Tulane Research and Innovation Award Projects 2025-2026

1: Tracking Induced Earthquakes in Louisiana

Professor: Dr. Cynthia Ebinger

Department: Earth and Environmental Sciences

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Independent monitoring of extractive industry activity is critical to the quality of groundwater and natural resources, as well as mitigation of induced earthquake hazards. The Haynesville Shale in east Texas and northern Louisiana is one of the most productive shale-gas plays in the U.S, but there is no permanent seismic network in Louisiana. Heterogeneous data sets indicate that the magnitude of earthquakes is increasing with time, motivating this request for funding for a 2-year seismic deployment in Louisiana to fill a critical gap in seismic monitoring as Louisiana implements a plan for a permanent network. Our objectives are to determine the spatial and temporal distribution of earthquakes, the geometry and kinematics of reactivated sedimentary and basement faults with respect to the regional stress field, and time-space relation of the earthquakes to fluid injection. This work will improve our understanding of induced earthquake hazards and fault slip and creep processes in rift basins. The student will compare earthquake locations with known faults, fluid injection wells, and other geological data to establish a strong framework for earthquake monitoring.

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2: Varying the Enantiomeric Ratio in Chiral Materials

Professor: Dr. Daniel Straus

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Chiral materials are highly valued in physics, chemistry, biology, and engineering because of their unique properties arising from their inherent handedness. A material is considered chiral if it cannot be superimposed on its mirror image, making it inherently left- or right-handed. These materials can manipulate circularly polarized light, catalyze stereoselective reactions, and detect chiral biomolecules.

The most common method to convert an achiral inorganic or organic-inorganic hybrid material into a chiral one involves synthesizing a variant that contains chiral organic molecules. Typically, three variants can be formed: a material containing exclusively left- or right-handed molecules, or a racemic (achiral) variant with a 1:1 ratio of left- and right-handed molecules because interactions between the chiral molecules generally inhibit the formation of materials with an arbitrary ratio of left- and right-handed chiral molecules.

However, we recently discovered a material that violates this principle, containing a 3:1 ratio of left- to right-handed molecules. In this project, a student will investigate this anomaly further by synthesizing and characterizing materials with differing ratios of left- and right-handed molecules to determine the factors that allow the formation of materials with an arbitrary ratio of left- and right-handed chiral molecules.

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3: Understanding the genomic basis of adaptation in co-evolving butterfly and plant species pair

Professor: Samridhi Chaturvedi

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Species with broad geographic ranges can respond to climate change by shifting their distributions or adapting locally (*in situ*). Rapid adaptation to environmental changes often relies on standing genetic variation (SGV) already present within populations. While evidence for adaptation through SGV exists, how this spatially distributed genetic variation changes over time is poorly understood. Since temporal environmental changes, such as fluctuations in temperature and precipitation, often reflect spatial patterns, a critical question arises: can adaptive variation across space predict a population's response to environmental changes over time? Neotropical Pipevine Swallowtail butterflies (genus *Battus*), specialist herbivores of toxic *Aristolochia* plants, are an ideal model for exploring these questions. Changes in precipitation and temperature can alter plant-herbivore dynamics, affecting both species' chemistry, physiology, and genetics. With their biogeographic distribution across diverse climates, these butterflies offer a valuable system for studying adaptive evolution. This research will investigate whether spatial genetic variation can predict temporal adaptive changes and whether SGV drives this change. Using century-old museum specimens, contemporary field sampling, machine learning models, high-throughput sequencing, and Bayesian modeling, we aim to use an integrative approach to predict evolutionary responses to climate change.

Undergraduate-specific project: This project offers several opportunities for undergraduate researchers to gain substantial experience in Ecological and Evolutionary Genomics. Students will be involved in research focused on identifying the genomic basis of adaptive evolution in Pipevine Swallowtail butterflies. The work employs a combined approach that includes DNA sequencing data generation, computational data analysis, bioinformatics, and statistics. Therefore, students can expect to develop research projects that involve the following: Fieldwork: Students can create projects that involve fieldwork in New Orleans,

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3: Understanding the genomic basis of adaptation in co-evolving butterfly and plant species pair (Continued)

California, Texas, and Florida to sample butterflies and their host plants. Molecular lab work: Our lab conducts genomics and transcriptomics research, utilizing this data to answer questions in evolutionary biology. To this end, students can expect to acquire genomic sequencing skills, including DNA extraction methods, genomic library preparation and quality assessment, and sequencing protocols. Data analyses: Genomic data analysis involves developing computational programming skills in UNIX, Python, and R programming languages. They can expect to cultivate analytical skills relevant to studying population genetics and adaptive evolution in nature. Publication: Depending on the project they choose, students will have the opportunity to author peer-reviewed articles based on their work and present at national conferences. Research funds can be used for fieldwork and molecular lab work supplies.

