Current Listing of Undergraduate Research Projects

The following is a list of specific undergraduate research projects available either during the academic year as Phys 195 / thesis projects or as paid summer research opportunities. Note that additional projects beyond this list are also possible. Students are encouraged to contact individual faculty members for additional information.

Project title(s): Statistical physics of biological evolution in range; Active matter
Faculty member: Dan Beller, dbeller@ucmerced.edu
Research area: Soft matter & biophysics
Experiment/Simulation/Theory: Numerical simulations
Term available: Summer 2021 or academic year
Project description: The Beller Soft Matter & Biological Physics Theory Group has openings for two PHYS195/196 research projects beginning in Fall 2021. There is also an opening for one of these projects to begin in Summer 2021 as paid summer research. Both projects focus on computer simulation of biophysical systems. Some experience in basics of computer programming (any language) is a plus. Both projects will most likely use Python. Some examples of specific research questions are described below, but the exact topic of the student's project may change by the start of summer or fall. Students who are potentially interested are encouraged to reach out to Prof. Beller.

Research area 1: Statistical physics of biological evolution in range expansions Reference publication: Beller et al., EPL 123: 58005 (2018), https://iopscience.iop.org/article/10.1209/0295-5075/123/58005/meta Potential project topic: Biological populations that spread in spatial extent as they grow, a process known as range expansion, become rapidly less genetically diverse in the newly colonized areas. This can have important evolutionary consequences such as loss of beneficial genes. The Beller Group uses statistical physics theory and computer simulations to shed light on spatial evolutionary dynamics, focusing on microbial colonies. The undergraduate student will conduct and analyze computer simulations of growing populations on a lattice. Current questions include: How does an inhomogeneous environment affect the likelihood of an advantageous mutation arising to dominate in a population? What is the optimal way to apply antibiotic drugs to a bacterial population while controlling the risk of antibiotic resistance emerging?

Research area 2: Active matter Reference publication: Duclos et al., Science 367: 1120 (2020), https://science.sciencemag.org/content/367/6482/1120.abstract Potential research topic: We are investigating collective motion — lifelike, complex dynamics among many particles arising from simple interaction rules — exhibited by cellular components reassembled outside the cell. The undergraduate student will run and analyze a type of computer simulation called Brownian dynamics. They will simulate the fluctuations and interactions of many microscopic, moving, flexible chains representing biopolymers. Current questions include: Under what circumstances do chains spontaneously sort themselves into configurations where

they're forced to be immobile? How does an uneven availability of energy affect the stability of collective motions?

Project title(s): The physics of coronavirus self-assembly
Faculty member: Ajay Gopinathan, agopinathan@ucmerced.edu
Research area: Soft matter & biophysics
Experiment/Simulation/Theory: Simulations and theory
Term available: Summer 2021 or academic year
Project description: Simple analytics and computer simulations of the assembly of coronavirus proteins to form a mature viral particle. This will be part of a multi-campus collaboration with experimentalists and other theorists.

Project title(s): Shear of granular materials with pinned disorder; Clogging of suspension flow
Faculty member: Brian Utter, brianutter@ucmerced.edu
Research area: Soft condensed matter
Experiment/Simulation/Theory: Experiment
Term available: Summer 2021 or academic year
Project description: Openings for both summer research and Phys 195 projects beginning in fall 2021 are available. For general information and videos/images, see https://sites.ucmerced.edu/utter/research. Interested students are encouraged to reach out to Prof. Utter directly.

Project 1: Granular shear within networks of pins: Shear of granular materials is an example of a complex system, where simple, frictional interactions of many particles lead to complex responses of the material, for instance sudden jamming and avalanching behavior. In this project, we will perform experiments using photoelastic grains to visualize forces under shear. We will introduce fixed pins as a source of imposed structural order to understand the stress and flow response. Potential applications include designer materials, with tunable rheological properties. This project involves the collaboration of colleagues working on related experiments and simulations. Positions beginning in summer or fall may be available. Relevant paper: https://journals.aps.org/pre/abstract/10.1103/PhysRevE.96.022903

Project 2: Clogging of suspension flows: Clogging is the sudden arrest of particle flow, for instance in sand flowing through an hourglass. In this project, we will study the clogging of bidirectional flow, where light and dense particles in suspension pass through each other in a channel. Despite it's simplicity, there are many intriguing questions about the interaction of grains and stability of the structures formed. Experiments will characterize the jamming probabilty and stability of clogs formed. Related experiments on clogging through millifluidic channels may also be possible. Work is in collaboration with a colleague working on similar flows in in simulations of pedestrian motion. Relevant paper: https://arxiv.org/abs/2003.06102

Project title(s): Molecular motor biophysics
Faculty member: Jing Xu, jxu8@ucmerced.edu
Research area: Biophysics
Experiment/Simulation/Theory: Numerical or experiment
Term available: Summer 2021 or academic year
Project description: http://xulab.ucmerced.edu/, project specifics will be matched to student preparation and interest.
