Abstract of projects:

1. Phospholipases and Phospholipids: Essential Roles in Cell Death (PIs: Dr. Tripta Bhatia and Dr. Abhishek Chaudhuri):

   Membrane damage caused by Phospholipases can change a cell's mechanical or chemical state and result in cell death. This proposal seeks to identify the core biophysical membrane principles that connect membrane damage, stages of cell death, and related membrane properties. We will combine experimental and computational methods from membrane biophysics and biology to achieve a comprehensive understanding. Ultimately, we aim to suggest new therapies that regulate these properties to prevent and treat inflammatory diseases.

   Desirable expertise: Biology, Biophysics, Physics, Biotechnology, Mechanical Engineering, Electrical Engineering. Preferable experience in Cell Culture, Protein purification.

2. Development of Novel Bent-Core Mesogens as Tunable Platforms for Chirality-Induced Spin Selectivity and Organic Spintronic Applications (PIs: Santanu Kumar Pal; Dr. Goutam Sheet):

   This project explores the interplay between chiral liquid crystals (CLCs) and the phenomenon of Chirality-Induced Spin Selectivity (CISS) to develop tunable spin-selective materials and devices. The primary aim is to investigate how variations in liquid crystal properties, induced by external stimuli such as temperature, phase transitions, and molecular ordering, can influence and control the CISS effect. The research methodology involves the stepwise organic synthesis of novel chiral bent-core liquid crystalline materials to obtain highly pure compounds. These synthesized materials will be characterized for their mesomorphic properties using techniques such as Polarized Optical Microscopy (POM), Differential Scanning Calorimetry (DSC), and SAXS/WAXS. Subsequently, these will be utilized for the fabrication of solution-processable thin films and device architectures suitable for CISS studies. Chiral bent-core systems are particularly significant because they exhibit a wide range of chiral liquid crystalline phases, leading to enhanced molecular organization and potential spin-selective behavior. By combining synthesis, liquid crystalline properties and device fabrication, this work aims to establish a tunable platform for studying spin-dependent charge transport and potential applications in next-generation spintronic technologies.

   Desirable expertise: Chemistry and Physics.

3. Impact of Quaternary glacial cycles on mammals in the Indian subcontinent: integrating geoarchaeological and evolutionary thinking. (PIs: Dr. Kritika M. Garg and Dr. Parth R Chauhan):

   The Quaternary glacial period is marked by repeated fluctuations in climatic conditions, with repeated cooling and warming cycles. These cycles have shaped the current biodiversity and modern human evolution. Just 20,000 years ago, the global temperatures were 7 to 8 0C below current temperatures, followed b warming which began roughly 11,650 years before present, known as the Holocene. The Holocene is also an epoch of human expansion and extensive modification of habitats. Humans had occupied all major continents by the beginning of the Holocene. The growth of agriculture and domestication practices allowed humans to shift from hunter-gatherer lifestyle and establish major civilizations. Several mega mammals went extinct during this phase, partly due to changes in climatic conditions and overhunting. The flora and fauna of the Indian Subcontinent was also impacted by the Quaternary glacial cycles. However, our knowledge of the impact of these glacial cycles on Indian fauna is limited. This focused doctoral project will target diverse scientific samples to attempt DNA

extraction from various Quaternary and modern geological contexts, including (but not limited to) modern animal bones, vertebrate fossils, ostrich eggshells, sedimentary deposits in open-air, rockshelter and cave contexts and relevant museum specimens in India and/or abroad.

Desirable expertise: Masters/B.Tech/B.E/MBBS/M.Tech/MA/MPhil. Prior experience in field work AND/or phylogenetic analysis will be preferred, BUT IS NOT MANDATORY.

4. Designing Ln(III)-based Molecular Magnets for Nanotechnological Applications (PIs: Dr. Kuduva R. Vignesh, Dr. Sanjay Singh, Dr. Sugumar Venkataramani):

