Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Skyler Jones
High School: Ossining High School
Mentor: Dr. Xiaoyang Zhu
Project Title: Large Polaron Formation as a Charge Carrier Protection Mechanism in $MAPbBr_3$ and $CsPbBr_3$ Perovskite Crystals

Perovskite crystals have attracted attention as solar cell semiconductor materials because of their low cost and unique structural properties, and have the potential for record efficiencies due to low nonradiative recombination rates. However, the charge carrier protection mechanisms facilitating these high efficiencies are not yet understood. This study investigated the presence of large polaron formation as a protection mechanism in $MAPbBr_3$ and $CsPbBr_3$ perovskites, and the relationship between crystal structure and transient birefringence lifetime. $MAPbBr_3$ and $CsPbBr_3$ perovskite crystals were grown and characterized using Time-Resolved Optical Kerr Effect (TR-OKE) spectroscopy. $MAPbBr_3$, which has organic cations and a room-temperature cubic phase, displayed transient birefringence lifetimes two times the length of those in $CsPbBr_3$, which has inorganic cations and a room-temperature orthorhombic phase. To explain this disparity, dynamics in orthorhombic and cubic $CsPbBr_3$ were compared through temperature-dependent transient reflectance spectroscopy. Little difference was found between cubic and orthorhombic $CsPbBr_3$, indicating that the varied transient birefringence lifetimes in $MAPbBr_3$ and $CsPbBr_3$ are caused by coupling between the different cations and their phase structures, rather than exclusively by phase structure. This novel understanding of structural dynamics and large polaron formation in perovskites is essential to the development of more efficient and inexpensive solar cells.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Brian Huang
High School: Hunter College High School
Mentor: Dr. Marcus Khuri
Project Title: On Sufficient Conditions for Trapped Surfaces in Spherically Symmetric Spacetimes

Black hole formation in a spacetime, while not fully understood, can be indicated by the local existence of a trapped surface. The Trapped Surface Conjecture (TSC) states that trapped surfaces will form from sufficiently high concentrations of matter. Progress on the TSC has only been made using several spacetime constraints, including spatial symmetries, time symmetry, and the maximal hypersurface. We investigated the TSC in spherical symmetry by utilizing non-positivity of null expansion of a trapped surface within the context of expressions for various geometrical quantities. We found that if certain inequalities involving energy density, proper radius, and proper area of a two-surface on a time-symmetric time slice are satisfied, then a trapped surface exists inside the two-surface. These criteria predict trapped surfaces in some spacetimes, including the constant-density star, where previous analyses fail to. In the non-time-symmetric case, we found that if a two-surface on a time slice satisfies constraints involving mean curvature, mass content, radial flow, and proper radius, then a trapped surface exists inside the two-surface. This generalizes the main non-time-symmetric result obtained by Bizon et al. 1988, removing the requirement for a maximal hypersurface. Our results constitute progress toward proving the TSC and understanding black hole formation.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Sri Yalamanchi
High School: Staten Island Technical High School
Mentor: Dr. Probal Banerjee
Project Title: Curcumin Causes NK Cell-Mediated Repolarization of Tumor-Associated Microglia and Elimination of Glioblastoma and Glioblastoma Stem Cells

Glioblastoma (GBM) is a deadly form of primary brain tumor with no effective cure and a life expectancy of 12-15 months from detection. In this study, GBM mice were treated with curcumin (CCP), after brains were immunostained and analyzed to test the effect CCP on eliminating GBM and recruiting the immune system. Results show that CCP treatment rescues GBM-harboring mice while repolarizing the tumor-associated microglia (TAM) from a tumorpromoting M2 population to a tumoricidal M1 milieu, which is boosted by the recruitment of natural killer cells (NK) by the CCP. In the TAM, CCP inhibits STAT3 transcription factor which is known to induce an immunosuppressive protein IL10 and activate STAT1 which triggers the expression of iNOS, thereby generating nitric oxide that kills GBM cells. In corroboration, peripheral administration of NK-cell-neutralizing NK1.1 antibody in GBM mice reversed CCP-evoked suppression of STAT3, ARG1, and IL10, activation of STAT1 and caspase 3, induction of iNOS and IL12, and elimination of CD133(+), SOX2(+) GBM stem cells, in GBM cells. Therefore, it is shown for the first time that recruited NK cells mediate a major part of CCP's ability to eliminate GBM and GBM stem cells and stabilize the TAM in the tumoricidal M1 state.

