Michael Caldwell
Department: Biology

Pre-requisite for a Summer Position:

Current plan for this summer's research to take place in person, either in the field or on campus.

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.

Jenna Craig (Buckwalter)
Department: Biology

Pre-requisite for a Summer Position:

Current plan for this summer's research to take place in person, either in the field or on campus.

Description of Research:
There are different molecular subtypes that have been identified in bladder cancer tumors that result in differences in tumor invasiveness and aggression. Bladder cancer tumors with a luminal molecular subtype are typically not invasive and have a more favorable therapeutic response. Meanwhile, tumors with a basal-squamous molecular subtype represents an aggressive, invasive and difficult to clinically treat phenotype. In addition, bladder cancer is known as a highly heterogeneous disease with both luminal and basal-squamous molecular subtypes co-occurring within the same tumor. Multiple morphological subtypes are also observed in bladder tumors. DNA methylation negatively regulates expression of an important transcription factor, *Forkhead Box A1* (*FOXA1*), in a CpG island specific manner in basal bladder cancer. However, the mechanisms that drive alterations in the DNA methylation landscape in basal bladder cancer compared to luminal bladder cancer are unknown. Finally, observations in other human cancers suggest that RB1 plays a regulatory role of DNMTs at gene promoters. Therefore, it is possible that alterations in RB1 status promote epigenetic silencing of *FOXA1* by regulating interactions of DNA methyltransferases (DNMTs). For on summer research intern, the goal of his or her project would be to explore and investigate candidate genes known to drive changes in DNA methylation in bladder cancer cells. The student would perform various cell and molecular techniques such as western botting, qRT-PCR, cell culture, and isolation of DNA, RNA, and protein from cells. Current plan is for research to be performed on-campus, in-person.

Description of Research:
Forkhead box A1 (*FOXA1*) is a gene often deleted or silenced in many different cancers. Thus, it is a worthwhile exploration to determine if DNA methylation is a regulator of *FOXA1* in a variety of cancers. This would be beneficial from the patient perspective in that a FOXA1 targeted therapy would be useful for patients with a variety of cancer types. The data analysis approach for this project will be entirely *in silico* using different databases to investigate the status of *FOXA1* in different cancer types. The Cancer Genome Atlas has a variety of data sets in regards to genes and cancer. For instance, expression at the RNA and protein level, epigenetic regulatory factors, and copy number variation. This project will be done in collaboration with a biostatistician at Penn State Hershey. The student will work on collecting web-based data from the CbioPortal and UCSC Genome Browser, finding and reading publications to corroborate *in silico* findings, and aid in writing a manuscript on the project in its entirety. The student will be credited authorship on the manuscript. This project can be done virtually or in person.

Veronique Delesalle
Department: Biology

Pre-requisite for a Summer Position:

Current plan is for research to be performed on-campus, in-person.

Description of Research:
Have you ever wondered about the factors that allow a pathogen to jump from one host to another? What makes a pathogen capable of invading lots of hosts or just a few hosts? These are ecological and evolutionary questions and my lab is answering these questions, using bacteriophages, viruses that "eat" bacteria, as the model pathogen. In particular, we want to understand:

- what factors determine a phage's host range (their ability to infect a few versus many bacterial strains, to be specialists versus generalists);
- how phages evolve as they exchange genetic material with other phages and as they encounter different bacterial strains to infect;
- the relative importance of mutation versus recombination (horizontal gene transfer) in the process of adaptation in phages; and
- the spatial and temporal scales at which these interactions take place (*e.g*., how does the diversity of phages and hosts change along these two dimensions).

To do this, we are using the phages of the bacterium, *Bacillus subtilis*. This soil bacterium is one of the best-studied bacterial species and working with this species comes with all the benefits associated with model organisms. We are describing the diversity of phages that can lyse this bacterium, exploring the genetic factors that determine the host range of our phages, and conducting experimental evolution studies. The following projects are planned for summer 2021:

1) Isolate novel phages, extract and sequence DNA, assemble and annotate novel genomes. Given what we know about phage genetic diversity, we still have lots of unknown phages to identify and study.
2) Determine the host range of our 45 novel phages on 24 *Bacillus* strains. Once we have a complete host range dataset, we can compare phages to determine which features (e.g., genome size, presence of particular genes) predict whether a phage has a narrow or broad host range.
3) Determine which phage cocktails (mixture of 2 or 3 phages) are better at controlling bacterial growth as opposed to single phages.
4) Conduct a coevolutionary experiment allowing related phages to evolve on and adapt to different bacterial hosts. At the end of seven weeks, phages will be resequenced to identify the genetic changes that allow these phages to better lyse their hosts.

Betty Ferster
Department: Biology

Prerequisite for a Summer Position:
Students should have an interest in ecology, plants and insects and be prepared to do a lot of walking through sometimes thick vegetation in the summer heat. There are no prerequisites.

Current plan is for research to be performed in-person.

Description of Research:
Grassland butterfly research at Gettysburg National Park and Gettysburg College campus
In the northeastern United States, grasslands are ephemeral and now dependent on human efforts to maintain them. Yet, grassland diversity has declined as habitat is fragmented and degraded with land-use changes. Regal fritillary butterflies were once widespread and common in the Northeast. In Pennsylvania, they were once abundant in and around what is now Gettysburg National Military Park (GETT) and the campus of Gettysburg College (GC). During the famous battle that took place at Gettysburg, the weather was favorable for butterfly nectaring, and regals persisted there until 1983. But northeastern populations began disappearing in the mid 1950's and now only one population remains. This species may be an indicator of grassland degradation and focusing restoration efforts on supporting this species will act to support grassland diversity.

Our work on the last remaining population of this butterfly in the Northeast, on an active military training facility at Fort Indiantown Gap (FIG), has established the importance of particular plants to the survival of this species where it persists. We will apply this knowledge to habitat assessment and restoration efforts in GETT and on GC campus. The 2021 summer data will be important to future measurements of success of manipulation of these grasslands.

Our summer 2021 work will measure diversity and abundance of grassland plant and butterfly species in grasslands at GETT as well as on the open spaces of GC and will provide information for recommendations on supplemental plantings that can be used to improve abundance of important plants.

- Weekly surveys of butterfly abundance in grassland and garden areas using a walking transect technique.
- Weekly surveys of flowering plant diversity in these same sites.
- Measure violet density and nectar plant abundance using different plant survey techniques.
- Design and build grassland habitat island (“pollinator garden”) for an island biogeography study of grassland butterfly dispersal.
- Nectar plant seed collection and germination in the college greenhouse
- Planting of nectar plants in Gettysburg National Park grassland sites and monitoring their success.

Peter Fong
Department: Biology

Pre-requisite for a Summer Position:
The students must have an overall GPA of 3.0 or better, and achieved a grade of B or better in Biology 111 and Biology 112. Students should be interested in organisms, bioactive chemicals, behavior, and the natural environment.

Current plan is for research to be performed on-campus, in-person.

Description of Research:
1. Disruption of marine snail and crab behaviors by exposure to the antifouling chemical, medetomidine.

The main project will be to test the effects of the antifouling chemical medetomidine on important behaviors (righting reflex, escape responses, locomotion) in marine snails and crabs. Results from previous experiments showed that medetomidine has toxic effects on amphibian tadpoles. In summer'21, my lab will investigate its possible modulation of behavior in snails and crabs. We will collect animals in Delaware, maintain them in the lab, and do a behavior experiment each day testing different concentrations of medetomidine. As pollution in the ocean continues to be a serious environmental problem, it is important to test emerging contaminants such as "new" antifouling chemicals that may pose unforeseen risks on aquatic organisms.

