SEAS Undergraduate Student Affairs and Global Programs,
the Engineering Student Council, and
the Columbia Undergraduate Scholars Program present
the Fifth Annual

Undergraduate Research Symposium

THURSDAY, OCTOBER 6TH, 2016

6:00 - 7:30 PM

Carleton Commons, 4th Floor Mudd

COLUMBIA | ENGINEERING
The Fu Foundation School of Engineering and Applied Science

Student Research Posters

The Role of Hematopoietic Differentiation Transcription Factors in TET2 and IDH2 Mutant Acute Myeloid Leukemias
Temitope Akinade, SEAS '19, Biomedical Engineering

Novel Method for Browning White Adipose Tissue Reduces Symptoms of Diabetes and Obesity in Mice
Janice Chung, SEAS '19, Biomedical Engineering

EDUARDO: Electrostatic Detainment Unit for Automated Removal of Debris in Orbit
Julia Di, SEAS '18, Electrical Engineering

A Method to Identify Touch Super Sensitive Mutants of Caenorhabditis elegans
Andre Fiks Salem, CC '19, Neuroscience and Behavior

Device Fabrication for High Precision Electrical Transport Measurements on Complex Oxide Thin Films
Betty Hu, SEAS '19, Applied Physics

Photocatalytic Suspensions Based on Low-Dimensional van der Waals Materials
Sophia Kurdziel, SEAS '18, Chemical Engineering

3D Dinner
Yadir Lakehal, SEAS '17, Mechanical Engineering

Applications of Deep Learning to Deception Detection
Kai-Zhan Lee, SEAS '19, Computer Science

Life Cycle Analysis and Emissions Model for Landfill Diversion in India
Anna Libey, SEAS '17, Earth and Environmental Engineering

Group Theoretic Cryptography: The Algebraic Eraser
Jiahui Liu, SEAS '17, Computer Science

Hepatic Orexin Receptor-1 Expression in Binge Eating Prone and Binge Eating Resistant Rats
Rachel Lujan, SEAS '19, Environmental Engineering

Effectiveness of Voluntary Principles in Mining Industry
Varshini Parthasarathy, SEAS '18, Environmental Engineering

A Method for Quantification of Scapular Dyskinesis and Winging Using Moiré Topography
Sidney Perkins, SEAS'17, Biomedical Engineering

Antibiotic Regulation of Ductus Arteriosus Tone: Better Choices for Neonatal Sepsis-Associated Patent Ductus Arteriosus
Stephanie Rager, SEAS '19, Biomedical Engineering

Light Beam Scanning in Catheters without Moving Mechanical Components
Rhiana Rivas, SEAS '18, Biomedical Engineering

Effects of Maternal Separation on Expression of Depression Candidate Genes in B6 Mice
Simona Sarafinovska, CC'18, Biochemistry

Assaying Permeability of Pre-treated Bovine Synovium using Fluorescent Dextran
Saiti Srabonti Halder, SEAS '19, Biomedical Engineering

The Role of Adenylyl Cyclase 3 in Osteocyte Mechanosensing
McKenzie Sup, SEAS '18, Biomedical Engineering

Development of Automated Batch Workflow and Real Time Large Data Processing for X-ray Fluorescence Tomography
Derek Tropf, SEAS '17, Applied Physics

Text-to-Speech for Low-Resource Languages
Xinyue Wang, SEAS '18, Computer Science

Measuring the Thermal Conductivity of Lithium-ion Battery Anodes Using a Simple Differential Steady-state Method
Shangzhou Xia, SEAS '19, Applied Physics

Investigating the Functional Role of EphB4 Receptor Clustering in Adult Neural Stem Cells
Sarah Yang, SEAS '17, Chemical Engineering

Trigger: A Dynamic Data Race Verification and Analysis Tool
Jason Zhao, SEAS '18, Computer Science,

E.N.G. Program Research Posters

Robotic Tactile Sensors
Ikram Hussain (ELLIS Preparatory Academy) & Jeremy Espinal (Columbia Secondary School)

Effects of Horizontal and Vertical Orientation of a Photoelectrode on Bubble Nucleation, Growth, and Detachment
Jhaelle Payne (Columbia Secondary School) & Eleanor Prickett-Morgan (Columbia Secondary School)

Simple Image Processing via Machine Learning
Sohel Rana (ELLIS Preparatory Academy), Ilan Rodriguez (Columbia Secondary School), & Alan Rice (Columbia Secondary School)

Photoluminescence of MBE Grown II-VI Semiconductors
Marva Tariq (Brooklyn Technical High School)

Development of a Phantom Uterus and Cervix to Mimic the Mechanical Environment of Pregnancy
Katie Vollen (Columbia Secondary School) & Roselkis Morla (ELLIS Preparatory Academy)

The Role of Hematopoietic Differentiation Transcription Factors in TET2 and IDH2 Mutant Acute Myeloid Leukemias

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Supervising Faculty, Sponsor, and Location of Research
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Abstract
Acute myeloid leukemia (AML) is a cancer characterized by the overproduction of myeloid progenitor-like cells in the bone marrow. In patients, common mutations associated with AML have been found in Isocitrate Dehydrogenase two (*IDH2*) and Ten-Eleven-Translocation-two (*TET2*) genes. Both these enzymes act in the same pathway and when either is mutated, methylation and epigenetic silencing of other genes can result. The phenotypic characteristics associated with these mutations are aberrant hematopoietic differentiation and increased self-renewal ability. However the specific genes they impact to produce these effects are unknown. One proposed mechanism of action of these mutations is that they block the proper expression of transcription factors proteins that are essential for hematopoiesis, or the differentiation of blood stem cells. The hypothesis of this project is that *IDH2/TET2* mutations lead to these transcription factors being expressed at improper levels, thus leading to abnormal hematopoietic cell development. In order to further understand the pathology of these mutations, this investigation utilized an IDH2 inhibitor drug, AGX, on IDH2 mutant and wild type mouse cell lines. Quantitative polymerase chain reaction (qPCR) was done to investigate the expression levels of essential transcription factors in mouse myeloid cell differentiation: mPU.1, mCEBPα, mRUNX1, mGATA1, and mGATA2. By studying the relative levels of transcription factors in AGX treated and untreated cells, a correlation was made between the disease and transcription factors, specifically mCEBPα and mRUNX1. Knowing the specific proteins affected in AML associated mutations has significant implications in understanding the mechanisms of response when targeting this pathway.

