biophysical characterization techniques and enzymatic assays.

Prof. Tim Funk

Department: Chemistry

Pre-requisite for a Summer Position:

Completion of Chem 107 and 108 is required. Completion of at least one semester of organic chemistry is preferred. No college-level biology background is required.

Description of Research:

Synthesis of triazine-based lipids for RNA-based therapeutics – applied organic synthesis!

There are many potential applications of RNA-based therapies, including silencing gene expression, gene editing, and developing mRNA vaccines. RNA must get inside cells to serve its purpose, but its size, charge, immunogenicity, and instability lead to its degradation and do not allow it to pass through the plasma membrane. One of the most effective ways to protect RNA and transport it into the cytoplasm is by packaging it in a lipid nanoparticle (LNP). A key component of LNP formulations is an ionizable lipid, and the lipid's structure plays an important role in determining its ability to form LNPs with RNA and deliver it into cells. Ionizable lipids have two main components: a hydrophilic (water-soluble) head and a hydrophobic (water-insoluble) tail.

Through a collaboration with Prof. Vince Venditto at the University of Kentucky's College of Pharmacy, we are designing and synthesizing ionizable lipids based on readily functionalizable cyanuric chloride (Figure 1A). The general lipid structures we are exploring and their reversible protonation are shown in Figure 1B. We have shown that structural modifications to the ionizable head groups and the hydrophobic tails can have a dramatic effect on the lipid's ability to form LNPs with mRNA and deliver it into cells.

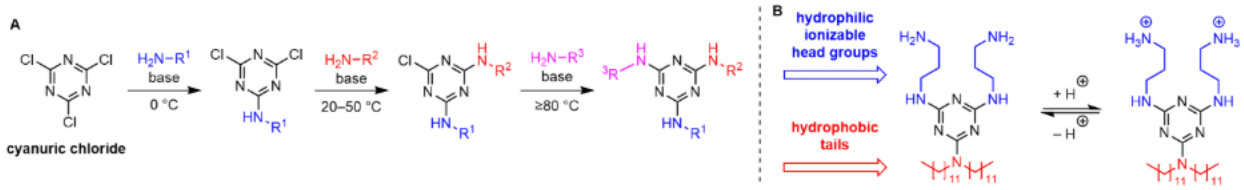


Figure 1. A. Temperature-dependent substitution of cyanuric chloride. **B**. Triazine-based lipids' reversible protonation.

This summer, we will be synthesizing triazine-based lipids with different head groups and tails. We will focus on unsymmetrical head groups containing mixtures of primary and tertiary amines and alcohols, and on hydrophobic tails containing unsaturation and branching. The general synthetic approach is shown in Figure 2, but in some cases, we will need to synthesize symmetrical and unsymmetrical secondary amines to use as hydrophobic tails. The goal is to prepare a library of lipids and determine how effectively they deliver mRNA into cells. **This summer, we will spend six weeks synthesizing lipids at Gettysburg College and two weeks making LNPs and exploring their properties at the University of Kentucky College of Pharmacy.**

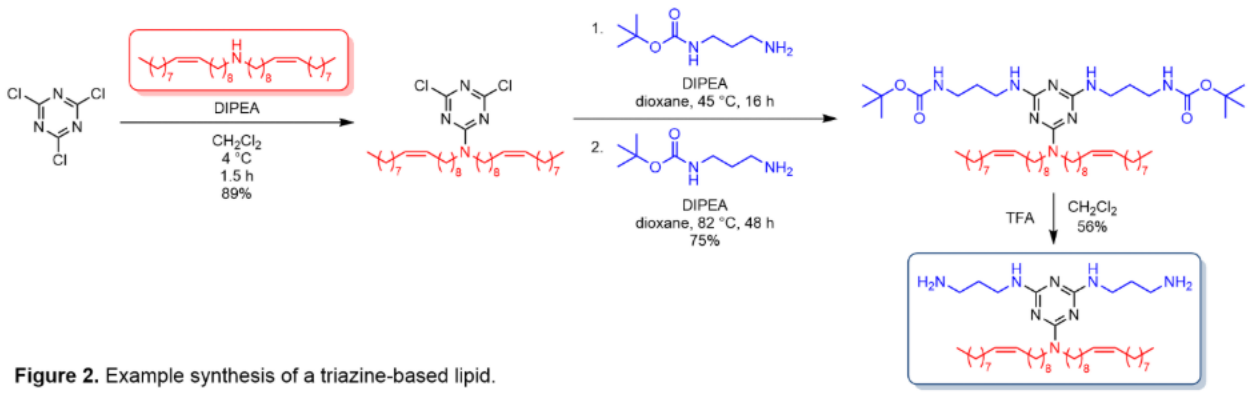


Figure 2. Example synthesis of a triazine-based lipid.

