Chemical Engineering
Spring/Summer and Fall 2022
Undergraduate Research Project Descriptions

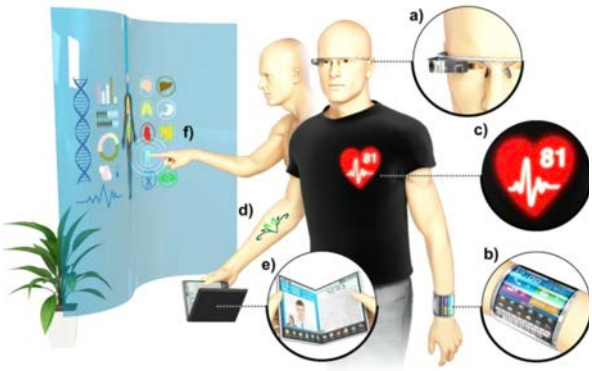
The following pages describe undergraduate research projects available in the chemical engineering department for pay, credit or as a volunteer during Spring/Summer and Fall 2022 terms.

See https://che.engin.umich.edu/research/research-programs-for-undergraduates/work-in-labs/ for more information on obtaining research positions.

Professor Xiwen Gong

Design New Hybrid Nanomaterials for Wearable Medical Devices

An aging population and increasing health expenditure demand for the next generation of medical devices that offer comfort, convenience, and accurate detection of body signals. Generation of flexible devices such as those shown here is the goal of the Gong Lab. Flexible medical devices offer the comfort of stretchability over the skin and the convenience of placement on anywhere on the body. This research project develops soft electronic materials that will emit light in the near infrared region (750 - 2500 nm) to detect body signals. Several substances in the human body including glucose and oxygen absorb in the infrared spectrum of light allowing us to detect these substances when infrared light is shined on the body. Students will work closely with graduate students within the lab to develop a wearable near infrared LED based bioelectronics that will offer ease of medical care. No prior experience in optoelectronics is required. Interested students will gain a strong foundation in material and optoelectronic synthesis and characterization.



Schematic of a variety of flexible devices adapted from Choi, M.K., et al. NPJ Flexible electronics (2018)

For more information, visit https://www.gong-research.com/

Professor Bryan Goldsmith

Microkinetic Modeling of Plasma-enhanced Heterogeneous Catalysis

We are interested in studying plasma-enhanced catalysis for CO_2 reduction to fuels and N_2 to NH_3 synthesis. This effort is part of the Center for Plasma Interactions with Complex Interfaces (PICI) (a multi-university and national laboratory collaboration, https://plasma-pici-doe.umich.edu/). We will do first-principles based microkinetic modeling to understand the roles of radical species and vibrational excitations in enhancing catalytic reaction rates and going beyond the equilibrium limit.

Professor Jinsang Kim

Purely organic phosphors for display and sensors

Phosphorescent materials are enhancing and broadening the usefulness of organic compounds in a wide variety of applications including OLED, photovoltaics, and sensors. OLEDs and solid-state lighting (SSL) research in both academic and commercial settings are driven by the promise of highly efficient devices manufactured via economic and versatile processes. Of the emissive materials employed in OLEDs and SSL, phosphorescent compounds produce much higher efficiency devices than those based

on fluorescent emitters by utilizing spin-parallel electrons and emitting photons from the decay of triplets. Organo-metallic compounds are thus often doped into organic hosts to impart a phosphorescent pathway into otherwise triplet-forbidding carbon-based materials. However, phosphorescence from metal free, purely organic, compounds is almost always either strictly forbidden or only extremely weakly allowed, leaving pure organics undesirable for useful applications. We developed a novel material system, metal-free purely organic phosphors recently and demonstrated. Directed intermolecular heavy atom effects are uniquely implemented in aromatic carbonyl molecules to promote spin-orbit coupling and suppress vibrational dissipation. Color tuning by rational molecular design, highly sensitive optical sensors, and PhOLED are the research topics for development.

