Brock Math and Science Council
Undergraduate Research Conference
Presentation List

Stutter Support: A Gamified Social Media Solution to Stuttering Therapy
Alexis Varsava

Stuttering negatively impacts students' academic performance and mental health, leading to lessened quality of life in adulthood. Behavioral therapies, including Fluency Shaping, have been proven to effectively reduce stuttering, and therapists need not be physically present for the therapy to be effective. However, the therapy is long and requires maintenance, and adolescent participants tend to disengage prematurely. Stutter Support is an Android app aiming to improve the retention of adolescents in speech therapy. The app offers gamified speech therapy and stress management exercises, designed to appeal to what adolescents have been shown to value: independent progress, positive feedback, and peer approval. Exercises include reading aloud to rehearse 'real life' speech scenarios (e.g., ordering food), measuring breath support and muscle relaxation, and deep breathing for anxiety management. To maintain engagement, the app uses phone notifications to remind the user to practice their speech skills, and tracks app usage and rewards the user for consistent use with praise and encouragement. After reaching certain usage milestones, the app offers the opportunity to post special congratulatory messages to social media accounts linked to the phone. This allows the adolescent user to receive peer support for their therapy through 'likes' and comments on their social network of choice. Stutter Support leverages the connectivity and portability the app format provides to make speech therapy seem positive and relevant to the adolescent population.

Creation of an Optogenetic Split Protease.
Gregory Foran

The ability for cells to communicate to each other is vital for cell functioning and cell survival. One key way cells communicate to each other is by introducing or changing the levels of transcription factors in a cell, to then modify the expression levels of genes. To be able to control when transcription factors become active is a key way to learn and analyse the functions of how they implement their effect on the cell. Up to this point, this was only possible through activation either; of a split protease that would require an external compound or to have a transcription factor under a repressor, which can be turned off and on, once again requiring an external compound. Both of these methods have major flaws that do not allow for a complete understanding of how cell signalling functions. The flaws being they either require an external compound to be functional, as well as they lack the ability to be temporally precise as to the period of these transcription factors becoming active. I present a system that eliminates both of these pitfalls; an optogenetic split protease. This system has shown to allow for both the visualization of the dimerization of the split protease, as well as the visualization of the transportation of the transcription factor to the nucleus while still sustaining the functionality of the transcription factors. This system has also been seen to be non-self-activatable, and non-functional when only one half of the system is present. Overall, this leads to point where we can begin to analyse and study how cellular signals relay their affects in real time in a controlled manner.

A Monte Carlo Model of the ELEKTA Agility Radiation Therapy Treatment Head

Alicia Martin

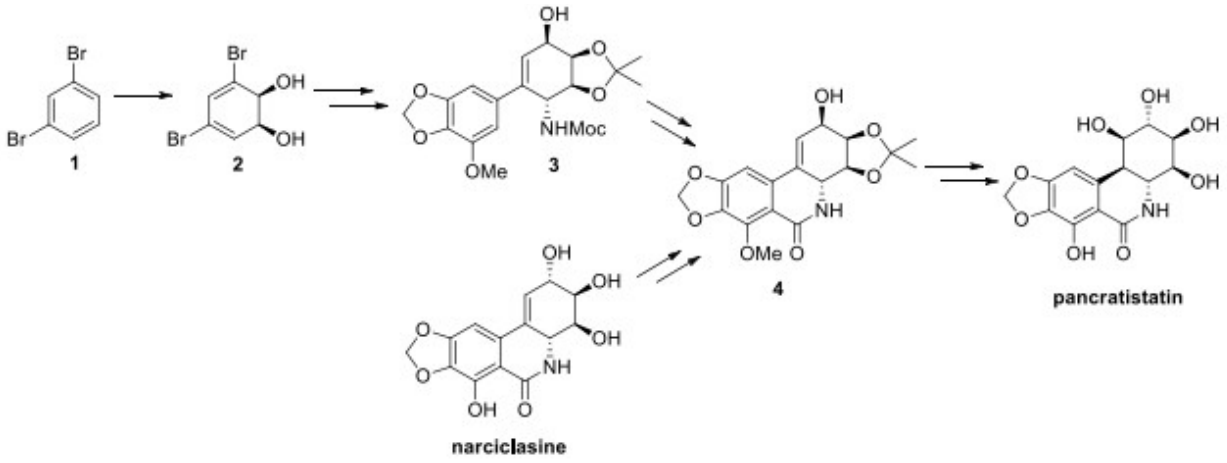
At the Walker Family Cancer Centre in St. Catharines, three linear accelerators (linacs) are used to deliver high doses of radiation to shrink tumors and kill cancer cells. Computer simulations of such linacs are used to simulate conditions and conduct experiments otherwise not achievable because of the high volume of patients that they treat, and the need to maintain the linacs within certain standards. Different cancer centers have their specific linacs tuned differently, and therefore Monte Carlo computer models must be made for each linac installation.