Keywords
Acute myeloid leukemia (AML), hematopoiesis, methylation, transcription factors, quantitative polymerase chain reaction (qPCR)

Novel Method for Browning White Adipose Tissue Reduces Symptoms of Diabetes and Obesity in Mice

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Supervising Faculty, Sponsor, Location of Research
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Abstract
Obesity and diabetes are increasing public health concerns in the US. The body's inability to efficiently metabolize glucose in the body is a major cause of diabetes and obesity. Increasing metabolic activity, and thereby glucose metabolism, in the body could help address these growing concerns. Two primary types of adipose are found in the mammalian body. White adipose tissue (WAT) stores excess energy, and excess WAT is thought to be a major contributor to obesity and diabetes. In contrast, brown adipose tissue (BAT) functions in the dissipation of chemical energy in the form of heat via mitochondrial uncoupling protein (UCP1). It has been shown that people with higher quantities of BAT have a leaner phenotype and higher metabolic activity than those with less BAT. In recent years, considerable interest has risen in the potential beneficial effects of stimulating WAT to take on a BAT-like phenotype, especially the fat-burning characteristics of BAT. The stimulated WAT is termed beige adipose tissue. A long-lasting solution for diabetes and obesity could be found in the controlled and sustained increase of metabolic activity through beige adipose tissue. The objective of this study was to analyze the influence of implanting beige adipose tissue on the metabolic activity of diet-induced-obese mice. Here we aim to show that our *ex vivo* method of browning WAT into beige adipose tissue increases metabolic activity in diet-induced obese (DIO) C57BL/6N mice. Mice injected with beige adipose tissue are expected to exhibit greater glucose tolerance, enhanced insulin sensitivity, a leaner phenotype, weight loss, and greater metabolic activity (as indicated by increased VO2 consumption and consistent RER values).These results would suggest that our method of browning could have potential as a therapeutic for obesity and diabetes.

Keywords
brown adipose tissue, browning, metabolic activity, obesity, diabetes

EDUARDO: Electrostatic Detainment Unit for Automated Removal of Debris in Orbit

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Supervising Faculty, Sponsor, and Location of Research
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Abstract
The U.S. Strategic Command is currently tracking over 16,000 objects in Earth orbit. The vast majority are considered orbital debris: pieces of older satellites, abandoned rockets, and other inoperable spacecraft. Frequently, larger debris breaks down into 'daughter debris', of which ~200,000 to 300,000 pieces exist, and orbital debris poses a serious threat to the active satellites functioning in Earth's vicinity. Satellites can be maneuvered to avoid debris, but this action consumes valuable fuel, so the Electrostatic Detainment Unit for Automated Removal of Debris in Orbit, EDUARDO, is developed to manage the larger debris. EDUARDO's capabilities are tested in a low friction environment to simulate microgravity, by evaluating EDUARDO's success in capturing a half-scale mock satellite, Landsat 7. EDUARDO is a multi-jointed mechanism with an electrostatic gripping pad end effector, designed to capture any debris it contacts. EDUARDO's robotic arm removes large debris to prevent the creation of daughter debris, and also enables repairs of malfunctioning or inactive satellites. The prototype for this arm has been constructed with a rotating motorized shoulder mount, dual extendable booms, and a rotating motorized joint for mounting the electrostatic gripper. It is built on a thruster-propelled air bearing mobility base designed to simulate motion in near-Earth orbit EDUARDO successfully captured the half-scale mock-up of Landsat 7. In future developments, EDUARDO will have the capability to autonomously locate and capture problematic debris or damaged satellites. This capability should be tested with a variety of satellite mock-ups to evaluate the universality of EDUARDO as a solution to our current space debris problem.

Keywords
satellite, electrostatic, air bearing, robotics, space

A Method to Identify Touch Super Sensitive Mutants of *Caenorhabditis elegans*

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Supervising Faculty, Sponsor, and Location of Research
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Abstract
In spite of research that defined the molecules essential to vision, smell, and taste, researchers still do not know or fully understand all the molecules responsible for mechanical senses. Scientists have learned about some of the proteins essential to mechanosensation in mutants of the *C. elegans* roundworm in which it has been genetically disrupted. The mutations are provoked by random chemical mutagenesis, which should yield insensitive as well as super sensitive mutants. However, the super sensitive mutants have not been studied because their phenotype cannot be discriminated easily from the already responsive wild type in the standard touch assay. We tested alterations to this assay in order to reduce overall response rate and allow super sensitive mutants to stand out from wild type. We concluded substituting the wild type for the temperature sensitive *mec-4(u45)* mutant, which has a reduced response rate at 22°C, will be helpful to identify super sensitives. In this new test, response rates to touch would be low and any animal that reverts to a high response should possess, along with the *u45* allele, a super sensitive mutation. In the future, we will use this method to test strains with suspected enhanced sensitivity and hopefully allow more research in the genes causing this phenotype so that we can further understand how organisms feel touch.

Keywords
C. elegans, mechanosensation, touch, super sensitive, mechanosensory.

Device Fabrication for High Precision Electrical Transport Measurements on Complex Oxide Thin Films

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Supervising Faculty, Sponsor, and Location of Research
Professor Kyle Shen, Cornell PARADIM REU, Cornell University

Abstract
The open shell configuration of transition metal cations and quantum interactions between electrons can give rise to novel and unexpected electronic properties in transition-metal oxides (TMOs). For example, the Ruddlesden-Popper ruthenate family of materials ($A_{n+1}Ru_nO_{3n+1}$, where A is an alkaline earth element), are known to exhibit a wide array of electronic ground states in the bulk, ranging from ferromagnetic metals ($SrRuO_3$, $BaRuO_3$) in the three-dimensional limit ($n = \infty$) to unconventional superconductors (Sr_2RuO_4) in quasi-two-dimensional single-layer ($n = 1$). This sensitivity of electronic and magnetic properties to subtle changes in crystal structure suggests that the former can be artificially "tuned" in thin films grown by molecular-beam epitaxy (MBE) by adjusting parameters that couple to the film crystal structure, such as the structure and orientation of the substrate on which the film is deposited. Besides providing a useful platform for studying fundamental problems in solid-state physics, understanding how to exploit these structure-property relationships in TMOs is a crucial step towards the broader goal of realizing emergent properties of correlated electrons—e.g. metal-insulator transitions, magnetism, and superconductivity—in targeted materials by design.
This project focused on using electrical transport measurements to characterize the interfacial electronic structure of both $CaRuO_3$ and Ca_2RuO_4 samples grown on $LaAlO_3$ substrates by MBE. $LaAlO_3$ in particular was chosen because resistivity measurements of $Ca_2RuO_4/LaAlO_3$ showed two metal-insulator transitions between 300 K and 4 K, suggesting this system is in close proximity to the electronic ordering instability observed in bulk Ca_2RuO_4, while the same measurements conducted on $CaRuO_3/LaAlO_3$ showed no metal-insulator transitions. Photolithography methods were used to fabricate gold devices—“Hall bars”—on the surfaces of the films to enable more directionally-precise transport measurements. Hall effect measurements on $CaRuO_3/LaAlO_3$ indicated a change from predominantly electrons as charge carriers below 80 K to predominantly holes as charge carriers above 80 K. In $Ca_2RuO_4/LaAlO_3$ an “anomalous Hall effect”, which is often observed in magnetically ordered materials with appreciable spin-orbit