Self-signal Amplifying Molecular Biosensors

We have been devising molecular sensors having a dual-signaling capability: visible color change and fluorescence emission. The capability to generate a visible color change upon recognition of a target analytes will allow equipment-free detection. Fluorescence emission signaling upon detection is designed to provide a high sensitivity by means of signal amplification via the fluorescence resonance energy transfer (FRET). The sensory molecules are composed of a receptor, a diacetylene moiety, and a fluorophore. The molecules are devised to self-assembled to form a liposome followed by topochemical polymerization of the diacetylene moiety. The receptor will undergo a shape change upon recognition of a target analyte. This shape change will turn on the mechanochroism of the polydiacetylene unit of the liposome and produce a color change and develop fluorescence emission. Once the fluorescence emission is turned on the fluorescence energy of the fluorophore will amplify the turned-on signal through FRET. This research project has various interesting aspects: molecular design, self-assembly, sensor physics, and device fabrication.

Professor Nicholas Kotov

Self-assembly of Nanoparticles; Chiral Nanomaterials (Chiral catalysis, origin of homochirality on Earth); Hedgehog Particles; Biomimetic Nanocomposites.

Please see details at https://kotov.engin.umich.edu/

Professor Mark J. Kushner

http://uigelz.eecs.umich.edu

Our research group computationally investigates how plasmas (partially ionized gases) activate chemistry for materials processing, energy and healthcare applications. A typical undergraduate research project might include, for example, aiding in the development and use of computer models to investigate how plasma activated liquids beneficially interact with tissue, or how reactive fluxes to surfaces can uniquely craft nano-scale electronics.

Atmospheric Pressure Plasmas for Catalysis

Atmospheric pressure plasmas are able to activate gases by creating radicals and ions at low gas and materials temperatures. An active area of research is plasma-catalysis, using this ability to efficiently produce radicals to speed the rate of processing of catalysts and improve their selectivity. These processes are being investigated to produce "solar fuels" – using solar generated electricity to produce plasmas, which convert CO_2 into high value fuels and hydrocarbon feedstocks. The research project will involve a computational investigation of reactor configurations and strategies to address chemical conversion in plasma catalysis.

Professor Joerg Lahann

Protein-based Gene Delivery, Therapeutic, and Contrast Agent Nanoparticles

Synthetic protein nanoparticles (SPNPs) are generated through a process known as electrohydrodynamic jetting, primarily, or through desolvation in solution.

This interdisciplinary research project consists of multiple thrusts: [1] determination of factors dictating structure-function relationships; [2] gene delivery through mRNA or pDNA; [3] delivery of targeted small molecule therapeutics; [3] investigation on the uptake mechanisms for nanoparticles into cells; [4] investigation into the mechanisms of endosomal escape after uptake; [5] novel contrast agents for theranostic applications.

We will utilize an electrified jetting process to produce monophasic or polyphasic nanoparticles. In this process, we apply high electrical potential on a jetting liquid to generate a cone and jet. At certain experimental conditions, this liquid jet is accelerated and eventually breaks down to form solid particles with diameter in nanometer scale. We will utilize several materials for this process and characterize the resulting nanoparticles with electron microscopes (SEM and TEM) and size/charge analysis (DLS). The produced nanoparticles will be used for the study a variety of genetic or therapeutic payloads to cells (confocal microscopy and flow cytometry). The possible applications of these studies are targeted drug delivery, cell imaging, and the development of gene therapies for immunization or the correction of genetic disorders.

Biomedical Scaffolds for Regenerative Medicine Research Applications

The main objective of these projects is the development of scaffolds that are capable of directing cell, tissue, and organoid growth in and on a substrate that mimics in-body conditions.

This is primarily achieved through the use of fibronectin and other extracellular membrane proteins which are shear assembled onto a bioprinted lattice. The major thrusts of this research are [1] organoid development; [2] high throughput scaffold production; [3] composite systems with a plurality of biomacromolecules; [4] micromechanically induced tension and deformation in the scaffolds; [5] post-production modification of scaffolds for enhanced biointeractions.

We will utilize a 3d bioprinter to develop lattices appropriate for protein deposition. A protein solution is then applied a variety of shear rates to the lattice, utilizing multiple geometries to impact the final alignment of the network that is formed. The process of network formation results in fibrilization and growth in various degrees, directions, and densities. We will utilize several materials for this process and characterize the resulting scaffolds with optical microscopies, micromechanical methods, and bioavailability assays. The produced scaffolds will be used for the study a variety of cell, tissue, and organoid growth studies, to include stem cell differentiation. Key methods will include cell room protocols, cell differentiation analysis, viability/toxicity, and cellular alignment. The possible applications of these studies are the large scale production of scaffolds for pre-clinical and translational medicine studies, tissue and organ regeneration, and stem cell-based therapies.

