Undergraduate Research Symposium May 20, 2016 Mary Gates Hall

Online Proceedings

Poster Session 1

Commons West, Easel 19

11:00 AM to 1:00 PM

Relating Growing Degree Days to Golden Paintbrush (*Castilleja levisecta*) Growth and Flowering Phenology

Leslie Allison (Leslie) Hirata, Senior, Biology (Ecology, Evolution & Conservation)
UW Honors Program
Mentor: Jonathan Bakker, Environmental and Forest Sciences
Mentor: Nathan Haan, School of Environmental and Forest Sciences

Growing degree days (GDDs) are a commonly used method for determining plant growth patterns in agricultural settings. This technique uses daily heat values, rather than calendar-based predictions, to help estimate total amounts of seasonal growth. This study is intended to determine how GDDs correlate to the flowering phenology and growth of golden paintbrush (*Castilleja levisecta*), a threatened species native to Washington State. I monitored 40 newly-grown and 40 3-year-old golden paintbrush plants, with approximately half of each group containing an additional host plant. Plants of both types were evenly assigned to four different temperature treatments within the Center for Urban Horticulture (outdoors, unheated hoophouse, spring growth chamber, and greenhouse), and were constantly monitored for air temperature by dataloggers placed onto the soil of select pots. I recorded weekly measurements of the growth of each plant in terms of plant size, percent fill, and flowering times, and am relating these variables to the GDDs associated with each treatment. We also collected data from field specimens in Puget Sound in order to analyze differences in growth based on field conditions, as opposed to controlled environments. Finding relationships between growing degree days and golden paintbrush phenology will help us understand when and why it flowers, which influences how many seeds are produced at restoration sites, as well as help our understanding of its sustainability as a food source for Taylor's checkerspot, an endangered butterfly species.

Poster Session 1

Commons East, Easel 78

11:00 AM to 1:00 PM

A Microfluidic Device for Measuring Clot Size and Force Generation

Magena Fura, Senior, Bioengineering
UW Honors Program
Mentor: Nathan Sniadecki, Mechanical Engineering

Vascular injury causes platelets to form hemostatic plugs. Platelets are activated by high shear and collagen, and adhere and contract to protect a clot from mechanical forces. The role of collagen and the anticoagulants heparin and ASA (Acetylsalicylic Acid), which inhibit thrombin and TxA2 (Thromboxane A2) respectively, are not fully understood. Our lab has designed a microfluidic device to measure clot forces and area. Microfluidic channels with block-post sensors generate shear gradients that induce platelet adhesion. Clots grow towards the post and contract, pulling the post closer. Fluorescence microscopy allows post deflection to be analyzed with MATLAB code using Hooke's Law, and phase images monitor area. First, channels were coated with and without collagen. Then, channels were collagen-coated and blood inhibited with heparin or ASA. Blood was incubated with 15 USP (U.S. Pharmacopeia standard) heparin lithium in H2O or 0.3 mM ASA in DMSO for 20 min. Clots in uncoated channels had lower forces than in collagen-coated channels. Blood with ASA in DMSO had less platelet adhesion and contraction than in blood incubated with DMSO. Blood with heparin in H2O had lower force but higher clot area than without heparin. Reduced force of clots formed in uncoated channels relative to collagen-coated channels suggests that collagen is important in force. Inability of platelets to adhere or produce normal force with ASA indicates that TxA2 promotes platelet aggregation and force. Heparin reduced force but not platelet aggregation, thus thrombin is involved in force generation only. This clot-on-a-chip technology can shed light on the clotting process and diagnose patient clotting issues.