We present the first Monte Carlo model of the linacs currently in use at the Walker Family Cancer Centre. The highly detailed model uses the open-source simulation platform GATE, which incorporates the particle tracking physics engine Geant4. Our simulation of the dose distribution of the 6 MV energy beam currently matches experimental results with over 90% of the data passing the gamma test at 3% and 3mm. The simulation is currently being extended to the 10 and 18 MV beams.

Synthesis of Pancratistatin from Natural Narciclasine

Nolan Nardangeli

Amaryllidaceae alkaloids are interesting synthetic and pharmaceutical targets. Hudlicky's group is currently pursuing the synthesis of unnatural derivatives of narciclasine and pancratistatin – two of the most promising constituents that have demonstrated high selectivity promoting apoptosis in cancerous cells. Recently, we used reductive transposition of allylic alcohol **3** in the formal synthesis of pancratistatin. Currently, the similar strategy is being applied to compound **4**, which can be synthesised from natural narciclasine or by employing a chemoenzymatic route from m-dibromobenzene **1**.



Simulation-guided Engineering of an Enzyme-powered Three-Dimensional DNA Walking Device for Discriminating Single Nucleotide Variants

Yongya Li

Single nucleotide variants (SNVs) are important both clinically and biologically, because single base differences in nucleic acid sequences can have profound biological consequences. Herein, we engineered a nicking endonuclease-powered three-dimensional (3D) DNA walking device that discriminates SNVs with both high senility and high specificity at low target concentrations. Particularly, we introduced a new in-solution tuning method that harnesses a

single fuel molecule to regulate the thermodynamic gain of the 3D walking device via noncovalent DNA catalysis. Our device produced discrimination factors that are comparable with commonly used molecular probes (e.g., molecular beacons and strand displacement beacons) but improved the assay sensitivity by ~100 times. Our results also demonstrate that rationally designed DNA catalysis can be used to quantitatively improve the molecular devices with high structural and functional complexity.

Properties of the Chalcogenide Family Semiconductors

Jeremy Dion

The Chalcogenide family of semiconductors are materials that contain a chalcogen element (S, Se or Te) and are important for applications due to their sensitive response to light, electrical current and heat. Recently a subgroup with the tetradymite crystal structure have been found to exhibit exotic electronic states including superconductivity upon doping. These materials, which are bulk insulators, have metallic surface states and are called topological insulators. Arsenic Telluride is a chalcogenide that exhibits multiple structural phases. The beta-phase is obtained by rapid quenching from a melt, and is isostructural with the topological insulator Bi2Te3. Upon doping with Copper Bi2Te3 becomes superconducting. Theoretical work has predicted that beta-As2Te3 may also have topological insulating states. To explore possible exotic electronic states in this material we have synthesized Cu-doped samples of the beta-phase of As2Te3 and investigated their properties by Xray Diffraction and Infrared Spectroscopy.

Optogenetic Control of Notch-Mediated Lateral Inhibition in Drosophila Neuroblasts Through CRY2-CIBN Clustering

Ryan Hallam

The process by which pluripotent cells in a developing embryo make decisions with respect to cell fate is critical for the formation of functionally distinct tissues from an equipotential precursor population. Communication between cells is achieved through many different molecular signaling pathways which regulate differential gene expression, allowing otherwise identical cells to adopt different fates. Notch, a highly conserved transmembrane receptor protein, is especially critical in the development of the nervous system of both vertebrates and invertebrates. Previous studies have shown that Notch-mutant Drosophila embryos adopt a lethal neurogenic phenotype, resulting in over-proliferation of neural precursors at the expense of epithelial tissue. Notch signaling is responsible for the activation and repression of proneural genes in a defined pattern within the neuroepithelium, specifying a subset of cells to adopt a neural fate in a process called lateral inhibition. However, the mechanisms by which lateral inhibition dynamically regulates neural precursor populations is not well understood. To determine whether developing Drosophila embryos can adapt to disruptions of Notch-mediated lateral inhibition, I propose an optogenetic strategy to selectively inhibit Notch signaling in the developing neuroepithelium. By introducing a synthetic Cryptochrome 2 (CRY2) protein fused with the fluorescent protein mScarlet, used in combination with a transgenic Drosophila line with the Notch ligand Delta fused to an N-terminally truncated cryptochrome-interacting basichelix-loop-helix 1 (CIBN) and a fluorescently tagged Notch receptor (Notch-YFP;Δ-CIBN), it will be possible to exogenously control the process of lateral inhibition during embryonic neurogenesis using light as a molecular switch. This project could potentially provide insights as to the ability of the developing Drosophila nervous system to dynamically respond to changes in the pattern of cell-fate determination.

