

SEAS Undergraduate Student Affairs and  
the Columbia Undergraduate Scholars Program  
present the Seventh Annual

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# SUMMER RESEARCH SYMPOSIUM

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Thursday, October 4<sup>th</sup>, 2018  
6:00 - 7:30 PM  
Carleton Commons - 4<sup>th</sup> Floor Mudd





**Welcome to Columbia University's 7th Annual Undergraduate Research Symposium organized by the Fu Foundation School of Engineering and Applied Science.**

Faculty in the Engineering School and throughout the University recognize the importance of research in enriching undergraduate education and strive to make opportunities available for our ambitious undergraduates. Similarly, our undergraduates recognize the value of the unique experiences they gain from conducting research and exploring the cutting-edge of science and engineering disciplines in world-class facilities. The Undergraduate Research Symposium provides a venue for undergraduate Columbia University students from Engineering and the College to share their experiences, discoveries, and enthusiasm with their fellow peers, faculty, and administrators.

This year, we have over 30 students participating in the Undergraduate Research Symposium wanting to share their experiences with you. Projects cover a wide range of subjects that are as varied as our student-body.

I encourage you to explore the posters and speak to the students to learn more about their exciting research - our students are doing amazing things!

Barclay Morrison  
Vice Dean of Undergraduate Programs  
Professor of Biomedical Engineering

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# ABSTRACTS

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## **Purification of Negative Caspase-3 Mutants for Cellular Deliver through Complex Coacervate Core Micelles**

Paulina Babiak, SEAS '19, Chemical Engineering, Columbia University  
pmb2155@columbia.edu

### **Supervising Faculty, Sponsor, and Location of Research**

Dr. Allie Obermeyer, Johnson & Johnson Scholar, Société de Chimie Industrielle Scholarship, Obermeyer Group Laboratory, Columbia University

### **Abstract**

Since their emergence in the 1980s, protein therapeutics have climbed their way into the daily lives of millions, most notably through the use of insulin replacement for diabetes treatment. Protein therapeutics provide a wide range of non-intrusive medical treatments that cannot be easily replicated by traditional medicine; replenishing deficient protein, replacing protein that has lost its activity due to a mutation, augmenting existing pathway, and interfering with harmful molecules are only a few examples of the plethora of applications of protein therapies. However, vast majority of potential that protein therapies could offer is limited due to current inability to transport proteins inside the cell, leaving a large unexplored area in the field. The scope of this research is to explore possibility of intracellular transport of proteins using thermodynamically driven phenomena of complex coacervation, using apoptotic caspase-3 as a vehicle of study, delivery of which could be utilized for cancer treatment. Exploiting chemistry of block co-polymers enables for the formation of complex coacervate core micelles, size of which could be manipulated to be adequate for endocytosis. Over the course of the study, six negative caspase-3 mutants were successfully cloned, expressed, purified, and tested for activity. While the mutants show partial or complete loss of activity, the potential for micelle formation is still to be investigated with turbidity assays.

**Keywords**

Complex coacervation, micelles, liquid-liquid equilibrium, caspase-3, protein therapeutics

## **Efficient and Scalable Zinc Mediated Tandem Electrolyzer and Battery Cell**

Maya Bhat, SEAS '19, Chemical Engineering, Columbia University  
bhat.maya@columbia.edu

### **Supervising Faculty, Sponsor, and Location of Research**

Dr. Esposito, Undergraduate Research Program, Solar Fuels Laboratory,  
Columbia University

### **Abstract**

Energy storage is a necessary field of technology that will allow for renewable energy to be more readily adopted. Currently, the forms of energy storage solutions include mechanical structures like hydrostorage and chemical storage in generating chemical bonds that would not spontaneously form. The Zn mediated electrolyzer and battery aims to allay a number of setbacks associated with scalability and cost of rechargeable batteries, gas crossover within electrolyzers, and rare material usage in fuel cells. In order to address the setbacks, a number of experiments were conducted including analysis of the morphology of Zn depositions, the improvement of overpotentials within the electrolyte solution, and the efficiency analysis of depositions on different electrodes materials. Zn is favorable to use due to its abundance and low cost however Zn depositions tend to have poor adhesion. This was solved through the addition of citric acid to the electrolyte solution. To improve overpotential numbers, increased Zn concentration experiments were performed due to the high solubility of Zn in water. For electrode materials, high faradaic efficiencies were obtained with both carbon cloth and carbon rods. Carbon cloth was tested for future device design that may require flexible electrodes.

The experiments performed allowed for improvements in overpotentials in the electrolyte solution, ability for Zn to form adhesive depositions, and the ability to use different electrode flexibility without sacrificing efficiency. As a result, it proved the feasibility of a low cost, easily constructed, high efficiency tandem electrolyzer and rechargeable battery. Using the data

collected, a Zn mediated electrolyzer and battery can be eventually scaled up for commercial and operational use. The adoption of this technology can help improve the adoption of renewable energies and allow for energy storage in the form of electricity and hydrogen fuel.

**Keywords**

Solar fuels, electrochemistry, electrolysis, rechargeable batteries, hydrogen fuel

# **Analyzing Velocity of Signal Propagation in Organotypic Hippocampal Slices After Blast Induced Traumatic Brain Injury**

Nicole Boyd, SEAS '19, Biomedical Engineering, Columbia University  
neb2148@columbia.edu

## **Supervising Faculty, Sponsor, and Location of Research**

Dr. Barclay Morrison III, Johnson and Johnson Scholar Program,  
Neurotrauma and Repair Laboratory, Columbia University

## **Abstract**

Between 2000 and 2015, there have been over 327,000 recorded cases of traumatic brain injuries among U.S. military personnel [1]. 15.2-22.8% of these reported cases are caused by blast related traumatic brain injuries (bTBI) [2]. The clinical situation greatly needs attention, as the effects of primary blast injury, caused by the shockwave interacting with the brain, remain unclear [2]. The Neurotrauma and Repair (NTAR) Lab studies the biomechanics of TBI and the mechanisms of cell injury from blast or stretch. NTAR sought to study the changes in the velocity of signal propagation along various hippocampal pathways as a result of blast. Within the blast levels that were tested, the preliminary findings suggest that higher blast levels exhibit a statistically significant increase in velocity of signal propagation. Further experiments will seek to investigate why this increase occurs

## **Keywords**

Organotypic hippocampal slices, blast traumatic brain injury, paired pulse

## **Liquid Biopsy Detection of Circulating Tumor DNA**

Janice Chung, SEAS '19, Biomedical Engineering, Columbia University  
jic2224@columbia.edu

### **Supervising Faculty, Sponsor, Location of Research**

Dr. Samuel Sia, Johnson & Johnson, Sia Laboratory, Columbia University

### **Abstract**

Cancer impacts more than 38% of the US population. At present, the methods used in healthcare can take at least 2 weeks from sample collection to result reports. While this length of time is not an issue for most forms of cancer, it can be a matter of life or death for rapidly progressing cancers such as non-small cell lung cancer (NSCLC). NSCLC is one of the most prominent forms of cancer in the US and is often not diagnosed until late-stage.

The objective of this project is to engineer a point-of-care (POC) device that can reduce the turnaround time from sample collection to results, as well as to enable serial monitoring to detect changes in therapy resistance over time. We do this through a liquid biopsy that can be performed rapidly, in the hospital. Unlike traditional methods of biopsies that require tissue samples from tumors, our method targets the cell-free circulating tumor DNA (ctDNA) that can be found in peripheral blood. However, as ctDNA is present in blood at very low concentrations, we require sensitive molecular assays for proper detection, which we aim to fulfill in this device. The overall project is an integrated POC device containing plasma extraction from whole blood, DNA amplification for genotyping, and detection. The input will be a fresh blood sample, and the output will be detection of the presence or absence of clinically relevant somatic mutations in ctDNA. The foci of the work presented here are optimizing the qPCR reaction to run directly from plasma, and characterizing a POC plasma extraction device. With our qPCR protocol, we were able to detect the clinically relevant ctDNA concentration range of 0.1 to 100ng/mL. Then, we characterized the performance of the plasma extraction device we had previously built against a standard protocol using the centrifuge and

found comparable results. Going forward, we will be quantifying the limit of detection and analyzing the performance of the fully integrated device, including the amplification and detection components.

