Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Matthew Dardet
High School: Pine Crest School
Mentor: Dr. Ken Dawson-Scully
Project Title: Utilizing a *D. melanogaster* Electroconvulsive Assay to Screen for Novel Antiepileptic Compounds

Approximately 3% of the United States population suffers from seizure disorders characterized by debilitating symptoms that arise from increased neural excitability. Contemporary attempts at solutions include antiepileptic drugs (AEDs) and invasive surgeries that have remained largely unchanged for years yet are still ineffective at minimizing disease symptoms (2012a; Guerrini *et al.* 2013). *Drosophila melanogaster* (fruit fly), a model organism for the study of neurological disorders, offers a compelling research model for the discovery of novel treatments as various unexplored neural pathways have the potential to yield promising results in terms of seizure incidence and pharmacological targets. One such target is the cGMP-Dependent Protein Kinase (PKG) pathway that modulates a downstream, neuronal potassium (K^+) channel (Dawson-Scully *et al.* 2010). Effects of PKG on seizure recovery were analyzed by first constructing an electroconvulsive assay involving a stimulator timing circuit in order to compare results derived from applying voltage to the central nervous system (CNS) of 3rd instar larvae of two natural variants of the *foraging* gene in *D. melanogaster*: rovers (high PKG activity) and sitters (low PKG activity) (Renger *et al.* 1999). The assay was additionally employed in combination with the known proconvulsant pentylenetetrazol (PTZ). Data were obtained that exhibit both marked decreases in seizure recovery time along with increased PKG levels and increases in seizure recovery due to PTZ.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Rose Hong and Jasmin Gao
High School: Del Norte High School and Northview High School
Mentor: Dr. Marcia Simon and Dr. Miriam Rafailovich
Project Title: *Effects of Fibrin Gel Scaffolds and Dexamethasone on the Differentiation of Human Dental Pulp Stem Cells for Applications in Regenerative Endodontics*

Regenerative endodontics aims to combat the critical issue of dental trauma by preserving and maintaining a functional dentin-pulp complex. However, current pulp revascularization methods involving blood clot induction are plagued with multiple problems, including the formation of non-pulp-like tissues and low success rates. In this study, we simulated blood clotting *in vitro* to investigate the ability of fibrin gel scaffolds to support the proliferation and differentiation of dental pulp stem cells (DPSCs). After analyzing the Young's modulus of the scaffolds, we plated AV1-eGFP DPSCs on fibrin gels made with 4 mg/mL, 8 mg/mL, and 15 mg/mL fibrinogen. Half of the samples were treated with differentiation-inducing medium containing dexamethasone (DEX). Interestingly, RT-PCR demonstrated that DEX significantly inhibited the upregulation of differentiation markers and prevented fibrinolysis on certain scaffolds. On the other hand, fibrin gels were discovered to independently support the differentiation of DPSCs and degrade without external inducers. Furthermore, we could control gel dissolution time by varying DEX treatment and fibrinogen concentration. These developments involving the novel combination of DPSCs and fibrin-based scaffolds are crucial to future cell delivery studies *in vivo* and ultimately present a promising solution for the replacement of injured dental tissues and the restoration of biological function.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Harriet Khang, Kelly Cho, Shinbe Choi
High School: Thomas Jefferson High School for Science and Technology, Mclean High School
Mentor: Dr. Ji Hoon Lee, Luminescent MD, LLC
Project Title: All-in-One Biosensor for the Prevention of Arrythmias through the 2-min Analyses of Coagulation Factors

In order to rapidly diagnose and prevent blood disorders (e.g., clots, bleeding), a cost-effective all-in-one biosensor capable of accurately quantifying and monitoring coagulation factors IIa and Xa was developed for the first time. IIa (or Xa), a protease protein, in human plasma reacted with a specific fluorogenic substrate-conjugated quencher for 2 minutes at ambient condition. Fluorescent dye, dissociated from the fluorogenic substrate-conjugated quencher after the reaction, emitted bright light with the addition of 1,1'-oxalyldiimidazole chemiluminescence (ODI-CL) reagents. With the increase of active IIa (or Xa), the strength of light emitted in the solution was enhanced. The dynamic range of the all-in-one biosensor with ODI-CL detection is so wide that it was able to rapidly diagnose and monitor blood disorders. The limit of detection (LOD = 3σ) of the all-in-one biosensor with ODI-CL detection, operated with good accuracy, precision, and reproducibility, for IIa and Xa were as low as 1.04 and 0.76 nM. Based on the concepts established in this research, more advanced all-in-one biosensors can be developed for the rapid diagnosis of infectious diseases such as HIV, West Nile virus, and Zika virus because the biomarkers used for the diagnosis of infectious diseases are protease proteins like IIa and Xa.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Alexander S. Kirov
High School: Greenbrier High School
Mentor: Erhard Bieberich, PhD, Medical College of Georgia at Augusta University