Lanthanide molecules that retain magnetisation at high temperatures are possible components of very high-density information storage devices and other nanotechnological applications. The axiality of the ligand field controls the crystal field (CF) around the Ln(III) center which strongly influences both the magnitude of the magnetic anisotropy and the energy barrier by suppressing the probability of tunneling and leading to the remarkable blocking temperatures (TB) as well. Therefore, this project is designed to synthesize Ln(III) single-molecule magnets (SMMs) in high symmetry, such as $C_{\infty v}$, D_{5h}, and D_{6h}, using strong axial ligands and to understand their magnetic relaxation mechanism in the race for higher TB. The photophysical properties, luminescent behaviour, of these Ln(III) complexes will be verified to make them photomagnetic complexes. The student will be trained to study magnetic relaxation and photomagnetism by three techniques. Firstly, by magnetic measurements using a PPMS or SQUID magnetometer on single crystals of Ln(III) SMMs. Secondly, the analysis of photophysical measures will be conducted utilizing a UV-Vis NIR spectrophotometer and a luminescent spectrofluorometer. Thirdly, by high-level electronic structure calculations. The team is interdisciplinary, comprises synthetic inorganic and organometallic chemists and a physical organic chemist, and covers a diverse area of research from the development of SMMs to the further applications.

Desirable expertise: M.Sc. in General Chemistry (preferably with good Physics and Mathematics knowledge). Hands-on experience in synthesis of metal complexes.

5. Translating insights from the ultrafast photophysics to the development of red fluorescent proteins for applications in bioimaging (PIs: Dr. Arijit K. De and Dr. Kausik Chattopadhyay):

Fluorescent proteins (FPs) exhibit remarkable molecular specificity, revolutionizing fluorescence microscopy and imaging and enabling unprecedented applications in gene expression, cellular biology, tissue and developmental biology, and biomedical imaging. Red fluorescent proteins with large Stokes shifts (LSS-RFPs) provide appreciable contrast due to large Stokes shifts of hundreds of nanometers. However, a poor understanding of the photophysics of their excited electronic states is a major bottleneck to realizing their full potential. Preliminary studies hinted at the coexistence of competing ultrafast relaxation pathways (proton transfer and isomerization), and a detailed understanding of these pathways and the intermediates involved is necessary to enable newer practical applications.
This work proposes to clone, express, and purify LSS-RFPs, perform advanced photophysical studies (using time-resolved optical spectroscopic techniques already developed in our lab, namely femtosecond pump-probe spectroscopy, pump-dump-probe spectroscopy, and time-resolved impulsive stimulated Raman spectroscopy), and study the effect of local environment on these photophysical properties. The processes unveiled in this work will enable the rational development of

new optical highlighters for dual- and multi-color bioimaging by fine-tuning the local environment via physicochemical parameters (e.g., pH and temperature).

Desirable expertise: B.Sc./B.S. in Chemistry/Physics, followed by M.Sc./M.Tech. in Chemistry/Physics/Biochemistry/Biophysics/Physiology/Biotechnology.

6. Designing and Exploring Earth-abundant 3d-metal Photocatalyst: A Tandem Synthetic and Ultrafast spectroscopic Approach (PIs: Drs. Debashis Adhikari and Dr. Arijit K De):

During the last decade, there is a renaissance of inorganic photochemistry as there is a clear drive for the development of new molecules for photocatalysis, photosensitization and photoluminescence. Along this line, significant efforts are invested in discovering new 3d-metal based photocatalysts, through clear understanding of the underlying photophysics of the molecules. In this project two teams will combine their efforts in designing and synthesizing new photocatalyst molecules and interrogating their excited state behavior by ultrafast pump-probe spectroscopy. The spectroscopic probation will provide crucial data to validate the design principle or will lead to a better design. In addition, the team will also look into the excited-state dynamics of COF-like material, which are popular in exhibiting semiconductor photocatalysis.

Desirable expertise: M.Sc in Physical Chemistry (preferable) with general competence in Mathematics. It is not mandatory. However, any synthetic or spectroscopic project experience will be helpful.

7. Intellectual and institutional history of Sciences in modern Punjab and its surrounding regions (PIs: Dr. V. Rajesh and Dr. Kavita Dorai):

In the historiography of science in modern India, there are fewer works on Punjab and its surrounding regions when compared to the former presidency capitals such as Calcutta, Madras and Bombay. Despite producing a galaxy of scientists and institutions, scholarly investigations into the emergence and growth of modern science in Punjab and its environs remain underexplored area of research. Moving beyond the diffusionist models of science from the West to the rest, the historiography of science in modern India over the last three decades has presented new frameworks that analyses the agency of regions, localities, people, institutions, networks, and the flow of ideas in the making of modern science. We invite proposals aimed at investigating intellectual and institutional history of sciences in modern Punjab and its surrounding regions. The themes of investigation can range from the history of institutions - scientific, administrative, educational, and civil society – within which science and science related issues were institutionalized and practiced, intellectual biographies of scientists of the region and the disciplinary histories of various branches of sciences. The project also involves creation of a database of sources and digital repositories related to the institutional and intellectual histories of sciences of the region.