**Keywords**

Circulating tumor DNA (ctDNA), plasma extraction, liquid biopsy, non-small cell lung cancer (NSCLC), point-of-care (POC) diagnostics, fully integrated diagnostic device



## **Cell Migration in *Drosophila melanogaster* during Embryonic Development**

Jake Dunn, SEAS '21, Mechanical Engineering, Columbia University  
jd3421@columbia.edu

### **Supervising Faculty, Sponsor, and Location of Research**

Karen Kasza, Kasza Living Materials Laboratory

### **Abstract**

This research, which was completed in the Kasza Living Materials Laboratory, strives to augment understanding of how myosin II filaments interact with hemocytes during embryonic development of *Drosophila melanogaster*. The goal was to understand how hemocytes in *Drosophila melanogaster*, which have had mutations in their genetic code pertaining to myosin II, migrate in different patterns than those of hemocytes in wild-type *Drosophila melanogaster*. Specifically, we looked at the hemocytes when they were migrating along the ventral midline of the embryo. Using a confocal microscope, we collected movies that display the migratory paths of hemocytes. Using these movies, we utilized Fast Fourier Transforms to analyze how the migratory paths differ between the mutant and wild-type *Drosophila melanogaster*. Additionally, wounding of *Drosophila melanogaster* was analyzed. Embryos were punctured and then visually analyzed to determine if the migratory path of the hemocytes to the wound site would differ in mutant *Drosophila melanogaster* compared to the hemocytes in wild-type strain. Based on quantitative and qualitative analysis, there is preliminary evidence that genetic alterations in myosin II influence hemocyte migration in *Drosophila melanogaster*. This evidence can be utilized to understand myosin II's role in chronic kidney disease, sensorineural deafness, and several types of cancer.

### **Keywords**

Hemocytes, *Drosophila melanogaster*, Confocal Imaging

## **Phenotypes of Atrial Fibrillation: Machine Learning Stroke Risk Prediction in a Hospital Network Database**

Daniel G Edelberg, SEAS '19, Applied Mathematics, Columbia University  
dge2107@columbia.edu

### **Supervising Faculty, Location of Research**

Dr. Calum MacRae, Brigham and Women's Hospital, Boston, MA

### **Abstract**

Atrial fibrillation (AF) is often associated with comorbid conditions impacting AF-related stroke risk. Defining phenotypes of patients in real-world clinical practice settings may improve prediction and subsequent management of AF-associated stroke risk. To address this, we applied machine learning techniques to assess stroke risk prediction in patients with AF from a longitudinal hospital network database using components of established clinical CHADS/CHA2DS2-VASc tools with conventional and data driven weighting as well as incorporation of additional clinical parameters including diagnostic codes and medications. The dataset consisted of 126,037 patients with a mean 11.29 +/- 7.96 years of follow up. As expected, stroke rates were associated with a diagnosis of AF and inversely with prescribed anticoagulant medications, stratified among four categories of treatment levels. Unexpectedly, conventionally calculated scores demonstrated a negative correlation with stroke risk. Reweighting of the components using a linear support vector machine revealed that the negative correlation was driven by diagnoses of heart failure, hypertension, and vascular disease. Reweighting produced a positive correlation with risk. Patients with the lowest score had a stroke rate of 10.7% vs. patients with highest revised score of 55.0%.

Conventional clinical tools did not correlate with stroke risk in a real world high risk patient population. Prior diagnoses of heart failure, hypertension and vascular disease negatively correlated with stroke rates. Development of a machine learning-based reweighting of components improved the correlation with real world stroke risk and may have utility in optimizing risk assessment and management.

**Keywords**

Atrial fibrillation, stroke, machine learning, risk score, population health

## **Analyzing Vanadium (IV) Transference Number of Nafion® Membrane for Redox Flow Battery Applications**

Jed-Joan Edziah, SEAS '18, Chemical Engineering, Columbia University  
je2513@columbia.edu

### **Supervising Faculty, Sponsor, and Location of Research**

Dr. Alan C. West, Johnson and Johnson Summer Research Scholarship,  
West Group Laboratory (1005 Mudd)

### **Abstract**

Renewable energy sources such as solar and wind, are intermittent, and therefore, present a key challenge in energy storage technology. Vanadium redox flow batteries are promising energy storage devices because they are scalable, have relatively high energy densities, and are not damaged by the mixing of anolyte and catholyte. During charge, the catholyte and anolyte of the battery consist, respectively, of the V(IV)/V(V) and V(II)/V(III) redox couples both solubilized in sulfuric acid. The electrolytes are pumped through a flow cell where conversion between vanadium oxidation states leads to energy storage or release. An ion-selective membrane is placed between the anolyte and catholyte to inhibit the mixing of vanadium species and allows the flux of protons to balance charge. However, some vanadium ions may crossover the membrane, which causes battery self-discharge and reduces the coulombic efficiency.

This study quantifies the crossover of vanadium across Nafion® 117 using the cationic transference number ( $t_+$ ). The measurement of  $t_+$  is carried out using the tracer method; the vanadium catholyte is replaced with magnesium to allow for the measurement of vanadium flux across the membrane with atomic absorption spectroscopy. The impact of using magnesium as the catholyte is quantified with dilute solution theory modeled in fortran95 and Monte Carlo simulations modeled in Python. For V(IV) we observed that transference number decreases as H<sub>2</sub>SO<sub>4</sub> concentration increases and likely becomes asymptotic at a lower limit. As the H<sub>2</sub>SO<sub>4</sub> to VOSO<sub>4</sub> concentration ratio ranged from 1:1 to 4:1, the  $t_+$  of V(IV) ranged from 0.15 to 0.06, respectively. Quantifying and understanding how to minimize  $t_+$  for vanadium will enhance the commercial implementation of flow battery technology.

### **Keywords**

Vanadium Redox Flow Battery, Transference Number, Nafion Membrane

## **Investigating the roles of myosin II in hemocyte cell migration and dispersal in *D. melanogaster* embryos**

Dahlia Ghoshal, SEAS '21, Mechanical Engineering, Columbia University  
dahlia.ghoshal@columbia.edu

### **Location of Research**

Kasza Living Materials Lab

### **Abstract**

MYH9 disorders have countless effects in humans, including severe hearing loss, platelet macrocytosis, and kidney failure. Despite the wide effects, the disorder is associated with point mutations in MYH9, the gene encoding the heavy chain of non-muscle myosin II (a protein vital for force generation and cell motility). To understand these disorders, the microscopic effects of the mutated protein must be explored.

Fruit flies provide an ideal opportunity to study these effects. During embryonic development, their transparent tissue and precise hemocyte (blood cell) migration patterns allow for clear imaging and comparison between wild-type and mutant embryos. Thus, my research objective was to quantify the differences in hemocyte (blood cell) migration and dispersal in normal and mutant fruit fly embryos, as a model for understanding MYH9 disorders in humans.

Methods include collecting stage 12 embryos from three *D. melanogaster* stocks of genotypes *yw;crq-Gal4/CyO;UAS-DsRed-NLS/UASp>GFPzip(\*)* (where (\*) is either WT (wild type), R707C, or N98K), and bleaching and imaging them using a confocal microscope. I then developed software tools to use in conjunction with ImageJ to analyze displacements and spacing of hemocytes, and distribution of myosin. Overall, results were as expected. Distribution of myosin within one cell is concentrated along outer cell border, and displacements and spacing of hemocytes were consistent across the wild-type and myosin mutants (R707C and N98K), which does not provide insight into how the mutations cause MYH9 disorder. Future endeavors include removing the effects of endogenous, non-mutated myosin in N98K and R707C stocks, to enable more accurate analysis.

**Keywords**

Embryonic development, myosin, *Drosophila melanogaster*, mutations, confocal microscopy

## **Analyzing Attitudinal Changes after AV Accidents Using Facebook Data**

Hannah Gu, SEAS '20, Computer Science, Columbia University  
hannah.gu@columbia.edu

### **Supervising Faculty, Sponsor, and Location of Research**

Professor Sharon Di, Johnson & Johnson Scholars, DitecT Lab,  
Columbia University

### **Abstract**

Recent crashes involving autonomous vehicles by Uber and Tesla have been heavily covered by news sources, bringing public attention to autonomous vehicles and increasing people's awareness of efforts being made to develop AV technologies. This research investigates the effects of such AV crash events on people's opinions towards AVs and can help public agencies and industries take appropriate actions towards the smooth adoption of autonomous driving technologies. Around 5000 total comments regarding AVs were collected from Facebook, and demographic information of the users was collected for 800 comments. Sentiment analysis was then performed on these comments using Google Cloud's Natural Language API to identify negative or positive feelings towards AVs. Results showed that overall sentiments towards AVs dropped the most after the Uber and Tesla crashes compared to other crash events involving AVs. People in their 50s and above and people working in the transportation field had the most negative sentiments out of their demographic categories.

