PSCB90H3 Physical Sciences Research Experience – Summer 2024

This course provides an opportunity for students to work with a faculty member and carry out original research. Students will provide assistance with one of the faculty member's research projects, while also earning credit. Students will gain first-hand exposure to current research methods, and share in the excitement of discovery of knowledge acquisition. Progress will be monitored by regular meetings with the faculty member and through a reflective journal. Final results will be presented in a written report and/or a presentation at the end of the term. **Approximately 120 hours of work is expected for the course.**

Prerequisite: Permission of the Course Coordinator (Dr. Alex Voznyy, o.voznyy@utoronto.ca)
Recommended Preparation: Completion of at least 4.0 credits in a relevant discipline.
Breadth Requirements: Natural Sciences
Link to UTSC Timetable: https://utsc.calendar.utoronto.ca/section/physical-sciences

Note: Confirm a project with a faculty supervisor, then reach out to the course coordinator (Dr. Alex Voznyy, o.voznyy@utoronto.ca) to request a *Supervised Study Form.* After this, you will be added to the course on ACORN automatically.
Typically, students enrolled in a program offered by the Department of Physical and Environmental Sciences and students who have a **CGPA of at least 2.5** are granted admission.

Please see below for a list of projects.

(If you don't find a relevant project, reach out to your favorite professor directly.)

Chemistry Projects

Project 1 (Chemistry)

Developing New Laboratory Experiments for CHMB41H

Supervisor: Prof. Shadi Dalili (sh.dalili@utoronto.ca)

Students involved in this project will be responsible for developing and testing new laboratory experiments for Introductory Organic Chemistry I (CHMB41H). Students in this placement will work with the course instructor to select new experiments from the chemistry education literature, test the experiments, and prepare accompanying lab manual pages and demonstrator notes. Students will learn skills such as literature searching and analysis, and utilize essential lab techniques such as extraction, distillation, recrystallization, reflux, etc. to develop new labs for the course. Students will also develop written scientific and communication skills through developing lab manual writeups, quizzes, and TA documents for each experiment developed.

Students Required: 1

Qualifications: Completion of CHMB41H/CHMB42H with a minimum course grade of B+ and lab grade of A; must be available for lab work 2 full days during the week between 9am-5pm, ideally Tues, Wed and/or Thurs. Please send updated resume and transcript to sh.dalili@utoronto.ca

Project 2 (Chemistry)

Campus Farm Project

Supervisor: Prof. Shadi Dalili (sh.dalili@utoronto.ca)

One of the goals of this project is to select several top proposals from prior experiential learning projects that student groups had submitted in previous semesters of the CHMB41H course and transform them into research-based undergraduate labs, not only for the course, but as research projects for our 2nd year (PSCB90Y) and 4th year (CHMD90Y) research students.

Students involved in this project will be responsible for testing out some of the top proposals for projects such as: a) identifying substances to favour the development of traditional tobacco plant microbiome in the soil; b) developing a natural rabbit repellent spray to protect farm crops; and c) preparing natural fertilizers using waste and compost generated on the farm using non-toxic and household products and chemical, to name only a few.

Students will visit the Campus Farm to collect samples and use them in the lab, employing techniques learned in analytical and organic chemistry courses, to test and develop protocols for the above mentioned projects. Successful methods and any developed materials will be given to the Campus Farm for testing and assessment of efficacy for their intended purposed.

Students will be responsible for writing lab manual protocols and reports on the final outcomes.

Students Required: 1-2

Qualifications: Completion of CHMB41H/CHMB42H and CHMB16H with a minimum course grade of B+ and lab grade of A; must be available for lab work 2 full days during the week between 9am-5pm, ideally Tues, Wed and/or Thurs. Please send updated resume and transcript to sh.dalili@utoronto.ca

Project 3 (Chemistry)

Generative AI in Chemistry: A Survey of the Literature and New Applications

Supervisor: Prof. Effie Sauer (effie.sauer@utoronto.ca)

Project Description: The students involved in this project will co-create a literature map to assess the current state of research on Generative AI in Chemistry Education. Each student will then pick a central theme from the mapping exercise and write a review paper summarizing the key articles from their chosen theme. Time permitting, students will use Generative AI tools to create new practice problems for use in CHMA11; these will be "find the error" type problems where students have to evaluate a provided solution and answer and check for accuracy.

