

# SUMMER RESEARCH 2010 IN THE ST. OLAF FNSM

Not all summer research projects in the sciences and mathematics are covered by this application form. If you are planning to work with someone not listed here please check with them directly for application process. We reserve the right to make any necessary changes in projects.

**Application Deadline: Feb 15**

## **BIOLOGY DEPARTMENT**

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### **Pat Ceas – Minnesota’s environmentally sensitive fishes: Continued studies of their ecology, behavior, and use as biological indicators of healthy waters**

We know that poor land use practices result in the degradation of our waters and a decrease/loss of environmentally sensitive aquatic species, yet we know surprisingly little about the ecology/life history of Minnesota’s sensitive (and rare) fish species. I am looking for three students who are eager to spend long days in the field as we begin a 2-year study on the life histories of two of our most sensitive species (longear sunfish and pugnose shiner), and continue studying the federally endangered Topeka shiner. These studies will add to our ongoing collaboration with the MN Department of Natural Resources and provide valuable data and advice for the DNR’s shoreland conservation & restoration efforts. We will split our time between (1) fieldwork in (mainly) northern Minnesota where we will collect these fishes, observe their feeding & reproductive habits, and gather habitat data, and (2) lab work on campus where we will conduct further observations on spawning behaviors and larval development, and examine freshly preserved specimens to determine changes in reproductive condition, growth rates, and diet (if you have an interest in aquatic invertebrates then this part of the study is for you!).

### **Eric Cole/Erica Zweifel Lab Summer Research Projects**

We have two significant research projects going on in the Cole/Zweifel laboratory this summer. Our mainstream project, **The Gene Stream**, involves exploring the molecular and biochemical basis of developmental events occurring during mating in the ciliated protist, *Tetrahymena thermophila*. In particular we are unraveling the role of a dense, intracellular body (“the conjusome”) that appears in mating cells during a period of intense, RNAi-mediated genome reorganization.

This project has two summer objectives: we need someone inclined towards doing biochemical fractionation to purify or enrich these organelles so that we can subsequently identify their protein constituents via Mass Spectrometry. The job involves learning cell husbandry, density-

gradient centrifugation, PAGE protein separation and fluorescence microscopy (among other things). Our goal is to produce a nearly pure sample of “conjusomes” for subsequent biochemical identification. The second objective is to test a hypothesis. We suspect that the conjusome is a “way-station” for stalled ribosomes. That is, we think that certain mRNAs (especially those encoding proteins involved in genome modification) begin to get translated, and then stop. These arrested polysomes then get shuttled to the conjusome until they receive a signal to release their contents. To test this, we need to develop *in situ* fluorescence hybridization to see if certain mRNAs are in fact located in this structure. This project involves cell husbandry, PCR, *in situ* hybridization and fluorescence microscopy. A background in genetics is required, molecular genetics is desirable.

We have up to three spots available for this work. We prefer students who would be interested in carrying their work forward into the following year, with intention to present their work at the 2011 FASEB summer research conference on Ciliate Molecular Biology (possibly in Crete).

Our second project is **The Hurricane Oyster Project**. We have found that scaly pearl oysters collected from different saltwater ponds on San Salvador Island show different life history trajectories. In particular, some are protandrous, (beginning life as males and converting to female as they mature), while in other ponds they appear dioecious (50:50 male and female). We want to document these life history trajectories and test whether or not these sex-determination pathways are result of genetic or environmental factors. A single student will be hired to perform wax-histology, (and possibly genetic analysis) on tissues from various populations. They will also be responsible for raising live oysters on home-grown marine algae with high or low PO<sub>4</sub> diets. A student who participates in this research will be invited to attend the 2011, 14<sup>th</sup> Natural History in the Bahamas Symposium to be held on San Salvador Island.

### **Jay Demas**

Intrinsically photosensitive retinal ganglion cells (ipRGCs) detect environmental light levels to distinguish between day and night. They signal these light levels to a part of the brain, the suprachiasmatic nucleus, that is the body's master clock, regulating our daily behavioral rhythms. In the last few years, the signal transduction cascade in the ipRGCs that converts light into a biological signal has begun to be characterized. Arrestins, a family of proteins that negatively regulate g-protein coupled receptor signaling, appear to play a critical role in terminating the light response of ipRGCs. In collaboration with Dr. Satchin Panda of the Salk Institute in San Diego, we will be characterizing the light responses of ipRGCs in arrestin knockout mice from *in vitro* planar multielectrode array recordings of dissected retinas. There is a possibility for one student to assist in these experiments. In addition to performing experiments, responsibilities will include animal husbandry, preparation of solutions, and large amounts of data analysis. The student will learn to harvest the retinas for recording, perform the extracellular recordings, and execute preliminary analyses using Matlab. Applicants must be willing to work very long hours and be comfortable with animal research. Travel to San Diego may be required.