Regression results with all the demographic variables collected showed that job type and age group had the most significance on sentiments. Further regressions analyzing the sensitivity of demographic groups towards the Uber crash showed that people working in health care, people 20-35 years, and people living in the Northeast were the most sensitive region to the Uber crash. Clustering analysis revealed different demographic groups' specific concerns and attitudes towards AVs, and analysis of comments

found identified the main factors of concern regarding AVs to include safety, responsibility issues, and lack of trust in technology. These findings identifying those most impacted by autonomous crash events and the issues the events brought up can help target consumers' concerns when developing AVs and help them be more readily adopted by the public.

**Keywords**

Autonomous vehicles, sentiment analysis, clustering analysis



## **A Functional Tissue Engineered Synovium Model to Study Osteoarthritis Progression and Treatment**

Saiti Srabonti Halder, SEAS '19, Biomedical Engineering, Columbia University  
ssh2164@columbia.edu

### **Supervising Faculty, Sponsor, and Location of Research**

Robert Michael Stefani, Dr. Clark T Hung

### **Abstract**

Little is known about the critical role of the synovium in joint homeostasis and osteoarthritis (OA). This research describes a novel in vitro tissue engineered (TE) model to investigate the structure-function of synovium through quantitative solute transport measures. This TE synovium model was developed using healthy bovine fibroblast-like synoviocytes (FLS) encapsulated in a Matrigel scaffold. Sheet-like TE constructs were pre-cultured to attain native protein composition and polarized structure, as determined by immunohistochemistry and confocal microscopy, and subsequently exposed to interleukin-1 $\alpha$  (IL) and/or dexamethasone (DEX). The biological responses, including nitric oxide and hyaluronic acid (HA) secretion, of engineered synovium paralleled that of native synovium. Lower permeability of 70 kDa dextran was strongly correlated ( $r = 0.9736$ ,  $p = 0.0264$ ) with a lower ratio of collagen to DNA in TE synovium, a trend that was qualitatively similar to explant tissue. Histological staining confirmed similar structural changes to TE and EXP specimens in response to DEX or IL, including intimal hyperplasia and matrix compaction. This suggests that in addition to inflammation leading to HA breakdown and increased joint clearance, competing factors such as changes in synovium matrix content and permeability to a given solute size, are also at play. Moreover, FLS-only engineered tissues, similar in cell composition to healthy native synovium, grew to contain CD14 $^{+}$  macrophage-like synoviocytes (MLS) in culture with interleukin, suggesting the potential role for cell transdifferentiation in the inflammatory response of synovium. Co-culturing FLS with MLS in this model also demonstrated the versatility to reverse engineer healthy and diseased synovium. Through the development of biofidelic synovium models, key gaps can be filled in the current understanding of synovium function in health and OA.

## **Characterizing White and Opaque *C. albicans* Interactions with Macrophages**

Allison Hung, CC '20, Biochemistry, Columbia University  
ah3446@columbia.edu

### **Supervising Faculty, Sponsor, and Location of Research**

Dr. Alexander Johnson, Amgen Scholars Program, Johnson Lab, University of California San Francisco

### **Abstract**

*Candida albicans* is an opportunistic fungal pathogen which lives asymptotically in healthy individuals, but causes serious illness in immunocompromised patients. Previous studies have linked the pathogenesis of *C. albicans* to its morphological plasticity. *C. albicans* strains also have the ability to switch between distinct white and opaque morphologies, although it is unclear how white-opaque switching contributes to pathogenesis. White and opaque cells are known to interact differently with the innate immune system – macrophages preferentially phagocytose white cells over opaque cells. Lab strains that are heterozygous at the mating type locus ( $a/\alpha$ ) are unable to switch due to inhibition of the regulatory protein WOR1. Yet, switching has recently been observed in clinical  $a/\alpha$  isolates. We evaluated the ability to switch in these clinical strains by measuring WOR1 production. Most strains had detectable WOR1 levels, although we found wide variation among strains. The variation suggests that these strains use different mechanisms to override the canonical  $a/\alpha$  block. We then used a murine macrophage infection model to determine how white and opaque clinical isolates interact with the host immune response. To evaluate whether these strains induce different inflammatory responses, we measured secretion of pro-inflammatory cytokine TNF- $\alpha$ . A significant reduction in cytokine production was observed in macrophages co-cultured with opaque cells compared to white cells and an overall dampened cytokine response was detected in clinical strains compared to lab strains. We then assessed whether these strains are differentially phagocytosed by quantifying the phagocytic index of white versus opaque cells. Most opaque strains were phagocytosed at a lower rate

than white strains. Finally, because *C. albicans* can survive in and rupture their host macrophages, we monitored survival of macrophages by measuring cytotoxicity following infection. We observed increased cytotoxicity in macrophages co- cultured with white strains compared to opaque strains. Taken together, these results indicate that opaque cells induce a dampened macrophage immune response in comparison to white cells, thus suggesting that opaque *C. albicans* can evade the immune system during infection.

**Keywords**

Microbiology, host-pathogen interactions, pathology, immunology

## **Using Deep Neural Inspector to Evaluate Predictive Embeddings in Gang-Affiliated Tweets**

Alyssa Hwang, SEAS 2020, Computer Science, Columbia University  
ahh2143@columbia.edu

### **Supervising Faculty, Sponsor, and Location of Research**

Dr. Kathy McKeown, Natural Language Text Processing Lab, Columbia University

Dr. Eugene Wu, Data Science Institute Scholars Program, Columbia University

Johnson and Johnson Summer Scholars Program, Columbia University

Egleston Scholars Program, Columbia University

### **Abstract**

The Deep Neural Inspector (DNI) is a data science software built by Columbia's Data Science Institute that evaluates how much a machine learning model has learned by using statistical methods to compare hypothesis functions to the output of a neuron or layer in the model. We used the DNI to evaluate a model built by the Natural Language Text Processing Lab that labels gang-related Tweets as aggression, loss, or other. Tweets classified as aggressive contain ideas of hatred or anger while loss Tweets usually display sadness or hopelessness. We represented each Tweet as a vector of values from the Dictionary of Affect in Language, which provides a decimal value between 1 and 3 for the level of pleasantness, activation, and imagery for each word. Using the DNI, we aimed to learn more about what the NLP model has learned in relation to the pleasantness, activation, or imagery of each word in a Tweet. We can use this information to understand the complex processes behind machine learning, improve other models, and save successful neurons and layers. The DNI requires several inputs: one or more models on which to perform the analysis, feature functions that return functions, and the raw dataset. We used aggression and loss models from the previous NLP project weighted with randomly initialized and pretrained word embeddings, for a total of four models. We compared findings from the trained model to the

corresponding random model. Our feature functions were written to produce vectors of pleasantness, activation, and imagery values for each word in a text input. We analyzed these values at the unigram level (first convolutional layer) and the bigram level (second convolutional layer). Our raw dataset is a corpus of Tweets posted by affiliates of a Chicago gang. We expected higher activity for Tweets with low pleasantness and high activation scores, which indicate angry or violent speech.

The results showed that the absolute correlation of the neurons for both layers were higher for the trained models than for the random models, with the logistic regression for each hypothesis function being higher in general. The F1 scores for the unigram layer were higher overall than those for the bigram layer. The Deep Neural Inspector has reported that the F1 scores for individual neurons and whole layers of the trained models are higher than those of the random models. This behavior was expected and supports two claims: that the NLP model to categorize Tweets as aggressive, loss, or other learns after being trained on data, and that the DNI can be used to analyze such a model.