Qualifications: Completion of at least 1.0 FCE in CHM courses with a minimum grade of A- in CHMA11 or CHMA12.

Number of Positions: 2

Additional Application Instructions: Please send a statement of interest and a transcript to Effie.sauer@utoronto.ca

Project 4 (Chemistry)

Synthesis of Porphyrins for Targeted Medical Imaging

Supervisor: Prof. Xiao-an Zhang (xiaoan.zhang@utoronto.ca)

Project Description: Medical imaging plays an increasingly important role in modern disease diagnosis, providing anatomic, functional and even molecular information of internal organs that is otherwise invisible to human eye. Among the common medical imaging modalities, magnetic resonance imaging (MRI) stands out for its unique advantages, including true noninvasiveness (free-of ionizing radiation), high penetration depth, high resolution and flexible functionalities. Paramagnetic contrast agents (CAs) have been routinely used in clinical settings to enhance the sensitivity and specificity of MRI for disease detection. The mainstream MRI CAs are predominantly based on gadolinium (Gd) complexes, which unfortunately suffer from suboptimal sensitivity and potential toxicity due to their low stability, causing the release and deposition of free Gd(III) ion in vivo. Our group has developed novel water-soluble Mn(III)-porphyrins (MnPs) as next-generation Gd-free MRI CAs, demonstrating higher sensitivity and stability.[1,2] As an endogenous micronutrient, Mn is also more biocompatible than Gd. In this project, students will learn how to synthesize and characterize porphyrins building blocks, and to explore opportunities to design new MnPs for targeted molecular imaging, with the long term goal to detect molecular biomarker for early and precise disease diagnosis.

References:

1. *J. Med. Chem.* **2014**, 57 (2), 516;
2. *Chem. Sci.* **2016**, 7, 4308

Qualifications: Completion of CHMB42 with a minimum course grade of B+ and lab grade of A-; must be available for lab work minimum 2 full days during the week.

Number of Positions: 2-3

Additional Application Instructions: Please send updated CV and transcript to **xiaoan.zhang@utoronto.ca**

Project 5 (Chemistry)

Porphyrin-Based Electrochemical Catalysts for Green Energy

Supervisor: Prof. Xiao-an Zhang (xiaoan.zhang@utoronto.ca)

Project Description: The climate change and energy crisis call for next generation renewable chemical energy sources to replace conventional fossil fuels. In recent years, notable strides have been taken in catalytically converting carbon dioxide (CO_2) into hydrocarbons or splitting water into H_2 and O_2, using solar energy or sustainable electricity. A diverse array of transition metal complexes, including Fe, Co, Cu, and Ni-based catalysts, has been developed and scrutinized for this purpose. Notably, metalloporphyrin stands out with unique advantages, encompassing high stability, efficient electron transfer, and structural adaptability. Our research,[1,2] along with others, has demonstrated that modifying porphyrin structures or altering the metal species can lead to enhanced activities, reduced overpotential, and improved catalytic efficiency.

In this project, students will be engaged in our further exploration in design, synthesis, and characterization of novel porphyrin ligands and their metal complexes, as well as testing their catalytic activities (in collaboration with the Prof. Bernie Kraatz). We particularly encourage students with an interest in and training in organic synthesis to apply.

References:

3. *ACS Appl. Energy Mater.* **2019**, 2 (2), 1330;
4. *ACS Sustainable Chemistry & Engineering* **2020**, 8 (25), 9549

Qualifications: Completion of CHMB42 with a minimum course grade of B+ and lab grade of A-; must be available for lab work minimum 2 full days during the week.

Number of Positions: 1-2

Additional Application Instructions: Please send updated CV and transcript to xiaoan.zhang@utoronto.ca

Project 6 (Chemistry)

Engaging Global Challenges: An Interdisciplinary Approach to Sustainable Agriculture

Supervisor: Prof. N. Thavarajah (nirusha.thavarajah@utoronto.ca)

Project Description: The University of Toronto Scarborough (UTSC) proposes an innovative international work-integrated learning (WIL) project for students enrolled in the "Physical Sciences Research Experience (PSCB90H3)" course and management courses (MGHC23 or MGHC53). This project will facilitate collaboration between UTSC students and counterparts from Sri Lanka, India, and Ghana to address urgent agricultural challenges in these regions.