### **Steve Freedberg**

We will be studying the population genetics and behavioral ecology of the smooth softshell turtle, *Apalone mutica*, in the Minnesota and Mississippi Rivers in Minnesota. Using a combination of radio tracking and molecular analysis, we will identify key aspects of their within-population movement and population genetic structure that will inform evolutionary models as well as conservation policies. By comparing measures of genetic variability with other turtle species possessing differing sex determining systems, we hope to also gain insight into how sex determination pattern impacts mutation accumulation over time. Work will include field trapping of turtles throughout southeastern Minnesota, DNA extraction and optimization of molecular markers, and population genetic analysis.

### **Laura Listenberger (Bio and Chem Depts) – Biochemistry and cell biology of lipid storage**

Surplus lipid is stored inside cells in structures called lipid droplets. Despite their ubiquitous presence in mammalian cells, and their obvious importance in obesity-related disorders, surprisingly little is known about lipid droplet synthesis and turnover. A major candidate for regulating these processes is adipocyte differentiation-related protein (ADRP). Our project this summer will explore how ADRP recognizes and binds to the surface of lipid droplets. Our experiments will use a variety of techniques including electrophoresis and western blotting, mammalian cell culture, subcellular fractionations, and microscopy. If you're interested in exploring the cell biology and biochemistry of lipids, please come talk to me to learn more about this research!

### **John Schade – *The Polaris Project: Rising Stars in the Arctic***

The Polaris Project is a multifaceted effort that includes a field course and research experience for undergraduate students (rising stars) in the Siberian Arctic; several new arctic-focused undergraduate courses taught by project Co-PIs (also rising stars) at their respective colleges across the United States and in Russia; the opportunity for Co-PIs to initiate research programs in the Siberian Arctic; and a wide range of outreach activities. The unifying scientific theme of the Polaris Project will be the transport and cycling of carbon and nutrients as they move with water from terrestrial uplands to the Arctic Ocean. I am looking for 1-2 students to travel to the Northeast Science Station in Cherskiy in the Siberian Arctic for the month of July. In addition, this student will have the opportunity to work with me to develop a research project and curriculum materials during the month of June to prepare for the trip. This student must be enrolled in BIO 320: **Arctic Ecosystems: An Analysis of Global Change** to attend the field course. In addition, **interested students must discuss this opportunity with me and must complete a separate application (see [www.thepolarisproject.org](http://www.thepolarisproject.org) for more information).**

### **Stephanie Schmidt - Anthropogenic impacts on aquatic food webs**

Anthropogenic activities, such as urban development and agriculture, alter riparian habitat and increase inputs of nutrients to aquatic ecosystems. Few studies, however,

have investigated the direct impacts of anthropogenic activities on the magnitude and timing of subsidies to/from aquatic food webs. I plan to examine how anthropogenic activities disrupt the reciprocal flow of subsidies between stream and riparian ecosystems in the Cannon River Watershed in south central Minnesota. I anticipate having one position for this project. The student will help select sampling sites based on land-use data from GIS analysis and water chemistry data collected by previous research students from St. Olaf College.

We will use stable isotopes (hydrogen and carbon) to quantify subsidy fluxes between aquatic and terrestrial habitats. To address the impacts of these subsidies on food web structure, we will analyze carbon and nitrogen isotopes in aquatic and terrestrial plant and consumer (i.e. invertebrates, fish, lizards, and birds) tissues to characterize food web structure across the landscape. The student working on this project will gain valuable field and laboratory experience, especially on our new stable isotope ratio mass spectrometer. This project is a great opportunity to explore how energy flow across ecosystem boundaries has major implications for structuring biotic communities. Perhaps most importantly, students will learn to think across ecosystems and reflect on how humans directly and indirectly influence the surrounding environment.

#### **Kathy Shea – Ecology of the St. Olaf Natural Lands**

Students working with me will focus on applied research studying restoration of forest and prairie habitats and various aspects of maintenance of natural areas. Tree growth patterns in restored forests of different ages and planting methods will be measured and compared. New data, including tree size, soil characteristics, and understory characteristics will be collected and added to the existing database. This summer we will assess a 20 year old planting and make plans for future management. We will also compare tree growth in areas planted with tree seedlings and tree seeds.