Poster Session 1

Commons East, Easel 76

11:00 AM to 1:00 PM

Contractility Measurements in Cardiomyocytes from Danon Disease Patients

Jessica Alison (Jessica) Trinh, Senior, Physics: Biophysics
Mentor: Nathan Sniadecki, Mechanical Engineering
Mentor: Andrea Leonard, Mechanical Engineering

Danon disease, a form of cardiomyopathy, results in deficient blood flow due to the weakening of heart muscles and can lead to a shortened lifespan. In collaboration with the Song lab at the University of Colorado, we aim to better understand the differences in contractile function between healthy cardiomyocytes and those from individuals with Danon disease. The Song lab obtained primary adult cells from two control groups—healthy individuals without cardiac problems—and three diseased groups—people suffering from Danon disease. The patient cells were used to generate induced pluripotent stem cells (iPSC), from which they derived cardiomyocytes that possess genetic information of the original donor. The Sniadecki lab has the technology to make micropost substrates from polydimethylsiloxane (PDMS), using a soft lithography process. The iPSC-cardiomyocytes were seeded onto the microposts. As the cardiomyocytes contract on the microposts, each post under the cell deflects. Videos were taken at the tips of the microposts underneath the beating cells, to record the post deflection over time. A still image was taken at the bottom of the microposts in order to determine the relative deflection of each post. From the deflection of the posts, we were able to measure contractile forces produced by the iPSC-cardiomyocytes using simple beam bending theory. For this experiment, we used microposts with following dimensions: height = 4.14 μm, diameter = 1.75 μm, and center-to-center spacing of 6 μm. These dimensions gave each post a stiffness = 56 nN/μm, which was used to calculate the force. We hypothesized that the diseased cells will produce lower contractile forces than the control cells. The results produced supported our hypothesis. We hope this study contributes to the effect of Danon disease on the contractile function of cardiomyocytes. Further, this work would exemplify a methodology to investigate cardiac disease modeling and treatments.

POSTER SESSION 1

Commons East, Easel 54

11:00 AM to 1:00 PM

Widefield Optical Imaging System for Acceleration of Prostate Cancer Histopathology

Jingwen Xiao, Senior, Bioengineering
Mary Gates Scholar, UW Honors Program, Washington Research Foundation Fellow
Mentor: Jonathan Liu, Mechanical Engineering

Cancer is a leading cause of mortality worldwide, and the number of new cases is projected to reach 22 million in the next two decades. Surgical resection of tissues is a standard of care for treatment of a variety of cancer patients. For the prostate, surgically removed tissues usually undergo a process of bread-loafing (cutting into 0.5-1.0 cm thickness), chemical fixation, embedding in paraffin (wax), sectioning (5-10 μm thick), staining, slide mounting and finally microscopic examination to determine whether all tumor growths have been excised. The procedure is labor-intensive, time-consuming and expensive. In addition, the majority of the prostate specimens are normal tissues that do not require detailed microscopic examination. These factors reveal the need to significantly accelerate the screening process and increase the efficient use of healthcare resources. Therefore, to reduce unnecessary processing time and costs, we proposed a fast and inexpensive imaging system to screen the surface of thick tissues for abnormality, before full histological processing. This system was designed to enable a wide imaging area and integrate deconvolution algorithms, which achieve high contrast and resolution. More specifically, the project was carried out in three phases: 1) design, construction, and optimization of a fluorescence microscope; 2) system calibration and optimization of deconvolution algorithms; and 3) system validation using fresh human tissues. The system is capable of generating a 1 x 1 cm^2 image in a few minutes with 4 nm resolution. Success of such a system will facilitate clinical translation and increase efficiency of histopathological procedures, which are beneficial to both patients and healthcare providers.