The project will unfold in a series of stages, beginning with cross-cultural orientation sessions to foster mutual understanding and build rapport among participants. Interdisciplinary teams comprising chemistry and management students will then engage in research and analysis to identify key issues facing the agricultural sectors of partner countries. Drawing upon their academic training and guidance from faculty mentors, teams will develop innovative solutions tailored to the specific needs and contexts of each community. Throughout the project, students will have the opportunity to interact with local farmers, community leaders, and agricultural experts to gain firsthand insights into the challenges and

opportunities within the farming sector. By applying principles of chemistry to enhance agricultural practices and leveraging management strategies to optimize resource allocation and organizational effectiveness, students will work towards sustainable solutions that promote economic development, environmental stewardship, and social equity.

The project will culminate in the presentation of proposed solutions to stakeholders in partner countries, providing students with valuable experience in communication, negotiation, and project management. By actively engaging with real-world challenges and collaborating across disciplines and cultures, participants will emerge from the project equipped with the knowledge, skills, and perspectives necessary to address complex global issues and effect positive change in their communities and beyond.

Learning Objectives:

1. Collaborative Problem-Solving: Students will learn to work effectively in interdisciplinary teams, leveraging their respective expertise in chemistry and human resource management to address complex challenges in global agriculture.
2. Intercultural Competence: Through engagement with international partners from Sri Lanka, India, and Ghana, students will develop cultural awareness and communication skills essential for effective global collaboration.
3. Real-World Application: Participants will gain practical experience in crisis management and solution development by tackling real-time agricultural issues affecting communities in partner countries.
4. Sustainable Solutions: Students will explore and propose environmentally and socially sustainable solutions to farming crises, applying principles of chemistry and management to create lasting positive impact.
5. Experiential Learning: Through hands-on engagement with faculty, peers, and community partners, students will deepen their understanding of course concepts and gain valuable insights into the complexities of real-world problem-solving.

Positions Available: 1

Qualification: Completion of CHMB42H3 with a minimum grade of A-. Please send updated CV & transcript to nirusha.thavarajah@utoronto.ca

Project 7 (Chemistry)

Investigating Innovative Approaches to Develop Hands-On Experiments for Introductory Chemistry Courses

Supervisor: Prof. N. Thavarajah (nirusha.thavarajah@utoronto.ca)

Project Decription:

This research project aims to explore and implement innovative strategies for developing hands-on experiments tailored for introductory courses across various disciplines. The project will focus on identifying learning objectives, brainstorming experiment ideas, considering accessibility and safety, designing experimental procedures, testing and refining the experiments, incorporating inquiry-based learning, providing guidance and support during experimentation, and assessing student learning outcomes. Through a systematic approach, this research seeks to enhance student engagement, foster critical thinking skills, and promote deeper understanding of fundamental concepts in introductory courses.

Hands-on experiments play a pivotal role in introductory chemistry courses, serving as tangible learning experiences that facilitate the comprehension of foundational concepts. However, developing effective experiments requires careful consideration of various factors, including learning objectives, accessibility, safety, and instructional strategies. This research project seeks to address these challenges by exploring innovative approaches to designing and implementing hands-on experiments in introductory courses.The research methodology will involve a multi-stage process, beginning with the identification of learning objectives for the targeted introductory courses. Brainstorming sessions will be conducted to generate a diverse range of experiment ideas that align with the identified learning objectives. Consideration will be given to accessibility and safety guidelines to ensure that experiments can be conducted safely and inclusively.

Experimental procedures will be meticulously designed, outlining step-by-step instructions and materials required for each experiment. These procedures will undergo rigorous testing and refinement through trial runs to address any potential issues or challenges. Throughout the experimentation process, inquiry-based learning principles will be incorporated to encourage students to ask questions, make predictions, and design their own experiments.The results of the research will be evaluated based on the effectiveness of the developed experiments in achieving the intended learning outcomes. Assessment methods such as quizzes, lab reports, and class discussions will be utilized to gauge student understanding and retention of the material. Feedback from both students and instructors will be collected to inform future iterations of the experiments and instructional strategies.