Siemens Competition
Math : Science : Technology
Regional Finalist

Name: Benjamin Firester
High School: Hunter College High School
Mentor: Dr. Lior Blank
Project Title: Modeling the Spatio-Temporal Dynamics of *Phytopthora infestans* on a Regional Scale

Potato late blight, a fatal pathogen to potatoes, caused the Irish Potato Famine and leads to billions of dollars of global crop damage annually. Predicting its spread remains problematic, resulting in farmers spraying their fields with fungicide at random intervals, in hopes of killing spores. Knowing when and how their fields will get infected will allow targeted fungicide spray and disease prevention. Consequently, this study created a new mathematical model that predicts the spread of late blight on a regional scale using empirical data. The model probabilistically tracks the disease and uses previous weather patterns and late blight infected fields to predict future spread. The model was validated using a novel approach for presence-only data from several independent data sets. Its accuracy was demonstrated using a contrapositive 'proof' by comparing predicted vs. actual weather patterns. The model was then used to create risk maps showing the likelihood of future infections. Since this model is accurate from initial inoculation, the information it provides allows famers to optimize late blight fungicide treatments, protecting their crops and regionally eradicating the disease. The novel type of model created and new methods for its validation can be extrapolated to organisms that spreads by quantifiable vectors.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Rahul Parthasarathy
High School: Syosset High School
Mentor: Aleksey Bolotnikov
Project Title: Fabricating and characterizing virtual Frisch-grid CZT detectors for gamma spectroscopy

Cadmium zinc telluride (CZT) has recently emerged as the leading semiconductor crystal for room temperature radiation detectors due to its high density and wide band gap. The low availability of high-quality CZT crystals inhibits their widespread use. Internal defects such as tellurium inclusions, sub-grain boundaries, and dislocations disrupt the electric field, producing electrical noise. By improving the fabrication and characterization of CZT detectors, the need to perform corrections for internal defects will be minimized. This project will improve the fabrication process by ensuring that additional defects are not produced on the crystal surface prior to spectroscopy. This project characterized 54 CZT crystals based on four qualities: leakage current, bulk resistivity, μτ product, and electrical noise. Leakage currents measurements found that 27 crystals had leakage currents less than 10 nA, which is ideal. Creating I-V curves is an effective method of calculating resistivity at small voltage ranges. The drift time method was found to be an effective alternative to the Hecht relation in calculating μτ product. Lastly, measuring photopeak width can show amounts of electrical noise. By improving crystal characterization, high-performing CZT detectors can be identified and then used for a variety of applications, ranging from medical imaging to national security.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Stanley Wong; Baokun Gu
High School: Hunter College High School; Manhasset High School
Mentor: Dr. Brett Bochner (Hofstra University)
Project Title: Evidence for Small-Strain Burst Sources Proliferating in Enhanced LIGO Time Series Data

Gravitational waves (GWs) are perturbations in space-time, propagated as waves and produced in measurable quantities by high-energy astrophysical phenomena such as supernovae, binary inspirals, and cosmic string cusps. With the discovery of three strong-signal Binary Black Hole (BBH) mergers within the past two years, these events have now been verified as primary Laser Interferometer Gravitational-Wave Observatory (LIGO) gravitational wave burst sources. However, the relative quantity of significantly weaker burst events, whose signals are likely more frequent but overwhelmingly masked by noise (e.g. thermal vibration, seismic disturbances, quantum effects), is still unknown. To determine the statistical prevalence of these events, we designed and executed a computer algorithm to search for excess coincidence between LIGO's two primary interferometers due to low-amplitude, short-period burst signals hiding in the LIGO Online Science Center (LOSC) database. Four methods of cross-correlating the time series data between the interferometers were constructed to search for excess positive correlation (i.e. potential burst signals). The presence of approximately 1,300 candidate signals were inferred in the currently available data, making this a promising approach to use in the Enhanced LIGO data. We anticipate these findings will be useful in gauging the promise of conducting further time-specific studies on low-amplitude burst signals in future LIGO data.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Sahith Vadada, Rushikesh Patel, and Vedant Singh
High School: Herricks High School and The Wheatley School
Mentor: Dr. Miriam Rafailovich, Stony Brook University
Project Title: Evaluating the Effects of Graphene-Loaded Poly(4-vinylpyridine) Electrospun Fiber Scaffolds and Spun-cast Thin Films on the Proliferation and Differentiation of Dental Pulp Stem Cells *in vitro*