coupling, was observed below the metal-insulator transition at 200 K. Based off this, it is very likely that this metal-insulator transition is accompanied by the formation of canted antiferromagnetic order.

Keywords
molecular-beam epitaxy, electrical transport measurement, photolithography, transition-metal oxide, anomalous Hall effect

Photocatalytic Suspensions Based on Low-Dimensional van der Waals Materials

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Supervising Faculty, Sponsor, and Location of Research
Professor Daniel Esposito, Columbia University MRSEC REU Program, Esposito Laboratory, Columbia University

Abstract
The functionalities of low-dimensional van der Waals (vdW) materials are currently under extensive examination for the unique properties they possess, especially in relation to their bulk states. One application of interest is photocatalysis, where vdW substances can be suspended in aqueous solutions and used to facilitate light-driven electrochemical reactions. The focus of this project was to study the reaction kinetics of methyl orange degradation in the presence of molybdenum disulfide (MoS_2) through ultraviolet-visual (UV-vis) spectroscopy. Before investigating the less comprehensively studied vdW materials, it was important to develop a reactor setup with a well-studied, readily available material as a baseline; titanium dioxide (TiO_2) was chosen for possessing these characteristics. Using a UV-LED penlight as the source of irradiation, methyl orange degradation was studied with $TiO_{2\ acting}$ as the photocatalyst in a UV-vis spectrometer. Analysis indicates that the degradation of methyl orange undergoes zero order reaction kinetics in the tested time interval. Investigating low-dimensional vdW materials required an exfoliation process where bulk substances were reduced to mono- or few-layer flakes; here, liquid exfoliation and dispersion of MoS2 in water was performed via use of a sonicator. Analysis of the exfoliation process was completed using UV-vis spectroscopy, where observable changes in spectra occurred as a result of the presence of few-layer flakes. After complete sonication for 60 hours, small troughs arose at 630 and 680 nanometers, which corresponded to the emergence of MoS2 in exfoliated form. Once the exfoliated MoS2 suspension was obtained, its photocatalytic properties were studied in the same methodology used for TiO_2 through methyl orange degradation. Under heavy UV-irradiation, photocatalytic activity was observed with the sonicated MoS_2 sample. These findings indicate potential for MoS_2 as a principal photocatalyst; in all, investigation of these vdW substances as photocatalysts is important relative to their possible use in solar energy applications.

Key Words *photocatalysis, UV-vis spectroscopy, methyl orange degradation, molybdenum disulfid*

3D Dinner

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Supervising Faculty, Sponsor, and Location of Research
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Abstract
Today, plastic and metal 3D printers are revolutionizing industries from medicine to aerospace, but what if they could print in materials that could affect our day to day lives? A food printer is a 3D printer capable of fabricating edible foods by computer-guided deposition and cooking edible materials including edible food pastes, gels, and powders. Food printers are designed to produce a variety of customized dishes by transforming frozen ingredients in cartridges into healthy meals that can supplement daily nutritional intake. While some printers have effectively printed food before, few have taken on the challenge of cooking. The goal of this project was to cook food as it is printing from a 3D printer.
A frozen food cartridge was placed on a robotic arm holding eight slots for frozen food cartridges. To cook the food, we installed an infrared, focused heating element behind the food cartridge to successfully cook the food as it is printing. To focus the heat into a minimized diameter, we used a focused beam of infrared light. The heat from the infrared halogen light spot was found to be powerful and focused enough to cook several types of foods and pastes. These achievements indicate that food printers, fitted with the right infrared technology, can print and cook any type of meal.

Keywords
3D printing, food, digital food, molecular gastronomy, infrared heating

Applications of Deep Learning to Deception Detection

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Supervising Faculty, Sponsor, and Location of Research

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Abstract

Deep learning is on the rise as a method of classification, due to the recent rapid increase in computational power. Deception detection in speech, in particular, is a task well-suited to neural networks, because of the sheer amount of data to be processed. Here, in this, we examine the accuracy on the Columbia Cross-culture Deception Corpus (CxD) of other high-performing classifiers compared to that of an optimized neural network. We use 6373 openSMILE features from the 2013 Interspeech Deception Challenge, as well as gender, ethnicity, and the five scores from the NEO-FFI personality test in our feature set. We find that neural nets perform with a 61.62% accuracy, an 18.49% relative improvement from majority-class baseline accuracy, and an 18.22% relative improvement over the highest-accuracy ensemble classifier, which performed at 15.64% above baseline.

Keywords

Deception detection, speech, Columbia Cross-culture Deception Corpus (CxD), deep learning, neural network

