Summer Undergraduate Research Experiences (SURE) 2022 Project Descriptions

Biology

The Center for Genomic Advocacy (Drs. Shaad Ahmad, Kyu Hong Cho, Rusty Gonser, Aaron Gooley, Jeff Kinne, Kris Schwab, and Michael Thompson)

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 understand the roles of Forkhead/Fox transcription factors in heart development and disease. While at least eight Fox domain transcription factors are required for proper cardiac development in mammals, and mutations in four Fox genes have been linked to human congenital heart defects, relatively little is known about the molecular mechanisms or the downstream targets by which these Fox-mediated developmental functions are brought about. The Ahmad Lab previously found and analyzed the *Drosophila* orthologs of Fox genes responsible for proper heart development and has now identified more than 2000 target genes regulated by the *Drosophila* Fox genes. SURE students will attempt to identify the target genes used for heart development by disrupting the individual target genes with mutations. The Ahmad Lab has also identified Zinc finger transcription factor proteins critical for heart development in both humans and *Drosophila.* SURE students will also attempt to pinpoint the specific cardiogenic processes mediated by these Zinc finger transcription factors.

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. Second messenger nucleotides play vital roles in the signal transduction pathways that convert external or internal signals into cellular activities. Cyclic di-adenosine monophosphate (c-di-AMP) is a recently discovered one involved in cell growth, survival, and virulence of many bacterial pathogens. Dysregulation of c-di-AMP balance reduces pathogens' survival inside their hosts, indicating that c-di-AMP signaling pathways could be the target for the development of antibacterial agents. A research goal in the Cho lab is to understand the detailed mechanism of c-di-AMP signaling and regulation using *Streptococcus pyogenes* as a model pathogen. *S. pyogenes* is a Gram-positive bacterial pathogen that causes various non-invasive and invasive diseases such as strep throat,

impetigo, rheumatic heart disease, necrotizing fasciitis, and so on. A minimum global burden by *S. pyogenes* infection is estimated over 18 million cases of severe diseases, resulting in over half a million annual deaths. Despite the dire consequences of this pathogen, commercial vaccines are not yet available. Our published studies indicate that c-di-AMP in *S. pyogenes* is required to properly respond to environmental stressors and to exert virulence.

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 embryonic, and later, the adult cardiovascular system. Perturbations of this gene regulatory network can cause the developmental malformations in the cardiovascular system that can vary from mild to severe defects. My laboratory is interested in identifying and describing the function of novel cardiac genes that regulate cardiomyocyte differentiation by using 1) high-throughput gene expression data and bioinformatic analyses to investigate cardiac gene expression changes during differentiation, 2) an *in vitro* experimental system that differentiates human pluripotent stem cells (hPSCs) into cardiomyocytes to assess gene function, and/or 3) *Drosophila melanogaster* as model system to study heart development. SURE students will utilize a combination of bioinformatic and molecular biology tools to analyze gene function during cardiogenesis.

The Thompson lab studies the regulation of inflammation. We use a combination of enzyme kinetic analysis and protein-protein interaction techniques to analyze the interaction and regulation of proteins that are involved in regulating the process and mitigating the effects of innate immune responses on normal body cells and tissues. Students joining the lab would be involved in a project examining the response of several intracellular and extracellular zinc-containing proteases to reactive oxygen-nitrogen species produced during inflammation, and in establishing protein expression systems to study the structure and function of metal-binding proteins that regulate these enzymes.

Students working with Dr. Kinne will join with one or more of the biology research projects that requires programming and analysis. Projects are in progress with the Schwab Lab, Ahmad Lab, and Cho Lab. Each project involves understanding experimental datasets and

using programming tools to perform analysis that is accurate reproducible. Each project has code and preliminary results that need to be improved and refined. The Schwab Lab project involves mining gene expression data to find key genes in heart development. The Ahmad Lab project involves automated searches of mutations to manipulate the binding of given transcription factors. The Cho Lab project involves the analysis of RNA-seq data from micro-organisms. 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.

Dr. Aaron Gooley (aaron.gooley@indstate.edu)
In the Wildlife Ecology & Ecotoxicology Laboratory we use both field investigations and laboratory work to 1) identify and investigate novel ecological questions, 2) develop and test new methods for the conservation of imperiled species, and 3) investigate the impacts environmental stressors on pollinators and other wildlife. Potential topics for SURE participants include investigating a) how field-realistic levels of pesticides impact honey bee foraging efficiency, b) how pesticides impact honey bee metabolic rates and how quickly they metabolize pesticides, c) analysis of state-collected rabies-negative bats, d) new field techniques for turtle research, d) wildlife ecology in areas around Terre Haute.

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)
We use computational chemistry methods to explore the structure (geometry) of molecules and to map reaction pathways as reactants are converted to products. Significant advances in resonance theory over the past three years allow us to understand complex systems using concepts that students learn in freshman and sophomore-level chemistry. I seek one

or two students to work full-time on the project. Students should have completed CHEM 106 or higher at ISU.

