Caltech Student-Faculty Programs

Session F Abstracts

Building cell radios for deep-tissue wireless detection of biochemical factors
Sudarshanagopal Kunnavakkkam
Mentors: Mikhail G. Shapiro and William Benman

Abstract withheld from publication at mentor's request.

Noninvasive monitoring of cardiovascular and endometriosis biomarkers using an engineered acoustic biosensor
Patrick T. Bednarz
Mentors: Mikhail G. Shapiro and Elizabeth Hughes

Abstract withheld from publication at mentor's request.

Investigating *Bacillus subtilis* as a microbial delivery system for sustained plant peptide hormone release in soil
Hannah R. Bachmann
Mentors: Gözde S. Demirer and Carl McCombe

Fertilizers enhance plant growth by enriching soils with essential nutrients. However, their overuse is environmentally damaging and unsustainable, prompting the need for alternative practices that reduce fertilizer dependence. One promising solution is the use of plant-associated microbial communities, which can naturally increase nutrient availability, yet our ability to engineer these interactions is limited by an incomplete understanding of how plants influence root microbiomes. Among the signaling molecules plants use to shape microbial interactions are peptide hormones, small, secreted proteins that regulate development and stress responses. This project aims to optimize a microbial delivery system for sustained peptide hormone release in the root environment, enabling investigation of their roles in microbiome modulation and potential in engineering beneficial interactions. We are using *Bacillus subtilis*, a natural soil-dwelling microbe with a well-characterised capacity for protein secretion. To optimize the *B. subtilis* system for peptide delivery, we have screened multiple gene promoters to drive peptide production and compared strains for their ability to colonize and persist on *Arabidopsis* roots. Peptide secretion was quantified using a high-throughput luminescence assay, while hormone function was assessed by monitoring changes in plant gene expression. These findings contribute to the advancement of microbial tools for improving sustainability in agriculture.

Rationalizing specific ion effects in electrochemical nitrate reduction using machine learning potential simulations
Ryan D. Yu
Mentors: Kara D. Fong and Madeline Murphy

Ammonia serves as a key component in fertilizers that help address the issue of world hunger. However, these ammonia-based fertilizers have increased nitrate water pollution by disrupting the natural nitrogen cycle. Electrochemical nitrate reduction to ammonia presents a promising way to both produce ammonia and help close the nitrogen cycle by consuming nitrates. In this process, though, the effect of pH and specific cations on nitrate density and distribution near the electrode is not well understood. Unfortunately, studying this with density functional theory is very computationally expensive, and traditional MD has accuracy limitations and restrictions. As such, we trained a machine learning potential to bridge the gap of accuracy and computational cost to give an atomistic view and study the properties of nitrate near a TiH_2 electrode interface.

Development of a microfluidic platform for uniform cell-laden hydrogel spheres

Ian E. Rocha
Mentors: Julia A. Kornfield, Raj S. Mukkamala, and Rohit Srikanth

The purpose of this research is to develop a microfluidic platform which can consistently create spherical alginate gel droplets with diameters under 300 μm and encapsulated bacterial cells for environmental sensing applications. Early designs were simulated in ANSYS Fluent fluid dynamic software and prototyped using dissolvable 3D printed microfluidic scaffolds embedded in polydimethylsiloxane (PDMS). A fabrication method to create microfluidic devices was developed using 3D printed positive channel molds and curing PDMS layers together, avoiding the usage of soft-lithography or plasma treatment. Thus far, alginate droplets with diameters less than 300 μm have been successfully created using the fabricated chips with either ethyl acetate or mineral oil as the continuous phase. Future work will focus on gelling created droplets, analyzing their physical shape and characteristics, and encapsulating bacteria into droplets.