### **Keywords**

Data science, natural language processing, Deep Neural Inspector, machine learning, Keras, Python, R

## **Earth Systems k-Means Toolbox: A Standardized Application of Multivariate k-Means Cluster Analysis on the Global Ocean Carbon Cycle**

Rebecca Latto, SEAS '19, Applied Physics and Applied Mathematics,  
Columbia University  
rl2797@columbia.edu

### **Abstract**

Advanced pattern recognition and data mining techniques are becoming exceedingly popular in Climate and Earth Sciences as means of decomposing big data into its most significant features. This is particularly important for studies of the global carbon cycle, where ample data is available yet unexplored because of its size and complexity. We need to study these data sets because a lack of understanding confounds our ability to accurately describe, understand, and predict CO<sub>2</sub> concentrations and their changes in the major planetary carbon reservoirs.

Here we describe the implementation of multivariate k-means clustering on pCO<sub>2</sub> (Landschuetzer product) and temperature at 10m depth (ARGO Coriolis product) in the global ocean for 2000-2015. As the observation-based data is organized into various regimes, which we will call “ocean carbon states”, we gain insight into the physical and/or biogeochemical processes controlling the ocean carbon cycle.

We show that k-means effectively produces dynamic states which demonstrate complex interannual and spatial variability. Using various correlational methods and a neural network application, we can also parameterize the ocean carbon states by relevant climate indices (ENSO, AO, NAO) and other physical fields like salinity and chlorophyll.

### **Keywords**

Data science, clustering, ocean carbon cycle

## **Design and Development of Modules to Support Live Microscopic Imaging on Ground-Based Microgravity Simulators**

Audrey Lee, SEAS '20, Biomedical Engineering, Columbia University  
al3626@columbia.edu

### **Supervising Faculty, Sponsor, and Location of Research**

NASA John F. Kennedy Space Center

### **Abstract**

In space, astronauts are exposed to environmental stressors that often result in physiological changes. One prominent stressor in spaceflight is microgravity, and research has shown that long term microgravity exposure causes muscle atrophy, bone loss, cardiovascular concerns, and vision impairment. It is critical to understand how altered gravity affects physiology on the cellular, molecular, and gene level in order to accurately assess health risks and to develop effective countermeasures. Ground-based microgravity simulators such as random positioning machines (RPMs) are used to produce some of the biological effects of altered gravity on different cell types and organisms. Real-time imaging during simulations are of particular interest as we can study how basic cell functions such as cell division, cell migration, and proliferation progress under microgravity conditions. However, design limitations of present microgravity simulators such as susceptibility to parasitic vibration and displacement of the sample from the center of rotation challenge the accuracy of experiment results and live images.

We have developed a cell culture sample holder module suitable for live microscopic imaging on an RPM. CAD modeling and 3D printing technology were used to implement modifications to the sample holder and to install a digital microscope to perform live bright-field and fluorescent imaging. Vibration damping materials were also investigated to allow for stable imaging while the microgravity simulator was within a cell culture incubator. Novel methods and hardware modifications for improving live

cell imaging on ground-based microgravity simulators were proposed and discussed.

**Keywords**

Simulated microgravity, biophysics, 3D printing, microscopy



## **Defining the molecular mechanism of LIM domain actin strain sensing**

Tiffany Li, SEAS '19, Biomedical Engineering, Columbia University  
tl2701@columbia.edu

### **Supervising Faculty, Sponsor, and Location of Research**

Dr. Gregory Alushin, Rockefeller Summer Undergraduate Research Fellowship, Laboratory of Structural Biophysics and Mechanobiology, Rockefeller University

### **Abstract**

The ability of a cell to sense and respond to physical forces is crucial for a variety of cellular functions, including differentiation, migration, and maintaining homeostasis. Contractile actin-myosin cables known as stress fibers are principal mediators of force dynamics. LIM domain proteins mediate mechanical signal transduction (“mechanotransduction”) by localizing to stress fibers under load (“mechanoaccumulation”) via unknown molecular mechanisms. We find that a phenylalanine residue conserved across mechanosensitive LIM domains is vital for mechanoaccumulation, mediating a direct interaction with strained actin filaments. Replacing the phenylalanine with histidine in each of the LIM domains of the protein Hic-5 retains its structural integrity but reduces its ability to bind to strained actin, as seen in a force reconstitution assay with TIRF microscopy. Additionally, we are working towards creating a polymerizable form of the LIM protein FHL3, which can be assembled using twin covalent protein/peptide pairs, to test whether increasing the number of LIM domains in series enhances actin strain sensing. These studies will pave the way for structural studies to visualize the mechanism of acting strain recognition by LIM proteins.

### **Keywords**

Actin, stress fibers, mechanotransduction, SpyTag/SpyCatcher, structural biology

## **Vanadium Oxide Supported on Activated Niobium Oxide for Pollution Control of Carbon Monoxide**

Yueli Liang, SEAS '19, Earth and Environmental Engineering, Columbia University  
yl3837@columbia.edu

### **Supervising Faculty, Sponsor, and Location of Research**

Dr. Farrauto, Catalysis for A Sustainable Environment, Columbia University

### **Abstract**

Pt-containing catalysts are commonly used for oxidizing the toxic carbon monoxide and hydrocarbons but they have low availability and high price. The goal of the research is to explore less expensive but more abundant catalysts to replace Pt. Niobium oxide (activated at 1000 °C) has been proven to be an effective support and/or promoter for cobalt and manganese for the oxidation of propane and carbon monoxide. We believe a specific high temperature structure of niobium oxide interacts with these metal oxides promoting their catalytic activity. This study was to explore whether activated niobium oxide can promote the catalytic activity for vanadium oxide complete oxidation/Vanadium oxide is commonly used in sulfuric acid production where SO<sub>2</sub> is converted to SO<sub>3</sub>. The present work reports that vanadium oxide promoted by niobium oxide prepared using incipient wetness method, did not show the advantages of the other metal oxides.

### **Keywords**

Catalysis, Activated Niobium Oxide, Carbon Monoxide Oxidation

## **Bulk Alkaline Structures vs Nano-dispersed Alkaline Adsorbents in Dual Function Material Applications for Carbon Capture and Conversion to Synthetic Natural Gas**

Malia Libby, SEAS '20, Chemical Engineering, Columbia University  
malia.libby@columbia.edu

### **Supervising Faculty, Location of Research, and Sponsor**

Dr. Robert Farrauto, “Catalysis for a Sustainable Environment Laboratory,”  
Earth and Environmental Engineering, Columbia University in the City of  
New York, Johnson & Johnson WiSTEM 2 D Scholars Award  
Program

### **Abstract**

Rising carbon dioxide (CO<sub>2</sub>) emissions due to increasing fossil fuel consumption has lasting consequences on human health and the state of the environment. A new carbon dioxide capture/conversion to fuel process shows promise in mitigating CO<sub>2</sub> emissions from power plants. Our lab, Catalysis for a Sustainable Environment, has developed Dual Function Materials (DFMs) consisting of dispersed catalyst and alkaline adsorbent materials on high surface area carriers. The DFM allows for capture and subsequent catalytic conversion of carbon dioxide from industrial flue gas to synthetic natural gas (CH<sub>4</sub>). For improved understanding and optimization of the DFM, this study focused on the variation in performances of metal oxide adsorbents in bulk and dispersed structures for capture and conversion of carbon dioxide. Cerium Oxide (CeO<sub>2</sub>), Lanthanum Oxide (La<sub>2</sub>O<sub>3</sub>) and Calcium Oxide (CaO), known alkaline solids, were prepared via thermal decomposition of cerium nitrate, lanthanum nitrate and calcium hydroxide and were used as bulk adsorbents. Incipient wetness impregnation was used to deposit highly dispersed Ru on the metal oxide adsorbents. For comparison gamma-alumina was impregnated separately with aqueous solutions of the same salts and ruthenium nitrate. Samples were tested in a fixed-bed reactor for 3 cycles at 320 °C for evaluation of CO<sub>2</sub> capture and conversion performance. Each cycle consisted of two steps: 1) carbon dioxide adsorption and 2)

hydrogenation of the adsorbed CO<sub>2</sub>. The samples were characterized using internal surface area measurements (BET methods) and thermal gravimetric analysis (TGA).