Environmental Studies

Prof. Sarah Principato

Department: Environmental Studies

Students working in my lab will work on projects related to glacial erosion from the small scale (striations) to the large scale (cirques). I will describe each project in more detail below. Students will have ownership of one of these projects, but also collaborate with each other, especially for the fieldwork component.

Pre-requisite for a Summer Position:

ES223 (required); ES230 (recommended)
Must be prepared to start working immediately after final exams (i.e. week of May 11th)

Description of Research:

Cirque project
A cirque is a bowl shaped depression created by a small glacier nestled in a mountainous region, and they are commonly used to reconstruct paleoclimate. One student will focus on a geomorphic analysis of ice free cirques in Wyoming and Montana and reconstruct past equilibrium line altitudes (paleo-ELAs). The student will build on the work started by Kate Anderson as part of her honors thesis project focused on the southern Absarokas, WY and expand the study area into the northern Absarokas (WY and MT). Cirques will be mapped using a combination of Google Earth and ArcGIS Pro, and the ACME2 tool will be used to quantify morphology. A variety of techniques will be used to reconstruct past paleo-ELAs. We will test the hypothesis that cirques glaciers in this study region were influenced by the rain shadow effect.

Striation project
Striations are scratches on rocks created by debris carried by glaciers, kind of like sandpaper smoothing out wood. They are used to understand processes at the bed of a glacier and help reconstruct paleo- ice flow direction. The striation project will build on the work by Holly Vollman examining striation morphology. We will simulate striations in the lab and quantify them using structure from motion analyses and manual measurements. The lab analyses will be compared with field measurements with the potential for fieldwork to be conducted in northeast PA, Kelleys Island, OH, and possibly other locations. Field measurements of length, width, depth, and orientation of striations will be collected manually. Digital photos of the outcrops will be curated into a DEM to digitally quantify the striations using procedures described by Holly. If time permits, this project will also involve quantifying striations on glacial sediments using the 3-D profiler/microscope. Ideally, a GIS database of striations documented from previous studies will be compiled to test hypotheses related to striation formation as well.

Prof. Natasha Gownaris

Department: Environmental Studies

Expected dates of May 30th – July 30th, most of which will be spent on Petit Manan Island. We will also need to find time in May for four to five days of training; you will be paid hourly for the training week.

Pre-requisite for a Summer Position:

To be a good fit, students should have completed ES 211 and, preferably, at least one upper-level ecology class in the Environmental Studies Department. Note that there is phone service and limited internet access on the island. We generally have solar power, but this isn't a given, and we shower once every 7-10 days. We have access to a kitchen with a propane refrigerator and stove, and food drop-offs occur every 1-2 weeks. Students should be comfortable with the idea of handling birds and working with blood samples for stable isotope analysis and should be ready for very early mornings (6:00am), regularly witnessing animal mortality, rugged field living conditions, limited internet access, and for spending all of June and July on this remote island. This position requires grit, flexibility, proactiveness, and openness to constructive criticism.

Description of Research:

Research in the Gownaris lab focuses on how seabirds change their foraging behavior and diet in response to rapid environmental change. Our current research site is Petit Manan Island, a small island off the coast of Maine that is home to seven species of breeding seabirds. The Gulf of Maine is warming faster than nearly anywhere else in the ocean. When waters warm, preferred diet items of seabirds in the Gulf of Maine (fishes like hake and herring), move deeper and farther offshore. Seabirds can respond in two ways: 1) they can change their foraging behavior, or 2) they can switch to less preferred prey items. Our research focuses on how seabirds are adjusting their breeding and foraging behavior to handle climate-driven changes in food availability and in how these behavioral adjustments influence their fitness.