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4: Capturing the 3D structure of reefs with drone-based photography

Professor: Dr. Tom DeCarlo

Department: Earth and Environmental Sciences

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Reef structures provide immense value to society by protecting shorelines from wave exposure and erosion. This service extends from oyster reefs protecting Louisiana marshes to coral reefs protecting tropical shorelines. However, their effectiveness for reducing waves depends on the shape and roughness of the reef. This project will explore new ways to assess reef roughness with photographs collected by unmanned aerial vehicles ("drones"). Series of photos collected from different orientations can be combined in a technique called photogrammetry to construct 3-dimensional models of objects or landscapes. Data collection will take place on restored oyster reefs in coastal Louisiana and/or on coral reefs in Brazil. The 3D reef models will then be compared to water flow and wave measurements to test whether this drone-based approach is an effective monitoring tool for reef ecosystem services.

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5: Reconstructing Atlantic climate from coral growth bands

Professor: Dr. Tom DeCarlo

Department: Earth and Environmental Sciences

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Coral skeletons are the “tree rings of the sea” as they contain alternating bands of density that form yearly. These bands provide information on the age of the coral and its growth rate over past decades to centuries. The growth rates are influenced by climate variability such as changing temperature and/or ocean currents, which allows us to use coral skeletons to reconstruct recent climate changes in the tropical oceans. New sets of coral skeleton samples were recently collected from the northern and southern latitudinal limits of corals in the Atlantic Ocean (Bermuda and Brazil, respectively). This project will analyze CT scans of these skeletons for growth rates with a custom-made software application called “CoralCT” (www.coralct.org). These growth rate data will then be related to Atlantic climate variability with the goal of identifying the factors that led to unprecedented warmth throughout the Atlantic Ocean in 2023 and 2024.

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6: Synthesis of Exact Masses for Calibration of Biological Products

Professor: Dr. Scott Grayson

Department: Chemistry

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Our group has completed a number of high molecular weight compounds which have only one peak for mass spectrometry from 1,000 Da (daltons) to 30,000 Da. This is from a simple chemical reaction that, once it is completed, has only one exact product. Our research group will expand these for other unique polymers, including increasing these for higher molecular weights, controlling the mass defect of our macromolecule, and confining the isotopic distribution, especially at increased masses.

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7: Solar Cells and Light Emitters from Ultra-Thin Nanomaterials

Professor: Dr. Matt Escarra

Department: Physics and Engineering Physics

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Two-dimensional nanomaterials such as MoS_2 and WSe_2 have very strong light-matter interactions despite their molecular thickness. These materials offer an exciting opportunity to improve the performance of solar cells and light emitters relative to existing platforms. This is particularly important for applications that are volume or weight constrained, from space power conversion to integrated circuits. The Escarra Group at Tulane synthesizes these materials at relatively large scale and uses them in a variety of optoelectronic devices. Undergraduates may support this project via material synthesis and characterization all the way through building solar modules for testing in a simulated space environment with NASA collaborators.

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8: Genetic control of craniofacial development

Professor: Dr. Fenglei He

Department: Cell and Molecular Biology

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Craniofacial defect is one of most common birth malformations. Among this category, midfacial defect, including cleft lip and/or palate, is on the top list. However, its etiologies remain largely unknown. Our long-term interest is to understand the fundamental mechanisms underlying craniofacial development, and how genetic mutation disrupts this process, by using a combinatorial approach of in vivo and in vitro models. Undergraduate students are welcome to join our team efforts to address critical questions in craniofacial development and malformation. They will be trained with basic experimental techniques of developmental biology and molecular biology, including DNA electrophoresis, genotyping of mouse models, embryos dissection, sample processing, immunohistochemistry, skeletal preparations and other essential skills.

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9: Kidney anomalies of Kabuki Syndrome

Professor: Dr. Fenglei He

Department: Cell and Molecular Biology

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One of our research interests lies in Kabuki syndrome, a rare congenital disorder that affects various parts of the body. It is characterized by distinctive facial features, kidney defects, developmental delays, and intellectual disabilities. Kabuki syndrome is primarily associated with mutations in two genes: KMT2D (also known as MLL4) and KDM6A. These genes are involved in epigenetic regulation, specifically histone modification, and play a crucial role in the normal development and function of various tissues in the body. However, it remains largely unknown how KMT2D regulates kidney development. Using genetic engineering mouse models, we found that Kmt2d is specifically essential for nephron progenitor cells during kidney formation. Undergraduate students will be trained with genotyping, DNA gel electrophoresis, embryos dissection, colony management, as well as histological analysis.