Chemical Vapor Polymerization (CVP) of Liquid-Crystal Templated Nanofibers and Area Selective Deposition Systems.

Broadly, this work is focused on the usage of a chemical vapor deposition (CVD) instrument to induce vapor phase activation of functional poly(para-xylylene)s (PPX) with subsequent polymerization on deposition.

This interdisciplinary research project consists of multiple thrusts: [1] use of various liquid crystals to direct nanofiber growth that results in nanocomplex surfaces with unique optical, chemical, physical, and biological properties; [2] use of various substrates and engineering controls to direct polymerization to only occur on specified regions of the substrate that results in controlled functionalization on the nano- and micro-scales.

We will utilize an CVD to produce reactive PPX-based monomers. In this process, we apply high heat and high vacuum to target a substrate in a cooled reaction chamber. At certain experimental

conditions, we can direct polymer formation into nanofibers that adopt conformations and properties that are directed by the LC templates. This results in highly regular nanoscale feature that can express chirality, curling, twisting, linearity, or networking based on LC type and reaction conditions. Additionally, we have discovered that PPX based monomers can be guided to polymerize on specific features of a multimaterial substrate, resulting in bottom-up polymeric features that can be directed precisely. We will utilize techniques to assess these systems: atomic force microscopy, photoluminescence spectroscopy, electron microscopy, surface reaction assays, surface energy assessment, and cell growth assessment. The possible applications of these studies are antifouling, antibiofouling, directed cell growth, unique barrier coatings, nanophotonics, and the structuring of polymeric materials at microchip feature scales.

Professor Ronald Larson

Polyelectrolyte phase behavior and rheology

Polyelectrolytes (PEs) widely exist in life, such as DNA/RNA, and they have many applications in fields such as drug delivery, underwater adhesives, food additives and others. When polyelectrolytes of opposite charge are mixed, they form complexes or "coacervates" with unusual flow properties, including high viscosity and gel-like structure important for their applications, and important in the structure of biological cells. The project is to mix well-defined polyelectrolyte and measure their properties experimentally, especially their flow properties using a mechanical rheometer. The work will be guided by a Ph.D. student and will train the student not only in polyelectrolyte physics and technology, but also in the measurement of properties of viscous solutions and gels.

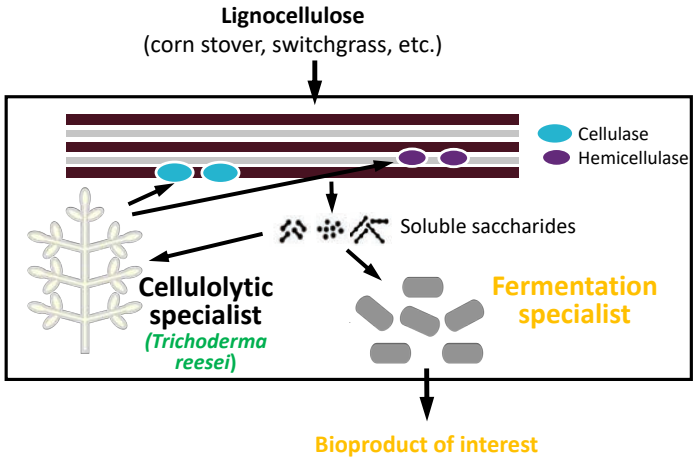
Polyelectrolyte Simulations

Polyelectrolytes (PEs) widely exist in life, such as DNA/RNA, and they have many applications in fields such as drug delivery, sewage treatment. However, we do not understand most of the aspects of how PE molecules behave, not only because there are too many variables controlling the PE phenomena, but also PE system is strongly correlated due to electrostatic interaction, dipole-dipole interaction, hydrogen bonding, and so on. Here we are interested in understanding the fundamentals of PE complexes using via all-atom or coarse-grained molecular dynamics simulations. The project will involve learning the molecular dynamics software package GROMACS, and directly simulating complex formation by oppositely charged polyelectrolytes. The results will be compared to experiments and theory.

