2023-2025 Projects

Engineering cell tissue development through patterning of topological features.

Abstract
This project will bring together an interdisciplinary group of experts from UofM and UiO to develop predictive models for collective motion and development in layered tissue (epithelium) and artificial models of embryos, so-called gastruloids. This initial seed project will coordinate existing efforts at the two universities and focus on a common project on 2D tissues. We aim to engineer systems for controlling deformation and movement of cells in a 2D epithelial cell sheet, which in turn impacts tissue development, architecture, and biological function. The proposed systems will use guided external mechanical cues, including printed extracellular matrix (ECM) patterns and patterned surface topology (collectively called substrate topography), which modulate cell traction forces to affect tissue development, and function. In particular, we will study how substrate topography changes traction stresses, cell ordering and cell migration and ultimately cell fate. The project builds on an advanced imaging tool kit including brightfield stroboscopic force spectroscopy developed in house, and last generation laser interferometry (tomographic holography) and on cutting edge mathematical modeling including X, Y, Z. The project will foster collaboration between Minnesota and Oslo to develop experimental tools and predictive models as a basis for tissue engineering.

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Impact of mixing dynamics in lakes on water quality and the release of methane to the atmosphere

Abstract:

Minnesota and Norwegian lakes usually mix from the top-to-bottom twice per year in the spring and fall. Mixing both replenishes gases such as oxygen that are consumed in lakes but it also releases gases such as carbon dioxide and methane that accumulate in lakes. These latter two gases are important because they are greenhouse gases that are contributing to climate change. Humans are making it harder for lakes to mix by applying de-icing road salts, especially in urban regions. Consequently, some lakes never mix which can be problematic, leading to low levels of dissolved oxygen and possibly high levels of greenhouse gases, especially methane. Here, we will explore the consequences of lakes that do not mix on these important water quality and climate properties as well as examine the potential to alleviate both problems by adding nitrate into the deep regions of lakes that do not mix to test the feasibility for CH4 mitigation by inhibiting CH4 formation and/or increasing CH4 oxidation.

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Translating Mechanisms of Lamin A/C Cardiomyopathy Myocardial Fibrosis Progression (LMNA-CMP)

Abstract:

The LMNA-CMP study aims to advance our understanding of lamin A/C cardiomyopathy. Lamin A/C cardiomyopathy is a common genetic heart disease due to mutations in the *LMNA* gene that results in sudden cardiac death (SCD) and severe heart failure and these patients have worse outcomes that other forms of genetic cardiomyopathies. Cardiac fibrosis precedes disease in patients with *LMNA* mutations and progression of fibrosis promotes arrhythmias, SCD, and severe heart failure. Understanding the mechanism of fibrosis and identifying early biomarkers of fibrosis can help to identify patients at risk of SCD and heart failure progression. Our objective is to advance the knowledge of fundamental mechanisms and fibrosis in lamin A/C cardiomyopathy through harnessing strengths of UMN and UiO investigator with synergistic experience in basic and clinical research and a large *LMNA* patient cohort. In this proposal we combine enabling technologies including *LMNA* stem cell-derived heart cells to understand how early fibrosis occurs, test collagen turnover as a marker of fibrosis, and discover protein profiles in the blood of lamin A/C cardiomyopathy patients that can identify the risk of disease progression along with robust clinical data. Our *hypothesis i*s that *LMNA* mutations promote increased fibrosis leading to life-threatening arrhythmias and heart failure progression and that stem cell-based modeling and patient serum sample testing can identify biomarkers of fibrosis. This *bench-to-bedside translational research* has the potential to enable the development of new therapies and non-invasive early detection methods to directly benefit lamin A/C cardiomyopathy patients, while training the next generation of researchers..

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Understanding coupled mineral dissolution and precipitation in reactive subsurface environments

Abstract:

Coupled fluid flow, solute transport, and biogeochemical reactions in porous and fractured media are critical for reducing carbon emissions, securing clean energy, and extracting critical minerals. Understanding mineral dissolution and precipitation is vital for subsurface applications such as carbon dioxide sequestration, underground hydrogen storage, geothermal extraction, contamination remediation, and mining mineral resources. These applications are key to addressing pressing environmental, societal, and climate challenges. Designing engineering practices, assessing performances, and evaluating environmental impacts of these interventions require a predictive understanding of complex physicochemical interactions between mineral surfaces, surrounding fluids, and evolving porous geometries. Most previous studies, however, have investigated dissolution and precipitation processes separately without considering their coupling. Experimental and numerical efforts often simplify the complexity of natural systems, such as geological media's physical and geochemical heterogeneity. In the subsurface, mineral dissolution and precipitation often occur simultaneously, where physical and geochemical heterogeneity is ubiquitous. We still lack a fundamental understanding of coupled dissolution and precipitation reactions, limiting our ability to predict geological media flow and transport processes. To address this knowledge gap, our primary objective is to elucidate the mechanisms governing interactions between dissolution and precipitation in porous systems with realistic physical and chemical heterogeneities. We will use a combination of micro-scale experiments and spatiotemporal simulations in analog and natural rock systems to identify constitutive relationships for describing these coupled reactions on larger scales.

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