Dr. Rob Noll (robert.noll@indstate.edu)
We are interested in electrochemical cells (or batteries) which can undergo thermally regenerative electrochemical cycles (TREC). These cells convert thermal energy (heat) into electricity, without the need for external recharging. TREC batteries thus represent an important potential renewable energy resource. These cells appear to be "self-recharging batteries." Of course, such devices would violate the laws of nature and be impossible. All the same, cells with TREC-capability can produce electricity until discharged, then can be heated and produce more electricity, again until discharged, at the higher temperature. Upon cooling, they can undergo this cycle again, producing more electricity, and, in principle, the cycle can be repeated many times.

Such a battery could use natural variations in temperature, such as heat from the sun during the daytime and the cool of night, as it source of heating and cooling. In preliminary theoretical work, we have identified 30 promising half-cell combinations based on aqueous systems. This summer, our aim will be to create demonstration cells capable of undergoing TREC cycles in the lab. I am interested in having two students work with me on this project this summer, full time or half-time is acceptable, although full-time is preferred. Students should have completed Chem 106/L.

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 reactions which use metal catalysts (such as copper or nickel) to couple two organic pieces together and develop new organic reagents for synthesis. Our goal is to make challenging bonds that could not otherwise be made by traditional organic synthesis. Students will work in teams and learn a number of laboratory techniques relevant to organic research such as working under oxygen-free conditions, working with reactive chemicals, and NMR spectroscopy.

Dr. Fan Zuo (fan.zuo@indstate.edu)
Electrochemistry and photoelectrochemistry. Research in my group is to design efficient catalysts for energy application. We have a complete set of facilities to synthesize electrocatalysts and study their electrocatalytic H_2 and O_2 evolution efficiency, and investigate the reaction mechanism. Integration with the solar simulator and monochromator, we have the capability to study some key characters for photocatalysts, such as the Incident Photo to Charge Carriers Efficiency (IPCE). Students in our group will learn how to use their chemistry knowledge to produce clean energy through electrical and photoelectrical strategy, and have the opportunity to access the state-of-the-art equipment for energy application.

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. Jeffery Stone (jeffery.stone@indstate.edu)
Students who engage in summer research in the Paleolimnology lab study modern lake and river systems or microfossil remains from lake sediments. Student projects can include analysis of modern or fossil diatoms, potentially including either paleoecology, paleoclimate, or taxonomy. Research usually involves some combination of field work, laboratory work (particularly on the light microscope), and some time and training using the Scanning Electron Microscope. Student projects can include materials from lakes around the world (US, Africa, South America, the Himalayas, etc.).

Physics

Dr. Sean Bartz (sean.bartz@indstate.edu)
I am looking for 1-2 students to work on projects in computational physics. Prior programming experience is beneficial, but not necessary.

Project 1: 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.

Project 2: Explorations in computational modeling. I have a project in modeling infectious disease spread using the physics of diffusion that will probably be about a half-time SURE project. A full-time student would then transition to a different modeling project, such as modeling elastic collisions or another project of mutual interest.

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.

College of Technology

Dr. Sheikh Fahad Ferdous (sheikh.ferdous@indstate.edu)
Project 1: This project is mainly based on 3D printer. It's a difficult job to 3D print objects where two materials meet in very small tolerance such as dental implant. Because of the heating, the 3D printed materials can be distorted and meeting required tolerance can be challenging while printing two materials side by side. The students will work on printing two materials side by side and find the optimal situation so that both materials don't distort because of thermal stress.

Project 2: This project involves in printing complex object by using 3D printer. As an example, it's difficult to print internal meshed gear. The students have to find a clever way to print such complex structures.

Dr. Maria Javaid (maria.javaid@indstate.edu)
Dr. Javaid has research background in robotics, mechatronics, and data science. Two of the projects she will be continuing during summer are briefly explained here.

Project 1: Developing a low cost haptic device and explore the possibilities of using this device for higher education. Haptic devices are kind of robots that provide force feedback to the user.

Project 2: Collect and analyze the vibration data obtained when drilling action is performed using drill casing of different shapes. This project is part of larger project performed in collaboration with Mechanical Engineering technology professor.

IU School of Medicine—Terre Haute

Dr. Scott Canfield (sccanfie@iu.edu)
Dr. Canfield's lab focuses on modeling the blood-brain barrier (BBB) utilizing human induced pluripotent stem cells (iPSCs). We have recently obtained Alzheimer's disease (AD)-derived iPSCs to model the AD BBB. Specifically, we are interested in investigating the effects of anesthetics on the AD-derived BBB. AD patients have been shown to be at an elevated risk of post-operative delirium following anesthesia treatment. Our working hypothesis is that anesthetic exposure is detrimental to critical barrier properties contributing to post-operative delirium in AD patients. A SURE student will be responsible in measuring barrier properties in AD-derived BBB models following exposure to varying anesthetic treatments.

Dr. Steven Templeton (sptemple@iupui.edu)
Dr. Templeton's lab focuses on learning about infection with and immune responses to the opportunistic fungal pathogen *Aspergillus fumigatus*. We have recently begun a collaboration with a laboratory at IUSM-Indy, investigating the effects of an antimicrobial electroceutical wound dressing on the growth and survival of filamentous fungi. This project will help to further determine the ability of this experimental material to prevent wound infections with fungal pathogens. A SURE student will work with members of my lab to grow different strains of fungi in the presence or absence of the appropriate dressing, using different techniques to assess the effect on growth and survival.