Professor Xiaoxia (Nina) Lin

Engineering of synthetic microbial consortia for sustainable biofuel/bioproduct manufacturing

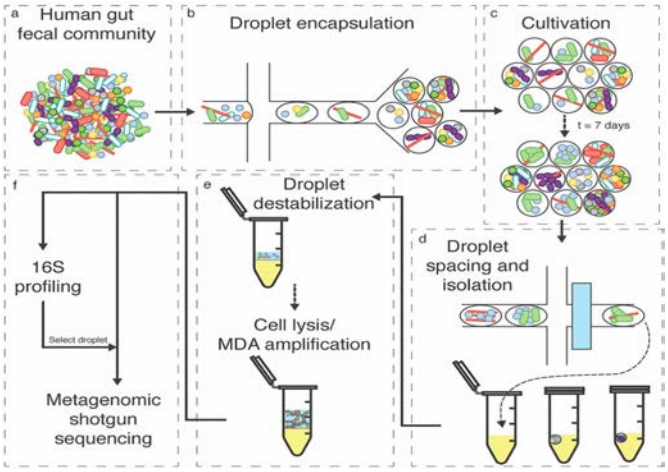
Microbes are everywhere in nature and they live in diverse communities that show remarkable metabolic capabilities and robustness. Inspired by these synergistic ecosystems, our lab has been developing a new approach for microbial engineering and biochemical production - design and construction of synthetic microbial consortia consisting of different specialists to accomplish a complicated task. One application focus has been synthesis of fuels and chemicals from lignocellulosic biomass. Our designed consortium (see figure) includes a cellulolytic member responsible for hydrolyzing hemicellulose and cellulose (main components



of lignocellulosic biomass) into mono and oligosaccharides and a fermenting member for converting mono and oligosaccharides into desired molecules such as isobutanol, an advanced biofuel. Such a synthetic microbial consortium integrating saccharification and fermentation capabilities will enable one-step "consolidated" bioprocessing (CBP), a potential breakthrough technology that can lead to cost-effective production of lignocellulosic biochemicals. The general framework of engineering defined co-cultures of coordinated specialists could offer exciting new opportunities for the efficient and flexible production of many valuable chemicals from other non-conventional bio-feedstocks.

Understanding and engineering microbiomes using microfluidic droplet technology

Our lab has been developing and applying new approaches and tools for the investigation of naturally occurring microbial consortia in order to discover the design principles underlying these complex systems. In particular, we have pioneered a technological pipeline, based on nanoliter-scale microfluidic droplets, to co-cultivate sub-communities and characterize member interactions that shape the structure and function of the microbial consortia. Several technological modules have been created and the pipeline is being applied to the investigation of a range of health or environment related microbiomes (see figure).

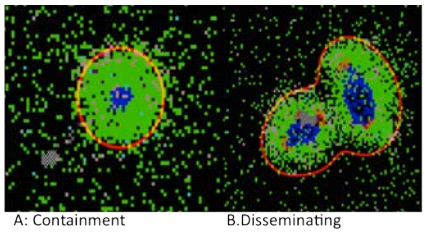


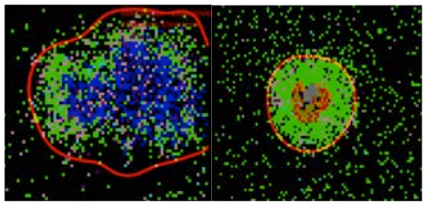
Tan et al., Co-cultivation of microbial sub-communities in microfluidic droplets facilitates high-resolution genomic dissection of microbial 'dark matter'. *Integrative Biology,* 2020, 12(11), 263–274.

Professor Jennifer Linderman (Spring/Summer only)

Systems Biology of Tuberculosis

An estimated one-third of the human population is infected with the bacteria *Mycobacterium tuberculosis* (Mtb). Granulomas are self-organizing collections of immune cells that form in the lungs after inhalation of Mtb. They both contain the infection and provide a niche for bacterial survival. Persons with latent tuberculosis can survive for decades with granulomas (and thus the bacteria) in their lungs. Understanding granuloma formation and maintenance thus provides a key to identifying as well as manipulating factors that lead to different outcomes following infection. We are developing computational models to understand the factors that influence granuloma formation. Students will study current tuberculosis treatments (antibiotics) and possible new strategies for treatment using simulations.





