Faculty: Michael Caldwell

Department: Biology

Prerequisite 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.

Faculty: Veronique Delesalle

Department: Biology

Prerequisite for a Summer Position:

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 2019:

1. Determine the host range of our 35 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.
2. Determine which of our bacterial strains produce biofilms and whether biofilm formation by bacteria is a defense mechanism against phage.
3. 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.
4. Conduct a coevolutionary experiment allowing three different phages to evolve on and adapt to three different bacterial hosts. At the end of six weeks, phages will be resequenced to identify the genetic changes that allow these phages to better lyse their hosts.

Faculty: Peter Fong

Department: Biology

Prerequisite for a Summer Position:
Biology 111 (or 113) and 112. The successful applicant will be motivated by the love of learning, and be interested in aquatic organisms, the natural environment, and pollution.

Description of Research:
Project #1: Insecticide toxicity of 2 invasive crayfish species. In our local streams, we have two species of invasive crayfish, *Orconectes rusticus* and *O. virilis*. How each responds to environmental pollutants such as insecticides may determine the extent of the competition between them.

- We will test the effect of two insecticides on the righting behavior (the ability to properly orient after dislodgement) claw raising behavior (defensive response), and habitat selection of these crayfishes. We aim to test different species of crayfish for their sensitivity to two insecticides.

Project #2: "Burrowing as a proxy for health in freshwater snails, Campeloma decisum. We will test the burrowing behavior of a local freshwater snail as as gauge of toxicity to antidepressants. Antidepressants have strong effects on locomotion behaviors of aquatic organisms.

- This will be a first attempt to measure an important locomotion behavior, burrowing. Campeloma decisum is a common species in local creeks, but rarely seen because it burrows. How exposure to antidepressants affects their ability to burrow is the aim of this project.

Project #3: "Sea anemone bleaching by antidepressants" Bleaching or the loss of symbiotic algae in corals and sea anemones is becoming more widespread in the ocean. Bleaching addresses pollution and other environmental stressors that affect the overall health of coral reefs.

- Previous experiments in our lab during fall of 2018 indicated a strong bleaching effect of the antidepressant Prozac on a common sea anemone, Aiptasia pallida. The questions are, what concentrations of Prozac induce this response and will other antidepressants also cause bleaching?

Faculty: Kazuo Hiraizumi

Department: Biology

Prerequisite for a Summer Position:

Description of Research:
The major focus of research is characterization of natural genetic variation for gene regulation using the dipeptidase genes in Drosophila melanogaster as a model system. Dipeptidases, a class of digestive enzymes, are found ubiquitously across organisms in every kingdom. These enzymes hydrolyze peptide bonds to provide amino acids for various metabolic and physiological processes. As is the case with almost all other enzymes, 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). The gene (Dip-B) that encodes the dipeptidase-B (DIP-B) enzyme in Drosophila melanogaster is different from the other peptidase genes in that multiple forms of mRNA are transcribed from the same gene. These 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). Given that reduction in enzymatic activity levels of certain dipeptidases in humans is associated with disorders such as Huntington Disease, Alzheimer Disease, Crohn's Disease, and Celiac (Coeliac) Disease, determination of genetic factors that affect regulation of these enzyme-coding genes has relevant medical applications.

Research Projects:
1) Developmental expression of DIP-B: Dipeptidase catalytic activity varies developmentally. Using anti-DIP-B antibodies, DIP-B protein can be quantified between two genetic strains that differ in the catalytic activity of DIP-B enzyme. Western analysis and ELISA assays can help to determine the relationship between enzyme activity and quantity of enzyme protein at each developmental stage (larva, pupa, adult by gender) between these two strains.

2) Characterization of new Dip-B mRNA isoforms: Former X-SIG students have discovered several unreported Dip-B mRNA isoforms in Drosophila melanogaster. Base sequences of these mRNA isoforms have yet to be elucidated. Comparison of their relative occurrence between genetic strains that differ in DIP-B enzyme activity would be a next step in this study.

3) Identification of regulatory sequence variability in 5' UTR: There are many different types of sequences that serve as promoters for transcription in Drosophila. Sequence data for existing and new Dip-B mRNA isoforms remain relatively unexplored to identify many such sequences and new splice junctions in the 5' UTR. This study will be continued using available bioinformatics tools.