Preliminary findings suggest non-uniform performance trends among bulk and dispersed DFM

pairings. Greater carbon dioxide adsorption in bulk samples did not translate directly to greater conversion efficiency over its dispersed counterpart. It is speculated that CO<sub>2</sub> adsorption on bulk adsorbent structures is due to the formation of stable carbonates. Conversely, in the nano-dispersed adsorbents, CO<sub>2</sub> is weakly bound by chemisorption bonds between CO<sub>2</sub> and the adsorbent. CeO<sub>2</sub> as a bulk adsorbent, containing Ru, shows promise as a viable carrier candidate in DFM applications. One key problem that must be resolved is the minimization of the desorption of CO<sub>2</sub> before methanation occurs. This will be addressed by the introduction of steam to strengthen bonding, increased catalyst loading, or optimization of the feed gas flow rates.

### **Keywords**

Dual function materials, carbon capture and conversion, synthetic natural gas production, ruthenium catalyst, alkaline metal oxide adsorbents, CO<sub>2</sub> mitigation

## **CRISPR/Cas9-Mediated PARP1 Disruption to Sensitize BRCA1 Mutated Breast Cancer Cells to Chemotherapy**

Rachel Mintz, SEAS '19, Biomedical Engineering, Columbia University  
rachel.mintz@columbia.edu

### **Supervising Faculty:**

Yeh-Hsing Lao 1 , Chun-Wei Chi 2 , Mingqiang Li 1 , Chai Hoon Quek 1 ,  
Sihong Wang 2 and Kam W. Leong 1,3\*

1 Department of Biomedical Engineering, Columbia University, New York  
NY, USA

2 Department of Biomedical Engineering, The City College of New York,  
New York NY, USA

3 Department of Systems Biology, Columbia University Medical Center,  
New York NY, USA

### **Abstract**

For patients carrying BRCA1 mutations, at least one-third develop triple negative breast cancer (TNBC). Not only is TNBC difficult to treat due to the lack of molecular target receptors, but BRCA1 mutations also result in chemotherapeutic resistance, making disease recurrence more likely. Although BRCA1 mutations are highly heterogeneous in those patients and are therefore difficult to target, BRCA1 gene's synthetic lethal pair, PARP1, is fortunately conserved in the BRCA1-mutated (BRCA1m) cancer cells. Therefore, we hypothesized that targeting PARP1 might be a fruitful direction to sensitize BRCA1m cancer cells to chemotherapy. We used CRISPR/Cas9 technology in conjunction with the transfection agent Lipofectamine to conduct multiple clonal selections and generate PARP1 deficiency in two TNBC cell lines, MDA-MB-231 (BRCA1 wild-type) and MDA-MB-436 (BRCA1m). The PARP1 knockout was confirmed and quantified with Sanger Sequencing. We explored whether this PARP1 disruption could significantly lower the chemotherapeutic dose necessary to achieve therapeutic efficacy. With both BRCA1 and PARP1 deficiency, the cancer cells were more sensitive to the three representative chemotherapeutic breast cancer drugs chosen, doxorubicin, gemcitabine, and docetaxel, compared with their PARP1 wild-type counterpart

( $p < 0.0001$ ). However, this chemotherapeutic sensitization by PARP1 knockout was not observed in the BRCA1 wild-type cells (MDA-MB-231). Collectively, these results highlight the selective synergism between PARP1 knockout and chemotherapy in the BRCAm cells, which may offer a potential approach to TNBC therapy.

**Keywords**

Triple negative breast cancer, CRISPR/Cas9, PARP1, BRCA1, precision medicine

# Characterization of the Binding of a Computationally Designed Transmembrane Peptide to the Erythropoietin Receptor

Sarah Nick, SEAS '19, Biomedical Engineering, Columbia University  
sen2130@columbia.edu

## Supervising Faculty, Sponsor, and Location of Research

Dr. Bill DeGrado, 2018 UCSF Summer Research Training Program,  
DeGrado Laboratory, University of California San Francisco

## Abstract

Membrane proteins regulate many essential cellular functions including transport, adhesion and signaling. Membrane-spanning  $\alpha$ -helices dictate folding, protein-protein interactions, and ultimately the protein function. However, the link between primary sequence and transmembrane (TM) helix self-association is unclear. One frequently observed sequence motif, the repeat of small amino acids (Gly/Ala/Ser) every other helical turn (7-residues), was found to mediate both parallel and antiparallel helix association in many natural membrane proteins. This sequence motif occurs at the dimerization interface of the erythropoietin receptor (EpoR), a cytokine receptor that directly regulates the production of red blood cells. Previously, an isolated TM  $\alpha$ -helix mimicking the EpoR-TM domain was made repeating serine, and associated in a parallel geometry. Thus, to test if antiparallel geometry can be achieved outside of the context of a full-sized protein, we designed a synthetic TM peptide containing this motif named 'CHAMP' (Computed Helical Anti-Membrane Protein). We hypothesized that CHAMP would form an antiparallel dimeric complex with EpoR-TM and inhibit parallel self-association of EpoR transmembrane domains. We previously demonstrated antiparallel binding of CHAMP to EpoR-TM and inhibition of full-length EpoR signaling in cells.

Herein, we aimed to characterize the CHAMP-EpoR-TM complex by fluorescence resonance energy transfer (FRET) between fluorescently-labelled CHAMP and EpoR-TM in detergent micelles. The FRET data were then fit to theoretical curves to determine binding affinity and complex stoichiometry. A clear association between CHAMP and EpoR-

TM was detected, based on the concentration-dependent quenching of donor emission and increased acceptor emission. Initial experiments suggest that a weak monomer-trimer equilibrium model best describes the experimental binding curves. These results indicate that a small amino acid 7-residue repeat successfully promotes antiparallel dimeric TM helix association and refine our understanding of how sequence drives protein-protein interactions and folding within membranes.

**Keywords**

Membrane proteins, computationally designed peptides, antiparallel geometry, erythropoietin receptor, fluorescence resonance energy transfer (FRET)



## **Nano-Organic Hybrid Materials and their Capture of CO<sub>2</sub>**

Avery Park, SEAS '20, Chemical Engineering, Columbia University  
aap2190@columbia.edu

### **Supervising Faculty, Sponsor, and Location of Research**

Ah-Hyung Alissa Park, Johnson & Johnson, Lenfest Center for Sustainability

### **Abstract**

Global climate change has been attributed to an increase of CO<sub>2</sub> levels in the atmosphere. Industrial factories and power plants are major contributors to this rise in greenhouse emission levels. Currently, amine scrubbing has been employed to capture CO<sub>2</sub>. This technology proves to be challenged by degradation of the aqueous amine over time, corrosion to the plant equipment, and a large energy cost. This study aims to determine the mixing behaviors of Nano-Organic Hybrid Materials, herein NOHMs, as well as their ability to capture CO<sub>2</sub> through physisorption. NOHMs are created through tethering the jeffamine polymer (C<sub>94</sub>H<sub>184</sub>O<sub>41</sub>N, MW: 2000) to a nano-particle core. The product is a highly viscous solvent. Understanding the mixing rules of NOHMs with secondary fluids is important so that a less viscous material can be produced and mass transfer can yield an increase in CO<sub>2</sub> capture. This study shows that NOHMs mix with ethyl acetate to produce a fluid with the lowest viscosity, when compared with dichloromethane and acetic acid. Larger scale structures, on the order of 1 micron, were observed in the mixture of NOHMs with dichloromethane, a non-polar solvent. Furthermore, use of a functionalized core in the NOHMs was studied. It was observed that titanium dioxide could be used as a photocatalytic core. TGA and FTIR analysis alludes to the confirmation of the synthesis of TiO<sub>2</sub>-NOHMs. Further research will study the NOHMs CO<sub>2</sub> capture ability and hypothesized photocatalytic conversion of CO<sub>2</sub>.

**Keywords**

Carbon Capture, Photocatalytic, Nano-organic Hybrid Materials, NOHMs, CO<sub>2</sub>, Carbon Conversion

## **Interactive Robotic Control with Augmented Reality**

John Pederson, SEAS '19, Mechanical Engineering, Columbia University  
jmp2252@columbia.edu

### **Supervising Faculty, Sponsor, and Location of Research**

Alessandro Cattaneo, Troy Harden, and Beth Boardman; Los Alamos  
Dynamics Summer School, Los Alamos National Laboratory

### **Abstract**

As robots become ever more commonplace in industry and manufacturing, the need for easy and precise robotic control is growing. Current robotic operators must use complicated manual controllers and receive hours of training to perform simple tasks; in addition, such tasks are hindered by the lack of force feedback, which can cause undesired dropping or crushing of objects. At the same time, augmented reality (AR) devices, such as Google Glass and the Microsoft HoloLens, are becoming cheaper and easier to develop.