Description of Research:
2. Pharmacological characterization of serotonin receptor mediating foot inflation in marine and freshwater clams.

My students will also characterize the serotonin receptor that mediates a foot response in marine and freshwater clams (bivalves). Serotonin is an ancient biochemical found in every phylum of animal, as well as in fruits and vegetables. The serotonin receptors that mediate responses in clams show a pharmacological profile sensitive to drugs that bind to human 5-HT1, 5-HT1A, and 5-HT2 receptor sites. We aim to characterize the serotonin receptor mediating foot inflation (a response that occurs in the presence of externally applied serotonin). We will collect animals in local streams and in Delaware, maintain them in the lab, and do an experiment each day testing them with serotonergic ligands that bind to human serotonin receptor sites.

Kazuo Hiraizumi
Department: Biology

Prerequisites for a summer research position: Completion of Biology 211 (Genetics) by the end of the Spring Semester of 2021 would be desirable. An alternative qualification would be completion of Biology 113/114, Biology 115, or Biology 212 (Cell Biology). Laboratory experience working with Drosophila would be a plus.

Current plan is for research to be performed on-campus, in-person.

Description of Research:
Dipeptidases, a class of digestive enzymes, 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 mRNA isoforms all 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 the other two dipeptidase genes, 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; 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; and 6) bioinformatics strategies for the identification of potential mRNA isoforms in other peptidase and proteinase genes. The summer internships offer an opportunity to contribute to these areas of research.

Steven James
Department: Biology

Prerequisites for a summer research position:

1. Bio 211 *Genetics -- required*
2. Bio 212 *Cell Biology – optional and preferred*

Current plan is for research to be performed on-campus, in-person.

Description of Research: Cells rely on a cytoskeleton to determine shape, structural integrity, movement of materials throughout the cell, and to mediate the faithful segregation of the genetic material (chromosomes) during nuclear division (mitosis) and cell division. This essential cytoskeletal framework is composed of microtubules, rodlike fibers consisting of heterodimers of alpha- and beta- tubulin proteins. We discovered a novel regulator of the microtubule cytoskeleton, which we named WD1. WD1 is a member of the WD40 repeat family of proteins, one of the largest protein families. WD40 proteins form a β-propeller — a non-enzymatic scaffold with a relatively flat plate structure ideal for facilitating protein-protein interactions. Cells lacking the WD1 gene (ΔWD1) exhibit strong cold-sensitive lethality at 20º. At this temperature, cells undergo mitotic catastrophe, *i.e.*, failed nuclear division, characterized by greatly reduced or absent cytoplasmic and spindle microtubules and fragmentation of chromosomes. Thus, WD1 serves a critical function in microtubule dynamics and cell proliferation. This gene is conserved across a wide span of the fungal kingdom, but unstudied in any other fungus, and therefore we have the opportunity to contribute new understandings of cytoskeleton stability/dynamics. Also, the WD1 gene is absent from animals and plants, making it a potentially useful target for antifungal drug development.

Project #1: **Identification and characterization of WD1-interacting genes:** How WD1 governs microtubule stability is unknown. By discovering genes that interact with WD1, we may uncover the complex in which WD1 operates and in this way identify its molecular function. To identify WD1-interacting genes, Katie Watson ('20) generated suppressor mutations that rescued (*aka* suppressed) ΔWD1 cold-sensitive lethality by restoring growth at low temperature. During spring and fall 2020, student researchers used genetic analysis to sort 10 independent suppressors into two genes, one with 8 alleles and the other represented by two alleles. During spring 2021, representative suppressor mutants will undergo whole-genome sequencing (WGS) to pinpoint mutations in candidate suppressor genes. During summer of 2021, **you** will combine Sanger DNA sequencing and genetic engineering to determine the molecular identity of one or both WD1-interacting genes. First, **you** will re-sequence candidate suppressor mutations to verify candidates revealed by WGS. Next, **you** will identify the *bona fide* suppressor gene(s) by using a knock-in strategy to engineer the verified genetic variation(s) into a ΔWD1 mutant and show that your genetically engineered knock-in mutation(s) rescues cold-sensitivity. Time-permitting, you may continue by installing a biochemical tag to a suppressor gene to allow protein characterization by western blotting and immunoprecipitation. *Through this project, you will develop proficiency at design and execution of PCR amplification, DNA sequence analysis, and genetic engineering and molecular diagnosis.*

Project #2: Measurement of tubulin protein levels in the WD1 mutant: Cells lacking WD1 suffer from a paucity of microtubules, with the following possible causes: (a) reduced expression (insufficient transcription) of tubulin genes; (b) reduced translation of tubulin proteins, *i.e.*, insufficient pools of tubulin proteins; or (c) inability to assemble microtubules from sufficient tubulin pools, caused by incomplete tubulin folding or failure to dimerize alpha- and beta-tubulin. **You** will measure tubulin protein levels in normal versus DWD1 mutant cells, and **you** will test the effects of overexpressing beta-tubulin in the DWD1 cold-sensitive mutant. **You** will perform total protein extractions, quantify protein yields, separate proteins using SDS-PAGE, and immunoblot using anti-alpha-tubulin and anti-beta-tubulin antibodies. anti-GAPDH antibody will serve as the internal loading control. Proteins will be detected using Horseradish Peroxidase (HRP)-conjugated secondary antibodies in combination with chemiluminescent HRP substrates. *Through this project, you will develop proficiency at techniques of protein biochemistry, quantitative densitometry, and genetic analysis.*

Ryan Kerney
Department: Biology

Prerequisites for a summer research position:

Current plan is for research to be performed on-campus, in-person.

Description of Research:
Our lab specializes on the ecology, evolution, and development of amphibians. Current projects include research on the diversity of skeletal development, the formation of “vestigial” structures, symbioses between salamander embryos and green algae, limb development, lung development, and descriptive morphology. While this work is focused on a specific taxonomic group, it touches on many fields within biology.

Lauren Klabonski
Department: Biology

Pre-requisite for a Summer Position: Bio 212 (Cell Biology) would be helpful, but is not required.

Current plan is for research to be performed on-campus, in-person.

Description of Research:
Growth factors are secreted proteins with well-studied roles in development, differentiation, metabolism, and many other cellular processes. Interestingly, local secretion of growth factors such as transforming growth factor beta (TGF-β) from neurons in the brain has been shown to ameliorate aspects of neuronal dysfunction in patients with neurodegenerative diseases, like Alzheimer's and Parkinson's disease. While targeting TGF-β biogenesis may be a potential avenue for neurodegenerative disease therapeutics, there is not much known about the mechanisms governing TGF-β synthesis and secretion from neurons. We are using the nematode worm *C. elegans,* to study *in vivo* biogenesis and neuronal secretion of TGF-β-like protein called DAF-7 and, hopefully, gain insight into these mechanisms.

Project 1: As with any protein, TGF-β/DAF-7 must be properly folded in order to function. To properly fold, many proteins require molecular chaperones, or folding assistants. As the TGF-β/DAF-7 protein has a complicated structure, it is likely that molecular chaperones are involved in its folding; however, it is unknown on which molecular chaperones the folding of the TGF-β/DAF-7 protein depends.

- You will conduct a targeted RNA interference (RNAi) screen in *C. elegans* with the goal of identifying molecular chaperones involved TGF-β/DAF-7 protein folding. Along the way, you will learn how to work with *C. elegans*, use fluorescence microscopy to image and score live animals, and quantify your images using image analysis software.