Invasive species are a constant problem in managing natural areas and we will focus on buckthorn, reed canary grass and garlic mustard. As the size of the natural lands has increased more wildlife is using the area. We will monitor and establish deer exclosures with the long-term goal of determining the effects of deer herbivory on tree seedling success.

Another project will examine experimental plots planted to analyze the effects of plant diversity on variation in biomass production, soil nutrient levels and C/N ratios in the plants and soils. From the study will gather information about factors that lead to maximum biomass production and the possibility of biofuel production from restored prairies.

In addition to an interest in fieldwork and a biology background, an interest in statistics will be helpful. Students working during the summer will be encouraged to use some of this research as the basis for independent research during the academic year.

### **Charles Umbanhowar – Climate change and responses of Manitoba tundra lakes**

This project is focused on understanding lake and terrestrial responses to climate change in the low arctic tundra. In particular we are interested how bogs and other wetlands surrounding a lake modify lake response to climate change through the export of dissolved organic carbon which can color water. Work in 2008-2009 resulted in collection of water and sediment from 51 lakes. The students working with me this year will be responsible for extracting Ca, Mg, Fe, C, N and P from lake sediments and analyzing them sediments using our Flow Injection Analyzer, Element Analyzer, and ICP. We will also be doing grain-size analysis on sediments and will likely be analyzing the C and N isotopic composition of sediment, peat, and soil. Preference will be given to students having at least one year of chemistry (and preferably analytical). Completion of Ecological Principles is desirable but not required.

## **CHEMISTRY DEPARTMENT**

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### **Laura Listenberger (Chem and Bio Depts) – Biochemistry and cell biology of lipid storage**

Surplus lipid is stored inside cells in structures called lipid droplets. Despite their ubiquitous presence in mammalian cells, and their obvious importance in obesity-related disorders, surprisingly little is known about lipid droplet synthesis and turnover. A major candidate for regulating these processes is adipocyte differentiation-related protein (ADRP). Our project this summer will explore how ADRP recognizes and binds to the surface of lipid droplets. Our experiments will use a variety of techniques including electrophoresis and western blotting, mammalian cell culture, subcellular fractionations, and microscopy. If you're interested in exploring the cell biology and biochemistry of lipids, please come talk to me to learn more about this research!

### **Jeff Schweinefus**

Do you have an interest in biochemistry, physical chemistry, or computational biology? Want to learn more about one or more of these scientific fields? If so, then I just may have a project you will be interested in. This research project is appropriate for biology, chemistry, computer science or physics students that have completed the Chem 121/123/126, Chem 125/126, or CH/BI 125/126/127 introductory course sequences.

### Cosolute Interactions with Nucleic Acids

For several years Professor Greg Muth and I have collaborated to explore the stability of folded nucleic acids, from simple, short DNA duplexes to complex RNA structures. Much of our effort has focused on the role that neutral organic molecules like urea or amino acids (which we generically call cosolutes) have in lowering the stability of folded nucleic acid structures. Using UV absorbance, differential scanning calorimetry, and vapor pressure osmometry, we have been able to calculate 1.) the excess (or deficiency) of these cosolutes in a local domain near the surface of a nucleic acid relative to bulk

solution, 2.) the amount of cosolute at the newly exposed surface area of an unfolded nucleic acid structure, and 3.) the hydration of nucleic acids. All of these calculations are important (especially 2.) to rationalize why these cosolutes destabilize nucleic acid folded structures. However, thermodynamic measurements do not provide information about specific interactions between cosolute and nucleic acid. What specific chemical functional groups on the nucleic acid do these cosolutes interact with? How do these cosolutes affect nucleic acid hydration?

To answer these questions, students working with me will simulate nucleic acids, from nucleotide monophosphates to DNA and RNA duplexes to larger RNA structures, in aqueous solutions using Amber, a molecular dynamics software package. Molecular dynamics simulates atomic motion as a function of time for all of the water, nucleic acid, and cosolute atoms in the simulation. These simulations have the benefit of allowing us to visualize interactions between water, cosolute, and nucleic acid as well as calculate the lifetime of these interactions to provide a molecular basis for our experimental measurements.