Professor Sunitha Nagrath

Developing Microfluidic Systems for the Isolation of Circulating Cell Populations From Blood

Liquid biopsies or the process of using fluid samples, such as blood, collected from patients for the detection and study of a disease offers unique benefits for improving patient treatment. Blood draws are already a common procedure in clinical settings and are less invasive than other biopsy methods such as tissue biopsy. To study specific diseases, it is necessary to isolate disease specific biomarkers from the blood. This can include isolating diseased cell for both the detection and characterization of the disease.

Isolation of these populations can be done using specially designed microfluidic devices that take advantage of specific cell characteristics including size or surface marker expression. The project will involve the design, fabrication, and/or experimental testing of microfluidic devices for cell isolation. Experimental testing will include the optimization of multiple device parameters and quantifying the device performance using specificity and sensitivity measurements. The devices in this project may be in the early stage of development or later stages of devices testing and optimization.

Isolation and Characterization of Circulating Tumor Cells from the Peripheral Blood of Cancer Patients

Metastasis is a complex, multi-step process which includes tumor cells enter the circulatory system, move throughout the body in the blood, enter into surrounding tissue, and finally proliferate to form secondary tumors. As metastasis form, they cause an increased health burden to patients and require the patients to undergo additional treatment and monitoring. It is estimated that metastasis are responsible for 90% of cancer deaths. To develop a deeper understanding of this process and to provide clinicians with patient specific information that may affect the patient's course of treatment, it is necessary to do an in depth investigation of these circulating tumor cells (CTCs) from cancer patients. The project will involve the isolation and analysis of CTCs using various technologies. Blood collected from cancer patients will be processed on microfluidic devices, such as the Labyrinth and graphene oxide chip, to isolate CTCs. Once isolated, CTCs will undergo enumeration and molecular profiling to determine specific characteristics of the cells. These analyses will provide important insight into the heterogeneity of CTC populations, the process of metastasis, and provide clinicians with information about how the cancer is progressing so they can provide patients with the best treatment option.

Microfluidic Systems for Extracellular Vesicle Isolation – Microenvironment Influence and Metastasis

Metastasis is no longer viewed as a linear cascade of events but rather as a series of concurrent, partially overlapping processes, as successfully metastasizing cancerous cells assume new phenotypes while jettisoning older behaviors. The lack of a systemic understanding of this complex phenomenon has limited progress in developing treatments for metastatic disease. Although, rediscovery of extracellular vesicle and their many roles in the metastatic process, has further complicated the metastatic microenvironment, it has also provided some insightfulness towards phenomenon. Extracellular vesicles (EVs), a class of heterogeneous membrane vesicles, are generally divided into exosomes and microvesicles on basis of their origination from the plasma membrane. EVs facilitate the bidirectional communication among various cell types that can aid in various cell-to-cell and cell-to-microenvironment interactions. Specifically, tumor-secreted EVs (TEVs) are critical mediators of intercellular communication between tumor and stromal cells in local and distant microenvironments. Accordingly, TEVs play an essential role in both primary tumor growth and metastatic evolution. TEVs orchestrate multiple systemic pathophysiological processes, such as coagulation, vascular leakiness, and reprogramming of stromal recipient cells to support pre-metastatic niche formation and subsequent metastasis. The research project is to develop a microfluidic platform for the specific isolation and characterization of TEVs, to study how these vesicles facilitate metastatic process. Additionally, TEV bioactive constituents have been shown to have immunostimulatory/immunomodulatory properties. This requires detailed analysis of the influence that these TEV have on immune cells (e.g., T-cell and NK cells).