Project 2: Neurons are polarized cells with distinct functional compartments called axons and dendrites. Polarity in neurons arises from precise sorting of specific membrane, cytosolic, and secreted proteins to the correct compartment. Despite the importance of polarity to neuronal function, our understanding of the polarized sorting mechanisms is limited to membrane proteins, like receptors. How soluble secreted proteins, like growth factors, are sorted into the correct vesicle, targeted, and, ultimately, secreted is unknown. We recently found the *C. elegans* TGF-β-like protein DAF-7 sorts specifically to and is secreted from dendrites while being completely excluded from axons of sensory neurons. This is an excellent model to elucidate the mechanisms responsible for sorting soluble dendritic proteins.

- You will conduct a targeted RNA interference (RNAi) screen with the goal of identifying cellular components involved in polarized sorting and trafficking of the TGF-β/DAF-7 protein (ex. adaptor proteins, vesicle components, molecular motors, etc.). Along the way, you will learn how to work with *C. elegans*, use fluorescence microscopy to image vesicles in the neurons of live animals, and quantify your images using image analysis software.

Project 3: I have a construct that fuses the DAF-7 protein to the fluorescent protein mCherry. The fluorescent TGF-β/DAF-7 construct was microinjected to create a new strain of worms with a red 'glowing' TGF-β protein in their neurons. Although the worm protein DAF-7 is similar in both structure and function, it is not identical to the human TGF-β protein. It is possible conclusions drawn from studying a worm TGF-β protein may not be applicable to humans and, thus, not clinically relevant. The specific goal of this project is to create a new transgenic strain of worms containing a human TGF-β protein labelled with green fluorescent protein (GFP).

- You will use basic bioinformatics and molecular biology techniques (PCR, restriction digest, cloning) to create a new human TGF-β::GFP construct and inject this construct into worms to generate your own strain. Along the way, you will also learn how to work with *C. elegans* and use fluorescence microscopy to visualize proteins in live animals.

Jennifer Powell
Department: Biology

Pre-requisite for a Summer Position: Highly motivated students who love genetics and plan to continue their research projects in the Powell lab during the school year. Preference given to rising sophomores and juniors.

Current plan is for research to be performed on-campus, in-person.

Bacteria are everywhere! The animal innate immune system is charged with the critical task of recognizing and responding to these bacteria so they do not cause potentially fatal infections in the host animal. Recognition of potentially pathogenic bacteria and other microorganisms by the immune system is relatively straightforward in sterile body tissues. Professional immune cells typically express receptors that bind conserved microbial components such as fragments of cell wall, flagella, etc. This method of identifying invading microbes works well as long as no microbes are permitted in that space.

But what about tissues such as the intestine? The animal gut is full of bacteria and so the cells lining the intestine are continuously exposed to myriad species of microorganisms. Because it depends on many of these microbes for health, an animal cannot simply wipe them out using its immune system. However, many gut microbes have the potential to be pathogenic, so the animal immune system cannot ignore them either.

The tiny nematode *C. elegans* is an outstanding model system to answer these fundamental biological questions. One exciting hypothesis is that epithelial cells such as those lining the intestine use a different method of detecting infection. Rather than scanning for bacteria and other microbes, these cells monitor signs of cellular stress that may accompany the early stages of infection. This indirect detection method allows the immune system to discriminate among benign or helpful microbes and harmful pathogens. To test this hypothesis, our lab uses molecular genetic analysis to explore the connections between the innate immune response and the response to other types of cellular stress.

Alex Trillo
Department: Biology

Pre-requisite for a Summer Position: Students should be highly motivated, be eligible for travel abroad, and be comfortable with intense tropical field-work. Preference will be given to students who have completed one semester of research in the Trillo Lab.

Important: If we can't schedule a trip to Panama this summer due to COVID restrictions, we will conduct work at my lab in Gettysburg, analyzing primary and secondary sexual trait variation in specimens of the tortoise beetle *A. sparsa* previously raised in chambers with very different levels of CO2.

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. We are currently examining the effects of eavesdropping predators and parasites on the calling dynamics of mixed-frog choruses.

Eavesdropper effects on mixed-species choruses of frogs: Males often use conspicuous mating calls that increase attractiveness to females. These calls, however, usually come with a cost: being attractive to females also means being attractive to eavesdropping predators and parasites. This trade-off, between attractiveness to mates on one hand, and attractiveness to eavesdroppers on the other, has been shown to strongly influence mating call evolution. We are particularly interested in how the mortality risk due to eavesdropping predators, such as the bat *Trachops cirrhosus*, and eavesdropping parasites, such as the midge *Corethrella* spp. gets transferred from one prey species to another in mixed-species aggregations of frogs. We investigate whether calling near males of another species makes signalers more or less vulnerable to 'eavesdroppers' – do attractive neighbors bring in additional eavesdroppers ("Collateral Damage"), or do these neighbors capture most eavesdropper attention themselves, reducing a male's risk ("Shadow of Safety")? Ultimately, we wish to understand how these prey species interactions drive calling site choice and calling behavior in mixed choruses of tropical frogs. This summer, we will also try to understand how signaling neighbors of the same species can influence eavesdropper pressure. Student researchers that work on this project conduct playback experiments, presenting a variety of acoustic stimuli to bats in flight chambers and in the field. They will be trained in experimental techniques, bat handling and mist-netting, bioacoustics software, behavioral analysis software, and methods in tropical fieldwork. This study is carried on at the Smithsonian Tropical Research Institute in Panama.

Katherine Buettner
Department: Chemistry

Pre-requisite for a Summer Position: Students should have completed general chemistry to work in the lab.

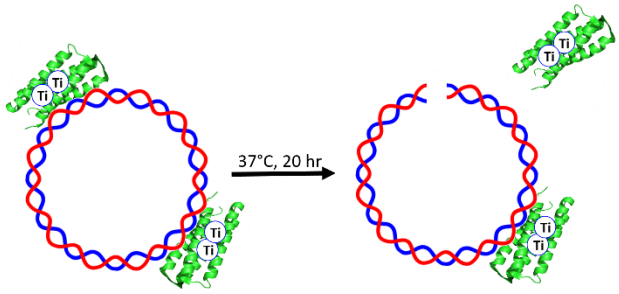
Current plan is for research to be performed on-campus, in-person.

Description of Research: The design and synthesis of mini-metalloenzymes

The aqueous chemistry of hydrolysis-prone metals is often avoided due to their reactivity with water. Avoiding hydrolysis through careful ligand choice opens new uses for these metals. Two such metals, titanium and vanadium, have many uses as catalysts and materials under non-natural conditions. Harnessing their reactivity with water using biological ligands will lead to novel applications of these metals. While titanium and vanadium are not commonly native to enzymes, their reactivity with water can be controlled in the binding sites of many natural proteins. We design novel enzyme active sites to bind hydrolysis-prone metals and utilize their reactivity to generate new enzymatic activities.

Many *de novo* designed proteins bind metals, however none have been reported to bind hydrolysis-prone metals, such as titanium and vanadium. These metals are relatively abundant, but underused in catalysis compared to precious metals. We have recently shown the ability of our enzymes to stabilize and functionalize titanium, providing the first report of a titanium enzyme, as well as the ability of our model system to mimic natural binuclear zinc hydrolases. Both our titanium and zinc enzymes are able to cleave DNA, showing their potential to act as therapeutics. We are now working to understand structure function relationships of these enzymes, and their ability to function against a variety of substrates.

Projects in the Buettner lab include: the design and development of new active sites in our current protein scaffolds to optimize metal binding as well as enzymatic activity; characterization of metal binding using a suite of biophysical techniques; and the optimization of enzymatic activity studies. We plan to do this work in person.