Life Cycle Analysis and Emissions Model for Landfill Diversion in India

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Supervising Faculty, Sponsor, and Location of Research
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Abstract
Three billion people (40 percent of world's population) do not have access to safe waste disposal facilities and two billion do not even receive basic trash pick-ups, according to the UN Environment Program. Waste which is not collected or disposed of safely is jeopardizing public health, degrading quality of life, and polluting environmental resources. As developing countries like India grow in population and affluence, the amount of waste is growing faster than governments can keep up. Waste can be an ever-increasing problem, but it is also an opportunity to extract resources and energy. As people come out of poverty, they demand cleaner cities and waste management services.
Citizengage is a renewable energy, logistics, and technology startup in Bangalore, India providing waste management services to bulk generators. By tracking waste from source to final destination, segregation is maintained for maximum value, and 89% of waste collected from customers is diverted from landfilling and instead recycled or anaerobically digested to produce biogas.
The goal was to apply the Life Cycle Analysis Method to determine the environmental impact from sustainable waste management. Cumulative and running totals of greenhouse gas emissions prevented, water pollution and wastage averted, and renewable electricity produced would help communicate the environmental impact of Citizengage's services for customers. The framework of a life cycle analysis was chosen to compare business as usual models of waste management – open dumping and burning – to Citizengage's Waste2Resource network. Additionally, by assessing emissions at every stage of the waste flow, from primary pickups of segregated waste, to secondary sorting at a Dry Waste Collection Center (DWCC), anaerobic digestion (AD), or rejection and transportation to a municipal landfill, areas of improvement could be identified to further reduce environmental impact or automate and streamline operations.
The final product created was a poster of carbon equivalencies communicated graphically for print and web to advertise Citizengage's environmental impact. The numbers speak for

themselves. Using emissions factors, Citizengage monthly emissions in May and June 2016 were actually found to be *negative* due to the large GHG savings from the BAU scenario. The average GHG emissions per month comes to -28,875.4 kg CO_2eq, giving a net 5,419.1 kg CO_2eq/month effectively sequestered.

Keywords
sustainable waste management, LCA, informal recycling, anaerobic digestion, urban msw, environmental impact, carbon

Group Theoretic Cryptography: The Algebraic Eraser

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Supervising faculty, Sponsor, and Location of Research

Dr. Jonathan Katz, Research Experiences for Undergraduates, University of Maryland College Park

Abstract

Algebraic Eraser(AE) is a function based on non-commutative group theory published in 2007 by people at SecureRF, used for Diffie-Hellman key exchange protocol and designed for device with limited computing power. In 2015 and 2016 there were mainly two attacks on AE published. The Ben-Zvi, Blackburn and Tsaban attack attacks a generalized version of AE key exchange protocol and recovers the shared secret; the Blackburn and Robshaw attack targets only the RFID setting with standardized parameters provided by Secure RF. But after adding a hash function to the protocol, the latter attack is not efficient anymore. In June 2016 SecureRF published a hash function based on a modified version of AE function. We've shown that the function is malleable under some input. We are still working on an attack of the AE hash function. We also explored using randomized method to solve the "Conjugacy Search Problem", a hard math problem Algebraic Eraser's security is partly based on.

Keywords

cryptography, security, key-exchange protocol, abstract algebra, group theory, hash function

Hepatic Orexin Receptor-1 Expression in Binge Eating Prone and Binge Eating Resistant Rats

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Supervising Faculty, Sponsor, and Location of Research

Dr. Kimberlei Richardson, Leadership Alliance Summer Research Early Identification Program, Department of Pharmacology, Howard University

Abstract

Binge eating of foods with high fat and sugar composition is linked to increased prevalence of metabolic diseases that target various organ systems. It is critical to identify neurochemical systems that may contribute to increased consumption of high fat and high sugar consumption because these systems contribute to the development of metabolic diseases (such as diabetes, fatty liver disease, etc.). Since excess sugar and fat intake is harmful to the liver, we seek to investigate the role of the orexin system in the liver. Orexin neurons are neuropeptides that have been shown to bidirectionally regulate gluconeogenesis in the liver and these neurons are activated during excess consumption of high fat and sugar. The purpose of this study is to compare orexin receptor 1 (OXR1) expression in liver homogenates of binge eating prone (BEP) and binge eating resistant (BER)rats. Female Sprague-Dawley rats (freely cycling, 250-300g, n= 6/group) were individually housed and underwent feeding tests to identify rats who were binge-eating prone and resistant to high fat and sugar diets. The feeding tests identified BEP and BER phenotypes based on the consumption of intermittently presented, highly palatable food (PF, 45% fat, 35% carb, 20% protein) pellets. After phenotypes were identified, a subgroup of animals received either vehicle or OXR1 antagonist, SB 334867 (SB, 20mg/kg, i.p.) and PF consumption was measured. Data show that SB significantly reduced PF consumption in BEP and BER rats versus vehicle ($p<0.05$). Liver homogenates from BEP, BEP + SB, BER, BER+SB and control groups were processed for OXR1 expression using Western Blot Hybridization. Studies are underway to determine differences in OXR1 expression for each group. This study is the first (to our knowledge) to investigate the impact of high fat and high sugar intake on OXR1 expression in the liver using a rodent binge eating model.

Keywords

Binge eating disorder, orexin receptor-1, hepatic, metabolic diseases

Effectiveness of Voluntary Principles in Mining Industry

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Supervising Faculty, Sponsor, and Location of Research
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Abstract
A voluntary principle is any sort of code, program, or standard that is voluntary in nature, often used to regulate global companies in the absence of domestic or international legislation. In an attempt to improve public perception of issues such as land degradation, water contamination, and worker safety, the mining industry especially experienced a proliferation of voluntary initiatives since the late 1990s. Existing literature has relied on primarily qualitative methods to assess the effectiveness of such voluntary programs. Our following analysis, however, utilizes a quantitative approach to assess the environmental performance of mines in Toward Sustainable Mining (TSM). TSM is an initiative that requires companies in the Mining Association of Canada to report and assess the performance of their Canadian-based mines on a scale from C to AAA. The environmental performance of these mines was measured by mines' annual violations to the Metal Mining Effluent Regulation (MMER). We applied a generalized linear model and a bootstrap sample means test to both datasets and concluded that TSM participants have statistically significant, fewer MMER violations than TSM nonparticipants. It remains uncertain whether or not TSM is the cause of this strong environmental performance–TSM participants are generally high-performing, profitable companies. Consequently, their significantly stronger environmental performance may be symptomatic of this status rather than TSM participation. Regardless, we conclude that voluntary programs remain effective platforms for stakeholder disclosure of behaviors that may otherwise be unregulated.

Keywords
mining industry, effluent regulation, voluntary principles, generalized linear model

A Method for Quantification of Scapular Dyskinesis and Winging Using Moiré Topography

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Supervising Faculty, Sponsor, and Location of Research

Dr. Katherine Reuther, Dean's Office Fund, Departments of Biomedical Engineering and Orthopedic Surgery

Abstract

Scapular dyskinesis and winging commonly present with shoulder injury. The clinical gold standard for diagnosis, developed by McClure et al, is qualitative, has limited inter-rater reliability, and has limitations in describing dysrhythmia through a range of motion. [1-4] Quantitative methods have emerged, but they are expensive and complex. Previously, Warner et al. used topographic moiré imaging, though through expensive and only semi-quantitative methods. [5] Recently, our group developed a novel approach to quantify scapular dyskinesis and winging using moiré topography. We hypothesized that H1) qualitatively dyskinetic subjects would score higher quantitatively using our novel dyskinesis metric and that H2) subjects qualitatively exhibiting winging would score higher quantitatively using our novel winging metric.