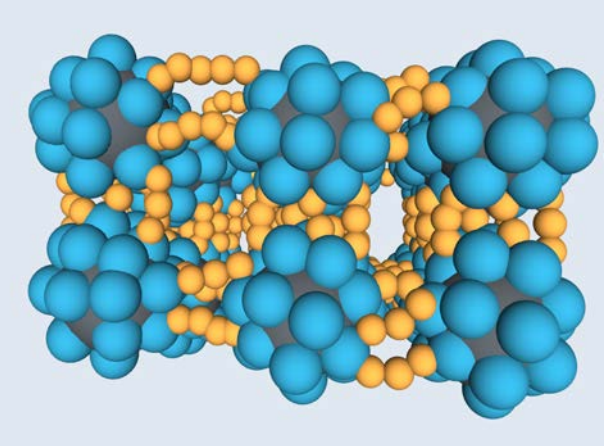
Investigation of Extracellular Vesicles in Blood Samples of Cancer Patients

Metastasis can be described as a multi-step phenomenon involving the release of cells from the primary tumor and their diffusion through the body. Currently, several hypotheses have been put forward in order to explain the origin of cancer metastasis, including epithelial–mesenchymal transition, mutagenesis of stem cells, and a facilitating role of macrophages, involving, for example, transformation or fusion hybridization with neoplastic cells. In this paradigm, TEVs play a pivotal role in cell communications, delivering a plethora of biomolecules including proteins, lipids, and nucleic acids. For their natural role in shuttling molecules, EVs have been considered an integral part of the metastatic cascade. They have a

prominent role in preparing the tumor microenvironment (TME) in target organs. However, we require a more detailed understanding of the packaging of TEV constituents and on the constituents themselves. To develop a deeper understanding and framework for the therapeutic capabilities of TEVs, it is imperative to do an in-depth investigation of TEVs from cancer patient. This investigation will include isolation of patient TEVs and identifying the various subgroups of TEVs expressed in their blood. Upon isolation of TEVs subgroups, investigating their immunostimulatory/immunomodulatory capabilities a therapeutic option will follow. This project involves the evaluation of TEVs as a patient-specific immunotherapeutic option for pre-metastatic cancer patients. In this project, we will study the interaction of TEVs and T-cells to evaluate the uptake and transfer of bioactive constituents. We plan to measure any immune activation response of the T-cell by measuring the expression levels of known immunostimulatory molecules (ex. IL-2 and IL-10). These analyses will provide important insight into the goal of TEVs as a personalized treatment option for pre-metastatic patients.

Professor Johannes Schwank

Synthesis and characterization of heterogeneous catalysts for VOC emission control



This project involves the synthesis and performance evaluation of a novel class of catalysts that are effective for removing indoor air pollution caused by the emission of volatile organic molecules from industrial processes such as painting of parts and outgassing of building materials. Air contamination due to carbon-based volatile organic compounds has been linked to an array of health and environmental concerns, including, increased mortality and instance of cardiovascular and respiratory disease. For example, formaldehyde (HCHO) is a major indoor atmospheric pollutant and is also emitted outdoors from diesel and gasoline vehicles, especially if the gasoline is blended with ethanol. The current state-of–the art in dealing with formaldehyde pollution relies on complete catalytic oxidation using precious metal catalysts.Catalytic combustion requires high temperatures and is not effective when the concentrations of VOC molecules are relatively low.As an alternative, we propose to develop a scalable solar-thermal catalytic materials that can be deployed on the surface of walls and ceilings of rooms in office buildings or factories, for abatement of VOCs under intermittent and low-intensity sunlight conditions and significantly lower temperatures as compared to catalytic combustion. Students are invited to participate in this project either as volunteers or for credit.

Professor Michael Solomon

Synthesis and Assembly of Nanocolloids

Nanocolloids are constituents of materials that are applied in many areas such as inks, coatings, optical materials, sensors and drug delivery. These particles are smaller than about one micron. In this project you will learn methods to synthesize, assemble and characterize such particles. The synthesis procedures you will master include methods to produce monodisperse particles. You will learn how to characterize what you make by electron and confocal microscopy. You will assemble particles by means of sedimentation, spin coating or applied electric fields. You will gain experience characterizing the rheological and electrokinetic properties of the particles you synthesize. At the conclusion of the project you will be well prepared to work or perform research in the many areas and industries that work with colloidal particles.

Physical Characterization of Bacterial Biofilms

To survive in the many environments they inhabit, bacteria may grow in communities in which individual organisms are embedded in a polysaccharide matrix. Biofilms are examples of such communities. Biofilms adhere to a variety of surfaces, including substrates relevant to human health, such as catheters. Confocal microscopy is a tool widely used in microbiological research because it can resolve multiple fluorescence emissions in three dimensions. Our aim here is for students to apply microscopy methods to characterize the microstructure of bacterial biofilms and aggregates. Students participating in the project will receive training in microscopy, computer image processing, and bacterial communities. This unique combination of research in soft matter/complex fluids and microbiology will provide students with a strong foundation from which to pursue subsequent research experiences and graduate training.