Our goal was to develop an AR application that would allow a user to intuitively control and manipulate a robotic arm with ease. In addition, a means to display the forces on each arm component would further assist the user.

Using the game engine Unity and Microsoft Visual Studio, we created an AR application to run on a Microsoft HoloLens; the app included an interactive robotic arm and a button-based user interface. We then used libraries in the Robot Operating System (ROS) to connect to the HoloLens, relay the instructions to motion planning libraries, and control a Yaskawa Motoman SIA5D robotic arm. We also used a MATLAB Simulink program to calculate the torque on each robot joint in near-realtime.

Our final result is an AR application that successfully allows a user to control and manipulate a robotic arm with little training. By manipulating an AR hologram of the robotic arm, the user can “click and drag” the robotic arm into a new position. In addition, the user can choose to “preview” the impending motion of the robot; in this mode, the torques on

each joint are calculated and displayed as colors, giving force feedback to the user.

The application represents a proof-of-concept means of robotic control that surpasses current control methods in ease of use and training requirements. Further work would include 3D mesh-based obstacle avoidance and adjustment of holographic scale for precision maneuvering.

**Keywords**

Augmented reality, robot, control, app, HoloLens

## **CRISPRi for the Modeling of Spinal Muscular**

### **Atrophy**

Jess Qu, SEAS '19, Biomedical Engineering, Columbia University  
yq2193@columbia.edu

### **Supervising Faculty, Sponsor, and Location of Research**

Professor Gordana Vunjak-Novakovic, Johnson and Johnson Scholar Program, Laboratory for Stem Cell and Tissue Engineering, Columbia University Medical Campus

### **Abstract**

Spinal muscular atrophy is the leading genetic cause of infant mortality. It is caused by reduced levels of the survival motor neuron protein (SMN) due to mutations of the SMN-1 gene, which is important for the maintenance of motor neurons. Animal studies have shown that the earliest physiological changes occur at neuromuscular junctions, which are synapses between motor neurons and skeletal muscle fibers. However, it is important to explore human models for better understanding of the cellular events that occur for SMA and to evaluate therapeutic approaches for clinical trials, eventually progressing to personalized medicine with the use of patient-derived stem cells. The aim of this study was to characterize the role of the SMN protein in neuromuscular junction maturation in a human spinal muscular atrophy model using CRISPRi (clustered regularly interspaced short palindromic repeats interference). CRISPRi regulates gene expression on a transcriptional level by using a catalytically dead Cas9 (dCas9); it can be used to repress or activate transcription of the target gene. First, Stbl3 cells underwent transformation for lentiviral plasmid transformation. Then, induced pluripotent stem cells were transfected with dCas9-KRAB lentiviral construct, which would repress transcription when induced with doxycycline. Then, RT-PCRs and Western blots were performed to validate the CRISPRi cell line. Further analysis will be performed to verify the transcription levels of the cell line. The next step is to use this CRISPRi line to derive motor neurons and introduce optogenetic protein channelrhodopsin-2 for use in the 3D microfluidic system. The goal will be to study the role of the SMN protein at different stages of neuromuscular junction maturation through the microfluidic system in order to better understand the early stages of spinal muscular atrophy.

**Keywords**

CRISPRi, spinal muscular atrophy, induced pluripotent stem cells (iPSCs), organ-on-a-chip platform, tissue engineering

## **Extraction of Magnesium Hydroxide from Seawater for Carbon-Negative Cement Production**

Julie Raiff, SEAS '21, Chemical Engineering, Columbia University  
jr3745@columbia.edu

### **Supervising Faculty, Sponsor, and Location of Research**

Dr. Daniel Esposito, Johnson and Johnson Scholars Program, Solar Fuels Engineering Lab, Columbia University

### **Abstract**

Most of today's cement is Portland cement, which is calcium-based and derived from limestone,  $\text{CaCO}_3$ . However, the production process releases a significant amount of carbon into the atmosphere, contributing to climate change. Some possible alternatives to traditional Portland cement are a variety of magnesium-based cements, which additionally have the potential to absorb atmospheric carbon. It is well-known that magnesium ions,  $\text{Mg}^{2+}$ , are abundant in seawater, thus this study aims to develop a method to extract magnesium from seawater in the form of magnesium hydroxide,  $\text{Mg}(\text{OH})_2$ , to be used as a starting material for magnesium-based cements. In order to accomplish this, a membraneless electrolyzer was designed to perform electrolysis on seawater, producing both acidic and alkaline streams. The elevated pH of the alkaline stream would cause the precipitation of  $\text{Mg}(\text{OH})_2$  for extraction. This study focused on electrolyzer design and the precipitation behavior of  $\text{Mg}(\text{OH})_2$ . The designs were drawn using CAD software and prototypes were 3D-printed so that the flow through the device could be tested. Additionally, titrations of  $\text{MgSO}_4$  solution by  $\text{NaOH}$  were performed to investigate the behavior of the  $\text{Mg}(\text{OH})_2$  precipitation process. Finally, preliminary electrochemistry was performed in a three-neck flask to obtain elementary current-voltage measurements that will later be performed on the electrolyzer itself. It was found that the device prototypes had satisfactory performance on the flow tests and that the titration reached the equivalence point at a pH just about 11.5. All of these components will be put together

for future investigations in order to start assembling a complete system to precipitate  $\text{Mg}(\text{OH})_2$  from seawater.

**Keywords**

Membraneless electrolyzer, seawater electrolysis, magnesium hydroxide precipitation



## **Optimization of AAPBA-containing biocompatible hydrogel for continuous glucose monitoring through dielectric spectroscopy**

Paul A. Spezza, SEAS '21, Biomedical and Mechanical Engineering,  
Columbia University  
pas2205@columbia.edu

### **Supervising Faculty, Sponsor, and Location of Research**

Professor Qiao Lin, CUSP Summer Enhancement Fellowship BioMEMS  
Laboratory, Department of Mechanical Engineering, Columbia University

### **Abstract**

Diabetes mellitus is characterized by the presence of high blood sugar levels in patients. The ever increasing prevalence of diabetes necessitates further exploration to reduce the risk of resulting complications. Continuous glucose monitoring (CGM) devices have been established to provide users with the prompt and reliable detection of glucose, thereby reducing risks due to hyperglycemia or hypoglycemia. However, existing sensors are predominately based on the electrochemical detection of enzymatic reactions which leads to the irreversible consumption of glucose and are thus limited by their brief operational period. Our work expands on the development of a hydrogel-based affinity glucose sensor through both a study to optimize response time and to further elucidate our mechanism of reaction, which will provide a guide towards optimized integration with microelectromechanical systems (MEMS) technology. Our sensor adopts gold interdigitated electrodes integrated with a thin film of hydrogel that is functionalized with N-3-acrylamidophenylboronic acid (AAPBA) for glucose detection. Experiments were run using an impedance analyzer to measure the glucose concentration-dependent changes in the impedance of the devices under steady state conditions. First, the sensor's sensitivity toward changes in dielectric constant was calibrated by testing multiple standard solutions with various relative dielectric constants, which also aligned well with our 3D static electric field simulation using Comsol. With confirmed accuracy to measure the dielectric property of solutions, our sensor studied the relationship between the frequency and dielectric constant of the AAPBA containing hydrogel over a range of glucose concentrations. The preliminary results demonstrate the high sensitivity of our device to detect glucose. Interestingly, the results also provide insights to elucidate the mechanism of reaction between AAPBA and glucose, as the frequency-based data are able to differentiate 1:1 and 1:2 binding between

glucose and AAPBA. These results demonstrate the strong performance of this device and the significant progress that has been made for applications of MEMS devices in the monitoring of glucose.