Shelli Frey
Department: Chemistry

Pre-requisite for a Summer Position: Should have completed a year of general chemistry.

Current plan is for research to be performed on-campus, in-person.

Description of Research: Measuring the interactions of huntingtin protein with model cell membranes

Huntington's disease is characterized by the accumulation of nanoscale protein aggregates in the brain and central nervous system. Genetic mutations which cause an expansion of polyglutamine (polyQ) amino acid stretches are responsible for the subsequent misfolding of the huntingtin's (htt) protein that contributes directly to the pathogenesis of Huntington's disease. Interestingly, the length of the polyQ region directly correlates with disease progression. Additionally, htt interacts with a variety of membraneous structures within the cell (Figure 1), and the N-terminus (Nt17) is implicated in lipid binding.

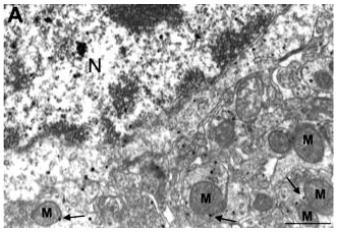


Figure 1: Huntingtin protein aggregates associated with mouse mitochondria

This project focuses on discerning the mechanism of this protein N-terminal membrane association. Since the Nt17 region of htt is random coil in aqueous solution and becomes alpha helical when bound to a membrane interface, circular dichroism (CD) will be used to monitor the kinetics of secondary structure structure as we step through membrane compositions to determine how membrane environment affects binding. Additional experiments with isothermal titration calorimetry (ITC) will be used to measure thermodynamic parameters of these binding events.

Project 2: Interaction of prion proteins with model cell membranes

When abnormal forms of prion protein accumulate in the brain, spongiform encephalopathies, a group of fatal neurodegenerative diseases, may result. Prion protein (PrP) is thought to function in copper transport and cell signaling and is associated with cell membranes through a C-terminal glycolipid anchor. Prion protein (PrP^{C}) may unfold and refold into an abnormal structure (PrP^{Sc}), leading to differing physical properties and function. PrP^{C} folded in its wild type form is highly α-helical, while PrP^{Sc} contains more β-sheet structures that lead to misfolded non-functioning aggregates. These differing structures result in their differing characteristics; PrP^{C} is easily degradable, while PrP^{Sc} is highly insoluble and demonstrates resistance to digestion. To investigate the role that lipid membranes have in this secondary structure conversion to PrP^{Sc}, we will use circular dichroism (CD) and isothermal titration calorimetry (ITC) to measure interactions of PrP(106-126), a short peptide fragment of PrP that recapitulates many of the known features of PrP^{Sc}, with model neuronal membranes.

Project 3: Imaging nanoparticle interactions with model cell membranes

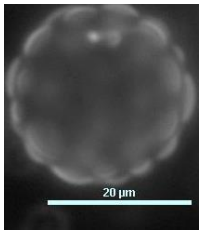


Figure 2: Fluorescence microscopy image of a giant unilamellar vesicle; obtained in Lipid Lab

Unique material properties of nanoparticles (NPs) contribute to a diversity of applications that range from increasing transparency and protection of sunscreen to transporting drugs across cell membranes without damaging the cell itself. The interactions of NPs with biological membranes have not been fully characterized to correlate surface physical and chemical characteristics with mode of action. We will expose model cell membranes to NPs to determine how NP surface functionalization affects interactions with membranes composed of different lipids. More specifically, lipid giant unilamellar vesicles (GUVs) (Figure 2) will be exposed to positively or negatively charged NPs of different sizes and then imaged with fluorescence microscopy to measure morphology changes and vesicle size distributions. In addition, effects on the membrane material properties will be determined by assembling phase diagrams under different nanoparticle conditions.

Timothy Funk
Department: Chemistry

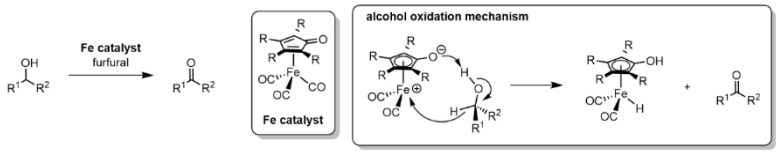
Pre-requisite for a Summer Position:

Current plan is for research to be performed on-campus, in-person.

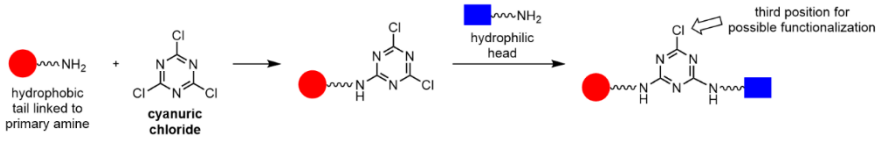
Description of Research:
Completion of Chem 107 and 108; at least one semester of organic chemistry would be helpful, but it is not required. These projects will only occur if we are in person and on campus.

Project 1: Sustainable Oxidations and Reductions. Synthetic chemistry drives many modern technologies, ranging from the development of new pharmaceuticals to the creation of innovative materials. One focus of 21st-century synthetic chemistry is improving the sustainability of chemical processes by using catalysts derived from earth-abundant metals, and research in the Funk lab is directed toward the development of (cyclopentadienone)iron carbonyl catalysts and applying them to redox transformations. Not only are these catalysts based on the second-most abundant metal in the earth's crust, but they also allow relatively benign, plant-derived organic compounds to act as terminal oxidants or reductants. Overall the goal is to develop more environmentally sustainable carbonyl reductions and alcohol oxidation reactions, both of which are fundamentally important transformations in the synthesis of pharmaceuticals and fine chemicals. Ideally, the processes would be efficient enough to be used in industrial syntheses.

During the summer of 2021 we will explore the following: 1. Optimizing and exploring the substrate scope of an iron-catalyzed alcohol oxidation process using renewable furfural as the terminal oxidant; and 2. Developing selective oxidations of primary and secondary alcohols through judicious catalyst and oxidant selection.



Project 2: Functionalizable Lipid Synthesis. Most lipids have two parts: a hydrophilic head and a hydrophobic tail. Through a collaboration with Prof. Vince Venditto at the University of Kentucky's College of Pharmacy, we are designing and synthesizing lipids with three parts by taking advantage of the structure and reactivity of cyanuric chloride. Prof. Venditto is studying vaccine development and has evidence that proteins ligated to cyanuric chloride-based lipids elicit a stronger immune response compared to those based on traditional lipids. Cyanuric chloride will serve as the tether linking the parts of the lipid together, and it allows for the tail and head groups in addition to a third group, which could be used to bind to other biological molecules. We are early in the project and our goal this summer is to connect a variety of hydrophobic tails (mainly cholesterol and some fatty acids) to cyanuric chloride through glycine or glycol-type linkers. If we are successful, we will start adding hydrophilic heads. Once we isolate these compounds, we will send them to Prof. Venditto for differential scanning calorimetry to gain insight into their transition temperatures.



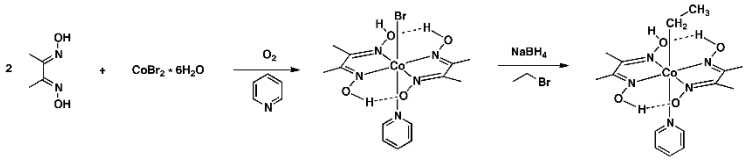
Donald Jameson
Department: Chemistry

Pre-requisite for a Summer Position:

Current plan is for research to be performed on-campus, in-person.