Faculty: Steve James *(2 pages)*

Department: Biology

Prerequisite for a Summer Position:
Completion of the following courses is required in order to apply for these research experiences:

1. Bio 211 *Genetics*
2. Bio 212 *Cell Biology*

Description of Research:
WD40 proteins constitute one of the largest known protein families and have been implicated in a wide variety of cellular processes from cytoskeleton and microtubule regulation to signal transduction and cell division. All WD40 proteins encode β-propeller proteins — non-enzymatic scaffold proteins with a relatively flat plate structure ideal for facilitating protein-protein interactions. We have identified a conserved fungal protein in *Aspergillus nidulans*, designated *WD-1*, containing seven WD40-repeat domains. A mutant lacking this gene (D*WD-1*) exhibits 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. In addition, the *DWD-1* mutant is hypersensitive to microtubule-destabilizing drugs, and *DWD-1* exhibits a striking genetic interaction by rescuing a severe growth defect conferred by loss of another gene, called *TBCA* (*T*ubulin-*B*inding *C*ofactor *A*), that is known to regulate microtubule assembly.

These observations reveal a critical role for the *WD-1* gene in promoting microtubule stability and cytoskeletal dynamics. These findings are unique, as this conserved microtubule-stabilizing protein is unstudied in any other model system.

I will sponsor three summer research projects designed to complete an initial study of *WD-1*, as follows:

(1) Functional dissection of the acidic C-terminus of the WD-1 protein: the C-terminal end of *WD-1* is unlike other WD-repeat proteins in being highly acidic, *i.e.*, it contains a long run of acidic amino acids (glutamic and aspartic acids). We have initiated a project to create three truncated versions of *WD-1* lacking part or the entire acidic region. **You** will install these truncated genes in *Aspergillus DWD-1* mutants and then assess their function using several methods, including fluorescence microscopy to visualize microtubules and chromosomes during the cell cycle, especially during mitosis.

(2) Co-purification of proteins that physically associate with the WD-1 protein: WD40 proteins stabilize multi-protein complexes by acting as scaffolds to mediate protein-protein interactions. To understand how WD-1 stabilizes microtubules, we must identify WD-1 binding partners. **You** will use the S-tag Protein Fusion Systemä for affinity purification of proteins. In this system, a protein fused with a short S-tag can be affinity-purified by specific binding of the S-tag to its binding partner, the S-peptide. Using an engineered *Aspergillus* strain containing a *WD-1-Stag* fusion, **you** will capture the WD-1-Stag protein complexed with its binding partners, and then use mass spectrometry to identify individual protein components.

(3) Genetic interactions between WD-1 and genes involved in microtubule assembly: Loss of *WD-1* (*DWD-1*) suppresses (rescues) growth defects conferred by mutation of the *TBCA* gene.

(cont'd)

Faculty: Steve James

Department: Biology

TBCA encodes a protein that binds the b-tubulin subunit of microtubules and shepherds it to a-tubulin, mediating their association to form the a/b heterodimer, the core subunit of microtubules. To further explore a potential role for *WD-1* in microtubule assembly, **you** will delete additional components of the complex that regulates microtubule assembly (TBCB, TBCC, TBCD, TBCE genes) in order to determine if *WD-1* acts specifically through TBCA/b-tubulin, or acts more generally to control microtubule assembly.

Faculty: Jennifer Powell

Department: Biology

Prerequisite 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.

Description of Research:
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.

Faculty: Alex Trillo

Department: Biology

Prerequisite for a Summer Position:
Students should be highly motivated, comfortable with intense tropical field-word, and have either completed one full semester in Dr. Trillo's lab, or taken at least one of the following courses before the summer: Animal Behavior, Entomology, or Tropical Terrestrial Biology

Description of Research:
Research in the Trillo lab integrates the fields of behavior, ecology, and evolution. We collect much of our data in the tropics, in affiliation with the Smithsonian Tropical Research Institute. We are currently pursuing two areas of research. The first area examines the effects of eavesdropping predators and parasites on the calling dynamics of mixed-frog choruses. The second area explores the influence of host-plant derived chemicals on antipredator defenses in beetles

1. 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. 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 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.

2. Test of the "escape and radiation" hypothesis in Chrysomelid beetles: The "escape and radiation" hypothesis states that a novel defense can "free" a lineage from its enemies and allow for this "enemy free" species to colonize new habitat, speciate and diversify. Most experimental studies for this hypothesis focus on plant-herbivore interactions. We are interested in testing this hypothesis in herbivore-predator interactions. We are especially interested in determining whether these novel defenses are effective against many different predators that exert similar predation pressure or whether they are effective against one single predator that exerts most of the predation pressure. Student researchers that work on this project will use established manipulation protocols to quantify the effect of different chemical compounds on insect predator deterrence. Students will be trained in experimental and insect field collection techniques as well as insect husbandry, behavioral analysis software, and laboratory skills in the area of chemical ecology. The study is carried on at the Smithsonian Tropical Research Institute in Panama.