POSTER SESSION 1

Commons East, Easel 53

11:00 AM to 1:00 PM

100-Fold Improvement in Detection Limit of Group-A Strep Lateral Flow Immunoassays using Isotachophoresis

Amanda Moon Levenson, Junior, Chemical Engineering
Mentor: Jonathan Posner, Mechanical Engineering
Mentor: Gary Kerr, Chemical Engineering

Sore throat is one of the top reasons that adults and children visit their primary physician. Group A streptococcus bacteria is a significant contributor to the prevalence of sore throat and is linked to roughly 11,300 invasive disease cases per year, with 1,800 of those leading to death in the United States alone. Lateral flow assays are a currently available rapid diagnostic of group A strep, but suffer from poor clinical sensitivity, thus requiring additional time consuming and expensive throat cultures for confirmation of negative rapid test results. The clinical sensitivity of commercial rapid immunoassays is limited by its relatively high limit of detection (LoD). The incorporation of electrokinetic techniques, such as isotachophoresis (ITP), has been shown to improve the limit of detection in surface reaction biosensors. ITP concentrates small amounts of colloidal gold-labeled target protein into a band at the interface between a fast-moving leading electrolyte (LE) and a slower trailing electrolyte (TE), which travels across a porous nitrocellulose membrane to a capture protein test line. The reaction between target and capture protein is greatly accelerated due to the high concentration of target protein in the

ITP band, consequently improving test sensitivity compared to standard LF tests. Our previous work demonstrated the ability of ITP to lower the limit of detection of fluorescent proteins in comparison to a lateral flow assay. We hypothesized that previous performance enhancement from ITP in a one-site colorimetric assay could be attained in an infectious disease sandwich assay. In this work, we show that integration of ITP into a strep sandwich immunoassay, by incorporating protein extraction chemistry into the LE solution, exhibits two orders-of-magnitude LoD compared to commercial rapid lateral flow assays. We also achieved 75x improvement in analytical sensitivity.

POSTER SESSION 1

Commons East, Easel 77

11:00 AM to 1:00 PM

Optical Detection of Hemoglobin in a Microfluidic Device
Kimsey Christian (Kimsey) Platten, Junior, Microbiology
Mentor: Nathan Sniadecki, Mechanical Engineering
Mentor: Nikita Taparia, Mechanical Engineering

Oxygen transportation in red blood cells occurs via a protein called hemoglobin. When hemoglobin is either absent, flawed, or impaired, the transportation of oxygen is hindered and this is known as anemia. Due to the prevalence and dangers of anemia, our goal is to effectively measure the concentration of hemoglobin in small volumes of a patient's blood in order to diagnose critical levels of anemia. In order to do this, we take advantage of Beer-Lambert's Law – a physical law that states concentration scales linearly with absorbance (a measure of how much light a molecule can absorb at a given wavelength). With the use of a microfluidic device, whole blood flows through an 8 mm x 250 μm x 50 μm channel and is illuminated by a white LED. A portion of the light is then absorbed by hemoglobin and continues at a reduced intensity to a green filter to focus our measurements to the visible green spectra, because it is known that hemoglobin absorbs the most light at about 540 nm, which is in this region. We demonstrate that our devices can determine hemoglobin concentration effectively with less than 40 μL of blood and at a low cost. The immediate impact of hemoglobin measurements of small volumes is its use towards children. The long-term impact is a diagnostic point of care device to solve global needs.

POSTER SESSION 2

MGH 241, Easel 131

1:00 PM to 2:30 PM

Low-Cost Flexible Three-dimensionally Printed Insoles with Embedded Sensors
Jesse Anthony (Jesse) Hernandez, Sophomore, Pre Engineering
Mentor: Santosh Devasia, Mechanical Engineering
Mentor: Jonathan Realmuto, Mechanical Engineering

Locomotion is a ubiquitous human behavior. The analysis of locomotion patterns is critical for diagnosing and monitoring musculoskeletal disorders. However, current analysis methods are limited to gait laboratories equipped with accurate optical systems and force plates. To address this limitation, this work focuses on developing a process for manufacturing low-cost, individualized, flexible foot insoles equipped with force, acceleration, and gyroscopic sensors. The approach is a three stage three-dimensional (3-D) printing process: (1) 3-D print flexible base layer with electronic compartments; (2) install electronics; and (3) 3-D print flexible closing top layer. The design of the insole with respect to the sensor location is highly modifiable, resulting in subject specific sensor layouts. Moreover, any miniaturized sensor/transducer can be incorporated in the design. The resulting structure is a flexible instrumented insole worn in the user's shoe. Currently, the main application is for real-time sensing for use with a bionic ankle prosthesis. Future applications include real-time sports analysis, sweat sensing for analysis of body chemistry, and energy conversion using piezo electric transducers. Thus, the main contribution of this work is a manufacturing process for low-cost flexible 3-D printed insoles with embedded sensors.