This summer, we will spend eight weeks on Petit Manan Island collecting data on four species of seabird (Atlantic puffins, black guillemots, Arctic terns, and common terns) that breed there. Each day on the island is slightly different, but a day's work is likely to include a mixture of these activities: measuring chicks, counting seabirds, observing what food items seabirds bring back to their chicks, collecting and processing blood samples, tagging adult birds and monitoring their nests, entering data. In the evenings and on rainy days, we will have time to cook meals and play games together or to take some solo downtime. Two Gettysburg students will be joining Dr. Gownaris and two field technicians hired by US Fish and Wildlife, along with visits from other researchers and USFWS staff. Interested students can learn more about this research from students' perspectives in this article and about life on Petit Manan Island in this slideshow.

In addition to contributing to all island activities and learning a variety of field approaches, each student will also have ownership of one of the projects below:

Project 1:

Examining the interaction between phenology and diet. This student will collect chick productivity (hatch date, growth) and provisioning (direct diet observation) data to assess (1) how hatch date influences chick diet and (2) how chick hatch date and size affect rejection rates of difficult-to-swallow prey (e.g., American butterfish).

Project 2:

Quantifying terrestrial subsidies to tern chick diets. This student will collect stable isotope samples and use models to (1) estimate the proportion of chick diets from terrestrial versus marine sources and (2) compare isotope-based and provisioning estimates of terrestrial contributions to diet.

Mathematics

Prof. Cayce Fylling

Department: Mathematics

Pre-requisite for a Summer Position:

Calculus I required, Python or Matlab coding, or Differential Equations recommended

Description of Research:

Mathematical Modeling of Hydrodynamic Effects and Biofilm Production induced by Metabolism and Solvents on Bacteria Swarms

Collective motion is ubiquitous in natural and synthetic systems. Bacteria, such as Serratia marcescens and Escherichia coli, among others, exhibit swarming and clustering behavior under different environmental regimes. Bacterial motility and reproduction increase in the presence of food and decrease in the presence of solvents, with varying impacts as described by previous laboratory research. In environments with low food availability, bacteria can "congeal" into a biofilm as a survival mechanism, forming a complex, dense, slimy matrix of bacteria and waste. When introduced, solvents such as alcohol can break up the biofilm matrix, causing structural degradation and dissolution. Understanding biofilm formation and dissolution is important to both theoretical and applied science. Biofilms may have been crucial in early microbial evolution and the development of multicellular life, as they are one of the earliest forms of cooperative bacterial behavior. Today, biofilms create challenges in healthcare settings, where they contribute to chronic infections and antibiotic resistance by protecting bacteria from antimicrobial agents. Despite their importance, the mechanisms governing biofilm formation and dissolution are not yet completely understood.

Mean-field continuum models, which use averaged quantities to simulate bacteria motion, are one way we can seek to understand more about bacteria motion, reactions to solvents, and biofilm production. In a continuum model, bacteria collisions are ignored in favor of hydrodynamic effects. While swimming, and with plenty of food and no solvents, bacteria reproduce exponentially and exert extensile mechanical stress (pushing outward) on the fluid around them. During biofilm production, the bacteria conserve energy by reducing reproduction and exerting contractile mechanical stress (pulling inward). When subjected to solvents, the bacteria's ability to exert mechanical stress is reduced, and reproduction slows considerably. All of these reactions can be described through a mean-field continuum model and its hydrodynamic parameters, but must be carefully tuned to data.

Students will choose a dataset and construct a 1-dimensional model to study biofilm formation and/or dissolution. They will implement and test the model, ultimately drawing conclusions relating food availability, solvents, species, and hydrodynamic effects to biofilm and dissolution phenomena. This project has no wet lab component and is entirely computational, mathematical, and theoretical. The results from this one-dimensional study will provide essential groundwork for future multi-dimensional models by establishing validated parameter ranges and identifying key mechanisms that govern biofilm dynamics in realistic geometries and flow conditions.

Physics

Prof. Kurt Andresen

Department: Physics

Pre-requisite for a Summer Position:

Description of Research:

1. The Entropy and Enthalpy of DNA systems

One of the major questions in biophysics is what energies and entropies drive complex systems to behave in the way they do. One of the systems I have been studying throughout my career is the self-attraction of DNA when in a solution of +3 ions. In this project, we will subject DNA systems to measurements utilizing our in-house isothermal calorimeter. We will explore how different ions and osmotic pressure affect the binding of DNA. Students will learn how to use the isothermal calorimeter, wet lab techniques, some basic thermodynamics, data analysis using the Python programming language, and some interesting biology. No previous knowledge is required or assumed.