### **Mary Walczak and Paul Jackson**

This summer we plan to develop new labs for Analytical Chemistry (Chem 255/256) focused on instrumental measurements of natural samples and emphasizing green chemistry approaches. Our first project involves collecting and analyzing water samples from the retention ponds behind Regents Hall for various metals. This series of four retention and infiltration ponds collect and purify surface water run-off from campus. The first pond, the settling pond is located between the two arms of the parking areas south of the building. We will employ a combination of field sensors and atomic spectroscopies (Atomic Absorption and Inductively Coupled Plasma Atomic Emission) to characterize the samples and track the extent to which the water quality is improved as it moves through the ponds. Of particular interest is the presence of copper, since it is used as decorative flashing on Regents Hall. We anticipate developing an ongoing protocol for data collection from the ponds each semester and creation of a long-term database.

In addition, we plan to develop other experiments for inclusion in the Analytical Chemistry lab program. In particular, we are interested in developing an electrochemistry experiment based on the pH dependent quinone/hydroquinone redox reaction, a GC and GC/MS experiment involving citrus essential oils, a spectroscopy experiment based on a system that illustrates the importance of matrix effects, and an experiment that utilizes capillary electrophoresis techniques. Undergraduates interested in this work should have completed analytical chemistry lab.

## MATH, STATS, CS DEPARTMENT

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### **Dick Brown - Parallel computing and Beowulf clusters**

Parallel computing, in which multiple computations occur simultaneously on one or more computers, is about to change the way software is designed. Building from St. Olaf's Beowulf clusters and our experience using them to solve problems in fields such as Biology, Environmental Science, Physics, and Political Science, we will carry out parallel computing research in the following areas:

1. Parallelism in CS courses. Fundamental changes in hardware design mean that all CS students must now learn about parallelism, because of its emerging role in computational problem solving. Student researchers will partner with faculty to producing software and materials for teaching parallelism in potentially all CS courses, in a collaborative project with Macalester.
2. Beowulf Cluster research. We will explore new forms of cluster computing involving topics such as virtualization (the foundation of our MistRidercluster), interactive cluster computing, and modeling new forms of parallel computation.
3. Applications of Beowulf cluster computing in other fields. This includes creation or extension of cluster applications for solving problems in other target disciplines (see [www.cs.stolaf.edu/projects/beowulf](http://www.cs.stolaf.edu/projects/beowulf) for examples), and also HiPerCiC projects to create user interfaces for researchers and students in those target disciplines to use those cluster applications. Qualifications: Students with Software Design backgrounds are encouraged to apply; courses with parallelism (CS 241, 273, 284, 300), "core" CS courses, and background in the natural sciences are assets.

### **Mike Weimerkirch - MATH/CS Summer Research Project in Combinatorial Game Theory**

Optimal strategies to certain Nim\*-like games under misere play have, until recently, been hard to find. An algorithm produced recently by Prof. Weimerkirch finds certain solutions. A computer programmer is needed to:

1) encode the algorithm so that more results might be found

AND

2) refine the algorithm to increase it's speed

This project could then be extended to search for patterns in the computer-produced results.

A minimum requirement is the ability to write code. Knowledge of complexity issues is a plus. Some abstract algebra may be learned as part of this project, but is not a prerequisite.

- See, for example; <http://en.wikipedia.org/wiki/Nim>

### **Alexander Woo - Bruhat graphs and pattern avoidance**

From each permutation (a list consisting of the first  $n$  numbers in some order) one can construct a graph (a collection of dots connected by curve segments) called the Bruhat graph of the permutation. I am interested in learning more about the set of permutations whose Bruhat graphs satisfy a particular property. For example, I want to know about the permutations whose Bruhat graphs can be drawn without curve segments crossing each other.

One particular structure on permutations is pattern avoidance. One longer permutation avoids a shorter permutation if there is no subsequence in the longer permutation whose entries are in the same order as the entries of the shorter permutation. I am particularly interested which properties of the graphs can be described the pattern avoidance. One example of an interesting property is if the graph can be drawn without curve segments crossing each other.

Summer researchers should expect to spend their time drawing Bruhat graphs associated to permutations and looking for patterns in their drawings, or convincing a computer to do the same, then trying to come up with mathematical proofs for the patterns they find. Previous study of combinatorics or abstract algebra would be helpful but is not required. No one is expected to understand the previous paragraphs without at least a few more minutes of explanation in person.