Faculty: Istvan Urcuyo

Department: Biology

Prerequisite for a Summer Position:
Interested students must be extremely comfortable actively participating in outdoors activities including hiking, climbing and backpacking. Candidates must be totally comfortable working in underground confined spaces in wet, muddy and cold conditions as well as willing to perform "dirty" hands-on jobs while handling live and/or preserved invertebrate specimens for collection, identification, cataloging and storage. Interested students must be able to lift/carry 50 pounds. A declared biology major with at least one year of biology courses and an interest in biodiversity research is preferred.

Description of Research:
Biodiversity is a subject of global importance and is the foundation of irreplaceable environmental services. However, as the human population continues to grow and increase its encroachment on natural environments, it becomes more urgent and critical to gain a better understanding of the biological diversity at risk. The first step to acquiring this knowledge is the identification of the species present in that environment. My cave invertebrate biodiversity research project is the first survey of macroinvertebrates found inside caves in Franklin County, PA. The primary goal of this research project is to examine and analyze the biodiversity of both aquatic and terrestrial macro invertebrates and environmental conditions of at least four “wild” caves located at an undisclosed location, 45-minutes away from campus. A pilot survey of both aquatic and terrestrial macro invertebrates was started in 2015 by performing *in-situ* collections via aquatic traps, pit-fall traps, or collected manually and preserved in 75% Ethanol. These 2015 samples need to be further evaluated, carefully sorted and all the organisms in this collection need to be identified to the species level. Along with determining the biodiversity of the cave-dwelling macro invertebrates we also will be measuring the following abiotic factors to characterize each of the cave habitats: air/water temperature, water pH, dissolved oxygen, and % humidity. These abiotic factors will be measured and compared at different horizontal distances from the cave entrance as well as compared between the sampled caves.

For this summer, I am looking for two undergraduate research assistant students who are interested in acquiring field-based and lab-based cave biodiversity research experience for 8 weeks. Students will receive hands-on experience measuring environmental data using *in-situ* loggers along with practical experience in environmental characterization as well as the collection, processing, organizing and analyzing of biodiversity data. Each student will be equally responsible for the sorting and identification of the samples collected in the previous surveys and will be directly involved in the design, manufacture and deployment of terrestrial fall-traps and aquatic baited traps in these caves. Both students will be required to work inside the caves to deploy and collect sampling traps (under the direct supervision and in the company of the faculty mentor) as well as being responsible for the preservation, sorting and taxonomic identification (to the lowest taxonomic level possible) of the collected organisms this summer.

Faculty: Kate Buettner

Department: Chemistry

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

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 are working to prove the ability of our proteins to bind to both of these metals using a variety of biophysical characterization techniques. We have also begun to test the ability of these mini-metalloenzymes to function as catalysts for hydrolytic cleavage. Initial experiments have shown promising results in DNA cutting as well as the cleavage of ester bonds in small molecules. These experiments are the first evidence of a titanium enzyme, natural or man-made.

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.

Our work developing mini-metalloenzymes will demonstrate the ability of these proteins to bind to hard, Lewis acidic metals including titanium and vanadium, and will show their ability to functionalize these metals for specific activities.

Faculty: Shelli Frey

Department: Chemistry

Prerequisite for a Summer Position:
Should have completed a year of general chemistry

Description of Research:

Project 1: Determination of the role of lipid composition in huntingtin protein association with 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 CAG triplet repeats encoding 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 (Figure 1). Interestingly, the length of the polyQ region directly correlates with disease progression. Additionally, htt interacts with a variety of membraneous structures within the cell, and the N-terminus (Nt17) is implicated in lipid binding.

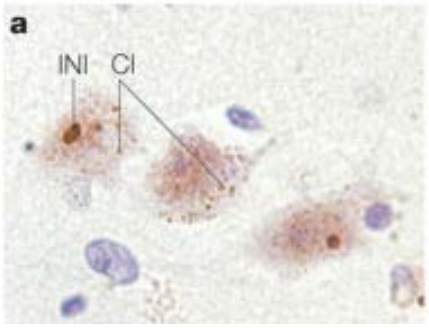

Figure 1: Protein aggregates in brain of patient with Huntington's disease

This project builds on recent findings during my sabbatical and 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 this secondary structural transformation 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 and determine how this interaction changes as membrane and protein context are varied.

Project 2: Imaging nanoparticle interactions with model cell membranes

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, fluorescently labeled NPs will be used to optically track nanoparticle adsorption to the surface of zwitterionic or negatively charged GUVs (to model biological surfaces) to provide insight to the mechanism of NP association, aggregation, and induced tabulation.