Vertical lines were projected onto the backs of fourteen healthy human subjects and shoulder range of motion tests were performed under video recording. [6] The motion was rated qualitatively using McClure's method. For dyskinesis, subjects were classified as being severely dyskinetic, mildly dyskinetic, or normal. For winging, shoulders were classified as having winging or not. Topographical moiré interference patterns were added to each video using Python. The apices of both shoulders were tracked and the resulting point clouds were registered using an iterative closest point (ICP) algorithm. The resulting root mean square error (RMSE) was used to assess dyskinesis. In addition, the gradient of each topogram was measured at 0°, 90°-ascending, 180°, and 90°-descending. The steepest pitch for each test was used as a quantitative measurement of winging for both shoulders.

Individuals exhibiting severe dyskinesis had 30% higher RMSE values than those individuals exhibiting no dyskinesis qualitatively ($p<0.05$). Additionally, the gradient increased by 85%, indicative of pronounced scapular winging, when comparing qualitatively normal and abnormal winging groups for both scapulae ($p<0.0001$). Quantitative assessments of scapular dyskinesis and winging correlated strongly with qualitative assessments. This low-cost,

portable technique can be used in the clinic to diagnose and monitor patients and further elucidate the role of the scapula in shoulder injury and treatment.

Keywords
Scapular Dyskinesis, Scapular Winging, Moiré Topography, Low-cost Diagnostics, Sports Medicine

Antibiotic Regulation of Ductus Arteriosus Tone: Better Choices for Neonatal Sepsis-Associated Patent Ductus Arteriosus

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Supervising Faculty, Sponsor, and Location of Research
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Abstract
The ductus arteriosus (DA) is a fetal blood vessel that connects the aorta to the main pulmonary artery, allowing deoxygenated blood to bypass the developing lungs so it can be enriched through placental gas exchange. The DA typically closes within 48 hours of birth to facilitate the transition from fetal to normal newborn respiration. However, in up to 60% of preterm infants, the ductus remains open, producing a left to right shunt and increasing the risk of pulmonary hemorrhage, necrotizing enterocolitis, and death. Recent studies have linked patency of the DA (PDA) to neonates treated for bacterial sepsis. We have previously shown that aminoglycosides, a class of antibiotics often used to treat neonates, cause relaxation of the DA. In this study, we investigate the effects of other commonly used antibiotics, hypothesizing that there may exist antibiotics that have neutral or beneficial vasoconstrictive effects on the ductus. To test this, pregnant CD1 mice were delivered on day 19 of gestation (term). Fetal DAs were isolated via microdissection and pressure myography was used to measure vasoactivity in response to increasing concentrations of antibiotics. The penicillin derivatives Ampicillin and Piperacillin caused dilation of the ductus lumen at the highest doses, while cephalosporins, the carbapenem Meropenem, and the glycopeptide Vancomycin caused statistically insignificant dilation. In contrast to isolated Piperacillin, Piperacillin-Tazobactam caused constriction of the ductus, particularly after pre-exposure of the vessel to oxygen, making it a better option for the treatment of infections in neonates susceptible to PDA. Future research will test the effects of these antibiotics on the DA *in vivo* through injection into septic d19 pups.

Keywords
Patent ductus arteriosus, neonatal sepsis, antibiotics, myography

Light Beam Scanning in Catheters Without Moving Mechanical Components

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Supervising Faculty, Sponsor, and Location of Research
Guillermo Tearney, MD, Ph.D. & Rohith Reddy, Ph.D., National Science Foundation, Massachusetts General Hospital & Harvard Medical School.

Abstract
The goal of this project is to eliminate the use of drive shaft motors or rotary junctions in medical imaging devices that depend on a scanning rotation of laser beam light to image in vivo tissues. The mechanical components of these motors spin the fiber optic cables that output the laser light. These mechanical motors in current catheter imaging systems are difficult to fabricate and source, therefore creating an obstacle in design production of the imaging system. Building a new system that voids the dependency on these motors to rotate the light has the potential create even smaller in vivo images devices that are exponentially faster, more accurate, less invasive than current in vivo imaging systems. This is extremely important for clinical disease diagnoses, especially in anatomical areas that are not easily accessible without endoscopic methods (such as the esophagus, coronary arteries, and the GI tract components to name a few). Smaller and faster real-time imaging equipment can make a significant impact for early disease and cancer diagnostics and prevention.
To design a new system that does not use mechanical components to create a scanning beam of light, we used a Digital Light Projector called a Digital Micromirror Device (DMD). The DMD consists of an extensive array of small mirrors that can be turned “on” or “off” depending on if they are tilted up or down. When the light output from a fiber optic cable is focused on the mirror array, a specific mirror configuration of “on” or “off” mirrors determines how the reflected light can be manipulated to generate a single converging spot of light within the area of the fiber optic cable’s output end. We coded algorithms to make the mirror configuration as accurate as possible for a sequence of spots in a specific radius, and ran the code in a loop to generate a “scanning beam” of light. The processing power of the Digital Micromirror Device has the capability of operating at 20 kHz which is exponentially faster than current systems that use Spatial Light Modulators. We were able to generate an effective scanning patter of light spots with rigorous algorithms in

a reasonable amount of time, which holds potential to eliminate driveshaft motors and rotary junctions in in vivo imaging systems.