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10: Biochemistry Authentic Scientific Inquiry (BASIL)

Professor: Dr. Liz Abboud

Department: Cell and Molecular Biology

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Are you curious about how proteins work and how their structures determine their functions? Join our lab's independent study research program, where you'll explore the fascinating world of protein science. Through hands-on experience, you'll learn advanced techniques to characterize protein structures, unravel their biological roles, and explore their impact on human health and disease. This is a unique opportunity to develop critical research skills in an inclusive and collaborative environment, while contributing to novel protein research. Our lab offers the opportunity to grow as a scientist and human being, while contributing to the greater scientific community focused on protein structure and function.

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11: The Chemistry of the Global Nitrogen Cycle

Professor: Dr. Alex McSkimming

Department: Chemistry

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The ‘fixing’ of atmospheric nitrogen by bacteria is critical in providing the fertilizer necessary to support plant life on Earth. It was recently discovered that so-called ‘metal hydrides’; i.e. molecules with a bond between a hydrogen atom and a metal atom, are essential in mediating this process. Our lab prepares and studies artificial metal hydrides to provide insights into bacterial nitrogen fixation. This research is very much interdisciplinary, and involves drawing from a number of chemistry fields, including biological, organic, inorganic and physical.

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12: Climate Change Effects on Plant-Fungal Interactions in Coastal Marshes

Professor: Dr. Emily Farrer

Department: Ecology and Evolutionary Biology

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Thousands of microbial species live inside plant tissues and in the soil. We have very little understanding of what these microbes do (are they beneficial or pathogenic?) and how they might be affected by climate change. This project aims to study the composition and function of fungal microbiomes that live in plant roots and soil in coastal marshes in Louisiana. Because of climate change, coastal marshes are experiencing salinity stress, as saline water moves inland due to sea level rise and increasing hurricanes and storms. We are surveying marshes across SE Louisiana and performing experiments testing how elevated salinity affects plant-fungal interactions. We culture the fungi (grow them on petri plates) and use metagenomic sequencing (DNA extractions, PCR) to characterize the composition of the fungal microbiomes. We also inoculate seeds and plants with different fungal strains to determine whether the fungi are beneficial or pathogenic to the plant. Overall, this work has implications for how wetland systems might change with climate change. Furthermore, if we identify fungi that are beneficial to plants and tolerant of salinity, these strains could be developed for use in restoration practice.

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13: Identification of Bioactive Natural Product Gene Clusters for Drug Discovery and AI-Based Protein Engineering for Improved Pharmaceutical Properties

Professor: Dr. Shuaihua Gao

Department: Chemical and Biomolecular Engineering

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The Gao Lab conducts research at the intersection of chemistry, biology, and engineering, with a particular focus on Protein Discovery and Engineering for medical, pharmaceutical, and chemical applications. As part of the TRIA program, students will work on genome mining of new bioactive natural product gene clusters and AI-based protein engineering for improved pharmaceutical properties. In this project, students will gain hands-on experience in bioinformatics-driven discovery of gene clusters responsible for producing natural products with antibacterial, antifungal, antitumor, or immunosuppressive activities. Additionally, by understanding the molecular basis of catalysis, students will apply machine learning techniques to enhance protein evolution, optimizing enzymatic properties for pharmaceutical applications. This project offers a unique opportunity to explore cutting-edge approaches in drug discovery, enzymatic synthetic machinery, and AI-driven protein engineering, preparing students to lead research at the forefront of biotechnology and medical innovation. A key strength of this project is its integration of both experimental and computational approaches, providing students with a well-rounded research experience. Students will develop a versatile skill set applicable to a wide range of scientific and industrial careers.

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14: Novel Energy Materials

Professor: Dr. Michael Naguib

Department: Physics and Engineering Physics

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The growing demand for reliable energy conversion and storage systems is driven by the rapid advancement of renewable energy technologies and the exponential increase in portable electronic devices. Consequently, the development of novel materials for energy conversion and storage has become critically important. Our research group is dedicated to exploring Novel Energy Materials as a central theme. We focus on the design and synthesis of new 2D nanomaterials for next-generation energy storage systems, including batteries beyond Li-ion technology, supercapacitors, and electrocatalysis. In addition to discovering and creating innovative materials, we are also committed to developing cost-effective materials for commercially available electrochemical energy storage systems, such as Li-ion batteries and supercapacitors. These efforts aim to contribute to environmentally sustainable and economically viable energy solutions.