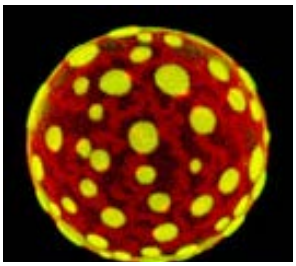

Figure 2: Fluorescence microscopy image of a giant unilamellar vesicle

Faculty: Tim Funk

Department: Chemistry

Prerequisite for a Summer Position:
Completion of Chem 107 and 108; at least one semester of organic chemistry would be helpful, but it is not required.

Description of Research:
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 organic compounds to act as terminal oxidants or reductants. Overall the goal is to develop more environmentally sustainable carbonyl reduction 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 2019 we will explore the following: 1. Synthesizing iron compounds bearing electron-rich cyclopentadienones and comparing their catalytic activity to other catalysts with varying electronics; and 2. Examining how the terminal oxidant (a carbonyl compound) or reductant (an alcohol) imparts chemoselectivity.

Project 1: Over the last year we have discovered that catalysts bearing electron-rich cyclopentadienone ligands are more active than those containing less electron density. This summer we will be synthesizing two new electron-rich cyclopentadienones and their corresponding iron compounds and using NMR spectroscopy to characterize them. Once we have them in hand, we will monitor their activities in carbonyl reductions and alcohol oxidations over time and compare them to other catalysts we have examined. Ideally we will develop more active, efficient catalysts.

Project 2: These iron catalysts work by transferring the equivalent of molecular hydrogen from one reactant to another. For example, an alcohol can be oxidized to a ketone, and the resulting hydrogens and electrons taken from the alcohol can be transferred to acetone, reducing it to isopropanol. If a highly active catalyst is used, the reaction is equilibrium driven and the reduction or oxidation potentials of the two reactants can be used to predict the outcome. By using the right carbonyl compound as a terminal oxidant or alcohol as a terminal reductant, we should have a large amount of control over the selectivity of the reactions. For example, one equivalent of acetone should selectively oxidize a secondary benzylic or allylic alcohol to a ketone in the presence of an aliphatic secondary alcohol. If we can achieve this type of selectivity, less protection/deprotection steps should be needed and more efficient syntheses can be developed.

This summer we will continue to explore how selective certain terminal oxidants (carbonyl compounds) or terminal reductants (alcohols) are when used with some of our most active iron catalysts. Students working on this project will synthesize molecules containing multiple alcohols or carbonyl groups and will run competition experiments with various catalysts and terminal oxidants or reductants to probe for selectivity.

Faculty: Donald Jameson

Department: Chemistry

Prerequisite for a Summer Position:
Eligible students should have completed a year of Organic Chemistry

Description of Research:
Troger's base is a chiral, bicyclic diamine in which two aromatic rings are rigidly held at about a 90° angle (Figure 1). The molecule, first prepared in 1887 by Julius Troger, has undergone a rebirth of interest in the last two decades. This is due to the fact that the molecule's right angle motif makes it an ideal structural element in the construction of nanometer sized supramolecular species. In a landmark paper in 1944, Prelog (1976 Nobel Prize in Chemistry) and Wieland succeeded in separating the enantiomers of Troger's base, making it the first chiral-at-nitrogen amine to ever be resolved. They accomplished this by chromatography using a stationary phase of D-lactose, probably the first example of chiral chromatography. In the course of this study, Prelog and Wieland noticed that enantiopure Troger's base racemized under the influence of acid.

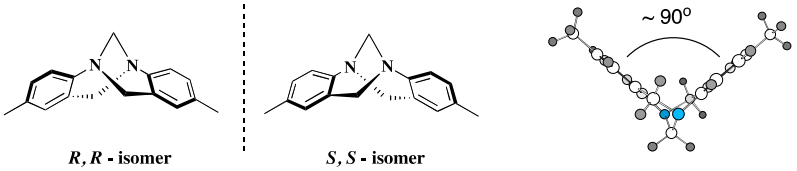

Figure 1

The renaissance in Troger's base has lead to a re-examination of this racemization reaction. A proposed mechanism is shown in Figure 2. In addition to protonation/deprotonation and ring cleavage/formation steps, there is a crucial ring inversion that is required by the racemization. Racemization is conveniently followed by monitoring loss of optical activity with time using a polarimeter. Our general procedure for the resolution of 2,8-disubstututed Troger's base derivatives gives provides an opportunity to study the effect of ring substituents on the rate of racemization. This Hammett analysis should provide information the role of charge buildup on the reaction mechanism. Additionally, it is possible to substitute the bridging methylene protons with deuterium atoms, allowing for detection of a secondary kinetic isotope effect (Figure 3). Results from these experiments should give insight into the rate determining step of the reaction.