Key Words
medical imaging, catheters, in vivo, optics, diagnostics

Effects of Maternal Separation on Expression of Depression Candidate Genes in B6 Mice

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Supervising Faculty, Sponsor, and Location of Research
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Abstract
Early-life adversity has been linked to depression, particularly through enduring modifications of the epigenome. Maternal separation is used as a model of early-life stress to induce depressive-like behaviors in mice. Genes implicated in the pathophysiology of depression include growth factors, such as the brain-derived neurotrophic growth factor (*Bdnf*) and nerve growth factor (*Ngf*) genes. Genes within the stress response pathway, especially the corticotrophin-releasing hormone (*Crh*) and glucocorticoid receptor (*Nr3c1*) genes, have been linked to stress-related disorders. The serotonin system is a key research area, with the tryptophan hydroxylase 2 (*Tph2*) gene, a key to the synthesis of serotonin, and the brain serotonin receptors, including *5-HTr1a*, as mediators of depression. Finally, the oxytocin system is fundamental for social behaviors, including maternal care behavior, and has demonstrated anxiolytic effects mediated through the oxytocin receptor (*Otr*). We aim to determine whether daily maternal separation affects levels of *Bdnf, Ngf, Crh, Nr3c1, Otr, 5-HTr1a* and *Tph2* expression in the hypothalamus, hippocampus and prefrontal cortex (PFC) of male and female B6 mice. A daily separation between dams and litters from postnatal days (1–14), was implemented in B6 mice and compared to a control rearing conditions (standard laboratory rearing with no separation). None of the results were statistically significant, although there was a near significant rearing group effect for *Otr* expression in the PFC of male pups; a significant sex effect in *Bdnf* hypothalamic expression and litter effect in the hypothalamic *Bdnf*, *Crh*, and *Ngf* expression, as well as PFC *Nr3c1* expression. Further epigenetic analysis, including determining DNA methylation of the gene promoters, combined with behavioral analysis of the mice, and supplemental analyses of receptor binding and blood peptide levels, should be a further course of study to shed more light on the pathways of depression and early-life adversity.

Keywords *maternal separation, depression, gene expression, HPA axis, epigenetics*

Assaying Permeability of Pre-treated Bovine Synovium using Fluorescent Dextran

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Supervising Faculty, Sponsor, Location of Research

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Abstract

Osteoarthritis is a common disease of the joint characterized by deterioration of integrity of the joint cartilage and synovium eventually leading to inflammation. Although mechanical knee replacement surgeries are becoming common, the process is still extremely expensive, invasive, and unavailable in many parts of the world. The need to devise a less invasive and less expensive strategy requires a better understanding of the behavior of the synovium, a thin lining of cells responsible for nourishing the cartilage and synthesizing various important lubricant molecules.

The aim of this study was to observe and assess the permeability of the synovium under control and treatment conditions. Trans-wells fitted with synovium samples pre-treated with different combinations of chemicals were utilized to mimic the different possible chemical conditions in an osteoarthritic joint. First, fluorescently labelled dextran solution was added to the upper chamber of the trans-well and samples were collected from the bottom chamber at regular time intervals. Then, these samples were assayed and the resulting data was analyzed to compare the differences in permeability. Our results show that there exists a negative correlation between any kind of treatment and permeability, with the unadulterated synovium showing the highest flow through of dextran molecules. These preliminary findings indicate that an osteoarthritic joint might prove vulnerable to various chemical stimulants and further optimization of the experiment can give us a better idea of transport properties of the synovium, allowing us to devise drugs and strategies with minimum side-effects.

Keywords

Osteoarthritis, Synovium, Fluorescent Dextran

The Role of Adenylyl Cyclase 3 in Osteocyte Mechanosensing

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Supervising Faculty, Sponsor, and Location of Research

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Abstract

Osteoporosis results in 8.9 million fractures each year. Caused by either losing too much bone or not making enough, the disease is closely related to the body's rate of bone formation. Primary cilia in osteocytes have been shown to play a role in sensing mechanical stimulus and responding with increased bone formation, and could therefore be a promising approach to treatment of osteoporosis. Ac3, an adenylyl cyclase isoform, is expressed at a relatively high concentration in osteocytes, but is understudied in these cells. It also localizes to the osteocyte primary cilia, which have been shown to have a role in mechanotransduction. Therefore, Ac3 could be a good candidate for a bone specific target in treatment of bone diseases like osteoporosis.

The objective of this study was to determine whether the presence of Ac3 affects the ability of osteocytes to sense mechanical stimulus. To answer this question, Ac3 expression was reduced in osteocyte-like cells (MLOY-4 cells), which were then subjected to mechanical stimulation and compared to stimulated cells with a normal level of Ac3. Lipofectamine and siRNA were used to knock down Ac3 expression. Then, cells were subjected to mechanical stimulus by fluid flow. Afterward, the relative levels of COX-2 expressed in each group of cells were compared because COX-2 is known to increase in mechanically stimulated osteocytes. For cells in which Ac3 was knocked down, COX-2 expression increased more with stimulation than in cells where Ac3 was present at a normal level. Therefore, Ac3 could have a role in regulating the mechanosensing process in bone, but the mechanism of this regulation is still unknown and is likely inhibitory.

Keywords

Adenylyl cyclase 3, osteocyte, mechanosensing, bone, primary ciliu

Development of Automated Batch Workflow and Real Time Large Data Processing for X-ray Fluorescence Tomography

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Supervising Faculty, Sponsor, and Location of Research

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Abstract

The unprecedented spatial resolution of the Hard X-ray Nanoprobe (HXN) beamline at the National Synchrotron Light Source II (NSLS-II) allows for material characterization on the scale of 10 nanometers (nm). Such resolution enables new frontiers of advanced material characterization. One of the important techniques, currently being developed at the HXN beamline, is 3D x-ray fluorescence microscopy, or fluorescence tomography, which allows scientists to visualize internal structures and quantify elemental composition. When excited by the incidence x-ray beam, the atoms in a sample emit characteristic fluorescence x-rays providing a unique fingerprint of elemental composition. Tomographic reconstruction of a set of 2D projection fluorescence images can reveal the 3D distribution of elemental composition within a sample – however, this technique requires the processing of large amounts of data. Currently, raw data is processed and analyzed in the PyXRF software developed at HXN. Although PyXRF provides an intuitive graphical user interface and advanced plotting capabilities, the software does not support real time data processing or automated batch workflow. This inherent bottleneck makes large data processing a timely and impractical endeavor. During my summer research, I developed a new automated workflow that processes large quantities of data in real time. The software I produced utilizes key functionality from PyXRF to eliminate the need for manual data processing and allows for immediate data analysis upon completion of an experiment. With such improvements, future efforts with HXN will focus on the problem of self-absorption in fluorescence tomography.

Keywords

X-ray, fluorescence, tomography, self-absorption, nanometer

Text-to-Speech for Low-Resource Languages

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Supervising Faculty, Sponsor, and Location of Research

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Abstract

As speech technology progressed enormously during the past decade, there now exists very natural-sounding text-to-speech (TTS) synthesis for major languages such as English, Spanish and Mandarin. However, many other languages in the world are only spoken by a very small fraction of people. Low-resource languages (LRLs) have very few natural language processing resources, so that their speakers could not benefit much from the speech technologies. Nevertheless, for many of these languages, there are large amounts of "non-professional" data readily available – such as chat over mobile phone and broadcast news.