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15: From Waste to Resource: Engineering Practical and Sustainable Solutions to Everyday Problems

Professor: Dr. Julie Albert

Department: Chemical and Biomolecular Engineering

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The Albert Lab is working with the New Orleans startup company, Glass Half Full, on turning recyclable waste into a resource. A student working on this project will learn how to apply human-centered design principles in research to advance one of the following solutions (of their choosing): (1) chemical-free water purification using recycled glass filter media for disaster recovery, or (2) replacing "forever plastics" in environmental restoration materials with a natural biodegradable plastic. These projects are part of the larger "ReCoast" project described at recycleforthecoast.org.

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16: Acoustic tweezing analysis of biological materials

Professor: Damir Khismatullin

Department: Biomedical Engineering

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In this project, students will be introduced to acoustic tweezing rheometry, a novel drop-of-sample technology for the rheological analysis of biological materials developed in Dr. Khismatullin's laboratory. This technology is based on acoustic levitation of a small drop of a biological sample and controlled deformation of the drop by different types of acoustic forcing. Students will learn about acoustic instrumentation, how to prepare biological samples for rheological analysis, how to run acoustic tweezing experiments, and how to collect and analyze experimental data. Students will be exposed to machine-learning algorithms when performing advanced analysis of the acoustic tweezing data.

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17: Modeling cell signaling pathways to expedite drug discovery

Professor: Dr. Daneil Howsmon

Department: Chemical and Biomolecular Engineering

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Cellular signaling pathways transmit information from the cell's environment to the nucleus where gene expression occurs. Modifying cell signaling pathways is also the primary ways in which drugs work. Through the TRIA program, an undergraduate in my lab will collect data on cell signaling pathways relevant to heart valve disease and develop computational/engineering reaction networks describing their findings. Heart valve diseases currently have no pharmaceutical therapies, leaving surgery as the only option. This TRIA project builds skills in experimental cell/molecular biology and computational modeling. Through broader group efforts, students will also be exposed to scientific machine learning for expediting discovery of these cell signaling pathways.

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18: Mechanisms and Therapeutics of degenerative eye diseases

Professor: Dr. Shusheng Wang

Department: Cellular and Molecular Biology

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Research in the Wang lab has been focused on the intersections of noncoding RNAs, vascular biology and retinal degeneration. Our research is highly relevant to degenerative retinal diseases including age-related macular degeneration (AMD). AMD is the leading cause of blindness in the elderly, affecting ~8.7% percent of the worldwide population. It has both wet and dry forms. Late-stage dry AMD is characterized by degeneration and loss of retinal pigment epithelial (RPE) cells, while wet AMD is characterized by choroidal neovascularization. The projects in the lab involve studying the AMD-related biological processes, including angiogenesis, fibrosis, cell death and cellular senescence, with the goal of finding novel therapeutics for AMD.

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19: Parallel Leaf Shape Evolution

Professor: Kathleen Ferris

Department: Ecology and Evolutionary Biology

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The Ferris lab studies the genetic basis of speciation and adaptation in a group of West Coast wildflowers, the yellow Monkeyflowers. We use a combination of genomic sequencing, genetic mapping, and lab and field experiments to understand how different Monkeyflower species have adapted to harsh rocky habitats. One main project in the lab is looking at the genetic basis of parallel evolution of leaf shape across Monkeyflower species. One of the central questions in evolutionary biology is whether evolution is predictable at the molecular level. This has been explored in several genetically simple traits such as stickleback fish body armor and animal pigmentation. Little is understood about the extent of parallel genetic evolution in polygenic phenotypes. We have found parallel leaf shape evolution across several Monkeyflower species native to rocky outcrop habitats. However, we do not know whether the same genetic loci underlie leaf shape evolution in each species. To test whether leaf shape has evolved from standing variation in an ancestral population or new mutation across research our research currently focuses on finding the individual genes involved in leaf shape evolution in three species: the cut-leaf Monkeyflower, the fern-leaved Monkeyflower, and the seep Monkeyflower. To identify the individual loci controlling leaf shape evolution across species, we are using molecular genetic mapping techniques (GWAS and QTL mapping) in both laboratory controlled crosses and natural hybrid Monkeyflower populations. **Characterizing individual loci and mutations will allow us to assess whether a complex trait has evolved due to independent genetic changes or selection on standing variation in an ancestral population and how predictable evolution is at the molecular level both within and between species.** Participating in research in the Ferris lab involves growing Monkeyflowers and measuring ecologically important traits like leaf shape or flowering time, performing genetic crosses in the greenhouse, doing molecular lab work for genomic sequencing, and performing manipulative field experiments in Yosemite National Park, CA.