**Keywords**

Continuous glucose monitoring (CGM), affinity sensing, interdigitated coplanar electrodes, hydrogel, N-3-acrylamidophenylboronic acid (AAPBA)

## **Two-step Mineral Carbonation of Heat-treated Serpentine using Dilute CO<sub>2</sub> Stream**

Dongyi Wang, SEAS '20, Environmental Engineering, Columbia University  
dw2736@columbia.edu

### **Supervising Faculty, Sponsor, and Location of Research**

Prof. Ah-Hyung Alissa Park, Lenfest Center for Sustainable Energy,  
Columbia University

### **Abstract**

The atmospheric CO<sub>2</sub> concentration has increased by roughly 30% since industrial revolution, and it causes global temperature change. The recent significant increase in CO<sub>2</sub> shows a remarkable constant relationship with fossil-fuel burning. If fossil-fuel burning continues at the current rate for next few centuries, CO<sub>2</sub> will continue to rise to order of 1500 ppm cause extreme weather change, sea level rise, and natural disasters. Therefore, it is important to develop technology for effective Carbon Capture, Utilization, and Storage (CCUS). One of the most eminent CCUS technologies is ex-situ mineral carbonation, which mimics the natural weathering process between silicate mineral and carbon dioxide. Specifically, my research this summer studies the dissolution behavior of heat-treated serpentine (Mg<sub>2</sub>SiO<sub>4</sub>) in an internal grinding system to enhance magnesium dissolution, which in turn increase CO<sub>2</sub> capture by the precipitation of Mg-carbonate. Various grinding media with different densities and diameters were tested to maximize the grinding performance and optimize the process condition. Two dominant attrition modes, abrasion and fragmentation, depending on the stress intensity, were tested. The fragmentation mode was found to be most effective in removing the passivation layer and promoting Mg extraction during the dissolution step. It was also found that the internal grinding system showed better dissolution performance than external grinding process because this system was able to continuously remove the newly formed Si-passivation layer during the dissolution process. This study will provide perspectives for developing highly efficient large scale P CO<sub>2</sub> swing mineral carbonation process.

**Keywords**

heat-treated serpentine dissolution kinetic, two-step mineral carbonation, Mg leaching, formation of amorphous silica passivation layer, ligand

## **Dendritic cell membrane-coated polymeric microfibrils as artificial antigen-presenting cells for ex vivo expansion of primary human T cells**

Moshe Willner, SEAS '20, Biomedical Engineering, Columbia University  
mjw2214@columbia.edu

### **Supervising Faculty, Sponsor, and Location of Research:**

Dr. Hyesung Kim, Dr. Tzu-Chieh Ho, and Professor Kam W. Leong,  
Egleston Scholar Program, Leong Lab Columbia University

### **Abstract**

Improving the rate and quality of T-cell expansion is crucial for effective cellular therapies such as T-cell based adoptive cell therapy. In this study, we develop an ex vivo T-cell expansion system using dendritic cell membrane-coated polymeric microfibrils (DC@MFs). The microfibrils are prepared by electrospinning polycaprolactone (PCL) and subsequently hydrolyzing the electrospun PCL microfiber into small fragments. To mimic native antigen presenting cells, the PCL microfibril is coated with human dendritic cell membranes and then decorated with anti-human CD3/CD28 antibodies via a copper-free click reaction. Here, we demonstrate that the T-cell specific stimuli-decorated DC@MF (Ab/DC@MF) significantly increases human T-cell expansion rates, especially CD8+ T-cell populations, in comparison with Dynabeads, which is the current gold standard for T-cell expansion. On day 21 of human primary T-cell culture, Ab/DC@MFs yields around a five-fold greater expansion compared with Dynabeads. In addition, the CD8-to-CD4 T-cell ratio of Ab/DC@MFs is 1.4-fold higher than that of Dynabeads. These results suggest that further studies would be warranted to improve and characterize this polymeric microfibril-based system for future, impactful cellular immunotherapy.

### **Keywords**

Adoptive cellular therapy, T cell expansion, cell membrane coating, microfiber, artificial antigen presenting cells

## Desalination of Hypersaline Brines: Temperature Swing Solvent Extraction

Robert Winton, SEAS '21, Electrical Engineering, Columbia University  
rkw2121@columbia.edu

### Abstract

Management and treatment of hypersaline brines, e.g., produced water, zero liquid discharge effluent, and flue gas desulfurization wastewater, are of growing environmental importance. While reverse osmosis (RO) is energy-efficient, the technique is confined to purifying seawater and lower salinities; hydraulic pressure restrictions render RO unsuitable for hypersaline streams. Temperature swing solvent extraction (TSSE) is an alternative desalination technique that is membrane-less and not based on evaporative phase-change. The technology utilizes a low-polarity solvent that is immiscible with aqueous solutions to extract water from hypersaline brines. The application of low-grade heat to the solvent phase then lowers the water solubility, causing the aqueous phase to demix from the solvent and yielding product water. Because the working principles of SE are radically different, the technology can sidestep the technical limitations plaguing the traditional methods when desalinating hypersaline streams. Additionally, TSSE is able to utilize low-grade thermal sources, such as industrial waste heat, shallow-well geothermal, and low-concentration solar collectors, to drive the desalination. Initial experimental results using a temperature swing of 51 °C (TL = 17 °C and TH = 68 °C) produce 2.4-56 moles of water for every 100 moles of triethylamine, with extraction efficacy lower at higher feed salinities. The concentration of the product water remains consistently low at ~104-138 mmol/L NaCl with a salt removal of 87.7-97.3%. This study demonstrates the potential of TSSE to desalinate hypersaline brines up to 235,000 ppm TDS ( $\approx 7\times$  seawater salinity) and projects the specific energy requirement of the technology. The enhanced salt removal achieved at higher feed TDS concentrations indicates that TSSE is especially favorable for desalination of ultrahigh salinities, whereas energy analysis signifies that temperature swing solvent extraction can be competitive with current thermal distillation methods.

## Reflectivity Modeling Insights to Improving the Efficiency of Thermophotovoltaics

Alice Wu, SEAS '20, Electrical Engineering, Columbia University  
aqw2106@columbia.edu

### Abstract

Thermophotovoltaics convert heat into electricity using a hot thermal emitter, in the range of 700 to 1300 o C, and a photovoltaic (PV) cell to capture the heat radiation from the emitter. Highly reflective mirrors on the back of the PV cell can recycle sub-bandgap energy photons back to the emitter, decreasing the thermal power absorbed by the cell and increasing the power conversion efficiency. Ganapati et al. have shown that the theoretical efficiency limit for this type of thermophotovoltaic system to be over 50%, which is much greater than the average 20% efficiency of a gasoline combustion engine [1]. As such, thermophotovoltaic engines present a potentially more energy efficient alternative to combustion engines, which can additionally be powered by renewable energy sources. Previously, Omair et al. achieved a record efficiency of  $28.8 \pm 0.3\%$  with an emitter temperature of 1207 o C and a PV cell reflectivity of 94% for sub-bandgap photons [2]. From previous analyses, we know reflectivity of the PV cell is the biggest factor in improving efficiency for this type of thermophotovoltaic system. Reflectivity may be improved by adding a low refractive index dielectric layer before the rear mirror, which increases the amount of total internal reflection.

We modeled the reflectivity of PV cells with two possible low index dielectric materials—SU8 and silica—using the transfer matrix method for optics. With the model, we determined that the optimal thicknesses for SU8 and silica were  $360 \pm 2.5\text{nm}$  and  $355 \pm 2.5\text{nm}$ , respectively. At the optimal thicknesses, SU8 and silica presented equally promising improvements to the reflectivity, both enabling a below-bandgap reflectivity of 97.65%. Moving forward, we have chosen to fabricate PV cells using silica as the low index dielectric layer, since preliminary tests have shown that silica achieves better surface contact with the semiconductor layers and the rear mirror.

**Keywords**

Thermophotovoltaics, photovoltaic cells, reflectivity

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Photovoltaic Band-Edge,” arXiv:1611.03544 [physics.optics] (2016).

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## **Exploration of Fractional Anisotropy in Diffusion Tensor Imaging for Neurodegenerative Disorders**

Katherine Xu, SEAS '20, Chemical Engineering, Columbia University  
kex2000@columbia.edu

### **Supervising Faculty, Sponsor, and Location of Research:**

Dr. Corey T. McMillan, Columbia Engineering Internship Fund, University of Pennsylvania, Frontotemporal Degeneration Center

### **Abstract**

Neurodegenerative disorders are characterized by gradual atrophy in the brain, resulting in a decline in behavior, motor skills, and/or language. The disease progression often includes social impairments and difficulty with executive functioning, which necessitates capable caregivers. Underlying causes, or pathology, include various protein misfolding or accumulation, including Tau and TDP proteins. The two pathologies differ in the amount of white and grey matter atrophy. The pathology can only be identified post-mortem, and thus poses difficulties in clinical studies for drug development. In clinic visits, it is often difficult to a) communicate to patients and their caregivers the results from MRIs due to their 3D nature and subtle differences to an untrained eye and b) discern the underlying pathology of the disease. Our objective was to develop a method to automatically render standardized images that would better communicate to patients their MRI results and use this data to predict the pathology. Using T1-weighted MRI scans from the Penn Frontotemporal Degeneration Center, fractional anisotropy (FA) values were calculated using Advanced Normalization Tools (ANTs). Fractional anisotropy is a measure of white matter density, and in these neurodegenerative conditions, white matter is expected to atrophy. To provide patients and clinicians with understandable results, we calculated z-scores of patients' FA values against healthy controls for every voxel in the MRI.

