Summer Undergraduate Research Experiences (SURE) 2019 Project Descriptions

Biology

The Center for Genomic Advocacy (Drs. Shaad Ahmad, Kyu Hong Cho, Hugo Gante, Rusty Gonser, Jeff Kinne, and Kris Schwab)

The Center for Genomic Advocacy (TCGA) offers a number of diverse research opportunities. The environment is collaborative with many faculty members working together. Students will first meet with Dr. Gonser, TCGA director (rusty.gonser@indstate.edu), to discuss the TCGA SURE program and their interests and goals in order to match students and faculty mentors. This method has produced a number of collaborative efforts through the years. TCGA usually takes anywhere from 4-12 students, depending on funding availability.

Some of the TCGA projects are listed below:

Dr. Ahmad's lab group is working to on the identification of Forkhead transcription factor-regulated genes in heart development. While at least eight Forkhead (Fkh/Fox) domain transcription factors are required for proper cardiac development in mammals, and mutations in four Fkh genes have been linked to human congenital heart defects, relatively little is known about the molecular mechanisms or the downstream targets by which these Fkh-mediated developmental functions are brought about. The Ahmad Lab previously found and analyzed the Drosophila orthologues of Fkh genes responsible for proper heart development and has now identified more than 2000 target genes regulated by the Drosophila Fkh genes. SURE students will attempt to identify the target genes used for heart development by disrupting the indidivdual target genes with mutations.

Dr. Cho's laboratory group studies the pathogenic mechanisms of the human bacterial pathogen, Streptococcus pyogenes. The SURE students joining the lab will be involved in investigating how the production of virulence factors such as toxins, capsules, and adhesins are regulated by environmental factors.

The Gante Lab uses a combination of approaches to study speciation, adaptation and persistence, traditionally but not exclusively, of freshwater fish species. The SURE students joining the lab will be involved in an international project aimed at investigating what species can be detected from environmental DNA present in water samples. The initial stages of the work (field sampling) will be conducted in the lower section of the Tagus River (Portugal). The work will involve collection and sequencing of water, diatom and fish samples.

The Gonser lab group investigates genetic and behavioral and evolutionary forces that affect populations. The white-tailed deer project utilized DNA extractions and PCR of

microsatellite markers to investigate how annual harvests affect genetic diversity of an putative isolated population in Southern Maryland. The other project involves the polymorphic white-throated sparrow. These ground nesting birds come in two plumage morphs that are determined by their genotype. Furthermore, the different morphs have distinguishable behavior and reproductive strategies. Therefore white-throated sparrows are one of the few species where we can link behavior to genotype. We utilize many research techniques to investigate why the polymorphism is maintained in the species.

The Schwab lab group investigates genetic regulation of mammalian cardiomyocyte differentiation. The development of the mammalian heart requires the step-wise activation of a complex gene regulatory network to specify and differentiate the cardiomyocyte, or heart muscle cell, populations that will generate the contraction force to propel blood through the cardiovascular system. Perturbations of this gene regulatory network can cause developmental malformations in the heart and cardiovascular system that can vary from mild to life-threatening conditions. My laboratory is interested in identifying and describing the molecular and genetic functions of cardiac genes that regulate cardiomyocyte differentiation by 1) using high-throughput gene expression data and bioinformatics to investigate cardiac gene expression changes during differentiation and 2) using an in vitro experimental system that differentiates human pluripotent stem cells (hPSCs) into cardiomyocytes to assess gene function. SURE students will utilize a combination of bioinformatic and molecular biology tools to analyze gene function during cardiogenesis.

Students working with Dr. Kinne will join with one or more of the biology research projects that requires programming and analysis. We are likely to continue working on a project with Dr. Schwab that analyzes differential expression of genes in the developing heart. In this project, we use the R programming language to determine which genes are the best candidates for having a key role to play in heart development. Biologists perform the experiments that create the data, and our role is to develop the programming scripts to perform the analysis. We may also support another biology project or two if the need arises. Requirements - Completed the first two courses in the CS major with an interest in programming. Introductory biology knowledge is a plus but not required. Some experience with R would be a plus but not required.

Chemistry

Dr. Rick Fitch (richard.fitch@indstate.edu)
Project 1: Analysis of Bioactive Alkaloids in Poison Frogs. Certain tropical frogs are brightly colored and contain toxic substances, generally alkaloids. We are interested in what alkaloids are present and in what amounts. We have collaborations with two ecology groups looking at frogs in South America and Madagascar. We use Gas Chromatography-Mass Spectrometry and Liquid Chromatography-Mass Spectrometry to identify and

quantify these alkaloids. Participants will get training on both as well as data analysis and automated identification techniques.