Therefore, this research aims to investigate the possibility of training intelligible HMM-based text-to-speech voices on non-professional, noisy data, in hope of developing natural-sounding TTS-technology in LRLs. This is achieved by comparing different filtering techniques on the English MACROPHONE corpus, which contains about 200,000 utterances collected over the telephone network from over 5000 participants. We created several subsets based on these selection methods. For example, we looked at prosodic characteristics such as mean and standard deviation of energy (ENG) and fundamental frequency (F0), and picked out voices without clipping and background noise etc. To evaluate the intelligibility of our voice, we both published listening test of trained voices on Amazon Mechanical Turk, and used several Automatic Speech Recognition APIs such as IBM Watson. Then we evaluated the intelligibility of each voice by computing its Word Error Rate (WER) after it was transcribed.

Based on research results, we observed that even in the presence of a very limited amount of professional data, we could still generate an intelligible TTS voice. WER results show in general that, voices with fast speaking rate and without transcribed noise give notably better performance in TTS. Our next step would be to try more filtering methods to identify the best utterances, and generalize this approach to new languages.

Keywords

text-to-speech (TTS), low-resource languages (LRLs), non-professional, filtering, intelligible, word error rate (WER)

Measuring the Thermal Conductivity of Lithium-ion Battery Anodes Using a Simple Differential Steady-State Method

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Supervising Faculty, Sponsor, and Location of Research

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Abstract

Measurement of thermal conductivity is crucial to various fields such as materials science and mechanical engineering. More specifically, measuring the thermal conductivity of electrodes in lithium-ion batteries gives us a clearer understanding of how heat is produced and transferred in the batteries, shedding light on some potential improvements of lithium-ion batteries' performance and efficiency. While some adopt dynamic-state methods, steady-state methods are also a plausible approach to the problem. In this project, we reduce the problem to one-dimensional and measured the thermal conductivity using a steady-state method that is derived directly from the Fourier Law of thermal conduction. Temperatures are measured using the Ktype thermocouples and the control of temperatures is realized through adjusting the powers supplied onto a heater and a cooler with a LabView program according to the feedback of temperature. Moreover, we adjust the temperature of the heater side of the sample to be at the same level as the ambient in order to eliminate the heat loss from the heater that might have caused inaccuracy of the measurement. Thermal paste is also applied onto the surfaces to ensure uniform and good thermal conduct between surfaces. The experiment is conducted with a piece of common anode in lithium-ion batteries, i.e. graphite on a copper substrate as the sample. After repeated experiments and calculations, we obtain the result of the thermal conductivity of the sample around 0.15 W/(mK).

Keywords

Thermal conductivity, lithium-ion battery, steady-state method

Investigating the Functional Role of EphB4 Receptor Clustering in Adult Neural Stem Cells

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Supervising Faculty, Sponsor, Location of Research
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Abstract:
Signal transduction of growth factors and morphogen cues is often initiated by multivalent interactions—the binding of multiple ligands on one entity to cognate receptors on another—that lead to receptor clustering. This includes Eph/ephrin signaling, which plays key roles in tissue development, cancer, and neurodegenerative diseases. Despite numerous insights into the function and operation of Eph receptors, the fundamental relationship between Eph clustering and signal transduction—such as the effect of the size and number of cluster—is currently unknown. This is partly due to limited ability to control multivalent interactions within cell-cell contacts in mixed cell culture, and poor efficiency and tunability of known receptor clustering techniques, such as antibody-induced clustering. Previously, the Schaffer lab designed a multivalent ligand by conjugating multiple ectodomains of ephrin B2 onto a hyaluronic acid backbone. While these engineered multivalent ligands have demonstrated a potent efficiency in clustering EphB4 receptors, which subsequently induced neurogenic differentiation of adult neural stem cells, their polydispersity (i.e. length of HA, inter-ligand spacing) has limited the precision with which clustering effects can be studied. We seek to create a new generation of multivalent ligands by designing a library of polymeric scaffolds, onto which a defined valency and inter-ligand spacing can be achieved. Specifically, the original hyaluronic acid backbone will be replaced with a polypeptide scaffold that separates multiple lysine ligand conjugation sites with spacers composed of GSA amino acid repeats. EphB4 binding peptides, previously identified by phage display, will then be conjugated to the scaffold. The effect of each ligand variant on receptor clustering will be studied by exposing NSCs expressing EphB4-mMaple3 to the ligands and imaging the resultant clusters using photoactivatable localization microscopy (PALM). Together, these techniques will allow us to precisely study and quantify how EphB4 receptor clustering results in downstream effects.

Keywords *Neural Stem Cells, PALM microscopy, protein engineering*

Trigger: A Dynamic Data Race Verification and Analysis Tool

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Supervising Faculty, Sponsor, and Location of Research

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Abstract

Fueled by the rise in ubiquity of multithreaded applications, new techniques are needed to detect and debug an increasing number of concurrency bugs and attacks. While many new race detectors have been proposed in recent years, current state-of-the-art detectors still struggle to balance completeness (missing no bugs) and soundness (eliminating false positives) in a way that is useful to the developer. We present Trigger, a race verification system to be used in conjunction with existing detectors, to solve this problem. Trigger is a novel, dynamic verification and analysis tool that trades completeness for practicality and soundness. Trigger is built on top of the LLDB Debugger and uses breakpoint analysis to "catch" the race "in the moment." By doing so, we guarantee that reported races are true races, allowing developers to focus their time on real, verified reports rather than false positives. In our testing on widely used C/C++ applications like Apache and MySQL, we found that Trigger was able to reduce the number of false positives from the commonly used race detector, ThreadSantizer, by 90% on average. This vast reduction in false positives represents a huge increase in the usability of race detectors like TSAN. Now, instead of verifying hundreds of reports by hand, developers only need to examine a few dozen. Additionally, Trigger can be used to inspect verified races "in the moment," allowing developers to control and study specific program inputs, thread schedules, and propagation paths in the target application. This feature allows developers to study races with fine grain control of the program and determine whether a bug is exploitable. In all, we believe Trigger will greatly reduce the manpower needed to find data races and their corresponding vulnerabilities.