Previously, we developed a method to display cortical thickness (CT) measurements over time for various disease phenotypes. Combined with the CT heatmaps, the FA heatmaps are valuable in assessing disease

phenotype, progression, and prognosis. Next, we took averaged FA and CT values for various regions of the brains. These average labels were use in principal component analysis to identify the two pathology groups, Tau and TDP. Furthermore, this data was trained using machine learning techniques to predict the accuracy of these label measures. Ten labels along with disease duration at the time of the scan were useful measurements in predicting underlying pathology. We hope to implement these heatmaps to improve MRI assessment and predictions for clinicians and patients.

**Keywords**

Frontotemporal degeneration, fractional anisotropy, machine learning, pathology

## **Effect of Rotator Cuff Tear Size on Scapular Winging Using Virtual Moiré Topography**

Mojdeh Yadollahikhales, SEAS '20, Biomedical Engineering, Columbia University  
my2511@columbia.edu

### **Supervising Faculty, Sponsor, and Location of Research:**

Dr. Reuther, Undergraduate Research Involvement Program, Columbia Medical Center Orthopedics, Columbia University

### **Abstract**

Scapular dyskinesis is an alteration in normal scapular position and motion which is found in association with most shoulder injuries, including rotator cuff tears. Recent understanding of rotator cuff pathologies effects on shoulder kinematics and range of motion has been expanding, however, the body of knowledge regarding how pain and tear size affect scapular motion is limited. Frequently, findings related to scapular motion and position provide information that is helpful in improving clinical outcomes and return to activity. Therefore, our objective for this study is to determine and quantify if the size of rotator cuff tear affects scapular winging. We hypothesized (1) Scapular dyskinesis is associated with greater tear size as a positive risk factor for rotator cuff repair failure. (2) Restoration of normal scapular motion is predictive of a patient's ability to return to sport or pre-injury activity level.

### **Keywords**

Scapular dyskinesis, Winging, Scapulohumeral Rhythm, Rotator Cuff Tear, Massive and Full Thickness Tear, Moiré Topography

## **In Vitro Tissue Engineered Blood Vessel System for Modeling Vascular Disease**

Joyce Zhou, SEAS '19, Biomedical Engineering, Columbia University  
jz2637@columbia.edu

### **Supervising Faculty, Sponsor, and Location of Research**

Dr. Kam Leong, Johnson & Johnson Scholar Program, Nanotherapeutics and Stem Cell Engineering Laboratory, Columbia University

### **Abstract**

Marfan syndrome (MFS) is a rare genetic disorder of the connective tissue caused by a mutation in the fibrillin-1 (FBN1) gene. Patients with MFS often suffer cardiovascular complications, most commonly thoracic aortic aneurysms. To help facilitate screening of drugs that may attenuate aortic aneurysm growth, it is valuable to develop a patient-specific in vitro 3D tissue model capable of recapitulating the disease phenotype and responding to vasoactive stimuli. Here, we fabricated functional tissue engineered blood vessels (TEBVs) using directly reprogrammed smooth muscle cells (SMCs) from an MFS patient and treated them with MFS drug candidates losartan and SB203580. Furthermore, we examined whether pulsatile flow conditions in our system could prompt SMCs to acquire their native in vivo circumferential cell alignment. Wild type and MFS patient dermal fibroblasts were transdifferentiated to iSMCs through MYOCD overexpression using a doxycycline (DOX)-inducible lentiviral delivery system. To fabricate TEBVs, iSMCs or umbilical artery smooth muscle cells (UASMCs) were incorporated in a dense collagen gel construct. TEBVs were matured in custom perfusion chambers integrated in a flow circuit for 1-2 weeks. 1 $\mu$ M losartan or SB203580 was added to the culture media for 1 week during iSMC TEBV perfusion. UASMC TEBVs were subject to pulsatile flow using a custom-built circuit with a solenoid pinch valve actuated at a frequency of 1 Hz. Changes in vessel diameter in response to phenylephrine and caffeine were recorded with a stereoscope and ISCapture software and quantified using ImageJ. Vessel sections were cut, fixed in 4% paraformaldehyde, and stained for nucleus, actin, FBN1,

and contractile SMC markers. Changes in SMC alignment were quantified using ParticleSizer (ImageJ). MFS iSMC TEBVs displayed abnormalities corresponding to the MFS disease phenotype, as demonstrated by larger inner and outer diameters, larger medial wall thickness, and reduced vasoactivity in comparison to wild type iSMC TEBVs. Treatment with losartan partially improved vessel contractility in response to 1 $\mu$ M caffeine but did not significantly attenuate diameter and wall thickness enlargement or recover FBN1 deposition, while treatment with SB203580 significantly reduced wall thickness, increased FBN1 deposition, and improved vessel contractility. Finally, pulsatile flow conditions resulted in a greater proportion of UASMCs aligned perpendicular to the direction of flow in comparison to continuous laminar flow conditions, indicating that pulsatile flow can generate circumferential cell alignment. These results suggest that our in vitro human cell-based TEBV model of MFS can be used to replicate disease characteristics and screen prospective drug candidates for efficacy. The ability of our system to recapitulate MFS abnormalities and respond to vasoactive stimuli validates its potential for future use as a platform for cardiovascular disease studies and drug testing.

**Keywords**

Marfan Syndrome, tissue engineered blood vessel, direct reprogramming

We are also delighted to welcome the Engineering the Next Generation Scholars. These local high school students completed a six-weeks research program in collaboration with Columbia University.

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**Stacking Process for BN-TI flakes**

Cayo Aponte, LaGuardia Community College  
Lia Krusin, Professor of Physics, City University of New York

**The Benefits of Taxi Route Optimization**

Admir Basic & Meraj Ibn-Kabir, Bronx Center/CSS  
Van-Anh Truong, Professor, Industrial Engineering Operations Research

**Purifying Mutated Caspase-3 for Purposes of Complex Coacervation**

Ahmet Mithat Bilgi, CSS  
Allie Obermeyer, Professor, Chemical Engineering

**Advanced Material for Lithium Ion Batteries with Improved Performance**

Dana Espinoza, LaGuardia Community College  
Yuan Yang, Professor, Applied Physics & Applied Mathematics

**Developing an optical setup for Fourier space excitation using structured light**

Owen Gao & Jiayang Lian, CCNY & HSME  
Vinod Menon, Professor of Physics, City University of New York

**Fluorescently-tagged cell markers for quantitative biophysical studies**

Dauris Jorge & Nabil Titikpina, Ellis  
Karen Kasza, Assistant Professor, Mechanical Engineering

### **Optimal Portfolio Choice for Fire Sales Games**

Justin Peralta & Eleazar Neri, CSS

Agostino Capponi, Assistant Professor, Industrial Engineering  
Operations Research

### **Arduino controlled syringe pump for scanning bubble microscopy**

Luciana Gil Rosario & Fatouma Doucoure, Ellis

Dan Esposito, Assistant Professor, Chemical Engineering

### **Reconstruction of Signals Subjected to Limited Data: Applications in Engineering Problems**

El-Hossin Salem & Samiratou Sanga, Ellis

Ioannis Kougioumtzoglou, Assistant Professor, Civil Engineering

### **Mutagenesis and protein expression for synthesis of a photo-switchable protein-polymer conjugate**

Mohona Yesmin, Marble Hill HS

Allie Obermeyer, Professor, Chemical Engineering



**Columbia Engineering**  
**The Fu Foundation School of Engineering**  
**and Applied Science**  
**500 W. 120<sup>th</sup> St.**  
**New York, NY 10027**