2. Measuring the Electrostatics of Gold Nanoparticles (in collaboration with Luke Thompson)

Gold nanoparticles have been a hot topic of research due to their unique, tunable optical properties and their possibility to treat diseases like cancer. Building on previously published work, we will be looking at understanding the complete electrostatic composition of gold nanoparticles. We will try to both measure the basic coating (CTAB) that coats a large majority of the nanoparticles that are used in scientific research. Furthermore, we will try to measure the number of ions around the nanoparticles. All of this will be done on our in-house ICP-AES AES (fancy machine that measures the concentration of elements in a sample). This research has the potential to result in high-impact publications as well as future funding and will be a great research project for a student looking to bridge the disciplines of chemistry and physics. Students will learn wet lab techniques (pipetting, equilibrium dialysis) and some interesting and physics. No previous knowledge is required or assumed.

3. Measuring Zn2+ binding to DNA

One of the fundamental questions in DNA electrostatics is whether or not certain ions bind strongly to specific parts of the DNA or whether they just bind through general electrostatic interactions. Building on previous work, we will be measuring the binding of Zn2+ to DNA utilizing a combination of circular dichroism and ICP-AES (a technique used to measure the concentration of ions around the DNA). We will investigate whether there is specific binding of the Zn2+ to the DNA, and if so, how much? These measurements will be useful in understanding how the small amounts of Zn2+ in our body affect DNA and the binding of other biomolecules (e.g. proteins) in the cell. Students will learn wet lab techniques (pipetting, equilibrium dialysis), basic Python analysis, and some interesting biology and physics. No previous knowledge is required or assumed.

Prof. Bret Crawford

Department: Physics

Pre-requisite for a Summer Position:

Description of Research:

Proton Energy Loss through Thin Films (Bret Crawford, Physics) (2 positions)

The Student Proton Accelerator at Gettysburg College (SPAGetty) creates beams of protons up to several microAmps with energies between 50 and 200 keV. Continuing on past years' work, I plan to use the accelerator to study proton energy loss through thin films. While this phenomenon has been well studied, accurate modeling gets more challenging at low energies. Energy loss is important for solid-state ion detectors which have thin "dead" layers of material through which the ion must pass before the entering the detector's active region. This dead layer significantly affects the detected energy spectrum for low-energy ions. In high-precision measurements that use these detectors, correct modeling of the detected energy spectrum can be quite important, e.g., the on-going neutron-lifetime measurement at NIST to which I am a collaborator. To study this, students and I will deposit thin films (10s of nm) of gold and other metals onto the bare silicon surface of our proton detectors, Passivated Implanted Planar Silicon (PIPS) detectors. The proton beam will then be adjusted so that it is detected either on the bare silicon of the PIPS or after first going through the layer of gold (or other material). Last year the students successfully used the new optical 3D profiler to measure film thickness (50-100nm) and further developed Python code used to analyze and compare energy spectra with simulated spectra. Past uses of Mo or W boats in the evaporator contaminated the gold, and the proper alumina-coated boat required too much current. We have installed a new power supply so we can evaporate pure gold this summer along with other materials (Ag, In, Al, Cr, Fe, …). While gold is relevant for the beta-decay measurements, measuring energy loss for more materials will create a clearer picture for a variety of materials versus tabulated data in our energy range.

The two summer students would learn about energy loss mechanisms, learn to run the accelerator, evaporate thin films, run the simulation software, collect proton energy data, develop and run Python scripts to analyze spectra, and become expert 3D optical profilers. There are sufficient tasks that the students will specialize on aspects but also work together.

Simulations of Neutron Spin Rotation Measurements (Bret Crawford, Physics) (1 position)

The Neutron Spin Rotation collaboration has developed a neutron polarimeter that can measure deviations in the average spin direction of a polarized neutron beam to a sensitivity in rotary power less than a micro-radian per meter of target matter. This precision allows us to study effects of the weak interaction and search for exotic fifth forces, depending on the target and apparatus configuration. The effect of ambient magnetic fields on the neutron spins, even after significant magnetic shielding, are sufficient to require a series of experiments, e.g., flipping the target orientation, to cancel remaining magnetic effects. The precision with which we can remove these potential systematic errors depends on a number of factors that can be studied through simulation of the neutron transport through our apparatus. We have two computer codes that we can use to study the neutron transport, one written in the FORTRAN programing language and one that uses a neutron transport simulation package called MCSTAS.