Professor Peter Tessier

Bioinformatics and computational methods for improving antibody discovery

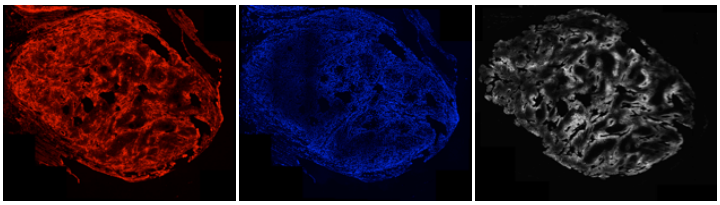
The success of therapeutic antibodies depends not only on their specific bioactivities but also on their highly variable and difficult-to-predict physicochemical properties (solubility, specificity, and biodistribution). The goals of this project are to develop predictive computational and bioinformatics methods for designing, optimizing and identifying drug-like monoclonal antibodies for therapeutic and diagnostic applications. Interested candidates should have experience in programming and MATLAB, and an interest in biotechnology.

Professor Greg Thurber

The human body can be treated as a large Chemical Engineering transport problem, where oxygen, nutrients, and drugs distribute based on a multitude of factors including passive transport (e.g. diffusion) and active mechanisms (e.g. drug transporters or 'pumps'). By utilizing simulations of drug transport across multiple length and time scales, novel diagnostic imaging agents and therapeutics can be 'designed' rather than 'screened,' improving the efficiency in development. Two areas in particular remain poorly understood: transient distribution of small molecule imaging agents and therapeutic distribution of novel biologics. Our lab is interested in integrating drug and physiological factors into simulations for designing more effective imaging agents and therapeutics. Transport across multiple length and time scales must be included in detailed simulations to predict the impact of drug delivery mechanisms and therapeutic design, from the whole body and organ level down to the tissue, cellular, and subcellular distribution of the drugs.

Novel Breast Cancer Imaging Agents for Early Diagnosis

Our lab is developing novel orally available imaging agents for the early diagnosis of breast cancer – in other words, a disease screening pill. The critical parameters for designing these new agents include the oral absorption and the target to background ratio (TBR). A high TBR agent can detect smaller cancer lesions against the background of normal tissue, allowing a surgeon to intervene early, resulting in better outcomes. The TBR is a complex function of passive diffusion through tissue, active binding to the target of interest, and clearance by the kidneys and other organs. In this project, the student will run computational simulations of imaging agent distribution as a function of molecular properties. If in-person work is possible, they will measure the specific binding affinity of novel imaging agents against a series of cancer



Distribution of three imaging agents within a ~5 mm tumor. The molecular weight, charge, lipophilicity, and target affinity all impact the pattern of uptake within the tumor (above) and surrounding healthy tissue (not shown) affecting the TBR. Images taken by Sumit Bhatnagar.

cells grown in the lab and measure passive transport rates across cell barriers (e.g. endothelial cells lining blood vessels). These rates can then be fed back into the simulation to predict the optimal properties.

Professor Angela Violi

Research in the Violi group focuses on nanoscale systems for various applications. We use state-of-the-art computational techniques to discover the fundamental principles that govern the behavior of nanoparticles, in order to control and engineer their characteristics. Projects available are:

Project Title: ***Nanoparticle formation in flames and engines***
Research Areas: ***Nanotechnology, Combustion, Chemistry***
Understanding the chemistry behind nanoparticle formation during combustion has large implications from public health (emission control) to industrial production (volume synthesis of ceramic and metallic nanoparticles) and aerospace (materials for radiation shielding or with enhanced mechanical properties). Our lab is in the position of developing a deeper understanding of the complex chemistry behind these phenomena through the development of a stochastic NanoParticle Simulator computational code. This unique code provides atomistic insights on the characteristics of carbonaceous nanoparticles formed during combustion and is currently being expanded to study inorganic materials.

