2015 HHMI Undergraduate Research Experience Topics

Dr. Craig Goergen

Ultrasound Analysis of Angiotensin II-Induced Murine Aortic Aneurysms
Abdominal aortic aneurysms (AAAs) are associated with significant morbidity and mortality. The underlying mechanisms that cause this inflammatory disease are not fully understood. Thus, rodent models that mimic the human condition have been developed to provide insight into the pathogenesis of AAAs. This project will utilize high-frequency ultrasound to characterize an angiotensin II-induced mouse AAA model. The student will help design experiments that utilize non-invasive in vivo imaging to monitor the progression of AAA formation. They will acquire, process, and quantify ultrasound images with software capable of estimating flow velocity and creating 3D volumes. Statistical analysis will be conducted to determine the appropriate group sizes, the extent of aortic dilation, and the reduction in Green-Lagrange strain (a marker of vessel stiffness). Knowledge gained will benefit future mesenchymal stem cell work aimed at preventing aneurysm formation by modulating the immune response.

Dr. Tamara Kinzer-Ursem

Protein-Engineering for Development of High-Throughput Assay Platforms
My lab is developing novel protein tagging methods that can be used to isolate proteins of interest rapidly and cost-effectively in the development of surface-based protein assay platforms. We seek to reduce the time and material costs of protein production and characterization by developing novel protein tagging and conjugation technologies that can be used to streamline assay development and aid in getting quantitative measures of protein function. This undergraduate research project will focus on implementing our current strategies to develop a novel assay for quantifying protein phosphatase activity. Experiments to quantitate protein production, tagging efficiency, protein conjugation efficiency, and protein specific activity will be designed and carried out. Students will be expected to analyze the data and report results with appropriate statistical rigor.

Dr. Zhongming Liu

Decode Brain Activity Using Machine Learning
Advancement in neural imaging, recording and stimulation technology has generated an enormous amount of informative data about the structure and function of the human brain. Tremendous challenges and opportunities exist in analyzing such "big data" to uncover complex neural codes by which the brain uses to enable our human behavior and cognition. The goal of this project is to reconstruct the visual and mental experience of human subjects by decoding brain activity observed with functional magnetic resonance imaging (fMRI) and electroencephalography (EEG). Students will be engaged in developing machine
learning algorithms to analyze dynamic brain images and recordings to retrieve information about what a person sees, hears or thinks in real-time.

**Dr. Nicholas Carpita**

**Genome-wide Association Mapping of Maize Cell Wall Traits**

Maize has a genetic diversity of almost 2% across the species. This diversity is captured in 280 near isogenic lines called the Association Panel. A high density mapping tools are available to associate any quantitative trait to candidate genes that contribute to trait. Students will learn fundamental biochemical quantitative analysis of cellulose, carbohydrates, and lignin as foundational data for a bioinformatic approach to identify genes responsible for their quantitative distribution.

**Dr. John Morgan**

**Mathematical Modeling of Plant Metabolism for Sustainable Chemicals**

The work will study key metabolic pathways in plants and photosynthetic microbes for the production of valuable chemicals. The work will initially be in silico simulations of metabolism to compute maximum theoretical yields of specific chemicals. Introduction of non-native pathways through metabolic engineering will also be simulated in silico. The student will also assist graduate students on the in vivo quantification of metabolic fluxes in microalgae for the production of oils and carbohydrates. The study will examine intracellular rates of metabolism under different illumination and nutrient conditions.

**Dr. Hyowon Lee**

**Self-clearing Implantable Device with Magnetic Nanoparticle Hyperthermia**

Chronically implanted medical devices are often plagued with bio-fouling and encapsulation that limit their functionality over time. Magnetic nanoparticles have a unique feature that enables localized heating (i.e., hyperthermia) due to their superparamagnetic property. By immobilizing commercially available magnetic nanoparticles on implants, it may be possible to improve device longevity by minimizing bio-fouling. The undergraduate student will help design and develop novel immobilization technique to integrate magnetic nanoparticles onto silicone substrate and evaluate its hyperthermia-based self-clearing capability. Using characterization techniques such as TEM, AFM, and IR visualization, the student will perform design of experiment to determine the effect of different variables (i.e., particle size, concentration, etc) on hyperthermia performance. Finally, the student will study the effect of hyperthermia on bio-fouling in in vitro models (i.e, inflammatory cells).
Dr. Joe Ogas

**Analysis of Epigenetic Regulators of Developmental Identity in Arabidopsis**

We study an epigenetic pathway that controls developmental identity in the model plant Arabidopsis. In the absence of the chromatin remodeling factor PKL, plants fail to develop properly (e.g. seedlings continue to express embryonic traits). We have identified mutations that enhance the phenotype of mutant plants that lack PKL, suggesting that they are mutant versions of factors that work with PKL to specify developmental identity in plants. Students working on the next step of this project will use genetics, phenotypic characterization of a variety of developmental traits, and statistical analysis to determine if the mutation is at a single locus and to investigate the phenotype of the mutation in the presence of a wild-type version of PKL. This project will help to illuminate how epigenetic machinery cooperates to determine developmental identity in plants and thereby identify possible strategies to modify crops of interest to increase their agronomic potential.