Desirable expertise: Modern Indian History; History and Sociology of Science. Applicants with experience in archival methods and ethnographic research will be given preference.

8. Geo-Hydrological Hazards over the Western Himalayan Region: Towards Developing Early Warning

System (PIs: Dr. Raju Attada & Dr. Yunus Ali Pulpadan):

This project aims to improve understanding and prediction of geo-hydrological hazards, particularly extreme rainfall events and rainfall-triggered landslides, in the Western Himalayan Region. It integrates long-term observations, climate projections, high-resolution simulations, and advanced machine learning techniques to identify hazard-prone hotspots and key triggering mechanisms of these hazards. The developed predictive framework will support localized early warning systems and decision-support tools. The outcomes of this project shall enhance disaster preparedness, reduce risks to vulnerable communities, and strengthen climate resilience and sustainable development in Western Himalayan mountainous regions.

Desirable expertise: An applicant should have an MSc/M. Tech/B.E./B.Tech degree with at least a high second class in one or more of the following subjects: Atmospheric Sciences / Computer Sciences and IT / Climate Sciences / Data Sciences / Artificial Intelligence / Environmental Sciences / Geophysics / Earth Sciences / Hydrology / Mathematics / Meteorology / Physics / Civil Engineering / Geomatics Engineering/Civil / Aerospace / Agriculture / Electrical / Electronics and Communication).

9. Nonequilibrium DNA Mechanics: Force–Extension Transitions in Active Environments (PIs: Dr. Anil K Dasanna, Dr. Sabyasachi Rakshit):

Inside a living cell, the environment is highly dynamic and constantly driven out of equilibrium by molecular motors, enzymatic reactions, ATP-powered activity, and other sources of active fluctuations that continuously inject energy into biomolecules. These active fluctuations can significantly influence how DNA responds to mechanical forces, affecting its stretching, structural organization, stability, and key biological processes such as transcription, replication, and chromatin organization that are essential for life. However, most studies of DNA mechanics have traditionally been carried out within the framework of equilibrium statistical physics. Using a multidisciplinary soft-matter physics approach, this project aims to bridge this gap and develop a deeper understanding of DNA mechanics under realistic non-equilibrium cellular conditions.

Desirable expertise: MSc in Physical Sciences, BE/BTech/ME/MTech in Electronics/ Mechanics/Mechanical Engineering. Applicants with interests in interdisciplinary research involving biophysics, soft matter, statistical physics, computational modeling, or single-molecule experiments are especially encouraged to apply. However, this is NOT mandatory.

10. Self-Propelled Lipid-Enzyme μ-Bots for Minimally Invasive Treatment of Solid Tumors via Internal Kineto-Mechanical Actuation (PIs: Dr. Sabyasachi Rakshit and Dr. Hasan Mohammad):

Looking for a motivated student with a background in Biology, Physical Sciences, Engineering Physics, or related disciplines to work on an interdisciplinary project at the interface of biology and physical sciences. The project focuses on the design and synthesis of biocompatible active matter systems capable of self-propulsion in biological environments such as blood, targeted delivery to specific sites, and functioning as therapeutic or theranostic agents. Broadly, the aim is to develop biocompatible microscopic robots that can navigate complex biological environments and perform controlled biomedical tasks. The work will involve the design, fabrication, and characterization of these active systems, followed by their evaluation in suitable animal models. This research builds upon our recent work on chiral active GUVs published in Advanced Materials (Kaur et al., 2025). The

project will combine techniques from molecular biology, microbiology, soft matter physics, microscopy, and animal studies. Students will gain interdisciplinary training in soft matter and biophysics, advanced microscopy, molecular and cell biology, and the handling of laboratory animal models.

Desirable expertise: M.Sc./MS in Physics, Biology, Chemistry, Biophysics, Biotechnology, or related areas; or B.Tech./B.E./M.Tech./M.E. in Engineering Physics, Biotechnology, or related interdisciplinary disciplines. Prior experience with biophysical tools, molecular biology techniques, or handling rodents is preferred but not mandatory.