Project Title: Exosomes in Amyloid Aggregates Promote Neuronal Damage: A Mechanism of Alzheimer's Pathology

Alzheimer's Disease (AD) is signified by progressive neuronal death, accumulation of neurotoxic and gliotoxic β-amyloid peptides (Aβ), amyloid plaques, and neurofibrillary tau tangles. Aβ buildup is likely the key trigger of AD, but the exact mechanism of amyloid aggregation is still unclear. Astrocyte-derived exosomes may actively contribute to AD progression. Accordingly, astrocytes exposed to Aβ release exosomes enriched with pro-apoptotic sphingolipid ceramide and its sensitizer pro-apoptotic protein, prostate apoptosis response 4 (PAR-4). These exosomes induce apoptosis in other astrocytes and form complexes with Aβ (Aβ/Exos) by unidentified mechanisms. Using Proximity Ligation Assay modified for identification of ceramide-binding proteins, we show that ceramide in the exosomal membrane binds directly to Aβ, elucidating the mechanism for amyloid aggregation. Next, we treated neuronal cultures with $A\beta_{42}$/Exos aggregates and revealed for the first time increased neuronal structural damage and death as compared to $A\beta_{42}$ oligomers or exosomes alone. Furthermore, using immunocytochemistry, we detected intracellular labeling for ceramide and PAR-4 in neurons exposed to $A\beta_{42}$/Exos suggesting transfer of ceramide and PAR-4 into neurons. Our data suggest that Aβ/Exos clustering is facilitated by ceramide-enriched astrocyte-derived exosomes and that these Aβ/Exos aggregates become increasingly neurotoxic because exosomes in these aggregates release ceramide and PAR-4, inducing neuronal death.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Emily Jiayuan Liu
High School: duPont Manual High School
Mentor: Dr. Ming Yu
Project Title: Quantum Mechanics-Based Computer Simulations of Collisions of a Buckyball with Graphene and Silicon Carbide Sheets

Collisions of a buckyball at various supersonic initial speeds with a single-layer graphene sheet, double-layer graphene, and single-layer SiC sheet were studied using quantum mechanics- based molecular dynamics computer simulations. The impact of the initial speed of the buckyball on the collision was studied in terms of the damage on the buckyball, damage on the sheet, translational and vibrational motion of the buckyball, chemical bonding between the buckyball and the sheet, etc. It is found that these collisions can be classified into several categories based on these factors, ranging from low-speed collisions that result in an undamaged buckyball bouncing off an undamaged sheet to high-speed collisions that result in fragmentation of the buckyball and permanent damage to the sheet. Additionally, it is found that collisions of a supersonic buckyball with a SiC sheet at speeds of 1 km/s or 3 km/s may cause the buckyball to retain a negative charge even after it bounces off the sheet.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Richard Lun and Elizabeth Ling
High School: Thomas Jefferson High School for Science and Technology
Mentor: Dr. Gefei Qian
Project Title: *Searching for new lead-free organic perovskite photovoltaics*
(Materials Science)

Hybrid organic-inorganic lead halide perovskites ($CH_3NH_3PbI_3$, known as ABX_3) are promising solar cell materials due to their inexpensive synthesis and constituent element abundance. While power conversion efficiencies (PCEs) have soared to over 20 percent in just four years, researchers continue to explore methods of eliminating toxic lead in these materials. In this study, we seek to identify new efficient and cost effective lead-free organic perovskite photovoltaics. We performed first-principles calculations in ABINIT to examine new ABX_3 materials by replacing Pb with Sn, Ge and Sr, the X halide with F, Ga, In, and Se, and the A cation with CH_3CN, $C_2H_6N_2$, and $C_2H_7ClN_2$. We discovered that the lead-free Sn perovskites CH_3CNSnI_3, $CH_3NH_3SnSe_3$, and $CH_3CNSnSe_3$ have suitable PV cell band gaps of 1.37, 2.54, and 2.60 eV, respectively. Additionally, we also found that the organic molecule CH_3CN and the X_3 halides F, In, and Se are all suitable for use in perovskite materials. These findings advance the search for environmentally friendly, efficient, and cost effective lead-free perovskite materials to replace silicon-based PV cells.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Nimisha Pant
High School: North Carolina School of Science and Mathematics
Mentor: Dr. Paul Maggard
Project Title: Photocatalytic Properties of Novel Copper Tantalum Niobium Oxide