Dental pulp stem cells (DPSCs) show major potential in tissue and bone regeneration using *in vitro* scaffolds. Graphene-polymer composite scaffolds are popular for their excellent mechanical, thermal, and electrical properties. Current studies focus on 2D substrates, which do not represent scaffolds in an *in vivo* environment and have difficulty in dispersing graphene. Our study presents graphene-loaded poly (4-vinylpyridine) as a 3D fibrous scaffold for DPSC proliferation and differentiation. We successfully introduced graphene into biocompatible P4VP matrices and fabricated nano- and micro-sized fibers through electrospinning. SEM and AFM characterization of scaffolds revealed uniform, defect-free fiber and thin film structures with high dispersion of graphene. Confocal and optical microscopy showed elongation of DPSC actin filaments along all fibrous scaffolds. SEM/EDAX displayed greater biomineralized deposits on P4VP/graphene thin films and showed collagen folding and biomineralization on all fibrous scaffolds. Therefore, graphene-based P4VP scaffolds may have directly influenced protein coiling and biomineralization through electrical pathways. Lastly, gene expressions from RT- PCR showed a significant upregulation ($p<0.001$) of the osteogenic marker osteocalcin on P4VP/graphene nanofibers and thin films without differentiation-inducing factors such as dexamethasone. This study presents the ability to control DPSC differentiation through varying P4VP surface morphology and electrical cues such as graphene.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Jang Hun Choi, Chris Lee, and Soohyun Ahn
High School: Jericho High School, Seoul International School, and Middlesex School
Mentor: Dan Ismailescu
Project Title: The Hadwiger-Nelson Problem with Two Forbidden Distances

In 1950 Edward Nelson asked the following simple sounding question:
How many colors are needed to color the plane such that no two points distance 1 *apart are colored the same?*
We say that 1 is a *forbidden* distance. Despite the passage of time, and the work of many mathematicians, we only know that the answer is 4, 5, 6, or 7. All efforts to reduce this list were unsuccessful.
In this paper we consider a related problem in which we require *two* forbidden distances, 1 and d. In other words, for a given positive number $d \neq 1$, how many colors are needed to color the plane such that no two points distance 1 or d apart are assigned the same color? We find several values of d, for which the answer to the previous question is at least 5. We also provide evidence that this version of the problem can be used to attack the original Nelson's question.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Alan Jian, Caitlyn Chen, Austin Lee
High School: Garden City High School, The Spence School, Roslyn High School
Mentor: Dr. Wei Zhu
Project Title: Synthesis and Evaluation of Novel Anti-Cancer Maleic Anhydride Derivatives for the Treatment of Cancers

Currently, poor aqueous solubility and toxicity towards healthy cells hinder chemotherapeutic drug administration and effectiveness. Through the use of micellar solubilization and co-solubilization, drugs can enhance their solubility and thereby increase tumor specificity. However, even as treatment improves, rising prices of chemotherapy make them inaccessible to patients (Rabin, 2014). We present here three novel maleic anhydride derivatives synthesized using the Diels-Alder reaction (novelty confirmed by cross referencing the chemical structures with Cambridge Crystallographic Structures and SciFinders Database). Through MTT, Colony Formation, Migration, and Attachment Assays, we found that these chemicals exhibited notable anticancer effects against colorectal and non-Hodgkin's lymphoma cancer cells. We also observed that the synergistic effects of two of these chemicals significantly increased the lethality of the treatment, which was facilitated by micelle formation. Our results provide an insight into potential use of this novel set of compounds as chemotherapeutic treatment.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Jillian Parker, Jiachen Lee, Arooba Ahmed
High School: Half Hollow Hills High School West/ High School East
Mentor: Dr. Ken-Ichi Takemaru
Project Title: The Cilium and Centrosome Associated Protein CCDC11 is Required for Cytokinesis via Midbody Recruitment of the ESCRT-III Membrane Scission Complex

Abscission is the final stage of cytokinesis, the division of the cytoplasm between daughter cells, in which cells are physically separated by severing the intercellular bridge on either side of the midbody structure. Components of the Endosomal Sorting Complex Required for Transport (ESCRT-III) machinery are utilized to accomplish this internal membrane fission mechanism. Based on a prior observation that the cilium-associated protein CCDC11 localized adjacent to the midbody during abscission in dividing retinal pigment epithelial cells (RPE1), a series of experiments were conducted to elucidate a potential cytokinetic role for CCDC11. Localization of both endogenous and ectopically expressed CCDC11 to midbody structures was validated in HeLa and U2OS cell lines through immunofluorescence microscopy. Additionally, two N-terminal coiled-coil domains (CCDs) present in CCDC11 were required for its midbody recruitment. Transient siRNA knockdown (KD) of CCDC11 in U2OS demonstrated significant increases in binucleated cells, indicative of cytokinetic defect. Furthermore, CCDC11 KD in U2OS cells demonstrate a depletion of CHMP2A at the midbody as compared to control, strongly suggesting the CCDC11 cytokinetic defect is attributed to a failure to recruit the ESCRT-III machinery to the midbody prior to abscission. This data provides for a novel, previously uncharacterized function for CCDC11 that may well encompass all cellular membrane scission events. Considering that synaptic pruning is also mediated by the ESCRT-III complex, the functional role of CCDC11 may be critical in combatting neurodegenerative disorders including amyotrophic lateral sclerosis (ALS), Huntington's disease, and Alzheimer's disease.