## **PHYSICS DEPARTMENT**

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### **Brian Borovsky - The Molecular Origins of Friction - A study across velocity regimes of phosphonate monolayers on alternative MEMS-type surfaces**

I am interested in studying what gives rise to the force of friction. What are the microscopic interactions that determine the frictional force opposing the sliding of one surface over another? How does this force generate heat at the interface? By pressing a high-resolution force probe onto a vibrating surface, we create a microscopic high-speed contact subject to friction. The speeds and contact sizes involved are the same as those encountered in working devices such as computer hard drives and micromachines. My research group pursuing a collaborative effort, with investigators from Luther College and Auburn University, to investigate a class of monolayers called alkanephosphonates that may be effective coatings for micromachines assembled from metal oxides rather than silicon. We will be studying lubricant films consisting of a single layer of chain-like hydrocarbon molecules. Our goal is to determine how the length of the lubricant molecules and the choice of substrate affect the levels of friction. Current models point to the importance of mutual interactions among the molecules in establishing a well-ordered layer with a minimum number of pathways for energy dissipation. This summer, I have two positions open for student researchers, funded by the National Science Foundation.

### **Bob Jacobel - Ice and Climate Geophysics Group (CEGSIC)**

The world's glaciers and ice sheets are a critical element in the global climate system now undergoing major change. Our group uses geophysical techniques: ice-penetrating radar and satellite imagery, to examine the surface, interior and base of ice sheets and glaciers. The characteristics of ice internal ice layers and the basal conditions that we measure with our radar, give us information about the evolution of the ice and enable us to study relationships between ice flow and climate change.

Currently we are in the final year of an Antarctic traverse project that is part of the International Polar Year (IPY), 2007-2009. Summer research in 2010 will focus on the final stages of the data analysis and interpretation from this traverse. Also, we have just received funding from NSF for a new five-year project involving a multidisciplinary collaboration of biologists and geoscientists studying a series of connected lakes beneath the ice in Antarctica. Part of our work in the summer of 2010 will be preparing experiments that will go into the field during the first season of this project in October, 2010.

Members in our group work extensively with computers and software to analyze ice-penetrating radar data and satellite imagery as well as learning to write new code in Matlab. We also utilize geopositioning satellite (GPS) data and satellite remote sensing imagery, together with geographic information software (GIS), to establish a spatial context for our radar results. Part of our summer research involves using radar and GPS in a local field setting so that all in the group have the opportunity to acquire new data and work through the analysis process from start to finish. We will read papers and proposals from our colleagues and present our own results to the community. Our research is supported by grants from the Office of Polar Programs, National Science Foundation.

### **David Nitz – Atomic Spectroscopy**

My research interests are in the general area of physics known as atomic physics, which uses a variety of experimental techniques to learn about the fundamental properties of free atoms and how they interact with each other. Recent projects have been in the area of atomic physics known as emission spectroscopy. The basic idea here is to take an element of interest, put it into an electrical discharge which will excite a collection of atoms into as many of its allowed electron configurations as possible, and analyze the light emitted by the atoms as they decay from highly-excited states to states of lower energy.

The question I have been studying can be summarized as follows: given an atom in a particular excited state, what are the different lower states to which it decays and what is the probability for each of the different decay channels? The strategy for doing this is to take an electronically recorded spectrum and use a computer program to systematically search for (and measure the strength of) signals whose photon energies correspond to known energy level differences in the atom. The information obtained

contributes to our fundamental understanding of atoms and is also of interest to scientists in other fields who use emission spectroscopy as a tool (e.g., for studying a complicated environment like the atmosphere of a star or for trying to figure out what trace elements to add to a fluorescent light to improve its color rendition and efficiency).

I will be looking for two students who have completed the Modern Physics course to work with me next summer on analyzing the spectrum of the rare-earth element cerium. In collaboration with a scientist at NIST (National Institute of Standards and Technology), we will be seeking to extend the number of fully-characterized decay branches of cerium from approximately 3000 up to about 10,000. Offers to work on this project will be contingent on receiving funding of an external proposal which is presently in process.

## **PSYCHOLOGY DEPARTMENT**

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### **Gary Muir - The Neural Basis of Spatial Navigation and Orientation**

My research program is guided primarily by questions about the neural mechanisms of spatial cognition and navigation. The firing activity of “head direction” cells is thought to represent the animal's perceived “sense of direction,” or orientation, but how is information contained in the firing activity of these cells used by the animal when solving a spatial task? I am also particularly interested in the role these cells play in enabling us to re-orient following a period of mis-orientation. To answer these questions, students will have the opportunity to observe a “behaving” brain in action by recording the activity of single neurons in freely moving rats. How does this neural activity relate to the animal's navigational decision-making behavior? Students will be involved in small animal handling, surgery, and behavioral training; single-unit electrophysiological data collection and analysis; and public presentation of the results.