With the growing need for clean alternative fuels, the importance of photocatalysts for use in splitting water for H_2 production is rapidly increasing. Currently, the most effective photocatalysts are semiconducting metal oxides, but these materials lack the ability to absorb visible light, which makes up most of the solar spectrum. A previously synthesized compound,$Cu_5Ta_{11}O_{30}$, shows promise in visible light water splitting. In order to optimize this compound by lowering the band gap further and thus potentially increasing its quantum yield, a lower energy transition metal, Nb(V), was incorporated into the structure of $Cu_5Ta_{11}O_{30}$in stoichiometric ratios (0%, 10%, 20%, 30%, 40%), creating $Cu_5(Ta_{1-x}Nb_x)_{11}O_{30}$. A Pt co-catalyst was deposited on the surface of some of the powders to drive visible light gas production. The powders were placed in K_2SO_3/ Na_2S, 20% CH_3OH, $AgNO_3$, or de-ionized water and irradiated with either visible light or UV-vis light. The compound was able to successfully produce gases in all solutions. 20% Nb was consistently the most active compound in solution under visible light but more tests must be done to confirm this result. Most importantly, the compound was able to produce gases in de-ionized water, indicating its promise in overall water splitting.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Mark Raj and Ruchi Sumanasekera
High School: duPont Manual High School
Mentor: Dr. Gamini Sumanasekera
Project Title: *The Effect of Nitrogen Doping of Graphene on the Effectiveness of Supercapacitors* (Chemistry)

The following experimentation investigated the effects of nitrogen doping on graphene-based supercapacitors. Graphene has been known to produce a large capacitance due to its honeycomb structure and very high surface area. Nitrogen doping, or the bonding of nitrogen atoms to the graphene structure, was hypothesized to greatly increase the capacitance due to redox reactions between the nitrogen and carbon, allowing for the beneficial effects of pseudocapacitance. The process of nitrogen doping involved the placing of graphene in nitrogen plasma for 2 and 4 hours. X-ray photoemission spectroscopy confirmed that the two-hour sample contained 1.2% nitrogen and the four-hour sample contained 2.5% nitrogen. 5 mg of pristine graphene, 1.2% nitrogen, or 2.5% nitrogen graphene samples were combined with 5mg of a binder with a drop of ethanol and pressed onto a circular stainless steel mesh. The mesh was spot welded onto a rod and the completed electrodes were suspended in a sodium sulfate (Na_2SO_4) solution. Each of the capacitors was connected to a source-measure device at a current of 1.0-3 Ampere while the voltage was varied from 0V to 1.5V. The specific capacitance of each type of capacitor was calculated: pristine graphene, 128 F/g; 1.2% nitrogen sample, 157 F/g; and 2.5% nitrogen sample, 204 F/g. The data supported the hypothesis and showed that nitrogen doping significantly increases specific capacitance. These capacitors have a variety of high power applications, such as electric cars and regenerative braking.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Nikhil Reddy, Charles Goodman
High School: North Carolina School of Science and Mathematics
Mentor: Cheryl Gann
Project Title: Passing Stones

Passing stones is a game played on the vertices of a graph. In Passing Stones, every vertex simultaneously passes one stone to each neighbor, given that it has enough stones to do so. The game itself is an important sub-problem of important combinatorial problems including the A-cordial graph problem. Complete graphs were primarily looked at in this paper. Every n-vertex complete graph with all vertices with fewer than $2n-1$ stones exhibited a cyclic nature with a key invariant when related to the ordering of the vertices. This invariant produced many notable results including multiple results about the end state. These results were then carried over to the remaining complete graphs. An open question is the number of steps for a graph with more than $2n-1$ stones to reach termination.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Amber Yang
High School: Trinity Preparatory School
Mentor: Dr. Lifarn Yang
Project Title: Orbital Recognition System for Space Debris Tracking Using Artificial Neural Networks—A Journey from Inner-Brain GPS to Outer-Space GPS

Space debris emerges as an imminent threat to space vehicles in low Earth orbit. Tracking space debris beforehand to alert spacecraft of a threat to maneuver spacecraft away from a collision path provides an alternative solution to avoiding catastrophic events. Conventional tracking tactics utilize statistical means to estimate waypoints along an orbital trajectory using state transition equations corrected through error covariance propagation. However, covariance-driven tracking tactics are vulnerable to orbital variations of space debris due to constantly changing astrodynamics subject to celestial disturbances. The orbital variations of space debris evolve geometrical features into orbital patterns that can be recognized by machine learning. An orbital recognition system is presented to detect, track, and catalog space debris as a space surveillance network via machine-learning Artificial Neural Networks (ANN) trained by both current and recorded data in a backpropagated manner. Orbital patterns and variations embedded within Keplerian elements are implemented as training inputs for ANN orbital recognition. Changes of Keplerian elements between consecutive waypoints are trained to predict an orbital trajectory for space debris tracking. Orbital dynamics is modeled for space surveillance simulation of space debris randomly created in orbit. Simulation results and experimental applications are used to validate the effectiveness of this space debris tracking approach using the orbital recognition system.