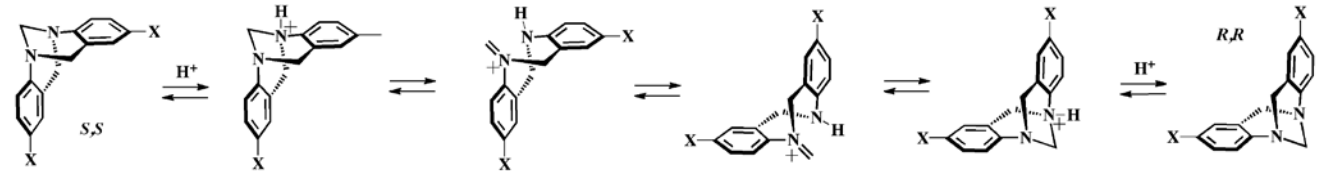

Figure 2

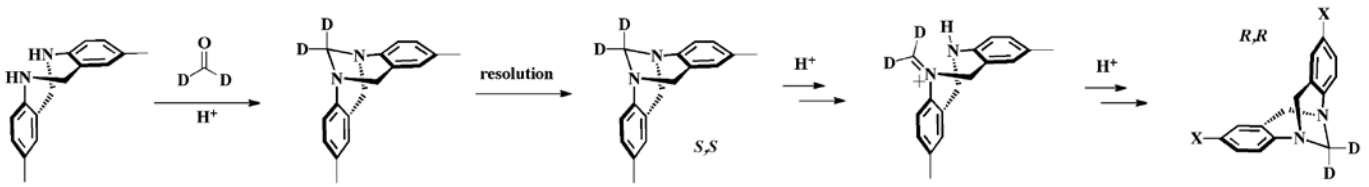

Figure 3

Faculty: Suvrajit Sengupta

Department: Chemistry

Prerequisite for a Summer Position:

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.

Project 1: Studies on Clathrate Hydrate Systems
To gain a deeper understanding of the interaction between water and hydrophobic molecules, my group will use clathrate hydrates as a model system. Clathrate hydrates are solid inclusion compounds formed when guest molecules such as methane, ethane, propane, carbon dioxide, etc., occupy host water cages. While normal ice is composed of layers of puckered hexagonal rings of water molecules, clathrate structures are composed of different water cages. Although the H_2O lattice of the hydrate is slightly less stable than that of hexagonal ice, the interaction with trapped gas molecules brings the free energy below that of the separated ice and gas. Using home-built equipment, students will be able to monitor the kinetics of clathrate hydrate formation from different gases and ice particles. The preliminary goal of this project is to characterize the change in hydrate formation kinetics, and host-guest dynamics in hydrate systems on addition of trace amounts of substances which perturb the host-guest interaction, such as alcohols and ionic solutes.

Project 2: Dynamics on water-regulation proteins
Aquaporins are a class of proteins that are involved in passive water transport across cell membranes in such varied tissues as liver cells, eye lens, intestines, etc. It should be noted that aquaporins transport water but prevent the transport of protons which are smaller and able to transfer through negatively charged sites. The goal of this project is to investigate the specific interactions between water and these proteins. The proteins will be expressed in bacterial or yeast cells with various isotopic labelling schemes suitable for solid-state NMR.

Faculty: Lucas Thompson

Department: Chemistry

Prerequisite for a Summer Position:

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 will study the surface modifications of gold nanoparticles with polymers.

One project will explore the electrostatically modulated surface modifications of charged nanoparticles with polyelectrolytes (highly charged polymers). More specifically, we will be taking a two pronged approach to understanding how polyelectrolyte modifications of gold nanoparticles engenders control and reversibility to the assembly of nanoparticles. In one part of this project we will be using a pH and temperature mediated structural transition 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). In the second part, we will be exploring the dynamics of cation valency on the assembly of negative polyelectrolytes. We have seen that divalent cations like Ca^{2+} and Mg^{2+} induce aggregation at dramatically different concentration regimes. Together, these projects 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 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.

Faculty: Sarah Principato

Department: Environmental Studies

Prerequisite for a Summer Position:
Course preparation from ES223 and ES318 is preferred

Description of Research:
My summer XSIG student will study glacial erosion features in Iceland and the Faroe Islands. We will use a combination of Google Earth and ArcGIS to conduct detailed spatial analyses to understand paleo-ice flow basal thermal regime. In addition to extensive computer work, my student will conduct field work (approximately 7 - 10 days) in the Faroe Islands or Iceland. We will ground-truth GIS analyses and look for sample sites for chronologic control.

Faculty: Andy Wilson

Department: Environmental Studies

Prerequisite for a Summer Position:
Students must love being out in the field, be early risers, and be resilient to the occasional uncomfortable fieldwork conditions.