The Effects of SRC on Plant Growth and Silica Content in Cover Crops and Grapes

Alana Wong

Recent issues surrounding agriculture sustainability and climate change have discouraged the use of synthetic fertilizers due to their negative effects on the environment. Although synthetic fertilizers are commonly known to improve plant growth, recent interest has shifted towards alternative soil amendments due to their more benign environmental impacts. In this study, the effects of Spanish River Carbonatite (SRC) agrominerals on plant growth and silica levels in cover crops and grapes were studied in comparison to a nitrogen, phosphorus, and potassium synthetic fertilizer (NPK). The experiment was carried out in three settings: 1) a controlled greenhouse, 2) semi-controlled garden, and 3) operational vineyard, each with three treatments: 1) SRC, 2) NPK, and 3) no amendment. Plant combinations included intercropped and individual alfalfa, radish, chicory and red clover, as well as monocropped and individual ryegrass. Root and shoot fresh weight, dry weight, and moisture content were measured for all samples. In addition, silica levels were measured for greenhouse intercrops and grape leaves, and percent herbivory was estimated for all plants in the gardens. Greenhouse results showed that alfalfa and red clover grew largest with SRC amendments, while chicory, radish, and rye grew largest with NPK. Some trends also demonstrated that the presence of SRC and NPK soil amendments increased silica levels in alfalfa, red clover, chicory, and radish. In the gardens and the vineyard, very few significant differences were observed. Overall, the addition of NPK and SRC both had benefits for plant growth, and the use of both in combination should be investigated.

Effects of Current Oscillation on the Production of Porous Silicon

Zach Cronkwright

Long wave pass filters (LWPF's) are optical filters that are used in a wide variety of devices to eliminate unwanted radiation beyond the IR regime. The typical LWPF consists of a layer of refractive particles covering an IR transparent substrate. When IR light is incident on the LWPF the particles scatter wavelengths of light shorter than the size of the particles. It has been shown that porous silicon structure also exhibits this behaviour. In this type of LWPF, pores etched into the silicon surface act as the scattering sites. The cut-off wavelength is related to the topological properties of the porous surface; in particular the pore density and pore-to- pore spacing. It has also been found that under the same etching conditions the cut-off is sharper when the current is oscillated between a high and low value than when it is constant. We have monitored the pore structure, via scanning electron microscopy (SEM), and infrared transmission of samples produced with constant and oscillating current in small time steps. The evolution of the cut-off wavelength with the topological properties determined from the SEM images using the image-analysis program ImageJ will be reported.

Determination of SNV Mutant to Wild-Type Ratio of Double-Stranded DNA

Nicholas Rosano

This project deals with the determination of SNV mutant to wild-type ratio of double-stranded DNA within a sample. This is accomplished by using fluorescently labelled toehold ‘exchange’ and ‘displacement’ beacons (TEB and SDB, respectively) coupled with a masking probe system. The masking probes are applied during heat denaturation of a dsDNA oligonucleotide enabling the liberation of a single ssDNA. The TEB undergoes a reversible toehold exchange reaction with the ssDNA. The presence of a SNV within the TEB binding region causes the TEB to be in an unstable configuration, eventually dissociating. Due to this dissociation, the fluorescence generated by the TEB is weaker in comparison to the fluorescence generated by a wild-type ssDNA complimentary to the TEB. There exists a separate channel on the ssDNA for

the reaction with the SDB. The SDB undergoes an irreversible toehold displacement reaction with the ssDNA, generating a fluorescent signal corresponding to ‘how much’ ssDNA is present. The two channels on the ssDNA will therefore generate two separate fluorescent signals. The strength of the fluorescence from the TEB channel can be compared to the fluorescence from the SDB channel. The ratio between the signals generated from the TEB and SDB regions allows for the determination of the mutant to wild-type ratio within the sample.

Nonuniform Fulde-Ferrell-Larkin-Ovchinnikov States in One-Dimensional Superconductors
Bill Truong

Superconductivity is a low temperature phenomenon, occurring only at temperatures on the order of a few kelvin. When a system enters the superconducting state, electrons at the Fermi surface form composite particles known as Cooper pairs which, according to conventional theories, have zero momentum. In the 1960s, superconducting states with Cooper pairs having nonzero momentum were demonstrated to exist in situations where an external magnetic field strongly affects the electron spins. These superconducting states, now referred to as Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) states, have since received extensive theoretical treatment but have remained experimentally elusive.

In this work, we use the Ginzburg-Landau (GL) theory to investigate a one-dimensional superconductor in the presence of a strong magnetic field. Due to the strong coupling of the magnetic field to the electron spins, we extend the usual GL theory and derive a higher order version of the GL differential equations. We show that particular solutions to these GL equations correspond to the FFLO state. Our main finding is that these states carry electric current in a substantially different manner compared to usual theory. Furthermore, by analyzing the stability of these states, we propose a new possible experimental signature of the FFLO state.

Increasing the detection limit of quantitative paper-based DNA reader using computer-assisted imaging analysis
Robert Martin

Microfluidic paper based devices are attractive low-cost tools for the detection of many different types of biomolecules. Our research group has recently developed a novel paper-based device (termed qPDR) capable of quantifying DNA using retention distance (dR) as a read-out. Currently, qPDR relies on human eyes to determine the dR for DNA quantification, which results in a high detection limit. To push the detection limit of qPDR, we propose to incorporate a cut channel design, which has been shown to successfully increase the flow rate in the presence of the analyte. In the experiment, we examine the effect of various cut channel designs on the detection limit. We have also developed a computer software package using python to determine the retention distance instead of the human eye. We found that the computer-assisted imaging analysis could significantly improve the accuracy to determine the dR and lead to better detection limit.