11. NMR-Based Metabolomics Investigation of the impact of Environmental Stress on Aging, Longevity and Immunity of Drosophila Melanogaster (PIs: Dr. Kavita Dorai and Dr. N.G. Prasad):

This project investigates how environmental stressors influence metabolism, immunity, and aging in Drosophila melanogaster using NMR-based metabolomics. Building on prior work showing that immune selection alters baseline metabolic profiles, the study aims to understand how stress conditions such as temperature, nutrition, and oxidative challenges reshape metabolomic responses and impact longevity. By combining experimental evolution with high-resolution NMR spectroscopy, the project will identify metabolic pathways that underlie trade-offs between immune function and lifespan. By integrating metabolomic and phenotypic data, the work seeks to establish predictive links between metabolic states and physiological outcomes, providing a systems-level understanding of adaptation under combined evolutionary and environmental pressures.
Desirable expertise: A Master's degree in Biology, Physics, or allied disciplines. The candidate should be comfortable with carrying out both experimental laboratory work and data-analytical tasks. Familiarity with statistical analysis and programming in R and/or Python will be an advantage.

12. Integrating Climate-Smart Microbial Communities (CSMCs) to Modulate Plant Nutrient Homeostasis in Saline-alkaline Stress. (PIs: Dr. Santhosh Satbhai and Dr. Sunil Patil):

This PhD project focuses on developing climate-smart microbial communities (CSMCs) to improve crop resilience and nutrient-use efficiency under multiple environmental stresses associated with climate change. Increasing temperatures, recurrent drought, salinity, and nutrient imbalances are severely affecting soil fertility, microbial diversity, and crop productivity worldwide. Beneficial plant-associated microbiomes offer a sustainable alternative to chemical-intensive agriculture by enhancing nutrient acquisition, stress tolerance, and soil health. However, microbial performance under combined stresses remains poorly understood, limiting the development of reliable bioinoculants for diverse agro-ecosystems. To this end, the project aims to isolate, characterize, and engineer multifunctional microbial communities with complementary traits for nutrient mobilization and stress mitigation. Special emphasis will be placed on understanding plant–microbe interactions and nutrient homeostasis under combined stress conditions using advanced culturomics and omics-based approaches. Candidate microbial consortia will be evaluated under controlled and field conditions across different agro-climatic environments to assess their effectiveness in improving crop growth and resilience. The research will contribute to the development of next-generation sustainable agricultural technologies that reduce dependence on synthetic fertilizers while enhancing productivity under changing climatic conditions. The outcomes are expected to support climate-resilient agriculture and provide innovative microbial solutions for long-term soil and crop health management.

Desirable expertise: M.Sc./B.Tech/M.Tech degree in Plant Sciences, Agriculture Biotechnology, Microbiology/Biotechnology, Plant Biotechnology, Botany.

13. Rational Design of Synthetic Polypeptides and Their Structural Characterization Using Advanced NMR Spectroscopy. (PIs: Dr. Raj Kumar Roy & Dr. Kavita Dorai):

The biological functions of proteins corelated with their amino acid sequences and the resulting three-dimensional structures. Inspired by this relationship, synthetic polypeptides have emerged as versatile materials that mimic protein-like behavior while offering greater control over molecular design. Their peptide backbone ensures biocompatibility and biodegradability, while the incorporation of natural and non-natural amino acids enables precise structural and functional modifications. Early studies of synthetic homopolypeptides, such as poly(L-lysine), poly(L-glutamic acid), poly(L-aspartic acid), and poly(L-proline), revealed how side-chain chemistry influences folding and secondary structure. Recent advances now allow functional side-chain incorporation and post-polymerization modifications that improve structural stability, self-assembly, and stimulus responsiveness, while enabling applications such as fluorescence labeling, drug delivery, and metal-ion coordination. These features make synthetic polypeptides as highly promising biomaterials. However, understanding sequence-dependent conformational behavior remains difficult because conventional techniques like circular dichroism and infrared spectroscopy lack site-specific structural resolution. Nuclear magnetic resonance (NMR) spectroscopy addresses this challenge by providing detailed information on backbone conformation, molecular dynamics, and intermolecular interactions. Advanced NMR methods reveal structural heterogeneity and dynamic solution behavior, enabling predictive structure–function relationships. This proposal aims to develop synthetic strategies for sequence-controlled polypeptides and characterize their structures to establish fundamental structure–property relationships for next-generation biomaterials.

Desirable expertise: The candidate must have Chemistry, Physics, and Mathematics subjects in their BSc or equivalent.