Description of Research:
Songbird surveys using drones
Drones are widely used in field biology and environmental sciences due to their ability to survey areas that are difficult or time-consuming to traverse by land or water. Use of drones in wildlife studies has focused on surveying large animals using imagery (photos and video), but my research group has pioneered the use of drones with audio recorders for bioacoustic surveys, in our case, of songbirds. Previous field seasons in 2015 and 2017 tested the overall feasibility of using drones for bioacoustics surveys (2015), and the possible impacts of drones on songbird behavior (2017). The first study was published in ornithology journal *Auk*, and was the first paper to demonstrate the use of drones for bioacoustics monitoring. Data analysis for the 2017 study is still underway, but preliminary analysis suggests that drones have minimal impact on songbird behavior.

This year, students will fly drones, study for the FAAs remote pilot certification, learn how to survey songbirds in the field, and be introduced to a variety of data analysis techniques. The main focus of our fieldwork this year will be to assess whether audio recordings from drone-mounted recorders can be used to estimate bird population densities, by using sound pressure level (i.e. how loud birdsongs are) as a proxy for distance to each bird. We will do this by completing a comprehensive mapping survey of target bird species on foot (standard “spot-mapping” technique), and then comparing the “known” population densities with those obtained from the drone. This is important because population densities are a widely used metric in wildlife studies because they allow for comparisons across species, space, and time. We will spend most fair-weather mornings out in the field (near Gettysburg) throughout May and June. This will require early starts--we’ll typically meet between 5:30 and 6am, but our work days will be completed by mid-afternoon. Afternoons and inclement weather days will be spent on fieldwork preparation, data collation, and data analysis.

Faculty: Josef Brandauer

Department: Health Sciences

Prerequisite for a Summer Position:

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.

One research project this summer will be an investigation of how endurance exercise affects NAD concentrations in skeletal muscle. The student working on this project will primarily assess NAD concentrations in existing exercise training samples and perform other assays/analyses on these tissues. In a related project, our lab will study the endocrine properties of skeletal muscle. Many tissues are known to secrete hormones into the bloodstream, and skeletal muscle is no exception. The student working on this research project will primarily optimize a muscle incubation technique which will help drive forward discoveries in this important field.

Student Expectations
For all of my research projects, I look for curious and motivated students who are interested in working on these topics in mouse models. With practice, students working in my lab routinely excel at the specific techniques my lab employs; while previous lab experience is generally helpful, it is not required. Rather, I look for self-directed students who are excited about scientific discovery, problem solving, and who are passionate about working collaboratively within a small team.

Faculty: Kimberly Spayd

Department: Mathematics

Prerequisite for a Summer Position:
Interested students should have taken and enjoyed Math 225 (Differential Equations). Additionally, it is preferable for students to have taken Math 325 (Partial Differential Equations) and have experience programming in Matlab. No specific lab skills are required.

Description of Research:
Mathematical models of fluid flow in porous media describe applications ranging from groundwater flow to crude oil recovery to the spread of a contaminant from compromised underground pipelines. Partial differential equations (PDE) are used to describe the evolution of such fluids in time and space. In an application such as contaminant flow, a PDE can help engineers understand and anticipate the fluid's behavior underground, thereby making cleanup easier and more effective.

In this project, we will work to validate and verify a specific model of two-fluid flow in compacted sand called the Modified Buckley-Leverett equation. We will start by constructing an experiment that resembles underground flow when one highly viscous fluid is displaced by a less viscous fluid. The volume fraction of one fluid will be recorded as it pushes the other fluid through the apparatus. We will compare this data with analytical solutions that have been studied extensively in theory.

Faculty: Kurt Andresen

Department: Physics

Prerequisite for a Summer Position:

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.

Faculty: Bret Crawford *(2 pages)*

Department: Physics

Prerequisite for a Summer Position:

Description of Research:
1. Fundamental constants in the theory of the weak interaction are not known with sufficient precision to adequately constrain theory. The simplest and most basic weak process is the decay of a free neutron. Measuring the lifetime of a free neutron, the 1/e point of the exponential decay, is an important part of determining these constants. In addition, models of the helium abundance in the universe are dependent on the knowledge of the neutron lifetime to accurately predict observations. Finally, an historic discrepancy between two different methods of measuring the neutron lifetime do not agree, which raises interesting questions. Is the discrepancy due to uncontrolled systematic errors in previous measurements or is there new physics (decay to a "dark matter" particle was recently explained as a possible channel) the can explain the difference between the methods. With these motivations, the Beam Lifetime 2 collaboration (BL2) is currently running a 0.1% lifetime measurement at NIST using the decay-in-flight, or beam, method. Neutrons in a beam from the NIST reactor/cold source spontaneously decay in flight. If the decay happens in the proton-trap region, the decay protons are held by magnetic and electric fields until they are released and counted. Measuring the neutron and proton rates to 0.1% is quite challenging and very sensitive to possible systematic errors.