POSTER SESSION 2

Commons East, Easel 64

1:00 PM to 2:30 PM

Quantifying the Extent of Microglial Cell Proliferation Following Ischemic Preconditioning
James Farel Jr (J.J.) Strosnider, Senior, Neurobiology, Anthropology: Medical Anth & Global Hlth
UW Honors Program
Mentor: Jonathan Weinstein, Neurology

Stroke accounts for more than half of all patients hospitalized for acute neurological disease in the United States, and is the second most common cause of death worldwide. Microglia, the brain's specialized tissue macrophages, play a major role in the innate immune response to many neurological diseases including stroke. Ischemic preconditioning (IPC) is a brief period of cerebral ischemia that confers robust but transient tolerance to subsequent ischemic challenge. Elucidating the mechanisms of IPC is a critical challenge in stroke research. A major focus of investigation in the Weinstein lab is the cellular and molecular mechanisms of IPC with a particular emphasis on elucidating the role of microglia in this experimental phenomenon. The Weinstein laboratory has demon-

strated using ex vivo flow cytometry that IPC induces a robust increase in the number of microglia that can be identified and sorted from the preconditioned (ipsilateral) cortex. Immunofluorescent microscopy and quantitative stereology on preconditioned mouse brain confirmed that IPC-induces a true in situ increase in the number of microglia. Recent efforts have sought to discriminate whether the origin of this in situ increase lies in cellular recruitment or cellular proliferation. My project has been to use immunofluorescent microscopy to evaluate the extent of double-staining present in preconditioned cortex when using antibodies targeted against cellular markers for microglia (Iba-1) and proliferating cells (Ki-67). Initial findings suggest that the increased counts observed in preconditioned cortex are the result of microglia cell proliferation. We have also begun to employ a protocol using Bromodeoxyuridine (BrdU), a stably incorporated cellular proliferation marker, followed by immunofluorescent microscopy/stereology to quantify the time course of microglial cell proliferation following IPC.

SESSION 2P

DYNAMICS AND NOVEL MATERIALS

Session Moderator: Nicholas Boechler, Mechanical Engineering

JHN 111

3:30 PM to 5:15 PM

* Note: Titles in order of presentation.

Dynamic Mode Decomposition for Resolution of Coherent Temporal-Spatial Plasma Structures

Roy Kenneth (Roy) Taylor, Senior, Political Science, Physics: Comprehensive Physics

Mary Gates Scholar

Mentor: Brian Nelson, Electrical Engineering

Mentor: J. Nathan Kutz, Applied Mathematics

Mentor: Kyle Morgan, Aeronautics and Astronautics

As magnetohydrodynamic (MHD) systems exhibit incredible nonlinearity, computational models have become increasingly common for parsing difficult engineering problems in plasma experiments. The dynamic mode decomposition (DMD) is a principled, data-driven, equation-free approach to extracting coherent temporal-spatial structures from raw data, with particular success in hydrodynamics and fluid-flow problems. We consider the DMD applied to MHD systems in the particular example of spheromak plasmas simulated in the Helicity Injected Torus experiment. We find that the DMD successfully resolves magnetic field structures in simulated magnetic field measurements that closely match expected physical properties. We further find that, under certain constraints, the DMD provides a powerful tool for further validation of simulation to experiment. Given the nonlinearity of magnetohydrodynamic systems, existing mechanisms for feedback controlling plasmas as instabilities occur are limited. Because the dynamic mode decomposition effectively serves as an approximate, linear reduced order model built from experimental and simulated magnetic field measurements on the fly, it offers considerable promise as a predictive feedback controller. This is significant as the detection of and control over plasma instabilities remains a major barrier to the use of spheromaks for fusion energy.