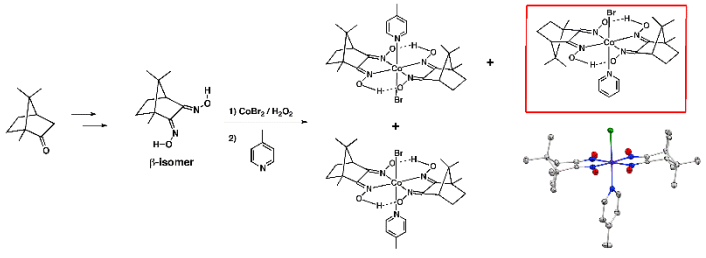
Description of Research: Cobalt complexes of camphorquinone dioxime

Cobaloximes, cobalt coordination complexes that are model complexes of vitamin B_{12}, were studied extensively in the 70s and 80s. Recent interest in these complexes focuses on their use as catalysts for both solar production of hydrogen and new organic photochemical reactions. The cobalt ion is in an octahedral geometry, bound by two dioxime ligands in the equatorial plane and anionic and neutral ligands in the axial positions. Cobaloximes are noteworthy for their ability to support a stable metal-carbon bond, a novel feature also found in vitamin B_{12}.



The dioxime of camphorquinone has been known since the early 1900s, but has never been used to prepare cobaloxime complexes. The interest in such a molecule arises from the fact that the camphorquinone ligand is chiral, which may confer on the cobaloximes unique properties, particularly as catalysts. Camphorquinone dioxime exists as four possible isomers, but only one can be used to make a cobaloxime. Furthermore, the cobaloxime complexes exist as three possible isomers and all three are a product of their synthesis. These problems present challenges for purification; some which we have solved and some which remain to be solved. It is worth noting that the +3 oxidation state of the cobalt atom renders the complexes diamagnetic and therefore amenable to structural analysis by NMR.

In summer 2019, Emma Armstrong (’21) prepared, isolated and was able to grow high-quality crystals of the complex possessing a 4-methylpyridine ligand. X-ray experiments (in collaboration with Nathan Schley at Vanderbilt) confirmed that the ligands have a cis orientation about the cobalt ion. The 3 possible isomers are shown below along with the crystal structure of the highlighted isomer.



Continuing work this summer will include preparation of new derivatives of these cobaloxime complexes (modifying both neutral and anionic ligands, including organometallic derivatives). We will be studying the properties of these molecules with an eye toward comparisons with the many related molecules that are reported in the literature. Among the ligand variations we will try are alkynes and N-heterocyclic carbenes, both of which would result in novel cobaloximes.

Jason Labonte
Department: Chemistry

Pre-requisite for a Summer Position:

Current plan is for research to be performed remotely.

Description of Research:
Despite its historical longevity, the "central dogma" of biology cannot account for the flow of all information in the "language of life". Methylation of DNA, the existence of inteins and prions, and post-translational modifications (PTMs) of proteins are all examples of information flow within biology that do not fit cleanly into the simple scheme where DNA leads to RNA, which leads to protein. A complete understanding of biology requires a deciphering of what factors control these alternative forms of information flow. These factors involve an understanding chemistry at a three-dimensional level. Computational modeling tools provide an efficient way to investigate the vast informational complexity of life encapsulated within the three-dimensional structures of biomolecules. However, to date, there is a lack of modeling tools available for researchers investigating PTM biology and chemistry.

Current algorithms rely on primary protein sequence to predict PTM sites. The innovation of my project is to include three-dimensional/structural data. I have developed a tool within the Rosetta modeling suite to read consensus sequences from a database and use this information to build models of post-translationally modified structures from starting "apo" structures. Such models can then be used to study the interactions of particular PTM enzyme systems.

The overarching goal of my research group is to develop computational tools to decipher the language of the cell at the chemical level, focusing on interactions with carbohydrates and other PTMs. Students in my lab learn skills in organic chemistry, biochemistry, and computational modeling, with a potential to learn programming skills.

Suvrajit Sengupta
Department: Chemistry

Pre-requisite for a Summer Position:

Current plan is for research to be performed on-campus, in-person.

Description of Research:
Hydrophobic interactions play an important role in protein folding, and formation of lipid micelles and bilayers. Current opinion regarding the arrangement of water around small hydrophobic molecules is that it is akin to those found in clathrate hydrates of natural gases. My research group will utilize a broad range of techniques spanning the fields of physical and biophysical chemistry to better understand water dynamics in clathrates and biological systems. Clathrate hydrates are non-stoichiometric compounds (*i.e.*, they don't have a fixed composition) composed of a host water "cage" and a "guest" molecule. In this way, they are a class of inclusion compounds – compounds that are formed by the entrapment (or, enclathration) of one or more molecules inside a larger molecular network. They occur naturally in the sea-floor and permafrost as "gas hydrates" with methane and ethane being the most common guests. They could serve as potential energy reserves, but also pose a danger to the environment because they can form spontaneously in pipelines and thus lead to blockages. On the other hand, they could prove to be efficient means of storage and transportation of a variety of gases.
Most guests that are found in clathrate hydrates are only partially soluble in water in the liquid state (exception being tetrahydrofuran (THF; C_4H_8O) and some other ring ethers), however, the solubility increases when water is in the solid phase! The structure of the hydrates themselves are very different from the hexagonal ice (I_h) structure we are familiar with. While ice has water molecules arranged in puckered hexagonal rings, hydrates have planar pentagonal and hexagonal rings which assemble together to form various cages. The structure of the hydrate lattice would be unstable without the guest gases (that is why ice has a very different structure) – however, non-covalent interactions between the guest and the water molecules somehow stabilize this structure and make it more favorable. This is a surprising result, considering most guests (such as methane, ethane, propane, etc.) are hydrophobic and have unfavorable interactions with water. There are many such unique and surprising aspects of the chemistry of clathrate hydrates. This summer, students working in my lab will work on three aspects of this research:

Project #1: Study the so-called "memory effect" of hydrate formation. It is suspected that hydrates are formed more easily from melts of previously formed hydrates than from the combination of freshly prepared reaction mixtures. Students will either use laser-cut cassettes already designed in our lab, or build new ones, to monitor the melting and reformation of tetrahydrofuran (THF) or cyclopentane (CP) hydrates under the microscope. They will also design and assemble associated equipment to monitor and maintain experimental variables such as temperature. The project may develop into monitoring the enclathration process at interfaces.

Project #2: Develop equipment to monitor the kinetics of hydrate formation from ice-particles and various guest gases. The gases may include fluoromethane and propane. Effects of various hydrate formation catalysts and inhibitors such as, alcohols, salts, and surfactants, could also be investigated. The preliminary work will focus on assembling a system capable of monitoring and maintaining temperature and pressure in a sealed hydrate formation chamber, and efficient means of generating well characterized ice particles. The work might also include programming (using Mathematica) to analyze the data generated.

Project #3: Investigate the effect of biologically relevant molecules such as, lipids, amino acids, and peptides on the formation kinetics and thermodynamic stability of hydrates. This might include protein synthesis, especially of antifreeze proteins which have been shown to influence ice and hydrate formation kinetics.

Luke Thompson
Department: Chemistry

Pre-requisite for a Summer Position:
There are no prerequisites to joining the NanoLab.

Current plan is for research to be performed on-campus, in-person.

Description of Research:
Nanoscale materials such as gold and silver demonstrate unique optical properties that can be harnessed for applications in drug delivery, photothermal therapeutics, sensing and imaging. Gold nanoparticles are probably one of the most well-known classes of nanomaterials in existence, yet there is still much to learn about their synthesis, growth, and self-assembly. One of the most common ways to control interfacial interactions is to chemically modify the surface of the nanoparticle with a polymer. Broadly, our work studies the surface modifications of gold nanoparticles with polymers.