Using our FORTRAN code, I have been investigating a subtle effect with our target used to search for exotic fifth forces. The target is a series of tungsten and glass plates with gaps in between. Neutrons that reflect from the two types of plates do so with slightly different probabilities. Thus, when we flip the target orientation to cancel rotations from magnetic fields, the change in reflection properties flips with the target and thus the magnetic rotations do not completely cancel. There are more cases to run to evaluate the size of the effect and how to mitigate the issue at two potential neutron sources, the NIST Center for Neutron Research (NCNR) and the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory.

The student will learn about these high-precision measurements which test fundamental forces and how simulations can help us understand potential systematic errors. They will learn to run the codes and make adjustments. They will then run various cases to study how the effect varies with changes in neutron reflection properties of the target materials, the subtle effect of gravity on the neutron beam, and compare beam from NCNR and SNS. We will run on our 176-CPU cluster in the physics department to get sufficient statistics to assess effects at the 1 in 1E7 level. The student will work in the Linux environment. There may be need to run some comparisons with our MCSTAS code as well.

Prof. Ryan Johnson

Department: Physics

Pre-requisite for a Summer Position:

Description of Research:

When you think of astrophysics, what comes to your mind? In the Johnson Cosmology lab, we explore the power of data to inform us about the natural world. In previous summers, students in my research lab have explored chaos in deterministic systems, 4D visualizations of relativistic effects on astronomical observations, temporal and spatial data forecasting, exploring possible dark matter candidates, among many other projects (please have a look at the previous XSIG research blogs!).

Do you want to learn how to plan astronomical observations (the specifics of what, where, when, and how you're going to perform an observation)? Are you interested in machine learning techniques for addressing big questions with data? Are you interested in developing interactive teaching simulations of astrophysical phenomena? These are types of projects I intend to offer as research opportunities to interested students during summer 2026.

Despite the varying subject matter, summer research projects in my lab all have one thing in common, and that is work with computers. Whether you're authoring your own Python code, revising someone else's code, or using astronomical planning software, much of your work will involve interacting with computers in some way. Depending on your research project and interest, we can go as shallow or deep into the world of computation as you're comfortable. Though experience with programming is a plus, it is not required to work in my lab. There is also possibility for continuing these projects as guided research during the semester. I expect to begin summer research on Monday, May 18.

Prof. Jena Meinecke

Department: Physics

Pre-requisite for a Summer Position:

Description of Research:

Magnetic fields are everywhere-- they're going through your body right now. Since we can't see them, it's easy to overlook the powerful role they play in our everyday lives and universe. Magnetic fields are like the invisible glue that holds our universe together and helps form compact objects like stars. We are also learning in fusion research, that magnetic fields may be the key to achieving sustainable, clean power.

Therefore, our research questions include (1) where do magnetic fields in our universe come from, and (2) how do they behave?

To answer these questions, we use lasers. Not just any laser, we use the most powerful lasers in the world. My students will be visiting the 2nd largest laser in the USA and participating in a shot day that costs ~$1 million. Students will be designing novel electronic induction probes to measure magnetic fields in laser-produced plasmas. Students will also be analyzing data from a recent laser experiment to support one or more publications. We will also try to develop a new technique for processing proton radiography (PRAD) data.

Students 1 and 2: Designing new induction probes. Electronics experience or interest needed. Analysis of probe data from recent experiment.

Students 3 and 4: Developing setup for processing PRAD data. Experience with chemical baths/solutions needed. Likely would work with the accelerator lab too.

Depending on interests, additional/alternative projects include: MHD simulations using FLASH code to predict plasma conditions, design and construction of a target chamber for generating laser-produced plasmas

Prof. Prasadh Sandanuwan Kalawila Vithanage

Department: Physics

Pre-requisite for a Summer Position:

Some introductory knowledge of astronomy and physics, combined with computer programming skills, is useful but not required.