The research student will work on simulations using GEANT4, an internationally developed particle transport platform, to investigate subtleties of the experiment. We are in the process of modeling the fields of the proton trap (using COMSOL a sophisticated physics simulation package) though which we will then simulate proton transport to study the effects of different electric fields in the trap to help place limits on systematic errors. The student will gain experience with COMSOL, GEANT4, and the root analysis software.

2. The Student Proton Accelerator at Gettysburg College (SPAGetty) creates beams of protons on the order of several microAmps with energies between 50 and 200 keV. While these low-energy beams can access some phenomena of nuclear interest, they are mostly used to study material surfaces. The main focus of our recent experiments has been the study of proton damage of polydimethylsiloxane (PDMS). One application of relevance is its use as a coating on satellites to protect delicate components from energetic particles present in low-earth orbits, but these coatings can be damaged by low-energy protons. There are other satellite materials of interest as well, such as white paint, solar cells, and carbon nano tubes which have been studied elsewhere. To reliably perform these damage studies, we need a beam of stable energy and flux. We have begun to address these issues by developing an Arduino-based feedback control of the proton energy (which stabilizes the energy and position of the beam). We have tested one of the feedback controls (column current) with success but need to test the slit feedback which samples the beam downstream from the analyzing magnet. We are currently making modifications to how the belt-charging system is powered.

The research student will complete the testing and implementation of the feedback system, help install a new thermo-mechanical gas leak, and design a new beam monitor system. The latter project would

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Faculty: Bret Crawford

Department: Physics

address our need to reliably measure the number of protons that hit the target. The usual method of using a thin foil upstream of the target is very difficult to do reliably as one would need a very thin (sub-micron) foil for these low-energy protons. Instead we will use a beam stop that repeatedly interrupts the beam to make a series of measurements interleaved with the target irradiation.

Faculty: Tim Good

Department: Physics

Prerequisite for a Summer Position:
Rising junior or senior physics major status. Completion of PHY 211 and PHY 310. Candidates with some machine shop experience are preferred, but not required. Trips to the Scime plasma physics lab of West Virginia University are planned in order to participate in and gain experience from spectroscopic studies of argon plasma exhibiting double layers.

Description of Research:
I will employ two students to assist in the installation and testing of several upgrades to the Pickets Charged Plasma Device (PCPD) and accompanying laser spectroscopy diagnostic system that we have designed, procured and constructed during the summer campaign of 2018. The two students will be employed for an eight week research campaign beginning June 3 and ending August 2, with one week break for the Fourth of July holidays.

The overarching goal of the plasma research is to study the ion response to ion acoustic waves, and to investigate the ion beam formation in double layer potential structures created in PCPD. Dr. Scime's team at WVU has recently observed stationary double layers in his plasma device, a high-density helicon plasma source coupled to a large space simulation chamber. It is our goal at GC to observe double layers in our double plasma device, the Pickets Charged Plasma Device, and to measure the resulting accelerated ion flow.

A common thread connecting my research endeavors with Dr. Scime is the fundamental study of plasma field-particle interactions employing powerful and elegant laser spectroscopic methods of diagnosis. Via measurements of the ion velocity distribution, laser-induced fluorescence (LIF) reveals the ion response to the fields, typically in the form of ion acceleration or heating. LIF spectroscopy is ideally suited for studying ion acceleration by double layers due to its high spatial, temporal and spectral resolution, and most significantly, because its application does not perturb ion trajectories.

Goals:

1. Install new fiber optics and related optics hardware to replace open air transport of the laser beam from the optics table to adjoining experiments in PCPD and the magnetized sodium gas cell. Particular emphasis will be placed on the efficient coupling of the laser at the fiber port to allow high power transmission from the optics table to the PCPD.
   This will enhance student eye safety and provide better beam pointing stability.
2. Carefully align the injected laser beam on axis of PCPD to the fluorescence collecting telescope that views through new window ports in the aluminum plate flanges. Adjusting two sets of lens optics to find the intersection of the laser beam and viewing volume of the telescope may sound trivial, but it is the most critical step for obtaining LIF measurements and requires painstaking effort with clever methods of observation.
3. Returning to an unattained goal from 2018, we will construct new PMT housing for LIF detection with machined parts obtained from Dr. Scime at WVU.
4. Having constructed a new Langmuir electrostatic probe diagnostic with an extended shaft, we will install a probe shaft driver mechanism to allow spatial scanning of density and potential structures.