Keywords

breakpoint analysis, race detector, concurrency bug, LLDB, threadsanitizer

Engineering the Next Generation at Columbia Engineering

The E.N.G. Program is a 6-week intensive summer research program at Columbia Engineering for academically competitive high school students. Rising high school seniors are placed in engineering labs, matched with research mentors, and supervised by faculty members. This program has rigorous demands and prepares students for the caliber of work expected of college students. Program components include research, mentoring, college preparation, presentation skills, as well as technical, academic, and professional development workshops. Students meet every morning for a research skills workshop curriculum, led by Columbia postdoctoral researchers, covering topics from experimental design and data analysis to writing primary research articles. In the lab, students learn time management, communication, and teamwork skills, which are all increasingly important for success in STEM fields and in higher education.

Robotic Tactile Sensors

Ikram Hussain (ELLIS Preparatory Academy) & Jeremy Espinal (Columbia Secondary School)

PI

Dr. Matei Ciocarlie

Abstract

Using a soft polymer, PDMS, and optic sensors embedded in the PDMS, we attempted to make a sample with no hysteresis and is still sensitive enough for practical use. We are using PDMS because its index of refraction allows light to be reflected internally instead of escaping. So any disturbance on the surface changes the way the light is being reflected allowing sensors to tell where and with how much force something is pressing. We made molds in SolidWorks with varying depths to hold PDMS. With these molds we mixed and poured different ratios of PDMS and curing agent to get different stiffnesses. We designed some models that have not been printed yet. These mold have room for more optic sensors to be put in them. Also from our observations, we noticed that samples that are bonded and have a fully opaque bottom are similar in their readings. This means that the issue of bonding can be circumvented by using an opaque bottom layer since PDMS bonds well to PDMS.

Effects of Horizontal and Vertical Orientation of a Photoelectrode on Bubble Nucleation, Growth, and Detachment.

Jhaelle Payne (Columbia Secondary School) & Eleanor Prickett-Morgan (Columbia Secondary School)

PI
Dr. Daniel Esposito

Abstract
Solar energy is a renewable and abundant source to use for electricity. The problem is it can only be used during peak times in the day because during cloudy days or at night it creates periods of intermittency. We need to be able to store this energy instead. Photovoltaic cells that are used now to utilize solar energy cannot effectively store excess energy that the sun gives off. Alternatively, Photoelectrochemical (PEC) cells can take the excess energy and perform electrolysis. However, bubbles begin to develop which decreases the surface area, then less energy is being stored making it inefficient. We want to reduce this inefficiency. We tested using two different PEC cells in a horizontal and vertical orientation, specifically looking to see if there was a relation between the contact angle and diameter in each orientation of the bubbles that develop and the size that the bubble departs from the photoelectrode. Using a specific voltages bubbles would grow. We hypothesized that the larger the bubble, the smaller the contact angle and that each bubble would have a similar detachment size. The measure the sizes, we used a computer program called Image J. What emerged from the data was, the average bubble detachment size was similar among most bubbles, but some bubbles did depart at a small size. The contact angle and size of the bubble have an inverse relationship. With continued research, we can learn how to control the bubbles on a PEC cell. To possibly prevent them from beginning to grow on the surface or to have faster departure time, all which may reduce its inefficiency.

Simple Image Processing via Machine Learning

Sohel Rana (ELLIS Preparatory Academy), Ilan Rodriguez (Columbia Secondary School), & Alan Rice (Columbia Secondary School)

PI

Dr. John Paisley

Abstract

There are numerous challenges in giving computers the ability to 'see data'. For the most part, computers do not have traditional senses or logic to interpret the world the way humans do. However, by utilizing conventional math and a matrix-focused programming language, we wrote a program that allows a computer to group images based on their similarities. The main purpose of this study is to learn how to utilize College-Level software, as well as receive a glimpse into what college-level Computer Science class can be.

Photoluminescence of MBE Grown II-VI Semiconductors

Marva Tariq (Brooklyn Technical High School)

PI

Dr. Maria Tamargo, CCNY

Abstract

Semiconductor quantum dots (QDs) have become an area of interest among scientists due to their zero-dimensional geometries and potential for device applications. The Tamargo lab at CCNY grows semiconductor QDs by molecular beam epitaxy (MBE). To characterize these samples, photoluminescence (PL) is a useful technique from which one can extract information about the structure and the quality of the samples. Recently, a new spectrometer (Princeton Instruments) was incorporated into our setup. This spectrometer is expected to detect a greater range of wavelengths and have greater sensitivity than the previous one. To ensure consistency and accuracy of our measurements, our experiment compared the data collected using the two spectrometers. Once we had confirmed that the instrumentation was giving optimal results, we conducted temperature dependent PL measurements to confirm the presence of QDs in our sample. The sample we used consisted of CdSe QDs in ZnSe grown on a GaAs substrate. We made PL measurements from 77K to 275K, in steps of 5K. For comparison, we also conducted temperature dependent PL measurements on a multiple quantum well (QW) sample. We plotted the full width at half maximum (FWHM) and integrated intensities of both samples as a function of temperature to make a comparison between the different behaviors observed. As expected, there was the unique signature in peak energy, FWHM and integrated intensity of QDs and QW with increasing temperature. Overall, the behavior of our sample is consistent with the presence of QDs.

Development of a Phantom Uterus and Cervix to Mimic the Mechanical Environment of Pregnancy

Katie Vollen (Columbia Secondary School) & Roselkis Morla (ELLIS Preparatory Academy)

PI

Dr. Kristin Myers

Abstract

The purpose of this research is to build a model uterus and determine, the stress and strain of each material that we use and also the way that the stress and strain affects the fetus when it is inside of the uterus. Two of the causes of preterm birth that we are focusing on are Cervical insufficiency and Water breaking early (PPROM). For achieving this project we used Creo (a software) to create a 3D mold of the uterus, and dog bones to mechanically test the materials that we will use. The material that we were working with was the Mold Max 14 because of its elastic properties that are similar to the human skin and the silicone type approached more elasticity. When we got the uterus mold from the 3D printer machine we poured that silicone into the mold and then we got the final uterus made of silicone. The results of this research can be used to test how the distribution of stress varies with the application of a biomedical device. The cervical pessary is a promising treatment method for preterm birth because it has the ability to provide structural support and compression to the cervix while redistributing some stress posteriorly. Our model can measure the effectiveness of this device and what changes can make it more effective.

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