Description of Research:

Data-Driven Study of Star Formation in Galaxy Clusters

The following three projects are part of a coherent research program that uses large public astronomical datasets and data-driven methods to study star formation and quenching in galaxy clusters.

Project 1: Data-Driven Classification of Star-Formation States in Cluster Galaxies

Galaxies in clusters exhibit a wide range of star-formation activity. Some are actively forming stars, some are in transition, and others have already stopped. Traditional color-based diagrams are often used to classify the star formation states of galaxies. However, they can obscure important physical differences, especially in dense cluster environments where dust and rapid changes in star formation are common.

In this project, students use large public datasets to describe each galaxy using a small set of key physical properties related to star formation, dust, and stellar mass. Instead of relying on simple color cuts, a data-driven approach is used to identify and clearly define different star-formation states present in cluster galaxies. We will explore how galaxies are distributed in a multiparameter space. Our final aim is to develop a new catalogue that classifies cluster galaxies into star-forming, quenched, and transforming stages based on the parameters available to us.

Project 2: Search for Galaxy Quenching Pathways from the Geometry of Data.

Galaxies in clusters do not all stop forming stars in the same way. Some fade slowly over time, while others shut down rapidly. Because galaxies are observed only at a single moment in time, it is difficult to directly track their evolution. This project takes a different approach by studying patterns across many galaxies.

We examine how galaxies are arranged when plotted using multiple star-formation–related properties. For example, examining how ultraviolet, infrared, and $H\alpha$ indicators change relative to each other across these structures, we identify patterns consistent with gradual fading or rapid shutdown of star formation, suggesting distinct quenching pathways.

Data-science tools such as principal component analysis, clustering, and graph-based methods are used to organize galaxies by similarity and reveal transitions between star-formation states. By examining changes in ultraviolet, infrared, and hydrogen-alpha indicators along these structures, we infer whether star formation declines gradually or shuts down rapidly.

Project 3: Predicting Star-Formation Quenching in Galaxy Clusters

Galaxy clusters are known to suppress star formation, but it is still unclear which factors play the dominant role. Is quenching driven mainly by the cluster environment or by a galaxy's own internal properties? This project addresses this question using a predictive, data-driven approach.

We combine galaxy properties, such as star-formation indicators and stellar mass, with information about each galaxy's location within a cluster. Using simple prediction tools or machine-learning methods, we plan to develop a model that predicts whether a galaxy is still forming stars or has quenched, based on its properties.

The trained model can then be used to explore how galaxies with different properties are likely to respond to environmental changes, such as entering a dense cluster.

Psychology

Prof. Sara Keefer

Department: Psychology

Pre-requisite for a Summer Position:

Prerequisites include Psych 236 and/or 237 or strong interest in neuroscience, behavior, and rodent research.

Description of Research:

The field of behavioral neuroscience first examines behavior in rodents that directly reflects behavior in humans. My overarching behavioral research goal is to examine motivated behaviors when they occur adaptively but also when they occur maladaptively in rats. Motivated behaviors that are adaptive include food seeking and using environmental cues to learn about and find rewards (e.g. Pavlovian conditioning). Motivated behaviors that are maladaptive include persistently attending to and seeking out food and food cues despite not being hungry or when there are negative consequences, such as during risk-taking behaviors. My research examines the innate differences between these behaviors and identifies ways to change them -behaviorally and neurobiologically.

As a neuroscientist, I am interested in studying the neurobiological mechanisms of adaptive and maladaptive behaviors by using psychopharmacological drugs and brain manipulation techniques to observe resulting changes in behavior. The behaviors described above can be combined with neuroscience manipulation techniques, such as lesions and pharmacology, to investigate the necessity and involvement of different brain regions (e.g. the amygdala, hypothalamus, nucleus accumbens, ventral tegmental area, and prefrontal cortex) and/or neurochemicals of interest (e.g. dopamine, orexin, serotonin, just to name a few!).

In the lab, students can expect to search for, read, and comprehend primary research articles relevant to the research question. From these readings, students will be involved in the planning of the project including minimal coding that is involved in equipment setup. Students will run the rats through the behavioral paradigms and be involved in data collection and analysis. If desired, students can be trained in rat brain surgery with heavy guidance from myself and at the end of the projects, be involved in brain collection, histology, and microscopy.