One ongoing project explores the electrostatically modulated surface modifications of charged nanoparticles with polyelectrolytes (highly charged polymers). More specifically, we want to understand how polyelectrolyte modifications of gold nanoparticles engenders control and reversibility of the assembly of nanoparticles. In one part of this project we will be using a pH and temperature mediated structural transition (from random coil to alpha helix when the solution pH is raised above the pKa) in an adsorbed polyelectrolyte, poly-l-lysine (PLL), to assemble rod shaped nanoparticles into higher order structures in a reversible manner. In addition to exploring pH and temperature, we will also test if the identity of the intermediate layer is important (PLL is positively charged so we need to have a negative layer between the particle and the PLL). This project requires a wide array of instrumentation from UV-Vis Spectroscopy and Circular Dichroism Spectroscopy to Dynamic Light Scattering and Transmission Electron Microscopy. This project will help us to better understand how the polyelectrolyte structural characteristics mediate the controllable and reversible assembly of nanoparticles.

Chemical modifications of nanoparticle surfaces with polymers allows for wide control of interfacial interactions that can enhance the utility of nanoparticles in advanced technologies like solar cells. The central question in this work is whether gold and silver nanoparticles will remain stable against aggregation when incorporated into a nonaqueous soluble polymer that does not interact strongly with the surface of the nanoparticle. Previous research with poly(methyl methacrylate) and poly(vinyl acetate) suggested that the lower the glass transition temperature (Tg) of the polymer, the higher the ratio of polymer molecules per nanoparticle needed to obtain a polymer film with evenly dispersed gold nanoparticles. With only two polymers incorporated into the previous work, our main focus for this summer is to determine the behavior in between the two Tg extremes. Our preliminary data shows that the glass transition temperature may not be the only variable that predicts stable films. This work explores trends that can be used to predict stability based on glass transition temperature, film evaporation rates, and polymer molecular weights, as well as increase the efficiency in our technique of creating nanoparticle polymeric composites.

Sunghee Kim
Department: Computer Science

Pre-requisite for a Summer Position:
Successful completion of CS216 + CS360 **OR** CS216 + website with DB experience (HTML, CSS, JavaScript), the ability to work independently, strong time management. Preference given to those with experience in using web framework.

Current plan is for research to be performed remotely for the first 2-4 weeks, then in-person.

Description of Research:
In many Computer Science classes students learn and practice important concepts and algorithms by visualizing the internal states typically using pencil and paper. Being able to correctly visualize the data structures and algorithms while processing particular data sets is an essential skill for computer scientists and must be practiced and assessed in assignments and tests.

The pandemic has created a significant challenge in this important assessment task in our courses since most of the tests have to be conducted online. Students had to draw on paper, take a photo of the paper, and upload the photo to Moodle. Faculty then would download and view the photo, often in poor quality, and evaluate the drawing on it. This requires many additional steps for students who are already under stress during tests and for faculty who now have to download/view many low-quality drawings for evaluating.

This project proposes to design and implement a user-friendly versatile online tree drawing system which allows the students to:
(1) draw and edit a tree/graph with a variety of data types,
(2) export the drawing as an image file, and
(3) submit the drawing for feedback.

This system will also allow the faculty to more easily collect, view, and comment on student work. An additional feature that would be particularly useful for the students would be automatically finding errors in the drawing to provide instant feedback to the students. This additional feature can also provide an opportunity to collect error data over time that can be analyzed to better understand common misunderstanding among the students.

Meg Blume-Kohout
Department: Economics

Prerequisite for a Summer Position: Successful completion of introductory statistics is preferred, but not strictly required.

Current plan is for research to be performed in-person.

Description of Research:
The BK Lab combines natural language text mining, statistical programming, econometric modeling, and theories from across the social sciences to investigate science policy questions, with particular focus on biomedical innovation and the scientific workforce. This summer, we have two core projects planned:

1. **Risky Business.** How does expanding insurance coverage for prescription drugs impact pharmaceutical companies' research and development (R&D) pipelines? Following on an earlier study by Blume-Kohout and Sood (*Journal of Public Economics*, 2013) that showed an increase in clinical trials for therapeutic classes most used by newly covered people, this project will investigate what happened next: Were those new R&D projects more risky, and/or less likely to result in real therapeutic advances for patients? For this project, I am seeking research fellows with (a) health sciences background/interest and at least introductory statistics, or (b) familiarity with python programming and interest in statistical modeling.

2. **Belonging in Science.** What influences STEM-interested undergraduates' persistence in STEM majors? Why are women students who graduate with STEM degrees less likely to remain in STEM occupations? For the former, does it matter whether women students have women instructors or a higher share of women students in their introductory courses? For the latter, we've previously shown preferences over job attributes (degree of independence, job security, etc.) and broader social norms, values, or attitudes significantly differ among STEM workers versus the general population, but are these preferences, norms, values, and attitudes also most prevalent among heterosexual white men? If so, the greater mismatch for individuals from other groups may contribute to lower sense of belonging, encouraging them to leave STEM. For this project, I am seeking research fellows with either: (a) interest and some background in mathematical modeling and data wrangling, preferably familiar with Stata statistical software or similar programs (e.g., R); or (b) strong reading and writing skills and interest in the topic to perform descriptive statistical analysis and help build our literature review.

Sarah Principato
Department: Environmental Studies

Pre-requisite for a Summer Position:
Successful completion of courses including ES223, ES230, and ES318 are preferred requirements for this position.

Current plan is for research to be performed in-person.

Description of Research:
This project will focus on analyzing glacial landforms in Iceland to understand patterns of past ice flow. Specifically for this summer, we will examine the morphology of ice scour lakes to study patterns of glacial erosion. Using the Arctic DEM and hydrology data from the National Land Survey of Iceland, we will quantify several morphologic properties of the lakes, such as length, width, elongation ratio, as well as lake density and distance to coastline. Since the lake dataset for all of Iceland is very large (as determined by a previous XSig student who focused on numbers of lakes and not morphology), we will investigate patterns and morphology of lakes in Northeast Iceland and expand to other regions if time permits.

Josef Brandauer
Department: Health Sciences

Pre-requisite for a Summer Position: While previous lab experience is generally helpful, it is not completely required. Rather, I look for motivated and hardworking individuals who are excited about scientific discovery, problem solving, and passionate about working collaboratively within a small team.

Current plan is for research to be performed on-campus, in-person.

Description of Research:
The current focus of my research lies on understanding how mammals regulate mitochondrial content and activity in various tissues. A particular focus is the investigation of how cellular concentrations of nicotinamide adenine dinucleotide (NAD) contribute to this regulation.

This summer, we will investigate mitochondrial biology in skeletal muscle of a mouse model of Down Syndrome. The student working on this project will primarily assess mitochondrial protein expression, activity, and NAD concentrations in skeletal muscle of these mice.

Student Expectations
For all of my research projects, I look for curious and motivated students who are interested in working in mouse models. With practice, students working in my lab routinely become quite skilled at the specific techniques my lab employs. While previous lab experience is generally helpful, it is not completely required. Rather, I look for motivated and hardworking individuals who are excited about scientific discovery, problem solving, and passionate about working collaboratively within a small team. I look forward to meeting you!

Kurt Andresen
Department: Physics

Pre-requisite for a Summer Position:

Current plan is for research to be performed on-campus, in-person.