Dr. Russell Main

**The Effects of Different Mechanical Stimuli on Bone Formation.**

The skeleton is sensitive and responsive to mechanical stimuli. Animal models are used as a means of understanding the mechanical and biological determinants for building new bone. However, different groups employ a variety of different mechanical loading protocols to understand these processes. Here, we will characterize the effectiveness of four commonly used mechanical loading protocols for formation of new bone in the mouse tibial loading model. The interested student will be conducting in vivo loading experiments with mice and analyzing the differences in bone geometry and architecture by micro-computed tomography following two weeks of controlled applied load using four different loading protocols in four groups of mice. The student will become familiar in working with mice, using a materials testing system for compression loading, and with the analysis of computed tomography scans. We will employ ANOVA statistical tests with appropriate post hoc tests during data analysis.

Dr. Yuk Fai Leung

**Visual Behaviour in Zebrafish for Drug Screening**

The student will conduct in vivo visual-behaviour tests in zebrafish to evaluate drug effect on visual performance of eye-disease mutant or one of the visual-behaviour tests in the lab for testing specific visual function.

Dr. Nancy Emery

**Plant Strategies for Surviving and Thriving in Unpredictable Environments**

This project will be investigating the physiological mechanisms by which three closely-related wetland plant species have adapted to the hydrological uncertainty
in their native environments. We will be conducting a controlled experiment in a growth chamber in which we will grow plants under different hydrological treatments that will simulate contrasting patterns of flooding and soil moisture predictability. We will measure how plants respond to these treatments by collecting phenotypic data (morphological traits) and fitness data (overall performance). The specific techniques that will be involved include plant propagation, treatment implementation, morphological data collection and analysis, and the statistical analysis of data using univariate, multivariate, and evolutionary methods.

Dr. Daisuke Kihara

Identification of Protein-protein Interactions in Arabidopsis

The project is aimed at identifying physically interacting proteins in a plant model organism, Arabidopsis thaliana by using bioinformatics and statistical methods to analyze mass spectrometry data, which will be provided by biology collaborators. The experiment data will provide candidate protein pairs that may be physically interacting in a cell. Our group will conduct bioinformatics and statistical analysis to select most probable interacting protein pairs. We will predict and investigate function of proteins, the 3D structures of proteins, and perform comparative genomics approaches to find signature of interacting proteins as well as statistical test to judge if experimental data is significant or not. The student will work with a graduate student and a postdoc in our lab.

Dr. Jeffrey Lucas

Social effects on Vocal Complexity in Chickadees and Titmice

This project involves rigorous comparative and experimental efforts to identify major selection processes driving communicative complexity in an avian vocal system. We will test three leading hypotheses to explain the structure and complexity of chick-a-dee calls of Carolina chickadees and tufted titmice. Questions we aim to answer - 1) What is the extent of structural and note order variation within the chick-a-dee call system of populations in our study? 2) To what extent do social complexity, habitat constraints, and predation pressure explain variation in the complexity of chick-a-dee calls of these two species? The project will include field studies to gather call recordings as well as behavioral observations. Data analysis will include cross-correlation of call propagation using PRAAT and analysis of call structure and complexity using Avisoft SASLab Pro, and statistical analysis using SAS.

Dr. Alexander Chubykin

Visually Guided Behaviors in Mice

We are interested in understanding how brain circuits form associations between visual stimuli and salient events, and how these associations drive behavioral
responses depending on previous experience. We have previously discovered this form of learning in neurons of the primary visual cortex, and are interested in characterizing behaviors driven by visual learning in mice. In our studies of visual circuits, we are using optogenetics, in vivo and in vitro electrophysiology, and behavior. The goal of this project is to use stereotaxic injections of viruses encoding light-sensitive opsins into the brain, and then use optogenetics to train visual cortical neurons to drive associated behaviors. We are looking for a motivated enthusiastic student with strong work ethics. We will use a number of different quantitative methods to measure behavior changes, including computer vision for automatic mouse tracking. Proficiency with python and OpenCV is a plus.

Dr. Dennis Minchella

Exploring Genetic Heterogeneity of the Human Parasite Schistosoma mansoni

The parasite Schistosoma mansoni is the primary causative agent of schistosomiasis, a debilitating human disease prevalent in the tropics. The adult parasites reside in mammalian hosts, mating and producing eggs that pass out with host feces. Upon contact with water the eggs hatch into miracidia, the larval stage infecting snail hosts. In the snail host, the parasites undergo asexual proliferation, producing many larvae (cercariae) that infect the mammalian host. Previous research shows that these clonal cercariae carry many somatic mutations, possibly due to mitotic recombination. We will attempt to quantify these genetic differences between clonal cercariae using quantitative PCR. Specifically we will estimate the copy number of transposable elements (jumping genes). We hypothesize that the clonal parasite will show variable numbers of gene copies due to mitotic recombination. Identification of such variations will enhance our understanding genetic diversity of schistosomes.

Dr. Julie Liu

Engineering Protein-Based Materials for Biomedical Applications

Our lab is developing protein-based biomaterials for biomedical applications such as tissue engineering or surgical adhesives. We are currently designing biomaterials, which are made up of recombinant proteins with different functional domains. In this project, the student will become familiar with recombinant DNA technology and will use a bacterial system to produce the desired protein scaffolds. The student will then purify the resulting protein and characterize the physical properties. The student will work closely with a graduate student mentor.