Faculty: Ryan Johnson

Department: Physics

Prerequisite for a Summer Position:

Description of Research:
The largest gravitationally bound objects in the universe are clusters of galaxies, like our own Milky Way, numbering in the thousands. Primarily, these systems are dynamically driven to evolve over cosmic timescales by the competing forces of gravity and dark energy. By modeling these systems numerically (in a computer simulation), and then comparing these models to observations, we are able to constrain the effect these two forces in the most extreme environment possible. My work focuses around the systematic effects that galaxy cluster mergers have on this analysis.

One of my projects is to use statistical measures to constrain various parameters of a binary galaxy cluster collision, such as: time since last approach, orbital period, and mass. The student will work to develop and test these statistical measures with an eye towards obtaining a set of robust, resilient, statistical estimators that may be used to constrain the timescale of the galaxy cluster merger. The data used will be from one of the largest numerical simulations of galaxy cluster mergers ever run.

A second project will be examining the effect of cluster merger dynamics on cluster mass estimates. There are two potential avenues to pursue this question. The first, from an observational perspective, where the goal will be to identify merging clusters in the literature and obtain their observables, to see if these observables depend in any way on the state of the galaxy cluster mergers. The second method would involve approaching this from a theoretical perspective, looking at merging clusters in simulations. Ideally, both of these research avenues would be combined to produce a final product.

Faculty: Jackie Milingo

Department: Physics

Prerequisite for a Summer Position:
There are no pre-requisites for these projects only the expectation that the students will be physics majors with a professional interest in STEM. Preference will be given to those students specifically interested in astronomy/astrophysics related fields.

Description of Research:
Observational Photometry and Spectroscopy at GCO and NURO

This program will include a variety of observational astronomy projects that fall under the theme of instrumentation, optical image acquisition, reduction, and analysis of astronomical targets of interest. Projects will include photometry, a wide range of 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 if needed.

Students will work together on all projects throughout this program. The photometry will require working with archived and newly acquired images from the National Undergraduate Research Observatory (NURO) in Flagstaff, AZ as well as GCO on campus. All CGS work will be done on campus. Students should expect to spend considerable time at GCO (including evenings as need be) and all students must be available in June for a NURO observing run. This is an 8-week program.

Faculty: James Puckett

Department: Physics

Prerequisite for a Summer Position:
See description of projects

Description of Research:
Material properties of fish schools
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 are complex and stochastic. Using schools of fish, we use dynamic light field to investigate how individuals negotiate both social and environmental information to form states of active matter. We will be treating the school of fish as if it were any other kind of material. Using the dynamic light field, we can push or pull on the school and observe how it response, measuring the material and thermodynamic properties of the school. Interested students will learn computer scripting (Matlab, Python), particle tracking, image analysis, signal processing, electronics, and data analysis. No programming experience is required.

Collective behavior: using simulations and machine learning
Collective animal behavior exists throughout the animal kingdom, from fish schools, bird flocks, and bee swarms to traffic and social networks. How and why do these collective behaviors occur? How does coordinated group patterns emerge from individual interactions? However, determining these interaction rules from trajectories of individuals is a challenging (if not impossible) inverse problem. Instead, we compare the performance of various interactions in problem solving and compare with experiments. Interested students will learn computer code (C++, Python, CUDA), signal processing, and data analysis.

Faculty: Chris Barlett

Department: Psychology

Prerequisite for a Summer Position:
To apply, students must have successfully completed Psych 205 and served at least one semester in the ARL prior to summer 2019.

Description of Research:
Dr. Barlett's Aggression Research Lab (ARL) will be conducting novel theoretically driven research, analyzing existing data sets, and prepare manuscripts related to understanding aggression (broadly defined).

Faculty: Kathy Berenson

Department: Psychology

Prerequisite for a Summer Position:
Completion of statistics and research methods courses (Psych 205 and 206/305) is a prerequisite. Some coursework in personality/clinical psychology (e.g., Psych 221, 222, 223, 321) is preferred but not required. Students are not necessarily expected to have previous experience working in a lab or handling data for research purposes – but must be interested in learning and practicing these things on the job.

Description of Research:
Personality Lab:
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. Over the last 2 years the Personality Lab has been working to fill this gap, by conducting nine 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.

X-SIG students will be hired to help manage and analyze these data, conduct literature searches, and prepare conference posters/ manuscripts. Together, the students will also carry out an internet-based follow-up study on the relationship between compassion and reactions to "positive" motivational slogans, which they will finish analyzing and writing up by the end of the summer. Finally, each student will be responsible for producing a 10-20 page project proposal for a new study to replicate/extend our recent research on ways to reduce mental illness stigma and better support peers in distress.