POSTER SESSION 4

Balcony, Easel 96

4:00 PM to 6:00 PM

The Influence of Calcium on Rates of Ligand Exchange between Strong Chelating Agents by Capillary Electrophoresis

Yi (Suzy) Xu, Senior, Chemistry, Environmental Studies, Whitman College

Mentor: Nathan Boland, Chemistry, Whitman College

Chelating agents are widely used in plants and human industries to capture metal ions and control free metal ion concentrations. Constituent ions in soils (e.g. Ca^2+, Mg^2+) influence the exchange of a metal ion between two chelating agents. Predicting changes in reaction pathways and the magnitude of kinetic effects is fundamental to understanding dynamic metal speciation where strong chelating ligands control metal ion speciation. This research focuses on the influence of calcium ions on the exchange rate of Ni between nitrilotriacetic acid (NTA) and 1,2-cyclohexylenedinitrilotetraacetic acid (CDTA). Capillary electrophoresis was used to monitor the changes in free chelating agent and nickel-chelating agent complex concentration with time at different pHs and reactant concentrations. Reaction rates and order were compared to those in the absence of calcium ion. The presence of calcium ions reduces overall exchange rates and alters reaction order under the conditions studied. Kinetic modeling is used to support a proposed mechanism for the influence of calcium on this exchange reaction. Knowledge about dynamic metal speciation is fundamental to understanding the ideal soil compositions for plants' uptake of essential metals and developing remediation methods for hazardous waste sites.

POSTER SESSION 4

MGH 241, Easel 146

4:00 PM to 6:00 PM

Validation of Sphingosine 1-Phosphate Functionalized Nanopatterned Scaffolds using S1PR1 Knockout Cells

Rakchanok (Som) Chavanachat, Junior, Bioengineering
NASA Space Grant Scholar
Mentor: Deok-Ho Kim, Bioengineering
Mentor: Jonathan Tsui, Bioengineering

Duchenne muscular dystrophy (DMD) is an incurable disease affecting approximately 1 in every 3600 males in the United States that is caused by a genetic mutation leading to the loss of dystrophin expression in muscles. Dystrophin is a protein that links the cytoskeleton of muscle cells to the extracellular matrix (ECM), and a lack of dystrophin leads to extensive damage to muscle fibers and subsequent loss of muscle function. Proposed methods of treatment, such as direct stem cell injections, have not been effective due to poor cell viability and difficulties associated with the culture of muscle stem cells in vitro. However, the development of implantable, vascularized and functionally mature skeletal muscle tissue patches may be able to address some of these issues. These tissues are made by growing primary muscle cells on biodegradable nanopatterned scaffolds that have been functionalized with sphingosine 1-phosphate (S1P), a potent angiogenic and myogenic biomolecule. The nanopatterning of these scaffolds is designed to mimic the nanotopography of native muscle ECM such that the anisotropic alignment and maturation of cultured muscle cells is induced. With this combination of topographical and biochemical cues, there was an observed increase in the formation of mature, contracting myotubes and the presence of differentiated endothelial cells. Furthermore, increased expression of myogenic and angiogenic genetic markers were found in cells cultured on substrates functionalized with S1P. Current work is focused on the validation of these results with cells featuring a knockout of the S1P receptor 1 gene. Lack of this receptor should lead to S1P-functionalized substrates having little to no effect on cell differentiation and tissue maturation, thereby illustrating the importance of S1P on the observed results. With further research and development, these tissue constructs may be used in the future to treat chronic muscle diseases such as DMD.