Project 2: Synthesis of Poison Frog Alkaloid Standards. Many poison frog alkaloids are not commercially available and we are synthesizing amines similar to these alkaloids to use for quantitation and identification of natural compounds. This involves conducting microscale to prepare a large number (~100-200) analogs for use in quantitative analysis. Participants will learn organic synthesis, purification and identification techniques including chromatography, mass spectrometry and NMR spectroscopy.

Dr. Eric Glendening (eric.glendening@indstate.edu)
Applications of Natural Resonance Theory. It is common for chemists to invoke resonance theory (RT) to interpret interesting structural and energetic properties of molecules. Recent advances in natural resonance theory, an implementation of resonance theory in the natural bond orbital methods, facilitate the application of RT to larger and more complex chemical systems than previously possible. This is a computational chemistry project. I seek one or two students to work full-time on the project. Students should have completed CHEM 106 or higher at ISU.

Dr. Ryan Van Hoveln (ryan.vanhoveln@indstate.edu)
Our research focuses on organometallic chemistry (the study of carbon-metal bonds). Currently, we are developing new copper complexes to use as catalysts for silylation chemistry (the addition of a silicon functional group to an organic compound). Students will work in teams and learn a number of laboratroy techniques germane to organic research such as working under air-free conditions, working with reactive chemicals, and NMR spectroscopy.

Dr. Fan Zuo (fan.zuo@indstate.edu)
Organic-inorganic hybrid quantum heterostructures for optoelectronics. Precise manipulation of inorganic frameworks and organic layer spacers in a desired way to construct hybrid materials. Compared to current inorganic 2D heterostrucures, hybrid system could provide tremendous richer chemistry tools to tailor the composition, structure, property and function, achieving novel optoelectronics. Proposed plan: Inspired by the success of self-assembly synthesis of organic-inorganic hybrid perovskite, a layer-by-layer self-assembly route is proposed here to construct hybrid quantum heterostructures: organic moiety with anchor groups such as carboxylic acid group (-COOH), phosphonic acid group (-PO3H2), or ammonium group (-NH3) will be robustly grafted to the surface-activated substrate via M-O bonds (M = Si, Ti, Al, etc.) or Coulomb force and form an organic monolayer; inorganic moiety is then added to the system and self-assembles into inorganic monolayer through covalent bonding or coulomb interaction with organic. Repeating the above process, a second inorganic monolayer with different composition will be fabricated to construct a quantum hybrid heterostructure.

Earth and Environmental Systems

Dr. Jen Latimer (jen.latimer@indstate.edu)
In the Biogeochemistry Lab, we use elemental data collected from soils, sediments, and water to study environmental change. Projects include past climate change in South Africa and the Indian Ocean, bioavailability of lead and other heavy metals in urban environments, and many others. Students should be comfortable handling chemicals and should have completed CHEM105.

Dr. Jim Speer (jim.speer@indstate.edu)
Dr. Speer from the Dendrochronology and Biogeography Laboratory is looking for students to conduct a biodiversity inventory of the ISU Community Garden during SURE 2019. These students will use an iPhone or Android App to take pictures of pollinators in the community garden, identify the organisms with the help of the iNaturalist App AI, and analyze the data to explore the biodiversity of pollinators in the garden in different treatments that are 12 years, 8 years, 6 years, and 0 years in cultivation. We have over 4000 observations documenting over 500 organisms from the fall of 2018 as a baseline for future studies. We hope to take on a team of individual that can make regular observations every day in the community garden using their cell phones and a digital SLR camera to document as many organisms as we can. We also plan to collect similar data at the White Violet Center for Ecojustice organic gardens at Saint Mary of the Woods College and local industrial agricultural sites as extreme controls of pollinator biodiversity during the course of the summer.

Physics

Dr. Sean Bartz (sean.bartz@indstate.edu)
Holographic model of deconfinement in quark matter. This is a project in theoretical/computational nuclear physics. We are examining the phase transition between ordinary nuclear matter and the quark-gluon plasma produced in heavy ion collisions. This project will involve reading and understanding the model from a different group's paper, and building the computer program to reproduce their results. This will allow us to extend their results in the future. I am looking for one student who has some familiarity with differential equations and basic computer programming.

Dr. Guoping Zhang (guoping.zhang@indstate.edu)
Project 1: Computer simulation of the interaction between amyloid beta plaques in Alzheimer diseases and olecanthal. The student is expected to use the computer program, Gromacs to carry out a massive simulation to understand the interaction between amyloid beta plaques in Alzheimer diseases and olecanthal (from olive oil).

Project 2. All-optical spin switching. This project targets a growing frontier for the magnetic storage devices.

Project 3. High harmonic generation in solids. High harmonic generation in solids becomes a focus of new light source for the future. Students will use some exotic materials to generate strong harmonic radiation.