Description of Research:

1. **Measuring Ions around Mononucleosomes**

There is two meters of DNA packed into the nuclei of every one of our cells (a container that is approximately one micrometer in diameter). One of the major steps in compacting this DNA is the wrapping of the DNA into hockey-puck shaped spools called nucleosomes. In this project, we will be using a few different biophysical and biochemical techniques to try to understand the electrostatics that drive these processes. In particular, using our in-house ICP-AES (fancy machine that measures the concentration of elements in a sample) we will try to measure the type and number of ions that surround nucleosomes, information that is vital to the physical understanding of nucleosome interactions. Furthermore, the student will perform exploratory measurements of nucleosome disassembly utilizing our new Circular Dichcroism spectrometer. Students will learn wet lab techniques (pipetting, equilibrium dialysis) and some interesting biology all while exploring the underlying physics that drives these processes.

2. **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. Recently, my collaborator and I have been studying the role of osmotic pressure (i.e. pushing the DNA together using force) in the physics of self-attracted DNA bundles. In this project, we will subject DNA systems to measurements utilizing our new calorimeter. We will explore how different ions affect the binding of DNA . Students will learn wet lab techniques, some basic thermodynamics, and some interesting biology.

3. **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.

Yunhua Ding
Department: Physics

Pre-requisite for a Summer Position:
For the 2021 X-SIG research project, students with some basic knowledge of quantum mechanics are preferred, but this is not a pre-requisite.

Current plan is for research to be performed remotely.

Description of Research:
My theoretical research addresses spacetime symmetries, with primary interest focused on testing Lorentz and CPT symmetry in precision experiments. It is known that the foundational principle of relativity, Lorentz invariance, can be naturally broken in models unifying gravity with quantum physics such as string theory. The tiny signals emerging from this breakdown provide a unique window to study the underlying theory. High-precision experiments offer an exceptional way to study the prospects for these symmetry-breaking signals.

One of my recent projects is exploring prospects for testing Lorentz- and CPT-violating quantum electrodynamics in experiments with Penning traps, a special apparatus designed to measure fundamental particle quantities, such as the magnetic moment and the charge-to-mass ratio, in an exceptional precision level. Interactions of a trapped particle with the electromagnetic fields in the trap can generate interesting types of Lorentz violation, including additional time-dependence feature of these measured physical quantities as the Earth rotates about the Sun.

The size of the Electric Dipole Moment (EDM) for a particle is intimately related to the question of why the Universe has much more matter than antimatter. The current broad searches for EDM signals in various experiments offer a powerful way to probe new physics beyond the Standard Model. It turns out that EDM-like signals can be naturally generated in Lorentz-violating quantum electrodynamics. The impressive sensitivity of the EDM-experiments therefore provides an exceptional way to study possible effects from breaking of Lorentz and CPT symmetry. Another of my current projects is motivated by this and is focused on testing Lorentz and CPT symmetry in experiments searching for nonzero EDMs. We have developed a theory to investigate such EDM-like effects arising from Lorentz violation and expect to obtain constraints on the size of Lorentz-violating effects in the near future.

Ryan Johnson
Department: Physics

Pre-requisite for a Summer Position:

No prior physics or astronomy background required. Student should be interested in learning to program in Python.
Current plan is for research to be performed on-campus, in-person, but can be done remotely as well.

Description of Research:

Project I: Quantifying the Effect of Light's Travel Time on Projected Galaxy Cluster Data. This project is a continuation of a study I began several years ago into the phenomenon of the effect of finite travel speed of light on astronomical observations of galaxy clusters. When we use simulations to predict where and how these clusters should evolve, we must project the data onto a 2D observational plane, in order to mimic the projection of that data onto our sky. Specifically, we will be examining the observational effect of projecting 3D astronomical data onto a 2D observational plane when the object we are projecting is so large that light takes millions of years to get from one side to the other. Because of this, all currently used data projection methods are not taking into account that different parts of the object are also being projected to different times. Our goal is to develop and test several different numerical projection methods which will both project the data onto the same plane, and correct it so that it will all be projected to the same time as well.

Project II: War! What is it Good For? Probability Analyses. This is a new project to explore statistical analyzes and probability on large data sets by programming a machine to play the card game "WAR." The essential question I want to answer is, given any current game state (the number and identity of cards in each player's hand), what is the statistical probability of winning the game? Since, in the traditional format, the order of all of the cards is preserved between rounds (no shuffling), the winning condition can be completely determined by the initial state of the cards when they are dealt. When one inserts random shuffling between rounds, the outcome is no longer certain as has been noted by several authors in the literature (Haqq-Misra, 2009, and Lakshtanov & Roshchina, 2011). I am proposing to follow these previous studies in order to quantify the effect of shuffling, or reordering, cards, on the victory probability. This project, while it may not appear related to my research on galaxy clusters, uses all of the same programming and algorithmic techniques that my students use on astronomical data (mean and variance, random and partial sampling of data, analysis of probabilities and trends, presentation and visualization of data). I am proposing this project to examine whether students pursuing a more tangible topic will more quickly and adroitly learn the coding necessary to assist me in my future research. No background knowledge in astronomy is required!

Project III: Visualization of the Time Dilation Throughout a Galaxy Cluster Merger. Albert Einstein demonstrated that, in regions of space where there is high matter-density, an interval of time will be made longer when measured relative to regions of space with low matter-density, his so-called *gravitational time dilation.* Because this effect depends on both the mass of the gravitating object and how distant one is from that object, one would expect that time will be dilated by different amounts in different parts of the object. In a spatially symmetric object, the time dilation would follow this same symmetry. For most astronomically interesting objects, their sizes and masses are too small for this time dilation to vary significantly across their dimensions. On the largest scales however, as in clusters of galaxies, which possess both tremendous mass and large spatial extents, one could expect to measure a variation of time on the order of a few percent for an isolated cluster center vs. its outskirts. When two clusters merge however, the rate at which the gravitational potentials are changing is an appreciable fraction of the speed of light, leading to significant variations in the time dilation for different regions in the cluster. The goal of this project is use simulated galaxy cluster data to develop and test a statistic that is sensitive to this gravitational time dilation effect and to create a visualization of how that statistic changes with time, viewing angle, and merger condition.

Project IV: Over the past 12 months, the policy response of national, state, and local governments to the spread of COVID-19 has run the gamut from no response, to serious restrictions on which businesses can be open to the public, to mask mandates. I am proposing a data science project, which will use publicly available COVID-19 data (case counts, hospitalizations, deaths as a function of geographic location) to examine the effect of different policies on these measurables. In particular, this project will address the question: to what degree have national, state, and local policies contributed to the spread, or lack thereof, of COVID-19? Beyond this question, I am also interested in including more granular demographic data such as age, sex, race/ethnicity, in order to identify and quantitatively assess any discrepancies within these subpopulations from the larger whole. This project will use publicly available data from usafacts.org, which is the central repository for all COVID data in the US.

Jackie Milingo
Department: Physics

Pre-requisite for a Summer Position: Preference will be given to those students specifically interested in astronomy/astrophysics related fields.

Current plan is for research to be performed on-campus, in-person.

Description of Research:
Observational Photometry and Spectroscopy

Given the uncertainty in travel and physical distancing I am considering a number of possible projects for students, both in-person and remote. Regardless this program will include a variety of observational projects that fall under the theme of instrumentation, optical image acquisition, reduction, and analysis of astronomical targets of interest. Projects could include time-series photometry (measuring how the light changes over time) of variable stars, continuing calibration and throughput work for the 16" telescope at the Gettysburg College Observatory (GCO), and the installation, testing, and calibration of a new compact grism spectrometer (CGS) designed for use at GCO. Work involving the CGS may include CAD and 3D printing as needed.