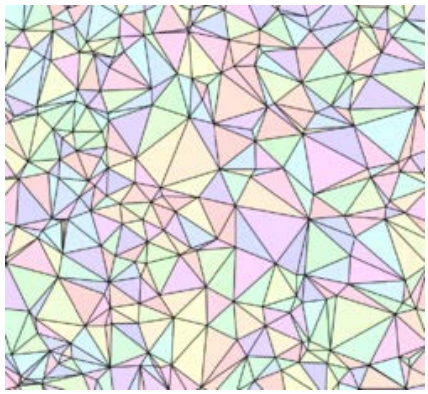
Project Title: **Design of tunable graphene quantum dots.**
Research Areas: **Materials, Nanotechnology, Quantum Dots, Molecular Dynamics**
Graphene quantum dots (GQDs) are relatively new materials with an exciting array of tunable properties. GQDs display properties and behaviors typical of nanomaterials, while retaining the functionalization flexibility typical of single molecules. We are investigating through molecular dynamics simulations how this flexibility affects GQDs properties, from their chirality and aggregation propensity to their optical and electrical properties. The understanding of the correlation between GQDs' structures and characteristics is a critical step in the design of tailored nanomaterials for a wide variety of applications.

Project Title: **Tailored nanomaterials for medical applications.**
Research Areas: **Nanotechnology, Bioengineering, Mechanobiology, Molecular Dynamics**
One of the most noteworthy applications of nanomaterials is in the medical field, from imaging to drug uptake and cancer treatment. Our lab employs different computational techniques to aid the design of these materials by understanding their interactions with different biological systems, like cellular membranes (to understand their uptake), and proteins (to understand their toxicity and effects on signaling).

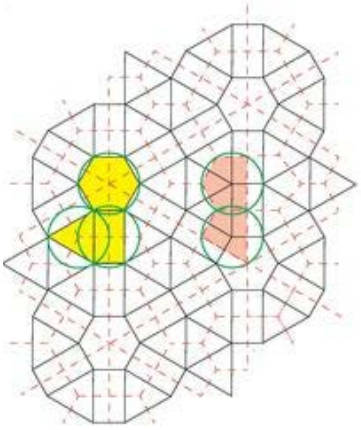
More information can be found at: http://www.umich.edu/~violilab/

Professor Robert Ziff

The Study of Networks and Percolation

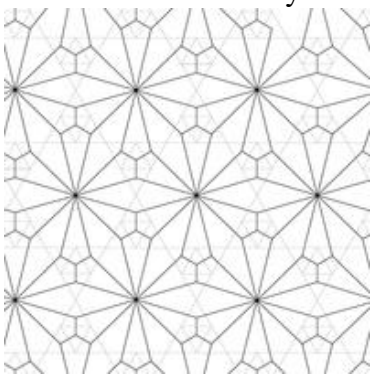


Many problems in science and engineering involve random networks and porous media. When the connection is sufficiently high, long-range flow is allowed and the system is known to "percolate." Related problems include electrical conductivity of random conductor/insulator mixtures, dissolution of pills that are made of soluble/insoluble aggregates, and the spread of disease though a population of susceptible and unsusceptible individuals.



These various problems can be modeled by a simple and elegant probabilistic geometrical model in which a regular lattice is made random by making some of the edges or “bonds” open or shut.

The project is to study various forms of these networks through computer simulation and mathematical analysis, to determine connectivity and transport processes, especially near the critical threshold. If you are interested in programming, the project can entail running jobs on a computer (based upon current programs, modified accordingly), and analyzing the results.



Other aspects of this project include literature searches, assistance in manuscript preparation (especially figures), and additions to web and Wikipedia pages on this subject. Several previous undergraduate student projects have resulted in publications in journals.

Drug delivery modeling

The process of drug delivery via ingested pills is modeled using concepts from chemical engineering, including reaction engineering, fluids, and thermodynamics. Analytic differential equation modeling as well as numeric solutions are used to find the behavior as the pill breaks up, dissolves, and moves through the different parts of the digestive track (stomach, duodenum, ileum, cecum). Percolation theory can be used to study the breakup of composite pills, and computer simulation can also be applied to this problem. The goal is related to a project to evaluate the efficacy of generic drugs compared with original drugs that have been tested on humans, without having to repeat the human testing trials.