By implementing innovative approaches to developing hands-on experiments for introductory courses, this research project aims to enhance student engagement, promote critical thinking skills, and deepen understanding of fundamental concepts. Through systematic experimentation and evaluation, this research seeks to contribute valuable insights and best practices for designing effective hands-on learning experiences in introductory education.

Learning Objective:

This research project aims to explore and implement innovative strategies for developing hands-on experiments tailored for introductory courses across various disciplines. The objective is to:

1. Identify Learning Objectives: Define clear and measurable learning outcomes for introductory courses, ensuring alignment with disciplinary standards and student needs.
2. Generate Experiment Ideas: Conduct brainstorming sessions to generate a diverse range of experiment ideas that effectively address the identified learning objectives.
3. Ensure Accessibility and Safety: Consider accessibility and safety guidelines to ensure that experiments can be conducted safely and inclusively by all students.
4. Design Experimental Procedures: Develop detailed experimental procedures, outlining step-by-step instructions and materials required for each experiment.
5. Test and Refine Experiments: Conduct rigorous testing and refinement of experiments through trial runs to address any potential issues or challenges.
6. Incorporate Inquiry-Based Learning: Integrate inquiry-based learning principles into experiment design to encourage student engagement, curiosity, and critical thinking.
7. Provide Guidance and Support: Offer guidance and support to students throughout the experimentation process, facilitating their understanding and mastery of experimental techniques.

8. Assess Student Learning Outcomes: Evaluate the effectiveness of developed experiments in achieving intended learning outcomes using assessment methods such as quizzes, lab reports, and class discussions.
9. Collect Feedback for Improvement: Gather feedback from both students and instructors to inform future iterations of experiments and instructional strategies, ensuring continuous improvement.

Positions Available: 1

Qualification: Completion of CHMB42H3 with a minimum grade of A-. Please send updated CV & transcript to nirusha.thavarajah@utoronto.ca

Environmental Sciences Projects

Project 1 (Environmental Science)

Supervisor: Prof. Tanzina Mohsin (tanzina.mohsin@utoronto.ca)

Project Description: Scientific evidence for warming of the climate system is clear. Countries, regions, and cities will have to continuously adopt to the consequences of climate change. However, recently the landscape of climate change have been changed dramatically with the unprecedented wildfire, heat alert days flooding etc. To tackle climate change crisis, part of the solution is to provide climate information in formats tailored to fit into the planning and design decisions of a variety of industries and for different sectors of the society, which can be a baseline for making defensible climate change decisions. I offer research projects related to various aspects of climate change at different sectors of the society. These projects are tailored to train student with critical skillsets for climate data analysis, interpretation, and communication of the scientific results through various forms including reports, posters, video clips etc. Students learn data analysis techniques through sophisticated statistical and modelling exercises/tools that are transferable to any data analysis work. Some examples of the past projects include impact of climate change on extremes weather events causing flooding in cities, impact of climate change on heat alert/cold alert days in the GTA, or impact of climate change on occurrences of forest fire in vulnerable locations in British Columbia or impact of Urban Heat Islan on energy demand in cities. Students can also propose a project of their interest and get approval before enrolling in the course.

Positions Available: 1

Learning Skills: Literature search, critical thinking, problem-solving, climate data analysis and scientific writing skills.

Qualification: Completion of EESB03 or equivalent with a minimum grade of B+. Please send updated CV & transcript to tanzina.mohsin@utoronto.ca

Project 2 (Environmental Science)

Supervisor: Professor Carl Mitchell (carl.mitchell@utoronto.ca)

Project description: For this project, a student will conduct laboratory experiments using stream sediment to assess mercury bioavailability to microbes who carry out reactions resulting in the production of the highly bioaccumulative form of mercury, methylmercury. The project will involve training in the anaerobic maintenance of oxygen-free soil and sediment, experimental approaches to bioavailability assessment (e.g., competitive ligand exchange, sequential extractions, bioreporters), and sample preparation and analytical techniques for mercury analysis.