While highly uncertain, an observing run at the National Undergraduate Research Observatory (NURO) in Flagstaff, AZ *might* be possible. NURO members are also communicating with Lowell Observatory to consider other options for remote or robotic observing. Remote only options would include continuing the RR Lyrae work (variable stars used as distance indicators) I've been doing for the past 2 years. The RR Lyrae work is designed to engage students in the research process providing access to a world-wide network of robotic telescopes and freely-available computational and sky atlas database resources. Remote and in-person projects could also possibly include a collaboration with Juniata, Kutztown, and Dickinson using our collection of telescopes, some of which have remote and robotic observing capabilities.

Students will work together on all projects throughout this program. The photometry will require working with archived and newly acquired images from NURO, GCO, and the RR Lyrae project. If we can work in-person, students should expect to spend considerable time at GCO (including evenings as need be) and, while highly uncertain, all students should be available in June for a possible NURO observing run. This is an 8-week program. There are no prerequisites for these projects only the expectation that the students will be physics majors with a professional interest in STEM.

James Puckett
Department: Physics

Pre-requisite for a Summer Position:

Completion of one of the following courses is strongly preferred: PHY255, PHY312, PHY319, or PHY240. Knowledge about Python programming language is desirable but not required.

Current plan is for research to be performed on-campus, in-person.

Description of Research:

Investigating to origin of rigidity in granular materials

Granular materials consist of collections of discrete, macroscopic particles, which have well understood interactions, however, they exhibit complex behaviors like jamming, strain-stiffening, stick-slip dynamics and the Jansen effect. Jamming is when the material goes from a liquid-like state to a solid-like state, e.g. think of sugar or salt seeming solid-like until it is tilted at too great an angle as it pours from the shaker like a liquid.
Recently, a third 'fragile' state was discovered in laboratory experiments of sheared granular materials. Fragile states are rigid in only one direction. Theoretically, these fragile states are hard to explain as the structures which give rigidity in one direction (force chains) tend to branch and therefore must terminate somewhere. However, there were two possible reasons why these states could arise in experiments, either it is due to the small (but finite) basal friction or it is a finite system size effect.

Using computer simulations, we can test each hypothesis independently. As particle-particle interactions are known and can be modelled with Hertz-Mindlin contact forces with Cundall-Strack friction. A discrete molecular dynamics (MD) simulation can illuminate the origin of these fragile states and unravel the origin of rigidity.

Investigating temperature-like variables of granular materials

Granular materials consist of collections of discrete, macroscopic particles, which have well understood interactions. However, these materials exhibit complex behavior like jamming in which the material 'freezes' (jamming) under certain conditions and is analogous to glassy materials. A framework for understanding the jamming transition uses non-equilibrium temperatures to describe the state of the material. Using both laboratory experiments and computer simulations, we test whether these temperatures make physical sense. That is, do they obey the zeroth law of thermodynamics? Do granular systems in contact reach thermodynamic equilibrium? Or have the assumptions of equipartition fail for systems far from equilibrium? Interested students will learn experimental design, computer scripting (Matlab, Python), particle tracking, image analysis, signal processing, electronics, and data analysis. Programming experience is preferred but not required.

Symmetry breaking in collective animal behavior

Theoretical models of social animals successfully reproduce many structures found in nature (e.g. swarms, flocks, mills) using simple interaction rules. However, the interactions between individuals is complex and undoubtedly depends on the environment. Using schools of fish, we use visual perturbations to investigate how individuals negotiate both social and environmental information to reach a consensus. Starting with an unpolarized school of fish, we examine how the symmetry is broken and will use network analysis to look for individuals that may (or may not) contribute more to this decision. Interested students will learn data acquisition, image analysis, particle tracking, signal processing, and electronics.

Yoshi Sato
Department: Physics

Pre-requisite for a Summer Position: Knowledge about Python programming language is desirable but not required. Completion of one of the following courses: PHY310, CHEM203, CHEM204, CHEM221, CHEM305, or CHEM306.

Current plan is for research to be performed on-campus, in-person.

Description of Research:
Molecular Excitation Energy and Charge Transfer Mechanisms in Photosynthesis.
Project abstract: Plants, algae, and many kinds of bacteria capture natural light to sustain their life by photosynthesis. These organisms are using specific proteins to convert the light energy into molecular excitation of pigments, and they eventually create electricity for subsequent chemical reactions of photosynthesis. These proteins are called reaction centers. A remarkable aspect of the reaction center is that efficiency of energy conversion is nearly 100%, much higher than the best commercially available photocells. How did they successfully develop such a mechanism in their course of evolution? Recent experimental and theoretical studies indicate that the quantum mechanics is playing a key role in keeping the efficiency.

In this project, we devise computer simulations to investigate how quantum mechanics is working in the photosynthetic reaction centers. We particularly focus on building a physical model of photo-induced charge transfer dynamics in photosystem II reaction centers, which are commonly found in oxigenic photosynthetic organisms such as plants and cyanobacteria. The simulations will be performed using a GPU-accelerated high-performance computing cluster located in Masters 202.

There are two subprojects available for students:
1) Running simulations and analyzing the results to extract properties of charge transfer dynamics in reaction center.
2) Developing a method for molecular dynamics and quantum chemical simulations on energetic properties of biomolecules including chlorophylls and carotenoid.

In both of the projects, the students will be much involved in data analysis using their knowledge about quantum physics and/or chemistry.

Christopher Barlett
Department: Psychology

Pre-requisite for a Summer Position:
Students must (a) be a psychology major, (b) successfully passed Psych 305, and (c) worked in the ARL for at least one semester. Current plan is for research to be performed on-campus, in-person.

Research can be conducted in person or remote, however in-person is encouraged if able.

Description of Research:
Dr. Christopher Barlett and his Aggression Research Lab (ARL) study the predictors and consequences of various forms of aggression, such as domestic violence, cyberbullying, aggressive personality, and interpersonal aggression. This summer, XSIG students will be expected to analyze several data sets that answer important theoretical questions, and write the results to submit to peer-reviewed journals. Finally, students will be expected to design their own study, collect the data, and analyze the results.

Kathy Berenson
Department: Psychology

Pre-requisite for a Summer Position: All applicants must be interested in learning how to manage/analyze data files and read/write about empirical research literature and conduct studies in personality/clinical psychology. There are no specific prerequisites, but if there are more applicants than available positions, preference will be for students with more preparation, including statistics and research methods courses (e.g., Psych 205, 305), personality/clinical psychology courses (e.g., Psych 221, 222, 223, 321, 400), and/or working as a research assistant.

The current plan is for this work to be an in-person experience on campus.

Compared to previous generations, young adults in the US today suffer from significantly more mental health problems and are significantly more invested in portraying themselves as 'positive' (e.g., self-confident, easy-going, and happy). Although many have begun to speculate that these two trends may be linked, little empirical research on this issue exists. In recent years the Personality Lab has been working to fill this gap, by conducting studies related to the hypothesis that over-valuing a 'positive' self-presentation may be a mental health risk because it diminishes compassion for ourselves and others. Two X-SIG students will be hired during the Summer of 2021 to help write and revise manuscripts from several data sets, involving experiments, open-ended responses, interviews, surveys, experience sampling, and measures of heart rate variability. The students will learn to manage and analyze these data and will also help conduct literature searches. Finally, each student will be responsible for developing an original study in personality/clinical psychology to extend a project recently conducted in the lab or on a related topic of the student's choice.